PROCEEDINGS

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BALI - INDONESIA

THE 16TH WORLD LAKE CONFERENCE

"Lake Ecosystem Health and Its Resilience: Diversity and Risks of Extinction"

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Lake Ecosystem Health and Its Resilience: Diversity and Risks of Extinction
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Foreword

Water, along with air, has always been the basic part of human's life. Among the water bodies, lakes are of severe impacted ecosystems despite its importance to the surroundings. Lakes confer numerous functional roles that may include defense over flood, recharge and storage of groundwater, biodiversity hot spot and the social economic services. Unfortunately, the alarming signals of lakes being under stress are underway. Contamination and pollution, sedimentation, wetland habitat degradation, alien species invasion, and other anthropogenic activities may have been the major stressors often associated with lake's deterioration. Since the issues on lake's deterioration have been globally emerged, a collected commitment should be engaged to supporting lake sustainability.

The World Lake Conference comes forward as an international forum serving to bridge communication among multi-sectoral parties towards sustainable management in lakes and basins. The 16th World Lake Conference, held from Nov 7th to 11th 2016 in Bali, Indonesia, invited distinguished keynote speakers around the globe; Prof. Takehiko Fukushima from University of Tsukuba, Prof. David Hamilton from GLEON, Prof. Walter Rast from ILEC Japan, Prof. Soontak Lee from IHP UNESCO, Dr. Fauzan Ali (Director of Research Center for Limnology, Indonesian Institute of Sciences) and Mr. Alue Dohong from Peatland Restoration Agency (Indonesia). It was also delightful that we had Governor Mikazuki from Shiga Prefectural Government (Japan) and Governor Hashimoto from Ibaraki Prefectural Government (Japan) to deliver their speeches.

The conference had also been completed nicely by the release of Bali Declaration. Another significant output of the conference is the publication of proceedings. The total papers reviewed and compiled in these proceedings are 83 which were broken up into several thematic sections. The sections comprise (1) climate change and water crisis (2) lake environment under stress and their restoration challenges (3) lake and lake basin management and policies (4) multiple water use purposes (5) water education, ecotourism, culture (6) database and knowledgebase systems, informatics and monitoring technologies (7) biodiversity and conservation (8) ecotechnology and ecohydrology (9) manmade lakes (10) limnology and limnological science fundamentals. Lastly, we acknowledge the creditable efforts and dedications that editors, reviewers and the proceeding team have been put forward.

July 2017

Prof. Gadis Sri Haryani
Chairperson of Scientific Advisory Board

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Topic 1. Climate change and water crisis

CLIMATE CHANGE IMPACTS ON NATURAL RESOURCES AND COMMUNITIES: A GEOSPATIAL APPROACH FOR MANAGEMENT

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ABSTRACT

Climate change causes environmental depletion which became threats to the global economy. The health and productivity of ecosystems underpins agriculture. Hence, stable ecosystems are the foundation for livelihood and food security. The objective of the study is to propose adaptation measures using geospatial technology for conserving the natural resources and improving the livelihood of the local community from climate change scenario. Planning & decisions on policies and programs are required for natural resource management need to be based on broad citizen participation and the engagement of rural communities. The adaptation measures will help the planning system to regulate the development for the natural resources and socio-economic environment. The major natural resources in the environment are land and water which destroyed by human interference and also by climate change. With the use of geospatial technology, the various thematic maps are prepared, which are helpful for the site suitability analysis for preparation of land & water management action plan and also socio-economic development. The study area is one of the micro watershed of Ansupa lake catchment under Cuttack district of Odisha, India. To reduce the impact of climate change on natural resources and livelihood, some adaptation measures have been proposed i.e. for afforestation 68.9 ha, gap plantation 13.94 ha., agro horticulture 389.62 ha., for farm pond, renovation of existing pond for pisciculture and dockery etc. 11.33 ha., for land management and 5 nos. of bore well, 8 nos. dug well, 51 nos. LBS / check dam, 4 nos. WHS etc. for water management.

Keywords: Climate, Geospatial, natural resource, LBS, WHS

INTRODUCTION

Watershed management is the rational utilization of land and water resources for optimum production with minimum hazard to natural resources (Tideman, 1996). Natural climate variability has always been a challenge to human livelihoods. Human-induced climate change has lent a complex new dimension to this challenge. Evidences show that the natural climatic variability, compounded with climate change will adversely affect millions of livelihoods around the world (IPCC, 2007). The rural communities in the developing countries are expected to be affected more due to their extensive dependence on climate sensitive livelihood options and limited adaptive capacity to adapt to the changes. Climate change is a global phenomenon, however its manifestations and impacts vary locally, so do the adaptation capacities, preferences and strategies. Effective planning for climate change adaptation programming requires an assessment of local vulnerabilities so as to bridge the gap between community needs and priorities at the local level and policy processes at the higher level.

Climatic stresses and shocks such as sea level rise, flooding and land erosion displace millions of people throughout the world (IPCC, 2007a) and their number is predicted to increase due to climate change (Nicholls et al., 2011). Climate- induced migration is more likely in drought-prone areas, flood-prone river valleys, low-lying coastal plains, deltas and small islands where livelihoods are dependent on natural resources (McLeman and Hunter, 2010). Fishing communities typically live on low-lying coasts and islands exposed to multiple climatic stresses and shocks (Daw et al., 2009). Thus they may be subjected to climate-induced displacement and migration. Climate-induced migration may reduce vulnerability or enhance adaptation to climate variability and change (Warner et al., 2008). On the other hand, it may also lead to loss of assets, reduced opportunities and increased vulnerability (Hunter, 2005). Migration outcomes are influenced by the degree to which migrants depend on the environment for their livelihood and social factors mitigating or exacerbating the impact of climatic stresses and shocks (Kniveton et al., 2008). Migration distances are also important. Risks lessen when migrants resettle within customary lands (Kuruppu and Liverman, 2011) but increase with migration distance (Barnett and O'Neill, 2012). Sensitivity is the degree to which a system will respond to a given change in climate, it measures, for example, how much the composition, structure and functioning of an ecosystem will respond to a given temperature rise.

Study Area

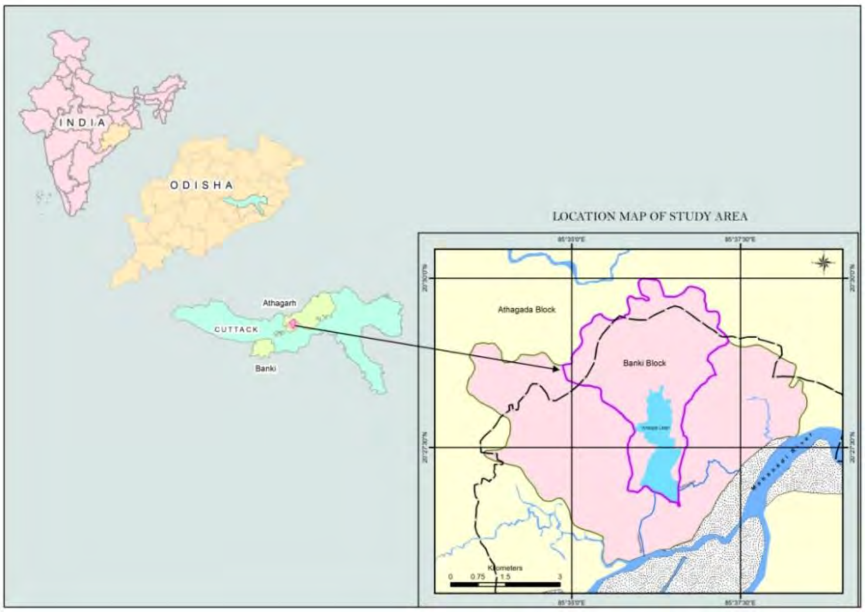

Figure 1. Location map of the study area.

The study area is one of the micro watershed of Ansupa lake catchment under Cuttack district of Odisha, India which is situated 20°26’37.864” to 20°29’59.228” N latitude and 85°34’52.697” to 85°37’19.271” E longitude. **Figure 1** indicates that the micro watershed situated in the border area of Banki and Athagarh block of Cuttack district. There are five numbers of villages has taken for
study purpose in this micro watershed i.e. Kadalibadi, Podapada, Mahidharpur, Radhadarsanpur and Baidehipur, but Baidehipur village has no habitation. This paper will conduct an in-depth analysis of the local level vulnerabilities by integrating quantitative analysis with qualitative information obtained from primary field survey.

DATABASE

Primary Source

The primary data collected through the Focus group discussions (FGD) & Key informant interviews technique.

Secondary Source

The Survey of India (SOI) Toposheet – 1:25,000 scale

High resolution satellite image (Cartosat II & Quickbird)

Demographic and data from Census of India.

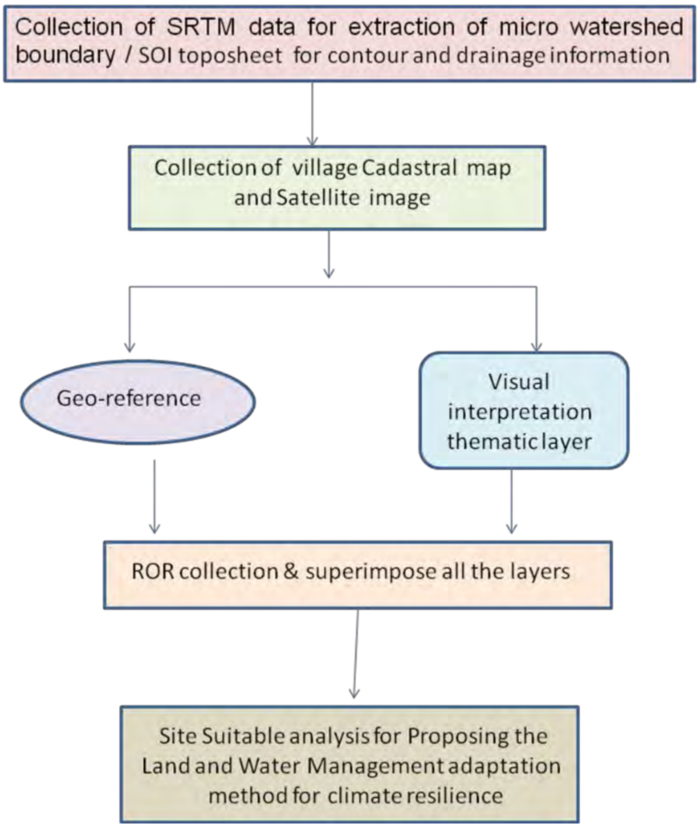

Figure 2. Geospatial approach for site suitability.

METHODS

Figure 2 indicates the geospatial methodology applied for preparation of maps. The SRTM data i.e. SOI toposheet collection were used to delineate the micro watershed boundary. Collection of village cadastral map digitization & mosaic the sheets. Plot wise land detail collected of all villages under the study area from right of record website. Ground control points collected from study area for geo-referencing the cadastral sheets & Cartosat II satellite image for preparation of existing land use, geomorphology, slope, soil, land capability with visual interpretation technique & site suitability analysis for adaptation measures of land and water resource.

Focus group discussions (FGD)

FGD is also a participatory method of data collection, which has become increasingly popular as a qualitative research method in social science (Longhurst, 2003). Like other participatory methods, a key characteristic of FGD is the interaction between the participants. However, being a participatory method, FGD has some potential drawbacks which were addressed during data collection in a similar manner as for the vulnerability matrix. The FGDs were conducted to gather the data on livelihood vulnerability, coping and adaptation related to climate variability and change. The focus group discussions sought to collect data on community perceptions about climate change and how the phenomenon had affected their livelihoods. Specific questions were asked on notable signs of climate change in local communities focusing on precipitation, temperature trends, yields of water sources, performance of crops, animals and the general ecosystem. Questions exploring how livelihoods had been impacted and how communities were adapting to climate change as they experienced it were also mainstreamed.

Key informant interviews

The key informants included individuals inside and outside of the communities. From inside the communities, community leaders and community members who were knowledgeable about the issues for this study were selected. During the reconnaissance study, the goals of key informant interviews were to develop the research objectives and methodology by exploring the research context and issues, becoming acquainted with the study area and people and researching the sources of secondary information. During the main data collection, the goals of key informant interviews were to collect data on the issues in the research objectives or issues raised by respondents during the other data collection methods key informant interviews were therefore conducted at a later stage of the main data collection.

RESULTS AND DISCUSSIONS

Micro watershed management aims to manage water supply, water quality, drainage water runoff and water rights. It also incorporates overall planning processes for the micro watersheds. It comprises the planning and coordination for sustainable use of water resources, agricultural resources, forest resources and grazing land. Micro Watershed development in India is working towards developing micro watersheds to create sustainable livelihood opportunities. Building on participatory approaches, increasing water availability, improving degraded environments, and choosing sustainable agricultural activities are key features. Micro watershed development is thus directly dependent on climate parameters like rainfall and temperature.

The major threats for the lake and the surrounding areas are degradation of physical habitat, deterioration of water quality, depletion of natural / food resources. The sources are anthropogenic interference, unregulated agricultural practices, erosion and deforestation of the catchment area, environmental pollution, spread of invasive species and unregulated fisheries activities.

Indicators of Climate Change for the study area

For the study purpose to know the impact of climate change on livelihood, some indicators have been taken for the analysis like rainfall, temperature, frequency of the calamity and soil erosion. For the study area, these four numbers of indicators are important because it is surrounded by hills in three sides and another one side is Ansupa lake. All the sediments are discharge to the lake and the lake has become shallow which also affect the fish production.

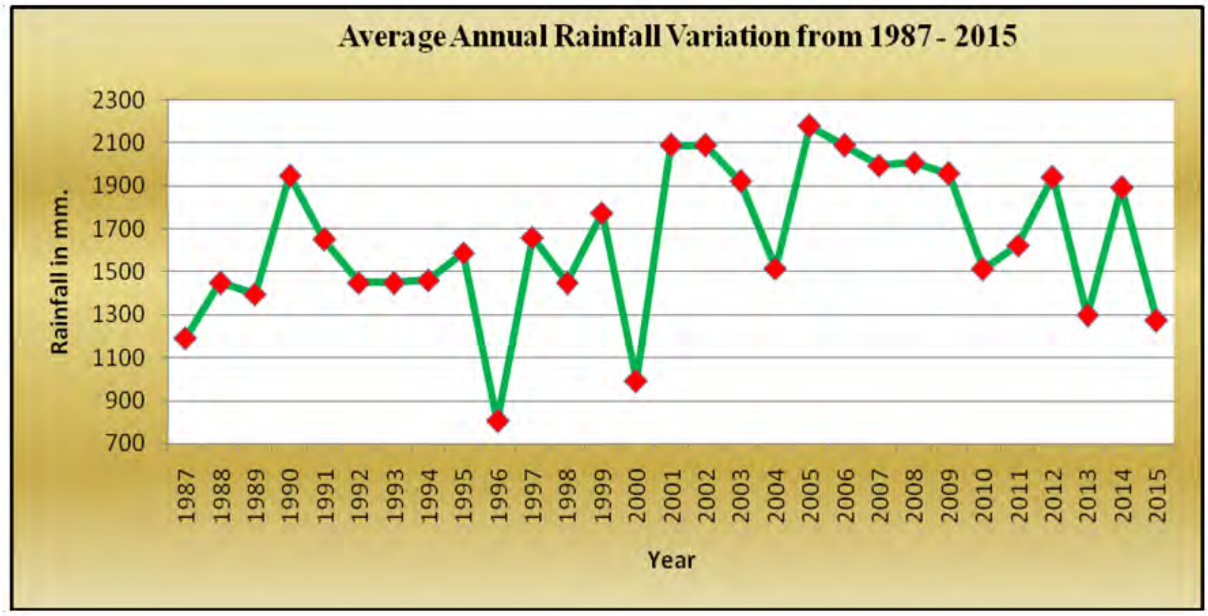

Figure 3. Rainfall distribution pattern.

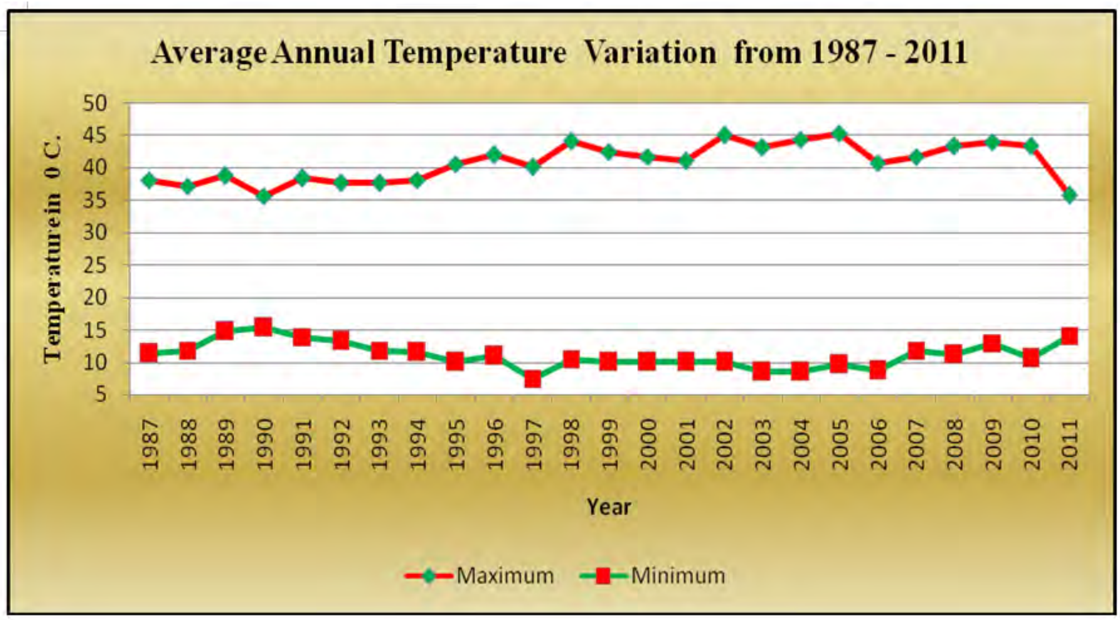

Figure 4. Temperature distribution pattern.

Figure 3 indicates that the average annual rainfall variation during 1987 to 2015. The graph shows that the annual total volume of rainfall has decreasing from the year 2005. Though the study area situated in the river bank of Mahanadi but there is no irrigation facility. Hence, people depend on rainfall for agricultural purpose. It is observed that the irregular rainfall is another factor for the loss of cropping. **Figure 4** indicates that the average annual temperature variation during the year 1987 to 2011. The annual average temperature has regularly increasing from the year 2005. The figure indicates that the average annual temperature has regularly increasing from the year 2007, but decreasing in the year 2011.

Table 1. Soil erosion status of the micro watershed

No	Name	Geographical area (ha.)	Slight erosion (%)	Moderate erosion (%)	Severe erosion	Very severe erosion (%)
1	Mahidharpur	239.12	39.16	45.47		10.88
2	Radhadarsanpur	75.71		71.61		
3	Podapada	68.72	62.89	22.26		
4	Kadalibadi	717.4		78.73		0.94
5	Badehipur	80.51	8.27	70.26		2.44

Climate Change Perception Timelines of Local Communities

Climate Variables	Trends	1960	1970	1980	1990	2000	2010-15
Rainfall Pattern	Erratic						
Rainfall Volume	Decrease						
Temperature	Increase						
Frequency of the Calamity	Increase						
Soil Erosion	Increase						

Figure 5. Timeline graph of people's perception about climate change

Figure 5 defines people's perception regarding climate change. The climate change perception timeline of local community shows that the trends of the climatic variables are increasing. The rainfall pattern has become erratic from the year 2005 onwards and the volume of rainfall also decreasing from the year 1995. The temperature has also increasing after 2005 onwards and the frequency of the calamity also increasing after 1985. The soil erosion process has increasing from the year 1980.

Table 2. Housing status of the study area

House Type	Kadalibadi (%)	Mahidharpur (%)	Podapada (%)	Radhadarsanpur (%)
House Less	5	4		10
Kutcha	76	72	57	65
Semi-Pucca	3	8	36	5
Pucca	16	16	7	20

Source – Primary data collected from ground level by Questionnaire method

Table 2 defines the housing status of the study area. The study area has no urban type of settlement and every village has maximum percentage of kutcha houses and Kadalibadi, Mahidharpur and Radhadarsanpur village has less percentage of semi pucca house but in Podapada village has less percentage of pucca house. The housing status defines the standard of the community in the study area.

Table 3. Average monthly income of the study area

No	Average Monthly Income	Kadalibadi (%)	Mahidharpur (%)	Podapada (%)	Radhadarsanpur (%)
1	Less than 250	66	4	57	25
2	250 - 499	29	48	29	60
3	500 - 1499	3	40	7	5
4	1500 - 2500		4		
5	More than 2500	2	4	7	10

Source – Primary data collected from ground level by Questionnaire method

Table 3 indicates that total household can be differed into 5 types of income group. Most households in Kadalibadi and Podapada village has average monthly income less than 250. Most households in Mahidharpur and Radhadarsanpur village are in 250 to 499 categories. It shows that in Kadalibadi and Podapada village people are economically behind other two villages.

Impact on Livelihood

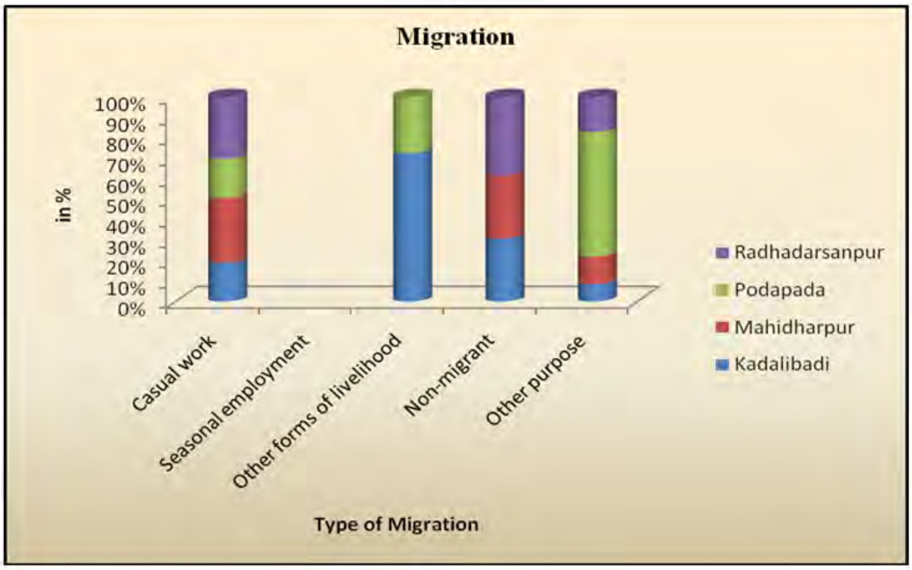

Figure 6. Migration status of the study area

Figure 6 indicates the migration status of the study area. Community has getting heavy loss in agriculture by irregular and non-monsoon rainfall and also unavailability of marketing strategy. There is no cold storage facility for stocking the vegetables. For better economic benefit people migrate to outside of the state and also many of them are working inside state. It is found that from the analysis there are 10 numbers of major problems in the study area and those problems are ranked as priority 1 to 10. The first and major problem which hampers the livelihood is the natural resource management and second is the irrigation because people depend on rainfall for agriculture activity. The all problems are interlinked and the overall livelihood depends on natural resources management of the community.

Community adaptation to cope with the impacts of climate change

Among the natural resource management tools that could be useful in addressing vulnerability to climate change, there are many local-scale environmental management measures that have been applied around the world. The first is soil management approach aimed for increasing the stability and productivity of soil which involves a range of specific techniques such as fallow cycling, forest buffering, selective planting, managed grazing etc. Soil management is recognized as central to combating desertification. The second is water harvesting techniques that have been used as a drought-proofing tool to increase water available for households, irrigation, as well as baseline water flow for watershed restoration. The third is intercropping technique of planting selected food crops within stands of trees to provide local communities with added food security and income through livelihood diversification, while at the same time reducing deforestation and desertification.

Adaptation measures focused on enhancing natural resource management can also more beneficial for the community. Thus, investing in the basic natural resource that sustains their livelihoods may have a direct positive impact on their immediate lives and long-term resilience to climate variability.

The impacts of climate change grouped as three types which are related with natural resources and communities, i.e. ecological, economic and social. Present land use/land cover, geomorphology, geology, ground water prospect, soil and slope layer, the site suitability analysis are important aspects regarding adaptation measures for conserving land and water resources. These adaptation measures are to reduce the impact of climate change and sustainable development of communities with analysis of the present infrastructure, health and communication facility.

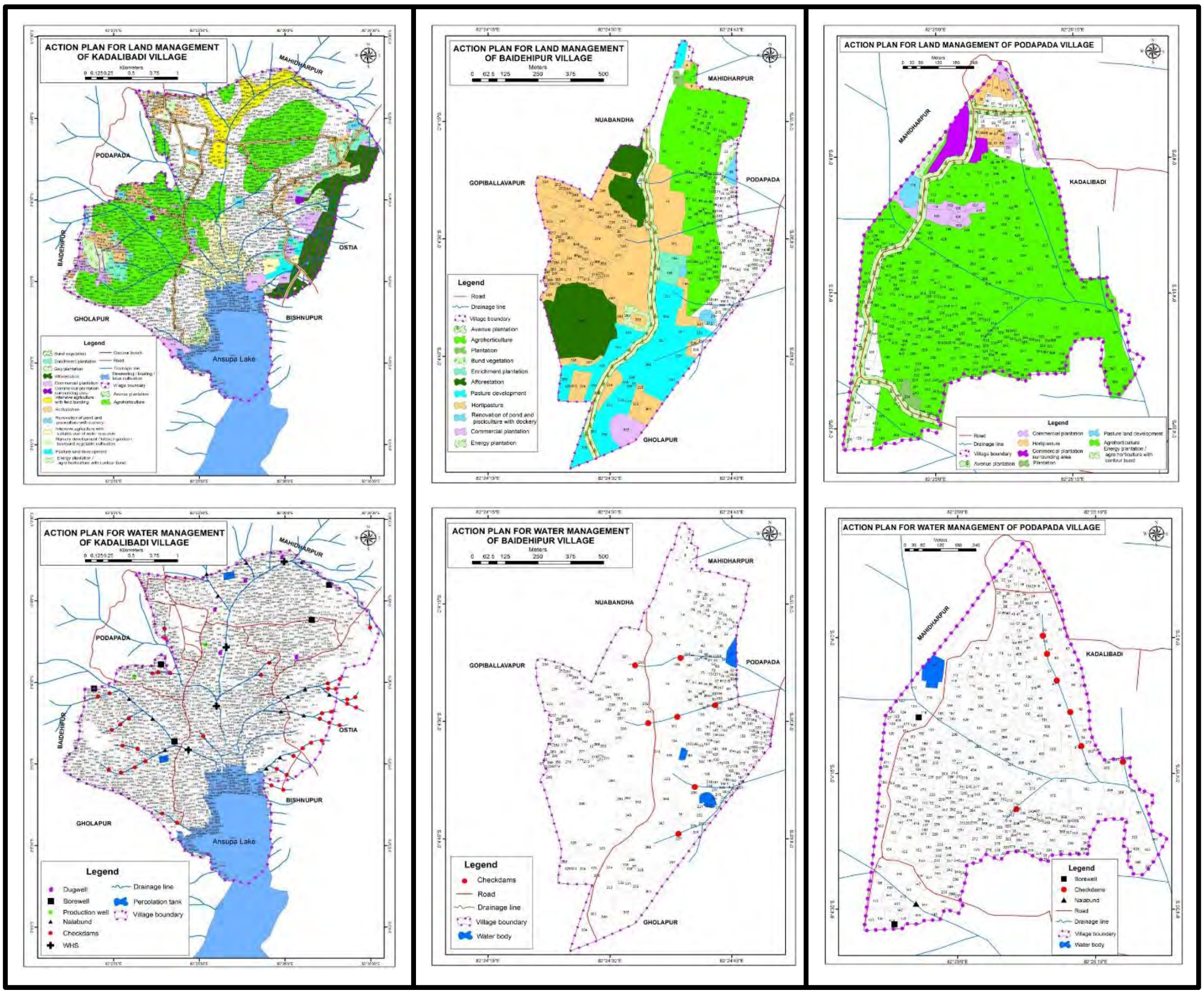

Figure 7. Proposed Adaptation measures for Land and Water Management of Kadalibadi, Baidehipur and Podapada village.

Figure 7 and 8 indicates all the village wise some adaptation measures which are adoptable by household and community level have been proposed i.e. Social fencing may be advisable to restrict the cattle grazing inside this area without any cost involvement or artificial bio fencing is to be provided. An area of 42.55 ha. in Kadalibadi ,9.91 ha. in Baidehipur,7.81 ha. in Mahidharpur and 8.63 ha. in Radhadarsanpur villages have suggested for afforestation in the micro watershed. Afforestation is the planting of trees for commercial purposes, usually on land supporting non-forest types. In open forest areas plantations should be taken up in priority to meet the demand for fuel, fodder and timber of local people. Gap plantation is suggested in an area of 7.35 ha. in Kadalibadi ,6.59 ha. in Mahidharpur village in the open forests (with canopy cover of 10-40%). Since there is a shortage of fuel - wood for domestic use of the people in the micro watershed, it is necessary to take up plantation of fuel - wood species by way of gap filling. The different fuel-wood species to be planted are Chakunda and Gambhari etc. A plantation is a long, artificially established forest, where crops are grown for sale. The barren rocky areas, inside the catchment can be taken up for plantations in consultation with the forest department officials. It has suggested 0.21 ha. in Baidehipur and 0.47 ha. in Podapda village in the Kadalibadi micro watershed. It has suggested for planting Cashew, Sal, Teak, Banyan and Neem etc. The lands with scrub, without scrub, grazing land and also forest area with uplands which come under pediplain and pediment have been planned for commercial plantation. An area of 29.54 ha. in Kadalibadi ,1.21 ha. in Baidehipur ,15.71 ha. in Mahidharpur ,2.44 ha. in Podapada and 3.1 ha. in Radhadarsanpur villages is suggested for commercial plantation in the study area. It has suggested for planting Cashew, Harida, Bahada, Amla, Cedar, Tamarind and Sal etc. and in between these trees Mushroom cultivation can be suggested. The open grazing is to be restricted and stall - feeding is to be encouraged. An area of 23.13 ha. in Kadalibadi,25.73 ha. in Baidehipur, 17.45 ha. in Mahidharpur ,1.41 ha. in Podapada and 1.77 ha. in Radhadarsanpur villages have suggested for this purpose. Horticulture will serve as a sustained source of regular income over very long periods and in addition to fruits, these trees provide fuel, fodder and small timber. Field bunds are suggested on these lands to avoid soil erosion and for moisture conservation in dry seasons. Agro-horticulture is a combination of agriculture and horticulture. It is very diverse in its activities, incorporating plants for food (fruits, vegetables, mushrooms, culinary herbs) and non-food crops (flowers, trees and shrubs, turf-grass, hops, medicinal herbs). The agricultural lands with pediplain area, inside the micro watershed have been suggested for agro - horticultural practices. It has suggested 227.74 ha. in Kadalibadi , 20.82 ha. in Baidehipur, 97.46 ha. in Mahidharpur, 5.83 ha. in Podapada, and 37.77 ha. in Radhadarsanpur villages. The nurseries should plan to produce healthy plants covering timber, fuel, fodder, fruits, non-wood forest produce and even ornamental species having good demand in the locality. It has suggested 4.42 ha. in Kadalibadi, 1.17 ha. in Mahidharpur and 5.31 ha. in Radhadarsanpur villages should developed under backyard vegetable cultivation, kitchen garden and nursery development in household level. The degraded grazing lands may also be used for managing the shortage of fodder for cattle for the following purposes. Provide employment opportunities to the rural poor and strengthen their livelihood resource base & supply fodder for the landless cattle rearers. It has suggested 13.96 ha. in Baidehipur and 4.72 ha. in Kadalibadi villages of the Kadalibadi micro watershed. It has suggested 3 nos. in Baidehipur, 11 nos. in Kadalibadi, 5 nos. in Mahidharpur, 1 nos. in Podapada and 1 nos. in Radhadarsanpur village have suggested for renovation. An area of 0.76 ha. in Baidehipur , 6.53 ha. in Kadalibadi , 3.18 ha. in Mahidharpur ,0.62 ha. in Podapada and 0.24 ha. has suggested for pisciculture and duckery in the micro watershed. The breeding, hatching and rearing of fish should be under controlled. The village people will benefit from the fruit and flower of the tree. It has suggested for planting Neem, Kadamba, Chakunda, Banyan, Mango, Bakula and Gulmohar etc. which make the road very beautiful with their fruit and flower. It has suggested 8 km. in Baidehipur, 15 km. in Kadalibadi, 13 km. in Mahidharpur, 7 km. in Podapada and 7 km. in Radhadarsanpur village in the study area for avenue plantation. There are 5 numbers of bore well, 8 numbers of dug well, 51 numbers LBS/check dam, 4 numbers WHS etc. for water management. These adaptation measures are required to community for depending on climate–sensitive livelihoods and are especially vulnerable to climate change events.

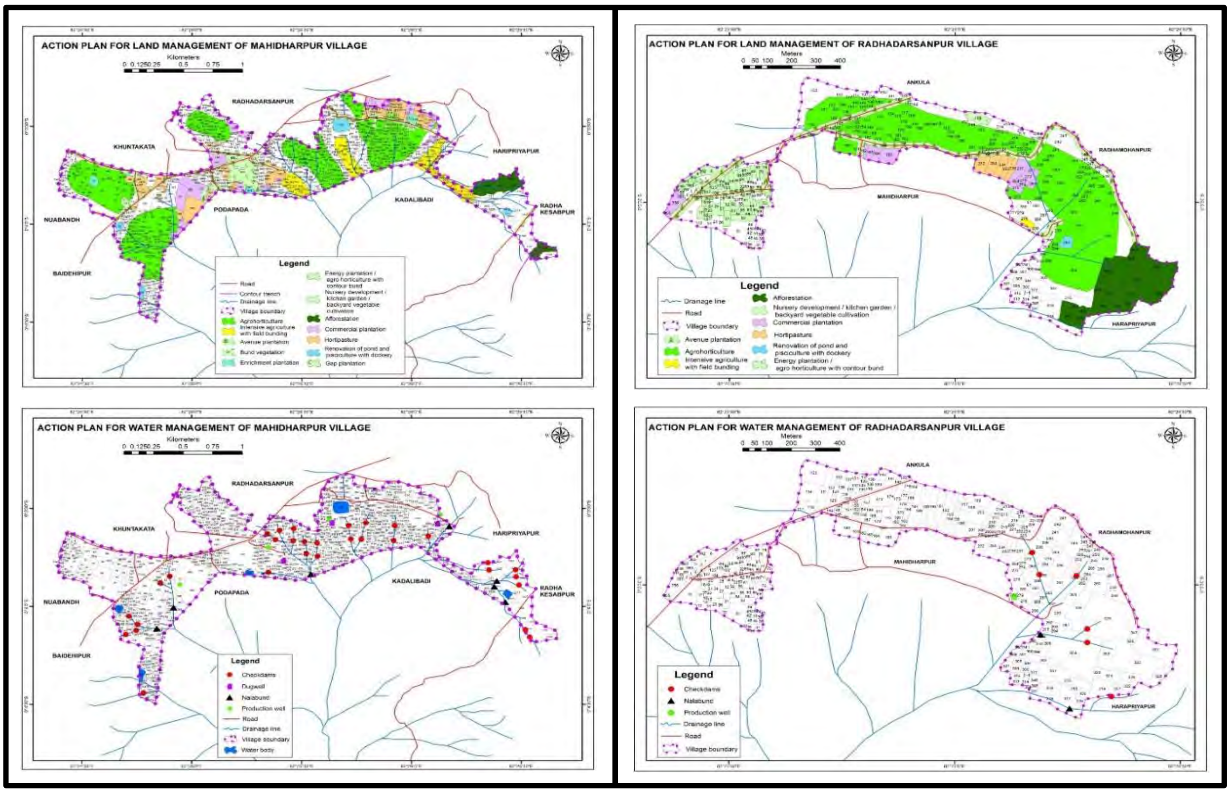

Figure 8. Proposed Adaptation measures for Land and Water Managemen of Mahidharpur and Radhadarsanpur village.

CONCLUSIONS

Community participation is an essential feature of climatic disaster mitigation programmes. Women's self-help groups can play an important role in a large number of measures targeted for mitigation programmes. Employment opportunities outside the agricultural sector such as engaging in construction activities, poultry farming can reduce the impacts of irregular rainfall events on farmers. There is a need to generate community awareness about existing livelihood generation government programs and link the community with respective government departments implementing these schemes. Crop insurance, subsidies and pricing policies related to water and energy could help in coping with the disasters. Enhanced natural resource management is playing a growing role in helping communities at all decision-making levels address the sources of disaster.

Adaptation is moving from a theoretical concern to becoming a central issue in negotiations and policy processes, with international legitimization in the form of a fund to assist developing countries, particularly the least - developed countries, in their efforts to adapt to climatic hazards. Moreover, it has become acknowledged that effective adaptation measures in regions and communities with the greatest vulnerability will likely depend on enhanced natural resource management, consistent with broader sustainable development planning objectives. The proposition shared by the disasters and climate change communities that enhanced natural resource management is a critical tool in reducing vulnerability to climatic hazards. It introduces the practice of natural resource conservation, describing some particular examples of targeted management activities being used to reduce disaster risk. It concludes that the cost-effective integration of multiple sustainable development objectives, disaster risk reduction, conservation of biodiversity, mitigation of climate change and targeting of the poor - could make targeted natural resource management a compelling "win-win" adaptation option, attractive to policymakers and donors, even among cash-strapped developing countries.

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Topic 2. Lake environment under stress and their restoration challenges

THE INCREASE OF FLOATING NET CAGES, AQUACULTURE AREA AND WATER QUALITY IN MANINJAU LAKE, WEST SUMATERA-INDONESIA

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ABSTRACT

This study was carried out to evaluate the increase of floating net cages, aquaculture area and water quality parameter in Maninjau lake. The results showed that the total floating net cages in the years of 2011 (15,000 units), 2012 (15,860 units), 2013 (16,120 units), 2014 (16,580 units) and 2015 (20,608 units) respectively. The location of floating net cages in Maninjau lake still dominant in littoral area, with distance 25 to 100 meter from the edge of the lake. The aquaculture areas which are used for 20,608 units of floating net cages are 113.7 hectares. Meanwhile, based on the size of fish, stocking density and oxygen used for aquaculture, the needed ideal area is 1416,04 hectares. The water quality around floating net cages showed there was no significant differences (p > 0.05) between sampling sites. The results obtained the levels of water transparancy was 1.91-1.99 meter, ammonia 0.35-0.65 mg/L, nitrite 0.210-0.254 mg/L and the total phosphorus 00.32-0.80 mg/L, respectively. We conclude that increasing of floating net cages around Maninjau lake is not suitable with aquaculture area which have negative effect to sanity of fish and water quality parameter.

Keywords: Maninjau Lake, floating net cages, aquaculture area, water quality.

INTRODUCTION

Maninjau lake is one of the fifteen lakes in Indonesia which becomes very important priority lake to be saved (Ministry of Environment of the Republic of Indonesia, 2012) because its plays an important role as hydroelectric plants with power 64 MW and the economic value was IDR 71.8 billion/year, tourism IDR 2.15 billion/year, fishing-capture IDR 1.12 billion/year (LIPI, 2009) and aquaculture activity of tilapia dan carp species by using floating net cages is 4,316 units with an investment of IDR 112 billion/year (Syandri, 2003). The total floating net cages in Maninjau lake for tilapia and carp farming always increase in every year. In the year 2001, the total floating net cages was 3,500 units, while in the year 2013 was increase to 16,120 units (Syandri et al., 2014a; Junaidi et al., 2014).

In this decade, the pressure of the environment condition in Maninjau lake not only caused by the increase of floating net cages (Syandri et al., 2014a; Syandri et al., 2016) but also intensive land used in the catchment area (Machbub, 2010) and used that area for settlement and conversion of paddy fields into fish ponds (Government Agam Regency, 2012; Syandri et al., 2014a). That activity caused directly increase of the organic loading in Maninjau lake and also have effect to the decrease of water quality (Henny, 2009; Yusuf et al., 2011; Junaidi et al., 2014; Syandri et al., 2015a) and the diversity of fish species (Dina et al., 2011; Syandri et al., 2014b).

In this work, we examined the used of Maninjau lake for the aquaculture of tilapia (*Oreochromis niloticus*) and carp (*Cyprinus carpio*) in the floating net cages in Agam Regency of West Sumatera Province, Indonesia. We analyze the increase of floating net cages, aquaculture area and some physico-chemical parameters.

METHODS

Study area

The Maninjau lake with a surface area 9,996 hectare is located in Tanjung Raya district of Agam Regency, West Sumatera Province - Indonesia, the geographical position E:00^{0}12'26.63"-S:0^{o}25'02.80" and E:100^{0}07'43.74"-S:100^{o}16'22.48", located at altitude 461.50 meter above sea level. The regional climate is classified as Schmidth-Ferguson Climate. This lake has characteristics of climate types A and annually receives an average rainfall 3,490 mm, with two distinct seasonal periods of precipitation: a dry season that normally extends between April and September, and rainy season from October to March. During this study, the monthly precipitations of the rainy season varied between 120 and 200 mm, and in the dry season between 10 and 50 mm.

Data floating net cages and the aquaculture area

The data of floating net cages was collected from the year 2011 to 2014 from Department of Marine and Fisheries science of Agam Regency, whereas the data in the year 2015 was calculated directly from the field. The calculation of aquaculture area in each village were analyzed based on the stocking density of fish, water temperature (26^{o}C), oxygen used/kg fish/hour (0,7 g O_2/kg fish/ hour), elevation of lake (461 meter above sea level), and the ratio of the oxygen used with the available oxygen in the water body. The amount of oxygen used which generated in one day under normal circumstances with water temperature is 26°C = 16.67g O_2 / m^2 which consists of photosynthesis 14.33g and 2.34g of air diffusion, to fish oxygen only provided 22% (3.67 g O_2 / m^2).

ARCGIS 10.1 programme was used for making aquaculture area maps of floating net cages in Maninjau lake. The data used in this study is a multi-temporal satellite image Landsat TM / ETM + and SPOT image of the 4 during the period from the year 2014 to 2015, DEM SRTM resolution of 17 meter.

The water samples were collected every three months in the year of 2015 in four sites from the lake at 1.0 meter depth: A – *Sungai Batang*; B – *Sungai Tampang*; C – *Bayur*; D – *Koto Kaciek* (Figure 1). The water samples in 2-litre per bottles were maintained at 4°C for up to 24 hours. The following physico-chemical parameters of water was analyzed; temperature, pH, amount of ammonia, nitrite, total phosphorus and dissolved oxygen according to the methods described by APHA (APHA, 1998).

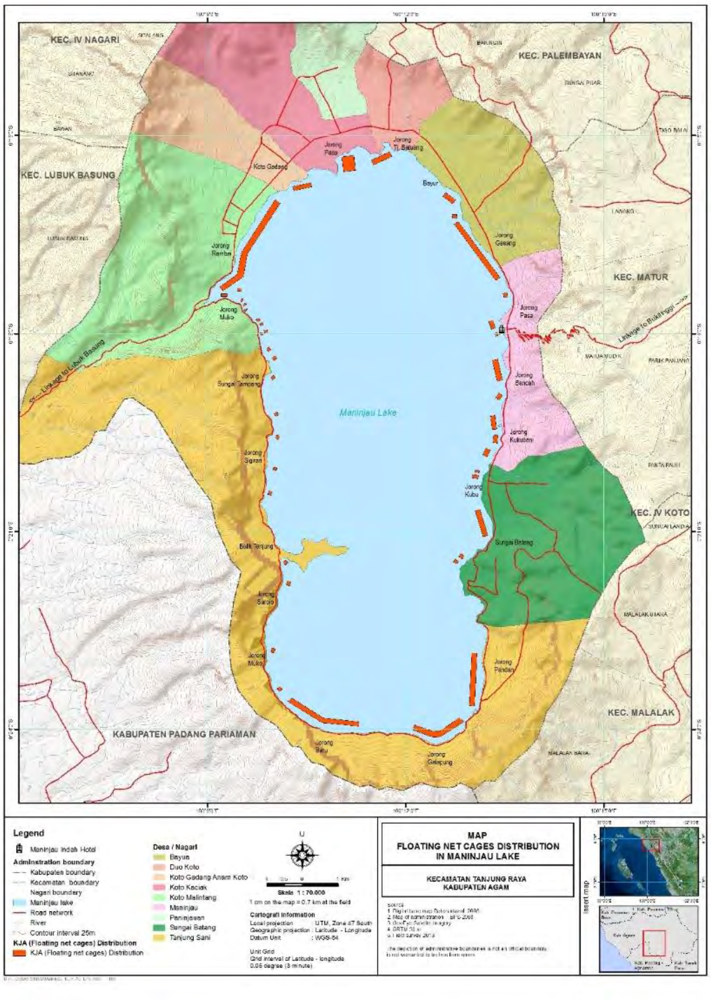

Figure 1. Map of study area in Maninjau lake of Agam Regency-Indonesia

RESULTS AND DISCUSSIONS

The total of floating net cages

The total of floating net cages from the year 2011 to 2015 at Maninjau lake in the district of Tanjung Raya, Agam Regency (**Table 1**).

Table 1. The total of floating net cages in Maninjau lake (units)

No	Village	2011	2012	2013	2014	2015
1	Maninjau	1531	1,743	1,795	1,843	1,597
2	Bayua	2324	2,349	2,425	2,856	4,178
3	II Koto	816	907	1,050	866	866
4	Koto Kaciek	1013	1,013	1,060	1,260	1,409
5	Koto Gadang	202	202	190	200	200
6	Koto Malintang	2448	3,768	3,850	3,650	3,612
7	Tanjung Sani	5194	4,140	4,000	4,108	5,461
8	Sungai Batang	1472	1,741	1,750	1,797	3,285
	Total	15,000	15,860	16,120	16,580	20,608

Sources : Data in the year 2011- 2014 was secondary data and the year 2015 is the primary data.

If we compared the total floating net cages in the year 2015 with the year 2011-2014, the unit was increased in every year. The increased of floating net cages has positive impact on fish farmers, fish feed traders, fish sales and other labor. According to (Nasution et al, 2011; Syandri et al., 2015a), business of tilapia and carp cultured on the floating net cages in Maninjau lake have positive impact to increase society income in the district of Tanjung Raya, Agam Regency. Meanwhile, that activity have negative impact on the water quality parameter (Henny, 2009; Syandri et al., 2014a; Syandri et al., 2015a; Syandri et al., 2016).

The aquaculture area around floating net cages in Maninjau lake still dominant in littoral area with distance 25 to 100 meter from the edge of the lake. Floating net cages was placed on water depth between 10 to 50 meter. The aquaculture area of floating net cages in *Sungai Batang*, *Tanjung Sani*, *Bayur*, and *Koto Kaciek* village are presented in **Figure 2,3,4,5**, respectively.

The aquaculture areas which are used for 20,608 units of floating net cages are 113.7 hectares. Meanwhile, based on the size of fish, stocking density and oxygen used for aquaculture, the needed ideal area is 1416,04 hectares (**Table 2**).

Table 2. The total floating net cages, aquaculture area in the field and ideal aquaculture area

Village	Floating net cages (units)	Aquaculture area in the field (hectare)	Ideal aquaculture area (hectare)
Maninjau	1,597	11.98	109.73
Bayur	4,178	31.34	287.08
II Koto	866	6.49	59.50
Koto Kaciek	1,409	10.57	96.82
Koto Gadang VI Koto	200	1.60	13.75
Koto Malintang	3,612	27.09	248.20
Tanjung Sani	5,461	40.95	375.24
Sungai Batang	3,285	24.63	225.72
Total	20,608	113.7	1,416.04

Source: Primary survey data, October 2015.

Figure 2. The aquaculture area of floating net cages in *Sungai Batang* village

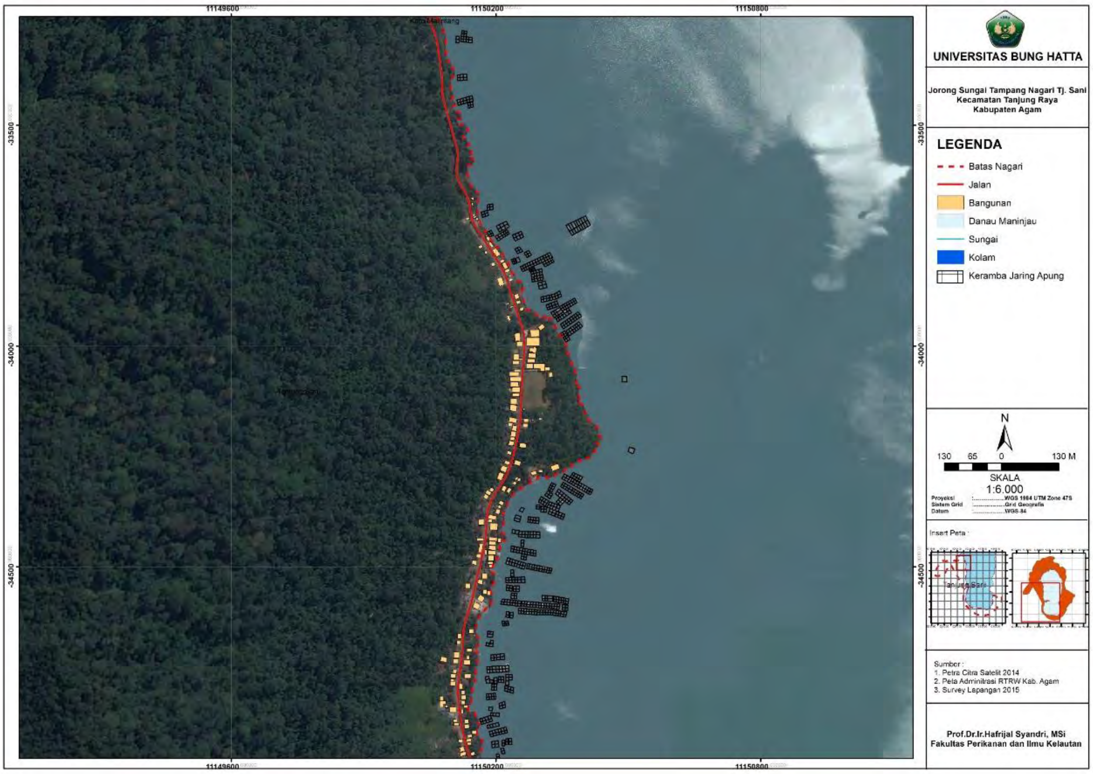

Figure 3. The aquaculture area of floating net cages in *Tanjung Sani* Village

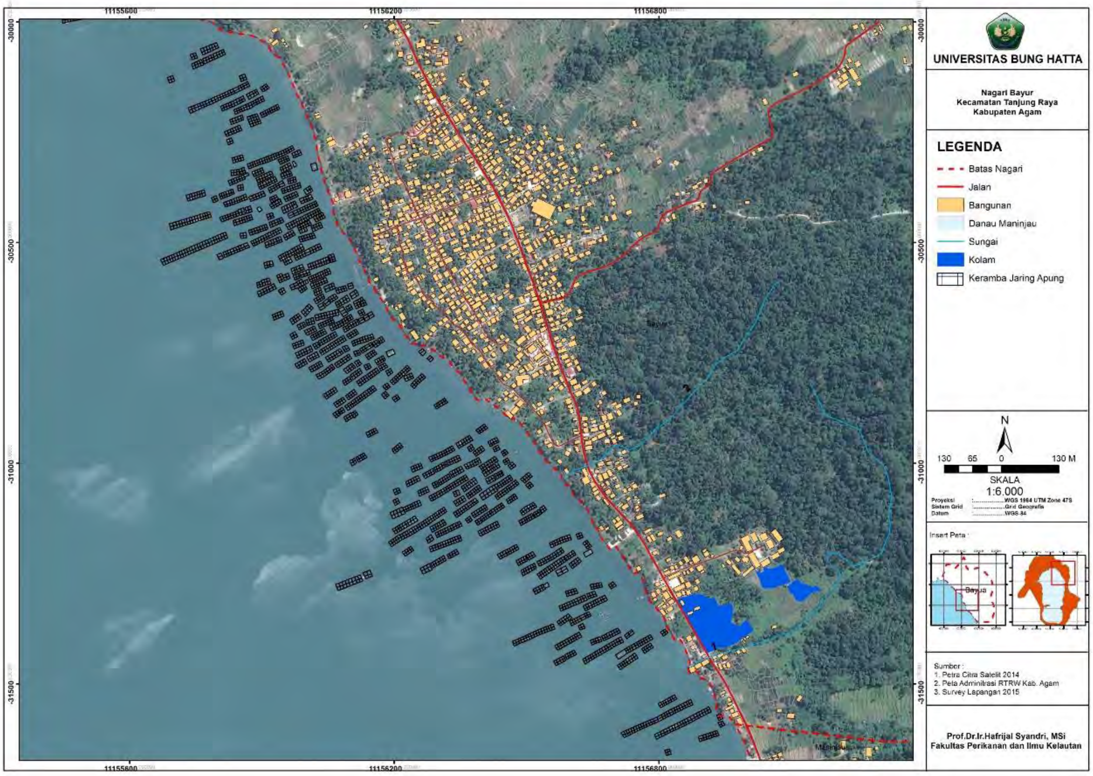

Figure 4. The aquaculture area of floating net cages in *Bayur* Village

Figure 5. The aquaculture area of floating net cages in *Koto Kaciek* Village

Water quality parameters in the floating net cages

The results on the physico-chemical parameters of the water samples from the four sampling sites on the fish farm in Maninjau lake are presented in **Table 3**. The average water transparancy in all sampling site varied between 1.91 m and 1.99 m. The temperature showed that strong fluctuations over the study periode (**Table 3**), especially in the *Bayur* site (26-30°C). Throughout the experiment, the amount of pH, ammonia, nitrite, total phosphorous and dissloved oxygen in Maninjau lake did not showed significantly different between sampling site ($p > 0.05$). The levels of pH varied from 7.29 to 8.10, with the higher means for the dominant of floating net cages (site C and D) (**Table 3**). The ammonia content varied from 0.35 to 0.65 mg/L, with higher means for the site A. The nitrite content varied from 0.210 to 0.254 mg/L, with similar means for all sites. The total phosphorus content ranged from 0.32 to 0.80 mg/L, and the highest concentrations refer to Sungai Tampang, due to many activities around floting net cages. Dissolved oxygen content was slightly varied between sampling sites, with average values between 6.14 and 6.80 mg/L (**Table 3**). The water quality of floating net cages was directly influences the productivity and sanity of fish (Henny, 2009; Syandri et al., 2015a; Syandri et al., 2016). According to Asir and Pulatsu (2008), intensive aquacultural activity causes release the organic waste and soluble inorganic nutrients, such as nitrogen and phosphorus content, which can cause or accelerate eutrophication in natural aquatic systems. Nutrient release (especially nitrogen and phosphorus) consists of dissolved and particulate fraction. The differences water quality parameters is not only between species, but also within species, depend on feeds employed, feeding regimes, culture systems, productivity, sanity of the fish, and environmental parameters of the local area (Gorlach-Lira, 2013; Junaidi et al., 2014; Syandri et al., 2015a; Syandri et al., 2016).

Table 3. Water quality parameters in floating net cages

	Site A	Site B	Site C	Site D
	Water transparancy (m)			
Mean	1.96	1.98	1.99	1.91
Standart deviation	0.14	0.07	0.10	0.10
Median	1.85	1.98	2.01	1.94
Min-Max	1.80-2.10	1.90-2.08	1.85-2.10	1.90-2.00
	Temperature (^{0}C)			
Mean	27.75	28.5	28.25	28.5.
Standart deviation	1.25	1.29	1.70	1.29
Median	28.5	28.5	28.5	28.5
Min-Max	26.0-29.0	27-30	26-30	27-30
	pH			
Mean	7.72	7.67	7.95	7.86
Standart deviation	0.35	0.33	0.23	0.16
Median	7.59	7.70	7.95	7.92
Min-Max	7.29-8.10	7.30-8.0	7.70-8.20	7.70-8.10
	Ammonia (mg/L)			
Mean	0.59	0.41	0.37	0.46
Standart deviation	0.06	0.03	0.02	0.05
Median	0.60	0.41	0.375	0.465
Min-Max	0.50-0.65	0.38-0.45	0.35-0.41	0.40-0.51
	Nitrite (mg/L)			
Mean	0.167	0.144	0.232	0.165
Standart deviation	0.017	0.044	0.018	0.047
Median	0.165	0.126	0.233	0.175
Min-Max	0.148-0.190	0.144-0.210	0.210-0.254	0.100-0.210
	Total phosphorus (mg/L)			
Mean	0.565	0.716	0.485	0.392
Standart deviation	0.031	0.111	0.050	0.056
Median	0.540	0.705	0.475	0.400
Min-Max	0.53-0.60	0.59-0.80	0.44-0.55	0.32-0.45
	Dissolved Oxygen (mg/L)			
Mean	6.307	6.375	6.140	6.805
Standart deviation	0.617	0.302	0.384	0.308
Median	6.41	6.355	5.985	6.66
Min-Max	5.49-6.92	6.07-6.72	5.50-6.45	6.37-7.08

A = Sungai Batang; B = Sungai Tampang; C = Bayur; D = Koto Kaciek

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BIO-ACCUMULATION OF MERCURY IN LAKE TALIWANG, WEST NUSA TENGGARA: IMPACT OF TRADITIONAL GOLD MINING

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ABSTRACT

*Traditional gold mining in Taliwang used to flow their waste directly to environment. Traditional gold mining separate gold from it rock using mercury for chelatting. Lake Taliwang recently suffered from mercury pollution and high sedimentation. Organisms live in the lake accumulating mercury in their body. The aim of this research was studying the amount of bio-accumulation in plankton, fishes, sediments, and measuring water quality of Lake Taliwang. Sampling took place in Lake Taliwang, West Nusa Tenggara in February 2016. There were four species of fishes taken: Damselfish (*Anabas testudineus*); Nile Tilapia (*Oreochromis niloticus*); Eel (*Monopterus albus*); and Snakehead murrel (*Channa striatus*). Sediments and plankton was collected in inlet; intensive; and outlet area. Water quality measured while collecting sediment samples. Water quality measured were Secchi depth, basin depth, water temperature, pH, Dissolved Oxygen, CO_2, and alkalinity. Samples were analyzed using mercury analyzer in LPPT UGM. Only fish livers were analyzed for mercury concentration. The average highest mercury bio-accumulation is in liver of damselfish, there were 204.6 µg/kg. Snakehead murrel has 38.4 µg/kg; Nile Tilapia 9.3 µg/kg; and Eel 1.3 µg/kg. The higher concentration of mercury in sediment was in inlet area. The lowest concentration of mercury was in outlet area. Plankton in Lake Taliwang also accumulate mercury. The accumulation of mercury in plankton higher in inlet than outlet.*

Keywords: bioaccumulation, Lake Taliwang, traditional gold mining

INTRODUCTION

Lake Taliwang is a tropical shallow lake situated in West Sumbawa, West Nusa Tenggara. This lake is located in geographic position between 9°41’20” - 9°43’00” E and 117°51’-17°52’ S. The size of Lake Taliwang is 8.12 km^2, water volume was 170.000.000 m^3. The maximum depth is 1.87 m and average depth is 1.73 m. There are many illegal gold mining activities in south-eastern sector of Lake Taliwang (BLH, 2014). Lake Taliwang recently suffered from mercury pollution and high sedimentation. Lake Taliwang lost 5 m of its depth and 300 acres of its size in 10 years. Traditional gold mining started from 2010 until now. Traditional gold mining separated gold from its rock using mercury thus organisms live in the lake accumulating mercury in their bodies. This method called amalgation. Amalgation is illegal in some countries while in Indonesia traditional people still use this method as it cheaper. Miners flow the waste directly into the environment (Gammons *et al.,* 2006).

Lake Taliwang used to be very clean. Local people can drink Lake Taliwang water directly. Now they only use the lake for fisheries. A few local species of fish catches from the lake are sold to the local community. Four dominant species of local fish were Damsel-fish (*Anabas testudineus*); Nile Tilapia (*Oreochromis niloticus*); Eel (*Monopterus albus*); and Snake-head murrel (*Channa striatus*). All of these fish species consumed by Taliwang community. This case will threaten public health. Human as the top predator accumulate the highest amount of mercury. Accumulation occurred as mercury progesively enter organism system and almost none are secreted throughout the body (Connel & Miller, 1995). The aim of this research is to study bio-accumulation in fish, plankton and sediments, and to find the wether there are difference of mercury concentration between *inlet*, intensive and *outlet* in Lake Taliwang.

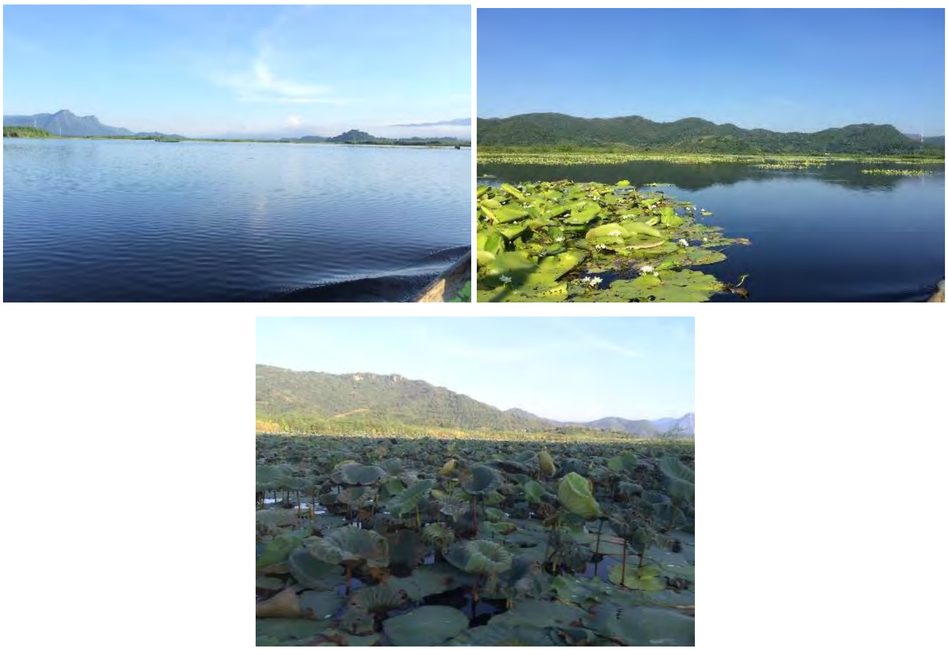

Figure 1. These pictures show different parts of Lake Taliwang. Left-top picture is an open water in intensive area, right-top picture shows weeds covered in intensive area. Bottom picture shows weeds covered the whole water in outlet area.

METHODS

The sampling technique of this research was purposive sampling in three locations: inlet; intensive (center); and outlet zone. In each location, we use random sampling. This research aims to study the amount of mercury bioaccumulation in plankton, fish, sediments, and measuring water quality of Lake Taliwang. Sampling took place in Lake Taliwang, West Nusa Tenggara in February 2016. The main laboratory kit used in this research is mercury analyzer in LPPT UGM.

Sediments and plankton was collected in inlet; utilization; and outlet area. There were two samples of each fish species were taken. Plankton samples were collected using water sampler. Fifty litters of water filtered then fixated with Formalin 4%. Sediment samples were collected using Ekman dredges. Water quality measured while collecting sediment samples. Water quality measured were Secchi depth using secchi disc, basin depth using water sampler, water temperature using mercury thermometer, pH using pH meter, Dissolved Oxygen, CO_2, and alkalinity with two replications. Dissolved Oxygen, CO_2, and alkalinity were measured using microwinkler method. Mercury in organisms was analyzed using mercury analyzer in LPPT UGM, only liver from fish were analyzed.

RESULTS AND DISCUSSIONS

Traditional gold mining in Taliwang used to flow their waste directly to environment. Traditional gold mining separate gold from it rock using mercury for chelatting. Lake Taliwang recently suffered from mercury pollution and high sedimentation. Results shown that organisms live in the lake accumulating mercury in their body. There were four species of fishes taken: Damsel-fish (*Anabas testudineus*); Nile Tilapia (*Oreochromis niloticus*); Eel (*Monopterus albus*); and Snake-head murrel (*Canna striatus*). The rate highest mercury bio-accumulation is in liver of damselfish, there were 204.6 µg/kg. Snake-head murrel has 38.4 µg/kg; Nile Tilapia 9.3 µg/kg; and Eel 1.3 µg/kg (**Table. 1**). Kaonga et al., 2001 informed there is effects of lead on reproduction systems in invertebrates. The Highest concentration of mercury is in damsel-fish because its feeding habits. This fish is omnivorous fish. They like to stir sediment to find food. Sediment is where mercury found the most.

The highest concentration of mercury in sediment is in inlet area (**Fig. 2**). This happens because mercury tend to bound with sediment (Malczyk et al. 2015). Water quality showed Lake Taliwang dissolved oxygen is very low (**Fig. 3**). It shows high rate of decomposition due to high sedimentation. Only fish with labyrinth organ can survive live in Lake Taliwang. All the fish found in Lake Taliwang have this organ and addapted to poor DO. Water pH is alkaline due to Lake Taliwang situated in karst ecosystem. Karst ecosystem are well known as vulnerable ecosystem. When karst forest cutted down, the top soil will easily wash away by rain. As in Lake Taliwang watershed, people cutted down forest for gold minning. Watershed then suplly high amount of sediment.

Table 1. Concentration of mercury in four fish species. A table with headings spanning two columns and containing notes[a]. Leave 6 pts of space between the caption and the top of the table.

Fish	Local name	Species	Inlet	Outlet
Damselfish	Betok	*A. testudineus*	251.25	157.95
Nile Tilapia	Nila	*O. niloticus*	12.61	6.05
Eel	Belut	*M. Albus*	1.86	0.66
Snakehead murrel	Gabus	*C. striatus*	10.69	66.14

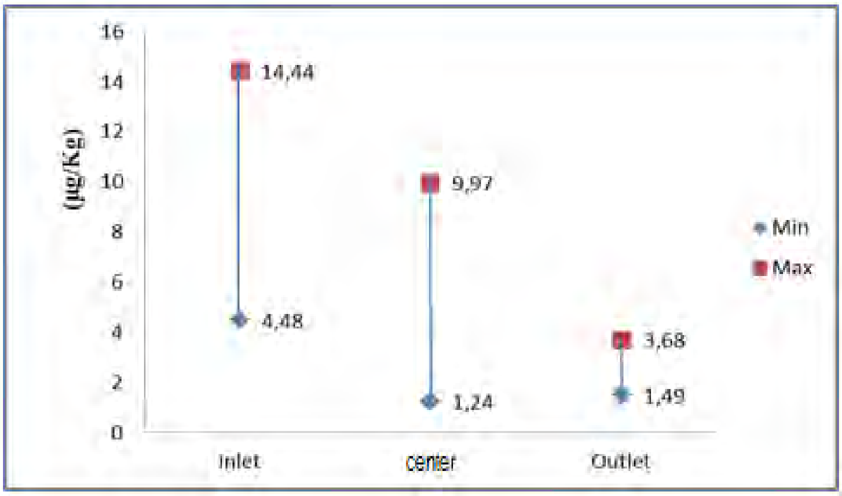

Figure 2. Mercury concentration in sediments.

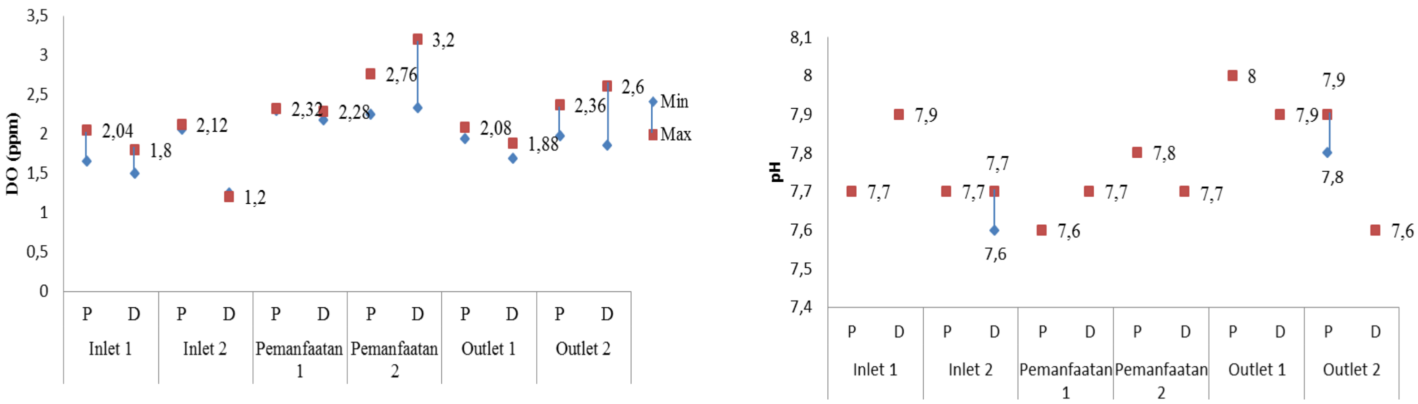

Figure 3. Left picture is DO concentration in each zone. Right picture is water pH

Concentration of mercury in plankton were inlet 6.30 µg/kg and outlet 4.53 µg/kg. Mercury concentration that recommended in open waters: 0.002 ppm; sediment: 0.5 -1.0 ppm (Anonimous 2001) but according to Ministry of Environment Regulation is 0.001 ppm (Anonimous 2004). FAO/WHO by 2011 limit of mercury consumed by human are 4 µg/Kg per week. People who consumed food contaminated by methyl-mercury will rise its effects as human are to predator (Alfian 2006). The effect might not show directly. Over exposed of mercury can caused cancer for human. As we can say fish from Lake Taliwang can not be consumed. Mercury concentration in one fish gives more mercury allowed for consumed in a week.

CONCLUSIONS

There were bioaccumulations in Lake Taliwang. There were differences of mercury concentrations in each fish species. The distribution of mercury concentration at *inlet* higher than *oulet.*

ACKNOWLEDGMENT

The first author is thankful to Dwinda and Amanda for the assistance.

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INCREASING HUMAN-ENVIRONMENTAL STRESSES ON CITARUM BASIN IN THE PAST DECADES

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ABSTRACT

The study site is the Jatiluhur Reservoir – Downstream area of the Citarum Basin. The study focus concerns the impacts of economic development in the past decades related to food production and availability of water resources in the study area that have undergone significant changes creating severe human-environmental stresses. The study approach and analysis were based on observed hydrologic data to reveal simple water balance of the basin and the long-term trends due to changing environment that further be related to food production capacity in the past decades. Some discussions on necessary management options were then given to deal with the sustainability issue by introducing the crop-water productivity strategy as means to ensure efficient use of available resources. Key findings on long term trends of decreasing rainfall of 28.3 mm/year that correspond to the increasing river discharge of 13.8 mm/year, indicated deterioration of the basin environment with increasing runoff coefficient in the past decades. On the demand side the basin is characterized by increasing population and the needs to support Jakarta water supply that require to increase food production under deterioration environment. Therefore, some basin management strategy need to be implemented as suggested.

Keywords: Human-environmental stresses, land and water degradation, simple water balance, food production and food security, Citarum

INTRODUCTION

Availability of water resources in a region is key factor to the agricultural production system, especially to ensure the national food security such as in providing staple food crops. This is true for Indonesia, a country blessed with abundant of water resources. However, with large population presently at 250 million people and still growing at a relatively high rate at 1.49% per year, producing enough food has always been a major challenge. To make matter worse is the imbalance of available resources and levels of economic development between regions in the country. Java Island with only 6.5% of land area of Indonesia and 4.5% of the country water resources is residence of some 60% of the country population. The increase of population in Java Island had been significant since early twentieth century. The Boeke report (Boeke, 1941) stated that there was a tenfold population increase in Java Island from four million people in 1800 to forty million in 1930 when the first population census was conducted in Indonesia, with the implication of significant increase to provide sufficient amount of needed staple food for the people. Therefore, Java Island has a long history as rice producing island and technical irrigation system had been introduced since the beginning of the Twentieth Century, while rice culture itself had been known for a millennium as depicted in a relief at Borobudur Temple. The Citarum river is one of the major river basins in Java Island that has the most developed water resources system in the country, with multi purposed dams for rice irrigation, flood control, domestic and industrial water supply, and electric power generation. The amount of water being utilized in the system already passed 50% of its annual river flow. **Figure 1** depicts the recent distribution of water utilization of the Citarum river. The river has been known with three large cascaded reservoirs that store about six billion cubic meters of water that generate electricity up to1,937.5 MWs, food production center for rice and fishes, and provide raw water amounting to 16 m^3/s for Jakarta drinking water treatment plant that serve almost 80 % of domestic water needs for Jakarta population.

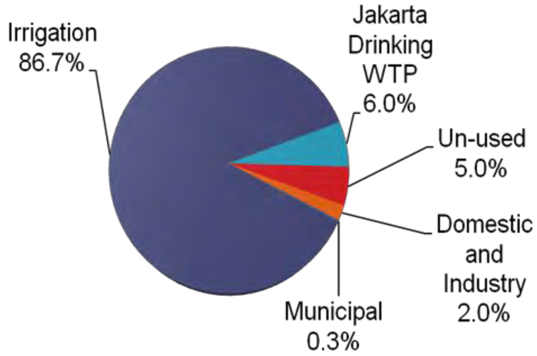


Figure 1. Distribution of Citarum reservoir water utilizations (Source: Perum Jasa Tirta II, 2014)

Increasing Human-Environmental Stresses were derived from high population in the basin area crossing six districts and three municipalities that were residence to about fifteen million people in 2010 that has become a major concern in economic development related to food production and availability of water resources. There has been a long-time concern to know the sustainability of these nexus resources for the Citarum basin, as it has become the rice producing areas with significant contribution to the country food supply system, while its proximity to good infrastructures supporting economic development in the region has threatened its very existence.

METHODS

A simple and direct approach conducted to assess quantity of water resources of the Citarum basin as the study area and how this limited resource to meet the increasing demand for human and environmental needs, especially in comparing the decreasing amount of water available due to progress of land use change and the likely climate change, and the increasing demands for food production system under pressing population increase. Estimate of water quantity in the basin will be based on a simple water budget from the biophysical description of the basin that is derived from trends of observed rainfall and river discharge data, and food production capacity is assessed from series of rice and fish productions in the past decades with their trends. Other demands of water that include increasing domestic and industrial water uses of the adjacent regions and the needs to neutralize grey water from pollutions to the environment would be considered as increasing human-environmental stresses that need to be dealt with to ensure a healthy and sustainable ecosystem services. Discussions on necessary management options will then be given.

RESULTS AND DISCUSSIONS

The Citarum basin has maintained good hydrologic telemetering system with main station and supported by 11 rainfall stations, three water level recordings, one station repeater and 17 warning stations. **Figure 2** showed the long-term trends of basin rainfall and river discharge at Plumbon hydrometric station from observed data between 1922-2008 that indicated a decreasing of annual rainfall of about 28.3 mm/year from the linear trend that was corresponding to increasing river discharge of 13.8 mm/year. Apparently, these rainfall and river discharge trends not only indicated the deterioration of basin biophysical conditions with reduce infiltration capacity and the consequence of increasing runoff coefficient, but also the likely occurrence of climate change with decreasing basin rainfall.

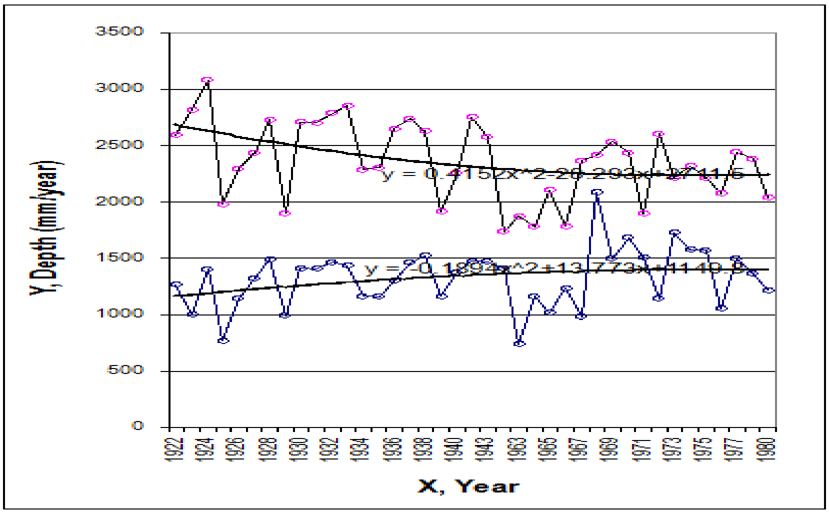


Figure 2. Trends of annual rainfall and river discharge at Citarum-Plumbon station

Table 1. Linear regression discharge (Y) from respected rainfall (X) in mm at Citarum-Plumbon station with basin area 4061.0 km^2 and simple water balance of the basin.

Month	Regression:	Rainfall [mm/mo]	Estimated discharge [m^3/s]	Basin losses [mm/mo]
Jan	Y=81.493+0.183(X)	293	236.1	130.0
Feb	Y=83.421+0.162(X)	255	245.9	106.7
Mar	Y=18.121+0.450(X)	304	264.4	173.0
Apr	Y=48.678+0.426(X)	262	285.3	78.0
May	Y=28.454+0.485(X)	184	211.5	50.1
Jun	Y=53.164+0.258(X)	106	114.1	30.6
Jul	Y=38.647+0.236(X)	85	67.9	34.9
Aug	Y=35.915+0.152(X)	70	51.4	35.3
Sep	Y=28.799+0.160(X)	104	50.4	67.2
Oct	Y=42.378+0.127(X)	191	96.2	127.2
Nov	Y=25.882+0.282(X)	291	174.4	117.9
Dec	Y=100.542+0.154(X)	297	256.1	128.9
Annual	Y=532.463+0.295(X)	2443	171.1	1096.4

Table 1 presents linear regressions of monthly river discharges from respected basin rainfall at Plumbon station, and indicate that these trends of rainfall and river discharge were also occurring in the seasonal patterns. Also presented are the simple water balance of the basin for the monthly rainfall and the generated river discharge at Plumbon hydrometric station and respected basin losses from evapotranspiration.

Water resources systems development in the Citarum basin

Series of large-scale water resources systems had been developed in Java Island since early nineteenth century, during the Dutch Colonial period. Many are still in operation along with the newly constructed after Indonesia independence in 1945. Within the Citarum basin areas, these old water infrastructures include the Walahar Irrigation System that was built in 1925 and irrigates 80,000 ha of paddy field with gated weir across Citarum River at Karawang District, about 60 km from its estuary. The Salam Darma Irrigation System constructed in 1930 with weir across Cipunegara River in Subang District, about 40 km from its estuary and designed to irrigate 37,000 ha of paddy field. The systems were operated separately and rely on run-off water from the rivers that limit the cropping intensity to 130%, as not all of the paddy field area in the systems could be irrigated during dry season and became the source of conflicts among that fight for the needed water. To increase this cropping intensity amidst the existing potential paddy fields had encouraged the national government to build suitable reservoirs that could extent irrigation in dry seasons. These development of water resources system in the Citarum basin was first based on the study paper written by van Blomenstein that was presented in Paris Seminar (1948) with the title “Integrated Water Resources Development in the Western Part of Java Island“ (Idrus *et al*., 2014). The intended irrigation command areas covered about 514,000 ha. of paddy fields that included some adjacent irrigation systems. Reviewed by van Schravendijk in 1956 in the form of “Integrated Water Resources Development in Citarum River Basin” indicated an irrigation of 240,000 ha of paddy field (Idrus *et al*., 2014). Realization of these plans was the construction of series of cascaded reservoirs along the Citarum river as given on **Table 2** with descriptions of these three large cascaded reservoirs.

Table 2. Description of the three cascaded large dams in Citarum basin.

Description:	Unit	Jatiluhur	Cirata	Saguling
Construction completed	-	1967	1984	1988
Maximum water level	m	107	220	643
Total volume	million m^3	3000	2160	881
Effective volume	million m^3	2100	796	609
Sedimentation	million m^3	140	1177	200
Electric power generation	GWh/yr	790	1426	2156

Source: Revised from Indonesia Power (2011)

Each of the dams was constructed with different main purposes. Jatiluhur-Juanda dam being the first constructed in time of scarcity not long after the country independence and revolution era was realization of long term plan to harness the might of Citarum river with targeted benefits of a multi-purpose project, among others:

1) Flood every year inundated and endanger fertile area (20,000 ha) could be controlled and minimized,
2) Technically irrigated of agricultural area of 240,000 ha with two crops annually,
3) Hydro-power electric generation with installed capacity of 187.5 MW,
4) Raw water supply for domestic, municipal, and industry.

General data of Jatiluhur dam:	
River name	Citarum
Catchment area	4.500 km^2
Annual mean runoff	5.5 billion m^3
Construction	1958 – 1967
Spillway structure type	Morning glory
Reservoir area at 107 m normal level	83 km^2
Reservoir perimeter at 107 m	150 km

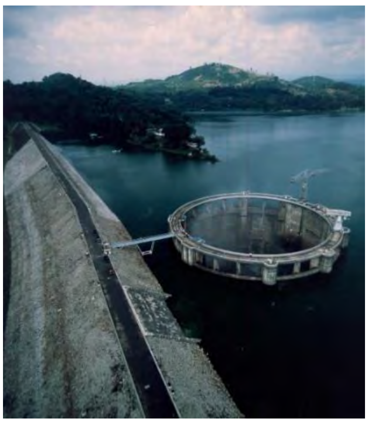


Figure 3. View of Jatiluhur dam with Morning Glory spillway structure with general data.

The operation of the Jatiluhur-Juanda dam was mandated to Jasa Tirta II Public Corporation under Government Regulation No. 94/1999, with scope of Works:

1) Exploitate and maintain water resources infrastructures and hydro-electric power generation
2) Water resources and hydro-electric power utilization,
3) Watershed management, such as: control, develop, and utilize water resources in Citarum River Basin
4) Rehabilitate water resources infrastructures and hydro-electric power plant as well.

The Company Aim and Objective (Government Regulation No. 94 of 1999, article 6):

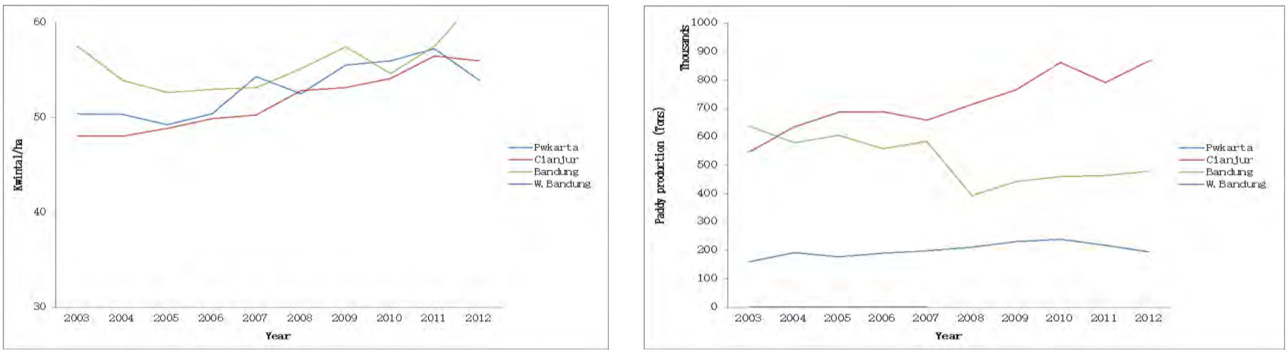
AIM: To operate water for public utilization and its qualifying water sources which sufficient to fulfill the necessity of all the people and to carry out certain tasks given by the government in managing the river basin and/or its sources including to give information, recommendation, consultation and guidance;

OBJECTIVE: to develop the national economy by participating in the program of national development in water management, water source and electric power.

There is another potential to build large hydroelectric power plant with 47 MW power downstream from Saguling dam that is at Rajamandala site and certainly many with smaller capacities.

Food production of Citarum basin

Rice productivity in the past decade for the region has not increased significantly, while total rice productions that was also determined by the total land being harvested have reduced significantly, especially for Bandung district (**Figure 4**).



(a) (b)

Figure 4. Trend of paddy productivity (a) and production (b) in Citarum command area (Source: West Java Agricultural Food Crops Service Office, 2014).

Trend of freshwater fish production as given on **Figure 5** showed a significant increase for Purwakarta district where the Jatiluhur dam reside indicated expansion of the floating fish caged culture that affected the water quality of the reservoir's water greatly. West Java fish production is dominated by cultured fish in floating fish caged (KJA= *karamba jaring apung*) which is operated mostly in open surface waters, such as in lakes and reservoirs.

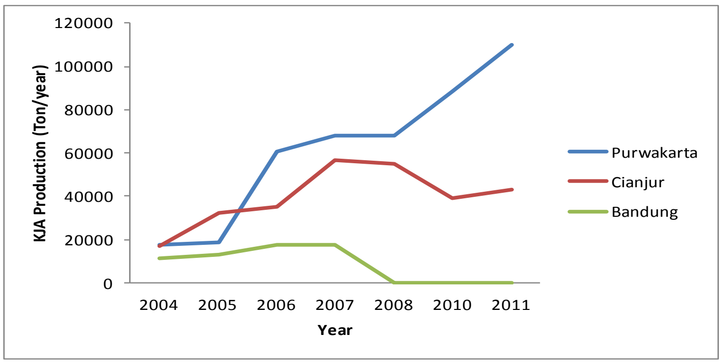


Figure 5. Trend of fish production in West Java, 2004-2011 (Source: Perum Jasa Tirta II)

Land degradation and water related hazards

Land and water degradation have become common environmental issues in developing areas in Indonesia, including for Citarum basin, and some issues could be noted for Citarum basin as rice producing center are as follows:

(i) degradation and loss of carrying capacity of water and land resources due to increased pollutions;
(ii) loss of irrigation infrastructure capacity in the middle of climate variability and change; and
(iii) determination of proper agricultural development strategy.

Land and forest degradation have been the most obvious phenomenon in Citarum basin with loss of forest cover reached 86% between 71,750 hectares in 2000 to about 9,899 hectares in 2009, and increasing critical land to 202 thousand hectares. During the period, increase of community settlements is from 81,688 hectares in 2000 to 176,442 hectares in 2009 (Ministry of Public Works, 2012). These progresses are as depicted in **Figure 6**. Obviously, the increase of settlements were not only catered by conversion of forest areas, but also taking the agricultural lands, including the irrigated rice fields that will reduce food production capacity of the areas from the upstream of Citarum basin down to Purwakarta and Karawang areas where most conversions occur from rice fields.

Figure 6. Trends of areas of forest cover and settlements in Citarum basin 2000-2009 (Source: Ministry of Public Works, 2012).

Agus and Irawan (2006) noted that land conversion from paddy field to other uses in Java Island was 484 thousand hectares in 1981-1999 and 107 thousand hectares in 1999-2002, and these trends of losing paddy fields was also occurring in the outer islands in the later period. This paddy fields conversion in Java island was mostly occurring in the Citarum irrigation service areas that certainly threaten to cut food production capacity of the areas. Conservative estimate of paddy fields loss was 30% or 30 thousand hectares occurring in Citarum basin.

Increasing human environmental stresses

Population pressure, especially in Java island, need to generate substantial food supply for its overcrowded people, conditioned by degraded water and land resources, increased extreme weather events with floods and droughts, increased pollution and exposure to water- and vector-borne diseases with consequences in decreased water availability and quality. These resource management issues had been adopted into the Water Law (Decree No.7/2004) that has been cancelled by the Constitution Commission on Feb.18th, 2015. A new water law would be necessary to be enacted soon to fill in the lack of legal certainty, especially to related water corporations. The seasonal nature of rainfall climate of the Citarum basin with abundance of water during wet rainy seasons and drought stricken dry seasons has limit water resources availability. The likely climate change with decreasing annual rainfalls and land use changes that increase surface runoff are indicators of increasing human environmental stresses to the basin that would certainly need serious attention from the different parties, including academicians, natural and technical researchers.

There are strong evidences that Citarum water quality has been deteriorating severely as observed from the three cascaded reservoirs. Very serious water quality conditions were experienced in the upper reservoirs of Saguling and Cirata that received heavy pollution wash loads from all different sources, including agricultural, domestic and municipal, livestock and fisheries that already pass the water quality standard. **Figure 7** below showed the water quality of Cirata reservoir over a period of

2007 to 2013. Regular fish kills were experienced on these upper reservoirs during certain drought conditions due to upwelling events.

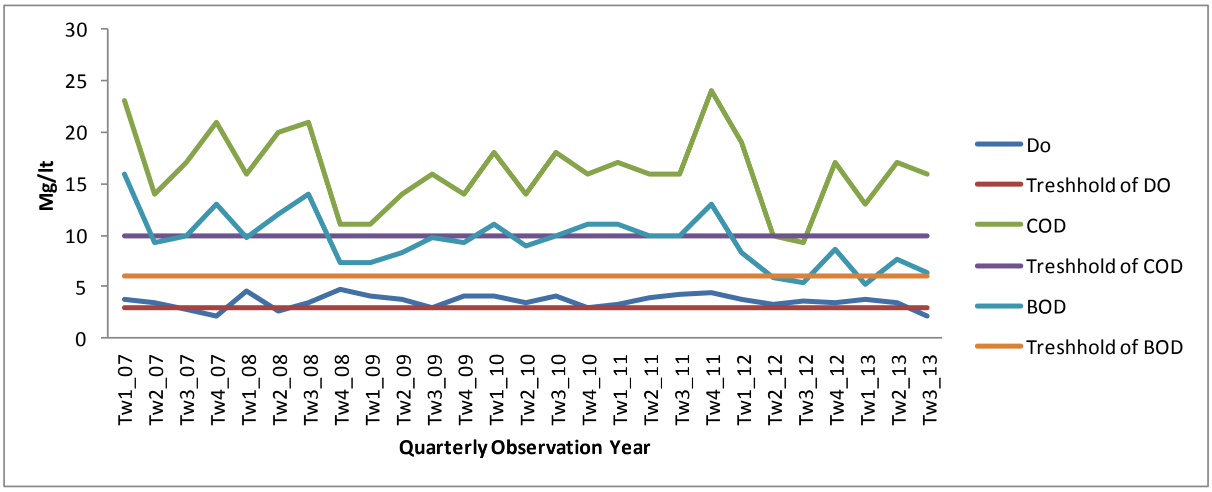


Figure 7. Sampled water quality at Cirata reservoir 2007-2013 (Source: PJB BPWC, 2014)

Downstream area of the Citarum River as given by Jatiluhur-Juanda reservoir where water quality is very important that determine the quality of raw water for WTP (water treatment plant) drinking water in Jakarta. The fortunate position being the lower one of the three cascaded reservoirs has safe the quality of water in Jatiluhur reservoir, as most of the sediment and pollutant loads from upstream areas already deposited along the way from Bandung City to Saguling and Cirata reservoirs. However, these downstream positions due to its vicinity to economic development areas also has attracted investors to make use the reservoirs as highly profitable enterprises in industrial estates, other commercial activities and also in cultured freshwater fisheries using floating cages that have burgeoning in the past decades. Strict regulations from dam operators and local government have been enforced, however effectiveness still need to be observed.

To improve water quality, it is necessary to routinely conduct water quality monitoring of the Citarum river through PROKASIH Program (Clean River Program). Routine water quality measurements at 25 points along Citarum river, 10 points along Bekasi river, other 13 points at non PROKASIH Program, 13 points on West Tarum Canal (WTC) and five points on North and East Tarum Main Canal, as well as industrial liquid waste quality analysis for 110 industries, and the out-put should be reported to related institutions periodically.

Challenging food security for the Citarum basin

Some questions still need to be asked concerning sustainability of food production capacity of Citarum basin and its implication to national food security, as follows:

- where and how is the state of agricultural land productivity in Citarum basin?
- what are the urgent issues need to be tackled with respect to its impacts on national food security?
- what are the factors that influence in the agricultural production subsector?
- what is suitable strategy and policy need to be taken?

The challenge of sustainable agricultural productivity in Citarum basin and its impact on national food security rely on the existing rice paddy areas. Citarum basin with its major reservoirs support almost one-half of paddy areas in West Java and contribute about 17% to national rice production. With the estimate of losing 30 thousand hectares would be equivalent to about 10% of rice production capacity, while at the same time there is increasing food demand. Therefore, contribution of Citarum basin to national food security would certainly reduce below the traditional 17%. Some ideas on challenges and opportunities of Citarum basin resource management:

- Coordination among sectors and stakeholders (as the Citarum cascaded dams are managed by the National Government and hydroelectric power generations by Indonesia Power corporate company);
- Improving bio-physical condition by introducing environmentally friendly technologies-ecotechnology adopting ecohydrology approach/concept;

- Become national priority program of integrated approaches, including adoption of Water-Energy-Food nexus concept.
- Introduce payment for environmental services in basin management
- Multi-stakeholder coordination through Townhall type meetings
- Community participation and empowerment

Establishment of conservation model such as an arboretum or protected forest for improving infiltration capacity at Wayang Windu spring area, and a cooperation between Indonesia Forest Company (PT. Perhutani), Government of Bandung District, NGO and communities was realized covering 40 hectares area. Some resource management strategy need to be taken to face this challenge of limiting nexus resources under increasing demand, among others, is with adoption of crop-water productivity strategy to ensure efficient water use practices taking advantage of local resources. Main efforts to accomplish this strategy are to improve productivity by producing more from less resource. In case of rice production, some practices have been implemented in the study area, such as the SRI (systems of rice intensification) and some of indigenous modifications that were adjusted to local conditions, including the organic rice farming systems.

CONCLUSIONS

Environmental degradation of the Citarum basin has reached an alarming level with rate of sedimentation has already passed the design threshold and has reduced significantly the economic life of the reservoirs system. Accumulation of sediment that mixed with wastes from industrial, domestic, and fish culture operations in the water bodies has threaten the sustainability of the existing reservoir infrastructures, disrupting hydropower operation and other environmental services. Water quality of the Saguling reservoir already reached level D criteria of limited uses, even for agricultural irrigation purposes. Key findings from simple water balance analysis are the long-term trends with decreasing rainfall of 28.3 mm/year that is accompanied by increasing river discharge of 13.8 mm/year, indicated deterioration of the basin environment with increasing runoff coefficient.

Challenges of Citarum basin management is to ensure sustainability of the water resources and also the food production systems to contribute to the national food security. To accomplish these, it is necessary to establish integrated and collaborative management framework among stakeholders that can enhance environmental services of the Citarum basin and its water resources system through restoration of the reservoirs capacity using science based eco-technology.

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HEAVY METALS CONTENT OF SEDIMENT AND MOLLUSC IN LAKE MANINJAU, WEST SUMATERA

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ABSTRACT

*Some evidence indicates that Lake Maninjau has been suffering from pollution in the last decade due to increasing activities either in the catchment area or in the lake waters. The aim of the research was to determine the stage of pollution of the lake through observation of Pb, Cd, Hg, Cr, and Fe content in the sediment and molluscs in some river mouths entering to the lake. The three times observations were conducted from March to September 2015 in seven (7) river mouths of Lake Maninjau. Sediment and molluscs of each location were sampled for metals content analyses. Some water quality characteristics were also observed. The molluscs are Corbicula moltkiana, Melanoides sp., and Anodonta woodiana. The metal contents of the sediment were Pb: 0.004-11.230 mg kg^{-1}; Cd: 0.005-0.019 mg kg^{-1}; Hg 0.0006-0.0590 mg kg^{-1}; Cr: undetected (<0.004 mg kg^{-1}); and Fe: 1.173-3.573 mg kg^{-1}. While the metals content in the molluscs were Pb: 0.002-4.170 mg kg^{-1}; Cd: 0.013-1.032 mg kg^{-1}; Hg: 0.0004- 0.1062 mg kg^{-1}; Cr: 0.040-0.098 mg kg^{-1}; and Fe: 0.040-0.948 mg kg^{-1}. The content of lead (Pb) and cadmium (Cd) in the lake sediment and molluscs (*C. moltkiana *and* A. woodiana*) were considered high or polluted. The lake water quality in the 7 stations seemed to be quite turbid with high content of nitrogen and phosphorus.*

Keywords: heavy metals, Maninjau, mollusc, sediment

INTRODUCTION

Lake Maninjau, is a tecto-vulcanic lake in West Sumatra and is supplied by about 88 small rivers or creeks from its catchment area, 34 rivers of it (38.6%) are flowing all year around (Fakhruddin et al. 2002). The lake was considered polluted, at least by nutrient and organic matter from various activities, including in lake activity, such as fish cage culture (Sulawesty et al., 2011; Marganof et al., 2007), and the activities in the catchment area including settlement, town activities, rice field and other agriculture, and plantation. Some mass fish killed were reported once or twice every year (Kompas, 2016; Tempo, 2014; NGI, 2014).

Heavy metals contamination of the inland waters has been widely reported, among others concerning heavy metals in the reservoirs (Wu et al., 2014; Dabrowska, 2016), and in the lakes (Tampubolon et al., 2013; Hidayah et al., 2014). In Lake Maninjau, there has been reported the peresence of heavy metals in the water column and sediment (Saputra et al., 2010), and also the containing of heavy metals in the sediment suroundings the cage cultures (Yusuf et al., 2011). Since some heavy metals may be released from the settlement or domestic wastes and town activities (Weiner, 2008) among others are from cars and motors repaired shops and form transportation activities (Metcalf & Eddy, 1991), it is important to determine the heavy metals content of the lake, especially in the sediments of some river mouths inflowing to the lake and in the biota, especially molluscs. The objective of the research was to determine the stage of pollution of the lake through observation the content of Pb, Cd, Hg, Cr, and Fe in the sediment and molluscs in some river mouths of the Lake Maninjau.

METHODS

Sediment samples and mollusc were taken from 7 sampling points or stations, namely St. 1 (Muko-Muko); St. 2 (Talao Tubo); St. 3 (Muaro Talao); St. 4 (Muaro Tanjung); St. 5 (Bayur); St. 6 (Muaro Pisang); and St. 7 (Pandan), which each is the mouth of the inflowing river (**Fig. 1**). Observations and samplings were conducted three times in the period of March to September 2015. Sediment samples were collected by Ekman grab, about 1500 g sediment from each station was oven dried at 30 ^{o}C and then extracted for further analyses. The sediment was then analysed using Atomic Absorption Spectrometer (AAS) Hitachi Z6100 for lead (Pb), cadmium (Cd), total chromium (Cr), total mercury (Hg) and iron (Fe) content according to APHA (2012). Samples of mollusc were also collected using Ekman grab from each station, and then separated from sediment using surber net. The mollusc selected for heavy metals analyses are the kinds which are common to be consumed by local peoples, i.e. the species of *Corbicula moltkiana* (pensi), *Melanoides tuberculate* (trumpet snail), and *Anodonta woodiana* (swan-mussel). A sufficient amount of the shell content of each species were taken, and oven dried at 30 ^oC, weighted, and then extracted for heavy metals analyses as for the sediment.

Some water quality characteristics, namely turbidity, pH, and dissolved oxygen (DO) were also observed. Turbidity, pH, and DO were observed using Water Quality Checker (HORIBA U 20).

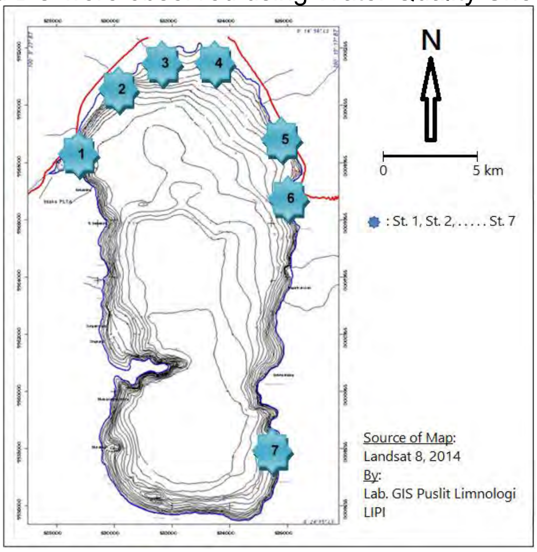

Figure 1. Location of observations (sampling stations) at Lake Maninjau, West Sumatra (From: Syawal et al. 2016)

RESULTS AND DISCUSSIONS

Heavy metals in the sediment

Iron (Fe) concentration in the sediment averaging between 1.17 – 3.57 mg/kg. There is no quite different between stations except relatively low concentration at St. 5 (Bayur) (**Fig. 2**). The highest iron content was found in the sediment of St. 1 (Muko Muko) (**Table 1**). The iron content in the sediment is considered low and non-polluted compared to the sediment criteria of US EPA, Region V that set up iron <17 mg/kg as non-polluted, and >25 mg/kg as heavily polluted in the sediment of Great Lake Harbors (Department of Water Resources State of California - DWRSC, 1995).

Table 1. Average concentration (mg/kg) of iron (Fe), lead (Pb), cadmium (Cd), and mercury (Hg) in the sediment of each observation stations in Lake Maninjau (From: Syawal et al., 2016)

Location	**Concentration in sediment (mg kg^{-1})**				
	Fe	**Pb**	**Cd**	**Cr**	**Hg**
St. 1 (Muko-Muko)	3.570 ± 0.500	4.150 ± 0.090	0.019 ± 0.027	<0.04	0.001 ± 0.001
St. 2 (Talao Tubo)	2.940 ± 0.280	4.634 ± 0.304	0.005 ± 0.003	<0.04	0.0006 ± 0.0005
St. 3 (Muaro Talao)	2.823 ± 0.289	0.004 ± 0.002	0.006 ± 0.002	<0.04	0.045 ± 0.007
St. 4 (Muaro Tanjung)	2.453 ± 0.491	0.004 ± 0.002	0.005 ± 0.002	<0.04	0.059 ± 0.013
St. 5 (Bayur)	1.173 ± 0.170	1.740 ± 0.121	0.006 ± 0.003	<0.04	0.0004±0.0005
St. 6 (Muaro Pisang)	3.037 ± 0.520	11.23 ± 1.004	0.004 ± 0.002	<0.04	0.004 ± 0.001
St. 7 (Pandan)	3.047 ± 0.083	0.005 ± 0.003	0.006 ± 0.003	<0.04	0.009 ± 0.001
Heavily polluted for Great Lake Harbors (US-EPA Region V*)	25	0.06	0.006	0.075	0.001
Lowest Effect Level (Burton, 2002)	-	31.0	0.60	26.0	0.20

*DWRSC (1995).

Lead (Pb) content of the sediment were highly varied among stations, relatively high in St. 1, St. 2, St. 5, and St. 6, from 1.74 mg/kg (St. 5) up to 11.230 mg/kg (St. 6, Muaro Pisang), and very low in St. 3, St. 4 and St. 7 (**Fig. 2** and **Table 1**). According to US EPA Region V for classifying sediments of Greta Lakes Harbors (DWRS, 1995), lead content in the sediment >0.06 mg/kg is considered heavily polluted (Table 2). However, lowest effect level (LEL) of lead for aquatic biota according to Burton (2002) is 31 mg/kg, thus the lead content in the sediment at all stations were basically still below the standard that may harm the environment.

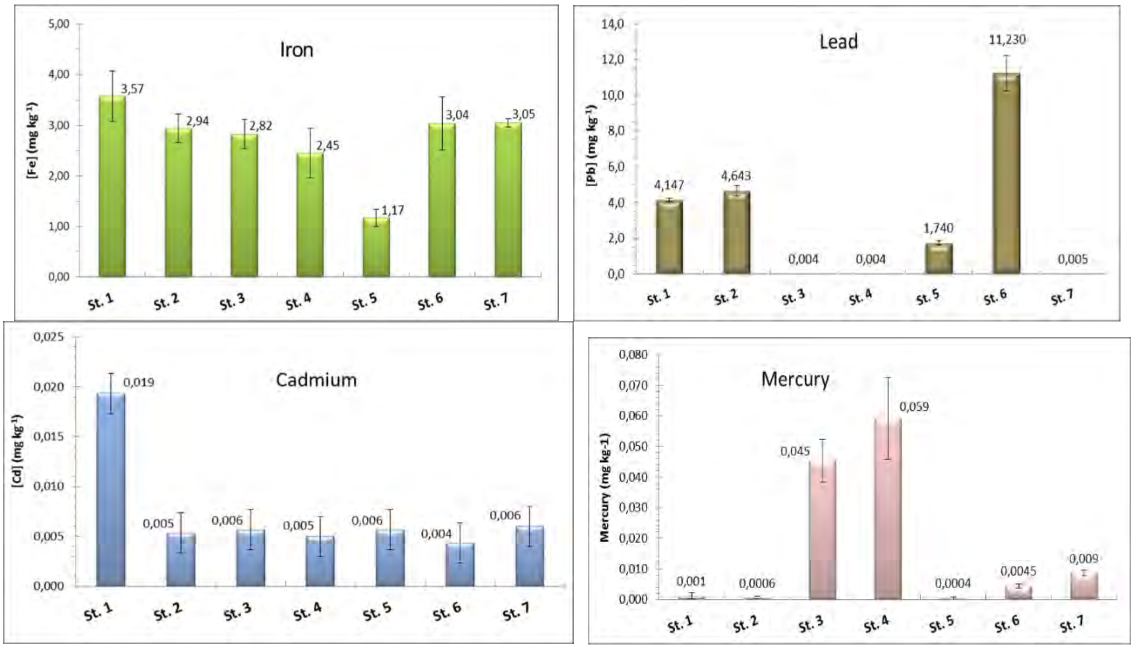

Figure 2. Concentration (mg/kg) of iron (Fe), lead (Pb), cadmium (Cd), and mercury (Hg) in the sediment of each observation stations in Lake Maninjau (From: Syawal et al. 2016)

Cadmium (Cd) in the sediments were observed between 0.004 – 0.019 mg/kg (**Table 1**). The highest content of cadmium in the sediment was observed in St. 1 (Muko Muko), while in the other stations the Cd concentrations were not quite different in the amount of around 0.004-0.006 mg/kg. The cadmium content in the sediment of St. 1 was classified as heavily polluted (>0.006 mg/kg) by US EPA Region V for Great Lakes Harbors, however, were considered low, far below the lowest effect level (LEL) of Burton (2002) which is 0.600 mg/kg (**Table 1**).

Analysis of total chromium (Cr) in the sediment sample of all stations resulting of undetected or less than 0.04 mg/kg. This finding indicates that there is no chromium pollution from activities in the catchment area of the lake, especially from the respected catchment area of the rivers of observation.

The mercury (Hg) content of the sediments varies among stations, from around 0.0004 mg/kg at St. 5 (Bayur) up to about 0.059 mg/kg at St. 4 (Muaro Tanjung) (**Table 1**). At the St. 3 (Muaro Talo), mercury content of the sediment was also quite high compare to other stations (**Fig. 2**). According to US EPA Region V for Great Lakes Harbors (DWRSC, 1995), mercury content of sediment more than 0.001 mg/kg was considered heavily polluted. However, the mercury content of the sediment at all stations were still far below 0,20 mg/kg as the Lowest Effect Level (LEL) for aquatic biota (Burton, 2002) and were not considered polluted.

Heavy metals in the molluscs

In general, heavy metals content of trumpet snail (*Melanoides tuberculate*) was the lowest compare to the other two molluscs, except for iron, Fe (**Table 2**). While pensi (*Corbicula moltkiana*) having the highest lead (Pb) content (up to 4.17 mg/kg dry weight), and swan-mussel (*Anondonta woodiana*) having the highest cadmium (Cd) and mercury (Hg) content (up to 1.032 mgCd/kg dry weight and 0.1062 mgHg/kg dry weight). Lead (Pb) content of swan-mussel was also considered high compared to in other two molluscs. Perhaps the larger individual size of *A. woodiana* compared to the other two species of mollusc, caused the higher accumulation in its tissue.

Iron concentration in *A. woodiana* quite varies among stations, the highest was at St. 1 (Muko Muko), while in *M. tuberculata* the highest was at St. 7 (Pandan). Iron concentration in *C. moltkiana* which were considered low, the highest was at St. 2 (**Fig. 2**). Provisional maximum tolerable daily intake *(*PMTDI) for iron (Fe) is 0.8 mg/kg of body weight (WHO, 2011), it is meant that the maximum intake for person with a body weight of 20 kg only around 16 mg of Fe per day. The highest content of iron in the mollusc found was 0.948 mg/kg, i.e. in *A. woodiana* from St. 1 (**Fig. 2**), and it is still allowable to consume up to 16 kg/day of the mollusc. Therefore, the iron content in all the three mollusc species was categorized as low and safe.

Table 2. Range and average (parenthetically) concentration (mg/kg) of iron (Fe), lead (Pb), cadmium (Cd), and mercury (Hg) in the molluscs in Lake Maninjau

Mollusc species	Fe (mg/kg)	Pb (mg/kg)	Cd (mg/kg)	Cr (mg/kg)	Hg (mg/kg)
Corbicula moltkiana	0.040-0.224 (0.129)	0.002-**4.170** (0.893)	0.236-0.580 (0.440)	<0.040 (<0.040)	0.0004-0.0502 (0.0188)
Melanoides tuberculata	0.120-0.640 (0.347)	0.002-0.098 (0.032)	0.013-0.580 (0.261)	<0.040 (<0.040)	0.0004-0.0668 (0.0137)
Anodonta woodiana	0.320-0.948 (0.632)	0.093-**3.224** (0.807)	0.662-**1.032** (0.831)	0.040-0.098 (0.057)	0.0049-**0.1062** (0.0478)

The concentration of total chromium (Cr) in the three species of mollusc in general were undetected (<0.04 mg/kg) at all stations, except in *A. woodiana* at St. 1, St. 5 and St. 7 total chromium were detected relatively low about 0.056 – 0.098 mg/kg (**Fig. 2**).

Lead (Pb) content in *C. moltkiana* was the highest and found at St. 1 (Muko Muko). The highest lead in *A. woodiana* was also found at St. 1 (Muko Muko) (**Fig. 2**). According to WHO (2011), provisional maximum tolerable daily intake *(*PMTDI) for lead (Pb) is 1.9 µg/kg of body weight or it is only about 0.036 mg Pb for person with body weight of 20 kg. Considering the standard, the mollusc containing of about 0.19 mgPb/kg was categorized as high, since the allowable maximum daily intake was only about 200 g of the mollusc. Therefore, lead content in *C. moltkiana* and in *A. woodiana* from all stations except from St. 5 (Bayur) were considered high and the two species of mollusc from the mention locations are having very high risk to be consumed.

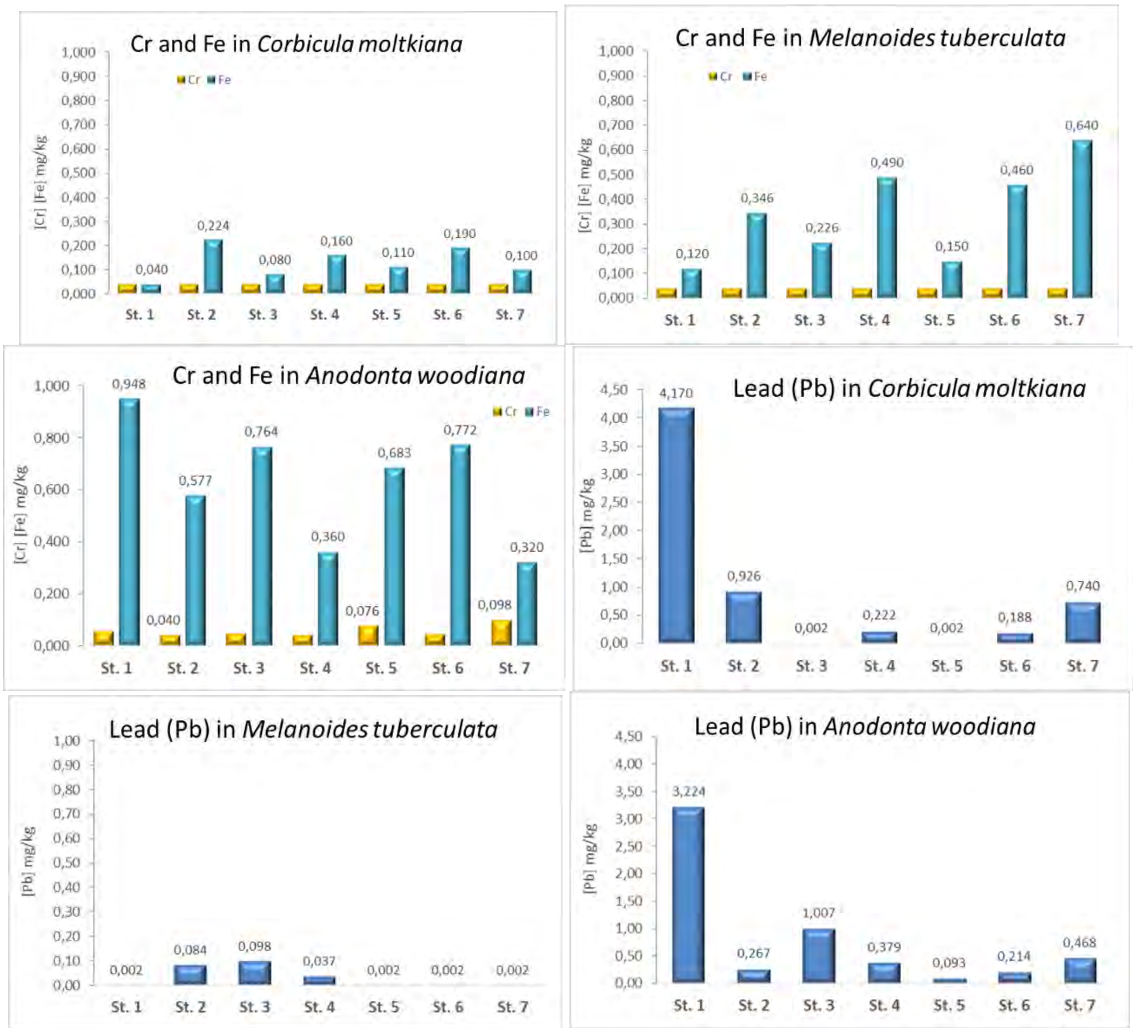

Figure 2. Chromium (Cr), iron (Fe) and lead (Pb) content of *Corbicula moltkiana*, *Melanoides tuberculata*, and *Anodonta woodiana* at each observation stations in Lake Maninjau

Provisional maximum tolerable daily intake *(*PMTDI) for cadmium (Cd) is 0.8 µg/kg of body weight (WHO, 2011), or it is only about 0.016 mg Cd for person with body weight of 20 kg. To have about 200 g of mollusc per day and it is still below the PMTDI, the mollusc should contain Cd in an amount of as much as 0.08 mgCd/kg. Therefore, cadmium content in the three species of mollusc from all stations were considered high and not in compliance with the WHO standard to be consumed, except for *M. tuberculata* from St. 1 (Muko Muko), St. 3 (Muara Talao) and St. 5 (Bayur) (**Fig. 3**).
For mercury (Hg), the provisional tolerable weekly intake (PTWI) is 1.6 µg/kg of body weight (WHO, 2011), or it is only about 0.032 mg Hg for person with body weight of 20 kg. For the mollusc containing 0.11 mgHg/kg, the tolerable weekly intake is as much as 320 g. Therefore, the mercury content of all the three species from all stations, in general were still in compliance with the WHO standard, with the precaution limited number to be consumed for *A. woodiana* from St. 1 and St. 7 (**Fig. 3**). In this two locations (Muko Muko and Pandan), the mercury content of *A. woodiana* was the highest, i.e. around 0.1 mg/kg.

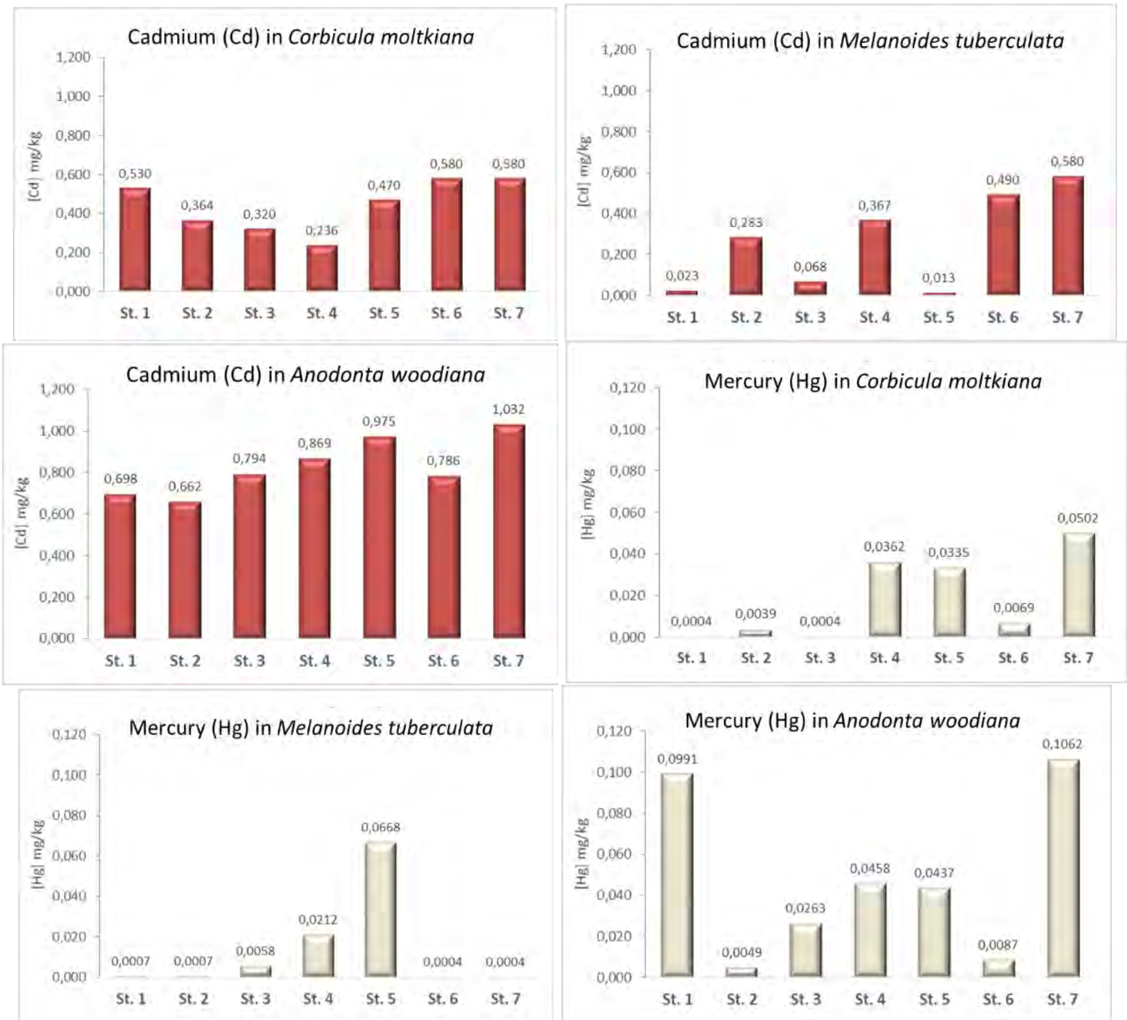

Figure 3. Cadmium (Cd) and mercury (Hg) content of *Corbicula moltkiana*, *Melanoides tuberculata*, and *Anodonta woodiana* at each observation stations in Lake Maninjau

CONCLUSIONS

Sediment content of total chromium (Cr) was very low or undetected at all observed inflowing river mouth in Lake Maninjau. The content of iron (Fe), lead (Pb), cadmium (Cd) and mercury (Hg) in the sediment of the seven observed locations were also considered low and below the lowest effect level. Considering the *Provisional Maximum Tolerable Daily Intake (*PMTDI) and *Provisional Tolerable Weekly Intake* (PTWI) (WHO, 2011), heavy metals content of the three mollusks were categorized as high. Cadmium (Cd) content was high in all the three molluscs (*Corbicula moltkiana, Melanoides tuberculata* and *Anodonta woodiana*) from all locations. The cadmium content in the molluscs in general was more than 0.8 mgCd/kg. Lead (Pb) content was high in *C. moltkiana* and in *A. woodiana* from all locations and the two species of mollusc are having very high risk to be consumed. The lead content in the two mollusc spesies from each location was more than 0.19 mgPb/kg. Mercury (Hg) content in the three mollusc species from all locations, in general was still in compliance with the PTWI of the WHO, with precaution to the molluscs from Muko Muko and Pandan. The content of iron (Fe) and total chromium (Cr) in the three mollusc species were considered as low and very low.

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CHALLENGES IN THE RESTORATION OF LAKE MANINJAU: BRIDGING ACTORS' INTERESTS FOR SUSTAINABILITY

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ABSTRACT

Lake Maninjau, situated in Agam District West Sumatera, has many strategic functions ranging from ecological to socio-economic for the surrounding areas. However, the lake condition in the last decades shows progressive environmental damage caused by extensive fish cultivation, pollution from domestic uses and degradation of the catchment areas. This condition if left unchecked, threatens not only Maninjau biodiversity but also threaten the ability of the lake to sustain the social and economic life of the surrounding community. The management of Lake Maninjau has become the interests of various parties, including local people, governments, environmental activists, and investors. Unfortunately, these interests are often not aligned, giving rise to conflicts. Broadly speaking, potential conflicts of interest in the management of Lake Maninjau is between economic interests and environmental interests. Therefore, to provide input for decision making related to quality improvement efforts and management of Lake Maninjau, this paper aims to identify the main problems of the lake management by using stakeholder mapping. Specifically, this paper (i) highlights the challenges in the restoration of the lake from stakeholders' perspectives and (ii) describes the alternatives in bridging actors' interest for the successful lake management. This study offers one potential approach in the management of the lake in Indonesia.

Keywords: lake management, Maninjau, stakeholder mapping

INTRODUCTION

Lake Maninjau is one of volcanic lakes in West Sumatera. It situated in Tanjung Raya, Agam District, Indonesia, at an altitude of 461.50 meters above sea level, with an area of 105 km^2 and an average depth of 105 meters. This lake is a caldera formed by the eruption of Mount Sitinjau about 52 thousand years ago. Because it is formed from volcanic eruptions, land around the lake is fertile and is currently used by the locals as the location of settlements and agricultural paddy and annual crops. Tourism activities are also growing in this area which has implications for the widespread construction of supporting facilities of tourism activities, such as hotels and restaurants. Whereas the lake waters is used for the cultivation of carp and tilapia through floating cages which are spread around the shores of Lake Maninjau. This activity becomes the main livelihood of the local communities in the surrounding area.

In terms of the environment, Maninjau contribute to maintaining biodiversity in the lake ecosystem. Study conducted by Roesma (2013) said there are 45 species of plants in the lake and nine of them are aquatic species. Some important species identified in the study are *Najas marina var. sumatrana, Mystacoleucos padangensis, Cyclocheilichthys dezwaani*, and *Psylopsis sp* which are endemic of the lake. Other study by Nontji (2016) said that Maninjau is the only natural lake in Sumatera that has *Angulla bicolor*, an eel species that spends its life in freshwater but as adult will be migrating to the ocean.

Lake Maninjau also serve as a source of clean water for the surrounding community. Based on data from PSDA West Sumatera (2015, in Arjuna, 2016), the water that goes into Lake Maninjau consists of rain water (281 million m^3/year), surface run-off (250 million m^3/year), and groundwater recharge (4.18 million m^3/year). While the water flowing out of the lake Maninjau via Batang Antokan River is 14.13 m^3/s or amounted to 445.6 million m^3/year. The magnitude of the potential of existing water in Lake Maninjau is proved not only to meet the needs of the community and provide clean water to the irrigation of agricultural land, but also used as a source of electricity generation in Maninjau hydropower plant with an installed capacity of 66 MW. Hydropower is not only delivering electrical service to the community in Agam, but also to the neighboring districts. Therefore, the change in water catchment areas around Lake Maninjau will greatly affect water availability, which in turn has implications not only on unmet demand for water but also energy needs.

Another thing that makes Maninjau increasingly strategic in terms of the environment is that the economic activities in the region are highly dependent on the quality of the existing environment. Growing tourism activities rely on the beauty of its nature, so that if it was damaged then the attractiveness of tourism in the region will disappear. Fishing activity through the floating cages were

strongly influenced by the quality of the water of Lake Maninjau. Similarly, agricultural activities of rice fields and annual crops will be affected if the land around Maninjau were damaged.
However, some studies suggest that the quality of the ecosystem of Lake Maninjau has indeed been damaged. Study conducted by Syandri (2015) showed that the waters of Lake Maninjau has been contaminated with chemical compounds, such as cadmium, copper, lead, iron, and zinc due to the accumulation of toxins in biota through atmospheric deposition, erosion and anthropogenic caused by industry, domestic waste, as well as waste from fishing activities. It is also reinforced by research conducted by Sulawesty et.al (2011) which stated the high content of nitrogen and phosphorus in the waters of Lake Maninjau (**Fig. 1**), characterized by high levels of turbidity, low temperature and dissolved oxygen along with the increasing depth, as well as the pH of the water that is alkaline. Sulawesty et.al (2011) added that with the current levels of phosphate (0.56 mg / liter), the water in Lake Maninjau is already above the threshold of quality standards established (<0.2 mg / liter), so it is not fit for use as a source of drinking water although it can still be used for aquaculture. Related with the aquaculture, assessment from LIPI (2009) states that Maninjau can only accommodate 6,000 floating cages before exceeded its carrying capacity. However, data from Agam Government (2016, in Jawa Pos 25 April 2016) states that there are already 20,620 units of floating cages so that if left unrestricted, they would threaten the sustainability of the environment of the lake.

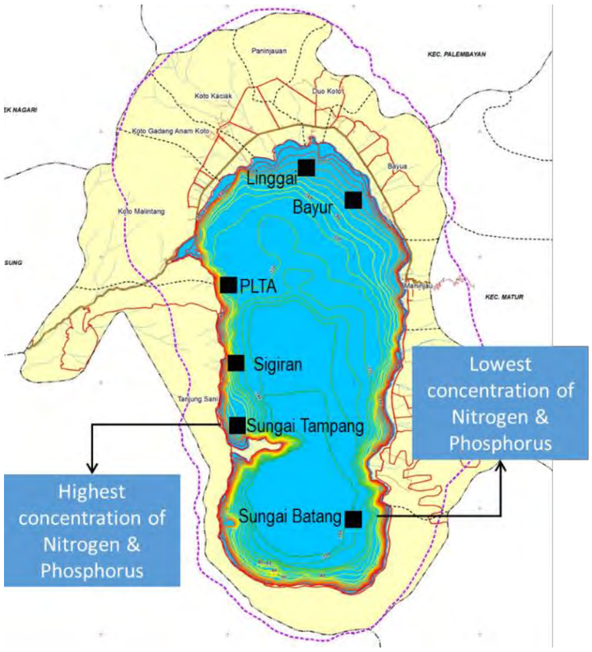

Figure 1. Water pollution in Lake Maninjau (Source: Sulawesty et.al, 2011)

The impact of environmental degradation of Lake Maninjau is already being felt by local communities. Reduction in forest cover in the catchment area around Maninjau has implications for the growing magnitude of the difference in water level of the lake between the rainy and dry seasons, thereby disrupting the operation of hydropower plant as well as the availability of energy for the community. Then, because of the severe pollution the water of Lake Maninjau also cannot be used by the local community since it has foul smell and also cause itching.
Aquaculture activities that are growing rapidly in this area turned out to have been adversely affected by the environmental damage. Tons of fish feed in the waters of the lake caused by less environmentally friendly fish breeding intensify water pollution that causes frequent catastrophic mass death of fish in the lake. This is compounded by the morphometric characteristic of Lake Maninjau which caused upwelling that stirred toxic substances from residual feed, fish feces and other substances from the lake bottom to the surface (Nasution et al., 2011), thereby increasing the risk of fish mortality. Over the past two decades, it was reported that several catastrophic mass fish mortality have occurred. In 1997, the first time the disaster occurred, the number of dead fish reached 950 tons with the loss of Rp. 2.7 billion (Syandri, 2015). In 2009, it was reported around 13,413 tons of dead fish with the loss of Rp. 150 billion, then in 2010 it was reported as 1,150 tons of dead fish (Nasution et al., 2011). Sari et al (2015) stated the amount and frequency of mass fish mortality continues to increase from year to year. These

conditions have a significant impact on the income of floating cages owners in Lake Maninjau. Not only fisheries, environmental damage of the lake also contribute to the decrease of tourists visiting the region, as the water of the lake have strong foul smell due to pollution and algae outbreak as reported by Sulawesty et.al (2011).

This condition if left uncontrolled, threatens not only the lake's biodiversity but also threaten the ability of the lake to sustain the social and economic life of the surrounding community. Related to this, comprehensive effort should be made for the restoration of Lake Maninjau and it should involve a variety of stakeholders. The involvement of various stakeholders are particularly important given the diversity of their roles and respective interests in the use of resources in the lake which led to increasing conflicts of interest and eventually leads to the deterioration of environmental quality. Moreover, the restoration efforts of Lake Maninjau that have been made by Agam District Local Government have not yet considered nor involved all stakeholders so that implementation of the program was not running optimally.

As a first step in the stakeholder-based environmental restoration of Lake Maninjau, this paper will focus on identifying the role, interests, and challenges based on the perspective of each stakeholder. The results of the analysis will be the basis for the formulation of alternatives in the successful management and restoration of the lake.

METHODS

This study uses qualitative research that focuses on the process of examination and interpretation of data in order to acquire meaning, understanding and build empirical knowledge (Corbin & Strauss, 2014, 2008; Dey, 2003) of the social phenomenon that consists of actors, events, places, and involve a lot of research methods in identifying problems (Marshall & Rossman, 2014). The qualitative approach was chosen because it allows the researcher to comprehensively review all the dynamics of resource utilization in Maninjau, mainly related to the role and interests of every stakeholder involved in it by looking at the perspective of each of the relevant stakeholders.

To get information from each stakeholder, in-depth interviews were conducted on key stakeholders in the utilization of resources in Lake Maninjau. According to various experts (i.e., Boyce & Neale, 2006; Marshall & Rossman, 2014), in-depth interview is a qualitative research techniques that lead to interviews of a small number of respondents to explore their perspectives in a certain situation, in this case related to the utilization of resources in the lake. In-depth interview in the study carried out by using a semi-structured questionnaire that had been prepared in advance but did not rule out the development of new questions as responses from the respondents' answers. Furthermore, the selection of respondents is done with the snowball method. With this method, the number of respondents interviewed were initially small then enlarges with provided referalls from the initial respondents. Each new referral is explored until primary data from sufficient amount of samples are collected.

Analysis were performed using stakeholder mapping to identify stakeholders and map the relative strength, influence, and their importance in the utilization of resources in Lake Maninjau, thus showing the pattern of relationships and priorities among stakeholders in achieving their respective goals. In the context of this study, stakeholder mapping become an important tool to achieve the discussion related to optimal resource management through the identification of coalitions between stakeholders and the pattern of relationship, so as to establish the legitimacy of resource management in Lake Maninjau.

RESULTS AND DISCUSSIONS

Maninjau as a resource can be used by local communities to meet their needs. *First*, in the form of products that can be consumed directly, such as fish for food and water as a source of energy and agricultural irrigation. *Second*, the lake can give indirect functional benefits, such as ecological and hydrological functions, flood control, and protection of the surrounding areas. *Third*, the lake can provide direct and indirect benefits for the future as storage media for biodiversity and ecosystems conserved.

The strategic role of the lake covering various aspects led to differing interests of stakeholders involved in the utilization of its resources. In general, stakeholders interested in the utilization of resources of the lake, can be classified as government, private sectors, community, and other non-governmental agencies, as described in **Table 1**.

Table 1 Classification of Stakeholders Involved in Resource Utilization in Lake Maninjau

Government	Private Sectors	Community	Other
1. Central Government: • Central government • Indonesia Institute of Science • State Electricity Company 2. West Sumatra Province: • Planning And Environment Control Agency • Marine and Fisheries Agency 3. Agam Regency: • Development Planning Agency • Marine and Fisheries Agency • Planning And Environment Control Agency • Agency for Sustainable Management of the Lake Maninjau • Nagari (Wali Nagari (village trustee), KAN, MTTS)	1. Tourism related business owners (hotel and homestay owners, food and beverages owners) 2. Fish feed company owners 3. Fish related business owners (from outside of the region)	1. Local community 2. Local traditional leaders	1. Non governmental organization

From the interviews, some role, interests, resource and influence, and potential conflict of interests of the actors involved in resource utilization of Lake Maninjau were identified (**Table 2**). Government role is to formulate policies in accordance with their respective authorities. Central Government in this case serves to formulate policies related to the strategic role of Lake Maninjau at the national level, specifically as the National Tourism Strategic Area. Other central government agencies, such as LIPI (Indonesia Institute of Science) provide support in terms of research and studies related to Lake Maninjau which can be used as a basis for decision making related to resource management in Lake Maninjau. Another is the State Electricity Company who operates Lake Maninjau hydropower plant which granted authority related to the provision of energy by utilizing water resources in Lake Maninjau to provide energy not only in Agam, but also its surrounding areas.

Government institutions at the provincial level, i.e. Planning and Environment Control Agency and Marine and Fisheries Agency of West Sumatra Province provide policy direction of environment and fisheries development at the provincial level. In addition, government at the provincial level also distribute the deconcentration funds from the central government to the district when there is a national government program conducted in Lake Maninjau.

In accordance with their respective duties, government institutions at the district level play greater role in the management of Lake Maninjau due to their authority to directly intervene on the problems that occurred there. Development Planning Agency, for example, contributes to spatial planning of Agam including Lake Maninjau. Then there is Agency for Sustainable Management of the Lake Maninjau to coordinate the management of and supporting the preservation of the lake. The role of this agency is actually significant in coordinating the interests between stakeholders in the utilization of resources in Lake Maninjau, but instead the results of interviews conducted found that the agency is not optimal in implementing its coordinating role.

Besides the government, there are other institutions that play important role in the utilization of resources in Lake Maninjau. Fisheries and tourism entrepreneurs have an interest to increase business turnover respectively. Local communities generally act as implementers of floating cage aquaculture and farmers on lands that surround the lake, so they have a huge interest in the utilization of resources. While the role of NGOs are to advocate the public in accordance with the evolving issues.

As noted in the previous section, the use of resources in the lake has led to various conflicts of interest in both the utilization of resources and authority of management that could threaten the sustainability of the resources. Moreover, the lake is common resources so that everyone can use it freely according to their needs. In general, potential conflicts of interest in Lake Maninjau is conflict between economic and environmental interests.

Conflicts between economic and environmental interests in Lake Maninjau develop into more complex ones which involve various growing sectors in the region, i.e. the tourism, fisheries, and water resources. From tourism, the natural beauty of the lake invites the presence of tourism activities in the region. Besides, this region becomes one of destinations route of Tour de Singkarak, an annual international event in West Sumatra. This event attracts entrepreneurs in the field of tourism, such as accommodation and food and beverage to set up business in the region. Tourism business is also supported by the policy of the Central Government that set this region as one of the National Tourism Strategic Areas. The main requirement for growing tourism sector is the existence of environmental sustainability in Maninjau. However, pollution in the lake has caused the rapidly growing environmental degradation and decline in tourist attraction and reduced tourist arrivals in Lake Maninjau. Stipulation of detailed spatial plan of Maninjau which expected to provide more space for tourism activity is also perceived by the tourism business as not able to limit fishery-related activities that have been growing very rapidly. Therefore, it can be said that the growing tourism activities have been in line with efforts to protect the lake, but contradictory to fishery.

Conflict in the fisheries sector starting from the growing use of floating cages that began to grow since the 1990s due to the rapid gains by the community from the activity. The prospect of profit obtained from the use of floating cages later attract more fish feed businessmen and investors from outside of Agam. Fish feed businessmen offer incentives in the form of profit sharing and ease in obtaining of fish feed for all owners of floating cages. Although feed prices rise simultaneously, the amount of incentive and the lack of public knowledge about environmentally-friendly fish cultivation causes people to feed fish in excess, and ultimately worsen the pollution which has long occurred. On the other hand, local communities increasingly marginalized because they ended up just working as laborers. This happens because investors from outside of Agam dominate ownership of the floating cages[1]. The absence of another alternative employment for local communities lead them to make defensive efforts against government policies which seek to reduce floating cages. On the side of the government, there is also conflict of interest between the Marine and Fisheries Agency that promote increased production of fishery commodities with Planning and Environment Control Agency that promote environmental sustainability of the lake. The outcome of this conflict is seen in the policy regarding floating net cages: the Marine and Fisheries Agency promotes extensification of floating cages for livelihoods, while Planning and Environment Control Agency tries to control the damage by reducing the floating cages to reduce pollution and restore the condition of Lake Maninjau.

Conflicts also occur in the water resources sector. Lake Maninjau was chosen for hydropower plant due to the increased demand for energy in West Sumatra and its potential of water resources. Maninjau hydropower development began in 1982 and started operating since 1992. However, the utilization of the lake water as an energy source is causing problems for local people both for those living around the lake and those living alongside Batang Antokan River, the main distributary of the lake. Research conducted by Asnil (2012) stated that during the rainy season the land owned by the people who live around the lake flooded due to damming at the river upstream which resulted in higher elevation of the lake that exceed normal conditions, while people living alongside Batang Antokan suffer losses because of their simple irrigation equipment and supplies drifted away when the floodgates opened to excessive water discharge. In contrast in the dry season, community wells around the lake experience drought due to lower water elevation of the lake while people living alongside Batang Antokan experiencing a shortage of water discharge for irrigation. Agam District Government has filed complaints addressing the issues, especially since the hydropower plant which also serves other districts in West Sumatera did not benefited the district in terms of revenue sharing. However, these complaints are not much addressed by the management of the plant.

Among the conflicts that have been described above, there are also relatively considered neutral institutions, i.e. Wali Nagari (village trustee) and traditional leaders. Both actors can accommodate the interests of various parties because both are in touch daily with communities and considered close to

[1] This information was obtained from interviews with community, district officials, and Marine and Fisheries Agency. The interviewees made approximation of the investors' composition by observation. Exact number of the investors, both local and outside of Agam, were not mentioned nor written on any reports at the time of the interviews (February-March, 2015). However on April 2016, Marine and Fisheries Agency stated that around 5,520 floating cages were owned by 134 local investors from five nagaries around the lake (posted in Singgalang Padang, 2016), meaning that from total 20,620 units of floating cages in Maninjau only about 27% were owned by the locals.

the customs and culture that is considered good and embraced by the people. On the other hand, they can also serve to oversee the government's policy and does not have opposition to government. Both of these actors have the potential to amplify or amplified by the system in order to play a greater role in breaking down and facilitate different interests over Lake Maninjau.

Table 2. Role, Interests, Influence, and Potential Conflicts of Interest of Each Stakeholders in Resource Utilization in Lake Maninjau

Stakeholder	Role	Interests	Resource and Influence	Potential Conflict of Interests
Central Government	Creating a national policy directive related to KSPN (National Tourism Strategic Area)	Realizing Maninjau as a driving force of tourism activities	Tourism planning policy (destinations, industry, marketing, etc.)	Conflicts of interest between government authority
Indonesia Institute of Science (LIPI)	Providing environmental studies related to Maninjau	Improving knowledge and provide information to the public and other stakeholders in a certain field	Is the central institution in charge of providing research study related to sciences	There is no direct conflict.
State Electricity Company	Providing a power source from the water of the lake	Utilizing the lake water as a source of electrical power	Is a central institution. Is supported with EIA.	Conflict with NGOs and part of the community because they considered the company have disrupted the flow of water.
Planning And Environment Control Agency – West Sumatera Province	Creating environmental policy within the scope of the province	Preserving the environment of the lake and its surroundings	environmental policy	Conflicts of interest between conservation and fisheries productivity
Marine and Fishery Agency - West Sumatera Province	Creating marine and fishery policies within the scope of the province	Increasing the production of fishery commodities	fisheries policy	Conflicts of interest between conservation and fisheries productivity
Development Planning Agency - Agam District	Creating spatial policy within the scope of the district	Realizing the sustainable utilization of space and able to accommodate the interests of various stakeholders	Spatial planning policy	Conflict in accommodate the interests of various stakeholders
Marine and Fishery Agency – Agam District	Creating a fisheries policy within the scope of the district	Increasing the production of fishery commodities	fisheries policy	Conflicts of interest between conservation and fisheries productivity
Planning and Environment Control Agency – Agam District	Creating environmental policy within the scope of the district	Preserving the environment of the lake and its surroundings	environmental policy	Conflicts of interest between conservation and fisheries productivity
Agency for Sustainable Management of the Lake Maninjau	Coordinating the activities of the management of Maninjau	Coordinating the activities of the management of Maninjau	The influence to the village head (as a member)	Conflicts of interest between management efforts to improve people's economic activities with efforts to reduce KJA (floating net) to preserve Lake Maninjau
Tourism related business owners	Providing accommodation needs of tourist	Increase the highest turnover	Influence on the development of tourism	Conflicts of interest between tourism development with an increase in floating net

Stakeholder	Role	Interests	Resource and Influence	Potential Conflict of Interests
				Pro toward environmental conservation
Fish feed company owners	Provide for the needs of fish feed	Increase the highest turnover	Determining the price of feed	Defensive toward the reduction of floating net because it will reduce revenue
Fish related business owners (from outside of the region)	large-scale aquaculture entrepreneurs	Increase the highest turnover	Owners of capital and “big boss” of floating net	Defensive toward the reduction of floating net because it will reduce revenue
Wali Nagari (village trustee) (from 9 nagaries /villages)	Coordinating the activities of the nagari	Guarding government policy	Influence to the society	Most conflict with NGOs
NGO	organize society	Some obtain funds from fishery related companies	Intensive approach to public	Conflict with government policy and State Electricity Company
Community	agriculture and fisheries businessman	earn income	Control over their lands and live around the lake	Defensive toward the reduction of floating net because it will reduce revenue
Local traditional leaders	Provide input to local communities and coordinate indigenous activities	Guarding government policy	Influence to the society	Most conflict with NGOs

The utilization of resources in Lake Maninjau is involving various stakeholders and has led to various conflicts of interests among stakeholders, as mapped in **Figure 2**. Economic activity in Lake Maninjau which continue to increase along with the many development policies that make Lake Maninjau as one tourism destination and center for the development of fisheries, as well as the low level of community welfare around the lake has the potential to increase the exploitation of natural resources. On the other side, growing economic activities in this region are economic activities that rely heavily on the sustainability of natural resources, so that damage to the ecosystem of the lake will have an impact on the region's economy discontinuation. Discrepancies between stakeholders and needs of each stakeholder to achieve their respective goals without considering the impact of their activities cause severe environmental degradation in Lake Maninjau. If this continues, Maninjau will become a dead lake.

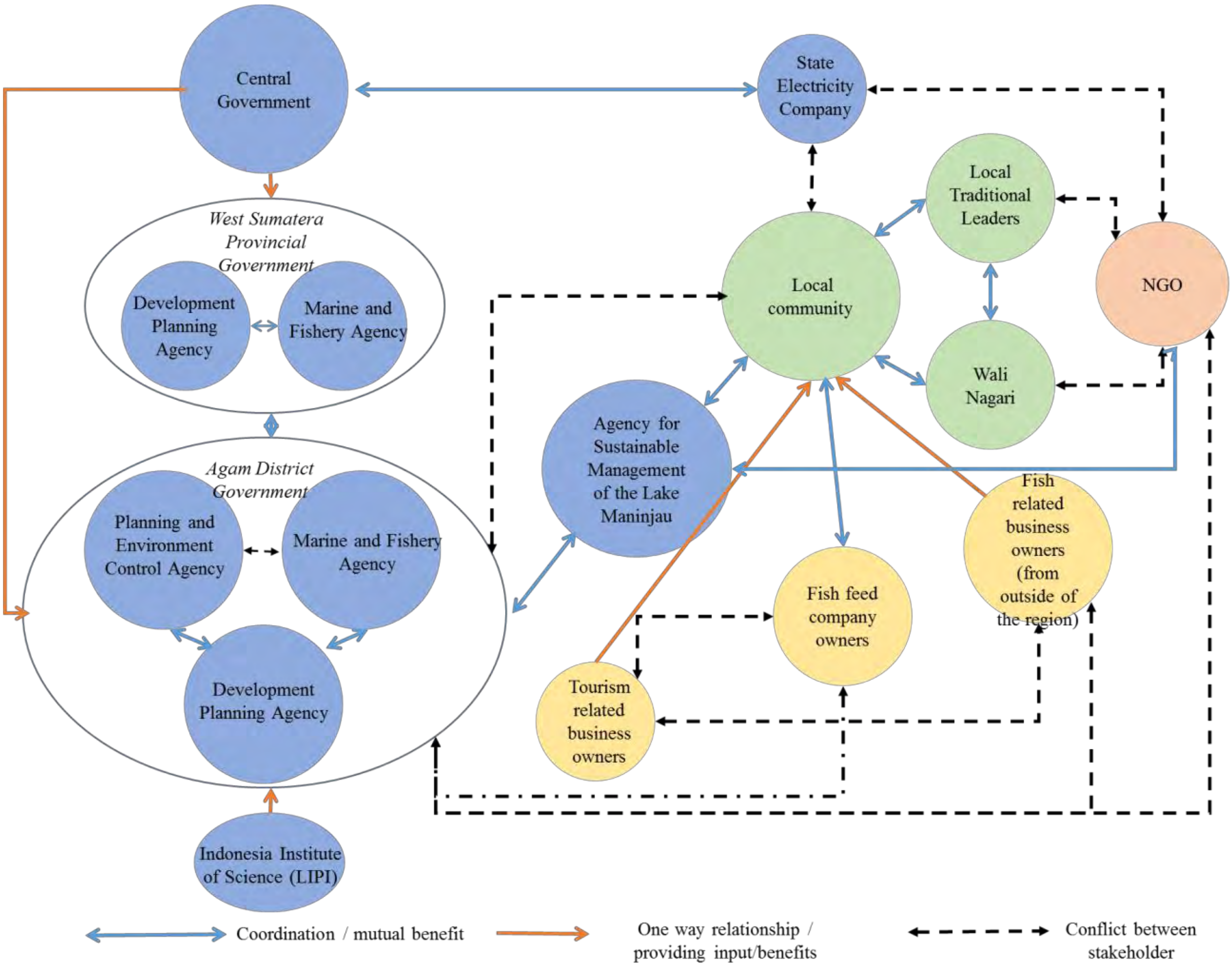

Figure 2. Stakeholder Mapping in Resource Utilization in Lake Maninjau

Various attempts have been made to overcome these problems. Agam District Government issued a Local Regulation No. 5 of 2014 on the Management of Sustainability of Lake Maninjau regulating the management, restoration and preservation of the lake. Currently, some Regent's Regulation (Peraturan Bupati) are being prepared to regulate the technical implementation. In addition, there are also management rules in accordance with the zoning area of Lake Maninjau through the Detailed Spatial Plan and Zoning Regulations. These efforts are already well on initiating the quality improvement of Lake Maninjau, but the toughest challenge in the implementation of these policies are the lack of integration and commitment among stakeholders to jointly promote the improvement of environmental quality of the lake.

Integration among stakeholders in resource utilization of Lake Maninjau becomes a big task in improving the quality of the environment in this region because of different perceptions, motives and interests among the stakeholders. In an effort to encourage integration between stakeholders, they need to set up a new institution that serves to control the exploitation, lowers pollution, and restore the environmental condition of Lake Maninjau. Different with the current Agency for Sustainable Management of the Lake Maninjau, this new institution will not only consist of government, but also the community, traditional leaders, Wali Nagari (village trustee), private sectors, and experts or academics. Community will be positioned as a manager who is responsible for the preservation of the lake, so that community participation is expected to be more effective and optimal. This institution is temporary until the condition of Lake Maninjau has recovered again.

CONCLUSIONS

From this study, it can be concluded that the utilization of resources in Lake Maninjau involves many stakeholders who have different motives and interests. Various stakeholders have made every effort to achieve their respective goals without concern that it leads to more severe ecological damage in the lake. These stakeholders also do not understand that those activities carried out at this time will lead to the discontinuation of regional economic activities in the long run. In addition, the conflicting interests of each stakeholder resulted in suboptimal efforts to improve environmental quality in Lake Maninjau. On the other hand, the intensity of regional economic activity is increasing thus restoration of Lake Maninjau become very urgent so that economic activity can continue in the long run. In this regard, efforts to improve the quality of the lake needs to be done by integrating the interests of various stakeholders in a new institution that was able to accommodate the interests of various parties. This institution will then serve to coordinate and integrate the planning of various sectors in Lake Maninjau.

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TRANSFORMATION OF ZOOPLANKTON COMMUNITIES DUE TO THE LAKES RECOVERY PROGRAMS

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ABSTRACT

Studies were carried out on three lakes in Kazan (Russia). The lakes were severely polluted due to sewage revenues of industrial enterprises. In the period of 1984-1995 two lakes have experienced measures to restore water quality. According to the project, the majority of industrial waste water was assigned to the treatment plant, bottom of contaminated sediment was cleaned, sewers were built, temporary water flow was organized, and beach has been landscaped. Water quality in lakes has improved considerably. We investigated changes in zooplankton communities during the recovery measures, after their completion and 20 years later. We have found that the response of zooplankton to reduce pollution represented in the increase in the number of zooplankton species, amount of dominant species, abundance and biomass. Share of Cladocera increased in the Lake N. Kaban lake, while Copepoda and Cladocera shares increased in S. Kaban. Enhanced development of these groups of zooplankton caused corresponding changes in taxonomic indicators based on the ratio of the values of abundance and biomass of zooplankton major groups, saprobic index. Follow-up study of the lakes showed that with existing high anthropogenic load repeated remediation is required in 15-20 years.
Keywords: zooplankton, restoration, lake, community

INTRODUCTION

If lakes are located in large cities they have strong anthropogenic influence, leading to their pollution and eutrophication. These lakes need measures to restore lost quality of lake resources. However, examples of successful restoration of the lakes are few due to the complexity and the insufficient knowledge of process. In addition, there are even less studied of changes of zooplankton communities during these processes.

The methods used for the restoration of water bodies can be divided into two groups: prevention, carried out on the territory of the watershed and restoration. In most of the cases aerated water used for the restoration of lakes. Another measure is removing sediment, the creation or strengthening of flowage, chemical and mechanical methods to combat blue-green algae, phosphorus deposition in water, the creation of bioplato of mollusks and higher water plants and biomanipulation (Jorgensen, 1985, Gulati, Pires & Donk, 2008, Ma, Huang & Li, 2015). One of the most illustrative examples of complex problem-solving in recent years is the situation with the river Rhine, where measures significantly improved ecological condition. Implementation included complex legislative, administrative, economic and technological measures taken jointly by the Netherlands, Germany, France and other countries in the river basin (Hering, Borja, Carstensen et al, 2010, Hilt, Gross, Hupferi et al, 2006). A significant number of projects and the restoration of water bodies as well as sustainable water management programs was successfully implemented and realized in the Danube River Basin and River Thames (Hering, Borja, Carstensen et al, 2010). In order to improve the condition of the Moscow River it is also encouraged to gradually clear river beds, including the extraction of contaminated sediment, and river water aeration.

This study devoted to the lakes, situated in Russia, Kazan city. The system of Kaban Lakes includes three lakes (Nizhnii, Srednii and Verchnii). Lakes Nizhnii and Srednii Kaban earlier had high water quality, but due to the receipt of industrial and domestic waste water were heavily contaminated by the 1970-s. In order to improve water quality in the lakes rehabilitation project was designed and realized in 1981-1995.

According to the project, the majority of industrial waste water was assigned to the treatment plant, bottom of contaminated sediment was cleaned, sewers were built, temporary water flow was organized and beach have been landscaped. However, nowadays, rain sewage in lakes dumped from the watershed. The lakes are located in the central part of the city and used for recreational, sports and other purposes. The aim of our study was to identify changes in the zooplankton communities of the lakes within the process of improving measures, directly after their completion and 25-30 years later in the conditions of continuing anthropogenic impact.

METHODS

Studies were carried out from 1989 and 2014. Samples were taken at 1-3 deep stations on each of the lakes. In 1995-1997. and in 2001 samples were collected every 10-14 days during the vegetation period (from April to October), in 1989 - monthly, in 1991-1994, 2002, 2009-2010 - once in the main seasons of the growing season, and in 2013-2014 - monthly throughout the summer. Until early 1995, integral samples were taken from the water column using a Molchanov GR-18 bathometer, followed by averaging and filtering through the Apshtein network. From 1995 to 2014, samples were collected by a Jedi network with a mesh size of 90 µm. Water horizons were selected according to the water temperature stratification. We calculated the abundance and the biomass of zooplankton at each station. The abundance was calculated in 1 m^3 of water. Biomass was calculated according to degree equations relating the length of an organism with its weigh (Guidelines, 1982).

We used indicators based on the assessment of the taxonomic structure of the zooplankton community to identify changes in the community: the ratio of major zooplankton groups by abundance and biomass (Kryuchkova, 1987); ratio of Crustacea biomass to Rotifera biomass (B_{Cr}/B_{Rot}); ratio of Cladocera abundance to Copepoda abundance (N_{Cl}/N_{Cop}); ratio of Cyclopoida biomass to Calanoida biomass (B_{Cycl}/B_{Cal}); The value of the average individual mass of the zooplankton for the community as a whole ŵ = B/N (Andronikova, 1996). In relation to the plankton of eutrophic (E) and oligotrophic (O) species, the index of trophic E/O was calculated (Hakkari, 1972). Species diversity of zooplankton was estimated by the Shannon index (by number and biomass) (Shennon, Weaver, 1965) according to the following formula:

H=- $\sum_{i=1}^{k} pi \log 2pi$, where H - Shannon index, *pi* - $\frac{Ni}{N}$ or $\frac{Bi}{B}$, where N_i и B_i – the abundance and the biomass of i-th type, *N* and *B* - the abundance and the biomass of all individuals in the sample, respectively.

Pantle and Bukka saprobic index in Sladechek modification was calculated using the following formula:

S= $\frac{\sum(sh)}{\sum h}$ **,** where S - saprobic index, s - individual value of saprobity, h - the frequency of occurred individuals (Sladecek, 1968).

A total of 732 quantitative samples of zooplankton were collected and treatment during the study period.

RESULTS AND DISCUSSIONS

In Lakes Nizhnii and Srednii Kaban strengthening industrial pollution has caused a significant decrease in the number of species of zooplankton. Lakes were mostly dominated by rotifers genius Brachionus. The species complex formed in this period can be considered resistant to the conditions of heavy pollution. Decline of the number of species and the dominance of Brachyonidae family species is typical for heavy polluted lakes. During the recovery measures rotifers and crustaceans appeared as the dominate complexes. The number of species increased as a result of the restoration measures. The list of zooplankton species found in lakes during the study period is presented in the Appendix (Table 1).

The lowest average values of abundance and biomass of zooplankton were observed in the lake Nizhnii Kaban during the most severe pollution. Lake Srednii Kaban has experienced lower zooplankton abundance and biomass in a period of strong pollution. Parameters were higher in a period of restoration measures.

In lake Verhnii Kaban during the study period there was a gradual increase of zooplankton in the growing season. In the case of the lake Verhnii Kaban growth of quantitative indicators is the result of intensive ongoing process of anthropogenic eutrophication.

Changing pollution levels at different stages of human impact caused a change in the proportion of indicator species in communities and values of saprobic index. According to saprobity index all three lakes values were within the β-mesosaprobic zone corresponding to the state of moderate contamination.

Our studies revealed trends in indicators of Kaban Lakes zooplankton at different stages and in different types of human exposure and health (**Table 1**).

Table 1. Trends in zooplankton indicators in different types of anthropogenic impact.

Index	Eutrophication[a]	Pollution[a]	N.Kaban 1984-1986	N.Kaban 1991-2014	S.Kaban 1989-1995	S.Kaban 1997-2014	V.Kaban 1994-2014
Number of species	=	↓	=	↑	↑	↓	↑
Number of dominant	↓	↓	=	↑	↑	=	=
B_{Cr}/B_{Rot}	↓	-	↑	↑	↑	↓	↑
N_{Clad}/N_{Cop}	↑	-	↑	↓	↑	↓	↑
B_{Cycl}/B_{Cal}	↑	-	-	↑	↑	↓	↑
H (N)	↓	↓	↑	↑	↑	↓	↑
H (B)	↓	↓	↑	↑	↑	↑	↑
ŵ	↓	↓	↑	↑	↑	↑	↓
R:Cl:Cop (N)	R↑ Cl↑ Cop↓	R- Cl↓ Cop-	R= Cl↑ Cop↓	R↑ Cl↓ Cop↓	R↓ Cl↑ Cop↑	R↑ Cl↓ Cop↓	R↑ Cl↑ Cop↓
R:Cl:Cop (B)	R↑ Cl↑ Cop↓	R- Cl↓ Cop-	R↓ Cl↑ Cop↓	R= Cl↑ Cop↓	R↓ Cl↑ Cop↑	R↑ Cl↑ Cop↓	R↑ Cl↑ Cop↓
E/O	↑	↑	↓	↑	↓	↑	↑
N total	↑	↓	↑	↑	↑	↓	↑
B total	↑ or ↓	↓	↑	↓	↑	↓	↑
S	↑	↑	↓	↓	↑	↑	↓

[a] according to the literature (Kryuchkova, 1987, Makrushin, 1974, Ivanova, 1976, Andronikova, 1996 et al.)

CONCLUSIONS

Studies have shown that the restoration activities carried out in 1984-1995 significantly improved the ecological condition of the lakes Nizhnii and Srednii Kaban. Reduction of the concentration of toxic substances led to water quality improvement and there have been recovery of zooplankton communities. Community response to pollution reduction showed an increase in the number of species, increase of the number of dominant species with the inclusion in a dominant complex of all taxonomic groups of zooplankton. The abundance and biomass of zooplankton have increased.

Therefore, such a range of restoration activities can be recommended for the recovery of water bodies polluted by industrial waste water. However, studies have shown that in case of continuous high anthropogenic load, single implementation of restoration measures is not enough. Restoration activities must be carried out in 15-20 years to maintain the ecosystem status.

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Appendix 1

Table 1. Occurrence of zooplankton species in Kaban lakes.

Species	N. Kaban	S. Kaban	V. Kaban
Asplanchna girodi de Guerne, 1888	+	+	+
A. priodonta Gosse, 1850	+	+	+
Ascomorpha ecaudis Perty, 1850	-	-	+
Brachionus angularis Gosse, 1851	+	+	+
B. calyciflorus Pallas, 1776	+	+	+
B. diversicornis (Daday, 1883)	+	+	+
B. quadridentatus Hermann, 1783	+	+	+
B. rubens Ehrenberg, 1838	-	-	+
B. urceus (Linnaeus, 1758)	+	+	-
Bipalpus hudsoni (Imhof, 1891) *Ploesoma hudsoni*	-	+	+
Conochilus unicornis Rousselet, 1892	-	-	+
Euchlanis dilatata Ehrenberg, 1832	+	+	+
E. oropha Gosse, 1887	+	+	+
E. triquetra Ehrenberg, 1838	+	+	+
Filinia longiseta (Ehrenberg, 1834)	+	+	+
F. terminalis (Plate, 1886)	+	-	-
Kellicottia longispina (Kellicott, 1879)	+	+	+
Keratella cochlearis (Gosse, 1851)	+	+	+
K. quadrata (Muller, 1786)	+	+	+
K. testudo (Ehrenberg, 1832)	-	+	+
K. valga (Ehrenberg, 1834)	-	+	-
Lecane (M.) lunaris (Ehrenberg, 1832)	+	+	+
L. (M.) quadridentata (Ehrenberg, 1832)	-	+	-
Lecane (s.str.) luna (Muller, 1776)	+	+	+
Mytilina mucronata (Muller, 1773)	-	+	-

M. ventralis (Ehrenberg, 1832)	+	+	+
Notholca acuminata (Ehrenberg, 1832)	+	+	+
N. squamula (Muller, 1786)	+	+	+
Polyarthra dolichoptera Idelson, 1925	+	+	+
P. euryptera Wierzejski, 1891	+	-	+
P. major Burckhard, 1900	+	+	+
P. vulgaris Carlin, 1943	+	+	+
Platyias quadricornis (Ehrenberg, 1838)	+	+	+
Synchaeta pectinata Ehrenberg, 1832	-	+	+
S. stylata Wierzejskii, 1893	-	-	+
Trichocerca (D.) similis (Wierzejski, 1893)	+	-	+
Trichocerca (s.str.) *capucina* (Wierz et Zacharias, 1893)	-	+	+
T. (s.str.) *longiseta* (Schrank, 1802)	+	+	+
T. (s.str.) *pusilla* (Lauterborn, 1898)	+	+	+
T. (s.str.) *rattus* (Muller, 1776)	-	-	+
Trichotria pocillum (Muller, 1776)	-	-	+
Rotifera	28	32	36
Acroperus harpae (Baird, 1843)	-	+	-
Alona guttata G.O. Sars, 1862	-	+	-
A. intermedia G.O. Sars, 1862	+	+	-
A. quadrangularis (O.F.Muller, 1785)	+	-	+
A. rectangula G.O. Sars, 1862	+	+	+
Alonopsis elongatus Sars,1862	-	-	+
Bosmina (B.) longirostris (O.F.Muller, 1785)	+	+	+
Bosmina (Eubosmina) cf. crassicornis Lilljeborg, 1887	-	+	-
B. (Eubosmina) cf. longispina Leydig, 1860	-	+	+
Canthocamptus rectirostris Sars, 1862	-	-	+
Ceriodaphnia laticaudata P.E.Muller, 1867	+	+	+
C. pulchella G.O. Sars, 1862	+	+	+
C. quadrangula (O.F.Muller, 1785)	+	+	+
C. reticulata (Jurine, 1820)	+	+	+
Chydorus latus Sars	+	+	-
C. ovalis Kurz, 1875	+	+	-
C. sphaericus (O.F.Muller, 1785)	+	+	+
Daphnia (Daphnia) cucullata Sars, 1862	+	+	+
D. (D.) longispina O.F.Muller, 1785	+	+	+
D. (D.) pulex Leydig, 1860	-	-	+
D. (C.) magna Straus, 1820	+	-	-
Diaphanosoma brachyurum (Lieven, 1848)	+	+	+
D. mongolianum Ueno, 1938	-	+	-
D. orghidani Negrea, 1982	+	+	+
Disparalona rostrata (Koch, 1841)	+	+	+
Eurycercus lamellatus (O.F.Muller, 1776)	-	-	+
Graptoleberis testudinaria (Fischer, 1851)	+	+	+
Leptodora kindtii (Focke, 1844)	+	+	+
Leydigia acanthocercoides (Fischer, 1854)	+	+	-

L. leidigii (Shoelder, 1863)	+	+	-
Macrothrix hirsuticornis Norman et Brady, 1876	-	+	+
M. laticornis (Jurine, 1820)	+	-	+
Moina brachiata (Jurine, 1820)	-	+	-
M. micrura Kurz, 1874	+	+	-
Monospilus dispar G.O. Sars, 1862	+	-	-
Pleuroxus aduncus (Jurine, 1820)	-	+	-
P. truncatus (O.F.Muller, 1785)	+	+	-
P. uncinatus Baird, 1850	+	+	+
Pseudochydorus globosus (Baird, 1843)	+	+	+
Scapholeberis mucronata (O.F.Muller, 1776)	+	+	+
Sida crystallina (O.F.Muller, 1776)	-	+	+
Simocephalus vetulus (O.F.Muller, 1776)	+	+	+
Cladocera	29	34	27
Acanthocyclops robustus (G.O. Sars, 1863)	-	-	+
A. venustus (Norman et Scott, 1906)	+	-	+
A. vernalis (Fischer, 1853)	+	+	+
Cyclops furcifer Claus, 1857	+	+	+
C. insignis Claus, 1857	+	-	-
C. kolensis Lilljeborg, 1901	+	+	+
C. lacustris Sars, 1863	-	+	+
C. strenuus Fischer, 1851	+	+	+
C. vicinus Uljanin, 1875	+	+	+
Diacyclops bisetosus (Rehberg, 1880)	+	-	-
Ectocyclops phaleratus (Koch, 1838)	-	+	-
Eudiaptomus gracilis (Sars, 1863)	+	+	+
Eucyclops macrurus (G.O. Sars, 1863)	+	+	+
E. serrulatus (Fischer, 1851)	-	+	+
E. speratus (Lilljeborg, 1901)	-	+	+
Macrocyclops albidus (Jurine, 1820)	+	+	+
M. distinctus (Richard, 1887)	+	+	-
M. fuscus (Jurine, 1820)	+	+	-
Megacyclops viridis (Jurine, 1820)	+	+	+
Mesocyclops leuckarti (Claus, 1857)	+	+	+
Paracyclops f. fimbriatus (Fischer, 1853)	-	-	+
Thermocyclops crassus (Fischer, 1853)	+	+	+
T. dybowskii (Lande, 1890)	-	-	+
T. oithonoides (Sars, 1863)	+	+	+
Copepoda	17	18	19
Total	74	84	82

CHANGES IN THE CHEMICAL ECOLOGY OF BLUE-GREEN ALGAE DURING PERIODS OF ACTIVE GROWTH

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ABSTRACT

It is well-known that tremendous growth of blue-green algae during summer is one of the causes for freshwater pollution all over the world. Although the importance of photosynthesis, nutrient, and water temperature on the growth mechanism of blue-green algae is well recognized, chemical ecology of blue-green algae has not been elucidated yet. To understand this, we elucidated the effect of chemical ecology of blue-green algae in various water depth on the growth mechanism by quantifying 110 chemicals relating requisite biological activity. In August, the best energetically season for the blue-green algae growing, we collected the stagnating water from a man-made lake including blue-green algae. Based on our results, the effect of living depth in freshwater was more important than that of sunlight exposure as to chemical ecology of blue-green algae. Indeed, higher concentration of nucleic acid-relating compounds and dipeptides were detected at the surface water layer, while higher concentration of free amino acids were found in mid-depth water layer. This correlation between the depth and composition of metabolites must be a significant fact to reveal unknown biological event of blue-green algae during periods of active growth.

Keywords: Blue-green algae, chemical ecology, water depth, metabolome, 110 chemicals required, photosynthesis

INTRODUCTION

The catchments area of water conservation forests for this study shown in **Fig.1** is located Kanto mountain aria covering west end Tokyo and east end Yamanashi. Rainfall exceeds 1,600mm/year. Elevations of watersheds are from 1,300m to 2,000m. Year average temperature is approximately 10°C. In the winter, the minimum temperature is below minus 10°C at watersheds. The total catchments area is 262.9km^2 and four rivers occupy 88.2% of the total river basin. In the basin, about 2,000 people are living and more than 1,000,000 tourists are visiting every year. There are settlement, guest house, campsite and fish breeding. Based on the biological characteristics observed, it is not believed that Anabaena was originally present in this study area, and PCR for Anabaena results indicate a strong connection with fisheries and tourism resources. in the same analysis Microcystis was detected at all survey sites along the river from the upper to lower reaches (Makino et al. 2016). Some shallows of this dam reservoir occurred in surface blooms of *Microcystis* and Anabaena from 1980s. The blooms in july 2015 were Anabaena, august change to *Microcystis*.

Development of blue-green algae due to an enormous proliferation of single-celled *Microcystis* in reservoirs in Japan has become a problem (Tomioka, N., Imai A. & Komatsu K., 2011). *Microcystis*, covered with biofilm caused by photosynthesis, form large met-like clusters at the surface water layer (Reynolds et al. 1988; Oliver et al. 2000). Meanwhile, blue-green algae underwater (in mid-depth water layers) are finely dispersed and transform into smaller clusters, more closely resembling the natural appearance of *Microcystis* (Reynolds et al. 1981). To understand different behaviour of *Microcystis* cell depending upon living water layer, we conducted metabolite analysis toward *Microcystis* cells. Dynamic range of Amino acids and Adenosine triphosphate (ATP) by the effects of water levels, on the basis of these two relationships, we discuss to metabolic product the cell division conditions.

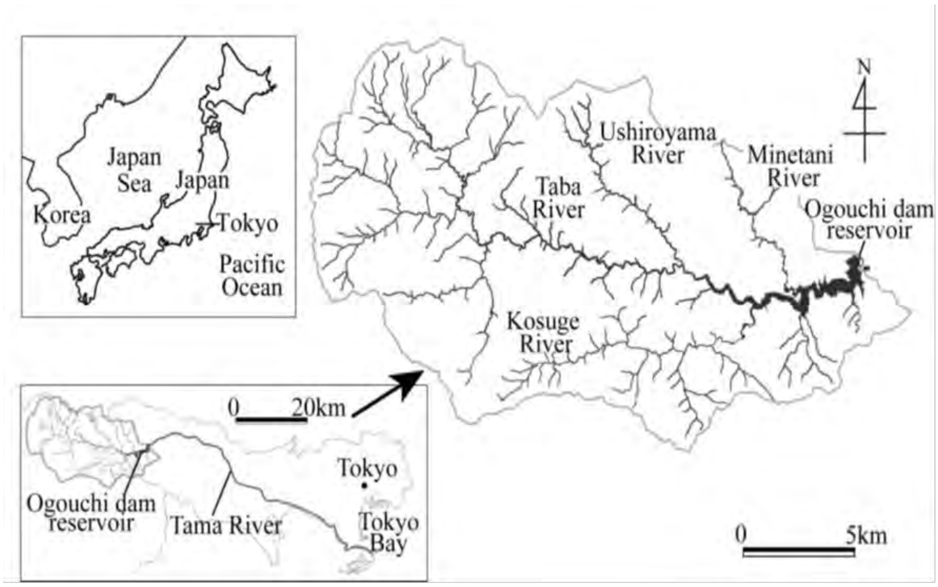


Figure 1. Catchments area and reservoir

METHODS

We collected blue green-algae during periods of active growth in man-made lake in August, in which blue-green algae actively reproduce, on a sunny day between 10:00 a.m. to 2:00 a.m. at the surface water layer (0.0 m depth) and mid-depth water layers (0.4 m depth) (**Table 1**). The samples blue-green algae were analyzed with an Agilent CE-TOFMS (capillary electrophoresis-time of flight mass spectrometry) system (Agilent Technologies) and the detected chemicals with a molecular weight of less than 1,000 were grouped by relevance.

Table 1. Sampling points

Sample No.	1	2	3	4	5	6
Sampling Time	a.m. 10:00	pm 14:00		a.m. 16:30		a.m. 2:00
Sampling water layer	Surface	Surface	Mid-depth	Surface	Mid-depth	Mid-depth
Sampling water depth	0.0 m	0.0 m	0.4m	0.0 m	0.4m	0.4m

RESULTS AND DISCUSSIONS

Fig. 2 shows heat map analysis of CE-TOFMS metabolomics. The surface water layer samples (number 1, 2, and 4) contained more nucleic acids, and peptides compared to the samples from lower layers regardless of the time of observation. The samples from the mid-depth water layers (number 3, 5, and 6) contained more amino acids and metabolites associated with tricarboxylic acid cycle (TCA cycle) compared to the surface water layer samples, irrespective of sampling time.

Nucleotides, which are essential substance for the synthesis of DNA and RNA, have an impact of the cellular division when lacking. The density of these nucleic acids (Adenine and Guanosine) was higher in the surface water layer relative to the mid-depth water layers, suggesting that most cellular division is taking place in the surface water layer (**Fig. 3**). Amino acids are precursors of secondary metabolic products including proteins, nucleic acids, and ammonium ion (Nishizawa et al. 2000; Tillett et al. 2000). Concentration of amino acids were observed at lower water layer, comparing with surface layer (**Fig. 4**). Higher concentration of amino acids such as Arginine and Asparagine were dense in all of the mid-depth water layers regardless of time and sparse in the surface water layers. TCA cycle is a circuit producing ATP which is the primary energy source for the cells. The density of citric acid (**Fig. 5**), malate acid (**Fig. 6**) in TCA cycle was higher in the mid-depth water layer relative to the surface water layers. Underwater attenuation in Microcystis spends a TCA cycle for production of ATP as a photosynthetic substitute.

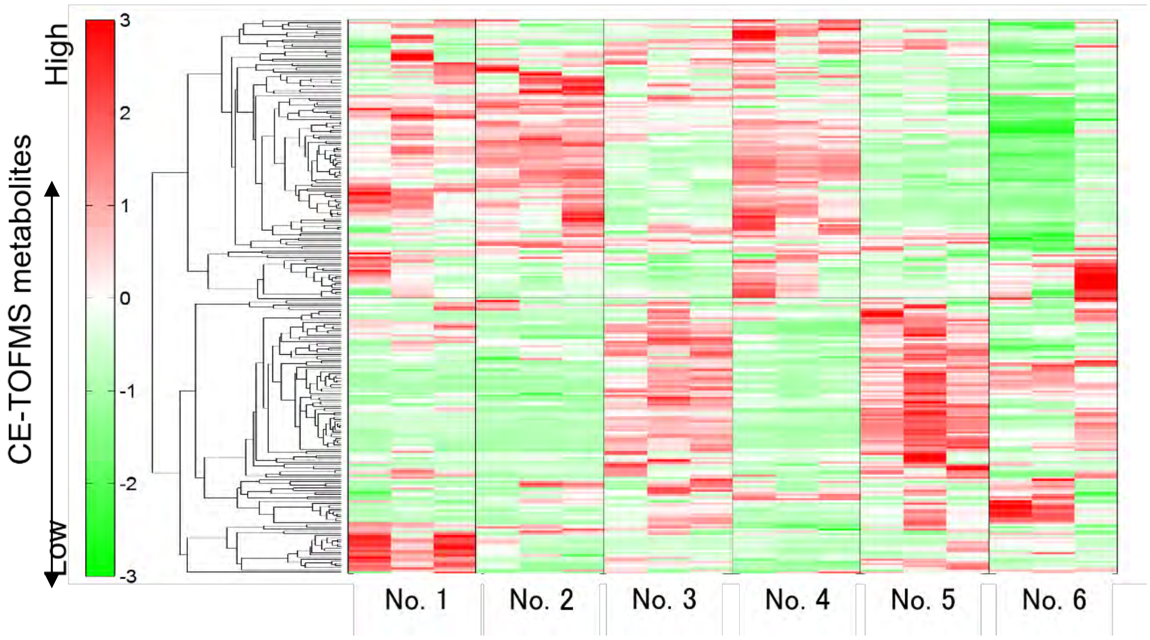
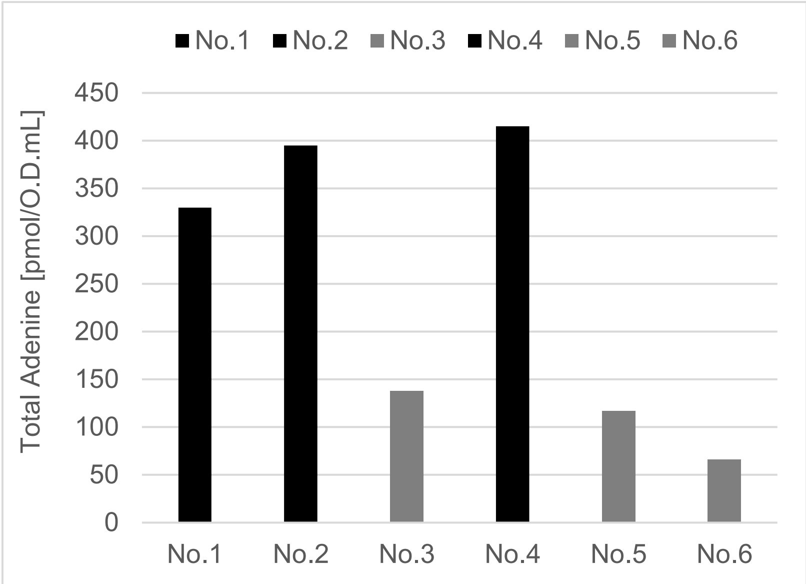


Figure 2. Metabolomics heatmap of *Microcystis* in blue-green alga samples (n=3)



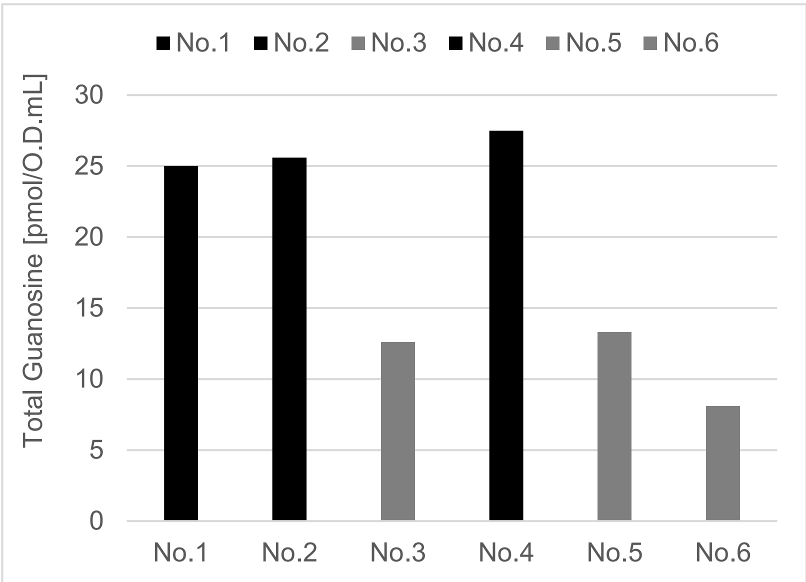


Figure 3. Total Adenine, Total Guanosine in Sample

*Total Adenine: Adenosine monophosphate+ Adenosine diphosphate+ Adenosine triphosphate, Total Guanosine: Guanylic acid+ Cyclic guanosine monophosphate+ Guanosine diphosphate+ Guanosine triphosphate

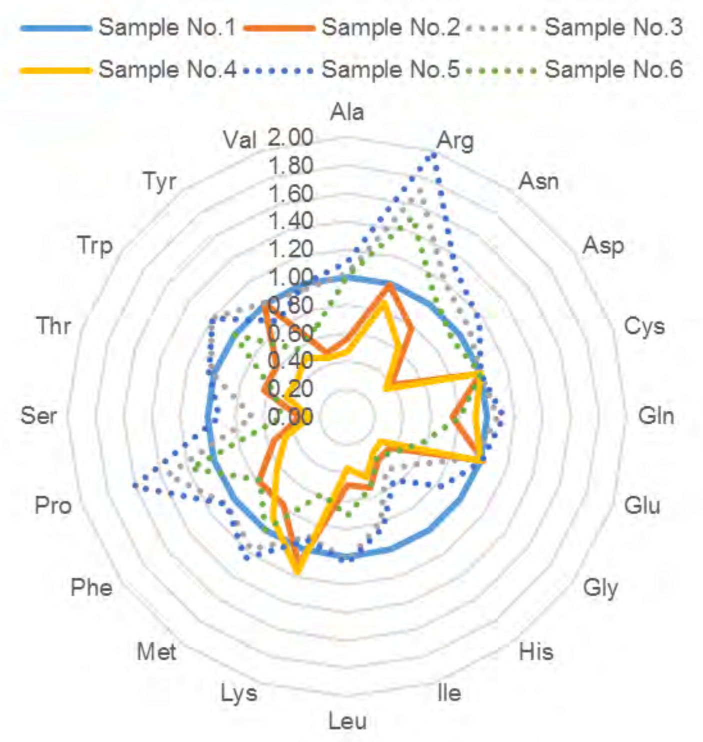


Figure 4. Rader chart of the twenty amino acid metabolism
***** Ala; alanine, Arg; arginine, Asn; asparagine, Cys; cysteine, Gln; glutamine, Glu; glutamic acid, Gly; glycine, His; histidine, Ile; isoleucine, Leu; leucine, Lys; lysine, Met; methionine, Phe; phenylalanine, Pro; proline, Ser; serine, Thr; threonine, Trp; Tryptophan, Tyr; tyrosine, Val; valine

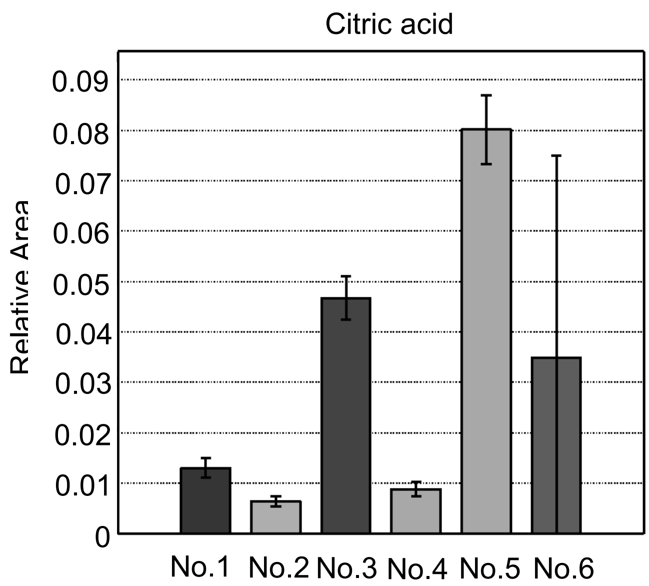


Figure 5. Citric acid in TCA cycle

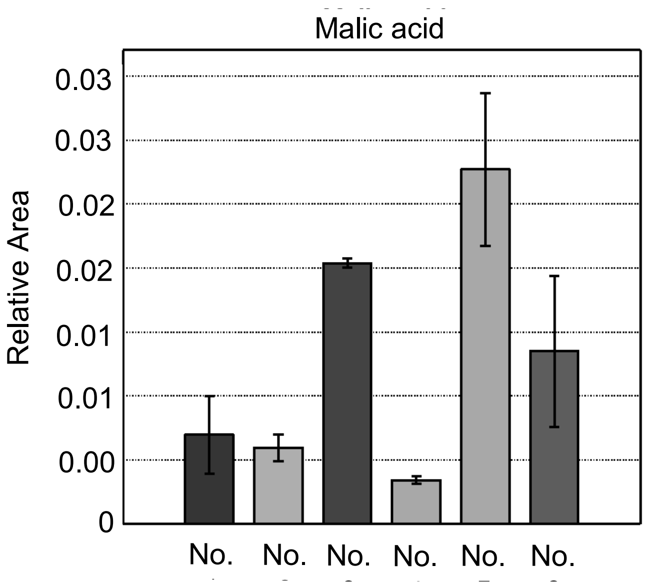


Figure 6. Malic acid in TCA cycle

CONCLUSIONS

We investigated changes in the metabolites to Microcystis cells in blue-green algae in August, which is the best month for biological activity of Microcystis. There was a pronounced indication that differences in the consistency of chemical substances inherent to the cells arose due to differences in water level, particularly for amino acids and nucleic acids. This implies that the exercise of at least some of cell function depends on water levels and could suggest that the enormous proliferation of Microcystis and development of blue-green algae could be due to: 1. the rising of the cells following biosynthesis of large amounts of amino acids in mid-depth water layers, 2. cellular division in the surface water layer caused by the synthesis of nucleic acids using these amino acids, and 3. the repetition of this process.

ACKNOWLEDGEMENT

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TROPHIC AND POLLUTION STATUS OF JAWAHAR SAGAR IN SOUTHERN RAJASTHAN, INDIA BASED ON WATER QUALITY AND MACROINVERTEBRATE FAUNA

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ABSTRACT

Jawahar Sagar reservoir is the third reservoir in the series of Chambal valley projects, located 29 Km up stream of Kota Barrage and 26 Km downstream of Rana Pratap Sagar dam across the river Chambal, a tributary of the Ganga River system in Rajasthan state of India. Water quality was analyzed for the period of one year (November 2004 to October 2005). Water of Jawahar Sagar indicated alkaline condition (pH 7.6 in winter to 8.8 in summer). The water temperature ranged between (18.5°C in winter to 32.0°C in monsoon). On the basis of water quality and especially depth of visibility, Jawahar Sagar could be categorized as "moderately eutrophic". Nitrate nitrogen values in Jawahar Sagar indicated 'Mesotrophic' status whereas orthophosphate levels in the Jawahar Sagar may be a sign of eutrophic status. Jawahar Sagar reservoir could be categorized as 'moderately hard' water based on hardness. In addition to water quality, benthic biodiversity of macroinvertebrates was also studied to indicate their role as bioindicator for assessing pollution status. From Jawahar Sagar 29 species of macroinvertebrates have been recorded. Among macroinvebrates most dominant five benthos in the decreasing order were Melanoides tuberculata, Chironomus larvae, Bellamya bengalensis, Lymnaea acuminata (Gracilior) and Goniobasis virginica in littoral zone. Total number of macroinvertebrates depicted by various species of benthos ranged from 858 to 1188 (No./m^2). The macrobenthic community showed dominance of molluscs probably due to congenial environmental conditions and availability of choice substratum. Organic pollution indicators viz: Lymnaea acuminata, Chironomus larvae, Limnodrilus hoffmeisteri and Indoplanorbis exustus fairly dominated in the Jawahar Sagar reservoir.

Keywords: Bioindicators, Macroinvetebrates, Pollution, Reservoir Jawahar Sagar and Water quality.

INTRODUCTION

Water is one of the abundantly available substances in nature which man has exploited more than any other resource for the sustenance of life. Water is perhaps the most valuable intake necessary for survival. It is an essential constituent of all animals and plants and forms 75% of the matter of the earth's crust. Water of good quality is required for sustenance of living organisms. The industrial growth, urbanization and consequent pollution let into the freshwater systems, is a challenge for the fragile freshwater ecosystem. The ability of water bodies to clean themselves may be affected adversely by the anthropogenic activities in and around the reservoir. These may affect the physical, chemical and biological nature of the freshwater system. The input of increasing load of pollutants and toxic substances into the surface waters has been causing serious disturbances in the aquatic ecosystems. The physico-chemical methods are used to detect the effects of pollution on the water quality (Kabir *et. al,* 2012). Change in the water quality is reflected in the biotic community structure as shown by occurrence, diversity and abundance pattern of species (Cairns, 1979).

Macroinvertebrates are important members of the food web and their well-being is reflected in the well-being of the higher forms such as fish. Many forms are important for digesting organic material and recycling nutrients. A community of macroinvertebrates in an aquatic ecosystem is very sensitive to stress and this characteristic serves as a useful tool for detecting environmental perturbation resulting from introduced contaminants. Apart from the normal ecological condition in polluted systems, natural changes induced by pollution are well manifested by certain organisms. The benthic biota acts as a bio-indicator of pollution. Biological examinations done to provide more accurate picture than the physico-chemical examination (Singh & Roy, 1991; Jana & Manna, 1995). In freshwater, the benthic macroinvertebretes play an essential role in key ecosystem processes, such as food chain dynamics, productivity, nutrient cycling and decomposition (Covich *et. al,* 1999). Usually various physicochemical methods are used to detect the effect of pollution on the water quality changes. Such alterations in water quality are also very well reflected in the structure and composition of biotic community as shown by occurrence, diversity and abundance pattern of species Kumar, (1994). The present investigation is an attempt to examine the composition and seasonal variations of benthic macroinvertebrates to evaluate the impact of human interference on the water quality of Jawahar Sagar reservoir, Bundi (Rajasthan).

Study Area:

The state of Rajasthan has an area of 3, 42,239 Sq. Km and is situated in the north-western corner of India. It is bounded by Punjab and Haryana states on north and north-eastern sides, Utter Pradesh and Madhya Pradesh on eastern, south-eastern and southern sides, while Gujarat is situated adjacent to its southern and south-western sides. Along the north-western is the international border with Pakistan (Plate-1). The southern region of the state, embracing the districts of Banswara, Chittorgarh, Rajsamand, Jhalawar and Kota consists of stony uplands settings which are ideal sites for water resources development. The maximum number of man-made lakes situated in this region. The Chambal ravine region lies along the river Chambal forming the boundary between Rajasthan and Madhya Pradesh states. Water released after power generation at Gandhi Sagar (Hydroelectric Power Station), Rana Pratap Sagar (Atomic Power and Hydroelectric Power Station) and Jawahar Sagar (Hydroelectric Power Station) is diverted by Kota Barrage for irrigation in Rajasthan and in Madhya Pradesh through canals (Plate-1& **Fig.-1**).

Jawahar Sagar dam is the fourth dam in the series of Chambal valley projects, located 29 Km up stream of Kota Barrage and 26 Km downstream of Rana Pratap Sagar dam, across the river Chambal. It is a concrete gravity dam 45 meters high and 393 m long the work was completed in 1972. The total catchment area of the dam is 27,195 km^2. The water of Jawahar Sagar dam is used for domestic and public supply, irrigation, industrial supply and hydroelectric power generation. Further details of this dam pertaining to morphometric features are indicated in **Table 1.**

METHODS

Water Sample:

The sampling frequency was kept monthly for a total period of 12 months (from November 2004 to October 2005). The water quality parameters such as temperature, pH, depth of visibility, alkalinity, electric conductivity, free CO_2 and dissolved oxygen were measured in the field. However, for the nitrate- nitrogen, orthophosphate, hardness (Calcium, Magnesium and total hardness) samples were brought to the laboratory in and analysed within 6 hours. Methods such as (APHA, 1989 and Sharma & Saini, 2003) were followed.

Sample collection and preservation of Macroinvertebrates:

Macroinvertebrates samples were collected with the use of Ekman dredge and secured in a bucket. Using US standard sieve No.40 the whole sample was sieved to obtain the macroinvertebrates (benthos). The residual organic matter etained in the sieve was transported to the laboratory with small amount of water to it (50 to 100 ml). To this, 5 g of sucrose was added for easy collection of benthos. In addition to this, 0.1 – 0.2 per cent eosin dye was also used to stain the benthos. Samples were preserved in 70 per cent ethanol.

For qualitative analysis, animals were examined using inverted microscope and standard keys (Needham and Needham 1962, Edmondson 1965, and Subba Rao, 1989). However, for quantitative analysis, animals were counted individually species wise in the whole sample or sub samples. The number of benthos per unit area was calculated as follows:

$$\text{Benthos No/m}^2 = \frac{N}{A} \times 10^4$$

(N = Number of organisms per sample., A = biting area of sampler (15 x 15 cm)).

RESULTS AND DISCUSSIONS

The results on physicochemical parameters of surface water of Jawahar Sagar Reservoir are presented in (**Table 2 & 3 and Fig 2 & 3**). The variations in water temperature were from 18.5°C in winter to 32.0°C in monsoon. It is evident that except for the month of January 2005 water temperature was warm. The statistical analysis of temperature had positive significant correlation with EC, pH, dissolved oxygen, bicarbonate alkalinity, total alkalinity, orthophosphate, calcium hardness, magnesium hardness and total hardness (**Table 3**). In Jawahar Sagar water indicated mild alkaline condition with pH variations between 7.4 (winter) to 8.8 (summer). In January 2005, lower pH coincided with higher free carbondioxide (**Fig. 2**). pH also showed significant, positive correlation with EC, depth of visibility, dissolved oxygen, bicarbonate alkalinity, total alkalinity, calcium, magnesium and total hardness. The values of electric conductivity showed variations between 0.183 to 0.257 mS during monsoon. This Conductivity exhibited lowest average in monsoon followed by summer and winter with relatively higher values. The EC also indicated significant positive relationship with depth of visibility, calcium hardness, bicarbonate alkalinity and total alkalinity. Water clarity values in Jawahar Sagar dam showed variations from minimum of 60 to maximum 280 cm during monsoon. This parameter indicated positive relationship with calcium hardness, bicarbonate and total alkalinity (**Table 3**).

It is satisfying to note that Jawahar Sagar maintained adequate of dissolved oxygen with over all variations between 6.8 to 10.4 mg/l in winter. However, the lowest average dissolved oxygen was noted for summer as compared to relatively higher values in winter and monsoon (**Table 2 and Fig. 2**). As regard coefficient of correlation, dissolved oxygen had positive significant relationship with total alkalinity, orthophosphate, calcium hardness and total hardness. Whenever present $C0_2$showed overall variations between 4 to 14 mg/l in winter. It is interesting to see that during monsoon period CO_2 was altogether absent. Further, free CO_2 indicated negative significant correlation with carbonate alkalinity (**Table 3**). Variations in total alkalinity were from 80 (monsoon) to 130 mg/l (summer), whereas average values were between 95.0 (winter) to 103.5 mg/l (monsoon). Further, this parameter showed significant positive relationship with calcium hardness and total hardness. The average values of nitrate nitrogen were higher (0.008 mg/l) in monsoon as compared to winter and summer. In general, nitrate nitrogen varied from 0.000 to 0.047 mg/l (summer). The level of orthophosphate recorded in Jawahar Sagar dam during the study period was fairly high with variations between 0.156 (winter) to 1.070 mg/l (summer). This parameter exhibited lowest average in winter followed by summer and monsoon with relatively higher values. The orthophosphate values also indicated significant positive relationship with magnesium hardness and total hardness.

From Jawahar Sagar 29 species of macroinvertebrates have been recorded (**Table 4**). Among macroinvebrates most dominant five benthos were *Melanoides tuberculata, Chironomus* larvae, *Bellamya bengalensis, Lymnaea acuminata* (Gracilior) and *Goniobasis virginica* in the littoral zone in decreasing order. From the data on microinvertebrates average density obtained for five benthos the following order of dominance was evident at Jawahar Sagar dam (**Table :5** and **Fig. 4 &5**).

M. tuberculata > *Chironomus* larvae > *B. bengalensis* > *L. acuminata* > *G. virginica*
(194) > (187) > (180) > (62) > (44).

Table 5 shows the seasonal variations in quantity of benthos in Jawahar Sagar during the study period. The total number of macroinvertebrates depicted by various species of benthos ranged from 858 to 1188 (No. /m^2) in Jawahar Sagar.

Results of present study (**Tables 1,2 & 3**) revealed richness of macroinvertebrete biodiversity Jawahar Sagar. In the present study, a positive relation between dissolved oxygen and temperature for Jawahar Sagar was seen (**Table 3**). It is well known that the solubility of dissolved oxygen increases by lowering the temperature (Mathew, 1978). This is supported by the present observations on Jawahar Sagar. It is reported that waters of large lakes undergo relatively small seasonal changes in pH (Welch, 1952). Alikunhi (1957) indicated that waters with pH values ranging from 7.5 to 8.5 are giving double the fish production as compared to waters having pH from 6.5-7.5. Yusoff and Patimah (1994) recorded comparatively low (6.77 to 7.93) pH in hypereutrophic water. Solomon (1994) also observed higher average pH in Picchola Lake coinciding with higher productivity. In the present study, it has been observed that pH of Jawahar Sagar was always on alkaline side. The total ionic load of water is represented by the electrical conductance values which may also be considered as an index of productivity (Holsinger, 1955). As per Rawson (1960) criterion, Jawahar Sagar (0.238 mS) with EC values well about 0.2 mS could be considered "eutrophic". Sharma (1980) and Solomon (1994) also assigned moderately eutrophic waters status to the lakes of Udaipur based on Water Clarity (101-200 cm) values. In the present investigation, average water clarity of Jawahar Sagar (178.2 cm) could be categorized as "moderately eutrophic" water.

As evident from (**Table 2 and 3**) during the study period dissolved oxygen increased with lowering of temperature. The overall variations in dissolved oxygen (Table:2) indicate critical levels of dissolved oxygen during the extreme summer period but the value increased in the subsequent period to attain supersaturation by the end of June in Jawahar Sagar Thereafter, the sharp decline in the dissolved oxygen was probably due to increased concentration of free carbondioxide. The presence of free carbon- dioxide in little excess in water body is an important parameter to indicate the suitability of a water body for fish. As regards dissolved oxygen and water temperature the relationship was significantly positive in Jawahar Sagar (**Table 3**). The inverse relationship of free CO_2 and dissolved oxygen is well established (Mathew, 1978) and once again justified in the present study on Jawahar

Sagar (Table 4). Further, free CO_2 also indicated negative significant correlationship with carbonate alkalinity of Jawahar Sagar (**Table 3**). The total alkalinity has been considered as an indicator of productivity (Alikunhi, 1957). On the lines of Alikunhi (1957) suggested the classification of water based on their total alkalinity. This study further supports the findings on Udaipur waters which recorded alkalinity values from 96 to 320 mg/l, falling under moderate to high productive waters (Sharma, 1980). In the present investigation, total alkalinity was (101.2 mg/l) in Jawahar Sagar. Thus, on this basis, it reservoir considered "Moderate high productivity". Zhang and Chang (1994) found 0.54 to 0.77 mg/l and 0.40 to 2.56 mg nitrogen per liter in the 'mesotropic' and 'eutrophic' lakes, respectively. Phosphorus and nitrogen are the basic nutrients which are important to determine the productivity of lakes. Atkins (1913) stated that inorganic phosphate of more than 0.5 mg/l is an indicator of organic pollution. Hynes (1965) reported an average phosphate of 0.02 mg/l and noticed higher value of phosphate due to sewage contamination in certain American lakes. Jin (1994) also reported very high level of phosphorus in Chinese lake.

Zhang and Chang (1994) studied oligotrophic, mesotrophic and eutrophic lakes and reported that in oligotrophic lake phosphorus and nitrogen levels were 0.01 and 0.21 mg/l respectively. While in eutrophic lake phosphorus and nitrogen levels were comparatively much higher (0.019 and 1.45 mg/l) than critical stage (0.02 mg/l for phosphorus and 0.2 mg/l for total nitrogen). The present study to indicated relative orthophosphate levels in Jawahar Sagar (0.718 mg/l)). Thus, on this basis, Jawahar Sagar reservoir may be considered "eutrophic". Sawyer (1960) classified waters on the basis of hardness as Soft water (Up to 75 mg/l), Moderate (75 to 150 mg/l), Hard water (150 to 300 mg/l), Very hard water (above 300 mg/l). Based on this classification also Jawahar Sagar could be categorized as "moderately hard" water (**Table 3**).

Benthos are organisms attached or resting on the bottom or living in the bottom sediments (Odum, 1971). The role of bottom biota as fish food has been emphasized by several workers. However, there exists difference of opinions with regards to the uses of bottom biota as an index to trophic level of the water bodies. Considering average values of total benthos per unit area Sharma (1980) made the groupings, Low (Average number of benthic animals upto 300/sq.m.), Moderate (Average number of benthic animals 300-600/sq.m.), High (Average number of benthic animals 600-1000/sq.m.) and Very high (Average number of benthic animals exceeding 1000/sq.m.). In the present investigations, average benthic density was (975 No./m^2) in Jawahar Sagar reservoir (**Table 4**). The littoral fauna is mainly shared by chironomids, annelids and molluscs in many Rajasthan waters. Similar observations for other water bodies were made by David *et. ai,* (1969) and Gupta (1976). In the present study benthos of littoral zones were mainly comprised of molluscs, annelids, chironomids, hemiptera, coleoptera and isopods. Diversity, distribution and abundance of benthos in Mouri River, Khulna, and Bangladesh were studies by (Khan, *et. al,* 2007)

Edgar and Moadows (1969) also reported random distribution in *Chironomus* larvae. Chironomid larvae have also been used as pollution indicators by a number of workers (Curry, 1962 and Chakravorty, *et. a,.* 2014). Thus, the high presence of chironomids in the benthic population may be due to an impact of altered nature of substrate due to organic pollution. This was also evident from the present study where dominance of chironomid (*Chironomus*) in Jawahar Sagar was observed. Chironomids have been used as indicator organisms for trophic characterization of lake. Many *Chironomus* species have ability to tolerate low oxygen water condition with physiological and behavioural adaptations habitats and their different resistance to anoxia (Bairlein, 1989). The biomass of *Chironomus* was high on freshly flooded land, for instance in new lowland reservoirs and ponds (Kajak, 1988). Effect of different physico-chemical parameter on benthic community in the west region of Uttar Pradesh (Kabir *et.al,* 2012). Impact of effluent on water quality and benthic macroinvertebrate fauna of Awba Stream and reservoir (Chakravorty *at el* 2014). The presence of *Tubifex* sp. *Limnodrilus* sp., *Limnaea accuminata* and *Chironomuswasm* corroborates with the work of Mason (1981).

Barbosa *et al.* (2001) used benthic macroinvertebrates as indicators of water quality and health of ecosystem. Brinkhurst and Cook (1974) observed that the abundance of tubificids relative to other organisms as well as the relative abundance of various species of worms is of particular importance in pollution studies. Further, the two tubificids (*Tubifex tubifes* and *Limnodrilus* sp.) have been reported to be indicators of pollution by mere their presence in considerable number by many workers in temperate and tropical conditions. Benthic macroinvertebrates have been used as for assessing water quality: in Karakaya Dam Lake Sengupta, (2008). *Limnodrilus hoffmeisteri* (48 No./m^2) were evident bioindicator at Jawahar Sagar. In the present investigation, a poor diversity of aquatic insect was observed with total 18 species belonging to 6 orders. The relative dominance of each constituent benthic group could be summarized in following order: mollusks (12), Diptera (05), Odonata (04 No/m^2), Annelids, (03 No/m^2), Hemiptera (02 No/m^2), coleopteran (02 No/m^2), and zygoptera (01No/m^2). Anitha *et al.* (2004) reported macrozoobenthos in Miralam Lake of Hyderabad (A.P.) and observed various kinds of benthos. Kahan and Auer (2002) reported dominance of Diporia (48%) followed by Chironomids (21.3), Oligochaetes (18.7) and others (8.4%). Further, abundance of Chironomids was seen in the month of September. in the present study. The benthic community showed dominance of molluscs at Jawahar Sagar probably due to congenial environmental conditions and availabilit*y of choice substratum. Organic pollution indicator Lymnaea acuminata,* Chironomus larvae, *Limnodrilus hoffmeisteri* and *Indoplanorbis exustus* fairly dominated in Jawahar Sagar reservoir (plate:2).

For sustainable management of Jawahar Sagar following conservatoires measures are suggested:

- For long-term scientific management of surface waters constant monitoring of waters quality should be undertaken. This may be helpful for sustainable use of these water resources for various human needs.
- As large amount of silt together with organic matter is coming to the water bodies efforts should be made to undertake periodical desilting operations. This will be helpful in maintaining water holding capacity of the water bodies.
- Pollution in various forms (liquid and solid wastes of diverse nature and magnitude) directly affect the physico-chemical and biological characteristics of aquatic system which may be ultimately injurious to the biota thus, all efforts be made to check only of pollutants.
- The impact of pollution is most severe on sensitive species of plants, animals and benthic fauna in particular because of their selective preference for habitat and limitations to migrate rapidly. All efforts should be made to effectively monitor and control aquatic pollution for the substance of biota as well as for maintaining the ecological balance in these surface water resources.
- Scientific fisheries management in surface water can be helpful not only for conversion of available fish food resources into fish protein but may be helpful in maintaining or improving water quality. The modern technique of ecotechnology or biomanipulation may be applied for desired restoration.
- In present study based on assessment of available fish food resources in from of benthos suitable capture fisheries strategy can be worked out for effectively harvesting the aquatic productivities in the form of fish.
- The role of fish in aquatic ecosystem is very significant and vital especially for maintaining the delicate balance of ecosystem. These facts should be brought to the notice of masses through appropriate formal and informal extension activities.

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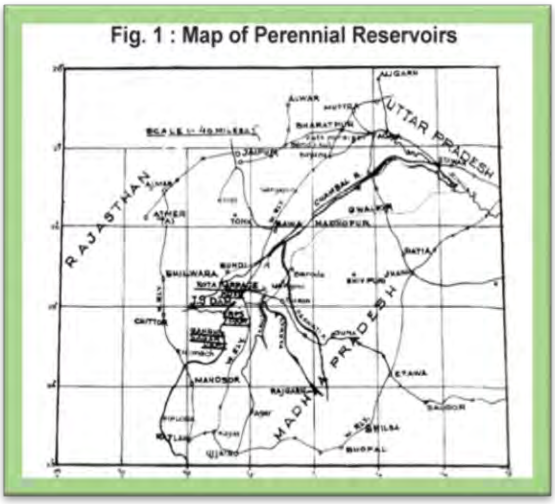


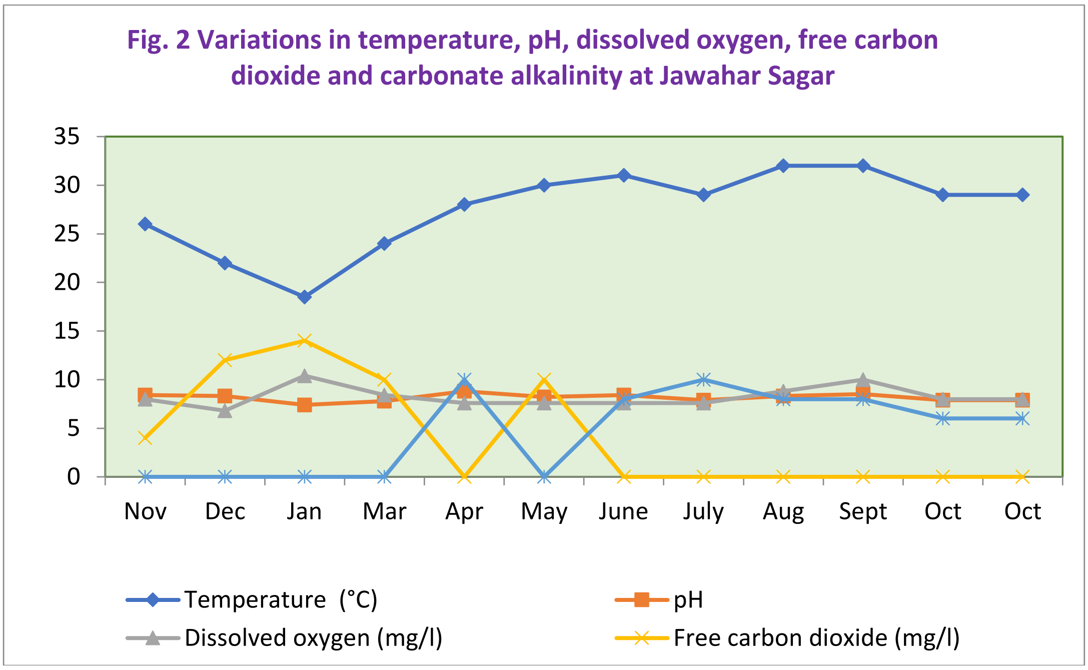
ON the River Chambal

Table 1. Morphometric features of Jawahar Sagar Reservoir, Rajasthan, India

S. No.	Items	Jawahar Sagar
1.	Locations:	
	Latitude	24°82.792N
	Longitude	76°52.072E
2.	Total Catchment area	27,195 km^2
3.	Average rainfall (inch)	32
4.	Maximum depth (m)	11.0
5.	Mean depth (m)	8.0
6.	Length of dam (m)	393.0
7.	Height of dam (m)	45.0
8.	Nature of dam	Cement concrete
9.	Year of impoundment	1960-1962
10.	Purpose	Hydel power generation
12.	Village / Town / City	Jawahar Nagar
13.	Tehsil and district	Taleda – Bundi district, Rajasthan

Table 2. Seasonal variations in of water quality parameters of Jawahar Sagar

S. No.	Parameters	Winter		Summer		Monsoon	
		Seasonal range	Average	Seasonal range	Average	Seasonal range	Average
1.	Temperature (°C)	18.5- 26.0	22.1	24- 31	28.3	29.0- 32.0	30.5
2.	pH	7.4- 8.4	8.0	7.8- 8.8	8.3	7.9- 8.5	8.2
3.	Electric conductivity (mS)	0.255- 0.256	0.255	0.218- 0.255	0.232	0.183- 0.257	0.229
4.	Depth of visibility (cm)	167-210	192.0	118- 210	164.5	60- 280	162.5
5.	Dissolved oxygen (mg/l)	6.8- 10 .4	8.4	7.6- 8.4	7.8	7.6- 10.0	8.6
6.	Free carbon dioxide (mg/l)	4.0- 14.0	10.0	Ni 10	5.0	Nil	Nil
7.	Carbonate alkalinity (mg/l)	Nil	Nil	Nil 10	4.5	6.0- 10.0	8.0
8.	Bicarbonate alkalinity (mg/l)	86.0- 100	95.0	80- 120	94.5	70.0-114.0	95.5
9.	Total alkalinity (mg/l)	86.0- 100	95.0	80- 130	99.0	80.0- 122.0	103.5
10.	Nitrate nitrogen (mg/l)	0.001- 0.002	0.002	0.0- 0.047	0.002	0.001- 0.019	0.008
11.	Orthophosphate (mg/l)	0.156- 0.675	0.339	0.743- 1.070	0.998	0.738- 0.938	0.819
12.	Calcium Hardness (mg/l)	56.0- 61.0	59.0	50- 54	52.5	50.0- 56.0	53.0
13.	Magnesium Hardness (mg/l)	24.0- 36.0	28.0	36- 54	44.2	14.0- 45.0	29.25
14.	Total Hardness (mg/l)	84- 92	87.0	86- 106	96.75	68.0-95.0	82.25



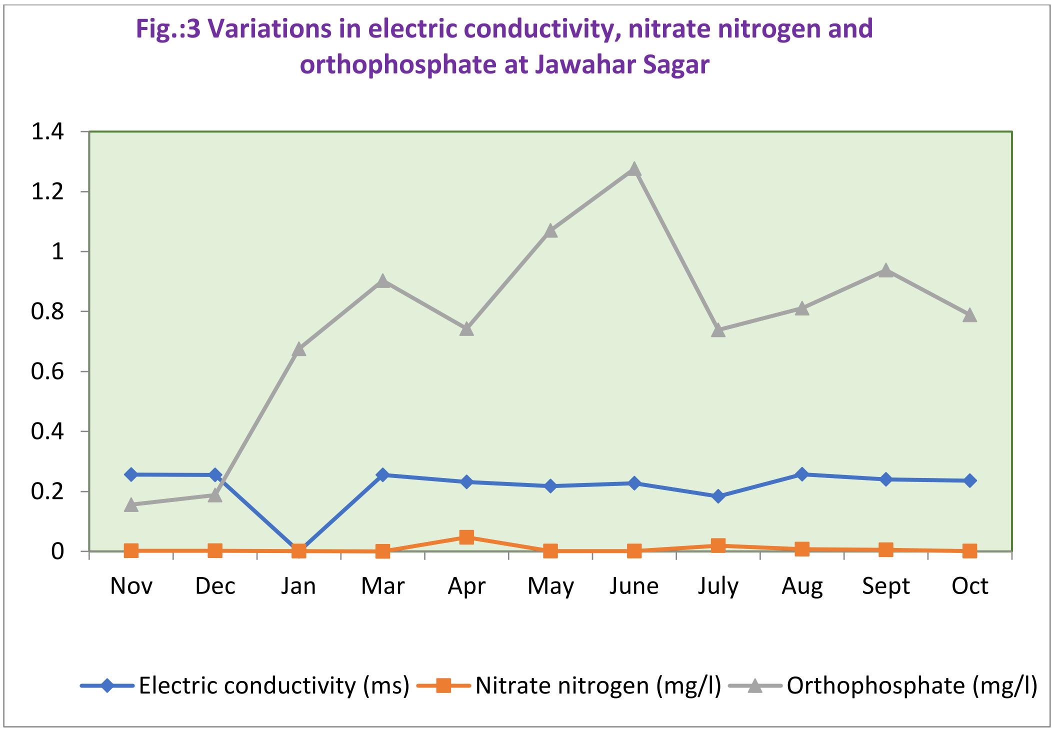


Table 4. Checklist of macro invertebrates of Jawahar Sagar

S.No.	Name of species	S.No.	Name of species
1.	*Bellamya bengalensis*	16.	*Berosus dolerosus*
2.	*Goniobasis virginica*	17.	*Chironomus* larvae
3.	*Melanoides tuberculata*	18.	*Chaoborus* larvae
4.	*Lymnaea acuminata* (Typica)	19.	*Tabanus* larvae
5.	*Parreysia caerulea*	20.	*Psychoda* larvae
6.	*Lymnaea acuminata* (Gracilior)	21.	*Rhaphidalobis* larvae
7.	*Gyraulus convexiusculus*	22.	*Erythrodiplax* sp.

8.	*Corbicula striatella*	23.	*Sympetrum*
9.	*Indoplanorbis exustus*	24.	*Helocordulia uhleri*
10.	*Parreysia favidens*	25.	*Argia* sp.
11.	*Scaphula deltae*	26.	*Tachopteryx theoreyi*
12.	*Lamellidens marginalis*	27.	*Herpobdelloidea lateroculata*
13.	*Laccotrephes griseus*	28.	*Limnodrilus hoffmeisteri*
14.	*Diplonyches rusticus*	29.	*Barbronia weberi*
15.	*Cybister tocipunetatus asiateus*		

Table 4. Seasonal quantitative analysis of macroinvertebrates (No. /m^2) of Jawahar Sagar

S. No.	Species of Macro-invertebrate	Winter		Summer		Monsoon		Average density
		Seasonal range	Average	Seasonal range	Average	Seasonal range	Average	
1.	*Bellamya bengalensis*	132-440	275	88-132	99.0	88-572	165	180
2.	*Goniobasis virginica*	197-220	99	0.0	0.0	0.0-132	33	44
3.	*Melanoides tuberculata*	176-440	231	88-572	297	88-132	55	194
4.	*Lymnaea acuminata* (T.)	88-132	55	0.0-88	22	0.0-88	22	33
5.	*Lymnaea acuminata* (G.)	0.0-132	33	132-220	88	0.0-132	66	62
6.	*Parreysia caerulea*	0.0-0.0	0.0	0.0-176	88	0.0-88	22	37
7.	*Scaphula deltae*	0.0-0.0	0.0	0.0-88	22	0.0-88	22	14.6
8.	*Parreysia favidens*	0.0-0.0	0.0	0.0-88	22	0.0-88	22	14.6
9.	*Gyraulus convexiusculus*	0.0-44.0	11.0	0.0-88	22	0.0-132	33	22
10.	*Corbicula striatella*	0.0-0.0	0.0	0.0-88	22	0.0	22	14.6
11.	*Indoplanorbis exustus*	0.0.-0.0	0.0	0.0-132	33	0.0-44.0	11	14.6
12.	*Lamellidens marginalis*	0.0-0.0	0.0	0.0-44.0	11	0.0-44.0	11	7.3
13.	*Laccotrephes griseus*	0.0-0.0	0.0	0.0	0.0	0.0-88	22	7.3
14.	*Diplonychus rusticus*	0.0-0.0	0.0	0.0-44.0	11	0.0	0.0	3.6
15.	*Cybister tocipunetatus*	0.0-0.0	0.0	0.0-44.0	11	0.0-88	22	11.0
16.	*Berosus dolerosus*	0.0-0.0	0.0	0.0	0.0	0.0-44.0	11	3.6
17.	*Chironomus* larvae	44.0-352	143	176-396	297	176-308	121	187
18.	*Psychoda* larvae	0.0-.0.0	0.0	0.0-88	44	0.0-88	44	22
19.	*Chaoborus* larvae	0.0-0.0	0.0	0.0-44.0	11	44.0-88	33	14.6
20.	*Tabanus* larvae	0.0-0.0	0.0	0.0	0.0	0.0-44.0	11	3.6
21.	*Rhaphidalobis* larvae	0.0-0.0	0.0	0.0	0.0	0.0-88	22	7.3
22.	*Erythrodiplax* sp.	0.0-0.0	0.0	0.0-88	22	0.0-44.0	11	11.0
23.	*Sympetrum*	0.0-88	22	0.0-88	22	0.0-88	22	22
24.	*Helocordulia uhleri*	0.0-0.0	0.0	0.0-44.0	11	0.0	0.0	3.6
25.	*Argia* sp.	0.0-0.0	0.0	0.0-44.0	11	0.0-88	22	11
26.	*Tachopteryx theoreyi*	0.0-0.0	0.0	0.0-88	22	0.0-132.0	33	18.3
27.	*Herpobdelloidea lateroculata*	0.0-44.0	11	0.0	0.0	0.0	0.0	3.6
28.	*Limnodrilus hoffmeisteri*	0.0-0.0	0.0	0.0-44.0	11	0.0-44.0	11	7.3
29.	*Barbronia weberi*	0.0-0.0	0.0	0.0-44.0	11	0.0	0.0	3.6
	Total	748-1012	880	792-1540	1188	528-1408	858	975

Plate:2 Indicator Species of Macroinvertebrates

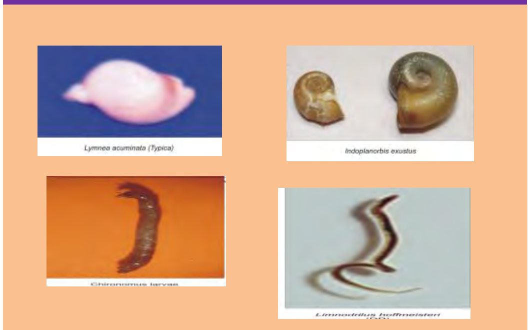


Fig.4 Seasonal quantitative analysis of macroinvertebrates (No./m of Jawahar Sagar

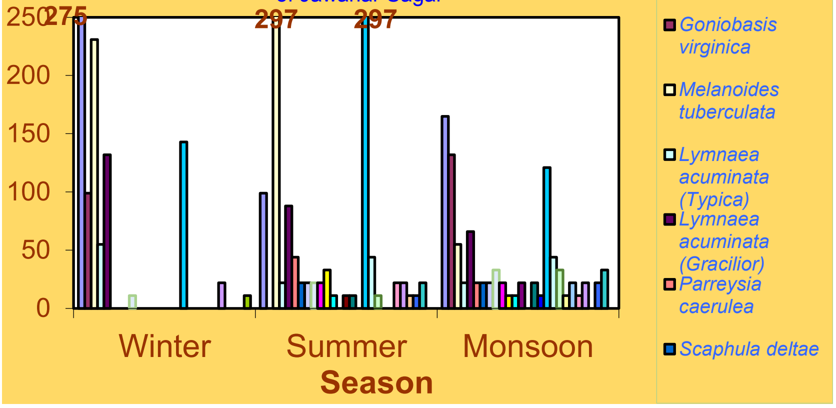
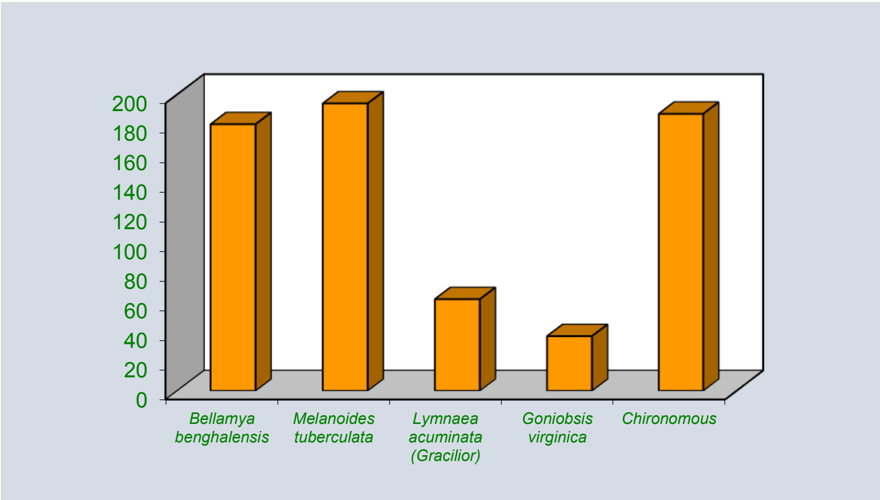


Fig. 5 Average density of five prominent benthos (No./m²) in Jawahar Sagar



Topic 3. Lake and lake basin management and policies

STRATEGY FOR CONSERVATION AND MANAGEMENT OF URBAN LAKES IN MUMBAI

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ABSTRACT

Studies on impact of massive urban development and anthropogenic activities on trophic status of Powai Lake, Vihar Lake, Bhavan's Pond, and Rain Water Harvesting (RWH) Pond in Mumbai city reveal deterioration of water quality leading to changes in the trophic status of these water bodies. Water Quality characteristics and trophic status of Powai Lake indicate it as a hyper- eutrophic. The lake is fully infested with water hyacinth as well as blooms of blue green algae Microcystis aeruginosa. Primary productivity studies on Vihar lake reveal that the lake is less productive with low plankton volume and low respiratory rates indicating its mesotrophic status. Bhavan's Pond and RWH Pond are relatively more productive with high Plankton volumes and respiratory rates and can be categorized as eutrophic in nature. Systematic efforts to evolve strategic action plan for conservation and management of these water bodies through stake holder and community participation are strongly recommended.

Keywords: Sarovar Samvardhini, trophic status, Water Quality, Urban lakes

INTRODUCTION

Sarovar Samvardhini or Conservation of Lakes, being implemented in India, is a concept based on integration of various local, regional, national and initiated international efforts for conservation and management of lakes in India. As a part of this initiative several lakes in the country have been identified and action programs have been developed for their implementation through stake holder participation.

Studies on water quality characteristics covering various physico-chemical and biological characteristics of water quality of water bodies viz. Vihar Lake, Powai lake, Bhavan's Pond, and RWH Pond along with impact of urbanization and prolific growth of anthropogenic activities on the ecological status of these water bodies in Mumbai Metropolitan Region have been carried out for two consecutive years (2010 -2012) as a part of this initiative.

An attempt has been made to evaluate these results in the light of findings of impact of urbanization on various other lakes in the country and an approach to develop a long-term action plan and strategy for its effective implementation through stake holder participation is recommended based on the Guidelines and approach developed by International Lake Basin Management (ILBM).

METHODS

Study Area

Mumbai, situated in the state of Maharashtra along the west coast of India, is a coastal megacity (with population more than 10 million), as well as the commercial capital of the country. The study area comprises four water bodies - Powai Lake, Vihar Lake, Bhavan's Pond, and Rain Water Harvesting (RWH) Pond of the Mumbai city as depicted in Table 1.

Powai and Vihar are two artificial lakes situated in northern Mumbai. Both the lakes were created for drinking water purpose by constructing dams between two hillocks across Mithi River.

Vihar Lake is located near Vihar village within the precincts of the Borivali National Park, also called the Sanjay Gandhi National Park, and so protected. The lake is 157 years old and spreads across an area of about 7.29 km^2.

Lake Powai is located in the north-eastern suburb of Mumbai. The lake is 125 years old and spreads across an area of about 2.1 km^2.Powai Lake is located downstream of Vihar Lake on Mithi River, which brings substantial discharge of exogenous nutrients and suspended solids into the lake. The lake water is not used for drinking purposes though used for non-potable purposes like gardening, angling and industrial use. This lake was included in "National Lake Conservation Plan" by the Ministry of Environment and Forests (Government of India) in the year 1991.

Bhavan's Pond is located in the western suburb of Mumbai.

Maharashtra Nature Park Society constructed a Rain water harvesting pond (RWH Pond) on garbage dump or land fill at Dharavi, Mumbai in year 2003 and did systematic plantation around it for development of Maharashtra Nature Park. The water spread area of the RWH Pond of MNP is about 4184.07 Sq.m. and the total area of the Municipal Solid Waste disposal site is about 37 Acres.

Table 1. Morphometry of four fresh water bodies of Mumbai, India

Particular	RWH Pond, MNP	Bhavan's Pond	Vihar lake	Powai lake
Location	Dharavi, Mumbai	Western suburban of Mumbai	North-eastern suburb of Mumbai	North-eastern suburb of Mumbai
Year of Impoundment	2003	….	1858	1891
Purpose	Irrigation	Irrigation	Drinking water	Drinking water
Constructed by	Maharashtra Nature Park Society	Bhavan's college	Mumbai Municipal Corporation	Mumbai Municipal Corporation
Lakes Types	Rain water harvesting Pond	Rain water harvesting Pond	Fresh water reservoir	Fresh water reservoir
Geographical features	19°05,295'N 72°51,345'E	19°07,283' N 72° 50, 057' E	19° 08, 384' N, 72° 54, 360' E	19°07,862'N 72°53,153'E
Water spread area (Wet season)	4184.0675 sq.m	11,329.32 sq.m	7.29 sq.km	2.1 sq.km
Maximum depth	3.71 meter	3 meter	34 meter	6.1 meter
Source of water	Rain Water	Rain Water	Rain Water	Rain Water
Main use of water	Irrigation	Irrigation	Drinking	Recreation and fishing

Collection and Analysis of Samples

Sampling was carried out on a monthly from 03 stations of each lake, usually between 09.00 and 10.00 hr. Sub-surface (0.3 m) water and plankton samples were collected from June 2010 to December 2012. Surface water sampling was done using 0.5 liter polythene cans. The can was washed in ambient water before sampling. Care was taken to preventing entry of air bubbles.

Standard methodology as per APHA (1981) has been used for sample collection, physicochemical and biological analysis of lake water.

RESULTS AND DISCUSSIONS

Powai lake, RWH Pond and Bhavan's Pond are significantly suffering from eutrophication which is evident from the symptoms such as foul odors, algal blooms, mats of macrophytes.

The variation in pH is an important parameter in water body since most of the aquatic organisms are adapted to average pH and do not withstand abrupt changes. Natural water with pH value of 6.0 to 8.0 can be considered as neutral water pH and of majority of potable water fall within this category. The study has shown pH values greater than 7.0 for all four water bodies, which indicate alkaline nature of lake water with varying scale of alkalinity. The average values of pH in RWH Pond (7.73), Bhavan's Pond (7.82) Powai lake (6.9) and Vihar lake (7.92) were found beyond permissible limits for drinking purposes. The data revealed no significant changes in pH of all the water bodies during study period.

The monsoon values of Hardness and chlorides of the water bodies were low indicating influence of dilution of water caused by monsoon water flow.

The transparency of water body is affected by the factors like planktonic growth, rainfall and water level. In the investigation transparency values were reduced in summer month which could be due to less water in the lake/pond saturated with more zooplankton and phytoplankton. The same trend was observed by Kedar and Patil (2002) in Rishi lake, Karanja in Maharashtra. Dissolved oxygen is the most important parameter which can be used as an index of water quality, primary production and pollution. The dissolved Oxygen varied from 4.5mg /l. to 7.3mg/l in RWH Pond, 3.1 mg/l to 7.2 mg/l in Bhavan's

Pond; Powai lake 3.9mg/l to 6.3mg/l and 6.2mg/l to 7.3mg/l in case of Vihar lake. Low content of dissolved oxygen is an assign of organic pollution; it's also due to inorganic reductants like Hydrogen sulphide, Ammonia, Nitrates, Ferrous ions and other such oxidisable substances (Ara et al., 2003). The higher Dissolved oxygen values of all four water bodies were in rainy season possibly due to comparatively high mixing of Oxygen from the air into water because of stronger winds in the season.
The alkalinity varied from 52.7mg/l to 36.3mg/l in RWH Pond, 28 mg/l to 232 mg/l in Bhavan's Pond, for Powai lake 96mg/l to 167mg/l and 14 mg/l to 74 mg/l in Vihar lake. The high alkalinity is a function of ions exchange that is calcium ions are replaced by Sodium ions and later contributed to alkalinity (Sharma and John 2009). Alkalinity may also be caused due to evolution of CO_2 during decomposition of organic matter. The steep fall during monsoon may be due to dilution of water.
Phosphates in water indicate degree of pollution. It is the key nutrient in the productivity of water in reservoirs (Piska, 2000). Phosphate values ranged from 0.07 – 0.49 mg/l in RWH Pond, 0.02 – 0.72 mg/l in Bhavan's Pond 0.06 – 067mg/l in Powai lake and 0.02 – 0.21 mg/l in Vihar lake. During monsoon period high values of phosphate were recorded. This was contributed by the surface run off and mixing with the influent water of the pond.
Nitrate entering aquatic systems arises from a variety of sources that include point and non-point sources of pollution, biological fixation of gaseous nitrogen, and the deposition of nitrogen oxides and ammonium (John Stoddard, 1994).Nitrate nitrogen in water in Indian reservoirs is mostly in traces and seldom exceeds 0.5 mg/l. Water with 0.2 – 0.5 mg/l of nitrates is of high productive reservoirs, up to 0.2 mg/l nitrates is in medium productive reservoirs, and in low productive reservoirs, the nitrates are negligible (Jhingran and Sugunan, 1990). The nitrate concentration ranged from 0.27 – 4.01 mg/l in RWH Pond, 0.38 – 2.03 mg/l in Bhavan's Pond 0.89 – 3.54mg/l in Powai lake and 0.08 – 1.45 mg/l in Vihar lake. The main source of Nitrate is the run-off and decomposition of organic matter. The higher inflow of water and consequent land drainage cause high value of Nitrate (Thilanga *et al.* 2005).
Chloride is one of the most important parameter in assessing the water quality. Munawar (1970) is of the opinion that higher concentration of chloride indicates higher degree of organic pollution. The Chloride contents varied from 22.33 mg/l to 124 mg/l for RWH Pond, 15.5 mg/l to 172 mg/l for Bhavan's Pond 39 mg/l to 76 mg/l in Powai lake and 10.9 mg/l to 28.6 mg/l in Vihar lake.
Sulphates are naturally occurring anion present in all kinds of natural water bodies and primarily related to the types of minerals found in watershed and acid rain and are carried in to the lakes by rainfall. The sulphates ranged from 2.2 – 90.3 mg/l in RWH Pond, 2.09 - 123 mg/l in Bhavan's Pond, 2.8 – 21.6 mg/l in Powai lake and 1.4 - 53 mg/l in Vihar lake.
The silica was very elaborate during monsoon probably due to runoff water carrying silicates to the water body. The silica concentration ranged from 0.97 -28.18 mg/l in RWH Pond, 1.64 – 14.93 mg/l in Bhavan's Pond, 4.68 – 13. 86 mg/l in Powailake and 1.73 – 20.03 mg/l in Vihar lake. Concentration of silica was comparatively less in Powai lake, RWH Pond and Bhavan's Pond as compared to Vihar lake. There might be some non-natural source of silica concentration.
Biochemical oxygen demands (BOD) varied from 4 – 14 mg/l in RWH Pond, 3 – 14 mg/l in Bhavan's Pond, 6.9 – 13.9 mg/l in Powai lake and 1.22 – 4.0 mg/l in Vihar lake. The higher levels of BOD in the urban lakes can be attributed to sewage influx through storm water drains, reduced circulation in water bodies. The BOD levels indicate higher levels of biodegradable organic matter, high oxygen consumption by heterotrophic organisms, and a high rate of organic matter remineralization.
Primary productivity studies on Vihar lake reveal that the lake is least productive and characterized by high transparency, low plankton volumes, and low respiratory rates. RWH Pond and Bhavan's Pond are relatively more productive than Vihar lake. Plankton volumes and respiratory rates were higher and transparency was less in both the water bodies. In contrast to the Vihar lake, plankton was abundant and respiratory rates were very high in Powai lake, RWH Pond and Bhavan's Pond.
The deteriorating water conditions in the lake was sorely reflected in the change of faunal and microflora pattern of the lakes. In the case of microalgae, blooms of blue green algae *Microcystis* species have become dominant in all three water bodies except Vihar lake. The blue green algae reproduce very quickly and they are not only known to deplete the dissolved oxygen level of water, especially during early morning, but also increase toxicity. From amongst macrophytes, the flowering plant water hyacinth in Powai lake, *Nymphaea species* (water lily) in Bhavan's Pond and *Pistia stratiotes* (Water lettuce) in RWH Pond develops dense growth at times, over the entire water surface. There are all the indicators of higher nutrient load, degrading water and sediment conditions.

Table 2. Average values of Water quality of four water bodies

Sr. No.	Parameters	Unit	RWH Pond	Bhavan's pond	Vihar lake	Powai lake
1	Water Temp.	ºC	27.2± 3.06	26.5±2.35	25.8±2.65	26.2±2.86
2	Ambient Temp.	ºC	28.9± 2.49	28.4±2.25	28.3±2.76	27.9±2.64
3	Transparency	cm	65.6±15.71	71.3±17.02	155.7±8.60	46.8±16.8
4	Turbidity	NTU	0.63±0.37	1.03±1.06	1.49±1.71	0.86±0.96
5	Dissolved Solids	mg/l	595.5±174.6	372.67±133.13	128.5±16.84	257.0±116.2
6	pH	…	7.7±0.43	7.8±0.25	7.9±0.32	6.9±0.46
7	Total Hardness	mg/l	229.6±69.94	139.8± 26.49	70.33±10.90	92.0±18.4
8	Total Chlorides	mg/l	58.7±23.09	33.86±12.82	16.14±5.24	50.05± 13.2
9	Dissolved Oxygen	mg/l	5.8±0.96	6.3±0.92	6.8±0.48	5.2±0.82
10	Total Alkalinity	mg/l	205.6±108.5	131.26±66.55	48.96±19.36	140.3±34.6
11	Phosphate	mg/l	0.23±0.12	0.22±0.20	0.11±0.09	0.21±0.11
12	Calcium	mg/l	48.32±24.14	34.28±7.74	15.02±3.60	20.46±6.22
13	Magnesium	mg/l	24.59± 7.66	12.47±6.33	7.95± 2.74	10.38±5.40
14	Sulphate	mg/l	35.25± 25.09	45.88±39.66	6.84±11.36	9.42±19.46
15	Silica	mg/l	8.53± 8.20	8.21±4.53	12.47±6.46	9.12±5.12
16	Free Carbon Dioxide	mg/l	1.13± 0.47	1.22±0.39	0.55±0.26	1.08±0.21
17	Nitrates Nitrogen	mg/l	2.96± 1.17	0.85±0.40	0.47±0.35	1.34±0.56
18	Salinity	%o	0.17± 0.20	0.08±0.13	0.04±0.02	0.14± 0.17
19	Sodium	mg/l	32.69± 15.13	18.19±8.95	7.8±3.45	21.43±6.32
20	Potassium	mg/l	11.78± 8.84	4.79±2.14	1.23±1.20	7.73±4.10
21	Lead	mg/l	0.01± 0.04	0.02±0.06	0.01±0.04	0.0048±0.05
22	a) Net Pri. Productivity	mgC/m³/day	756.83± 304.52	1138.5±525.00	509.96±237.61	713.00± 394.23
23	b) Gross Pri. Productivity	mgC/m³/day	1698.35± 416.21	2222.22±762.95	816.66±352.13	1687.1±486.42
24	BOD (5-days at 20ºC)	mg/l	6.28± 2.78	5.5±2.47	3.11±0.74	8.6± 3.34
25	C.O.D.	mg/l	44.67± 14.10	33.78±14.69	19.38±5.68	54.8±9.84
	Trophic State Index (TSI) Based on Carlson's Method		77.46 (Hyper-eutrophic)	73.89 ((Hyper-eutrophic)	54.78 (Mesotrophic)	69.24 (Eutrophic)

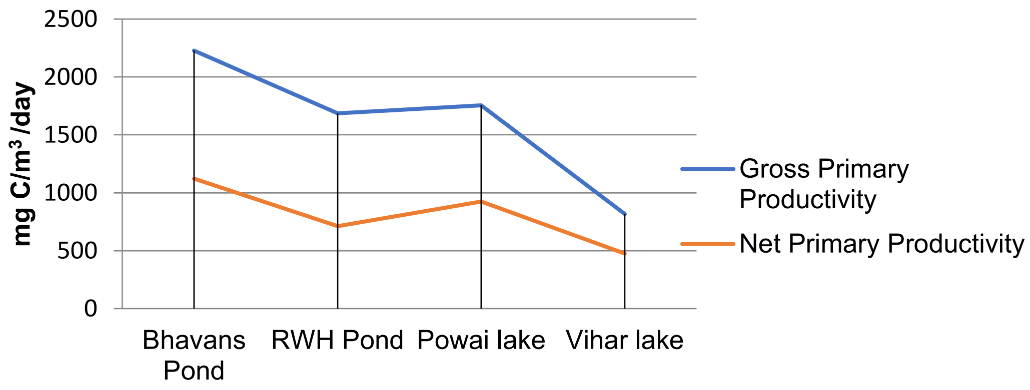

Fig.1 Average values of Primary Productivity of RWH Pond, Bhavan's Pond , Vihar lake & Powai lake

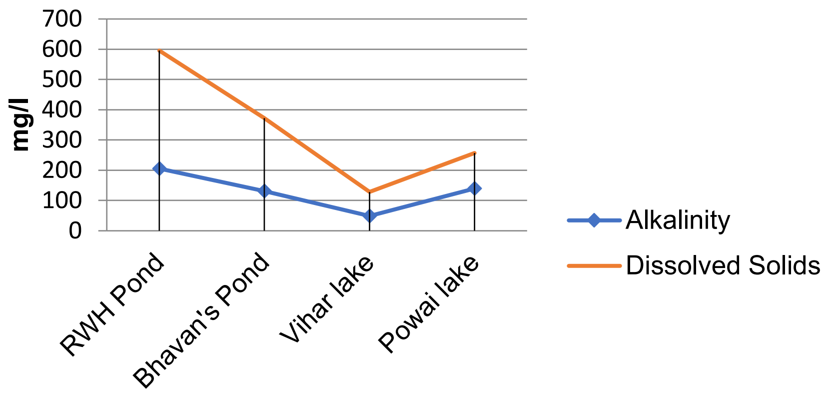

Fig. 2 Average values of Total Alkalinity and Dissolved Solids

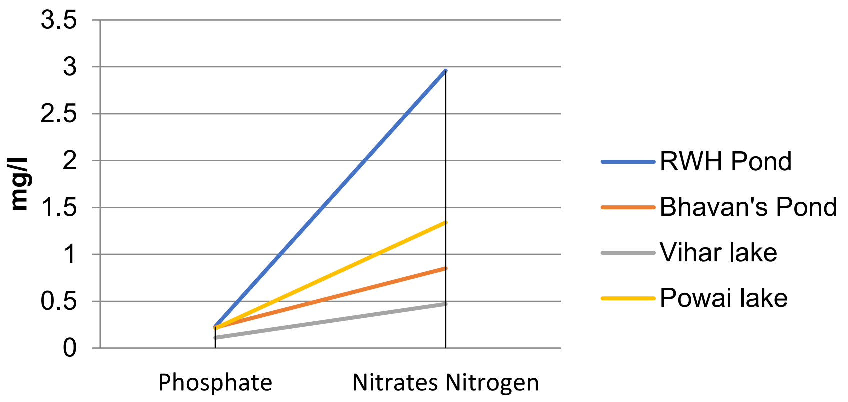

Fig. 3 Average values of Nitrate and Phosphate

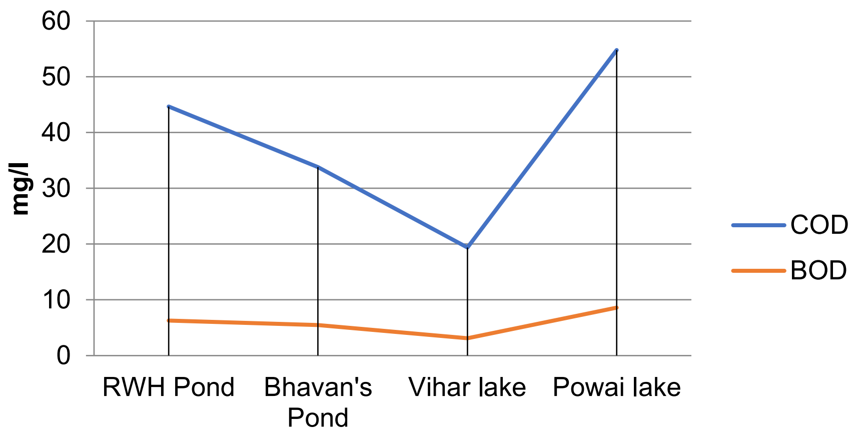

Fig. 4 Average values of COD and BOD

Findings and arguments

Water quality characteristics of various physico-chemical parameters of Powai lake, Vihar Lake, Bhavan's Pond and RWH Pond are summarized in Table 1. Relatively higher values of dissolved solids, nitrates and phosphates as well as COD and BOD and primary productivity along with significant decrease in transparency in Powailake indicate hyper eutrophic conditions. This is further corroborated with symptoms such as foul odors, prolific growth of water hyacinth (*Eichornia crassipus*) and blooms of blue green algae (*Microcystis sp.)* Viharlake exhibits water quality with relatively low levels of BOD and COD as well as poor nutrient levels indicating mesotrophic status of this lake.

RWH Pond and Bhavan's Pond however can be classified as eutrophic in nature based on their water quality during the period of observation.

Strategies and actions

Systematic efforts for monitoring of water quality of these water bodies through Naushad Ali Sarovar Samvardhini are strongly recommended so as to evolve strategic planning and action plan for conservation and management through stake holder and community participation. During the last ten years, action such as organizing training programmes, workshops, seminars in regional languages involving local public and students, stakeholders were initiated for increasing awareness towards water related problems.

Naushad Ali Sarovar Samvardhini made the following recommendations

1. Organise mass awareness training programmes for the locals about importance of the water bodies
2. Create public participation and involve other water related agencies in maintenance of the lake
3. Involve educational and scientific institutions in periodically monitoring the quality of lake water and in conducting biodiversity survey
4. Collate the scientific data collected and make it available to everyone, so that management strategies can be devised.
5. Complete involvement of all stakeholders is the necessary for conservation and management of lake and stress on lake is not reduce by blaming the Municipal Corporation, Community or the government. NGOs, residents and civic body can be roped in to conduct regular cleanup drives, only then can the quality of lake be restored.

Lessons Learned

1. Since the water body with healthy environment has potential to bestow many benefits, protecting and enhancing its economical, ecological, cultural and aesthetic values is in the interest of one and all.
2. Regular harvesting of algae and macrophyte biomass can reduce nutrient load on the lake and thereby reversing the eutrophication. The harvest can be up to 50% or sometimes up to 70% of the macrophytes
3. Stocking the lake with major carps adds to the food security and protein availability to population and introduction of larvivorous fishes reduces mosquito menace.
4. The harvested macrophytes can also be composted to produce fertilizer. However, this can be done if the macrophytes are to heavily contaminated with heavy metals or pesticides. Macrophytes can also be used for de-polluting the lake of pesticides, heavy metals and other pollutants
5. Desilting the Ganesh immersion sites, a month after the conclusion of the festival, has potential to reduce impact of this cultural siltation on the lake ecosystem.
6. Whenever there are good monsoon rains lake water should be released to remove bottom stagnation This can be done for deep water bodies. The deep water can be flushed out (either by pumping out from bottom or by opening the lower part of gates in case of dams) Care should be taken to avoid mixing of the deep water in the Lake as it may prove hazardous.
7. Educating and creating awareness about limited nature of fresh water and need for protection of lakes among the common man goes a long way in protection of lakes.
8. Educating children about water-related issues is a beneficial long-term measure for achieving sustainable lake use. It is necessary to educate use of free P detergents and also pre treatment of domestic wastes before releasing then in water bodies.
9. Propagation of World Lake Vision (WLV) through training programmes and other activities can be a very effective measure to implement Integrated Lake Basin Management (ILBM).

CONCLUSIONS

The physico-chemical and biological parameters thus revealed the present pollution level and trophic status of the lakes. Primary productivity studies on Vihar lake reveal that the lake is least productive and characterized by high transparency, low plankton volumes, and low respiratory rates. RWH Pond and Bhavan's Pond are relatively more productive than Vihar lake. Plankton volumes and respiratory rates were higher and transparency was less in both the water bodies. In contrast to the Vihar lake, plankton was abundant and respiratory rates were very high in Powai lake, RWH Pond and Bhavan's Pond. Low productivity, high transparency etc. of Vihar lake can be mainly attributed to the more depth (34 m) of Vihar lake; due to which there are limitations of light – penetration and mixing of water bodies. Powai Lake is polluted mainly by sewage disposal, growth, death and decay of aquatic weeds, and blooms in the lake. Regular cleaning of the macrophytes, enhancing public awareness, scavenging of polluted sediments, bioremediation, proper regulatory measures for anthropogenic waste disposal and strict measures to prevent further encroachment to the catchment area are needed for the restoration of Powai Lake. Vihar Lake is comparatively less polluted and is suitable for public water supply. However, it being deep lake, further research on the characteristics of the deeper layers of water column has to be carried out to get proper idea of the metabolism in Vihar lake.

Considering the importance of water resource from the lakes, particularly in urban areas all such water bodies we need to protect and conserve for their sustainable use for the benefit of communities and others. To generate public interest and involvement in the lake's conservation, there is a need of bringing together diverse groups of stake holders including NGOs, Civic body, Fishermen, Angler's Association and other organized sections of the society.

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POTENTIAL TRADE-OFFS BETWEEN CLIMATE CHANGE ADAPTATION AND MITIGATION IN RIVER BASIN SCALE WATER MANAGEMENT

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ABSTRACT

Climate change mitigation measures aim at reducing greenhouse gas emissions while adaptation measures should reduce the vulnerability of societies and ecosystems to adverse effects of climate change. In respect of water resources and ecological status of water bodies, the two approaches are often disconnected that, instead of synergies, can create trade-offs between them. In the present paper, we review the circumstances in which trade-offs occur between CC adaptation and mitigation measures and exemplify a number of cases when those measures may have adverse effects on water resources, their quality and ecological status. Careful spatial planning should avoid trade-offs between mitigation and adaptation, and make it possible to combine the reduction of vulnerability with mitigation of greenhouse gas emissions. Environmental impact assessment and strategic environmental assessment should be applied to analyse the environmental effects of proposed measures.

Keywords: water, river basin management, climate change, nutrients, cross-sectorial trade-offs

INTRODUCTION

Climate change represents a major challenge for the management of freshwater resources as water is the main channel through which the impact of climate change will be felt and the key to developing successful adaptation strategies (OECD 2013). The carbon balance of aquatic and terrestrial ecosystems is tightly linked with cycles of other nutrients, first of all with nitrogen and phosphorus, and with the CNP stoichiometry in food webs (Peñuelas et al. 2013). All these processes are sensitive to climate change (CC) and transform as a result of global trends. The recent study by Stips et al. (2016) unambiguously shows that greenhouse gases (GHG), and specifically CO_2, are the main causal drivers of the recent warming. Paradoxically, climate change itself could have a minor impact on water bodies compared to indirect pressures from human responses to climate change (both adaptation and mitigation) (WFD CIS, 2009).

CC mitigation measures aim to reduce GHG emissions while adaptation measures should reduce the vulnerability of societies and ecosystems to adverse effects of CC. In respect of water resources and ecological status of water bodies, the two approaches are often disconnected that, instead of synergies, can create trade-offs between them. It is well-known that large-scale biofuel production increases water demand and contamination, hydro-electric power plants fragmentise the river ecosystem integrity and affect biodiversity, dams and water reservoirs can emit additional GHGs, and seawater desalination as a drought combating measure accelerates energy consumption. It is much less known that even afforestration/reforestation, wetland reconstruction, floodplain restoration or creating buffer strips, usually considered as win-win measures (Nixon, 2008), may locally become antagonistic to other adaptation and mitigation measures. Given that ecosystems can provide mitigation and adaptation services at the same time, policies and local initiatives related to ecosystem management have the potential to contribute to both climate change strategies and to avoid trade-offs between them (Locatelli 2016).

In the present paper, we review the circumstances in which trade-offs occur between CC adaptation and mitigation measures and exemplify a number of cases when those measures may have adverse effects on water resources, their quality and ecological status.

METHODS

The review is based on recent scientific literature, some guidance documents and policy reports (e.g. FAO, 2008; WFD CIS, 2009; UN, 2009; OECD, 2013), and the databases of CC mitigation and adaptation measures, represented in River Basin Management Plans (RBMPs) during their preparation phase (Nixon, 2008) and after adoption (Nõges et al., 2010).

RESULTS AND DISCUSSIONS

Mitigation measures potentially impacting water resources and water quality

Carbon dioxide capture and storage. Carbon dioxide capture and storage is considered a crucial strategy for meeting CO_2 emission reduction target. Three different geological formations are commonly considered for CO_2 storage: depleted oil and gas reservoirs, coalbeds, and saline aquifers (Leung et al., 2014). Deep ocean storage is also a feasible option for CO_2 storage (Herzog & Golomb, 2004) although environmental concerns such as ocean acidification and eutrophication will likely limit its application. As potential impacts to water resources, the United Nations guidance (UN, 2009) mentions the degradation of groundwater quality due to leakage of CO_2 from injection and abandoned wells, leakage across faults and ineffective confining layers and as precaution and remediation measures – careful site selection, effective regulatory oversight, and appropriate monitoring of the condition of the storage sites. The criteria and approaches for selecting suitable geological sites for storing CO_2 should include the tectonic setting and geology of the basin, its geothermal regime, hydrology of formation waters, hydrocarbon potential and basin maturity (Bachu, 2000).

Geothermal energy production. Use of drinking water aquifers for the generation of shallow geothermal energy causes temperature perturbations far beyond the natural variations that may mobilize various trace elements affecting groundwater quality. Column experiments with anoxic sandy sediments showed a significantly increased of As concentration at 25 °C while at 60 °C, significant increases were observed in pH and DOC, P, K, Si, As, Mo, V, B, and F concentrations (Bonte et al. 2013). Besides those mentioned, other pollutant chemicals in the liquid fraction may be hydrogen sulfide (H_2S), mercury (Hg) and other heavy metals such as Pb, Cd, Fe, Zn and Mn. Lithium (Li) and ammonia (NH_3), as well as aluminium, may also occur in harmful concentrations as well as brines, whose excessive salt concentrations can cause direct damage to the environment (Kristmannsdottir & Armannsson, 2003). Remediation techniques include appropriate spatial planning for the location of facilities, use of appropriate techniques including those of re-injection (UN, 2009).

Biofuel production. Common feedstocks for sustainable biofuel production include (1) perennial plants grown on degraded lands abandoned from agricultural use, (2) crop residues, (3) wood and forest residues, (4) double crops and mixed cropping systems, and (5) solid municipal and industrial wastes (Tilman et al., 2010). As environmental challenges related to land-based biofuel production, the United Nations guidance (UN, 2009) lists the increased water demand, enhanced leaching of pesticides and nutrients leading to contamination of water, biodiversity impacts, conflicts with food production and land use changes, leading to indirect effects on water resources and increased vulnerability to droughts. A specific water related branch in biofuel production is the use of microalgae for making biodiesel (Chisti & Yan, 2011). A life-cycle analysis on biodiesel production from microalgae (Yang et al., 2011) confirmed the competitiveness of microalgae-based biofuels and highlighted the necessity of recycling harvested water and using sea/wastewater as water source. The authors showed that to generate 1 kg biodiesel, 3726 kg water, 0.33 kg nitrogen, and 0.71 kg phosphate are required if freshwater is used without recycling. Recycling harvest water reduces the water and nutrients usage by 84% and 55%. Using sea/wastewater decreases 90% water requirement and eliminates the need of all the nutrients except phosphate. To date, microalgae-based biofuel production has not yet been commercialized to large-scale due to potential impacts, especially on water usage.

Hydropower is the most important and widely-used renewable source of energy. However, fish populations can be impacted if fish cannot pass impoundment dams and migrate upstream to spawning grounds or if they cannot migrate downstream to the ocean (Hendry et al, 2003). Hydropower can also impact water quality and flow. Hydropower plants can cause low dissolved oxygen levels in the water, a problem that is harmful to riparian (riverbank) habitats. The hydropeaking downstream of a hydropower installation caused by a variable operating water demand is also critical for the survival of river habitats (Shen & Diplas, 2010). Future changes in the occurrence of low flows and droughts may also affect the output of hydroelectric power plants. New hydropower facilities lead to losses of natural habitats and even human settlements and may compete with other forms of landuse. Those alternative uses may be more highly valued than power generation. Local cultures and historical sites may be impinged upon. Some older hydropower facilities may have historic value, so renovations of these facilities must also be sensitive to such preservation concerns and to impacts on plant and animal life.

It is urgent that an ecological compensation mechanism is established for hydropower to promote its sustainable development. Ecological compensation can be defined as the substitution of ecological functions or qualities that are impaired by human development (Cuperus et al., 1999) that at present has developed into an effective measure to balance efficiency and equity during economic development and environmental protection. Within a new compensation mechanism framework (Yu & Xu, 2016), the displaced people, inundated habitats, and regulated rivers are identified as the recipients, whereas the beneficiaries from the hydropower development as the payers. The market-led and government-led compensation should be integrated when designing natural habitat restoration, resettlement compensation, and payment for ecosystem services in hydropower development.

Afforestation/reforestration. The process by which carbon sinks remove carbon dioxide from the atmosphere is known as carbon sequestration. During the 1980s and 1990s, global terrestrial ecosystems took up carbon at a rate of 1–4 Pg y-1 offsetting 10–60% of the fossil-fuel emissions (Houghton, 2007). However, afforestation/reforestration of upland catchments with fast growing plantations can have significant impact on local water use, with consequent impacts on water availability downstream. If converted to forest, about 27% (200 Mha) deemed suitable for the Clean Development Mechanism-Afforestation/Reforestation (CDM-AR) prevalent in drier areas would cause an 80–100% decrease in runoff. Reduced emissions from deforestation as a mitigation measures, can threaten the land rights and livelihoods of rural people and undermine efforts to improve food security and sustainable development (FAO, 2008). It will become increasingly important to consider implications on local to regional water resources, and how the hydrologic dimension of CDM-AR impacts sustainability, local communities, and food security (Trabucco et al., 2008).

Wetlands and wetland restoration. Long regarded as wastelands, wetlands are now recognized as important features in the landscape that provide numerous beneficial services for people and for fish and wildlife. Some of these services, or functions, include (US EPA, 2001): protecting and improving water quality, providing fish and wildlife habitats, storing floodwaters, and maintaining surface water flow during dry periods. In wetland restoration, large uncertainties are included in the possibilities to maintain the necessary hydrological regime and loading of wetlands which determines their efficiency as sites for carbon sequestration (Hefting et al., 2003) and denitrification (Mulholland et al., 2008). Increased methane production and leaching of nitrogen and dissolved organic carbon may be expected from drained fens after restoring their water regime (Urbanová et al., 2011).

Land management for soil carbon conservation. Soil management practices that minimize carbon loss, the disruption of the soil's structure and natural biodiversity known as 'conservation tillage' (CT) can improve soil stability thereby facilitating better drainage and water holding capacity that reduces the extremes of water logging and drought (Holland, 2004). These improvements to soil structure also reduce the risk of runoff and pollution of surface waters with sediment, pesticides and nutrients. Although CT generally can prevent nutrient loss, long-term use of CT can cause compaction and, as a consequence, phosphate can accumulate on the soil surface increasing loss via runoff (Rasmussen, 1999). The risk is higher if phosphate applications continue (Baker & Laflen, 1983) but can be minimized by adjusted fertilizer application rates that is an additional benefit from applying CT (Gilley, 1995). The type of soil cultivation also strongly influences nitrate leaching but the evidence that leaching losses are higher for inversion compared to CT is contradictory (Holland, 2004).

Efficiency of riparian buffer zones questioned. In rural watersheds, the riparian land use remains a crucial link between the agricultural lands and the stream environment. It has been widely believed that these riparian buffer zones are effective in reducing the nutrient concentrations in water that pass through them. The first evidence for the role of riparian zones in buffering nutrient input from adjacent fields was provided by Peterjohn & Correll (1984); since then, numerous studies have evaluated the capacity of these channel-marginal wetlands to retain or remove nutrients and other pollutants. Studies of perennial streams have identified denitrification within riparian zone as one of the dominant mechanisms removing nitrogen (Woodward et al., 2009), however, this process has intrinsic limitations. In a field study in riparian zones of small Dutch streams, Hefting et al. (2003) found that nitrogen buffering capacity decreased with nitrate load but that the rate of emission of nitrous oxide (N_2O), a potent greenhouse gas, increased dramatically with nitrogen load. High nitrate availability inhibits or retards N_2O reduction and, as a result, substantial quantities of N_2O may be emitted from riparian buffer zones in agricultural environments. Also, an experiment with N addition to streams across multiple biomes and land uses in the U.S. (Mulholland et al., 2008) showed that both total uptake velocity and denitrification rate decreased with increasing nitrate concentration.

Floodplain restoration means large changes in the landscape and everyday life of the inhabitants. Increased flooding upstream in the 'flood expansion areas' may affect the agriculture causing partial or total destruction of crops and resulting in serious losses for the farmers. Norway has also pointed out (Nixon, 2008) that several flood protection measures may in some cases reduce drainage capacity of rivers.

Water abstraction. Global aridity has increased substantially since the 1970s due to recent drying over Africa, southern Europe, East and South Asia, and eastern Australia (Dai, 2011) that together with the doubling of the population number has multiplied water needs in agriculture and households. Although climate change will aggravate hydrological impacts on river systems, currently high water abstraction rates remain the principal contributor to reduced system flows (Grafton et al., 2012). Irrigation's additional water needs, such as in the Ganges region, reduce flows and affect seasonal spawning and fish productivity (Meyers et al., 2012). For lakes in endorheic areas which water budget is controlled by the gentle balance between inflow and evaporation, any change of the inflow amounts results immediately in changing water levels, the Aral Sea being an alarming example of devastating human impact (Micklin, 2007). Changes in governance, including sharing the variability between the environment and consumers, are urgently required to maintain or restore the health of these aquatic systems.

Adaptation measures in the water sector which can have negative impacts on climate change mitigation
Desalinization of marine water or rainwater harvesting for water supply? The energy use in the water sector is increasing because, water resource adaptation will often require more energy to meet the rising demand, regulatory standards and the effects of climate change (Rothausen & Conway, 2011). The close link between water and energy is often referred to as the water-energy nexus (Stokes et al., 2014) and comprises the use of water in many processes of power generation, as well as the use of energy in water supply and wastewater treatment. Some adaptation options to climate change, such as desalination and pumping, are very energy intensive. In water supply sector, there is a clear trade-off between solutions containing rainwater tanks which are expensive and desalinated water supply which greatly increases GHG emissions (Paton et al 2014). While desalination plants may be good adaptation options to climate change due to their climate-independence, rainwater may be a better mitigation response, albeit more expensive. As a possible beneficial solution, Paton et al. (2014) suggest applying a multiobjective evolutionary algorithm (MOEA), which can evolve an approximation of entire trade-off fronts of multiple objectives in a single run.

GHG emissions for water reservoirs. Besides adverse effects on freshwater ecological flow, river habitats, fish movement and water quality, freshwater dams are a potential source of greenhouse gases (GHGs). Three GHGs are potentially emitted from lakes and reservoirs: carbon dioxide, methane, and nitrous oxide with methane fluxes having the greatest significance relative to global GHG budgets (MacKay et al., 2009). Variability in GHG fluxes from lakes and reservoirs has been attributed to their age, residence time, nature and type of vegetation and soils inundated, quantity of biomass inundated, morphometry, operational conditions, nutrient status, and carbon sources, as well as climatic influences. It is anticipated that fluxes of greenhouse gases to the atmosphere from all reservoirs will increase in the future because they are needed as a relatively clean alternative to energy produced by fossil fuel combustion and because of needs for water and food as well as the industrial and recreational demands of a growing global population (St. Louis et al., 2000). The authors estimate that greenhouse gas fluxes from hydroelectric reservoirs only, which comprise 25% of the surface area of all reservoir types, could reach approximately 15% of the global warming potential of all other current anthropogenic emissions.

Trade-off between adaptation and mitigation for sea level rise. Sea level rise is threatening a number of countries by 2100 with severe consequences. Analysis using the FUND model (Climate Framework for Uncertainty, Negotiation and Distribution) showed that adaptation would reduce potential impacts by a factor 10–100 (Tol, 2007) coming at a minor cost compared to the damage avoided whereas mitigation can reduce impacts only to a limited extent. Stabilising carbon dioxide concentrations at 550 ppm would cut impacts in 2100 by about 10%. That basic insight shows that adaptation and mitigation are not just alternative policy options for climate change. If mitigation is higher, less adaptation is needed, but there is also less adaptation possible or desirable. Adaptation and mitigation strategies should be studied together.

The United Nations guidance (UN, 2009) provides five pragmatic suggestions for broadening climate policy to take into account the linkages between adaptation and mitigation: (1) avoid trade-offs when designing policies for mitigation or adaptation, (2) identify synergies, (3) enhance response capacity by enhancing the generic capacity to both adapt and mitigate through non-climate policies (education, institutional capacity, etc.), (4) develop institutional links between adaptation and mitigation – e.g. in national institutions and in international negotiations, and (5) mainstream adaptation and mitigation considerations into broader sustainable development policies.

CONCLUSIONS

Careful spatial planning should avoid trade-offs between mitigation and adaptation, and make it possible to combine the reduction of vulnerability with mitigation of GHG emissions. Environmental impact assessment and strategic environmental assessment should be applied to analyse the environmental effects of proposed measures and to find an optimal prioritisation of the Multiple Uses and Functions of Water Services (MUFS).

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PEOPLE'S ACTIVITIES IN LAKE DANAO, PACIJAN ISLAND, CEBU, PHILIPPINES

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ABSTRACT

Pacijan Island is blessed to have Lake Danao as the largest and cleanest lake throughout Region 7 and one to the tourist destinations in Camotes islands. The study on people's activity was made to find out their effects to the lake as well as their nature, problems and solutions. Actual interview with the respondents and visits in the Lake Danao and workplace of the respondents was using an interview guide to gather data throughout the barangays surrounding the lake namely, Northern Poblacion, Sta. Cruz, Cabunga-an, Esperanza, Union and Campo. Results as to capture fisheries shows that pole and line dominates as the fishing gadget throughout the six barangays followed by spear fishing, fish pots, drag seine and gillnet. Fishes caught are tilapia, mudfish, freshwater catfish, climbing perch, therapon, shrimps and goby. Aquaculture activities were only done by the BFAR-7 and D.A- Municipal Office. Post-harvest processing of caught fishes were drying, frying, pickled, stewed, broiled and tinola. Agricultural activities are planting corn, rice, coconut, cassava, vegetables and cow and chicken raising. Recreational activities and business includes the construction and operation of Green Lake Park, White Lake Park, bike trail, and sakanaw. Conservation and sustainability of Lake Danao as an aquatic site involves Lake Danao Clean-up, clearing the area and tree planting. Problems encountered are stealing of caught fish in fish pots, restricting fishing, using gillnets becomes a problem because fishing is the major livelihood of the people. Soli-soli weavers have no specific areas for gathering the raw materials. Rainy season becomes their problem because the soli-soli is not thoroughly and immediately dried resulting to poor quality of the product. Perceptions as to the conditions of the lake show that during summer months water is shallower and during rainy days the water is very deep. Crocodiles, leeches and land turtles are already gone and replaced by therapons. Species of birds are diminishing due to disturbance and hurting of birds which were stopped for the last 10 years. The people participate in maintaining the lake for its sustainabilty

Keywords: Lake Danao, Pacijan Island

INTRODUCTION

There are millions of Filipinos who are dependent on fishing and fisheries as their livelihood. This accounts on the fact that our country is rich in fishery resources and presently unemployment problem besets the country. Furthermore, being an archipelago it as long and wider coastal and freshwater areas where most of the Filipinos prefer to live in the fishing villages. Human population increases and Camotes island is not exempted of this social phenomenon. Camotes Island is having freshwater areas where it inhabits flora and fauna which can be of use to the people economically and socially. Due to this, Perez and Mendoza (1998) commented that the aquatic biodiversity is threatened because a higher population which means more mouths to feed. Resource extraction has increased like fishing and gleaning including the types of implements used and the rate of extraction contributed to the declined catch in the lakes and other freshwater areas in the country. Pacijan Isand is one of islands in Camotes island has Lake Danao which is a picturesque eight- shaped inland body of water with an area of 649 ha with a 1-acre (4,047 sq.m.) islet at the middle. It is the largest and longest lake in the Visayas (Tanduyan and Bontia, 2001). It is surrounded by six out of 15 barangays in the town of San Francisco, Cebu. The lake supplies water to the rice fields in Sitio Danao and Patabog. Its shoreline ranges from rocky to soft mud. The type of soil is coarse, silty and sandy. The depth of the water ranges from 27-29^{0}C. Water has a pH of 8.5-9.0. Salinity ranges from 0-0.5 ppt. The lake water is free from pollutants, except for some allochthonous materials (Station Profile of Carmen Lake Danao Fishery Complex/Research Station for Freshwater Fisheries Development Zone, Union, San Francisco, Cebu. 1995). It has no definite inlet and outlet, but it is presumed that a subterranean spring supplies water to the lake. Assorted vegetation such as hydrilla, water lily, water hyacinth, and kangkong "*Ipomaea aquatica* are found in the lake. "Soli-soli", palawan, nipa and coconuts grow along the periphery of the lake. The "soli-soli" plant (Typha latifolia) present in the lake are made into different articles like mat, hat, centerpiece, bags of different styles, wall décor and doormats to enhance the cottage industry of the inhabitants. It has also some fishes and invertebrates inhabiting in Lake Danao. The lake is a tourist attraction where boat trips could be for recreation. Majority of the households living nearby the lake catch fish in the lake for food and for the market. The lake is also used for bathing and washing of clothes.

Objectives of the study

The objectives of the study are to determine the activities of the people in Lake Danao which include either fishing, aquaculture, post-harvest processing, agriculture and other businesses. To find out the effects of the activities to the lake like environmental and socio-economic To find out the problems met by the people on doing such activities and to find out the proposed solutions they made to solve the problems

MATERIALS AND METHODS

Study Sites

Lake Danao of Pacijan Island with San Francisco as the municipality is the focus of the study. Pacijan Island is one of the Islands of Camotes where it is located in the Northern part of the Cebu province under 5th district. It has an area of 649 has and with six barangays surrounding it. People representing the six barangays namely: Northern Poblacion, Sta Cruz, Cabonga-an, Esperanza, Union and Campo were interviewed to gather the data (**Fig. 3**).

Map of the Research Area

Fig. 1. Map of the Philippines

Fig. 2. Map of Cebu

Fig. 3. Map of Camotes Island

Fig. 4. Map of Lake Danao, San Francisco (Photo from San Francisco Lake Danao Report)

METHODS

This study is a descriptive research using interview guide in gathering the data. Actual interview of the respondents and field visits were done to get empirical data. A self-made questionnaire was used reflective of questions related to the objectives sought.

RESULTS AND DISCUSSION

Fishing Activites

Table 1 presents the fishing activities in Lake Danao. It is noted that the use pole and line as the method of gathering fishes in Lake Danao was the most dominant (149) followed by the use of gill net(144) the use of fishpo t(87) ;the use of fish scare (sinsin) comes next (36) and spear fishing is the last (8).This is distributed throughout the six barangays surrounding the lake.

Table 1. Fishing Activities in Lake Danao San Francisco, Cebu

Barangay/ Nature of Fishing	Pole and Line (Number of Users)	Fish Pot (Number of Users)	Gill Net (Number of Users)	Fish Care (Sin-sin) (Number of Users)	Spear Fishing (Number of Users)
1. Union Proper	7	-	5	5	-
- Patabog	15		10	10	-
-Kantuwak	10	10	None	None	-
2. Campo					-
-Canuche	5	17	22	12	-
					-
3. Northern Poblacion -Danao	15	18	15	-	-
4. Sta. Cruz					
-Li-ong	2	3	5	4	5
-Lawis	5	7	7	5	3
5. Cabunga-an					
-Batang	20	5	19	-	-
-Timobo	25	13	26	-	-
-Ubos	30	4	7	-	-
6. Esperanza					
-Igot	15	10	28	-	-
Total	**149**	**87**	**144**	**36**	**8**

Fig.5. Pole and Line used for fishing

Fig. 6. Fish pot

Fig. 7. Hook and Line

Fig. 8. Gill net

Aquaculture Activities

Table 2 Presents the aquaculture activities in Lake Danao. It is noted that Union proper where the BFAR Research Outreach Station is located has dominated the aquaculture facility which ranges from fish cages (31 units) followed by Northern Poblacion (10units). It has one fish pen and 12 units fish tanks.

Table 2. Aquaculture Activities in Lake Danao, San Francisco, Cebu, Philippines

Barangay/Aquaculture Facility	Fish Cage	Hapa Net	Fish pen	Fish Tank
1. Union Proper (BFAR)	30 units	3	1	12 units
-SitioPatabog	1	None	-	
-SitioKantuwak	-	-	-	
2. Campo				
-SitioCanuche	-	-	-	-
3. Northern Poblacion				
-SitioDanao	10 units	-	-	-
4. Sta. Cruz				
-SitioLi-ong	-	-	-	-
-SitioLawis	-	-	-	-
5. Cabunga-an				
-SitioBatang	-	-	-	-
-SitioTimobo				
-SitioUbos				
6. Esperanza				
-SitioIgot	-	-	-	-
Total	41	3	1	12

Fig. 9 Fish cages

Fig. 10 Fish Tank

Fig. 11 Hapa net

Fig. 12 Fish pens

Post-Harvest Activities

Table 3 presents the post-harvest activities of the people in Lake Danao. Stewed, pickled fishes and fried fish preparations dominated among other post-harvest fish preparation. This is followed by broiling and drying. Canning of tilapia and other fishes in Lake Danao was done experimentally by the students in the Cebu Technological University.

Table 3. Post-Harvest Activities in Lake Danao, San Francisco, Cebu

Barangay/Households	Drying	Broiling	Pickled fish	Stewed	Fried
1. Union Proper (BFAR)	5	20	150	200	
-SitioPatabog	35	25	94	94	
-SitioKantuwak	22	22	91	91	
2. Campo					
-SitioCanuche	5	20	60	60	
3. Northern Poblacion					
-SitioDanao	5	25	68	70	
4. Sta. Cruz					
-SitioLi-ong	3	30	67	67	
-SitioLawis	12	30	69	69	
5. Cabunga-an					
-SitioBatang	25	25	63	63	
-SitioTimobo	4	10	20	30	
-SitioUbos	15	40	85	85	
6. Esperanza					
-SitioIgot	30	42	121	121	
Total	161	289	887	950	855

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Fig. 13. Fish processing done by the students of Cebu Technological University, San Francisco Campus

Agricultural Activities

Table 4. presents the agricultural activities around Lake Danao. Rice farming dominated in Lake Danao consisting of 51 families followed by corn farming which (42) and then vegetable gardening. Northern Poblacion particularly in Sitio Danao and Sitio Canuche and Cabonga-an.

Table 4. Agricultural Activities in Lake Danao San Francisco, Cebu

Barangay	Corn	Rice	Banana	Kangkong	Ampalaya	Egg plant	String beans	Pepper	Okra
1. Union Proper (BFAR)	1	-	1	-	1	1	-	1	1
-SitioPatabog									
-SitioKantuwak	3	-	3	-	1	5	1	5	10
	5	-	3	-	-	10	1	5	3
2. Campo									
-SitioCanuche	5	15	4	-	-	-	2	-	-
3. Northern Poblacion									
-SitoDanao									
	10	25	10	1	5	5	3	2	2
4. Sta. Cruz									
-SitioLi-ong	3	-	5	-	-	-	2	3	2
-SitioLawis	6	-	8	-	-	-	-	3	3
5. Cabunga-an									
-SitioBatang									
-SitioTimobo	-	5	2	1	-	-	-	-	3
-SitioUbos	-	-	2	-	-	-	-	-	-
	-	6	3	2	-	-	-	-	6
6. Esperanza									
-SitioIgot	10	-	10	-	-	-	-	-	-
Total	43	51	51	4	7	21	9	19	30

Fig. 14 The corn farm

Fig. 15 Newly harvested rice field

Fig. 16 Bananas

Fig. 17 Kangkong

Fig. 18. Egg plant

Fig. 19. String

Fig. 20. Pepper

Fig. 21. Okra

Table 5 presents the different businesses activities engaged by the people of Lake Danao.Barangay Union tops among the businesses activities in Lake Danao followed by Cabunga-an and Sta. Cruz and Northern Poblacion. No business activities happened in Esperanza particularly in SitioIgot. Soli-soli waving tops among the businesses followed by nipa shingles making. This plant (soli-soli and nipa) are commonly found along the shores of Lake Danao that is why this business proliferates here.

Union Proper tops among the barangays surrounding Lake Danao it is because of the presents of the Lake Danao Park and Green Lake Park. In here, boat tour around in Lake Danao happens using Sakanaw (boat of Lake Danao) where tourist are moved around the Lake by this boat with a fare of Php.500/trip. Several row boats and other boat rides were done so people usually are gathered here for the viewing Lake Danao. Naturally other businesses like entertainment, food and hotel are present. Green Lake Hotel is built near the Lake Danao Park. Barangay Cabunga-an has also a hotel where it is named as White Lake Hotel with some entertainment activities.

Table 5. Other Businesses in Lake Danao San Francisco, Cebu

Barangay	Recreational	Food	Entertainment	Hotel	Nipa*(Nyph afruticans)* Shingles	Soli-soli (*Typhalatif olia)* weaving
1. Union Proper (BFAR)						
-SitioPatabog	✓	✓	✓	✓	✓	✓
-SitioKantuwak	-	-	-	-	✓	✓
2. Campo						
-SitioCanuche	-	-	-	-	-	✓
3. Northern Poblacion						
-SitioDanao	-	-	-	-	✓	✓
4. Sta. Cruz						
-SitioLi-ong	-	-	-	-	✓	✓
-SitioLawis	-	-	-	-	✓	✓
5. Cabunga-an						
-SitioBatang	-	-	-	-	✓	-
-SitioTimobo	-	-	-	-	-	-
-SitioUbos	✓	-	✓	✓	✓	✓
6. Esperanza						
-SitioIgot	-	-	-	-	-	-
Total	2	1	2	2	7	7

Fig. 22. Lake Danao Park

Fig. 23. Tandem boat and Sakanaw

Fig. 24. Duck raw

Fig. 25. Green Lake Park

Fig. 26. Horseback

Fig. 27. Food

Fig. 28. White Lake Park and Hotel

Fig. 29. Kanlingiw swimming pool, Lake Danao Park

Fig. 30. Entertainment business

Fig. 31. Nipa plant

Fig. 32. Nipa shingles

Fig. 33. Drying soli-soli (***Typhalatifolia***)

Fig. 34. The thoroughly dried soli-soli ready for waving into different articles

Fig. 35. Actual weaving of soli-soli into mats

Fig.36. Almost done weaving of soli-soli mats

Fig. 37. Finished product of soli-soli mats

Environmental Conservation Activities

Table 6 presents the Environmental activities of the People. Although there were extractions made by the people they also participated in Lake Danao Clean-Up, tree planting and clearing of the lake periphery. These are some of the positive values of the people.

Table 6. Environmental Conservation Activities in Lake Danao, San Francisco, Cebu

Activity	Date
1. Lake Clean-Up	In September 18, each year simultaneously with international Coastal Clean-Up
2. Cleaning the area. The peripheral part of the Lake are cleared of its grasses and small shrubs to widened the area for the bike trail	As ordered by the LGU
3. Tree planting The people will engage in tree planting as part of the environmental conservation program.	As ordered by the LGU

Effects of the Activities

Table 7 presents the perception of the people in Lake in term of environmental and socio economic aspects. As perceived by the inhabitants in the Lake climate change has affected the abundance of plants and animals especially during summer. There is low water level in the Lake during summer people will go on fishing (especially the soli-soli weavers and soli-soli shingles maker) due to less abundance of this plants during summer. However some pare occupied by these plants are developed into bike trail and Lake Danao Park and White Lake Park this add livelihood options for the people.

Table 7. The effects of the activities to the Lake in terms of Environmental and Socio-Economic Aspects

Environmental Effects	Socio-economicEffects
Due to climate change during summer the water level in Lake Danao is very much lower today than before. Many plants and animals were lost during this time unlike before.	The people went on fishing mostly when soli-soli weaving and nipa shingles making have less market, A part of the area occupied by nipa and soli-soli are now developed into bike trail, Lake Danao Park and White Lake Resort found in Ubos, Cabunga-an.

Fig. 38. Bike trail

Use of Water in Lake Danao

Table 8 presents the use of water in the Lake. Human and Animal bathing tops among the uses of water throughout the barangays around the Lake. Followed by washing, deep well pumping for household use. Two water refilling stations were established in barangay Campo and Union.

Table 8. Use of Water in Lake Danao, San Francisco, Cebu

Barangay/Water	Water refilling	Washing Human	Drinking Human	Bathing Human	Animal Bathing	Deep well pumping
1. Union	✓	-		✓	✓	✓
2. Campo	✓	-	✓	✓	✓ (Carabao and tied domisticatedpigs)	✓
3.NorthernPob.	-	✓	✓	✓	✓	✓
4. Sta. Cruz	-	✓	✓	✓	✓	
5. Cabunga-an	-	✓	✓	✓	✓	✓
6. Esperanza	-	✓		✓	✓	
Total	2	4	4	6	6	4

Fig. 39. Water refilling station

Fig. 40. Washing their clothes

Fig. 41. Bathing

Fig. 42. Deep well pumping

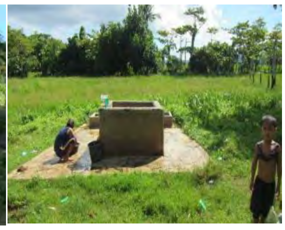

Fig. 43. The deep well

Problems met by the People in Lake Danao

Table 9 presents the problems meet by the people of Lake Danao as they underwent on their activities. It was shown that catching regulation of the fishes of the Lake was the no. 1 problem including size limit of mesh size of gill nets. Followed by pilferage of fishes caught and gill nets and fish pots and marketing of soli-soli during lean months.

Table 9. Problems met by the People in Lake Danao

Problems	Inhabitants Union	Campo	Northern Poblacion	Sta. Cruz	Cabungaan	Esperanza
1. Pilferage of fishes caught in gill nets and fish pots	✓			✓	✓	✓
2. Periodic regulations on banning of catching fishes in the lake	✓	✓	✓	✓	✓	✓
3. Size limit of mesh size of gill nets	✓	✓	✓	✓	✓	✓
4. total banning of the use of drag seine locally known as sinsin	✓				✓	
5. Unfavorable climatic condition in drying and processing of soli-soli	✓	✓				
6. Stealing of dried and newly -harvested soli-soli		✓				
7. Marketing of soli-soli during lean months from June to September	✓	✓	✓			
8. Less guests during week days experienced by resorts owners	✓				✓	
9. Legality of ownership of videoke entertainment bar	✓					
10. Some people will get the dried soli –soli	✓	✓				
11. Difficulty of drying soli-soli during rainy seasons hence soli-soli article making will be affected.	✓	✓	✓	✓	✓	✓
Total	**10**	**7**	**4**	**4**	**6**	**4**

Socio- Economic Effects of People's Activities in Lake Danao

Table 10 presents the socio-economics effects of the people's activities in Lake Danao. It shows that their activities satisfy the food requirements of the people as well buying minor appliances. This was followed by house-construction and other needs such as buying of fertilizers, clothes and others. This means that the activities are purely for food consumption and buying of other minor necessities of the family. This further means that people living in Lake Danao are low income families.

Table 10. Socio- Economic Effects of People's Activities in Lake Danao

	Fishing	Agriculture	Business resorts	Parks	Entertainment	Soli-soli
1. House construction	✓		✓			✓
2. Food	✓	✓	✓	✓	✓	✓
3. Purchase of minor appliances	✓	✓	✓	✓	✓	✓
4.Aquasition of motorcycle through the activities			✓		✓	✓
5. Other basic needs such as buying of fertilizer, clothes, etc.		✓	✓	✓	✓	✓
Total	**3**	**3**	**5**	**3**	**4**	**5**

Perceived Environmental Effects of People's Activities in Lake Danao

Table 11 presents the perceived environmental effects of Lake Danao. There is over extraction of the resource through fishing. Same with soli-soli plants and cutting of trees. The use of fertilizer usually is leached into the Lake during rainy seasons and also bathing will contribute pollution of the water. However, due to the monitoring of the physico-chemical components in the lake it showed that all values in pH, D.O. and transparency are still on normal values.

Table 11. Perceived Environmental Effects of People's Activities in Lake Danao

Activities	Union	Campo	Northern Poblacion	Sta. Cruz	Cabunga-an	Esperanza
1. Over extraction of the resource	✓	✓				
2. Cutting of Trees	✓	✓	✓	✓	✓	✓
3. Pollution of the Lake		Leaching of fertilizers into the Lake				
4. Fishing	✓	✓	✓	✓	✓	✓
5. Agriculture	✓	✓	✓	✓	✓	✓
6. Business	✓	✓	✓	✓	✓	✓
7. Parks	✓				✓	
8. Entertainment	✓				✓	
9. Soli-soli industry	✓	✓				
10. Bathing and washing of clothes	✓	✓	✓	✓	✓	✓
Total	**9**	**7**	**5**	**5**	**7**	**5**

Proposed Solutions in Solving the Problems by the People living in the Lake Danao

Table 12 presents the problems and proposed solutions by the people. It shows that on the banning regulations on fishing, they just follow the ordinance. Drying of Soli-soli during rainy days was done in their homes. Marketing problems of Soli-soli during lean months will be expanded to nearby Cities like Ormoc City, Leyte and in Cebu City.

Table 12. Proposed Solutions in Solving the Problems by the People living in the Lake Danao

Problems	**Proposed Solutions**
1. Pilferage of fishes caught in gill nets and fish pots	None
2. Periodic regulations on banning of catching fishes in the lake	Just follow the ordinance
3. Size limit of mesh size of gill nets	Just follow the ordinance
4. Total banning of the use of drag seine locally known as sinsin	Just follow the ordinance
5. Unfavorable climatic condition in drying and processing of soli-soli	Air drying of soli-soli strips in their homes or working area
6. Stealing of dried and newly -harvested soli-soli	Harvested soli-soli were brought directly to their work place and dried with their close supervision
7. Marketing of soli-soli during lean months from June to September	Expanding their market outlet to Ormoc City or Cebu City since there is less demand in the local market
8. Less guests during week days experienced by resorts owners	None
9. Legality of ownership of videoke entertainment bar	Presenting authentic documents claiming as the legal owner of the lot of videoke bar.

DISCUSSIONS

Fishing Activities in Lake Danao

The use of different fishing methods (**Table 1**) and the number of fishermen dominated in Barangay Cabunga-an. This is so because the deepest part of the Lake was found in the place and usually deeper part of the Lake usually serves as resting place of the fishes and other organisms. This is also the least disturbed area in the whole lake. Pole and line tops among the fishing methods because the local government of Pacijan Island prohibits the use of fine meshed net in fishing so people just adopt mostly this fishing method.

Aquaculture Activities in Lake Danao

The LGU limits the construction of Aquaculture facility in Lake Danao and this is only given to BFAR, CTU and DA. Only these 3 government agencies were allowed to establish aquaculture facilities in Lake Danao. No private individuals or corporation are allowed. This is so because the LGU wanted to maintain the natural freshness of the Lake environment. And by letting the government agencies engage in it since these agencies serves also as a regulating body of the aquaculture activities in the Lake. The LGU wanted this to be maintained since the Lake is a titlist as the first runner up of the cleanest and greenish Lake in the whole Philippines.

Post-harvest Activities in Lake Danao

Stewed, pickling and fried fish preparations dominated in post-harvest preparation of the fishes caught in Lake Danao since this is more on family consumption. The fishes caught in lake Danao has somewhat fishy odor so frying, stewing and pickling usually are the ones used by the people in cooking the fish since usually this uses the vinegar and other condiments to ease away the fishy odor.

Agriculture Activities in Lake Danao

Rice farming was only done in Campo, Northern Poblacion and Cabunga-anit is because these barangays are the low elevated barangays surrounding Lake Danao. Other barangays are highly elevated that is why the people resorted to the planting of corn and vegetables.

Uses of Water in Lake Danao

Bathing of human and animals are dominant uses of water in the Lake. However, this are not frequently done since most of them have deep well locally known as “atabay” as a source of water for household bathing, washing and other uses.

Problems met by the peoples in Lake Danao

Periodic regulation on banning the size limit catching of fishes and the use of small mesh size of gill nets are the number one problem of the people due to the desire of the LGU and other agencies in San Francisco in Lake Danao Management banning was done so as not to deplete the resources in the Lake. Although it has been explained to them the benefits of minimizing the catching activity, still there and other individuals who really don’t understand the essence of the restrictions. People usually of this type are thinking of the present needs not on the future effects of the activity. Maybe more explanation through public hearing scheme be done to let the people fully knew the reasons of doing such restrictions. Another problem is marketing of soli-soli during lean months. Vacation time like December to January, during fiestas (March each year) and during summer soli-soli products and salable at this time. Lean months include during the months of July to October. There is the problem of soli-soli products dealers. However, it is suggested that the government will have to establish a marketing scheme of these products and may provide other livelihood options for these as to solve problems during lean months. Simultaneously, there are less guests on hotels on these months.

CONCLUSIONS

1. There are five major activities of people living near Lake Danao which are fisheries, agriculture, businesses, bathing and washing of clothes.
2. The dominant activities are the fishery activities followed by businesses, agriculture, bathing and washing of clothes.
3. Extraction of fishery resources was great and are regulated by ordinance limiting size limits of gears used.
4. Socio-economic effects of the fishing activities range from construction of their houses up to food and other basic needs.
5. Pilferage of caught fishes in in the fishing gears, unfavorable climatic/weather condition felt bysoli-soli weavers and periodic banning of the catching of the fishes in the lake are the major perceived problems met by the people living near the lake.

RECOMMENDATIONS

1. Proper dissemination on ordinances relative to lake operations and resource extraction be made so that the people will have a thorough knowledge of them.
2. Alternative livelihood be given to Lake Danao dwellers and users to prevent over extraction of the resource.

3. The Soli-soli weavers and other resource users in Lake Danao will be organized through the initiative of the San Francisco LGU units to facilitate the marketing of the products out of soli-soli and other resources in the Lake.

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EFFORTS TO IMPROVE WATER QUALITY IN LAKE KASUMIGAURA BY IBARAKI PREFECTURAL GOVERNMENT

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ABSTRACT

Lake Kasumigaura is the second largest lake in Japan and a million people lives Kasumigaura watershed. Lake Kasumigaura is expected to support economic development of Ibaraki and the metropolitan area as precious water resources. However, the economy developed caused deterioration of lake water quality. Therefore, Ibaraki Prefectural Government has placed Lake Kasumigaura water purification at important prefectural administration and has formulated Lake Kasumigaura Water Quality Conservation plan for 30years. The plan consists of various efforts i.e. Household Wastewater Management, Livestock Waste Management, Agricultural Measures, etc. Ibaraki Prefecture make Prevent Eutrophication in Lake Kasumigaura ordinance was established in 1982(reformed the Ordinance to Water Conservation in Lake Kasumigaura in 2007). The ordinance focused on the idea of reducing the amount of nitrogen and phosphate in the wastewater and included a ban on the use and sale of phosphorus detergent and the strict wastewater standards for the factories. In 2005, Ibaraki Kasumigaura Environmental Science Center was established to conduct the conservation of rivers and lakes, as an opportunity which the Governor propose its establishment during the 6th World Lake Conference held in Ibaraki prefecture in 1995.Moreover, to be a financial source to conserve lake Kasumigaura project, Ibaraki Prefectural Government introduced a local tax called 'Forest and Lake Environment Conservation Tax' in 2008. As a result of these efforts, economy and population have been growing up whereas Lake Kasumigaura water quality remains on the same level recent years.

Keywords: Lake Kasumigaura, Water Quality Conservation plan, Eutrophication, Ibaraki Kasumigaura Environmental Science Center, Forest and Lake Environment Conservation Tax

INTRODUCTION

Lake Kasumigaura is located in the plains of southern Ibaraki Prefecture (**Fig.1**). It is the second largest lake in Japan. Lake Kasumigaura attracted attention early on as an important resource for the development of Ibaraki prefecture. This water is divided among agricultural use, industrial use, and public water supply. The region is a major agricultural production area, and is also experiencing marked urbanization. As of 2010, about 973,000 people live in the basin (**Table.1**). It is extremely shallow lake as the average depth is 4m. For this reason, Kasumigaura is at high risk of pollution.

Examining the trends in water quality, it can be noted that in the late1950s and 1960s, COD_{Mn} (the amount of oxygen consumed when organic substances in water are decomposed by chemical oxidants) hovered around 3~4 mg/L level. The increase of economic activities in the basin starting in the 1970s rapidly brought pollution. In 1979, COD_{Mn} climbed 11 mg/L, the highest pollution level in the history of the lake to date (**Fig.2**).

THE SYSTEM FOR WATER QUALITY IMPROVEMENT

The pollution process of Lake Kasumigaura is a complex one indeed. In order to come up with an effective system to improve the Lake's water quality, many different kinds of measures must be taken to combat each factor causing the pollution. It is this kind of thinking that has given rise to a consolidated system based on eutrophication in Lake Kasumigaura ordinance and the Water Quality Conservation Plan for Lake Kasumigaura.

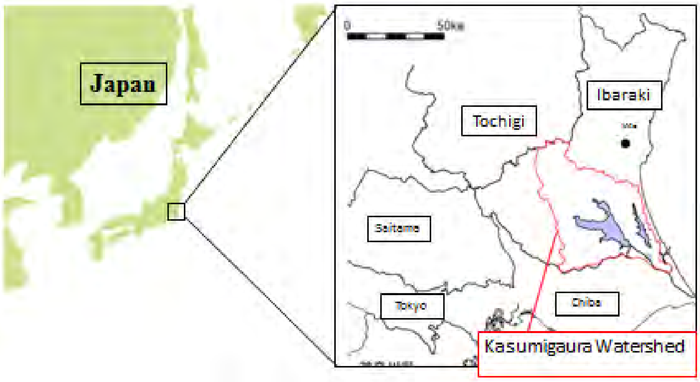

Figure 1. Location of Lake Kasumigaura

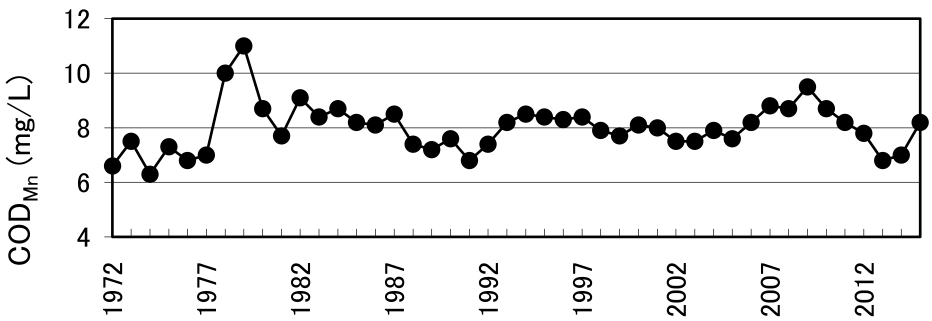

Figure 2. COD_{Mn}

Table 1. Statistics Lake Kasumigaura

Category	Item	Unit	Lake Kasumigaura
	Origin	-	Inland sea
	Maximum Depth	m	7
	Average Depth	m	4
Lake	Surface area	km^2	220
	Shoreline	km	252
	Volume	Billion m^3	Approx. 0.85
	Average water turnover	days	Approx. 200
	Surface area	km^2	2,157
Watershed area	Municipalities in the watershed area	-	24
	Watershed-area population	-	Approx.973,000people(2011)

POLICY DETAIL

1. Household measures (Domestic wastewater)

It is very important to treat both black water (the waste water from toilet) and gray water (the waste water from kitchen, washing and bathing) about household measures.

・Fundamental to household measures is the installation of sewage systems.Sewage systems are required populous areas. The growth rate of the population supported by the sewage system serving Kasumigaura Lake has increased.

・Integrated johkaso(a kind of septic tank) treatment systems are desirable in places where there are no sewage systems. In kasumigaura watershed, Installation of Nitrogen and phosphorous removal type Johkaso is required. Ibaraki prefectural government have established subsidies to promote this type Johkaso.

Tandoku-shorijohkaso which is designed for treating wastewater from exclusively flush toilets were forbidden in Kasumigaura watershed.

2. Agricultural measures
Essential guidelines have been established for fertilization, water control and healthy soil building methods conducive to the prevention of fertilizer run-off from paddies and dry fields.
・Acknowledgement of eco-friendly farmers is to be promoted to reduce the use of chemical fertilizer and agricultural chemicals.
・Advice is given using a computer tool called 'Fertilizer Navigation', so that the proper amount and type of fertilizer is used.
・With this system, agricultural wastewater is recycled as irrigation water, preventing wastewater from flowing directly into the lake.
3. Livestock farming measures
Essential guidelines for livestock farming businesses have been established for the basic purpose of recycling domestic animal excrement for agricultural use. Guideline is provided on the proper treatment of such waste, while taking into consideration the stabilization of business management.
・In order to prevent wastewater from draining out of the barn, regulation is taken in modifying the barn and wastewater treatment facilities. Proper management of these facilities is also promoted.
・The construction of facilities which turn livestock waste into fertilizer effectively and properly is promoted by subsidizing construction costs.
・Distribution of compost outside the catchment area is promoted.
4. Measures for factories and businesses
All factories and plants are required to maintain wastewater standards based on the water pollution control law by such practices on the spot inspection. The quality of corporate wastewater has been strictly regulated by effluent standards, but stricter effluent standards are being applied because of the inclusion of small factories and other facilities not conventionally covered by these regulations in Kasumigaura watershed.
5. Direct purification measures
Water quality will be improved by dredging river and lake subsoil, constructing vegetation-based purification facilities, and removing and other algae.
・Lake Bottom Sediment Dredging. Nitrogen and phosphorous dissolving into the water from sediment accumulating on the bottom of the Lake is one cause of water pollution.
・Vegetation-based purification involves the use of emerging aquatic plants endogenous to the shallows and shorelines of Lake Kasumigaura to improve its water quality.

FOREST AND LAKE ENVIRONMENT CONSERVATION TAX
Ibaraki Prefectural Government introduced the forest and lake environment conservation tax in 2008 and has promoted environmental conservation of the lake and responsible forestry management in the Kasumigaura basin. The taxable period of the tax in Ibaraki Prefecture is ten years (2008–2017). The tax rates for one year are 1,000 yen for an individual with an address in Ibaraki Prefecture, and 10% of an equally divided prefectural corporation tax for corporations with an office in Ibaraki Prefecture. The income from tax revenues for one year is about 1,600 million yen. Half the total tax revenues are used for forest conservation, and the remaining half are used for measures against water pollution of Lake Kasumigaura.

IBARAKI KASUMIGAURA ENVIRONMENTAL SCIENCE CENTER
Ibaraki Kasumigaura Environmental Science Center (IKESC) was founded in 2005, after advocation for its establishment at the 6th World LakeConference held in 1995 in Tsukuba and Tsuchiura. IKESC aims to effectively perform its four functions research and technical development, environmental education, cooperation with and support for citizen's activities, and information exchange. These functions performed through partnership with citizens, researchers, businesses, andgovernments bodies in order to tackle issues related to the conservation of lakes and riversin Ibaraki.

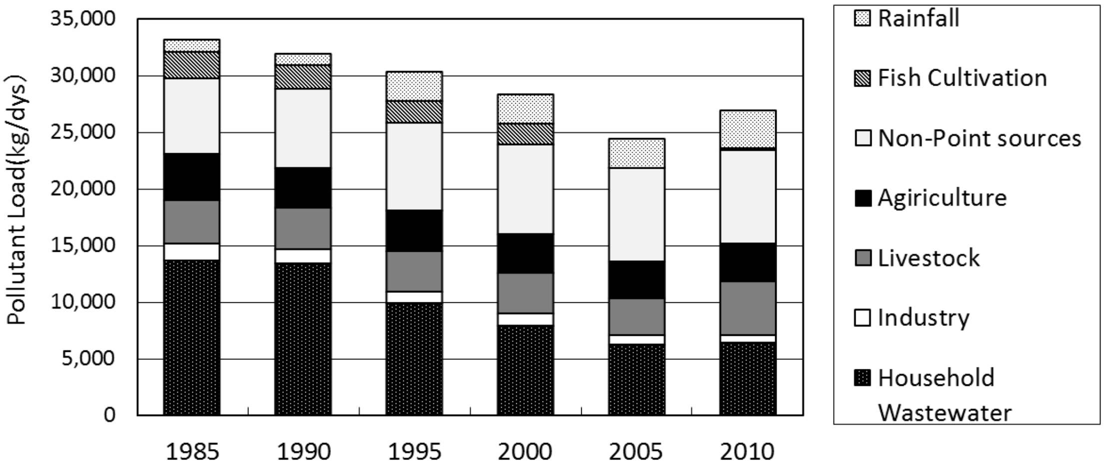

Figure 3. COD_{Mn} Pollutant Load

CONCLUSIONS

Ibaraki prefectural government drown up the water quality conservation plan since 1985. Although Pollutant Load has tended to decrease (**Fig.3**), Lake Kasumigaura is still eutrophication. It is the earnest wish of the citizens of Ibaraki that the water be purified, not only because the water of Lake Kasumigaura has been and is a valuable resource supporting the development of the prefecture, but also because the lake is the symbol of the abundance of nature. For these reasons, the national, prefectural, and municipal governments, as well as the residents in the basin, are working together to put forth the maximum effort to improve the quality of the lake's water.

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THE GOVERNANCE OF LAKE RAWAPENING: AN INTERORGANIZATIONAL NETWORK ANALYSIS

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ABSTRACT

Lake governance is an inherently complex process. Much of literature dealing with lake governance relates to the limnological sciences and the technological dimensions. There is an increasing need to understand the multi-stakeholder governance arrangements that emerge from the cross-scale nature and multifunctional role of lake. This study aims to examine networks between organizations that either directly or indirectly influence the sustainability of Lake Rawapening in Indonesia. The data were collected using a questionnaire and semi-structured interviews of 47 organizations, including community-based organization, governmental agencies, universities and NGOs. Results show that there is no organization that coordinates activities related to lake-ecosystem governance at the lake catchment scale. Furthermore, an important result is that environmental protection agency at provincial level plays a crucial role linking otherwise disconnected actors. Instead of imposing institutional arrangements, it is more promising to identify and build on existing inter-organizational network structures. Social network analysis can help to identify existing social structures and points for interventions to increase the problem-solving capacity of the governance network

Keywords: lake governance, social network analysis, Lake Rawapening, watershed, Indonesia.

INTRODUCTION

Lakes are fundamental component of freshwater resource potential of Indonesia. There are more than 1,000 natural and semi-natural lakes located on almost all over islands. The total volume of water held is approximately more than 100,000 km^3 (Pusat Data dan Teknologi Informasi, 2016). They serve as main sources of raw water of drinking water of municipalities or regencies; in particular those are located in nearby the lakes. In addition, the lakes are also important for hydropower generation, agricultural irrigation, inland fishery production, flood control, biodiversity conservation and so on. It is therefore not an exaggeration to say that lake conservation is imperative to sustaining their ecosystem services.

Although lake-ecosystem services have been well recognized, a number of lakes, in particular those are situated in ever-growing economic and population areas, are deteriorating due to sedimentation, pollution and eutrophication. According to Indonesian Ministry of Environment and Forestry, there are at least 15 lakes demanding restoration or otherwise ceasing to provide ecosystem services (Ministry of Environment and Forestry of the Republic of Indonesia, 2016). To reverse the tendencies of lake-ecosystem degradation, Indonesian government since 2011 has launched a national movement of saving Indonesian lakes (*Gerakan Penyelamatan Danau* abbreviated as GERMADAN). This movement is similar to integrated lake basin management developed by International Lake Environment Committee Foundation (ILEC) (Soeprobowati, 2015), which is an integrated approach and involving many stakeholders with various interests. This movement, nevertheless, has not been running well as it was planned. Likewise, a number of previous government efforts in restoring the lakes seem likely only good on the planning paper, but lost its performance at implementation stages. One of the main reasons frequently putted forward is the lack of coordination among governmental agencies at all levels.

Integrated approaches of lake-ecosystem management which are recently advocated by environmental scholars are inherently complex processes since they encompass social-ecological systems and consequently they involve many actors and sectors that either directly or indirectly influence lake-ecosystem at multiple scales. Awareness of this complexity is a necessary but not sufficient condition to improve lake-ecosystem management. Recently, different types of governance systems have been advocated as solution to address socio-ecological interactions. Evidences derived from a number of empirical research projects, however, show that there is no single governance system works across all cases and all scales (Ostrom, 2005, 2008, 2010). Attention has therefore been directed at governance systems involving multiple actors to various degrees in the governing processes. These ideas are captured in the concept of polycentric and multi-level institutional arrangement, where the underlying rationale is that by involving different actors in the governing process, the complexities inherent in both ecosystems and the social arrangements constructed around these can be more adequately addressed.

However, realising polycentric and multi-level governance, as it is captured in GERMADAN, requires solid coordination of activities among stakeholders and this, according to a number of empirical evidences, is often difficult, albeit not impossible, to achieve in practice (Ananda & Proctor, 2013; Blomquist & Schlager, 2005; Ostrom, 2005).
Governments and nongovernmental organizations have invested in building networks among stakeholders of natural resources in order to improve coordination and cooperation among them. Cross-scale linkages, horizontally across landscapes and vertically between actors from local to watershed-scale, are especially important for shared resources, such as lake-ecosystem (Cash et al., 2006; Olsson, Folke, Galaz, Hahn, & Schultz, 2007). Cooperation in inter-organizational networks can generate benefits through sharing resources, knowledge and core competencies if involved actors, which may lead to accomplishment of common goals, increased performance and innovative behaviour. This has led inter-organizational network forms of organization gained significance in the realm of natural resource management (e.g. Rathwell & Peterson, 2012). In line with this reasoning this article is to explore whether the structure of inter-organizational networks currently established in the Lake Rawapening is likely to align with integrated approaches of lake management. The information gained from this research is partly important to inform policy makers in fostering effective and efficient cooperation among organizations in governing Lake Rawapening.

Description of Study Area
Lake Rawapening is a semi-natural lake, situated in the upper course of Tuntang River, about 40 kilometers south of Semarang, a capital city of Central Java (see **Fig.1**). The lake is fed by 9 rivers running down the slopes of Merbabu, Telomoyo, and Ungaran Volcano, and by a number of springs in the lake. Its altitude is around 463.9 meters above sea level (Goeltenboth & Kristyanto, 1994). This is comparatively a small lake having maximum surface area from circa 26.7 km^2 in rainy season to 16.5 km^2 in dry season, but in extreme situations the size can reduce up to 6.5 km^2 (Goeltenboth & Kristyanto, 1994; Hayashi, Pancho, & Sastroutomo, 1978). Like many other lakes, it is of considerable importance to large number of people because it provides hydro-electric power, irrigation, recreational services, raw water of drinking water and fishing. The volume of the lake can reach its maximum at 40 million m^3. When water levels in the lake dropped due to the opening of water-gate at the outlet channel or during dry season, between March and October, the lakeshore area is cultivated by the farmers who lived in the villages in the vicinity of the lake. The productivity of rice field was from 10 to 13 tons per hectare every planting season. The water body of the lake is mainly used for capture and cage fishery as well as tourism.

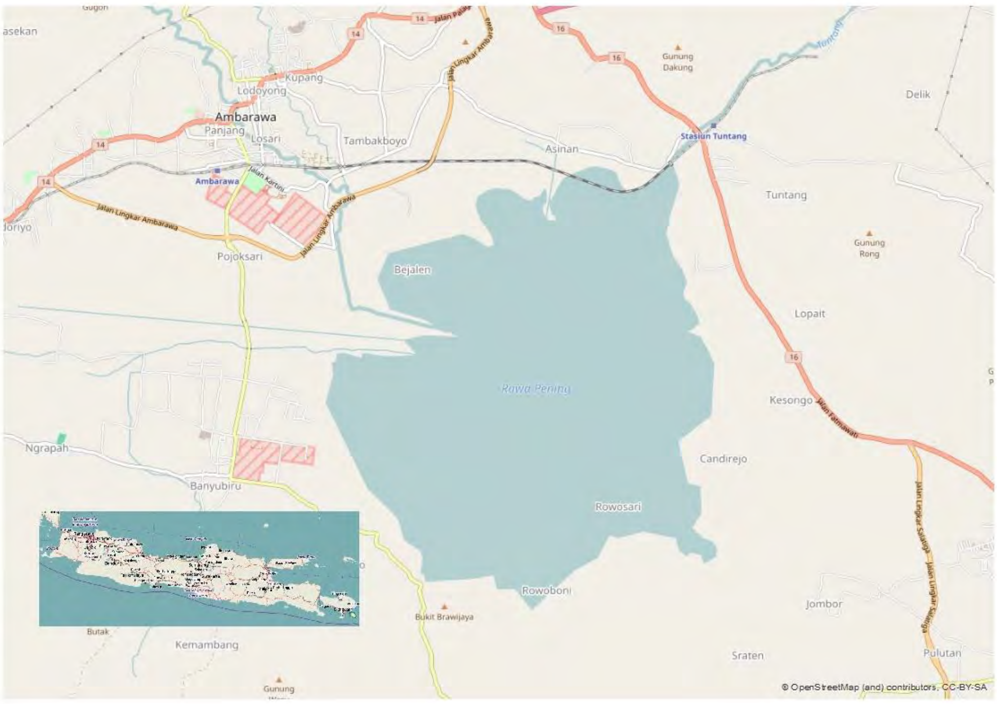

Figure 1. Map of Lake Rawapening

A recurrent problem of the Lake Rawapening is the explosive occurrence of aquatic weeds, in particular water hyacinth (*Eichhornia crassipes*). The weeds regularly clog the entrance channel to the hydro-power station and parts of them would sink to the bottom. Furthermore, they also have induced a reduction of fish population. Because of those problems, a number of policies and technologies have been suggested for its removal. Yet, none of those policies has shown positive results. Water hyacinth causes a great nuisance, due to its high propagation capacity. It could grow at rate of 7.1 to 10% every month at suitable conditions. Recent estimation showed the weeds have covered 70% of the lake's surface (Partomo, Mangkuprawira, Hubeis, & Adrianto, 2011).

METHODS

Data collection

This study generated data through a combination of semi-structured interviews and focus group discussions of governmental agencies as well as non-governmental organizations at national, provincial and local level, which were conducted between March to August 2016. The first step was to create a list of potentially relevant organizations to lake management. This list was derived from a number of archival documents and interviews with key-informants and it then came up with 60 potentially relevant organizations directly or indirectly to lake management. The number of organizations in the list was finally reduced to 47 organizations after a focus group discussion in which a number of duplication of organizations has been identified by participants. This final list was then used as a basis for data collection.

The interviews were targeted to high-level spokespersons from organizations on the list that had at least 2 years of tenure in the organization as respondents. The respondents were given an alphabetical roster of all organizations and asked about cooperative relations to each of these organizations. In addition, respondents were asked about organizational attributes (e.g. governmental level of organization, for-profit or non-profit orientation, and sector) and individual perception concerning barriers to cooperation within the networks.

Data analysis

The cooperative relation between organizations was coded as a square matrix, so-called an adjacency matrix, with 47 rows and 47 columns. The adjacency matrix was then symmetrized for data analysis in order to capture the reciprocal nature of cooperative relations. Hence, the relations of organizations were considered as undirected ties. This study used standard measurements of a social network analysis. Degree of centrality and betweeness centrality were used to locate influential organizations or actors (Freeman, 1978). The former means to identify those organizations that are extensively involved in relationships with other organizations, whereas the latter means to be central in the sense of sitting-down in-between many others. Degree of centrality measurement proposed by Freeman (1978), however, has its drawbacks. Having the same degree does not necessarily make an organization equally important. To account for this disadvantage, Bonacich (1987) proposed a centrality measure that is a function of the number of connections an actor has and the number of connections the actors in the neighbourhood have. This study used this Bonacich's centrality to complement Freeman's centrality measure. The data was analysed using UCINET 6.0.

RESULTS AND DISCUSSIONS

The analysed Lake Rawapening governance network consists of 47 organizations, linked through 186 cooperative ties. More than 80% is non-profit-oriented organizations. The governmental agencies at all levels accounted for 61.7% of the network, where most of them were provincial and local agencies. Only two organizations operated at river-basin level. Both of them were national agencies.

The network density is 0.086. It means only 8.6% of the potential ties present in the network. Yet, the network is just one component, i.e. the whole network was held together and no isolates exist. **Fig 2**. shows the complete network of organizational actors directly or indirectly involved in the governance of Lake Rawapening. Furthermore, the average degree (indicating the average number of cooperative ties per organizational actor) was 3.957 (SD = 0.280). By considering the value of network density and average degree, the organizational actors in the network is sparsely connected. The global clustering coefficient was 0.454 indicating substantial clustering in the network or the tendency for two-paths to close. This means that there is considerable cooperation in the inter-organizational governance of Lake Rawapening that take place in triplets (i.e., between three actors). This clustering effect can also be observed in **Fig. 2**. Besides a high number of closed triangles, the figure reveals that there are many peripheral organizations connected to the network only through one other organization acting as a bridge to these otherwise unconnected organizations.

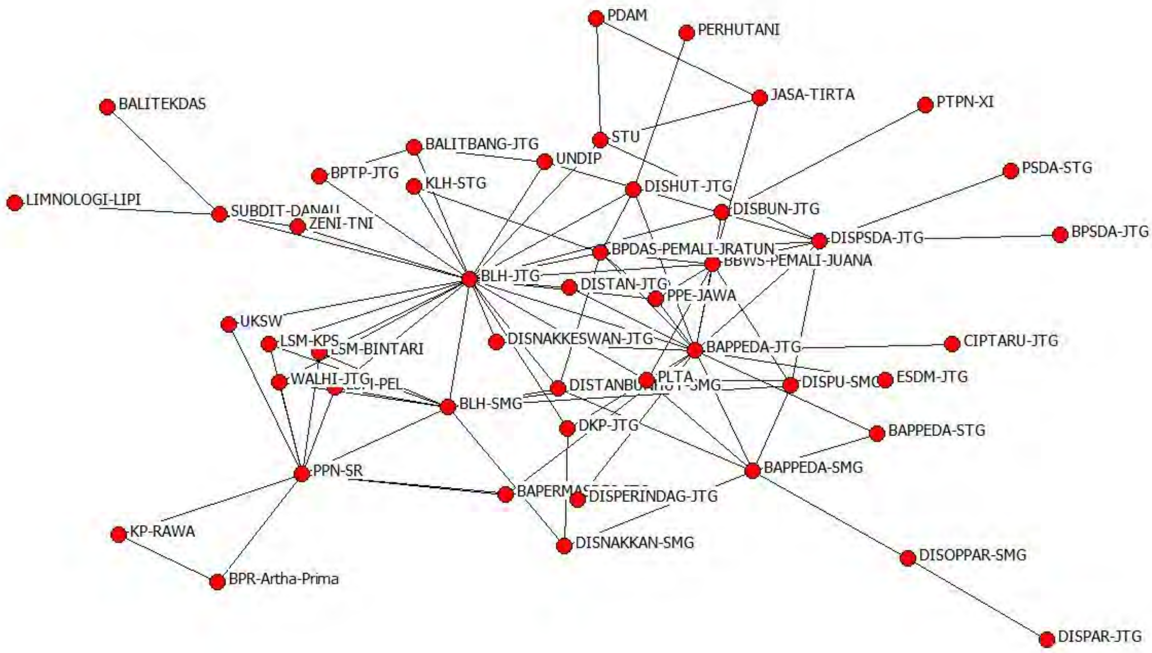

Figure 2. Inter-organizational network of Lake Rawapening

Moving to local scale, the network of organizations directly involved in the catchment and water body of the lake consists of 20 organizational actors. **Fig 3**. shows the reciprocated cooperative ties between the organizational actors. The network consists of one component and two organizational actors are isolated. The network density is 0.189 meaning that there are 18.9% of potential ties present in the network. This value of density is higher than that of overall inter-organizational network provided in **Fig 2**. The average degree, which is a measure indicating the average number of cooperative ties per organization, was 3.6 (SD = 0.392). Both network measures (network density and average degree) point toward a sparse network. The global clustering coefficient was 0.212 indicating the existence of substantial clustering, but it is less than that of overall inter-organizational network provided in **Fig.2**. This means that the number of triplet cooperation ties between organizations at local scale is less than in the overall inter-organizational network. Likewise, **Fig. 3** reveals that there are four peripheral organizations connected to the network only through one other organization acting as a bridge.

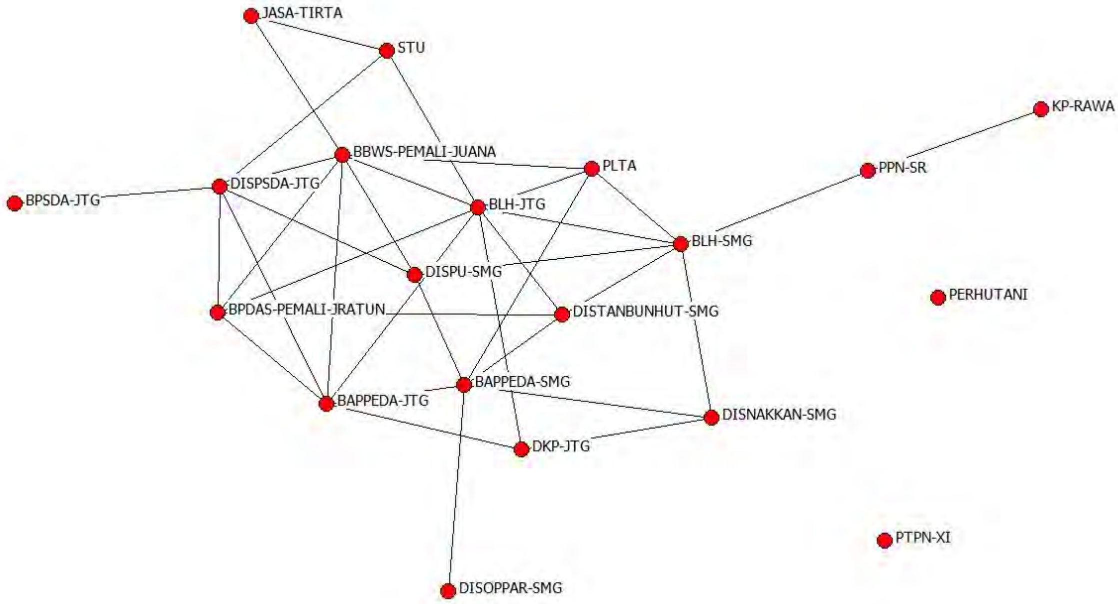

Figure 3. Inter-organizational network of Lake Rawapening at catchment scale

The integrated nature of natural resources or lake-ecosystem governance corresponds to horizontal and vertical cooperation among different stakeholders at different scales in order to address lake-ecosystem issues across scales (Varis, Enckell, & Keskinen, 2014). It means that the organizations operate at catchment level should be able maintain cooperative ties with other organizations at higher-level. To gain better understanding of how inter-organization network is structured at catchment and higher level, the adjacency matrix was rearranged into two blocks. The first block constituted the catchment level organizations directly involved in Lake Rawapening and the second block are higher-level organizations that indirectly involved in the governance of the lake. The mean connectivity within catchment level was 0.189, whereas the mean connectivity of higher-level organizations was 0.014. The results suggest that the cooperative ties are stronger than that of within higher-level organizations. The mean connectivity between two blocks was 0.096, considerably lower than within block 1, but six times higher than block 2. This result importantly suggests that the network is not well integrated across spatial and administrative scales.

The structure of inter-organization network in Lake Rawapening can be further scrutinized to identify the influential or central actors in the network. To do this we employed degree and betweenness centrality measurements. Degree of centrality was measured using Freeman's degree of centrality and Bonacich power. Scores were calculated for all 47 actors in the network. The results centrality and betweeness measures were depicted in **Fig. 4**, **Fig.5** and **Fig. 6**, respectively. The size of the node in the network represents the value of the index. The bigger the size of the node indicates the higher of value of centrality index.

Based on degree of centrality of Freeman's score, Provincial Environmental Protection Agency (*Badan Lingkungan Hidup Provinsi Jawa Tengah*) having most ties to other actors represents the most central actor with respect to activities related to lake management. The second most central position is held by Provincial Development Planning Agency (*Badan Perencanaan Pembangunan Daerah Provinsi Jawa Tengah*), followed by Environmental Protection Agency of Semarang Regency and Association of Farmers and Fishers of Lake Rawapening (Paguyuban Petani dan Nelayan Sidorukun Rawapening). The actors with the lowest score are the ones that had been connected to the network only through one actor.

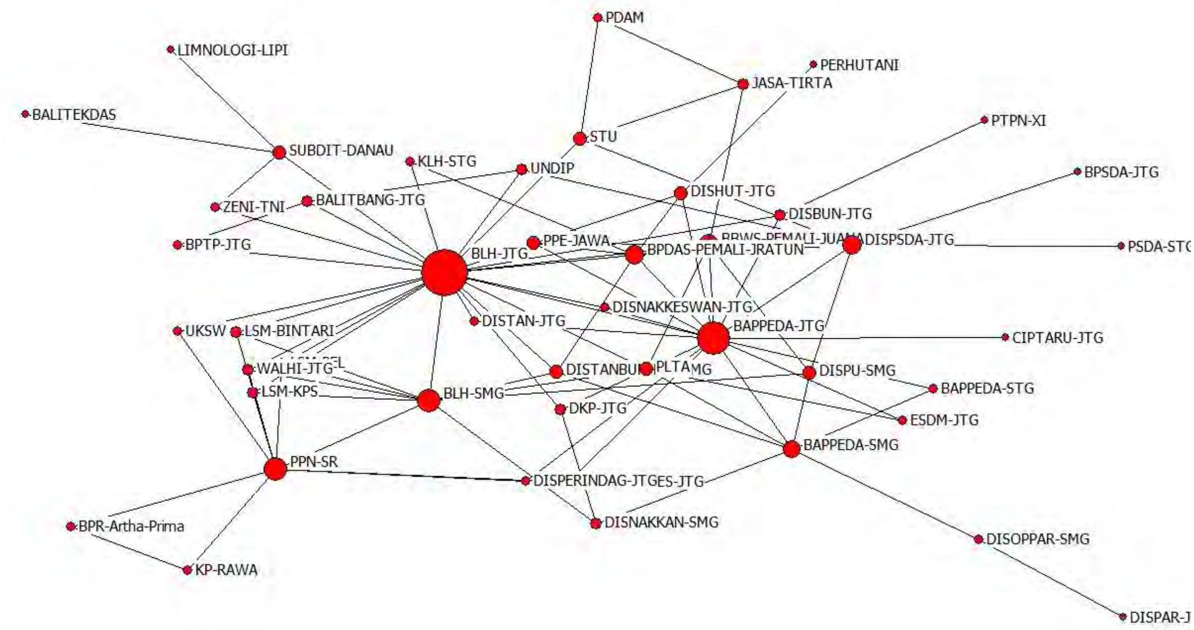

Figure 4. Inter-organizational network of Lake Rawapening based on Freeman's Degree of Centrality

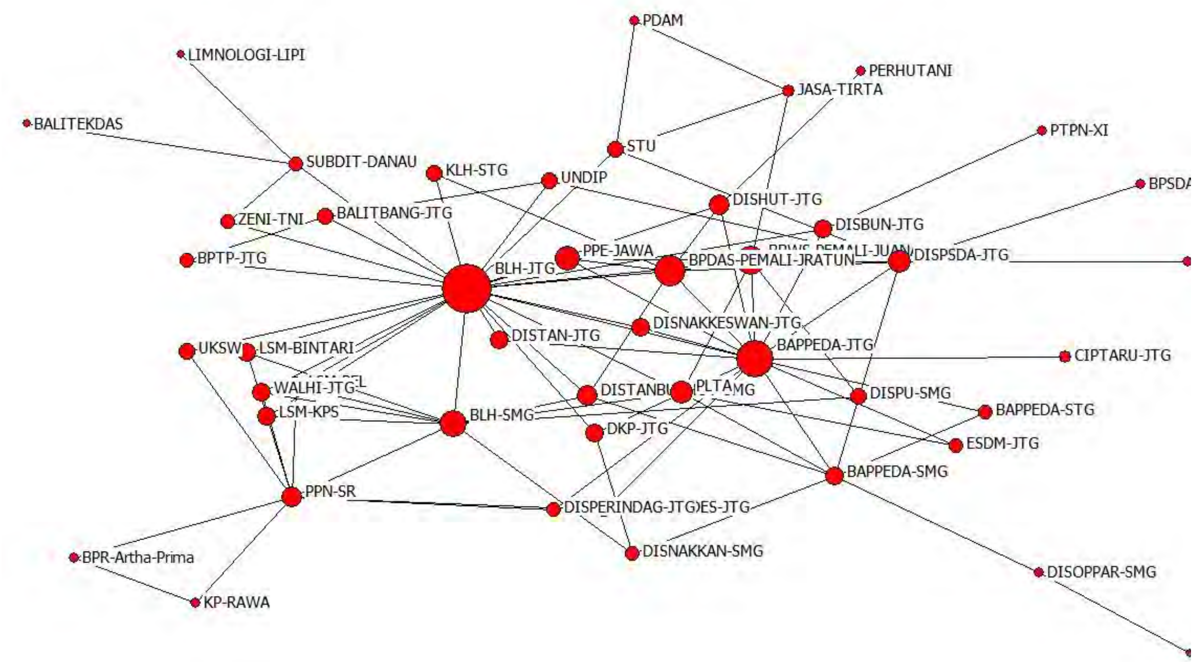

Figure 5. Inter-organizational network of Lake Rawapening based on Bonacich Power of Centrality

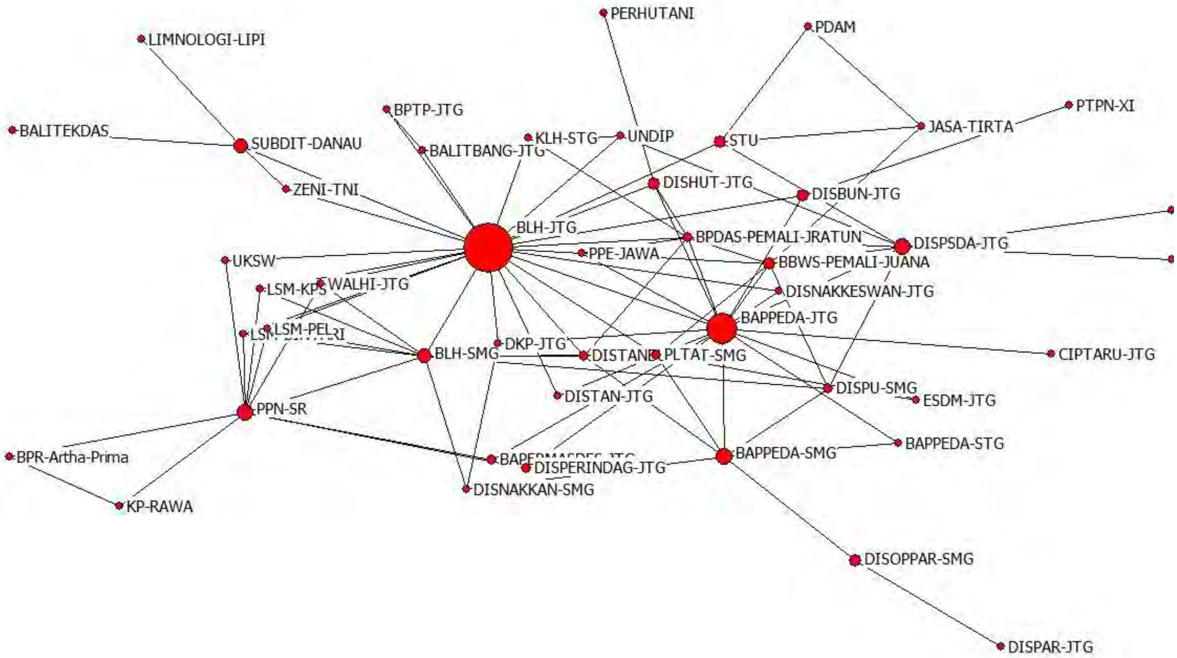

Figure 6. Inter-organizational network of Lake Rawapening based on Betweeness Score

The score of Bonacich power was used to identify which actors have power in the network. The higher score indicates that the actor has more power than the actor. Based on the score of Bonacich power, Provincial Agency of Environmental Protection (*Badan Lingkungan Hidup Provinsi Jawa Tengah*) having most power to other actors indicated the most influential actor with respect to activities related to lake management. Provincial Development Planning Agency and Pemali-Jratun Watershed Management Agency were in the second and third place, respectively, in term of its power in influencing other actors.

The results of analysis of Freeman degree and Bonacich power of centrality are largely consistent with each other, as demonstrated in **Fig. 4** and **Fig. 5**. Both measures suggested that Provincial Environmental Protection Agency and Provincial Development Planning Agency were the most important actors in the network. This reflects that the both actors were central actors that may have power in influencing the effectiveness of the governance of Lake Rawapening.

While centrality degree is straightforward measure that considers the number of direct ties, indirect measures of centrality can provide a deeper insight into central actors. Because cooperation and coordination involves communication and the flow of information throughout the entire network, it is useful to consider betweenness centrality. **Fig.6** illustrates the result of betweenness scores calculation of the actors in the networks. Again, Provincial Environmental Protection Agency and Provincial Development Planning Agency were the main actors having highest score of betweenness centrality. This indicates that both actors held central position.

CONCLUSIONS

This article has demonstrated the inter-organizational network analysis of the governance of Lake Rawapening. The social network analysis method used in this study provides a promising approach to map out the inter-organizational complexity that underpins the governance of the lake. Results show that there is no organization that coordinates the various lake resources related activities at the lake catchment scale. Furthermore, an important result is that Environmental Protection Agency and Development Planning Agency at provincial level plays a crucial role linking otherwise disconnected actors. Instead of imposing institutional arrangements, it is more promising to identify and build on existing inter-organizational network structures. Social network analysis can help to identify existing social structures and points for interventions to increase the problem-solving capacity of the governance network

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CAGE CULTURE AND LAKE MANAGEMENT PRACTICES IN LAKE DANAO, SAN FRANCISCO, CENTRAL PHILIPPINES

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ABSTRACT

Lake Danao is a first runner up of the cleanest and greenest lake throughout the Philippines. This has also become a tourist destination. Its aquaculture activities are controlled by the government so as to maintain its status as a tourist destination. Cage culture was undertaken by the Bureau of Fisheries and Aquatic Resources (BFAR), Department of Agriculture (DA) and the Cebu Technological University (CTU). Freshwater fishes like tilapia, carps, mudfish and catfish were stocked in the cages fed with both commercial feeds and local feeds. The BFAR engaged in grow out and breeding of tilapia and other freshwater fishes and distributed throughout Central Visayas as seedlings and breeders for grow out and propagation purposes. The Department of Agriculture reared tilapia until they reach marketable sizes and were sold to tourists where it is placed in the cages for dispersal in Lake Danao Park and the tourists will catch them through hook and line and weighed and priced then they are cooked according to the choice of the tourists. The CTU undergo research activities of tilapia cultivation and processing using different types of feeds and processing techniques on the value-added products of tilapia and other freshwater fishes. The BFAR stocked 150,000 tilapia fingerlings into the Lake every quarter to replenish the tilapia caught by fishermen in the lake. Fishing in the lake was regulated by imposing ordinances on regulated mesh size of the gill net and banning fine meshed net fishing. Proper waste disposal, banning the washing of clothes, tree planting, using paddle boats in fishing and no private aquaculture activities in the lake except the three government agencies were imposed in the lake to sustain the lake as a tourist destination and as part of the management of Lake Danao.

Keywords: Cage culture, Lake Danao, Central Philippines

INTRODUCTION

Lakes are natural impoundments which are body of waters surrounded by land masses. Pacijan Island of Camotes group of Islands has lake called as Lake Danao. They provide water of some human activities near the area and it provides source of food for humans and other animals especially those living far from the sea. Lakes are also bodies of standing water surrounded by land (Palma 2005p.1). It is also an inland body of water that occupies a depression (Castillo, 2005 p.10). Lakes have played a significant role in man's social, cultural and economic activities and as an ecosystem it supports different biological communities. San Francisco where Lake Danao is located was established as a municipality in 1963 (Socio-economic Profile of San Francisco, Cebu, 1996) with 15 barangays. It is located in the Pacijan Island, one of the three islands comprising the Camotes group of islands. San Francisco is 38 nautical miles from Cebu City and has a total land area of 9,982 has.

Lake Danao is a picturesque eight- shaped inland waters body with an area of 649 ha with a 1-acre (4,047 sq.m.) islet at the middle. It is the largest and longest lake in the Visayas (Tanduyan and Bontia, 2001). It is surrounded by six out of 15 barangays in the town of San Francisco, Cebu. The lake supplies water to the rice fields in Sitio Danao and Patabog. Its shoreline ranges from rocky to soft mud. The type of soil is coarse, silty and sandy. The depth of the water ranges from 27-29^{0}C. Water has a pH of 8.5-9.0. Salinity ranges from 0-0.5 ppt. The lake water is free from pollutants, except for some allochthonous materials (Station Profile of Carmen Lake Danao Fishery Complex/Research Station for Freshwater Fisheries Development Zone, Union, San Francisco, Cebu. 1995). It has no definite inlet and outlet, but it is presumed that a subterranean spring supplies water to the lake. Assorted vegetation such as hydrilla, water lily, water hyacinth, and kangkong "*Ipomaea aquatica* are found in the lake. "Suli-suli", palawan nipa and coconuts grow along the periphery of the lake. The "suli-suli" plant present in the lake are made into different articles like mat, hat, centerpiece, bags of different styles, wall décor and doormats to enhance the cottage industry of the inhabitants. The lake is a tourist attraction where boat trips could be for recreation. Majority of the households living nearby the lake catch fish in the lake for food and for the market. The lake is also used for bathing and washing of clothes.

Lakes aside from having natural resources have been subjected to aquaculture where fish cages and pens are being constructed where different species of fishes are being stocked and fed with various feeds grown up to marketable sizes or into breeders for reproduction. Lake Danao is not exempted from this although this was judged as the second placer for the greenish and cleanest lake throughout the

Philippine archipelago. However, the culture of fishes in Lake Danao has been controlled by different agencies in order to maintain its national status and title as the cleanest and greenish lake throughout the Philippines. Lake Danao was adjudged as the Cleanest Inland Body of Water for CY 1996 by the Department of Interior and Local Government (DILG) on September 30, 1996 (Tanduyan and Bontia 2001). An Award of Recognition to Lake Danao as the 1996 Cleanest Lake of Region VII was given by the Committee on Presidential Awards for the Cleanest Inland Bodies of Water in the Philippines for Region VII on December 11, 1996. An award for excellence was conferred to Lake Danao as a national finalist in the 1996 Search for the Cleanest Inland Bodies of Water. This lake is a potential area for cultivation of fishes in pens and cages.

Objectives of the study

The following are the objectives of the study which are to find out the cage culture practices in Lake Danao, San Francisco, Cebu in terms of type of cages used, fish stock stocking rates, feeds and feeding and cage maintenance and management. Another is to determine the marketing and harvesting procedures adopted by the cage owners in terms of harvesting techniques, marketing technique and types of buyers and recipients of the harvest product. Then another is to find out the lake management practices adopted by the agencies of Pacijan for Lake Danao in terms of legal executive aspects, research and development conservation and preservation aspects and tourism activities.

METHODS

This study is a descriptive research using interview guide in gathering the data. Actual interview of the respondents and field visits were done to get empirical data. A self-made questionnaire was used reflective of questions related to the objectives sought.

The Respondents

The respondents of the study consist of the different key personnel and project in charge of the different agencies of Pacijan Island namely: The Local Government Units (LGU), Department of Agriculture (DA), Bureau of Fisheries and Aquatic Resources (BFAR), the Cebu Technological University (CTU) and some fisher folks and stakeholders of Lake Danao.

The Research Environment

Lake Danao of Pacijan Island with San Francisco as the municipality is the focus of the study. Pacijan Island is one of the Islands of Camotes where it is located in the Northern part of the Cebu province under 5th district. It has an area of 648 has and with six barangays surrounding it.

Profile of San Francisco

Based from the Municipality profile report the municipality of San Francisco is currently classified as a 3rd class municipality and belongs to the 5th District of Cebu. It is located northeast of Cebu Province which is approximately 38 nautical miles from Cebu City. It is bounded by Camotes Sea on the North, South and West and the Ponson Sea bound on the East (**Fig.1**). The major livelihoods of the people are coconut and crop production, and fishing. Just recently, tourism starts to boom due to its acquired beautiful, glistening and enameled white sand beaches that stretched along the western and northern coasts of the island. There are also discovered beautiful caves and the enchanting lake Danao which is a national major winner for inland bodies of water (municipal profile).

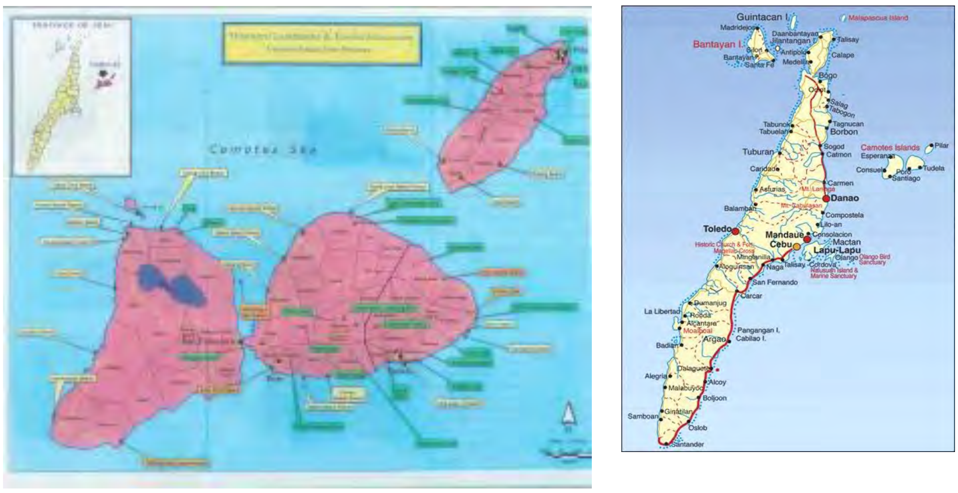

Fig.1. Map of San Francisco, Cebu

RESULTS AND DISCUSSION

Type of Cages in Lake Danao

Cages used in aquaculture activities in Lake Danao are rectangular shapes with dimensions of 2.5 x 3.5 meters. It uses polyethylene nets. The nets are sewn in an invented mosquito net which are attached to the bamboo structures to tie on and permanently attached to the poles.

Agencies engaged in Aquaculture Activities in Lake Danao

As part of the preservation of the lake as a tourist destination only the Carmen Lake Danao Research Outreach Station of the Bureau of Fisheries and Aquatic Resources, Regional Office No. 7, Department of Agriculture (DA) and the Cebu Technological University are allowed engage in Aquaculture activities in Lake Danao.

The BFAR 7 Carmen-Lake Danao Research Outreach Station

Fish Stock in the Cages

Tilapia, carps, catfish, etc are the fishes stocked in the cages. These are provided by the BFAR ROS VII. Usually they are taken as fingerlings. They are placed in polyethylene bags inflated with oxygen tied with rubber band and brought into the area in the lake where cages are set. The suggested stocking density of tilapia is 450 pcs per cage.

GOVERNMENT AGENCIES

A. Carmen Lake Danao Fishery Complex Outreach Station

The Carmen Lake Danao Research Outreach Station under the Bureau of Fisheries and Aquatic Resources Regional Office No. 7 (**Fig. 2**) was established in San Francisco, Cebu particularly in Barangay Union, San Francisco, Cebu. They are undergoing aquaculture activities and research where they are producing fingerlings of tilapia (different varieties) (**Fig. 4**) hito and carp. They are tasked to develop and promote appropriate technologies on freshwater hatchery management and grow out system for the benefit of fisher folks, to propagate freshwater fingerlings and improve quality of broodstocks for dispersal, disseminate package of appropriate technologies on freshwater fisheries in key research sites through linkages with LGUs/ NGOs and other institutions.

To attain their mandates, they conducted training for the prospective aquaculturists and provide fingerlings for them to raise throughout Region 7, they also accept student trainees (practicum) all over Region 7 to undergo the On the Job Training. The provide assistance to fishery technicians throughout the islands in the implementation of fishery activities in the Department of Agriculture. Aside from the land based aquaculture tanks (**Fig. 3**) they are also rearing tilapia and other freshwater fishes in the lake (**Fig. 4**). They reared the fingerlings into breeder sizes for reproduction. Fingerlings are sold at 0.35 each to fish farmers so as to cover some of the administrative costs of the project. Culled breeders are sold also at lower prices.

B. The Department of Agriculture (DA)

The Municipal Agricultural Office of San Francisco (**Figs. 6-7**) is tasked also to implement the different ordinance, rules and regulation in the lake aside from the specially created task forces including the Barangay Officials around the lake. They are engaging in aquaculture in cages (**Figs. 27-28**) to supply tilapia and other freshwater fishes for tourist orders. They constructed their cages besides the cages of the BFAR. They also placed their marketable cages in Lake Danao Park (**Fig. 26**) for direct orders from the tourists.

Fig. 2. The Carmen Lake Danao Research Outreach Station

Fig. 3. Land based aquaculture tanks

Fig. 4. Fish cages in the lake

Fig. 5. The tilapia in different varieties

Figs. 6-7. The office of the Department of Agriculture

Fig. 8. Marketable cages of tilapia in Lake Danao Park

Fig. 9-10. The fish cages of tilapia managed by the DA in Lake Danao

*) all pictures by S. N Tanduyan

C. Cebu Technological University (CTU), San Francisco, Cebu Campus

The Cebu Technological University (CTU), San Francisco, Cebu Campus is an academic institution and the only state university in Camotes Islands (**Figs. 11-12**) was conducted researches on Fish Culture in Cages in Lake Danao, San Francisco, Cebu (**Fig. 13**), Rate of Growth of Genetically Farm Tilapia Fed with *Ipomea aquatica* (Kangkong) (**Fig. 14**) and Commercial Feeds in Cages in Lake Danao, San Francisco, Cebu, Philippines and Socio-Economic Study of the Inhabitants Surrounding Lake Danao, San Francisco, Cebu Basis For Livelihood Enhancement, Management and Conservation Options, The Culture of Tilapia in Aquaria Fed with Kangkong and Sea Cucumber, The Acceptability of Bottled Tilapia Using Different Canning Styles (**Fig. 16**) Fish Borne Concentrate out of Tilapia sp, Preparation of Tilapia Longanisa (*Tilapia mosambica*) (**Fig. 15**) added with different levels of Pork: A Techno Guide and Tilapia *(Oreochromis niloticus* Peters) Processing: Technology Transfer. It organized Lake Danao Fishermen and Farmers Association (LDFFA) and presently conducted a research entitled Limnological Studies of Lake Danao. The vision of the CTU San Francisco, Cebu Campus is that by the year 2010, the CSCST – Fishery and Industrial College is the center of educational training for Limnological, Mariculture and Industrial Studies and to produce quality and competitive graduates in Limnological, Mariculture, Industrial Technology, Marine Technology and Hospitality Management as part of the vision.

Figs. 11-12. The Cebu Technological University (CTU), San Francisco, Cebu, Campus

Fig. 13. The fish culture in cages of tilapia conducted by the CTU

Fig. 14. The research on the Rate of Growth of Genetically Farm Tilapia

Figs. 15-16. Researches on the post harvest processing of Tilapia

*) all pictures by S.N Tanduyan

D. Municipality of San Francisco Local Government Unit (Fig. 35)
The LGU tilapia cages initially are 10 unit of cages with a stocking density of 450 fingerlings/ cage. It measures 2.5 x 3.5 meters. The feeds used were feeds from the overseas feed mill with variants of fry ash, starch grower and finisher using the fish conversion ratio (FCR) of 1.8 for 5 months. There is less mortality encountered and they only experienced 5% mortality rate. Usually when they marketed the fish there is 3 pieces to a kilo with a price ranging from Php. 100.00 (2006); Php. 120.00 (2007-2009) and Php. 150.00 (2001 to the present). There is no problem in marketing for this is only enough for the lake Danao Park Tourists. Problems encountered are overcrowding especially when they are almost fully grown. Thinning was done separating the smaller ones from bigger ones. Delayed delivery of the feeds is another problem due to governmental processes and procedure. Bad weather conditions contribute to the delayed delivery. There was shifting of feed companies as suppliers and it was found out that the latest feeds supplied gives less growth performance of the fishes. Another problem is safety of the stock. So far, there is only 1 personnel in charge of the project and it is planned that additional personnel be recruited but the number of cage units will be increased.

GOVERNMENT INITIATIVES
A. Lake Danao as the Fauna and Flora Sanctuary of the Municipality of San Francisco, Cebu
The members of Sangguniang Bayan of San Francisco declared Lake Danao as a Fauna Sanctuary based on Resolution No. 68-93. The purpose was for the conservation of forests and wild life of the municipality, promotion of ecotourism and to promote better level of environmental awareness where it is the duty of every Filipino citizen to protect and safeguard especially the endangered species. The barangays surrounding Lake Danao which are Sonog, Esperanza, Union, and Campo are the very barangays included in the site where 50 meters from the lake shore are considered to be the extent of the area covering the faunal sanctuary including the forest, lagoons and wetlands therein. This was made and approved last July 13, 1993 and was authored by Hon. Hilaria G. Nudalo SB member, Hon. Aly A. Arquilano and Hon. Sixto A. Castardo, Jr. as Mayor and Vice Mayor respectively. This resolution was fully implemented banning the catching of wild ducks (little grebe) locally known as gakit. The catching of fish was controlled with a regulated mesh size of nets which is 7 inches.
B. Urging the Barangay Captains of the Six Barangays surrounding Lake Danao to Spearhead in the Protection of Lake Danao.
Resolution No. 73-99 entitled urging the barangay Captains of Campo, Union, Esperanza, Sonog, Cabongaan and Northern Poblacion to spearhead the activities in the protection of Lake System, Lake Danao, San Francisco, Cebu. This was made because Lake Danao is considered as a God given prestigious natural resources that gives many benefits to the people. This is also made in order to protect the lake from biodiversity degeneration, pollution, sedimentation and salt water intruism. This also includes greening of the lake, maintenance on lakescape program and plans. This was approved last September 6, 1999 during the incumbency of Hon. Aly A. Arquillano and Hon. Avelino S. Obenza as municipal and vice mayors respectively.
C. Declaring every 18th day of September of every year as Municipal Coastal Clean up Day in all Marine and Lake Waters of San Francisco, Cebu
Resolution No. 74-99, A resolution ordained by the Sangguniang Bayan members declaring every 18th day of September of every year as Municipal Coastal Clean up Day in all Marine and Lake Waters of San Francisco, Cebu under Municipal Ordinance No. 99-02. This is done in order to collect/ gather

debris or trash in the surface water, underwater and coastlines and lakeshores and finally a reporting of all data to proper and higher authorities on the standard data cards for the purpose. It is stipulated on this resolution under section 2a; that leaders of the barangay living in the coastlines shell lead people of all walks of life volunteering to get and gather debris in their jurisdiction and in section 2b provides that leaders of barangay surrounding Lake Danao shall likewise do the same in the lakeshores, water surfaces and underwater. This resolution was approved by all SB members of the municipality of San Francisco in the leadership of Mayor Aly A. Arquillano and Vice Mayor Avelino S. Obenza last September 2002. This is already adopted throughout the municipality.

D. Requiring all Soli -Soli Cutters/ Weavers to Secure Mayor's Permit before they are Entitled to Full Utilization of Soli Soli Materials

Resolution No. 93-011, A resolution requiring all soli-soli cutters/ weavers within the Municipality of San Francisco, Cebu or any interested investor shall secure mayor's permit before they are entitled to full utilization of soli- soli raw materials and the right to sell their products by products of such, within or outside the municipality, and selling/ bringing of soli-soli raw materials outside the municipality is strictly prohibited and any body who violates this ordinance shall be penalized with a fine of Two hundred pesos (Php. 200.00) for the first offense; Php. 300.00 for the second offense and for third offense cancellation of the mayor's permit and/ or imprisonment of not more than 6 months at the discretion of the court. Soli soli is an indigenous plant grown within the lakeshores of Lake Danao and used to make mats, bags and other handicrafts industries. This resolution was approved last March 1993 by Hon. Aly A. Arquillano as the municipal mayor. Already implemented and the weavers were charged Php 100/annum as permit fee.

This gathering of soli soli (*Typha latifolia*) was regulated by which gatherers will pay a permit fee of Php. 100.00 per annum.

E. Protection of Lake Danao and Imposition of Penalties

Resolution No. 48-96 provides the protection and imposition of penalties for those whose acts result in the pollution of the lake.

This was supported by Municipal Ordinance No. 96-005 "An ordinance prohibiting the use of motorized vessels in Lake Dana except by the use of outboard motorboats". Anyone who violated this ordinance will be fined Php. 500.00 for the first offense then Php. 1,000.00 for the second offense and for the third and succeeding offences a fine of Two thousand five hundred pesos (Php. 2, 5000.00). An entrance fee of P15.00 and P10.00 for adult and children respectively are collected. This was done last September 11, 1996 under the leadership of Mayor Aly A. Arquillano and Vice Mayor Sixto A. Castardo. No motorized boats were used by the people excluding the SAKANAO (**Figs. 17-18**) which is owned by the LGU. All fishermen using paddle to traverse any part of the lake. The washing of clothes in the lake was totally implemented. There are minimal individuals doing this but the level of awareness is high since they really knew that washing was really prohibited.

Figs. 17-18. Signages on disallowing the use of motorized boats except the SAKANAO during traversing any part of the lake.

*) all pictures by S.N Tanduyan

F. Adopting and Implementing Articles 51 and 52 of RA 1067 (prohibiting construction of dwellings and other structures twenty meters from lakeshore)

Municipal Ordinance No. 96-004 ordained by the Sangguniang Bayan of San Francisco, Cebu to adopt and implements the Articles of RA 1067. Article 51 states that the banks of rivers and streams and shores of the lakes throughout their entire and within a zone of three (3) meters in urban areas, twenty (20) meters in Agricultural areas and forty (40) meters in forests areas, along their margins, are

subjected to the easement of public use in the interest of recreation, navigation, flotage, fishing and salvage or to build structures of any kind. Article 52 states the provisions of the Civil Code shall govern the establishment, extent, form and conditions of easement of water, not expressly determined by the provisions of this code. Anyone who violates these articles shall be penalized by a fine of not less One thousand pesos (Php. 1,000.00) but not more than two thousands and five hundred Pesos (P2,500.00) and/ or an imprisonment of not less than one (1) month but not more than six months at the discretion of the court. This ordinance was approved last April 1996 under the leadership of Mayor Aly A. Arquillano. So far this was fully implemented and no more dwellers who constructed their houses in 20 meters buffer zone from the lakeshore. The Municipal Health Unit (MHU) of the municipality were tasked to inspect the toilets of the dwellers following the standards set by the DOH and DENR.
The lake personnel including the visitors are already aware of this ordinance where a trash bin was provided and urinating usually done in the toilets not just anywhere else (**Figs. 19-21**).

Figs. 19-21. The trash bins provided near the lake and a toilet for the tourists to be used.

*) all pictures by S.N Tanduyan

G. Creation of the San Fran Lake Watch
Executive Order No. 02-2003, an order issued by virtue of the powers vested to Hon. Alfredo A. Arquillano, Jr. as the municipal mayor to create the San Fran Lake Watch to take the lead in all efforts to preserve and clean the lake. This was done because Lake Danao as an important natural resource needs to be preserved and nurtured. So, there is a need to unite all stakeholders especially those who interact with the lake frequency or on a regular basis recognizing their vital role in protecting and cleaning the lake. The San Fran Lake Watch composed with the Chairman, the representative from the office of the Municipal Mayor (to be designated by the municipal mayor); the vice chair, the Head from Carmen- Lake Danao Fishery Development Complex and the members are the President, Soli- soli weavers association, President, Lake Danao Fishermen's Association, President of the Lake Danao Boatmen Association, Presidents from all Lakeside Residents Association, School Principal and the SGO President of Lorenzo C. Tanza Memorial National High School. The San Fran Lake Watch have the duties and functions as the primary planning body in the protection and clean up of the lake, take the lead in all efforts to preserve the lake and protect it from all incriminating human activities, conduct or cause to conduct a regular clean up on the lake shore and clear the lake of floating debris, perform all other functions as maybe assigned by the municipal mayor and submit quarterly reports or as often as necessary. This executive order was issued last February 2003.
Prospects of the Different Agencies

1. The Local Government Unit (LGU) of San Francisco who spearheads the lake conservation and sustainability plans to implement strictly the ordinances made and scouting more financers of the project of Lake Danao and other activities.
2. The BFAR RO7 will continue to engage in aquaculture activities of the freshwater fishes including their breeding and restocking the lake. Continued monitoring on pollution parameters will be made to make the lake fit all the time.
3. The Department of Agriculture will from time to time extend support to the farmers and the fishermen introduce alternative livelihood to the users of the lake.
4. The Cebu Technological University (CTU) will continue to conduct limnological researches, aquaculture techniques and post harvest processing techniques of tilapia and other freshwater fishes so that maximum utilization of the catch of the fishermen will be made.

CONCLUSIONS

1. The government agencies throughout the municipality of San Francisco are in one mission to confront the activities of Lake Danao, sustain production and conserve the lake being the nature's gift to the San Franciscohanons.
2. All the agencies have specific role to play in Lake Danao Conservation and Sustainability.

RECOMMENDATIONS

1. Values reorientation should be done to all the workers in the lake in order to sustain commitment and dedication.
2. More financial support be given to sustain and improve the lake as a tourist destination and as a resource.
3. Comprehensive and progressive plan on the biological, ecological, physical and anthropological studies be made so as to maintain the lake where balance on every all aspects are gleaned.

ACKNOWLEDGEMENT

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Thank you very much and God Bless!

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IDENTIFICATION OF LAKE SENTARUM'S POTENTIAL ECOSYSTEM SERVICES, SOCIAL AND INSTITUTIONAL PROFILES TO SUPPORT ECOTOURISM DEVELOPMENT (A REVIEW PAPER)

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ABSTRACT

A memorandum of understanding of ecotourism development in Kapuas Hulu District has been signed by several institutions. Among some covered ecosystems, Lake Sentarum as a very unique ecosystem is the prime destination included in the tourism plan. This paper is aimed to review and identify the lake's potential ecosystem services (i.e. biodiversity, water supply) as well as social and institutional profiles of the surrounding areas which are the main elements of the tourism plan. Moreover, a useful information that can be easily read by the decision makers about the strengths, weaknesses, opportunities, and threats is also presented in the paper. The information was obtained by reviewing all possibly accessed papers and then they were analyzed by using a strength, weakness, opportunity and threat (SWOT) analysis. The results of the analysis show that the biodiversity and unique ecohydrological process are the main strength of the area. At the same time, limited access and insfrastucture is identified as the main weakness. The main identified opportunity is the fast growth of ecotourism in global scale. Whilst the identified main treats are both deforestation and land use changing. Eventually, it is concluded that even though Lake Sentarum is significantly potential for ecotourism development, structural and institutional improvement is imperative to be conducted to support the tourism plan.

Keywords*:* Lake Sentarum, ecotourism, ecosystem services

INTRODUCTION

The World Wide Fund (WWF) and Kapuas Hulu District Office of Tourism and Culture Ministry, Danau Sentarum National Park (Taman Nasional Danau Sentarum/ TNDS), Kapuas Hulu Forest Management Agency (Kesatuan Pengelolaan Hutan (KPH) Model Kapuas Hulu), and Melemba Village Government have signed the memorandum of understanding of ecotourism development in Kapuas Hulu District. The ecotourism plan is aimed to support both ecological and economical benefits. In the future, the development of ecotourism may include Lake Sentarum as the main tourist attractor. Lake Sentarum, located in Central Kalimantan Indonesia, is a unique floodplain system impressively connected with its surrounding ecosystem such as peat forests, peat swamps, and riparian forests and many other ecosystems. Moreover, cultural richness and social structure in the area are fascinating to be explored and they provide valuable contribution for the development of the area. There have been tons of researches conducting in this area. The reasearches were mostly done by national and international NGO (i.e. CIFOR), Universities (i.e IPB), and govermental research Institute (i.e Research Centre for Limnology LIPI). In order to provide an elaborate paper and a guideline paper for the decission makers in considering the best policies to manage the area, this paper is written. It is hoped that this paper can provide a simple summary and a guideline to address such needs.

The main chapters of the paper will be divided into two main parts. The first part is the summary of all possibly accessed literature comprising biological resources, non-biological resources (i.e.water and carbon stock capacity), economic values, social profiles, institutional profiles, and resource use patterns. Whilst, the second part will be the SWOT analysis identifying the useful and informative information generated from the review materials and its discussion.

METHODS

The review is accomplished by reviewing all possibly accessed literatures such as the publications from CIFOR, LIPI, as well as related online publications. Thereafter, SWOT analysis is performed to achieve the objectives.

RESULTS AND DISCUSSIONS

REVIEW

The Lake's main potential resources are its astonishing biodiversities and hydrological patterns. This chapter will briefly describe those characteristics as well as explore the economic values, social profiles, institutional profiles, and resource use patterns that can be summarized from various literature.

Biological Resources

Fin-Fish

Several researchers have identified the biological resources of Lake Sentarum and its surrounding ecosystems. One of the most distinctive researches was a fishery survey conducted by Dudley (2000). The author wrote about the fishery productivity based on 1992 to 1995 data, and he concluded that the lake can support up to 97.5-162.5 kg of fish catch per ha per year. Meanwhile, Kottelat *et al.* (2005) identified that there were 303 fish species captured in the lake area and Kapuas River area in 1991. This number increasing quite significantly become 315 species in the survey conducted in 1995 by Kottelat *et al*. (1995). Jeanes (2000) stated that there were about 10 main fish species in the lake which are *Balantiocheilos melanopterus*, *Scleropages formosus*, *Kalimantania* cf. lawak, *Osteochilus pentalineatus*, *Parachela cyanea*, *Puntius aff. binotatus* 2, *Puntius* cf. *lineatus*, *Rasbora* aff. *sumatrana*, *Mystus*, *Silurichthys* cf. *hasseltii*.

Non-Fin Fish

Tortoises and softshelled turtles are other biological resources that have been researched and exploited bythe locals. Walter (2001) identified that at least three soft shell turtes living in the lake area; which are *Amyda cartilagenea*, *Dogania suplana*, and *Orlitia borneensis*. The author also mentioned that there were about 11 tortoises and turtles living in the lake area and none of them is native in Kalimantan. They are Asian brown tortoise, Black marsh turtle, Asian box turtle, Asian leaf/stream turtle, Spiny turtle, Ricefield/snail eating turtle, Malaysian giant turtle, Keeled box turtle, Asian softshelled turtle, Malayan softshelled turtle, dan Asian giant softshelled turtle (Walter, 2000). On the other hand, other biotas such as crabs, shrimps, and Gastropods are relatively barely observed by the researchers. Only few studies can be found about the biotas. One of the study was done by Giesen (1987) cited in Jeanes (2000). The study mentioned about several gastropod species that can be found; which are *Pilla ampucea*, *Ctenodesma* sp., *Schepmania* sp., and 2 species of *Bellamya.* In addition, the study also described about 2 unidentified crab species. A study about the occurenc of a native prawn species (*Macrobrachium sintangense*) in the Lake was conducted by Said *et al*. (2014). They also concluded that in the study year, there were no any introduced prawn and shrimp species found in the Lake. Phytoplankton, as the primary producer in the lake area, also has been observed. Sulawesty (2013) identified that Chlorophytes (38 species) in particular desmid group (i.e. *Staurastrum)* were mostly found in the Lake compared to other groups. On the contrary, the least abundant group was Pyrrophytes (1 species). It was stated by the author that the observation results are coherent with the lake's physical condition which is acidic.

Terestrial Flora and Fauna

Giesen (2000) conducted a survey that recorded 504 plant species. Several described main plant groups are adalah *Dipterocarpaceae* (40 species), *Euphorbiceae* (10 species), *Rubiaceae* (35 species), *Myrtaceae* (26 species), *Fabaceae* (21 species), and so on. In particular the author also lined up 13 wild orchid species from the area. These orchids have been managed as sustainable local economy in the area (Prasetyo, *et al*., 2010). Whilst, Jeanes (2000) identified 293 bird sецies and 143 mammal species in the area. Moreover, the author also stated about 24 reptile species listed from the area.

Non-biological Resources

Water is the main non-biological resource supplied by the lake. The lake ecosystem absorbs 25% Kapuas River's water in rainy season while in the dry season this lake flows 50% of its water to the river (Yuliani *et al*., 2007). Giesen *et al*. (2000) stated that the lake hydrological system is a function of rainfall rate which is about 3,900 mm/year in the lake area. At the same manner, the lake ecosyste is an enormous carbon sink. If the peat swamp conversion is minimized, the lake ecosystem (especially peat swamp forest area) can absorb 2,879 tonnes of carbon/ha or similar to 10,000 tonnes of CO2/ha (Anshari, 2010).

Social Profiles

Social Groups

There are to prime user groups around Lake Sentarum National Park. The first group is Moslem Malay who mainly works as fishers. This group shares about 93% of total population in the area (Indriatmoko, 2010 cited in Wadley, dkk., 2010). The second group, Christian Iban, enggage as terrace farmers and hunters (Colfer, *et al.,* 1999). The livelihood discrepancy further endorses different life styles between the groups. The main difference is seasonal migration done by Malay group due to the fish harvesting season. Meanwhile, Iban group experiences daily migration sue to their farming and hunting activities.

Economic Values

Roslinda (2013) conducted a research on several economic values of the lake ecosystem. The result of the study is summarized in **Table 1**. The researcher calculated that total value generated by the lake ecosystem was 139.1 billion IDR with 2010 currency. Whilst, total cost spent by the government to manage the lake ecosystem was 6.7 bilion IDR in 2010 currency. Specifically, Aglionby (1999) cited in Dudley (2000) stated that capture fishery sector shared 1.5 Million USD and the aquacultue sector provided 0.7 million USD.

Table 1. Economic Values of Lake Sentarum National Park (Roslinda, 2013) (all values are stated in 2010 IDR/ year)

NO.	Economic Value Elements	Components	Value	Economic Value per ha IDR/ year	%
1	Direct values	• Capture Fishery	15,505,805,000	117,468.22	2.79
		• Honey Production	729,630,000	5,527.5	0.07
		• Ruber	2,218,796,000	16,809.06	0.15
		• Paddyfield	81,200,000	615.15	0.03
		• Firewood	3,329,492	25.22	0.00
		• Tourism	14,426,000	109.29	0.00
2	Indirect Values	• Domestic Use	964,476,000	7,306.64	0.08
		• Transportation	28,736,100,000	217,697.73	5.72
		• Fishery Use	4,587,500,000	34,753.79	0.98
		• Carbon Stock	431,636,400,000	3,269,972.73	75.19
3	Option Values	• Option	86,205,000,000	653,068.18	14.99
Total			570,703,707,492	4,323,353.51	100.00

It can be summarized from the Table that indirect values in particular carbon stock dominated the caculated value. This matter gets high interest from the internatioanl world since the Lake is a great carbon absorber in term of the concern for climate change. However, the discrepancy among direct and indirect values may threaten the conservation effort apllied in the lake cosystem. It may lead to the occurence of land conversion into something providing instant access to economic impact. This matter is also shown by the relatively high calculated option value. Thus, various optional plans such as ecoturism and alternative livelihood provision have to be planned ahead to improve the direct values of the lake ecosystem. Therefore, local people will receive the benefits of the lake occurence to limit such threads.

Institutional Profiles

Lake Sentarum Natural Resources Conservation Board (Balai Konservasi Sumber Daya Alam/BKSDA) is the main institution involving in the management of the lake area. Other participating institutional are international and local NGOs, national agencies, and local governmental relationships are and their roles are illustrated in **Figure 1.** It can be assumed from the Figure that there are two main groups who actively enggage in the management process. BKSDA as the main decission maker and the prime manager also act as the coordinator among the institutions. BKSDA is the permission letter issuer agency is the legal representative of The Republic of Indonesia Government. Meanwhile, NGOs such as CIFOR and Yayasan Riak Bumi participate in various conservation activities such as alternative livelihood, conservation planning, and local coordination and cooperation. Both institutions (BKSDA and NGOs) actively provide fund for many activities conducted in the lake.

At the same manner, local people as the main stakeholders who use and manage the resources holds the central role in the manangement process. Iban group, although only a minority group, employs shifting cultivation, thus they relatively create significant land use changing. Moreover, they also hunt their prey in the lake catchment area; therefore, their activities give direct impacts to the lake ecosystem. The central role of Iban group was studied by Wadley (2002). Whilst, Malay activities are considered not significantly impact to the changing of lake ecosystem since they mostly enggage on fishery activitiesand they migrate along with harvesting season. Nevertheless, their roles in the management should not be neglected since they are the dominant population.

Local government shares the resposibility by both technical and non-technical efforts as well as coordinating roles in managing the lake ecosystem. At the same time, the government also shares their roles to the impacting activities as they hold the authority to issue permit for many activities such as palm oil plantation. Roslinda (2013) found similar finding after conducting a stakeholder analysis. The author revealed that BKSDA is the main stakeholder by empowering both high interest and influence. On the other hand, local communities are categorized as the parties with hgh interest but low influences since they do not have access to decission making process. Whilst, international oganzation; for instances, CIFOR and CANOPY share low interest and influence. At the same time, local government represented by Local Planning Agency (BAPPEDA) showed high influence and low interest. Thus, both BKSDA and BAPPEDA should be the prime leader for good management movement. Moreover, local community roles should be empowered and invited to participate more in the management process since they have high interest to the resources and they acquire great knowledge about the resources.

SWOT ANALYSIS FOR ECOTOURISM DEVELOPMENT

To elevate local economic impact as well as to support conservation program in the lake's ecosystem, The World Wide Fund (WWF) and Kapuas Hulu District Office of Tourism and Culture Ministry, Danau Sentarum National Park (Taman Nasional Danau Sentarum/ TNDS), Kapuas Hulu Forest Management Agency (Kesatuan Pengelolaan Hutan (KPH) Model Kapuas Hulu), and Melemba Village Government have developed an initial process for ecotourism at Melemba Village. The tourism has to be supported by various aspects; for examples: insfrastructure development and local people empowerment. In this paper, a SWOT analysis is proposed for the improvement of the ecotourism plan. The analysis is presented in **Table 2**. Overall, the main strength for ecotourism development is the lake's wonderful biodiversity. Whilst, the main identified weakness is limited accessibiity and insfrastructure. This statement is supported by a tourism expedition conducted by Kompas held in 2013.The journalist member of the expedition wrote that it was relatively expensive, difficult, and dangerous to access the lake area (Kompas, 2013).

Table 2. SWOT analysis to support ecotourism development in Lake Sentarum

	Helpful for ecotourism development	**Harmful for ecotourism development**
Internal factors	**STRENGTHS**	**WEAKNESSES**
	• Amazing biodiversity • Endemic species • Abundant water resources • Unique hydrological processes • Huge amount of carbon sequestration	• Very limited infrastructure and transportation/ Low Accessibility • Differences among dry and wet season hydrological processes is a threat for water transportation continuation • Acidic peat water limits tourism activities • Limitation of local people involvement by the planning agency • Very few bridging research and or discussion
External factors	**OPPORTUNITIES** • Emerging ecotourism trend in the world • Various research availibility • Low identified direct economic values from other activities • Supports from Governmental Boards and private invitation • Support from both international and local NGOs	**THREATS** • Deforestation • Land use changing

The success of ecotourism development cannot be separated with the increase of global ecotourism demands. Ecotourism is becoming a worldwide new trend; thus, it should be optimized by promoting Lake Sentarum as a unique ecotourism experience. In order to promote Lake Sentarum's ecotourism globally, the available support from both governmental and international institutions is an opportunity that should be captured by the tourism developer. At the same manner, it is also presented that low identified direct economic value is the opportunity that should be seen since ecotourism
On the other hand, the development of ecotourism is mostly threatened by alteration of land use surrounding the lake area. There are plenty popular articles (i.e. Kompas, 2015 and Republika, 2011) citing that opening of palm oil plantation in the lake's catchment area created disturbances on the ecosystem. Although some popular media have explored the danger of palm oil plantation to Lake Sentarum's ecosystem, there is no scientific publication has been found to describe detail impacts of palm oil plantation to Lake Sentarum's ecosystem. Unfortunately, this lack of scientific research creates an opportunity for the local government to state that there is no interrelationship between palm oil plantation with reduction of fish capture (Antaranews.com, no date available). Therefore, it is necessary to be aware that expansion of palm oil plantation may be continuing. The threats of palm oil plantation to the ecosystem in other areas actually have been well documented. One of the most recent studies focusing on the impacts of alteration of secondary peat swamp forest into a mature palm oil plantation was conducted by Tonks *et* al. (2017) in Malaysia. The study found that the conversion forfeited C storage and water holding capacity of the swamp. Other studies such as Saswattecha *et al*. (2015) and Silalertruksa (2016) highlight some concerns related to green house, water footprint, and acidification as the impacts that should be aware to be generated by the expansion of the plantation. Thus, the impacts of palm oil expansion to the water holding capacity and C storage may pose great threats to the development of ecotourism since the lake main strengths include aquatic biodiversity and carbon stocks.

CONCLUSIONS

To succeed the ecotourism plan that have been signed, the moment of global ecotourism booming should not be missed by the manager. Thus, some major threats should be resolved before they devastate the occurring plan since the identified threat can disrupt the main strengths such as water capacity and carbon sequestration which eventually impact the marvelous lake diversity. The identified threats are land conversion and deforestation. In line with the plan development, a massive progress of infrastructure development as well as increment of local people involvement is a top priority work that should be finished promptly. All in all, should all aspects are synergies a well-developed and sustainable ecotourism may be performed and in the end local people welfare may also be improved.

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CONFIGURATION OF LAKE TOBA MANAGEMENT BASED ON PRESIDENTIAL REGULATION NO. 81/2014

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ABSTRACT

Utilization of lake area continues on expanding and, especially in multipurpose lake, has led to the vexing problems multi-dimensionally either in ecological, economical, and sociological aspect. Lake Toba, known as the largest lake in Indonesia and located in seven districts in North Sumatra Province, has a variety of functions with an intensive utilization rate. Management of the multifunctional lake requires profound attention towards the existing interests. The Indonesian Government through the Government Regulation number 26/2008, on the National Spatial Planning, has set a list of areas projected as National Strategy Region (NSR), and among them is Lake Toba area. The decision on incorporating Lake Toba as NSA is based on lake's location which is shared within seven regencies, various sectors' exploitation, as well as the presence of utilization associated with the national interest. Lake Toba management is a comprehensive activity that relates to how to support the sustainability of the ecosystem and benefit values for the locals in the surrounding area. Presidential Decree No. 81/ 2014 has authorized the management of Lake Toba area, which aims to: i) manage the catchment area pertaining to the maintenance of the water resources sustainability, and minimize the erosion to prevent sedimentation; ii) maintain the water quality and protect against the land and water contamination; iii) sustain the biological resources and the stocks through the biodiversity and endemic biota protection, as well as maintain the stability of biological production that bestows myriad benefit for locals. To conclude, Presidential Decree number 81/2014 synergistically binds together scientific and local wisdom aspects.

Keywords: Lake Toba, National Strategy Region, Presidential Regulation number 81/2014.

INTRODUCTION

Increasing utilization of waters, especially in multipurpose lakes, has arisen complicated problems with various dimension including in ecological, economic, and sociological aspects. Lake is common property area, having potential of economic resource which can be a livelihood source for the surrounding community. On the other side, lake as an ecosystem is a medium for inhabiting the variety of life in which susceptibility to changes has strong association to human activities. Various interests have utilized the available resources in the lake, which can cause conflicts because of different criterion needs and sensitivity level of each use. Toba, as the largest lake in Indonesia has various functions and intensive use. Lake Toba has a function as area of tourism and fishing area, Hydroelectric Power Plant (HEPP) and a source of raw water (**Fig. 1**). Centre of tourism has been growing in Lake Toba region and use its panoramic view as main object of the sites. In national policy, Lake Toba and several other lakes such as Lake Maninjau and Lake Batur are the basis of the National Tourism Development Master Plan (Ardika, 1999). The fishery activities in Lake Toba has been continuing for a long-time age, since 1950s, the dominant fish caught is tilapia (*Tilapia mossambica*) (Soerjani *et al*, 1979).

Another activity expanded in the Lake Toba is fish culture in floating net (cage aquaculture; CA), which was first tried in 1988 (Dharma, 1988). The total production of fish from CA in 2010 was 47,478 tons, which was dominant from the Regency of Samosir (24,420 tons), Toba Samosir (10,372 tons) and from Simalungun (9,807 tons) (Anonymous, 2011). River Asahan, the outlet of Lake Toba, has been used to support HEPP of Sigura-gura whose capacity reached 450 megawatts (MW). River Renun is the lake inlet and it has been used as another HEPP with capacity of 82 MW.

The utilization of the lake waters that is more concerning to the local community life is a source of raw water for drinking water. Approximately 70% of villages around of Lake Toba utilize lake water as a source of raw water and drinking water, besides, three Regional Water Companies also utilize of Lake Toba water for raw water, namely in Pangururan, Balige, and Laguboti cities.

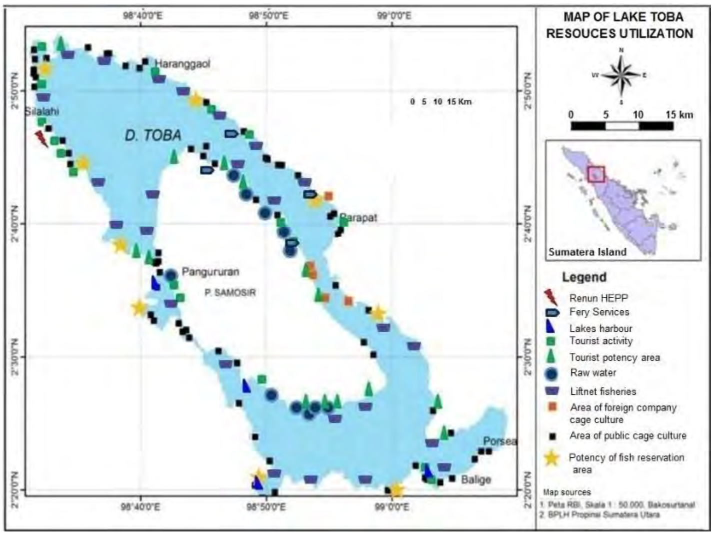

Figure 1. Map of Lake Toba water area utilization (Lukman, 2013).

In lake catchment area, the land use is intensive enough, not only agricultural but also the settlement. Large areas of land utilization for cultivation activity is around 48.6% of the catchment area, which is mostly for agriculture in dry land (27.6%) and open land (20.6%) area. The composition of forest land covered only 23% of catchment (BP DAS Barumun *in* Lukman et al., 2010). The agricultural activity in lake catchment reached 129,448 ha (**Table 1**), or approximately 53% of the total catchment area, with the highest proportion in Toba Samosir Regency that reached 56 138 ha.

Table 1. Agriculture land area on Lake Toba catchment in each regency

No.	Regency	Agriculture land area (Ha)
1	Toba Samosir	56,138
2	Samosir	48,971
3	Simalungun	12,699
4	Humbang Hasundutan	7,908
5	Dairi	2,062
6	Karo	1,670
Total		129,448

Source: Calculate from Earth Image Map (Bakosurtanal Map)

According to Klessig (2001), the lake can only provide optimal social benefits if the policy setting management fully recognizes the potential contribution of the lake for the community and the policy is integrated to provide a balanced attention on all the values that the lake can give. Thus, the utilization of the lake waters will be positive as long as its ecological balance, within the limits of carrying capacity consider the interests of others.

TOBA LAKE AS A NATIONAL STRATEGY REGION

The Government of Republic Indonesia through the Government Regulation number 26/2008 on the National Spatial Plan, has set 76 regions throughout Indonesia into the National Strategy Region (NSR). Lake Toba is one of 76 areas within NSR. The aim of Government Regulation declared was to achieve: i) the harmonization between the natural and manmade environment; ii) the integration of planning, utilizing and controlling of land use; iii) balance and harmonize of development between regions and between sectors. Categorization of Lake Toba as an NSR is appropriate because it refers to the lake physical characteristics which belong to seven districts in North Sumatra **(Fig 2**), lake utilization by various sectors, as well as utilization related with the presence of national importance such as hydropower-Sigura-gura.

Since the status of Lake Toba is as NSR, therefore, the spatial plan is on authority of the central government's. It refers to the National Spatial Plan (NSP), in which confirms the policy direction and utilization strategy of state space regions.

Figure 2. The map of regency distribution in Lake Toba area.

In article (Art.) 9 (1) of President Regulation No. 26/2008, it is stated about the policy of NSR development, including the preservation and improvement of environment function and carrying capacity, to maintain and improve the ecological balance, preserve biodiversity, maintain and improve the function of protection area, preserving the uniqueness landscape and national cultural heritage;

To support policies that Lake Toba and surrounding area as a National Strategy Region (NSR) area of national strategy (KSN), the Lake Toba spatial planning, as direction of its area utilization, determined by the Presidential Regulation number 81 of 2014, The Lake Toba Spatial Plan was set. Presidential Regulation number 81/2014 serves, among others, as a guide of: i) Development plans preparation in Lake Toba area; ii) Spatial planning at provincial and district area in Lake Toba; iii) Realization of the integration, interrelation, and balance development between district area, as well as the harmonization between sectors in Lake Toba area; iv) Determining the location and functionalism of investments in Lake Toba area; iv) Management of Lake Toba area; and v) Achievement the development plan integrity of Lake Toba with the surrounding area.

TOBA LAKE MANAGEMENT WITH REFERENCE TO THE PRESIDENTIAL REGULATION

Lake Toba management is a comprehensive activity related to how to support the sustainability of the ecosystem, the biota in it and utilization value for human being. Thus, such management should be directed to: i) the management of catchment area related to the maintenance of the sustainability of water resources and minimize erosion to prevent silting; ii) maintain water quality and protect against contamination from the land and water; iii) the sustainability of biological resources availability through the protection of biodiversity and endemic biota, as well as maintain the stability of the biological production for people utilization. President Regulation number 81/2014 of the President stated explicitly that the purpose of arrangement mentioned is related to the management of the lake that includes the preservation of the catchment region as the water of life the communities and ecosystems, as well as fish culture control, that has to correspond on lake carrying capacity and integrate to tourism development (Art. 6),

Watershed Management

Sustainability of the water supply is of major importance for the aquatic ecosystem of the lake, both in relation to aspects of preservation of aquatic and biological resources in it or linkage with the need for water resources for energy. Thus, catchment area management is directed at spatial arrangements that is relevant to each region carrying capacity and the implementation of environmental friendly land use. President Regulation number 81/2014 concerns both water body, catchment and ground water recharge area (Art. 5). In Lake Toba area, there are 25 sub catchments (Art. 5; 3) and 9 water recharge areas (Art. 5: 4). Management strategy of catchment area that will be implemented include: i) The management of protected forest areas (Art. 8; 1a); ii) Management of groundwater recharge areas (Art. 8; 1b); iii) Control land use around water sources and riparian (Art. 8; 1c); iv) Setting an infiltration function on the slope of > 40% (Art. 8, 1d); v) Built the sediment trap (Art. 8, 1i); v) Control the residential development around protected forests (Art. 8 1h); vi) Control cultivation area in the ground water recharge (Art. 8.1l); and v) Restructure the tourism area in lake border area and on the land with a slope of > 40% (Art. 8.4.b). The strategy in the cultivation area for regional preservation of crop and horticulture, through: i) Development of terracing system on lands with a slope of 25% -35% (Art. 8.6b); ii) Pollution control in cultivated areas by organic farming application (Art. 8.6d); iii) Control of protected forest destruction and water pollution from agricultural activity (Art. 8.7a); iv) The development of environmental friendly farms (Art. 8.7b). Management strategies of watershed will also be realized through maintenance cooperation pattern of environmental quality, in terms of: i) Management and maintenance of water resources in the catchment and water recharge area (Art. 8.8a); ii) Application of lake water quality standards based on water quality standard Class I (Art. 8.8b); and iii) Integrated management of waste water network system and solid waste (Art. 8.8g).

Pollution Management

The main concern of lake management is to maintain the water quality in a condition to fulfil qualification of related the water purpose. People activities in the waters and also in the terrestrial area will give impact on lake water quality. Activities in terrestrial area will increase the allochthonous matters into the water. The agriculture impact is characterized by elevated nutrients and pesticide level and domestic activities are characterized by increasing levels of organic material. Management to minimize the effects of pollution includes the development of environmental friendly farming systems, to set the border corridor as a buffer or transition zone which role as filter the entry of various pollutants from the mainland, and the development of waste management.

Activities on the lake that have the potential to provide pollution are transportation, cage aquaculture activity and washing and bathing activity. The policy on pollution management is declared in President Regulation number 81/2014, they are: i) Maintain the stability of lake water quantity and water quality control (Art. 7; a); ii) Control of cage aquaculture area in the lake (Art. 7; e); c iii) Control of livestock area, horticulture and development the community-based plantation and environmental friendly farming (Art. 7; g). The strategy to implement the pollution management policy, are: i) Provide the water quality monitoring facility (Art. 8.1.f); ii) Pollutant emission reducing vegetation development on the banks of lake (Art. 8.1.g); iii) Development of bio filtration on rivers to reduce pollutant load (Art. 8.1 h); iv) Development of wastewater treatment plant in the area of livestock (Art. 8.7c); v) Control of production process on the agricultural area in watershed which produce waste and hazardous waste (Art. 8.1o); vi) Development of waste management systems and the wastewater network (Art. 8.1p); vii) control the use of the lake water with reuse model (Art. 8.1k); viii) Control of lake space utilization for aquaculture (Art.8.1 m); viii) Recovery of lake water quality which polluted by fish farming activities (Art.8.1.r).

Management of pollutant on cage aquaculture activity becomes an important concern that is related to their activity in water body and people economic source. Therefore, special strategy was developed in President Regulation No.81/2014 through zone arrangement of cage location and the production that refers to carrying capacity of the lake. President Regulation mentioned the strategy for aquaculture development in lake area through: i) Cage aquaculture area control and water quality on this area need to fulfil the water quality standard on class I (Art. 8; 5a); ii) Prohibition of aquaculture activity in the lake banks until 30 m depth as littoral zone which has function as benthic animal habitats and fish spawning area (Article 8; 5b); iii) Control of cage aquaculture activity in open water with a depth of 30-100 meters and in lake outlet waters area, that refers to environment carrying capacity and the water quality need to meet the water quality standard on class I (Article 8; 5c); iv) Controlling cage aquaculture activity in depth waters (> 100 meters) as decomposer zone (Article 8; 5d);

Sustainability of Biological Resource Availability

Management is directed to ensure the sustainable utilization of biological resources through the establishment of protection zones, especially for endemic biota, endangered species, as well as settings the zone that keep reproduction processes continuity of biological resources, including establishment of protected zones for migration route and fish spawning ground. Lake management to support availability of biological resources continuously has been accommodated in President Regulation by setting conservation of important ecosystem (Art. 7b). The strategy to implement those policy, will execute by establishing the protected areas (Art..8.2 a), including conservation of local and natural protected area (Art. 30).

Local protected area consists of riparian (river bank) zone, around (bank) of lake, green open land area (Art.32). Area of natural conservation for conserve of biodiversity, ecosystem type and genetic resources, setting for spawning ground of Lake Toba endemic fish (Art. 33).

The implementation level of zone arrangement direction further has to consult to Detail Plan of Zone Utilization which is put up through Regional Regulation (Art. 117). It is also related to Lake Toba area located on seven of regency administration.

SCIENTIFIC REVIEW OF LAKE TOBA CONDITION

Direction of Lake Toba area utilization with refer to President Regulation No.81/2014, namely Space Planning of Lake Toba Area, it is expected that lake resource utilization should be sustainable. Science and technological information and local wisdom are useful to suppot the implementation of policy, for instance: to increase the awareness of hidrological dan geological condition. As known the tophography of Lake Toba catchment characterized by slight elevation (slope degree 3-8%) it is just 30% from the total area, the rest is rather steep to very steep (70%) (BP DAS Barumun *in* Lukman et al., 2010). Regulation of land management have been written on President Regulation number 81/2014 stating that the use of land in the Lake Toba catchment must pay attention ton the hydrological factors. President regulation in the utilization of land space, generally had regarded the nature susceptibility and ecological specific of utilization areas that should be protected. However, we must keep in mind that the ecological characteristics of the lake waters are different from other ecological sites. In lake area, there are some areas (habitat) need to be considered related to the purpose utilization regulation of lake space, such as the edges of the lake, littoral zone, lake inlets or area of rivers entering the lake, and wetland areas. Ecological importance of the lake edge is an ecotone zone and energy supplier. This area generally has high biotic diversity. The riparian vegetation that grows along the banks part is thought as fauna habitat land water specific, supplier of organic matter and nutrients to waters as lake energy source.

From the lake management point of view, the banks are part of border regions, which should be open for public access to carry out various activities in the waters. The banks area can be an inspection corridor and can be a hub to the processing of land-based activities, such as the treatment of sewage, raw water intake and environmental monitoring. Littoral zone is part the waters generally located on the lake edge, where the bottom waters are still on sunlight penetration (euphotic zone) which still support the development of autotroph photosynthetic organisms. This region develops a variety of aquatic plants, benthic biota, as well as being the main area of fish spawning zone. Littoral zone of Lake Toba is known to a depth of between 18-36 meters, or an average of 27 meters and its range is estimated at 10.64 km^2 or 0.95% of the entire of lake area (**Figure 3**) (Lukman, 2011).

The inlet area where river goes into the lake needs to be considered because it is an area where the influx of pollutants from land-based activities and fish migration way to spawning ground. Inlets of the lake can be used as monitoring stations of pollution from the land, and on the other hand, this area should be open so that it will not disturb the fish migrating activity.

Wetland regions which are widely distributed on the lakes shores often become an important habitat of water birds, even among the migratory birds. The wetlands which also have quite high plant populations are generally the habitat for many animals who live between land and water.

The utilization of water area for the development of cage aquaculture has to concern the lake carrying capacity. Referring to Beveridge's (1984) criteria, the carrying capacity is the maximum production level that can be achieved based on the total phosphorus levels acceptable as appropriate of waters utilization, particularly it is related to the impact namely eutrophication. In fact, the criteria are ignoring the organic matter accumulation impact in the bottom waters causing anoxic conditions and changes in the structure of benthic habitat. It also needs to pay attention to avoid habitat benthic damage, especially in the littoral zone. In a more specific point, Bengtson (2012) also imposed the aspect of carrying capacity which pays more attention to the ecological and sociological conditions.

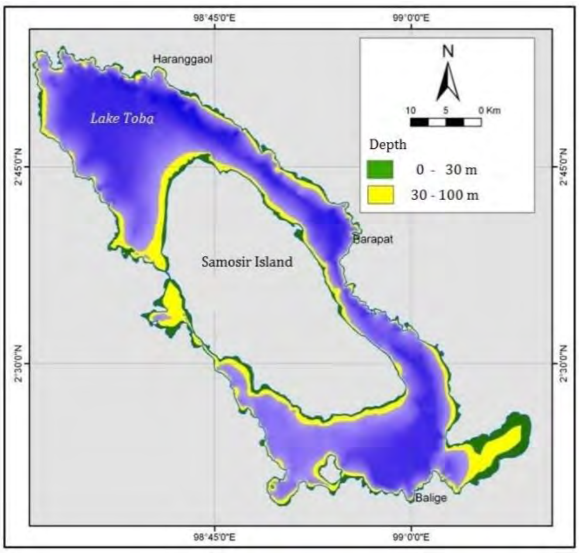

Figure 3. The littoral zone of Lake Toba (Depth of 0-30 m; green) (Source: Lukman, 2011)

Several ecological factors and the waters space utilization become determining criteria of cage aquaculture development area (Lukman, 2011a; 2013), they are: i) Hydro morphometric character and water mass flow patterns; ii) Outside the littoral zone; iii) Considering to the length of each regency coastline; iv) Agricultural land area and their activity in each regency; v) Considering the number of local residents; vi) Outside the territory of other activities that already exist such as raw water intake area, business activity and the port, outside of the tourism area and tourism potential; and outside the fish reservation zone. Considering to the water quality, water mass circulation factors and the estimated area use both the existing and potential use in the future, the grading direction of potential development area for cage aquaculture has been defined (**Figure 4**).

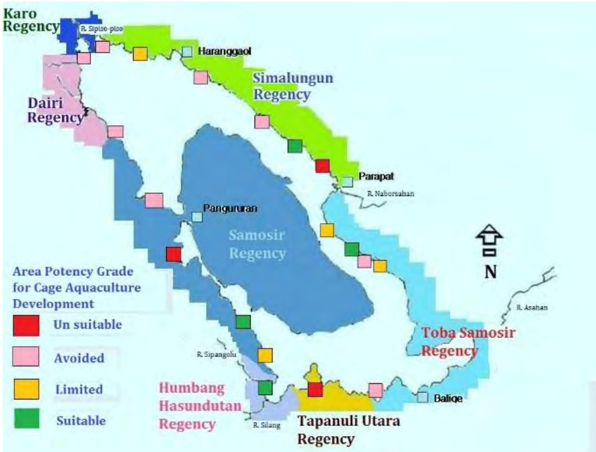

Figure 4. Potential area grade for cage aquaculture development in Lake Toba (Sumber: Lukman *et al*, 2013).

Referring to the Government Regulation (PP) number 28/2009 that is related to Water Pollution Load Capacity on Lake and/or reservoirs, with a range of phosphorus criteria for oligotrophic waters, scenarios for fish production from cage can be achieved until 35,282 tons / year (Lukman and Hamdani, 2012).

CONCLUSIONS

The Lake Toba which is included as one of the national strategy regions has become a major concern from the central government of the republic Indonesia. The policy of Lake Toba management has been directed to develop into one of the world's tourist destinations. Each activity will be and has been growing in the Lake Toba and that should be in line with and support to those policies. Government policies determined by Presidential Regulation are comprehensive and sufficient to keep the implementation of target lake management also in line and accommodative to the characteristic the lake ecological and hydrological conditions. However, in implementation level has to consider the social and economic development aspects and how to build the balance between the regions. Lake Toba is one ecosystem but there are seven regencies using Lake Toba with different policies and requirements. On waters area utilization, especially for the cage aquaculture activities, we have to decide the target of fish production, which refers to the total production level based of carrying capacity, and also the specified allocation needed for each district. In addition, specific zones of cage aquaculture activity for each regency shall be established and does not interfere with other activities that will grow and have been growing in the Lake Toba. Finally, the implementation of government policies related to the management of Lake Toba should be the main mind set of stakeholders and the community. The successful management of Lake Toba can hopefully be the reference to the management of other lakes in Indonesia.

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PROMOTING INTEGRATED LAKE BASIN MANAGEMENT IN LAKE NAKURU WATERSHED, KENYA

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ABSTRACT

Lake Nakuru National Park lies between longitude 36°05' E and Latitude 0°24' S, and is located within Nakuru County in Rift Valley region of Kenya. Lake Nakuru is a shallow alkaline-saline (soda) lake with a surface area of approximately 40-60 km² and the catchment covering 1,800 km². The lake basin uses include; biodiversity conservation, tourism, urban development, rural human settlements, water supply, geothermal prospects, agriculture and livestock, prehistoric sites, waste water treatment and waste assimilation, education centres, learning institutions, research stations, transport networks, and small - scale mining. The lake now faces various challenges, ranging from climate change, land use/ land cover changes, deforestation & degradation of forested areas, environmental degradation, pollution, loss of biodiversity, urbanization, water shortage, flooding, landslides, poor crop yields and damaged infrastructure, loss of tourism revenue, poverty. To address the above issues, Integrated Lake Basin Management (ILBM) and its platform process was formally launched in Nakuru in December 2011. The first ILBM activity was the preparation of the Lake Nakuru Brief which described the current state of Lake Basin Management. We conducted analysis of issues, needs, and challenges regarding six Governance Pillars using the Issue-Challenge- Six pillar matrix, followed by adoption of integrated ways and means for meeting the challenges and implementing the agreed actions.

ILBM has evolved as an important approach for achieving sustainable management of Lake Nakuru through gradual, continuous and holistic improvement of basin governance, including sustained efforts for integration of institutional responsibilities, policy directions, stakeholder participation, scientific and traditional knowledge, technological possibilities and funding prospects. We are seeking to integrate ILBM into the Integrated Water Resource Management (IWRM) approaches, enhance a cooperative framework among the participants by sharing information and knowledge and planning to develop a National Lake Basin Management Strategy that echoes the ILBM achievements and challenges.

Keywords: Biodiversity, Governance, Lake Basin, Landuses, Integrated Management

INTRODUCTION

Lake Nakuru (**Figure 1**) location 360 05' E, 000 24' S; and at 1860m asl. (Lake Nakuru Ecosystem Management Plan, 2002-2012). The lake with an area of 44 km² is part of a 188-km² National Park that is located close to a rapidly growing urban center, Nakuru City. The catchment is a unique ecosystem containing a variety of habitats that include an alkaline lake which is home to thousands of flamingos previously referred to as "the greatest ornithological spectacle on earth", the largest Euphorbia forest stand in East Africa, a wildlife rich savannah and highland moist forests. The vegetation comprises of grasslands and scrublands at the lower parts of the basin with acacia bush land along the lakeshore and flood plains and riverine vegetation along the river courses. Lake Nakuru alone forms 0.008% of Kenya's land area, while the lake together with its catchment composes 0.316% of Kenya's surface area. Lake Nakuru is a discrete ecosystem and there is no ecosystem fragmentation. Lake Nakuru National Park is an important habitat for about 450 birds and 50 mammalian species, and is a closed ecosystem. It is also the first wetland to be declared a Ramsar Site in the country (listed sites or wetlands of international importance for the management of migratory waterfowls) and a popular tourist attraction point, particularly so because of the presence of the world-famous flamingos. In 2005, KWS branded Lake Nakuru as the Bird Watchers Paradise. In 2009, Lake Nakuru was declared an Important Bird Area (IBA). In 2011, the park was designated as a UNESCO World Heritage Site.

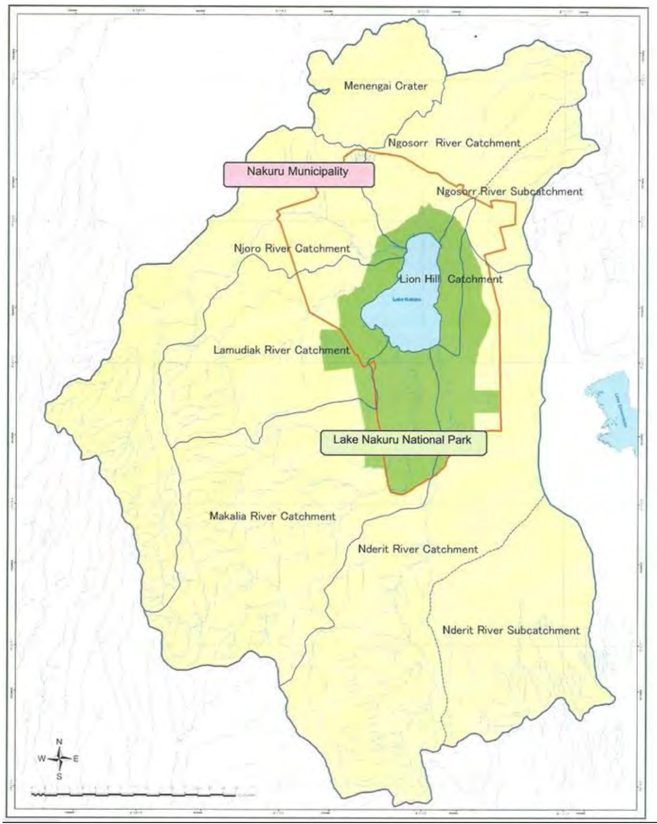

Figure 1. Map of Lake Nakuru catchment basin

The saline-alkaline Rift Valley lake has mean pH of 10.5, high conductivity, as well as other climatic, physicochemical, and biological features, which permit only a small variety of life forms to survive (Vareschi, 1982). The main primary producer in the saline-alkaline lakes is a species of cyanobacterium *Arthrospira fusiformis* (formerly known as *Spirulina platensis*), which forms the major food base for the filter-feeding lesser flamingo and tilapia fish. The lesser flamingo (*Phoenicopterus minor*), and the tilapia fish (*Sarotherodon alcalicus grahami*), are both filter-feeders and share the same food base formed by *A. fusiformis*. The lesser flamingo is the only known waterfowl that feeds almost entirely on *Arthrospira fusiformis*. The flamingo species migrate from one saline-alkaline lake to another within and beyond the country at will. There is a strong indication that one of the major factors attributable to the inter-lake movements is algal density and other physicochemical factors in the water (Vareschi, 1978). The breeding and fledgling site in the region, however, is Lake Natron in Tanzania (Brown, 1959). There is a possibility that these birds could be migrating as far north as Ethiopia and Southern Africa. There has been no confirmation so far as to the exact migratory area or range in the region. The tilapia fish was introduced into Lake Nakuru during the fifties and sixties, from Lake Magadi, for the purpose of controlling the mosquito menace (Brown, 1959). The fish in Lake Nakuru was reported to have increased to an estimated biomass of up to 400 tons dry weight in the seventies (Vareschi, 1979). One impact of tilapia introduction was an increase in the local biodiversity associated with a new population of a number of fish-eating birds. In the 1970s, the major consumer of the primary producer (*Arthrospira fusiformis*) was the lesser flamingo (72 +/- 6.5 gm /bird/day), followed by the tilapia fish, copepods, and rotifers (Vareschi, 1978). Algal blooms have been known to produce lethal toxins, and consequent die-offs in some aquatic and terrestrial vertebrates (Beasley et al, 1991). A comparison of watersheds surrounding the Rift Valley lakes in Kenya would indicate that levels of environmental pollution with pesticides and heavy metals as well as eutrophication is higher in the Lake Nakuru catchment basin. In the recent past, Lake Nakuru has been flooded, a factor that has significant impact on the lake's ecology. However, within the catchment, land subdivision has occurred for agricultural uses hence causing land fragmentations with severe ecological consequences i.e. extremes of flooding and dry-outs (Raini 2009, Koyo, 2000; Lake Nakuru Ecosystem Management Plan, 2002-2012; Githaiga, 1997). This is one of the factors contributing to the observed frequent and unexpected outmigration of the lesser flamingos to other areas. The lesser flamingo population in the region migrates from one saline-alkaline lake to another, depending on the climatic, physical, chemical, and biological changes which determine the availability of their food base, as well as the quality and quantity of fresh water available for drinking. Factors associated with flamingo densities include pH, conductivity, and algal density. *Arthrospira fusiformis* which is the major food base is very sensitive to physicochemical and biological changes.

METHODS

Stakeholders in Nakuru have been championing the Integrated Lake Basin Management (ILBM) as an approach for improving lake basin governance since the official launch in December 2011. Integrated Lake Basin Management is an approach for achieving sustainable management of lakes and reservoirs through continuous and holistic improvement of basin governance, including sustained efforts for integration of institutional responsibilities, policy directions, stakeholder participation, scientific and traditional knowledge, technological possibilities and funding prospects.

Based on comprehensive surveys conducted over the past decade, relevant review questions have been categorized into six thematic pillars. They are (1) Institutions to manage a lake and its basin for the benefit of all basin users; (2) policies to govern people's use of lake resources, and its impacts on lakes; (3) involvement of people; (4), technological possibilities and limitations that often dictate long-term decisions; (5) knowledge and information as origins of informed decisions; and (6) sustainable finances to support implementation of all the above noted activities.

To further the ILBM Platform Process, the International Lake Environment Committee Foundation sponsored two East African Expert Group meetings. The objectives for the expert group meetings are:

(a) To help initiate the ILBM platform process targeted at specific lakes in Kenya (Lakes Nakuru, Naivasha, Baringo, Elementeita and Victoria),

b) To strategize how to integrate ILBM into the integrated water resource management (IWRM) approaches which national or county governments to ensure sustainable management of lake basins in Kenya and its neighboring countries; and

c) To enhance a cooperative framework among the participants by sharing information and knowledge on ILBM.

RESULTS

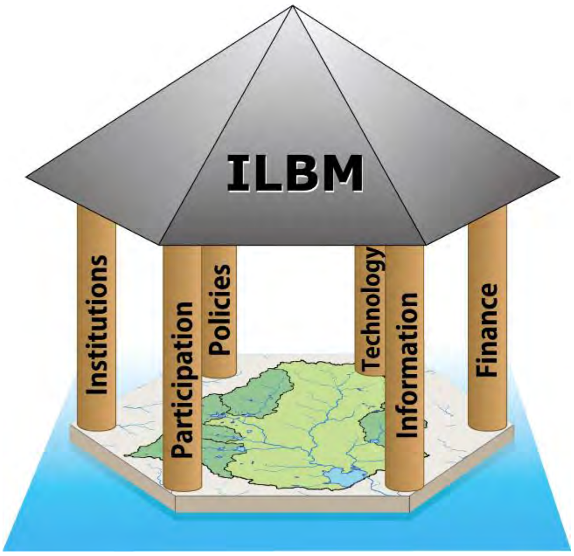

Figure 2. Six Pillars of Lake Basin Governance

A brief analysis of the Six Governance Pillars as they relate to Lake Nakuru Basin is as below:

Institutions

The project has been actively working to build the partnership for Lake Nakuru watershed management. Key institutions include; the County Government of Nakuru, Kenya Wildlife Service, Kenya Forest Service, National Environment Management Authority, Nakuru County Government, Nakuru Water & Sanitation Services Co. Ltd, Water Resources Management Authority, Ministry of Agriculture, Livestock & Fisheries, Rift Valley Water Services Board, Geothermal Development Company Ltd and Rift Valley

Water Services Board. Each organization has its own mandate and working modalities. Therefore, in any project requiring the involvement of more than one organization, it is recommended that a formal agreement be concluded to clarify the roles and responsibilities of each organization in the project before it commences. A series of meetings/seminars were organized, inviting County Government of Nakuru (CGN), NAWASSCO, KWS, KFS, Egerton University and NGOs, to exchange information as well as to facilitate the cooperation among the stakeholders. The ILBM secretariat has been engaging in collaborative efforts with various stakeholders for integrated and participatory environmental management of the catchment, identification of key stakeholders/lead organizations, clarification of responsibility demarcation, maximum utilization of the existing coordination arrangement and continuous awareness raising for better participatory management. Effective environmental education, awareness and advocacy is best achieved with partnerships, practical demos of successful models, formal groups, vocal and respected members of the community.

Policies

The Constitution of Kenya 2010 distributes functions between the National government and the County Governments. Environmental Institutions are regulated by several legal instruments and policies, the main ones being the Environmental Management & Coordination Act 1999, which sets the requirements and procedures for obtaining permits and licenses, and the National Water Policy of 2012 (NWP 2012) that has been developed in response to the mandate, vision and mission of the ministry responsible for water affairs in Kenya. It is informed by the gains made during the past decade of implementation of reforms in the water sector anchored on the National Water Policy of 1999 (NWP 1999) also referred to as Sessional Paper No. 1 on National Policy on Water Resources Management and Development, the Water Act 2002, existing related policy documents, and the globally recognized Integrated Water Resources Management (IWRM) approach. These reforms have culminated into the development of the WSSP 2010 – 2015, which is designed to institutionalize a stakeholder and participatory approach to the management of water affairs in the country.

This policy takes into account requirements of the new Constitution of Kenya 2010 (CoK, 2010); with regard to (1) consideration of water body as public land, and (2) the right to water by all; the Kenya Vision 2030; the Millennium Development Goals (MDGs), SDGs and other national policies and Strategies. In this regard, it will inform the development of the new Water Act 2012 which will replace the Water Act 2002. Challenges include; ineffective enforcement of policies and legislation, weak institutional linkages to undertake participatory & multidisciplinary approaches, lack of political support and conflicts of interest. Projects' functionalities are dependent upon the existing relevant policies as governed by the legal framework and institutions. The policies dictate the application of the project processes'. Projects identity is acquired by registering with relevant authorities. Such a registration provides a mechanism for participation in formulation of resource management plans e.g. forest management plans, EIAs; community exploitation of resources e.g. WRUAs; etc.

Participation of stakeholders

The Constitution places public participation at the core of the devolved system of governance. In the past, the trend in the practice of public communication in government has been one-way, top-down, and focused on instructions from government to citizens. The content has also been about government activities and decisions rather than the exchange of ideas between citizens and government, and among citizens. This resulted in exclusion of citizens' contributions in decision-making processes and influence in the development agenda.

The constitution provides for "participation of the people" as a national value and principle of governance. This pre-supposes that the citizens ought to; by right participate in determining how they are governed. The need for a Nakuru County policy framework on citizen participation is anchored on the Constitution of Kenya 2010 and relevant Acts of parliament particularly the County Government Act 2012. Though the Constitution has clearly provided for the participation of citizens in the affairs of their governments, it does not provide a clear framework for their participation. For this lack of clarity, citizen participation in various governance processes has hitherto been haphazard.

Participation in lake basin management is enhanced through Civil Society Organisations such as FlamingoNet, Community Forest Associations and Water Resource Users Associations. Participatory planning approaches are used as a tool to reconcile key stakeholders' interests through development of mutually enforceable agreements and decision-making that defines their respective roles, rights, responsibilities and authority in Lake Basin management. This requires individual attitude and leadership changes that include; transparent and accountable collaboration between government agencies, CSOs and communities, positive attitudes by everyone involved, working with available resources to avoid stereotype that donor funding is the only way to manage lake basins, involve stakeholders using an integrated approach, and change from control and command to dialogue and adaptive management.

Technological interventions

Technology has mainly been applied to address the challenge of wastewater management. Nakuru City has two conventional sewage treatment plants (STPs) managed by NAWASSCO. The two STPs were rehabilitated and expanded to target design 16,200m^3/day capacity in 1990s through the yen loan-budget for GNWSP & and grant aid by the Japanese government. Recent findings indicate that the Njoro STP receives only 52.8% of the target sewage discharge volume while the Town STP receives only 42.2%. Tertiary treatment at the Town STP is not effective; there is inadequate maintenance of grassplots and damage of grassplots by wild animals. Primary and secondary stages of sewage treatment at Njoro STP are not effective and Facultative Ponds are functioning anaerobically. While seepage loss at the Town STP insignificant, leakage at Njoro STP approximately 100%. Leaking points are located under concrete culverts and are controlled by fault line plane boundaries.

Knowledge and information

Both scientific and indigenous knowledge and information occupies a core place guiding multi-stakeholder initiatives towards Lake Basin management. If well-coordinated, data and information can create linkages among the stakeholders in addressing issues from various angles and in a complementary way. One hundred publications on Lake Nakuru were reviewed recently as part of literature review study of scientific and technical publications on Lake Nakuru. Substantial information on several disciplines already exists to aid lake management efforts. Indeed, there is knowledge dearth especially on a sustained long-term basis in almost all disciplines but current information gaps need not hinder management efforts, as these gaps do not amount to the ostensible general paucity of information. Especially the results of ILBM-ESSVA (Ecosystem Service Shared Value Assessment) which was conducted at Lake Nakuru last year will be very important in further strengthening the information and Participation pillar. ILBM-ESSVA is an important methodology for the effective functioning of the ILBM platform process. In the methodology, residents evaluate the current status of ecosystem services in their basin, including lakes and rivers, and the effects on their lives. And the results of their evaluation will be intended to reflect in the improvement of the basin governance.

Financing

Funding is critical to sustainable lake basin management. Lake Nakuru basin has three categories of funds; locally generated funds, national funding and external funding. Locally generated revenues consist of payment for user fees, permits and services provided by the lake basin. Lake Nakuru National Park generates about Ksh.2 billion annually from gate entry fees. However, the legal framework requires that all money collected from user fees from the Kenya Wildlife Service and Kenya Forest Service etc. has to go to the national treasury. Local corporate firms occasionally support reforestation of the Mau forest as part of the CSR. Most external funding sources in the past 5 years have closed. Currently, only three small community projects are ongoing funded the government through CDTF, hence the need to secure sustainable local and external funding to undertake ILBM in the Nakuru basin.

The ILBM Secretariat is institutionalized at the Nakuru County Government. Representatives from the following institutions were elected: Chairman-Kenya Wildlife Service, Vice Chairperson-NEMA, Secretary –County Government, Vice Secretary-KFS, and Coordinator-FlamingoNet.

CONCLUSIONS

ILBM is a conceptual framework for assisting Lake Basin managers and stakeholders in achieving sustainable management of lakes and their basins. It takes into account the biophysical features of a lake as well as managerial requirements for Lake Basin systems that are associated with the lentic (standing or static) water properties of lakes as well as the inherent dynamics between humans and nature in the process of development, use and conservation of lake and basin resources. ILBM aims to achieve sustainable management of Lake Nakuru through continuous and holistic improvement of basin governance, including sustained efforts for;(I) sharing knowledge and information broadly among the various lake basin stakeholders; (II) developing the necessary institutional framework; (III) a new policy framework that goes beyond the existing sectoral approach; (IV) wide participation of stakeholders to attain balance in policy development; (V) investigation of the potential technological options; (VI) and possible restructuring of the financing mechanism. Especially the results of ILBM-ESSVA (Ecosystem Service Shared Value Assessment) will be very useful in supporting effective functioning of the ILBM platform process to the future.

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STAKEHOLDER PARTICIPATORY ROLE IN MALAYSIAN ILBM INITIATIVES RESEARCH PERSPECTIVES

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ABSTRACT

This paper explores the status and challenges in adopting the lake basin heartware concept in Malaysian integrated lake basin management initiatives. Realizing the importance of interacting with stakeholders to buy-in their supports, stakeholder consultative approach has been used to develop a national research agenda and a management tool for lake. This work is based on review of the development process of three national studies over the period of 2.5 years to strengthen the research pillars to support the national ILBM initiatives following to the implementation of the strategic plan for sustainable management of lakes in the country. The study confirmed the positive involvement of various stakeholders in developing together the research agenda and national water quality criteria for lakes. A case study on the challenges in strengthening the ILBM process of Chini Lake through stakeholder consultative approach is also discussed.

Keywords: Heartware, Malaysia, Stakeholder participation, Sustainable management.

INTRODUCTION

Integrated lake basin management (ILBM) initiatives in Malaysia has started since 2004 after the completion of a national desk study on the status of lake eutrophication. Similar to the integrated water resources management (IWRM) and integrated river basin management (IRBM) concept, the adoption of ILBM approach requires stakeholders' participatory involvement. Stakeholder participation has also been identified as one of the important pillars of ILBM. Stakeholders were defined by the International Lake Environment Committee as '*individuals or groups who make use of, have an impact on, or are impacted by, decisions regarding the use and management of lake basin resources*' (ILEC 2005). By this definition, stakeholders include all users as well as decision makers and managers of the lake and the basin resources. Lake users can be local communities that lives within the lake basin and depend on the lake resources for living or enjoying the aesthetic and recreational potential. Public at large that have interest on lake for its ecosystem services or also known as communities of interest is also considered as stakeholders by ILEC (2005). Authorities and managers are another important groups of stakeholders as they exert decisions pertaining to management of lake. Stakeholder participation can be perceived as involvement of stakeholders through information sharing or engaging them to partake or contribute over decisions or management related to lake (RSCE - Shiga University and ILEC 2011). Therefore, to support sustainable management of lake basin, National Hydraulic Research Institute of Malaysia (NAHRIM) has embarked in undertaking few national-based research on lakes since 2014 following endorsement by the National Water Resources Council in 2012 as national centre for lake research. Stakeholders have been identified as major component in the implementation of national studies, which include the lake basin heartware elements in the research. According to Harashima (1996), the term "heartware" includes heart, culture, mind and memory. This "heartware" term has been embedded by ILEC in their proposition to strengthen the governance in lake basin management besides the "hardware" and "software" terms. The term "hardware" refers to physical pillars of ILBM namely science and technology while "software" refers to pillars of institutions, policies, finance, information and participation. Sergio (2014) further elaborated that the lake basin heartware as a concept that incorporate Lake Basin beliefs, interests, concerns and positions in the basin management (Sergio A. 2014). It promotes stakeholder collaboration in finding and working to achieve joint solutions towards environmental preservation. Stakeholder participation can be viewed as an enabler to strengthen the ILBM pillars. Few country and researchers have used heartware approaches in promoting catchment management (Mohamad, et al., 2015) however as of this written paper, there is limited data showing the role of stakeholder in ILBM research to support effective response to lake problem specifically in Malaysia. This paper explores the status and challenges in adopting the lake basin heartware concept in three of the Malaysian ILBM initiatives namely development of the (i) Blueprint for lake research and development (ii) National lake water quality standards (iii) Chini Lake management plan. Realizing the importance of interacting with stakeholders to buy-in their supports, stakeholder consultative approach has been used in every study. In general, stakeholders in Malaysia can be categorised into four focus groups namely (i) government departments and regulatory bodies, (ii) universities and research institutes, (iii) local communities and (iv) private sectors and non-government organisations. The aims of the stakeholder consultations is to attain consensus from all types of stakeholders in national or basin management studies.

METHODS

In the first part of this work, the process of the stakeholder engagement in national projects including challenges in adopting the basin heartware was presented. The focus group of stakeholders was identified and their role were described (Table 1). In the second part, the process of the stakeholder engagement including challenges in adopting the basin heartware concept in a localized environment was presented through a case study in one specific lake at the Pekan district levels. In all research, levels of participation were based on one-way presentation, two-way consultation and collaboration.

National Projects

1. Blueprint for lake research and development

Stakeholders for the study on 'Blueprint for lake research and development' involves scientist as well as lake managers. Selection of stakeholders were selected based on their expertise in different disciplines of lake studies. Earlier, seven disciplines were proposed in the action plan by Academy of Sciences Malaysia, NAHRIM and NRE, and the research subject were harmonized by a Research committee on lake. Based on the disciplines, 85 participants of the workshop were grouped into seven research cluster and moderated by expert leaders. The grouped discussed based on specific templates. Collaborative decisions were carried out through three deliberations with the National Research Committee on Lakes.

2. National Lake Water Quality Standards

Stakeholders for the study on 'National Lake Water Quality Standards' were divided into three categories namely (i) regulator, water authority or state authority (ii) researchers and scientists (iii) private sectors including water industry and laboratory service providers. A total of three series of consultations were carried out involving the various stakeholders over the year 2015. Specific meeting was made with two key departments administrating environment and health. A dedicated committee comprising key stakeholders and water quality experts refined the standards and criteria. The findings were presented to stakeholders through various forums and seminars which formed as second round of consultative sessions. Finally, the standard was presented at the Permanent Committee on Lakes for endorsement.

Case study: Chini Lake Management study

This specific study was part of ILBM evolvement process that has been undertaken for Chini Lake. The development of the lake brief for this lake was completed in 2010. Continuing development pressures surrounding the lake basin has led to negative perceptions among communities and deterioration of the environment. An intensive study that includes stakeholder engagement is needed to adopt the basin heartware approach for the lake basin. Stakeholders for this study were divided into two group's namely local communities and technical departments. Local communities involve the native communities (Orang Asli), resort operators, fisherman, miners and FELDA farmers. A total of 12 technical departments in Pekan District were identified. Consultations were carried out separately for the two focus groups. Two series of consultations were carried out for each group; the first is to gain inputs on threats and issues whilst the second targeted to gain feedback on the proposed solution to address the challenges. The study was carried out between June to December 2014.

RESULTS AND DISCUSSIONS

In all studies, information sharing such as presentations and consultation were undertaken with respective stakeholders. Advocacy was also performed to share research findings with various stakeholders. **Table 1** presented the aim, participatory process and challenges in the ILBM initiatives.

Table 1: The aim, participatory processes and challenges in the ILBM initiatives

Study	Stakeholder consultation aim	Focus group	Type of participation	No. of consultation	Challenges	Heart-ware essence
Blueprint	Consensus on • research goals and timelines • Focus disciplines and research program • Focus study areas and projects	i. Government departments ii. Universities researchers iii. Private consultants	1. Consultation 2. Information sharing 3. Collaboration	One Three Three	Participation of researchers constraint by funding availability	Research agenda towards sustainable management of lakes
Standards	Consensus on • Classifications, • Monitoring parameters • Threshold limits	i. Government department ii. Universities/ Researchers iii. Private sector incl. laboratory service providers and water industries	1. Consultation 2. Information sharing 3. Collaboration	Three Four One	• Setting a threshold limit due to unavailability of field data; • Differences in opinion on threshold limits for certain parameters; • Classification of lakes based on intended uses.	Common direction on lake monitoring
Chini Management Plan	Consensus on • Identifying strength, weakness, opportunity and threats • Identifying 'champion' for Chini Lake management • Developing an operational management plan	i. Technical department ii. Universities/ Researchers iii. Communities incl. orang asli, villagers iv. Private sectors i.e. mining companies	1. Consultation 2. Information sharing	Two One	• Some sceptics from native communities	Sustainable management of lake basin

Blueprint for lake research and development
The need to develop blueprint for lake research and development stems from the need to implement Strategy 2 of National Strategy Plan and Strategy 11 of Lake Management Action Plan (LMAP). Strategy 2 of the strategic plan emphasize the need to establish a National Lake Resource Centre to undertake ILBM research and stock-taking lake information (Akademi Sains Malaysia and NAHRIM, 2009) while Strategy 11 of LMAP specify the need to enhance research, development and innovation on lakes (NAHRIM 2016). At present, there is limited research supporting sustainable lake management (NAHRIM 2009, NAHRIM 2014a). Research on lakes were sporadic and based on researches specific interests rather than lake basin focused research that meet stakeholder's need (Sharip et al 2016). The overall stakeholder engagement process is shown in **Figure 1**.

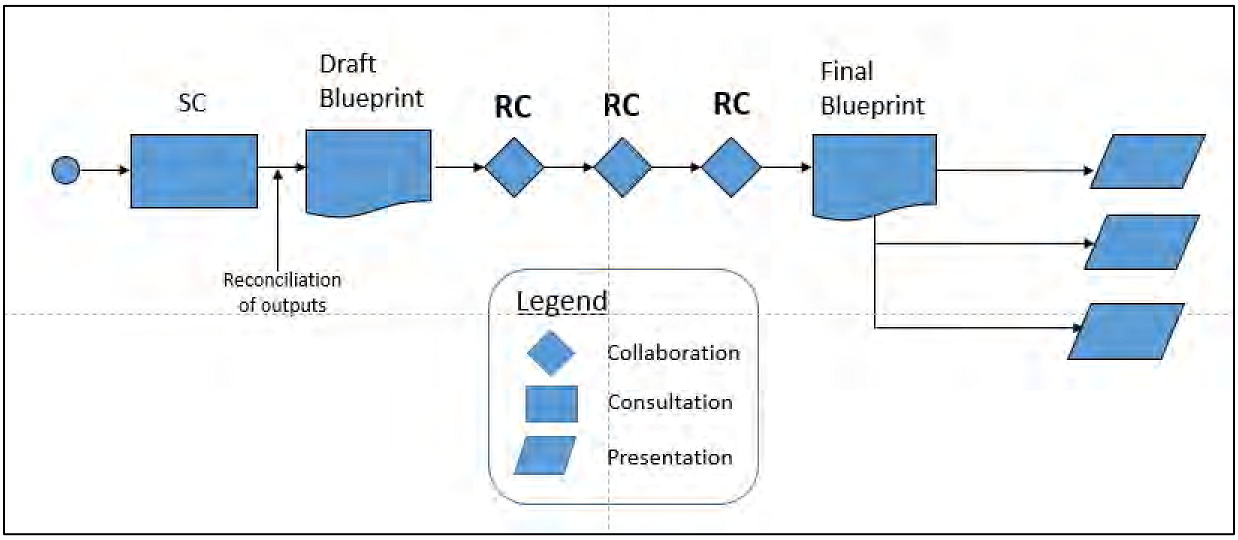

Figure 1. Stakeholder consultative process in the development of blueprint for lake research. SC - stakeholder consultation; RC - research committee

Since the blueprint study was aimed to enhance the research activities towards sustainable lake management, stakeholder consultations were focused to gain agreement between researchers and managers on research goals, research program and focus disciplines and areas. The discussion focus on short, medium and long term objectives, primary thrust and research matrix and kind of studies. The essence of the heartware is research agenda towards sustainable management of lakes. Both focus groups deliberated on the needs of research to support lake management specifically research areas much needed by the lake managers to support ILBM.
The outputs of this study include list of studied areas and projects to be implemented in the coming Malaysia Development Plan (NAHRIM 2014a). The only challenge that affect the study was the constraint on funding availability to encourage participation from various experts and researchers to undertake collaborative research. The study was successfully presented at four seminars organized by NAHRIM and other agencies.
National Lake Water Quality Standards (NLWQS)
The research need for developing a standard on lakes water quality stem around on the limited water quality monitoring data for lakes. These lack of measurable water quality standards may represents a serious threat to the lake's water quality and its ecosystem. Being a national document that could help monitoring the water quality of lakes, the consultation for the standard document was targeted towards lake managers. Many lakes, however, were not monitored in terms of water quality. Lake that are used for water supply were monitored by the water industry to ensure the quality of supply prior to treatment. Parameters measured includes pH, ammonia and turbidity. Measurement by the Ministry of Health were targeted for health purposes. These measurements are not representative of ambient level. Few researchers have measured water quality of lakes. These measurements, which were limited to funding availability, are carried out over a one-year period. Consultations with the stakeholders were required on classifications, monitoring parameters and their threshold limits. In this research, the heartware essence is to achieve common direction on monitoring water quality in lakes. Promoting water quality monitoring is necessary to ensure the understanding of the actual ecosystem state of the lake as well

as to aid in decision making for management and/or rehabilitation. The overall stakeholder engagement process is shown in **Figure 2**.

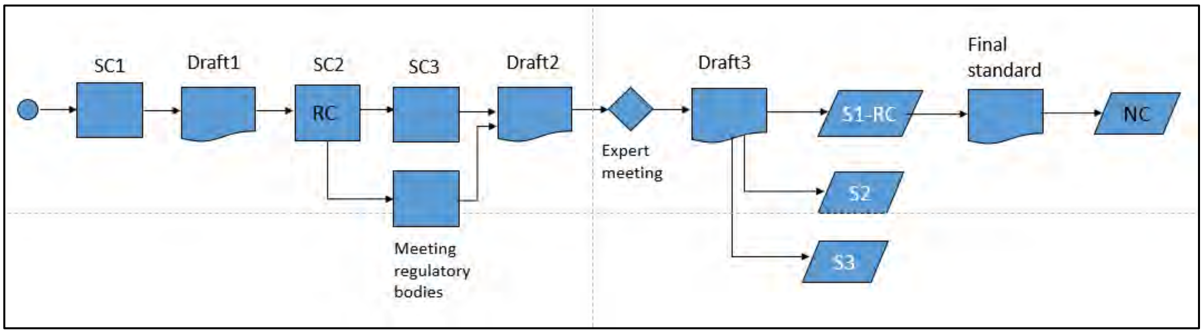

Figure 2: Stakeholder consultative process in the development of NLWQS. SC - stakeholder consultation; S-seminar; numbers indicate number of seminar; RC - research committee; NC – National committee on Lakes

The biggest challenges in this study is to attain consensus on the classification and setting the threshold limits for some parameters due to unavailability of data and differences in opinion between experts based on their past experiences on different water bodies. Among the parameter that were difficult to decide as parameters for classification includes e-coli, faecal coliform and enterococci. There are conflicting findings on the use of these parameters for tropical freshwater system (Sharip and Suratman 2016). The output of the study was a classification that comprises four categories of criteria (NAHRIM 2015). The aim is to promote monitoring of parameters that are of concern for human health (Category A and B) and environment (Category C and D). A total of 17 parameters were identified to determine the classifications. The threshold limits for each category were listed for all the parameters.

Chini Lake Management study

Based on the observations and surveys of past studies, Chini Lake is one of the well-studied lake in the country. Catchment pressures through conversion of forest for agriculture and mining remain a biggest threat due to unavailability of core institution with appropriate enforcement and legislation requirement. Stakeholder consultations using strength, weaknesses, opportunities and threats (SWOT) analysis were aimed to make the stakeholders identified the issues and viewed possible solutions based on strengths and opportunities provided by Chini Lake. Limited communication among various technical departments and universities were identified as some of the weaknesses in Chini management (NAHRIM 2014b). Sectoral management focusing on short term based goal with no single authority responsible for managing the lake basin remain the biggest challenges for Chini Lake (Sharip and Jusoh 2010). The overall stakeholder engagement process is shown in **Figure 3**.

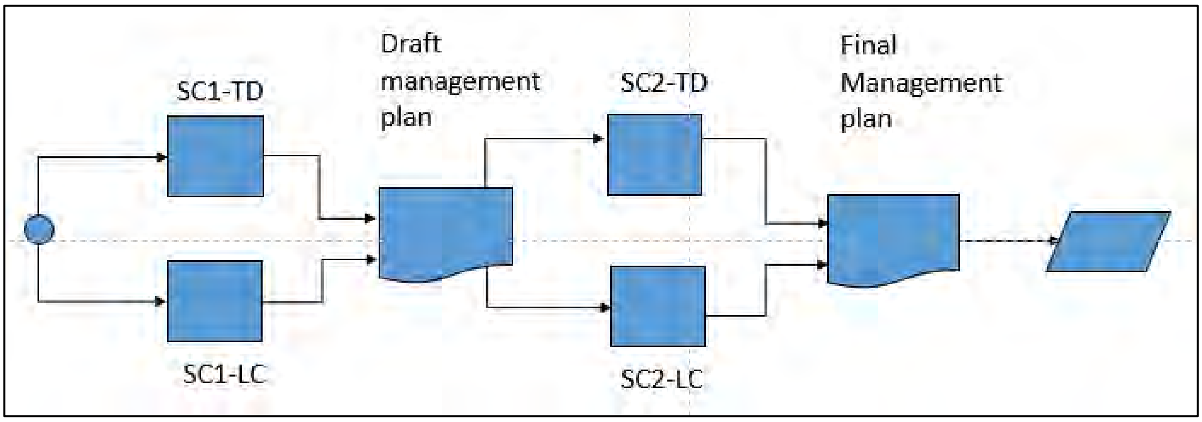

Figure 3. Stakeholder consultative process in the development of Chini Lake Management Plan. SC-TD - stakeholder consultation with technical departments; SC-LC - stakeholder consultation with local communities.

The same group of people were involved in the consultative sessions. The first session was aimed to inform the stakeholder about the study whilst the second session was to get an agreement on the proposed findings of the research (**Figure 4**). Sceptics by the local communities on the study were observed during the first consultation but eventually the communities supported the forum through discussion in second consultation. Based on the consultation, the heartware essence is sustainable management of Chini lake basin. The output of the study includes recommendation for the setting up of Centre of Excellence for Chini Lake to be led by Pejabat Daerah and Tanah of Pekan (District office) (NAHRIM 2014b). The strengthening of the function of the Pejabat Daerah and Tanah of Pekan is the best approach to ensure the department to act as the manager for Chini Lake Basin.

Figure 4. Stakeholder consultative process in the development of (a) Blueprint for lake research and development (b) National lake water quality standards (c) Chini Lake management plan

CONCLUSIONS

Based on our research, positive involvement of various stakeholders was observed in developing together the research agenda and national water quality criteria for lakes. Similarly, we managed to get full participation from the stakeholders in developing the Chini Lake operational plan. The stakeholder provided important feedback to improve in the findings of the studies.

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Topic 4. Multiple water use purposes

MOBILE DRINKING WATER TREATMENT PLANT (TYPE IG5M30) FOR DISASTER EMERGENCY RESPONSE

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ABSTRACT

Emergency conditions due to floods, landslides and droughts cause shortages of clean water and drinking water to meet daily needs. These conditions require immediate solution to provide clean water and drinking water to the people in the disaster area. This research activity aims to develop mobile drinking water treatment system beeing capable for processing of marginal raw water into drinking water in the affected areas, in order to help people in the region to access water. Development of systems URC-IPAMB Type IG5M30 is an important step to address the needs of water services in the disaster areas, especially floods. URC-IPAMB Type IG5M30 has been completed and the results of operating system and installation testing were satisfied. The quality of water produced has met the standard. Some adjustments and system improvements URC-IPAMB Type IG5M30 still needed in order to optimalize the installation function.

Keywords: mobile plant, operating systems, water quality, clean water, RO system

INTRODUCTION

Clean water is a basic need for human life, where the source can be obtained either from surface water or groundwater. Utilization of water to meet the needs of clean water becomes an important factor for the development and improvement of people's welfare. Water use is increasing in line with population growth and standard of life. In general, the source of water needs is coming from surface water, except several marginal areas such as flooding, or polluted area (Sutapa (2014), Sutapa 2015).

Emergency situations such as floods, landslides and droughts make basic needs (foods, drinking water and other logictics) are difficult to obtain. This condition requires a rapid solution for the people in the disaster area. Surface water conditions after disaster (floods, tsunamis, landslides) generally has a characteristic: brown to blackish colour, muddy and smelly. Such raw water is considered as marginal water, basically not eligible to serve for drinking water or used directly to meet their daily needs. Development of mobile drinking water treatment system will help people in the disaster region in obtaining clean water and drinking water required.

Water treatment is an important solution to overcome the shortage of drinking water. The processes of water treatment are the removal of contaminants from untreated water to produce pure water for human utilization (Faisal Siddiqui, M. et al.(2015), Tran, N.H. et al. (2015)). Three main substances that are withdrawn during the procedure of drinking water treatment are (Tran, N.H et al. (2015), Särkkä, H., et al (2015)): suspended solids, dissolved matter and biological matter. Several types of water contaminant are mineral pollutants, organic pollutants, biological pollutants, suspended solids, dissolved matter or biological organisms (Liu, X.et al., (2013), Särkkä, H., et al (2015)).

Other strategies to deliver water supply different form wellsprings are progressively investigated and used especially in waterfront areas. One of them is desalination of brackish or saline water (Sadhwani, J.J et al (2005), Miri, R. and Chouikhi, A. (2005), Van Dam, R. and Chapman, J. (2002)). Thermal, membrane reverse osmosis (RO) and ion exchange methods are the three main techniques for treatment for this kind of water (Lattemann, S. and Höpner, T. (2008), Trousdale, S. and Henderson, E. (2009) , Mitchell, E.J.(2002), Chapman, P.M. (2000)). The system of reverse osmosis has turned out to be the most reduced cost strategy concurring to numerous studies (Falkenberg, L.J. and Styan, C.A. (2015)). Several other advantages of RO system are: simple operation, reduced sizes, low ecological effects. Water treatment using reverse osmosis system may withdraw inorganic particles as well as natural matters, infections and microorganisms (Tularam, G.A. and Ilahee, M. (2007), Falkenberg, L.J. and Styan, C.A. (2015)).

Osmosis is a natural phenomenon which can be defined as the movement of pure water through a semi permeable membrane from a low to a high concentration solution. The membrane is permeable to water and some ions but rejects almost all ions and dissolved solids. This process (movement of water) occurs until the osmotic equilibrium is reached, or until the chemical potential is equal on both sides of the

membrane (http://lewabrane.com/). Reverse osmosis is a membrane separation process for removing solvent from a solution. When a semi permeable membrane separates a dilute solution from a concentrated solution, solvent crosses from the dilute to the concentrated side of the membrane in an attempt to equalize concentrations. The flow of solvent can be prevented by applying an opposing hydrostatic pressure to the concentrated solution. (https://www.aquatechnology.net /reverseosmosistheory.html). In order to use reverse osmosis as a water purification process, the feed water is pressurized on one side of a semi permeable membrane. The pressure must be high enough to exceed the osmotic pressure to cause reverse osmotic flow of water. If the membrane is highly permeable to water, but essentially impermeable to dissolved solutes, pure water crosses the membrane and is known as product water and the concentration of dissolved impurities increases in the remaining feed water.
The purpose of this research activity is to develop a mobile drinking water treatment plant in order to cover clean water and drinking water need in disaster areas as emergency response to overcome the water crisis. Reverse osmosis system is the main component in the moblie plant.

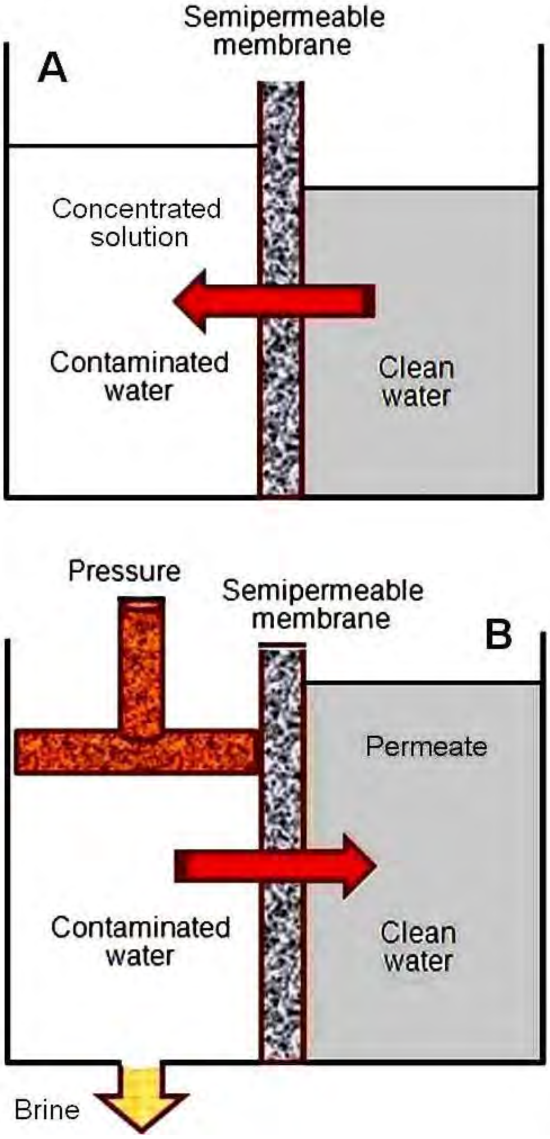

Figure 1. Basic mechanisms of osmosis (A) and reverse osmosis (B) (Sunil J. Wimalawansa (2013)

METHODS

System of URC-IPAMB Type IG5M30

The planning design for the Rapid Response Unit - Installation of Mobile Drinking Water Treatment (URC-IPAMB) Type IG5M30 with Brackish Water Reverse Osmosis system (BWRO) is designed to limit the produced water conditions as follows (**Table 1**).

Tabel 1. Design of water quailty treated by URC-IPAMB Type IG5M30

No	Parameter	Standard
1	Colour	No colour
2	pH	6.5 – 8.5
3	Turbidity	< 5 NTU
4	Smell	No smelly
5	Taste	No taste
6	Fe	0
7	Fat and oil	0
8	Organic bacterial	0
9	Chlorine and other toxic	0
10	Clean Water Flow	60 L/mn
11	Drinking water flow	20 – 30 L/mn
12	Total Dissolved Solid	< 80 mg/l

Five (5) main componens of the mobile plant for drinking water treatment are : pretreatment, BBRO system, disinfection system, distribution system and electrical system.

a. Pretreatment. The main components of the pretreatment process consist of raw water pumps, sand filter, activated carbon filter and clean water tank as shown in Table 2.
b. BWRO system. Brackish Water Reverse Osmosis (BWRO) System is composed by several components including: feeder pump, filter, booster pump, membranes, control panel, product tank and pump.
c. Disinfection system. Disinfection system used in URC-IPAMB Type IG5M30 consists of ozone sterilizer and UV sterilizer.
d. Water Distribution System . The main components of water distribution system in URC-IPAMB Type IG5M30 is Posh tretment Cartridge and Charging Filler.
e. Electricity system. Electrical systems of the URC-IPAMB Type IG5M30 consists of: Control Panel Electric System, 3 Phase Generator Set and 1 Phase Generator Set.

Technical devices URC-IPAMB Type IG5M30 compiled and assembled in mobile containers in the form of a trailer with two (2) wheels. The trailer has dimensions of 300 cm long, 180 cm wide and 150 cm high. Distance basis trailer to the ground is made high enough (60 cm), which allows the unit to reach a flood disaster area. Figures 1 and 2 show a schematic URC-IPAMB Type IG5M30 with the container. **Figure 3** shows the components of URC-IPAMB Type IG5M30.

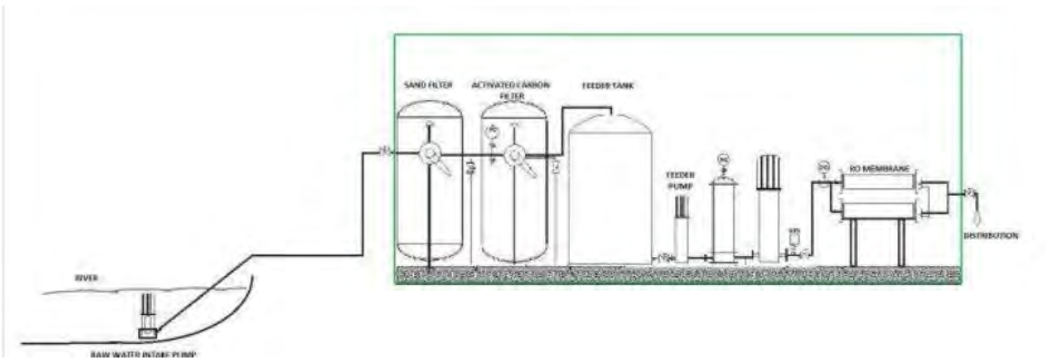

Figure 2. Scheme of operation URC-IPAMB Type IG5M30

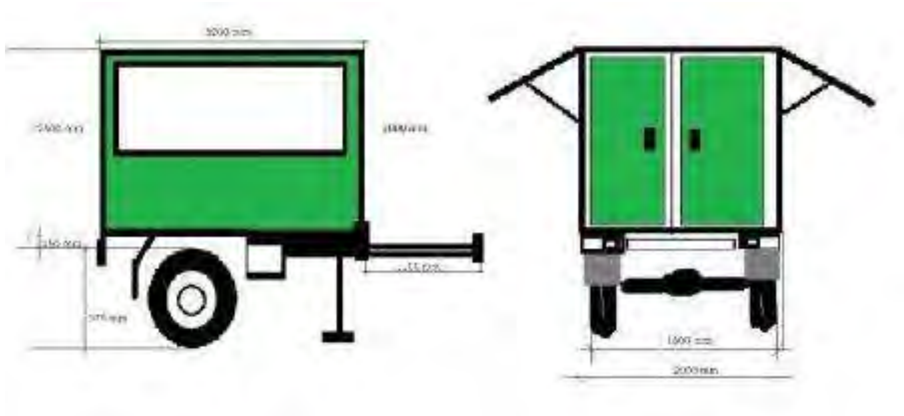

Figure 3. Schematic container of URC-IPAMB Type IG5M30

Figure 4. Mobile Plant System of URC-IPAMB Type IG5M30

Location of mobile plant testing

The testing location of mobile plant was arround Cibinong Science Centre area in Bogor District. Water samples analysis were conducted in the Laboratory of Research Centre for Limnology LIPI Cibinong Bogor, West Java.

Sampling and analysis of samples

As describe by Sutapa (2015), the method for water samples analysis is based on APHA 2005 and consists of several stages:

- Direct observation on some potential area to select the location that meets the standards to be processed as a raw water source.
- Physical parameters include; color, taste, conductivity or electrical conductivity to TDS meter, turbidity using turbidimetry, temperature, and salinity using Water Quality Checker (WQC) in situ measurement.
- Chemical parameters include mainly the content of non-metallic. Analysis of non-metal content; pH, sulfate content, total organic matter (TOM), ammonia, nitrate, nitrite, hardness, cyanide, fluoride, total N, Phosphate, Total P, and phenol with titrtimetri method.
- Biological parameter that is based on the presence or absence of pollution indicator bacteria E. coli and Coliform. 0:45 nm porous cellulose membranes placed on a sterile filter tools by using tweezers. Filtered water samples with a volume of 100 ml and 50 ml.

RESULTS AND DISCUSSIONS

Physical Parameter Analysis

Table 2 summarizes the result of physical parameter analysis. Water color intensity of raw water has a range of 20 - 25 TCU (Total Color Unit). This color intensity decrease up to 4 – 5 TCU and meet the standard Regulation of Health Minister RI No. 492 of 2010, setting the standard normal threshold of clean water a maximum of 15 TCU. Slightly tasty raw water becomes tasteless after treatment as shown in the Table 4. Some other physical parameters showed same trend in decreasing: turbidity form 15 – 20 NTU to 0.0 – 1.0 NTU, TDS form 60 – 65 mg/l to 20 – 22 mg/l and temperature in the range of 30 – 32 C. In general, all physical paramaters analysis of water quality after treatment meet the standard.

Tabel 2 Physical parameter analysis of water quality

Physical Parameter	Raw Water	Treated Water	Standard (Minister of Health Regulation No. 492/2010)
Total Dissolved Solid (ppm)	60 – 65	20 – 22	500
Turbidity (NTU)	15 – 20	0.0 – 1.0	5
Color (TCU)	20 – 25	4 – 5	15
Taste	Slightly Tasty	No taste	No taste
Temperature (^oC)	30 – 31	31 – 32	Air temp. +/- 3

Chemical Parameters Analysis

The results of chemical analysis of water before and after treatment are shown in Table 3. The normal range of several chemical parameters is summarized. The treatment process tend to increase the quality of water and meet the standard. The pH value of raw water which is in the range of 7.5 – 7.8, slightly decreases to 6.9 – 7.1. This value is in the water quality standards of 6.5-8.5. Sulfate concentration of raw water is in the range of 15.50 - 17.54 mg / l and becomes 8.20 - 10.99 mg/l after treatment. The concentration of Total organic matter (TOM) is between 6.36 - 8.50 mg / l and and decreases to 2.40 - 3.97 mg/l. Some other parameters are below the standard after treatment : of ammonia 0.75 - 1.00 mg/l (from 2.50 - 3.79 mg / l), nitrate 0.06 – 0.10 mg / l (from 0.12 – 1.5 mg/l), and nitrite <0.00001 – 0.001 mg / l (from 0.01 – 0.15 mg/l), Total N 1.90 - 2.17 mg/l (from 3.30 - 4.46 mg/l) and Total P 0.09 – 0.10 mg/l (from 0.07 – 0.26 mg/l). The result of chemical parameters analysis show that mobile plant increases water quality of raw water and meet the standard for drinking water.

Tabel 3. Result of chemical analysis

Chemical Parameter	Raw Water	Treated Water	Standard (Minister of Health Regulation No. 492/2010)
pH	7.5 - 7.8	6.9 – 7.1	6.5 – 8.5
Nitrate(mg/L)	0.12 – 1.5	0.06 – 0.10	50
Nitrite(mg/L)	0.01 – 0.15	<0.00001 – 0.001	3
Ammonium (mg/L)	2.50 - 3.79	0.75 - 1.00	1.5
Total N (mg/L)	3.30 - 4.46	1.90 - 2.17	na
Total P (mg/L)	0.07 – 0.26	0.09 – 0.10	na
Sulphate (mg/L)	15.50 - 17.54	8.20 - 10.99	250
Total Organic Matter (mg/L)	6.36 – 8.50	2.40 - 3.97	10

Biological Parameters Analysis

Analysis of the biological quality of drinking water requirements follows the rules by using the parameters of E. coli and total coliform bacteria (Sutapa 2015). Coliform is a group of bacteria used as an indicator of pollution, waste and bad conditions of water, food, milk and dairy products. Table 4 shows the result of bacterial analysis. Raw water contents 75 – 100 70 Col / 100 ml of E. Coli and 200

- 250 Col / 100 ml of Coliform. These results indicate that the water does not meet the standard in accordance with Regulation of Minister of Health No. 492 in 2010. The quality of treated water by mobile plant increases and does not content either *E. Coli* or Coliform.

Tabel 4 Result of biological parameter analysis

Biological Parameter	Raw Water	Treated Water	Standard (Minister of Health Regulation No. 492/2010)
E-coli (cfu/ml)	70 – 100	0	0
Total Coliform (cfu/ml)	200 – 250	0	0

CONCLUSION

This study shows that mobile device URC-IPAMB installation Type IG5M30 can increase the quality raw water up to drinking water quality in accordance to Minister of Health Regulation No. 492/2010. The results of laboratory analysis related to physical, chemical and biological parameters are inline with the regulation standard. The development of mobile drinking water treatment system that is capable for treating of marginal raw water into drinking water is very promoting. This mobile plant can be alternatif in the affected area to help people in the region in obtaining clean water and drinking water required. However, some adjustments and system improvements URC-IPAMB Type IG5M30 are still needed in order to optimalize the installation function. Beside this, water quality test should be conducted periodically to ensure that the installation is functioning properly.

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Topic 5. Water education, ecotourism, culture

PRACTICE OF WATER ENVIRONMENTAL EDUCATION IN KASUMIGAURA WATERSHED BY TSUCHIURA CITY

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ABSTRACT

Lake Kasumigaura is a symbol of Tsuchiura city, and supports the lives of its 140,000 citizens. The city is situated along the western shore of the lake with inflowing 56 rivers and the lakesides are rich in diversity. However, the lake has been giving citizens negative impression including offensive odors caused by putrid aoko (blue green algae) and debris in and around the lake. Therefore, the citizen has been concerned about water environment as familiar issue for a long time. As regards to the eight rivers in Tsuchiura city, which started water quality observation in 1970s, these rivers water quality tend to improve in recent years. The city has been carrying out practical water environmental education for purposes of creating awareness of familiar water environment and experience at first hand even for the citizens inhabiting off-site waterfront. The three major education themes are to Know, to Touch and to Communicate through a real experience. The paper shows some Tsuchiura city's programs that provide elementary school students opportunities for learning good place and water environment including 'Sakura-river Eco Adventure tour'.

Keywords: Lake Kasumigaura, Water environmental education

INTRODUCTION

Lake Kasumigaura (the general term for Lake Nishiura, Lake Kitaura and Hitachi Tone River), is in Ibaraki prefecture and located north-east of Tokyo. The lakes watershed stretches over three prefectures "Ibaraki", "Chiba", and "Tochigi. Most of watershed is vast and it extend over southern Ibaraki prefecture. The region of watershed is 2,157km^2 that contains population of over 970,000 people and 24 municipalities. Tsuchiura city faces the west side of Lake Kasumigaura (Lake Nishiura). (**Table 1, Figure1**) Therefore the city is known as "Waterfront" city (**Photo1**).

Table1. Outline of Kasumigaura watershed and Tsuchiura city

Class / Item	Kasumigaura Watershed	Tsuchiura City
Size of Region	2,157km^2	123km^2
Approximate Population	970,000 (Ibaraki, Chiba, Tochigi)	140,000
Municipality	24 (City, Town, Village)	1/24
Inflowing Rivers	56	8

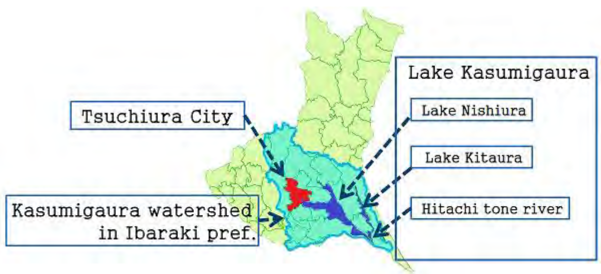

Figure 1. Map of Kasumigaura watershed in Ibaraki Prefecture

Photo1. "Waterfront Tsuchiura"

However, the lake has been giving citizens negative impression including offensive odors caused by putrid aoko (blue green algae) and debris in and around the lake. Therefore, the citizen has been concerned about water environment as familiar issue for a long time.

In 1991, Tsuchiura city was designated as Priority Area of Domestic Wastewater Measure, based on Water Pollution Control Law. That means the pollution and eutrophication of Lake Kasumigaura caused by domestic wastewater has been serious and Tsuchiura city has needing to tackle on this problem (**Figure 2**). It was the first case in Ibaraki prefecture. Concomitantly, the city has been making promotion plans for domestic wastewater measure since 1993 (**Figure 3**).

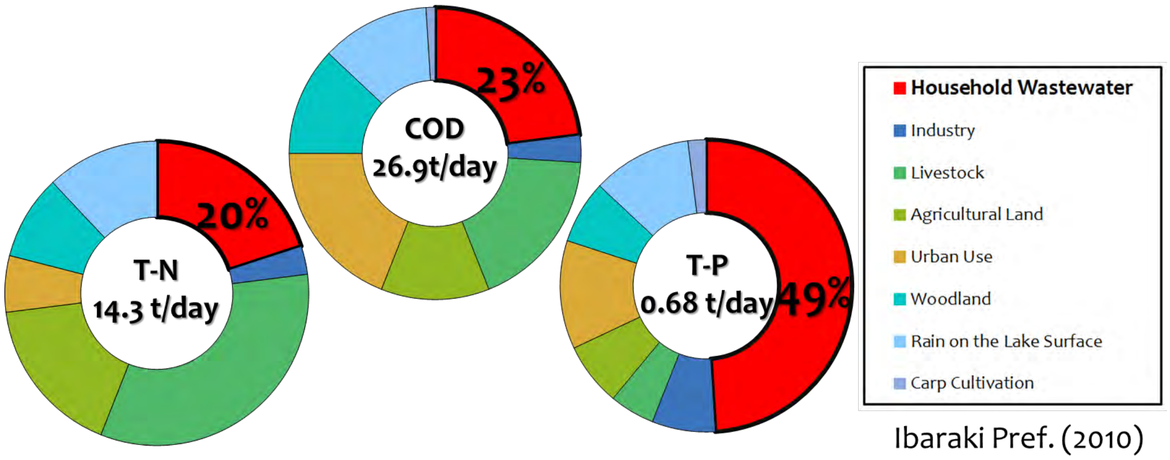

Figure 2. Pollutant load of Lake Kasumigaura

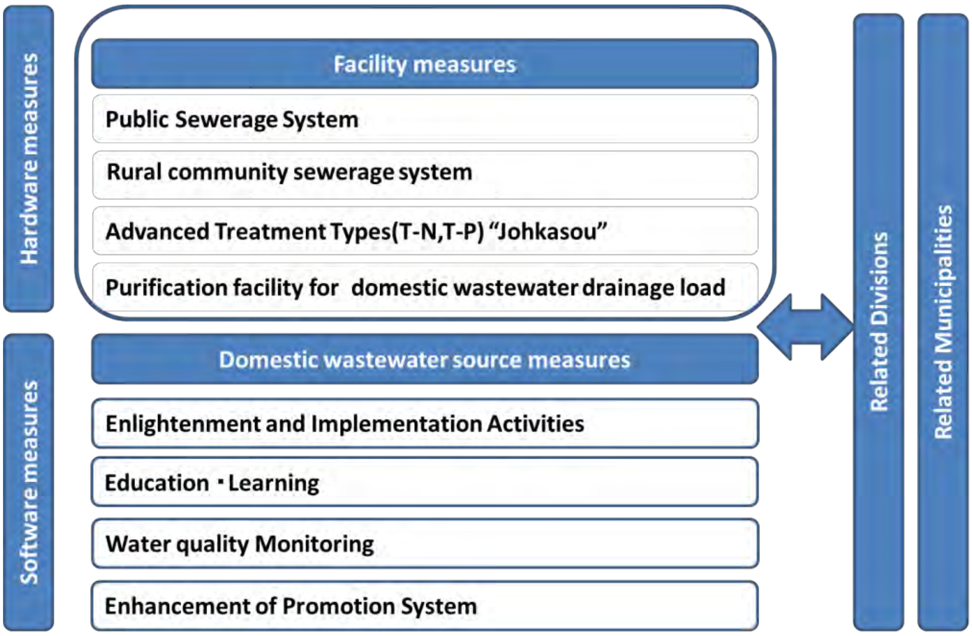

Figure 3. Outline of promotion plan for domestic wastewater measure of second late term by Tsuchiura city, since 2014

As regards to the rivers in Tsuchiura city, these water quality (BOD) tend to improve (**Figure 4**) through various counterplan: e.g. promotion plan for domestic wastewater measure by Tsuchiura city.

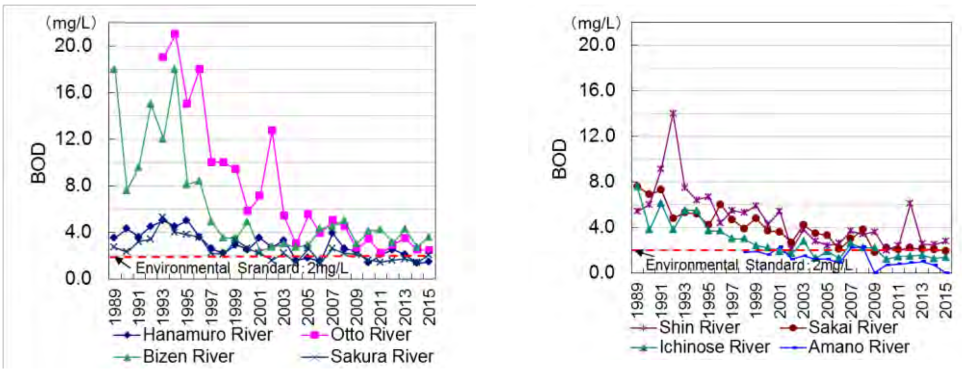

Figure 4. Water quality (BOD) of eight rivers in Tsuchiura city (1989-2015)

Table 2. Diffusion ratio of sewage treatment population in Tsuchiura city (2011-2015)

Year	Population	PSS		RCSS		Johkasou		Total diffusion ratio (%)
		Sewerage treatment population	Diffusion ratio (%)	Sewerage treatment population	Diffusion ratio (%)	Sewerage treatment population	Diffusion ratio (%)	
2011	142,993	126,405	88.4	4,806	3.4	8,749	6.1	97.9
2012	145,843	126,712	86.9	4,311	3.0	11,277	7.7	97.6
2013	145,125	126,808	87.4	4,291	3.0	11,333	7.8	98.1
2014	144,532	126,855	87.8	4,211	2.9	11,377	7.9	98.6
2015	143,726	126,263	87.8	4,107	2.9	11,433	8.0	98.7

PSS: Public sewerage system
RCSS: Rural community sewerage system
Johkasou: Combined domestic wastewater treatment “Johkasou”

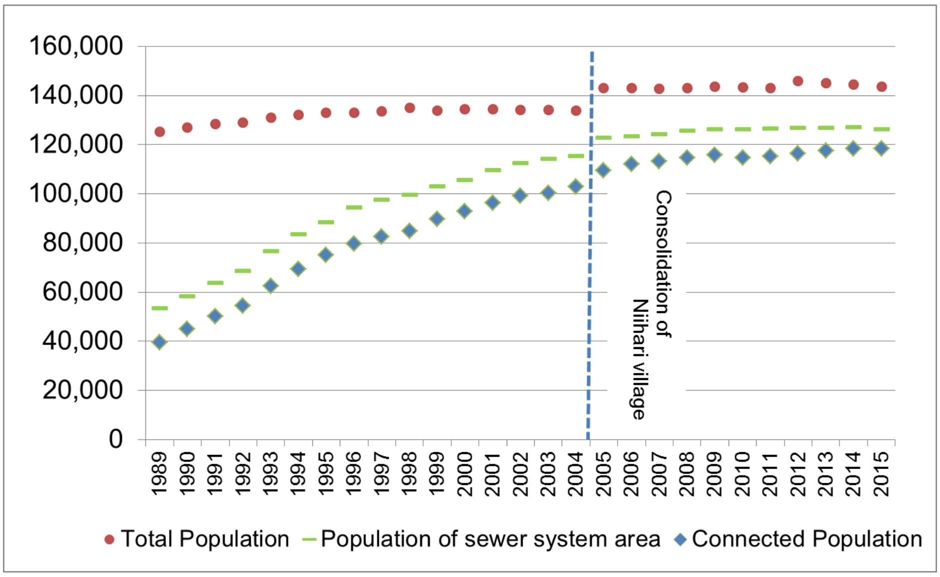

Figure 5. Connected population of public sewerage system in Tsuchiura city

Table 3. Rural community wastewater treatment facilities in Tsuchiura city
SBRASP: Sequencing Batch Reactor Activated Sludge Process

Region	Start of Treatment	Treatment System	Planed Population	Average sewerage Volume (m^3/day)	Connection Ratio (2015) (%)
Takaoka	1989	SBRASP +SB +FS +RSF	940	254	92
Seibu	1992	SBRASP +SB +FS +RSF	780	211	90
Sawabe	1993	SBRASP +SB +FS +RSF	850	230	85
Hokubu	1995	SBRASP +SB +FS +RSF	950	257	88
Tobu	1999	SBRASP(ATT) +PRP	1,770	478	77
Nishine	2009	SBRASP(ATT) +PRP	690	186	50

SB: Submerged Biofilter
FS: Flocculation and sedimentation
RSF: Rapid Sand Filter
ATT: Advanced Treatment Type
PRP: Phosphorus removal process using iron ions

Table 4. Financial assistance for installation of advanced treatment types “Johkasou” in Tsuchiura city

Type	2011	2012	2013	2014	2015	Total (2003-2015)	
Nitrogen removal types	21	18	21	21	23	279	Cases
Nitrogen and Phosphorus removal types	0	0	0	0	0	4	Cases

PRACTICE OF WATER ENVIRONMENTAL EDUCATION
As a software measure, the city has been carrying out water environmental education programs (**Table 5**). Because, to solve problems, it is essential to improve residents’ consciousness on water purification for citizen. Citizens be given the opportunity to think about the familiar water environment themselves by various programs (**Table 5**).

Table 5. Water environmental education programs by Tsuchiura city (Data of Tsuchiura city,2016)

Program	Target	Style	Number of participants
"Kasumigaura doctor" training course	9-10 years old	Class	500 (6 schools)
Expert of Kasumigaura	8-12 years old	Lecture and Experiment	20 (1 time)
Survey on the rivers flowing into Kasumigaura	8-12 years old	Experience	15 (2 times)
Exchange Meeting about water for Elementary students	9-12 years old	Lecture and Experiment	30 (1 time)
Sakura River Eco Adventure tour	6-12 years old and parent	Experience	80 (3 times)
Junior high school students water environment workshop	12-15 years old	Experience	30 (1 time)
On the lake seminar for the general public	General public	Experience	60 (2 times)

Table 6. Number of students and class for elementary school in Tsuchiura city (Data of Tsuchiura city,2016)

Grade (Age)	1 (6-7)	2 (7-8)	3 (8-9)	4 (9-10)	5 (10-11)	6 (11-12)	Total/ 19 schools
Number of students	1,056	1,146	1,097	1,209	1,148	1,183	6,839
Ordinary class	41	43	38	42	38	42	244

Table 7. Number of students and class for junior high school in Tsuchiura city (Data of Tsuchiura city,2016)

Grade (Age)	1 (12-13)	2 (13-14)	3 (14-15)	Total/ 8 schools
Number of students	1149	1171	1152	3472
Ordinary class	37	32	33	102

Photo 2. "Kasumigaura doctor" training course

Photo 3. Expert of Kasumigaura

Photo 4. Survey on the rivers flowing into Kasumigaura

Photo 5. Exchange Meeting on water for Elementary students

Photo 6. Junior high school students water environment workshop

Especially, it is very important for children is to Know, to Touch and to Communicate through their real experience. In the next section shows Tsuchiura city's new programs since 2015 that has been provided elementary school students opportunity for learning good place and water environment, that is named as 'Sakura River Eco Adventure tour'.

SAKURA RIVER ECO ADVENTURE TOUR

The concept of this program is to learn comprehensively about the water environment around us through real experience. The program has four steps, i.e. which has story that series of experiences from upstream to downstream (**Figure 6**)

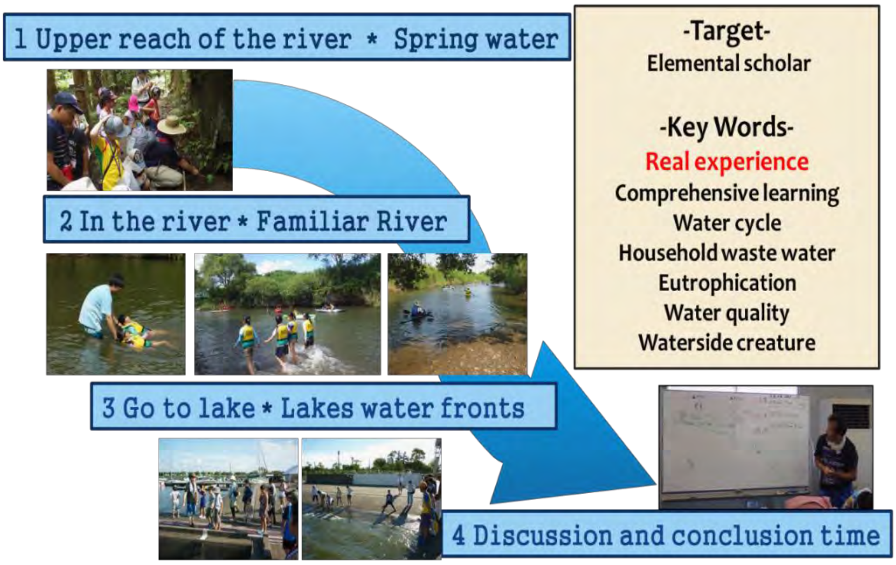

Figure 6. Outline of Sakura River Eco Adventure tour

First, going to upper reach of the river, and exploring spring water. In the upper reach of the river's step, students climb the hill and on the way they look for living creatures and landform change. When they arrive at spring water, they conduct simplified water quality analysis. Then they look for living creatures around spring water (**Figure 7**).

Figure 7. The state of students at first step

Second, walking into the river and learning about familiar riverside as well as going down the river in a canoe and seeing the city from the river. Then staff of Sakura river fishermen's union give them lecture on living creatures in the river (**Figure 8**).

Figure 8. The state of students at second step

Third, going to the lakeside of Kasumigaura and learning Kasumigaura, where our domestic wastewater enters (**Figure 9**).

Figure 9. The state of students at third step

Finally, Students complete the ideas what they experienced in this program, especially paying attention to the changes from river to lake. In this step, the most important point is to let students thinking themselves through real experience. We sometimes give "Hint words" for students as their own ideas promote (**Figure 10**).

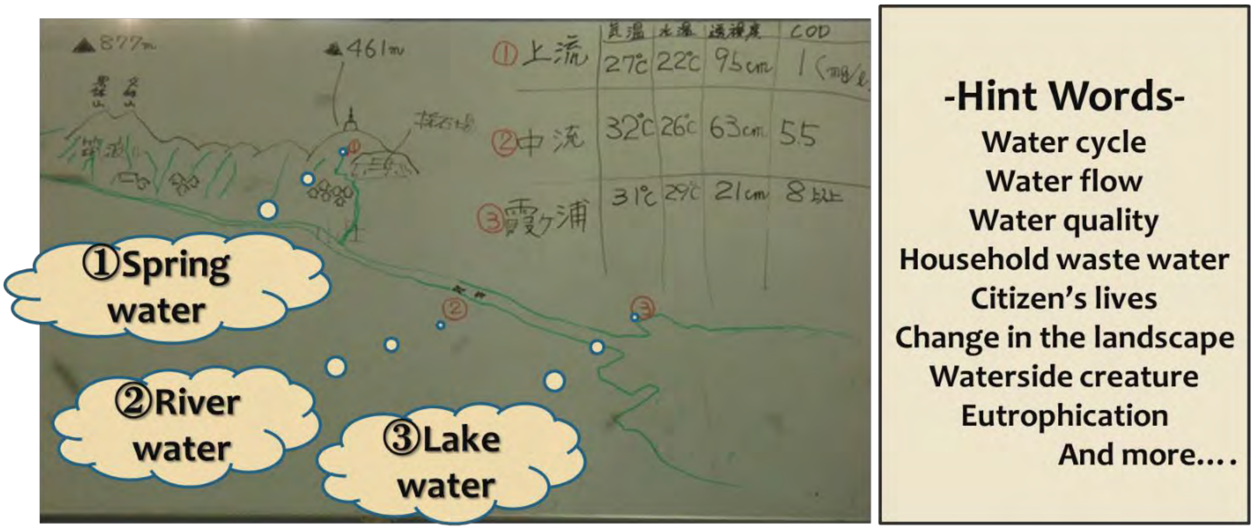

Figure 10. Discussion and conclusion

CONCLUSION

Lake Kasumigaura has symbolic meanings for the municipals in the Kasumigaura watershed and it's the source of people's life. It is very important to recognize its importance, preciousness, and relationship to our life of Kasumigaura in their childhood. We hope that the children, who are responsible for the future, will conserve the environment of Kasumigaura, the resource of our life, sustainably. These environmental education programs are not only our idea. These contents are considered by taking activities of other municipals, opinions of specialists, and suggestion of the residents into account. For the environmental education for children, it is necessary to upgrade the programs constantly and carrying out sustainably.

Every municipal in the Kasumigaura watershed, not only Tsuchiura, has been making use of their characteristic as closest government to people to carry out many kinds of programs, including water environmental education or activities that consist of both private and government.

We will continue to work hard to conserve the better water environment in cooperation with government of Japan, Ibaraki prefecture, municipals in the Kasumigaura watershed, residents, companies, and research institutions.

Photo 7. Sakura River
(http:// www.tsuchiura-pr.jp)

Photo 8. Tsuchiura harbor

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POTENTIAL IDENTIFICATION OF FLORA AND FAUNA LAKE BUYAN AS BASIS FOR TOURISM DEVELOPMENT STRATEGY BASED ON AQUATIC ECOSYSTEMS

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ABSTRACT

Lake Buyan is located in the Sub district of Sukasada District of Buleleng is a highland lake in Bali which has been used for a variety of human activities quite intensive, such as fishing, aquaculture, tourism and recreation. Water Tourism is one of the great potentials that has been developed in the Lake Buyan includes boat trips, recreation and fishing. The development of tourism activities in Lake Buyan have done quite intensive and it is feared that it may decrease the potential and diversity of aquatic resources. As a system of natural resources, the waters of Lake Buyan contain the potential of biological and non-biological resources that have not been recorded and inventoried adequately in order to empower the development of multi-activity and general water conservation. Therefore, it is necessary to conduct a research entitled "The Potential of Flora and Fauna in Lake Buyan as a Basis for Ecosystem-Based Tourism Development of Water". The purpose of this study was to identify the flora and fauna as a basis for tourism development strategy in Lake Buyan. The research was conducted during the two months from June to July 2015. Sampling of aquatic plants parameter was carried out in 9 sites of observation using 1 x 1 m transects, while the parameters of fish resources was conducted in all waters by boat with fishing equipment and fishing nets. There were eight kinds of aquatic plants found namely Scirpus mucronatus (L.) Palla*,* Salvinia molesta D. Mitch.*,* Myriophyllum brasiliense*,* Brachiaria mutica (Forssk.) Stapf, Cyperus odoratus L., Eichornia crassipes (Mart.) Solms solms, Ludwigia adscendens (L.) H. Hara, Salvinia natans (L.) All., Ceratophyllum demersum L.. Species S. molesta *is a species found at each point of observation, whereas* S. natans *was only found in one site of (site 8). There were six types of fish catches, namely* Ostheocillus hasselti *(Valenciennes, 1842),* Amatitlania nigrofascia *(Günther, 1867),* Orechromis niloticus *(Linnaeus, 1758) tilapia*, Oreochromis mosambicus *(W. K. H. Peters, 1852), fresh water shrimp,* Cyprinus carpio Linnaeus*, 1758 Nilem, Zebra, Tilapia, Shrimp, Mujair, and Gold fish. The number of fish catches the most was zebra fish species (218 animals) and the type of fish catches the least found was carp (1).*

Keywords: Aquatic Plant, Fish, Lake Buyan, Tourism Development.

INTRODUCTION

Bali has four lakes, namely Lake Batur in Bangli, Lake Beratan in District of Tabanan, Lake Buyan and Lake Tamblingan in District of Buleleng. Lake Buyan and Tamblingan located in the Subdistrict of Sukasada District of Buleleng is a highland lake in Bali as the water reserve important for North Bali. As a system of natural resources, the waters of Lake Buyan contain the potential of biological and non-biological resources that have not been recorded and inventored adequately in order to empower the development of multi-activity and conservation of public waters. Fisheries development as an alternative to community activity has a strategic significance in the context of economic empowerment of communities around the lake, nature tourism development and biodiversity conservation lake.

To know the resource potential of the lake to support the plans for development and community empowerment plans need the basic data (base data) of the potential resource of biological and non-biological affecting capacity levels. All lakes in Bali do not yet have sufficient data and information on the potential of its natural resources for the development of fisheries, tourism and others including Lake Buyan. It became one of the factors that hinder optimal policy interventions in developing fisheries, tourism, and other alternatives in the lake sustainably and as the principles of sustainable use of natural resources. In addition, a variety of strategic issues and environmental problems that also affect the carrying capacity of the lake waters for development in the future.

Aquatic plants are plants that part or whole of their life-cycle are in water, has a role as primary producers in the waters which are food source for primary consumers or biofag (this includes fish). In addition, aquatic plants also assist aerated waters through photosynthesis, regulates the flow of water, cleaning polluted streams through the process of sedimentation, as well as particles and mineral absorption, aquatic plants are nurseries for fish, insects, and other animals. Some types of aquatic plants also provide a direct food source for humans such as kale (Ipomoea aquatica) (Utomo et al., 2001). In addition, some aquatic plants also have negative impacts on the ecosystem Room (1984);

Soerjani (1978) said that water weed is a plant that can interfere with water usage by humans and aquatic plants as aquatic weeds in a state and a certain time are not desired, because they result in losses that exceed a favorable role. Specific ecosystem makes the potential of Lake Buyan quite good with a variety of organisms that live in it, especially the fish. Lake Buyan is rich in fish species, among the fish there are economically valuable fish. Today, with the increasing number of activities around and introduced fish like zebra fish and tilapia from other areas in Lake Buyan the changing structure of fish communities in terms of both as well as the number of fish in Lake Buyan. The presence of data and information on the characteristics of fish and aquatic plants in Lake Buyan is expected to become an input for the management of tourism in the future

METHODS

This study was conducted in Lake Buyan for 3 months starting from June to August 2016. The determination of research's location was done by method of pusporsive sampling on 9 sites of sampling (**Figure 1**).

Figure 1. Research Location in Lake Buyan

Sampling of Aquatic Plants

The sampling of aquatic plants parameter was done on 9 sites of observation using plot 1 x 1 m, the type of aquatic plants contained in the plot were identified and counted? on each plot was done by three repetitions. Various types of aquatic plants in Lake Buyan was retrieved as a sample such as roots, branch, vine stems, leaves, flowers, and fruit, and then selected with most undamaged shape and cleaned from dirts such as mud, especially on the roots and then left open to dry. Samples of aquatic plants were put into a plastic bag and labeled, written on tracing paper using pencil 2B. The label recorded the serial number or code, local name, place and date of sampling, the label is inserted in a plastic bag and tied with a rubber band quite strong and tight. Furthermore, it was packed in bags neatly and kept for identification (Burnawi & G. Subroto, 2010). Identify aquatic plants with the following steps: a. several observations of aquatic plants like shape of the fruit, seeds, roots, stems, branches, vine stem, leaf shape and leaf length. b Examples of aquatic plants were matched to the image based on the method said by Room (1984); Soerjani (1978) and identified too with www. with plant list.org

Sampling of Fish

Samples of fish, obtained by capturing them using different types of fishing gear (gill nets, net, Bubu).. The data taken includes the number, type, standard length and weight of each species of fish catches. Samples were photographed and then preserved in alcohol 70% and were identified by using the key determination according to Saanin, (1968) and Kottelat, *et al*. (1993).

RESULTS AND DISCUSSIONS

Results

Aquatic plants

During the observation in Buyan Lake to 9 areas of observation, obtained 9 types of aquatic plants. The types of aquatic plants found were *Scirpus mucronatus (L.) Palla, Salvinia molesta D.Mitch., Myriophyllum brasiliense, Brachiaria mutica (Forssk.) Stapf, Cyperus odoratus L., Eichornia crassipes (Mart.) Solms solms, Ludwigia adscendens (L.) H. Hara, Salvinia natans (L.) All.[1], Ceratophyllum demersum L.. Salvinia molesta* is a type of aquatic plant found in each observation station. There were species only found in one observation station, such as Ludwigia adscendens in station 3 and Salvinia natans in station 8 (**Table 1**).

Table 1. Types of aquatic plant found in every station of observation in Buyan Lake

Jenis Tumbuhan Air	Danau Buyan								
	1	2	3	4	5	6	7	8	9
Scirpus mucronatus	√								√
Salvinia molesta	√	√	√	√	√	√	√	√	√
Myriophyllum brasiliense	√	√	√					√	
Brachiaria mutica	√	√	√				√	√	√
Cyperus odoratus	√	√	√		√				
Eichornia crassipes solms		√		√	√	√			√
Ludwigia adscendens			√						
Salvinia natans								√	
Ceratophyllum demersum L.				√	√	√			

The number of aquatic plants mostly found were in observation station 1, 2, and 3, as well as the least aquatic plants found was in station 7. This was may be due to the location of station 1, 2, and 3 that were close to residential areas, making plants to obtain sufficient nutrient input. Whereas in station 7, it was close to forest, thus the nutrition input was lacking. The presence of nutrition for plants is one of the important factors in the growth of aquatic plants.

Fish resources

In Buyan lake It was found six species of fish, there were *Ostheocillus hasselti, Amatitlania nigrofascia, Orechromis tilapia, Oreochromis mosambicus,* fresh water shrimp*, Cyprinus carpio*. The most fish catches in Buyan lake was *Amatitlania nigrofascia* (218 animals) and the lowest was *Oreochromis niloticus* (1 fish). The originally fish species from buyan lake only *Ostheocillus hasseltii*, and fresh water shrimp. The other fish species come from other place and one species is become a pests in buyan lake is *Amatitlania nigrofascia* (**Figure 2**)

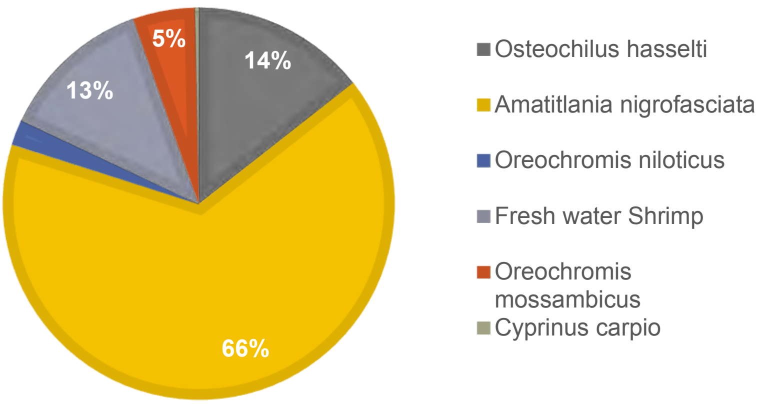

Figure 2. Composisiton of Fish Catch on the Lake Buyan

Fish Growth

Growth is a change of length, weight, or volume that occurs within a specified time. The study of the growth is basically the determination of body size as a function of age (Sparre and Venema 1999). Weight can be considered as a function of length. The relationship of length weight is described by W = a Lb, where a and b are constants obtained from the calculation of regression, whereas W is weight and L is length. The relationship of length weight is following the law of cubic namely that the weight of fish as the cube of its length (Effendie 1997).

The relationship between the two variables can be known by using the analysis of regression. Analysis of regression is useful to obtain functional relationship between two variables or more or obtain an influence between the variable of Predictor against criterion variable or predicts the influence of predictor variable against criterion variable (Usman and Akbar 2006). The relationship of length weight of *Ostheocillus hasseltii* can be seen in **Figure 3**.

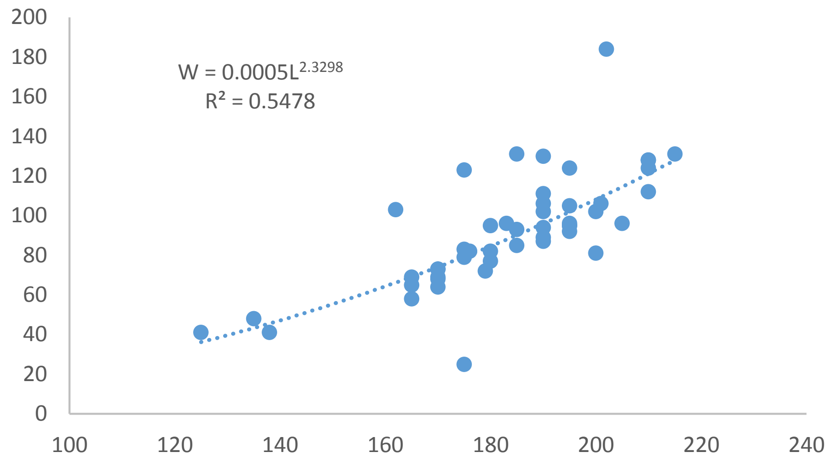

Figure 3. Relationship of Length and Weight of *Ostheocillus hasseltii* (n=48)

Similarities of the relationship of length and weight of *Ostheocillus hasseltii* ie W = 0.0005L2.3298. The value of t count obtained >ttab, which means that reject H0. The value of slope (b) obtained is < 3, thus the pattern of *Ostheocillus hasseltii* growth is allometric negative. Allometric negative means that the length growth is more dominant than the weight gain. This indicates that *Ostheocillus hasseltii* has a slender body. Effendie (2002) stated that the growth is influence by internal and external factors. External factors that affect growth is the amount of available food and water quality (Pratiwi, 2013). Status of Water Quality in Lake Buyan including heavily polluted (STORET Index) and lightly polluted (Pollution Index) (Saputra, 2016). This model has a value of R^2 amounted to 54.78%, thus this model can be said to represent the real situation on the nature of 54.78%.
Similarities of the relationship of length and weight of *Amatitlania nigrofascia* is W = 0.0002L2.4442. Value of t >ttab, which means that reject H0 and the value of slope (b) obtained < 3, thus the pattern of *Amatitlania nigrofascia* growth allometric negative.. This indicates that the *Amatitlania nigrofascia* has a slender body. This model has a value of R^2 amounted to 53.89%, thus this model can be said to represent the real situation on the nature of 53.89% (**Figure 4**). Lengh and Weigh have a non linier relationship, which mean that the increase of lenght not always follow by the increase of weight.

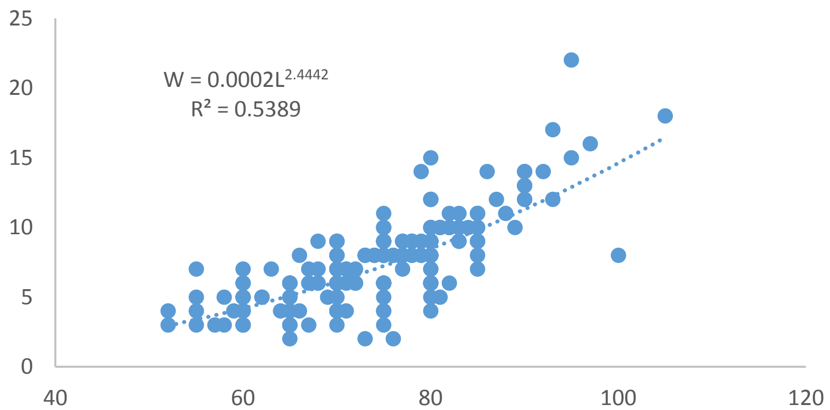

Figure 4. Relationship of Length Weight of Zebra Fish

Discussions
Potential of Aquatic Plants and Fish Resources
The potential of flora or aquatic plant contained in Lake Buyan has a considerable number of species, namely 9 kinds of aquatic plants. Aquatic plants species found in Danau Buyan was quite low when

compared with aquatic plants in Tondano Lake found 14 species of Aquatic plannts (Nebath,2008), Lutan Lake Palang Karaya found 10 species of aquatic plants (Augusta, 2015). The variety of aquatic plants located in Lake Buyan can be caused by nutrient inputs received by the waters of Lake Buyan derived from a variety of sources. The input source of nutrients in Lake Buyan such as agricultural activities, settlements, aquaculture systems Keramba Jaring Apung (KJA) or floating net and tourism. The inputs of nutrients can increase the fertility of Lake Buyan. Aquatic plant is a plant that can live well if there are sources of nutrients. The high nutrient input to the waters of Lake Buyan also can cause negative effects such as the occurrence of eutrophication (deepening of waters). Wijaya 2010, the water quality of Lake Buyan is based on several parameters measured showed was polluted and other parameters show has not been contaminated and eutrophication process of lakes Buyan involving agricultural activities and natural phenomena thus increasing the fertility of the lake ecosystem. This siltation is caused by the abundance or density of aquatic plants. However, management activities appropriate to the diversity of aquatic plants can improve the efficiency of the local community economy.
The composition of fish catch most dominant is the species of *Amatitlania nigrofascia*. This species is an introduced fish catch to the waters of Lake Buyan. *Amatitlania nigrofascia* is a fish that has good adaptation ability and the presence *Amatitlania nigrofascia* found in Lake Beratan, Bali is almost even in every location of observation (Rahmat et al., 2012). This indicates that there has been a competition inpopulating an area and food and *Amatitlania nigrofascia* fish has successfully dominating against the native fish from Lake Buyan (*Ostheocillus hasseltii*).
The composition of fish catch type in Lake Buyan is dominated by an introduction fish. There are only two types of fish catch that are native form Lake Buyan namely *Ostheocillus hasseltii*, and fresh water shrimp. This is almost similar to the condition of fish catch in Lake Batur consisting of 12 types that the overall are introduced fish (Sentosa and Wijaya, 2013). A variety of factors causing the decline in the diversity of freshwater fish can be classified into six main categories namely: alteration or disappearance of habitats, exploitation, introduction of foreign fish, pollution, competition of water use and global warming. Most of freshwater fish that extinct are caused by the change / disappearance of habitat (35%), introduction of foreign fish (30%), and exploitation (4%) (Reid & Miller 1989; Vloyle ct Leidy 1992; Dudgeon (2000). In Buyan Lake there were several factors causing the diversity of fish, introduction of foreign fish, pollution, and blooming of aquatic plant.
Study of growth patterns can describe the condition of the fish in a body of water. In Nilem and Zebra fish both of them have the same b value smaller than 3, thus that growth is allometric negative. Rochmatin et al. (2014) states that Nilem fish growth pattern (*Osteochilus hasselti*) contained in the waters of Rawa Pening, Semarang is allometric negative with a value of 0.0000296 and b value of 2.8392. Meanwhile, the research conducted at the Lake Beratan found that the growth pattern of Zebra Fish (*Amatitlania nigrofasciata*) is isometric with the value of b = 3 (Sentosa and Wijaya 2013). The difference of growth patterns of Zebra Fish (*Amatitlania nigrofasciata*) in Lake Buyan and Lake Beratan can be caused by internal and external factors, such as food availability, water quality and genes. Effendie (2002) states that the growth of is influenced by internal factors (race, sex, age, and disease.) And external (the amount of available food and water quality).
If the value of b is smaller than 3 showed slower weight gain than the increase in length (Effendie 2005). This indicates that the fish are relatively thin which may be caused by competition of food and space in their habitat. Bagenal and Tesch in Kunto (2005) adds that the value of the constant b is also influenced by geographical location, environmental conditions such as the season, the level of fullness of the stomach, diseases and parasites that show the growth pattern of fish.
The potential of Aquatic Water and Fish Resources as Nature Tourism
Aquatic plants have been regarded as a weed, because the abundance of aquatic plants can cause silting. However aquatic plant is a plant that is special because besides being able to live in the waters they are also having a particular shape and beautiful flowers. The correct management of aquatic plants to make the aquatic plants as a tourist attraction will be able to bring direct economic benefits for the surrounding communities. The potential of fish catch *Amatitlania nigrofascia* is also seen as week fish which threatened endemic fish resources in Lake Buyan. So, *Amatitlania nigrofascia* can be utilized as a tourist attraction in Lake Buyan. Suggestions for the management of tourism activities in the Lake Buyan recommended are;

a) Making aquatic plantsas tourism attraction especially for educational tourism. Aquatic plants have unique characteristic and Buyan Lake have 10 species of aquatic plant.
b) Making fishing activities with traditional boats and traditional fishing gear as tourist activities. The activities of fishing done in Lake Buyan are still done traditionally by rowboat. It becomes unique for tourists and can be used as a tourist attraction in Lake Buyan.

c) Making the species of *Amatitlania nigrofascia* as biota for tourist destination especially fishing tourism Tourism activities at Lake Buyan performed is like fishing has long been done and can lead to a positive economic impact. Many tourists who are fishing caught *Amatitlania nigrofascia*. The species of Amatitlania nigrofascia is also the dominant species of fish caught in Lake Buyan. This species also has particularly beautiful shape (black stripe) like ornamental fish, thus it would be fine to be used as a tourist attraction in Lake Buyan.

CONCLUSIONS

1. There are nine species of aquatic plants found; *Scirpus mucronatus, Salvinia molesta, S. natans, Myriophylum Brasiliense, Brachiaria mutica, Cyperus odoratus, Eichornia crassipes Solms, Ludwigia adscendens*, and *Ceratophyllum demersum*. *L. Salvinia molesta* was found in every observation point, whereas *S. natans* found only in one observation point (point 8). It was found six species of fish, there were *Ostheocillus hasselti, Amatitlania nigrofascia, Orechromis nilocromis, Oreochromis mosambicus*, fresh water shrimp, *Cyprinus carpio*. The most fish catches was *Amatitlania nigrofascia* (218 animals) and the lowest was *Orechromis nilocromis* (1 fish).
2. The growth pattern of *Amatitlania nigrofascia* and *Ostheocillus hasseltiis* is allometric negative. This indicates that they will be less fish growth both in nature and in competition to occupy the space and feeding, so that the fish are a skinny. Thus need the regulation about fishing activity such as mesh size of fishing gear and size of the capturing fish.
3. The development strategy that can be done at Buyan lake is; a) Making aquatic plants as a major tourist attraction, b) Making fishing activities with traditional boats and traditional fishing gear as a tourist activities, and c) Making zoning area for fisheries and tourism utilization.

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Topic 6. Database and knowledgebase systems, informatics and monitoring technologies

SWAT APPLICATION TO ASSESS DIFFERENT FERTILIZATION EFFECTS ON WATER QUALITY IN AN AGRICULTURAL WATERSHED

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ABSTRACT

To study the desirable balance of agriculture and water conservation, SWAT (Soil and Water Assessment Tool) was applied to estimate water, sediment (SED), and nutrient discharges, and to assess effects of different fertilizations on water quality in an agricultural watershed (335km2) leading to the Lake Kasumigaura, Japan. For model calibration and validation, daily stream water flow rate, and sediment (suspended solid), total nitrogen (T-N), total phosphorus (T-P), nitrate nitrogen (NO3-N), phosphate phosphorus (PO4-P) concentrations measured a few times a month at a downstream observatory station were used, and 3 years (2000~2002) were assigned to the warm-up, 3 years and 7 months (2003~Jul. 2006) to the calibration, and the following 2 years and 5months (Aug. 2006~2008) to the validation. By simulations with adjusting several parameters, good estimations for daily stream water flow and SED with R2>0.6, NS (Nash-Sutcliffe efficiency coefficient)>0.6, and almost acceptable estimations for NO3-N, organic phosphate (Org-P) with R2 from 0.5~0.9 and NS from 0.1~0.3 were attained for the validation period. By introducing improved fertilizations (smaller and more frequent fertilizations with 0~50% decreased N-amount) to paddy, upland, and pasture fields, equal or greater crop yields and mitigated stream NO3-N discharge by 21% were estimated.

Keywords: SWAT, Non-point source pollution, fertilization, Sakura River

INTRODUCTION

Human activity, especially agriculture, and environment, especially water conservation, are apt to conflict. The Lake Kasumigaura; the second largest lake in Japan is also no exception. Its water is used for domestic, agricultural and industrial purposes in spite of insufficient water purity.

To study the desirable balance of agriculture and water conservation, SWAT (Soil and Water Assessment Tool) was thought to be promising. The model has been used to estimate the impacts of climate and management on water use, non-point source loads, and has been extensively validated across the United States for the stream flow and sediment yields (Arnold et al, 1988). The SWAT model has proven to be an effective tool for a wide range of scales and environmental conditions across the glove (Gassman et al., 2007). However, SWAT is still not popular in Japan. The reason seemed to be insufficiency of data sets on soil properties such as volcanic ash soils, on paddy fields structure and related properties, and on crops growth such as paddy rice which are popular in Japan but not in the United States. Recently, Soil-Profile Physical Properties Dataset “Solphy-J” has been furnished by NARO, Japan (Eguchi et al, 2011). Studies on application of SWAT to paddy fields basins have been increasing. Julien et al. (2014) reported SWAT application to paddy fields by using “pothole” function which is for pond water movement originally. Geometrical change for paddy fields was tried for water movement (Sakaguchi et al. 2014). Sangjun et al. (2007) reported SWAT to paddy fields by adjustment CN value to reflect paddy’s high-water retention and to fit experiment results. Here. we applied SWAT to an agricultural watershed leading to the Lake Kasumigaura, To characterize paddy fields in SWAT, parameters like USLE_P (USLE practice factor) and CN2 (curve number) etc. were adjusted to fit total stream flow and sediment. The main aim of this study is to validate SWAT model for stream flow and sediment flow and nutrient (mainly NO3-N) flow in an agricultural watershed in Japan, and thereafter to assess the effects on nitrogen discharge after application of revised fertilization to agricultural fields.

METHODS

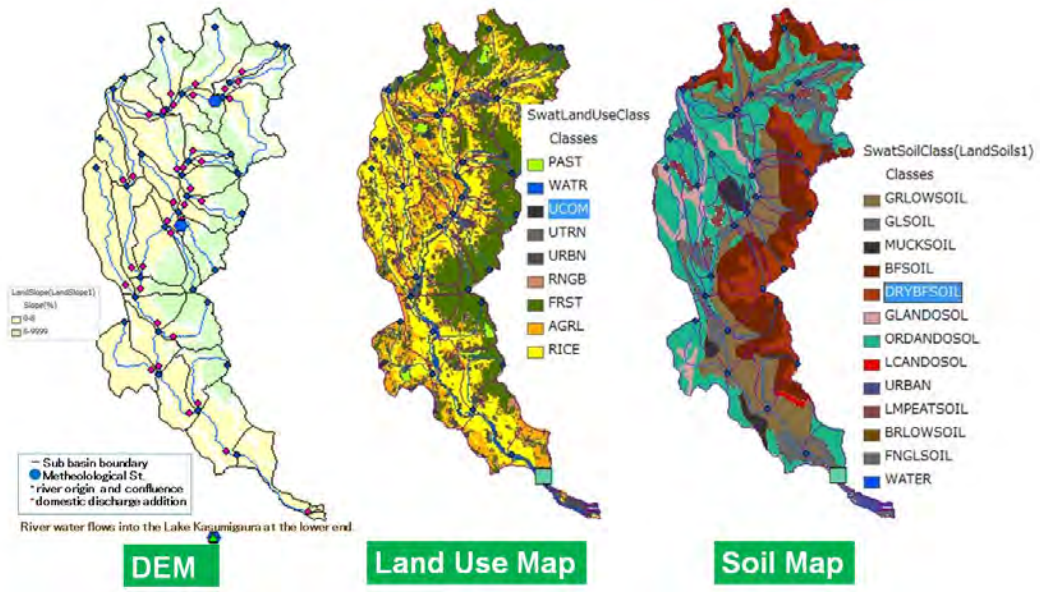
The Study watershed description

The study area was the Sakura River basin, one of the river basins leading to the Lake Kasumigaura, located in the central part of Ibaraki, Japan (**Fig 1**).

Figure 1. Location of the studied watershed

The Sakura River basin was 335 km2 and was in humid temperate climate with an annual mean rainfall of 1283 mm and an annual mean temperature of 13.8 ℃. The 29% of the basin was paddy fields and 20% was upland fields, 34% was forest and 14% was urban area. The soil of the basin was 32% of Andisol, 20% of Glay lowland soil, 29% of Brown forest soil, 9% of Gley soil, 5% of Andic gley soil and others.

The altitude of the basin ranges from 0 m to 877 m which is the peak of a mountain located in the middle-east part of the basin, and decreases from north to south basically (**Fig.2**). Though the water quality of the Sakura River was relatively good among rivers leading to the Lake Kasumigaura, it seemed to be sensitive to fertilization because of relatively high ratio of cropland fields of the basin among river basins leading to the lake. Population in the basin was estimated 126 thousands at 2000. And Sewage coverage was still low in the study period from 2000 to 2008. Upland crops cultured in the basin were Chinese cabbage, sweet potato, lettuce, green pepper etc. Most of paddy fields were irrigated by Kasumigaura Yousui Canal.



Sakura River Watershed

Area 335km^2, ⊿H 877m, subbasin 35, HRU 424 (Threshold: LandUse/Soil/Slope = 5% /10% /20%)

LundUse：Forest 34%, Paddy (RICE) 29%, Upland fileds (AGRL) 20%, Urban (residence，road etc.) 14%, Water 2%, Pasture 1%，others 1%

Soil：Andisol 32%, Glay lowland soil 20%, Brown forest soil 29%, Gley soil 9%, Andic gley soil 5%, Black soil 2%, others 3%

Figure 2. Outline of the studied watershed

SWAT model description

Theoretical explanation of Soil and Water Assessment Tool (SWAT) is described in the "Soil and Water Assessment Tool Theoretical Documentation Version 2009" (Neitsch et al, 2011). SWAT was a hydrologic/water quality model developed by United States Department of Agriculture-Agricultural Research Service (USDA-ARS) (Santhi et al. 2001). It was a continuous time model that operates on a daily time step mainly. SWAT was developed to predict the impact of management on water, sediments and agricultural chemical yields in large ungauged basins with GIS technology (Grizzetti 2005). Based on the spatial data on topography, land use and land cover, soil properties, climate, management practices, the model could simulate the water, sediments, agricultural chemicals movements. The basin spatial variability was represented by a semi-distributed approach. The basin area of study was subdivided into a number of sub-basins, which were characterized by one or more hydrological response units (HRUs). The major components simulated by SWAT include hydrology, weather, erosion, crop growth, agricultural management, and nutrients and pesticide fate. For predicting surface runoff yield, a modified version of the soil conservation science curve number (SCS CN) method was used in SWAT (USDA-SCS 1972). Erosion and sediment yield were estimated for each sub-basin with the Modified Universal soil loss equation (MUSLE) (Williams and Laseur 1975). Channel routing consists of flood and sediment routing. The flood routing model uses a variable storage coefficient method developed by Williams (1969). As for nitrogen cycle, three major forms of nitrogen in mineral soils are organic nitrogen associated with humus, mineral forms of nitrogen held by soil colloids, and mineral forms of nitrogen in solution. Nitrogen may be added to the soil by fertilizer, manure or residue application, fixation by symbiotic or nonsymbiotic bacteria, and rain. Nitrogen is removed from the soil by plant uptake, leaching, volatilization, denitrification and erosion. Fate of nitrogen among the three major forms is ruled by physical, chemical, biological, and empirical parameters in relation to decomposition of fertilizer, manure and humus etc., nitrogen fixation, denitrification, solubility, absorption by plants and so on in SWAT (Arnold et al. 1998, Bradbury et al. 1993). As for phosphorus cycle, the three major forms of phosphorus in mineral soils are organic phosphorus associated with humus, insoluble forms of mineral phosphorus, and plant available phosphorus in soil solution. Phosphorus may be added to the soil by fertilizer, manure or residue application. Phosphorus is removed from the soil by plant uptake and erosion. Fate of phosphorus among the three major forms is ruled by physical, chemical, biological, and empirical parameters in relation to decomposition of fertilizer, manure and humus etc., solubility, absorption by plants, sorption to soil particle and so on in SWAT (Barrow and Shaw 1975, Jones et al. 1984).

Preparation of SWAT simulations

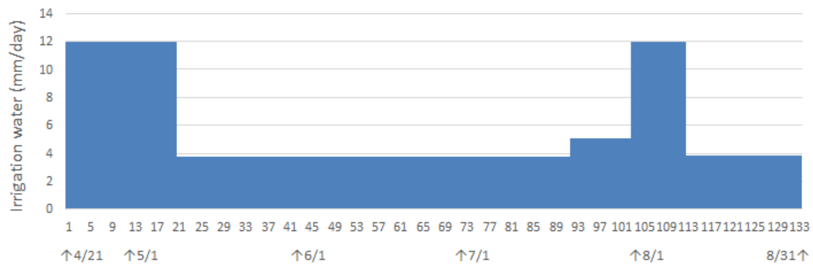
For modelling the basin characteristics, digital data including DEM (10m mesh, Ministry of Land, Instructure, Transport and Tourism (MLIT), Japan, 2000), land use and land cover data (100m mesh, MLIT, Japan, 2005), and soil map data (1/50000, MILT, Japan, 2000) were used (**Fig. 1**). Weather data from 3 meteorological stations (Tateno, Makabe, and Iwase; cf. 3 Blue Points in DEM map in **Fig.2**). Soil-Profile Physical Properties Dataset ("Solphy-J" by NARO, Japan), irrigation water supplying data (Kasumigaura Yousui Canal O & M Office), and general crop managements were used for model configuration. Solphy-J was constructed based on all-japan soil survey data, and including average values on common soil physical properties for each soil series and each soil layer with the average thickness. Domestic discharge such as water, sediment (SED in SWAT), organic nitrogen (ORGN in SWAT), nitrate nitrogen (NO3N in SWAT), organic phosphorus (ORGP in SWAT), and inorganic phosphorus (MINP in SWAT) were assumed to constantly flow out from each sub basin in proportion to its urban area. For model run, "Daily Rain/CN (curve number) / Daily Route method" was used for the surface runoff, and "Priestley-Taylor method" was used for estimation of the potential evapotranspiration (Priestley and Taylor, 1972). Priestley-Taylor method was developed for humid conditions in which soil surface are wet. The precondition of the method was thought to suit to Japan climate and soil surface condition including paddy fields. Three years (2000~2002) were assigned to the warm-up, 3 years and 7 months (2003~Jul. 2006) to the calibration, and the following 2 years and 5 months (Aug. 2006 ~ 2008) to the validation.

Other Input data for model configuration

Weather data ・・・precipitation, temperature, radiation etc. at 3 meteorological stations

Soil-profile physical properties data (Solphy-J, NARO) ・・・thickness of soil layers, bulk density, sand-silt clay contents, pore ratio, volumetric water contents at several water potentials, saturated water permeability, and total carbon content for 60 soil series, for 5 Landuses such as paddy field, common upland field, orchard, pasture, and protected horticulture based on amount of data gathered from all of japan during 1979 ~1998.

Irrigation water supplying data (calculated from Kasumigaura Yousui M&O Office data)



General management (fertilization, tillage etc. by standard fertilization of the regions by hearing from farmers etc.)

Domestic discharge (cf. Ibaraki Pref. data) Septic diffusion ratio was low in the watershed. Most of domestic discharge was processed by septic tank and discharged to canal to river. Constant flow out from each sub basin in proportion to its urban area was settled.

water 0.2m^3, SED 1g, TN 2g, TP 0.2g /capita/day

SWAT RUN

"Daily Rain/CN (curve number)/Daily Route" method

"Priestley-Taylor" method

Calibration

Comparing modelled FlOW, SED, ORGN, NO3N, ORGP, MINP with observed data from Ministry of the Environment and Ibaraki Pref.

Parameterization

Fine adjustment of parameters using SWAT-CUP (SWAT Calibration and Uncertainty Programs)

Validation

Comparing modeled values with observed data

Evaluation by R^2 and NS (Nash-Sutcliffe model efficiency coefficient)

Warm-up (2000~2002), Calibration (2003~Jul.2006), Validation (Aug.2006~2008)

Figure 3. Modelling procedure

For model calibration and validation, modelled flow (FLOW), sediment (SED), organic nitrogen (ORGN), nitrate nitrogen (NO_3N), organic phosphorus (ORGP), and mineral phosphorus (MINP; that is inorganic phosphorus) were compared with daily stream water flow, suspended solid, total nitrogen (T-N) minus nitrate nitrogen (NO_3-N), NO_3-N, total phosphorus (T-P) minus phosphate phosphorus (PO_4-P), and PO_4-P measured a few times a month at a downstream observatory station. For parameterization, default values or adequate values from SWAT database were settled. For fine adjustment SWAT CUP (SWAT Calibration and Uncertainty Programs) (Abbaspour 2015) was used step by step in the order; Flow, SED, ORGN/NO3N, and ORGP /MINP consecutively. Regression correlation coefficient (R2) and the Nash-Sutcliffe coefficient (NS) (Nash and Sutcliffe 1970) were used to evaluate simulation accuracy. NS remained the most commonly used good-of-fit indicator in assessing hydrologic prediction, and $0.5 \leq NS \leq 1$ is sufficient, $0 \leq NS \leq 0.5$ is not bad and acceptable, $NS < 0$ is bad. SWAT simulation procedure is shown in **Fig.3**.
For the water quality items whose modelling accuracies were acceptable, several scenario analyses were conducted on fertilization methods' changes. The settled scenario on fertilization change are shown in **Fig. 4**. Current fertilization is set as basal and additional fertilization, that is, 1 or 2 times fertilization for cultivation period. Revised fertilization is set as small and frequent fertilization. In SWAT, 'Auto fertilization' conducts small and frequent fertilization harmonized with crop's demand. Max nitrogen applied was set as the same for paddy, and half for upland fields, and 10% reduced for pasture.

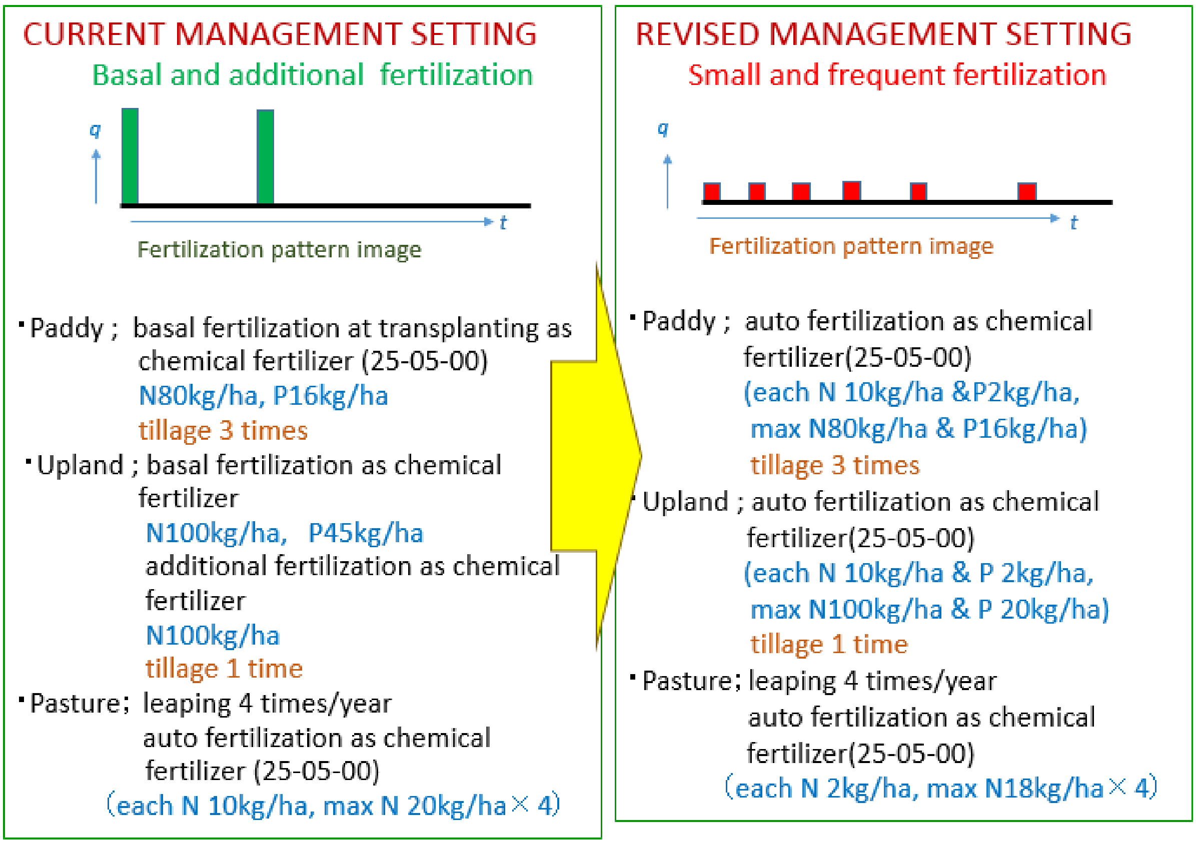


Figure 4. Scenario with fertilization changes

RESULTS AND DISCUSSIONS

Modelled FLOW

The results are shown in **Fig. 5**. The average annual rainfall from 2003 to 2008 was 1375mm, and average river water run-off rates were 59% for both modelled flow and observed flow. Counting irrigation water into input water like rainfall, the run-off rate decreased to 52%. Regression correlation coefficient (R2) and the NS were 0.64 and 0.63 for the calibration period, and 0.64 and 0.72 for the validation period, respectively. In the chart graph, green shows modelled values, red shows observed values. Sufficient modelling accuracy was obtained for river flow.

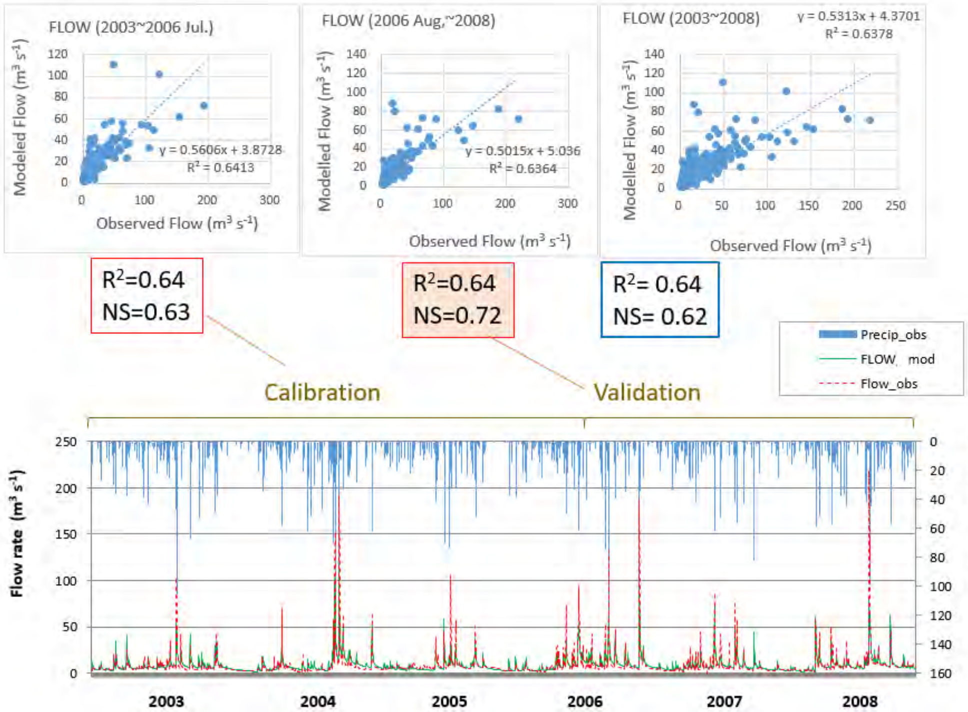


Figure 5. Comparison of modelled Flow with observed Flow

Modelled SED

The results are shown in **Fig.6**. The 89 observed SS (Suspended Solid) data for 6 years were multiplied with the daily flows observed, and compared with modelled daily SED. Regression correlation coefficient (R2) and the NS were 0.65 and 0.60 for the calibration period, and 0.88 and 0.75 for the validation period, respectively. In the chart graph, green shows modelled values, red shows observed values. Sufficient modelling accuracy was obtained for SED, however accumulation of data especially at the time of the flood were thought to be needed.

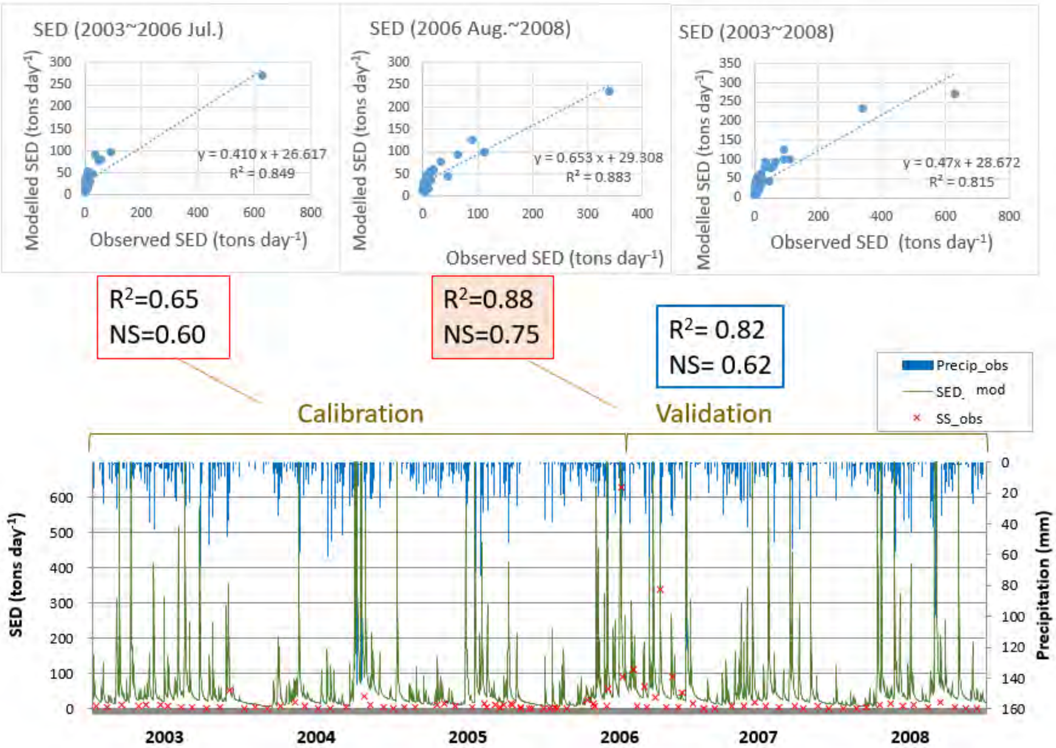


Figure 6. Comparison of modelled SED with observed SED

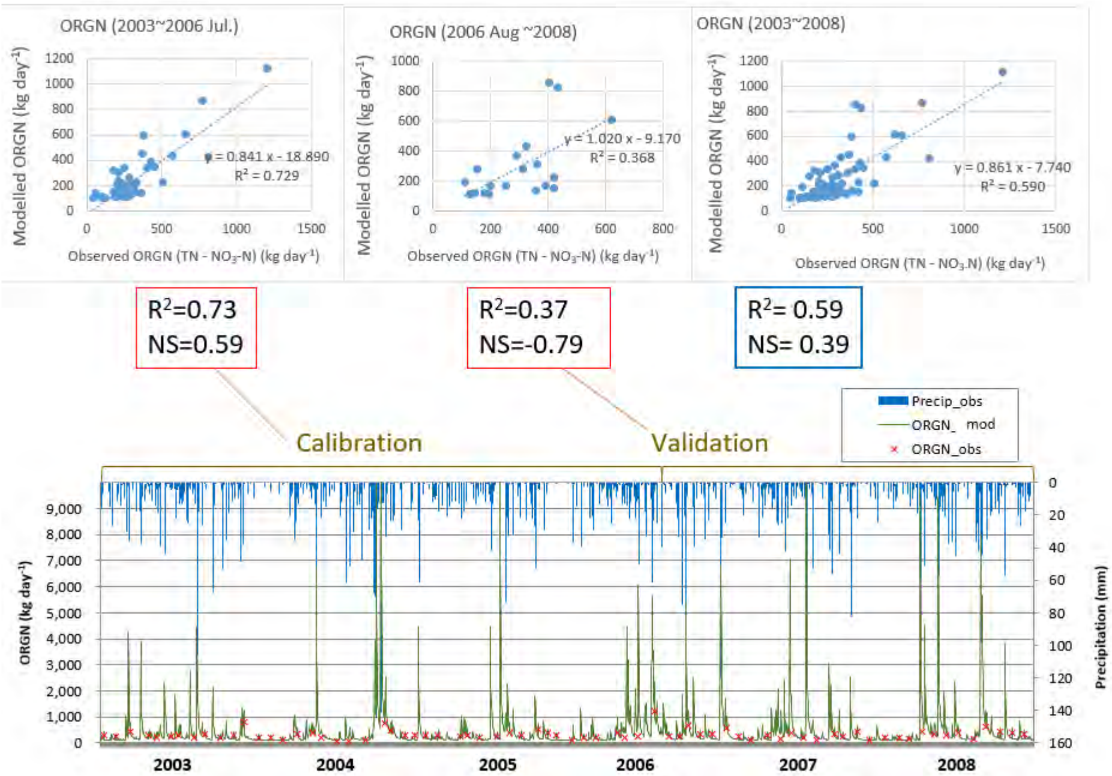


Figure 7. Comparison of modelled ORGN with observed ORGN

Modelled ORGN

The results are shown in **Fig.7**. The 71 observed “T-N – NO_3-N” data for 6 years were multiplied with the daily flows observed, and compared with modelled daily ORGN. Here, NO_4-N and NO_2-N were not taken into consideration, because those concentrations were found to be very low or not detected in the river. Regression correlation coefficient (R2) and the NS were 0.73 and 0.59 for the calibration period, but 0.37 and - 0.79 for the validation period, respectively. In the chart graph, green shows modelled values, red shows observed values. Insufficient modelling accuracy was obtained for ORGN though it was not so low.

Modelled NO_3-N

The results are shown in **Fig.8**. The 90 observed NO_3-N data for 6 years were multiplied with the daily flows observed, and compared with modelled daily NO_3N. Regression correlation coefficient (R2) and the NS were 0.91 and 0.15 for the calibration period, but 0.87 and 0.10 for the validation period, respectively. In the chart graph, green shows modelled values, red shows observed values. Although the NS values were not sufficient, the modelling results for NO_3N were thought to be acceptable because of the high R2 values.

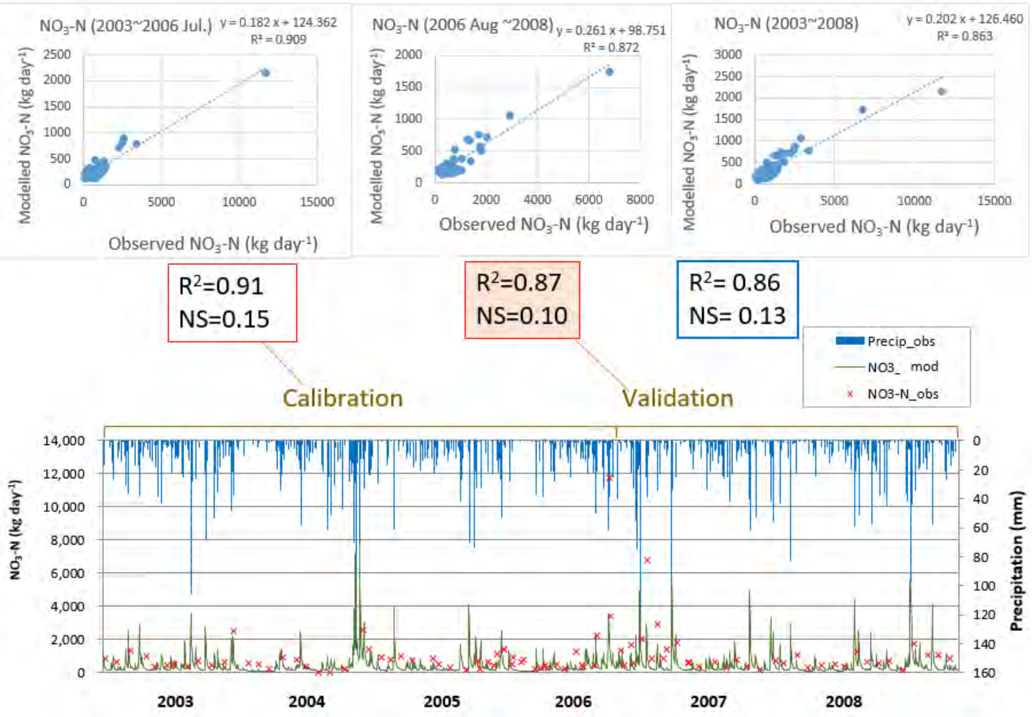


Figure 8. Comparison of modelled NO3-N with observed NO3-N

Moddeled ORGP

The results are shown in **Fig.9**. The 27 observed "T-P – PO_4-P" data for 6 years were multiplied with the daily flows observed, and compared with modelled daily ORGP. Regression correlation coefficient (R2) and the NS were 0.50 and 0.35 for the calibration period and 0.47 and 0.33 for the validation period, respectively. In the chart graph, green shows modelled values, red shows observed values. The modelling accuracy for ORGP was not so low however more data are desirable.

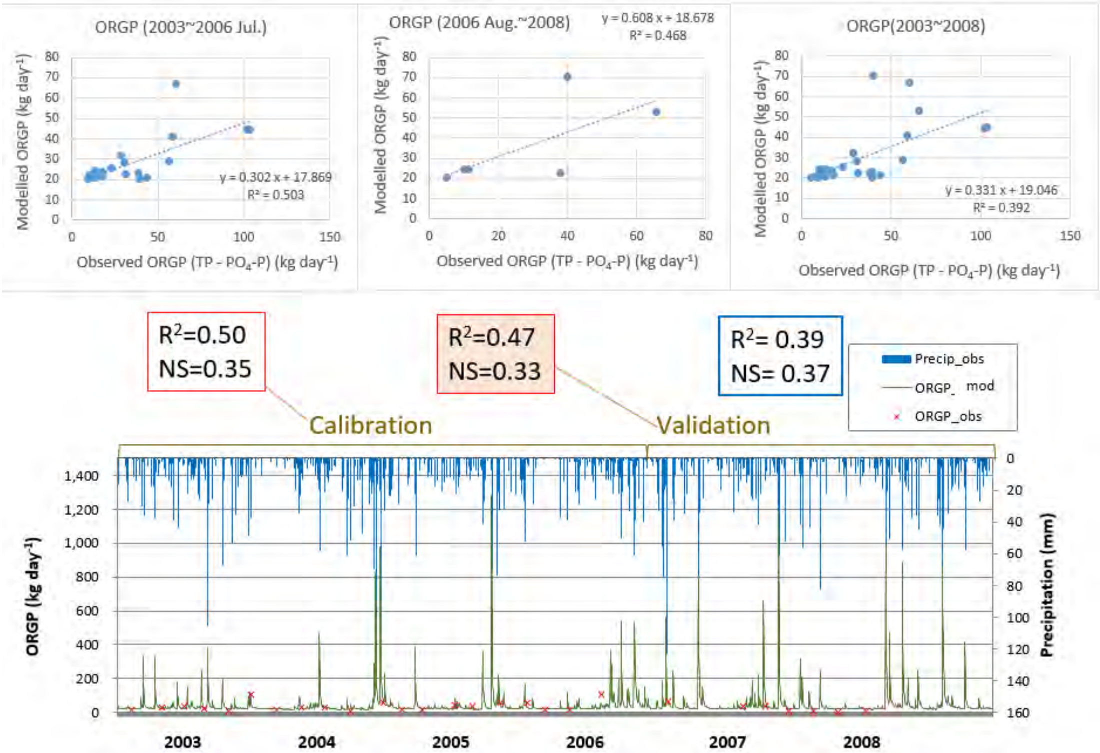


Figure 9. Comparison of modelled ORGP with observed ORGP

Modelled MINP

The results are shown in **Fig.10**. The 27 observed PO_4-P data for 6 years were multiplied with the daily flows observed, and compared with modelled daily MINP. Regression correlation coefficient (R2) and the NS were 0.29 and -8.44 for the calibration period and 0.35 and - 0.73 for the validation period, respectively. In the chart graph, green shows modelled values, red shows observed values. The modelling accuracy was low. Modelled MINP were overestimated the PO4-P observed. It might be caused from high phosphoric acid absorptivity of Andosols which spread widely in the watershed.

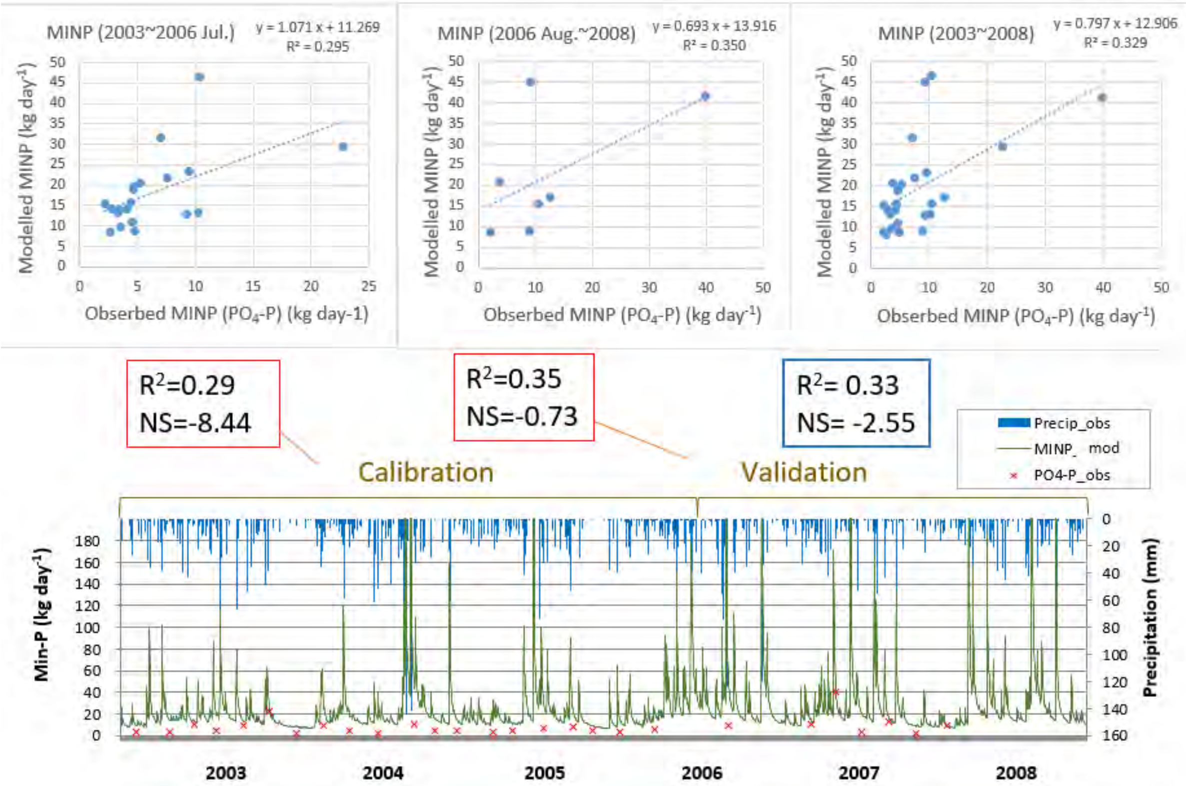


Figure 10. Comparison of modelled MINP with observed PO4-P

Scenario analysis for agricultural management change

Almost acceptable estimation for FLOW, SED and NO_3N and ORGP, scenario analysis with fertilization change was conducted. The results were shown in **Fig.11**. By introducing improved fertilizations (smaller and more frequent fertilizations with 0 ~ 50% decreased N-amount) to paddy, upland, and pasture fields, equal or greater crop yields were estimated. By introducing revised fertilization, equal or greater crop yields were estimated (**Fig.11**). The results showed that paddy rice and grass pasture yields changed little, but upland crop yield increased largely under the revised fertilization. Large part of basal fertilized nitrogen was thought not to be absorbed by upland crops by those still-poor root development and easiness of runoff or denitrification of chemical nitrogen fertilizer. NO_3-N discharge was calculated to be decreased by 21% (**Fig.12**), however ORGP discharge were not decreased.

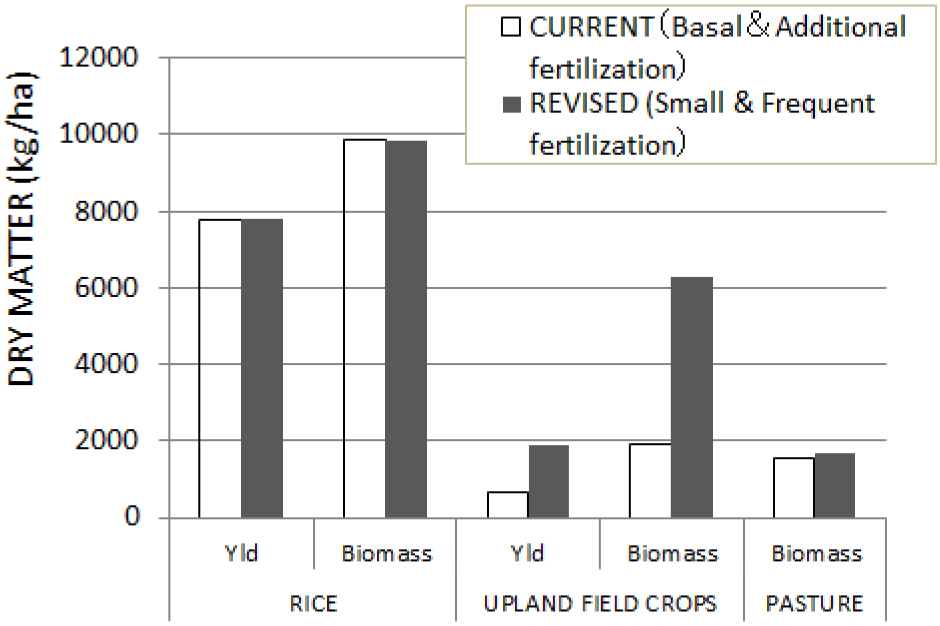


Figure 10. Estimated dry matter change

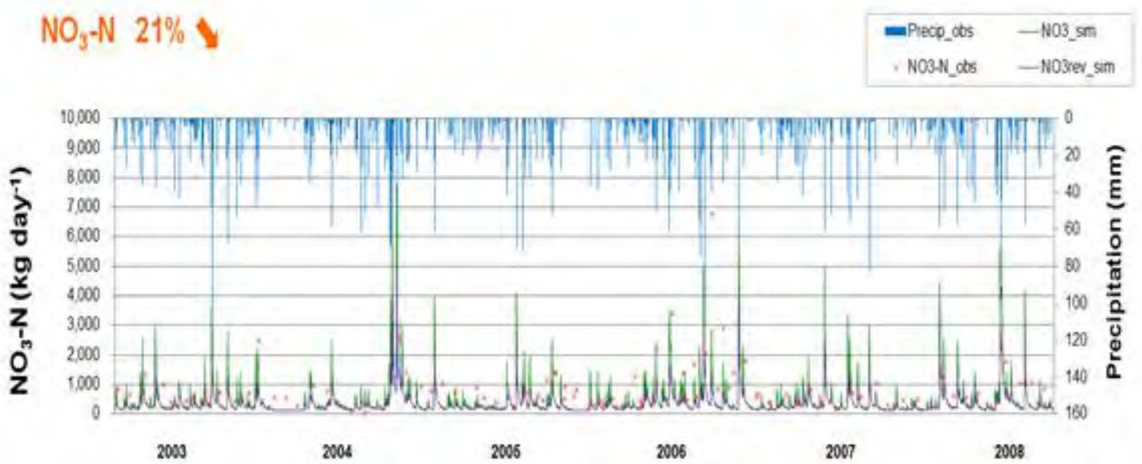


Figure 11. Change in NO3-N flows by management changes; NO3_sim (under current managements) NO3rev_sim (under revised managements)

CONCLUSIONS

SWAT was applied to assessing effects of different fertilizations on water quality in an agricultural watershed. After calibration and validation, good estimations for daily stream water flow and SED, and reasonable estimations for NO_3N and ORGP were attained. The results of scenario analysis for agricultural management changes showed that smaller and more frequent fertilization is effective for crop production and mitigation of NO_3-N pollution.

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ESTIMATING LAKE EXTENT AND WATER VOLUME OF FLOODPLAIN LAKES OF KALIMANTAN USING RADAR IMAGES

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ABSTRACT

Lakes hold about 80% of global liquid surface freshwater and encompassing crucial contributors to biodiversity. In time of increasing water demand and climate uncertainty, establishing fundamental patterns of natural variability of water resources including those in lakes is vital. Currently, storage capacity of tropical lakes is rarely reported due to the lack of data. In this contribution, we use radar images from the Phase Array Synthetic Aperture Radar (PALSAR) with a pixel spacing of 75m for the years 2007 through 2010 and lake level data to quantify the volume of floodplain lakes in the Mahakam (East Kalimantan) and the Kapuas (West Kalimantan) lakes region. From flooded pixels, we obtain areas of lakes inundation. Area of floodplain lakes is following seasonal inundation pattern as a result of variable rainfall rate; we use rainfall estimates from the Tropical Rainfall Measuring Mission for this analysis. The period of the Mahakam lakes depth measurements was coincided with part of PALSAR data acquisition dates. Therefore, we are able to derive a depth-area relationship that is used to estimate lake's water levels beyond our measurement period. Correlation analysis reveals that depth of the lakes is well-correlated with two-month moving average of areal rainfall. We obtained a linear depth–rainfall relation that was applied to approximate depth of the Kapuas lakes. An estimate of total volume of lakes is derived from total area of flooded pixels and lake's depth. Within the study period, the highest estimated total volume of water in the Mahakam lakes is 6.5 billion m^3 during the PALSAR data acquisition on 4 May 2007, while that of the Kapuas is about 3 billion m^3 during the PALSAR data acquisition on 8 April 2009.

Keywords: Floodplain lakes, volume estimation, PALSAR, Mahakam, Kapuas.

INTRODUCTION

The flood-pulse of the large rivers triggers ecological processes of the floodplain systems inducing a severe seasonality in the annual cycle between the aquatic and the terrestrial phase (Schongart & Junk 2006). It is not only important as subsidy of organic matter to the main channel, but it plays a role in defining floodplain's plant community composition and distribution, affecting ecosystem processes such as methane emissions, and in serving as a (temporary) habitat for diverse assemblage of fish and invertebrates (Benke et al., 2000).

Lake Sentarum National Park is located in the upper Kapuas River, West Kalimantan (**Fig. 1**). It represents one of old tropical peat formations in Late Pleistocene (Anshari et al 2001, 2004). The Kapuas wetlands are important for their respective local communities not only as a source of water for domestic purposes, but also to sustain the livelihood of the people especially in the open water fishery sub-sector. The Kapuas wetland with its seasonally inundated lakes produces about 18,000 tons of freshwater fish annually (BPS-Kalbar, 2015). These fishing industry figures express the high economic value of the wetland areas we study. The unique tropical wetland ecosystems are rich in biodiversity of typical aquatic as well as terrestrial flora and fauna, which is why they are listed as a Ramsar site.

The wetlands act as hydrological buffers and hence contribute to natural flow regulation, which has rarely been quantified. There is a lack of knowledge on processes involved in seasonal flooding in tropical lowland areas, including backwater effects. Not with standing their ecological, hydrological and economical importance, the Kapuas and Mahakam wetlands in particular and the two river basins in general have been increasingly threatened by a variety of factors including pollution, forest fires, deforestation, and mono cultures (Rautner et al., 2005; Chokkalingam, 2005).

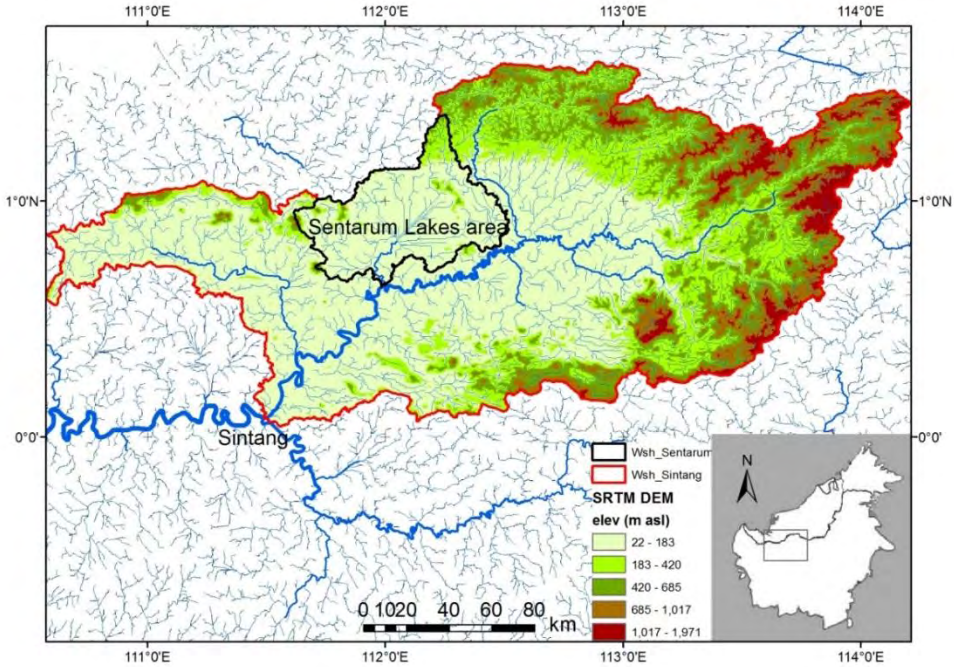

Figure 1. The Kapuas catchment upstream of the city of Sintang (red line) in West Kalimantan, featuring the catchment of the Sentarum lakes area (black line) delineated using SRTM digital elevation model.

The aims of the study were to estimate the extent and storage capacity of two floodplain lakes areas in Kalimantan, Indonesia. This paper continues with description of the study area, data collection, and method of lake volume estimation in Sect 2. In Sect. 3 we present the results followed by conclusions in Sect. 4.

METHODS

Inundation maps were obtained from the analysis of Phase Array L-band Synthetic Aperture Radar (PALSAR) images of 2007—2010. Lake inundation areas were mapped following the method for flood mapping of open water (Hidayat et al. 2012). Crucial in this method is the determination of the upper threshold for open water. Radar backscatter statistics from regions covering the main river and lakes known to be permanently inundated were taken to determine threshold values for open water flood occurrence mapping. The mean plus one standard deviation was taken as the upper threshold for open water flooding. From area of inundation and lake's water level, we estimated the total volume of water in the lakes region.

From area of inundation and lake's water level, we estimated the total volume of water in the lakes region. Areas of floodplain lakes are following the seasonal inundation pattern as a result of variable rainfall rates. The period of Mahakam water level measurements coincided with part of the PALSAR data acquisition dates. Therefore, we were able to derive a lake depth (h) - area (A) relationship that was used to estimate the lakes' water levels beyond the period of our measurements (**Fig. 2**). For the Kapuas, our water level measurement did not coincide with the PALSAR observation period. With an assumption of uniform distribution of depths, we develop a depth-rainfall relationship. Correlation analysis reveals that the depth of the lakes is well-correlated with the two-month moving average of areal rainfall (P_{2m}). We obtained a linear depth–rainfall relation that was applied to approximate water levels of the Kapuas lakes, reading: $h = 0.021 * P_{2m} – 2.4$ (**Fig. 3**).

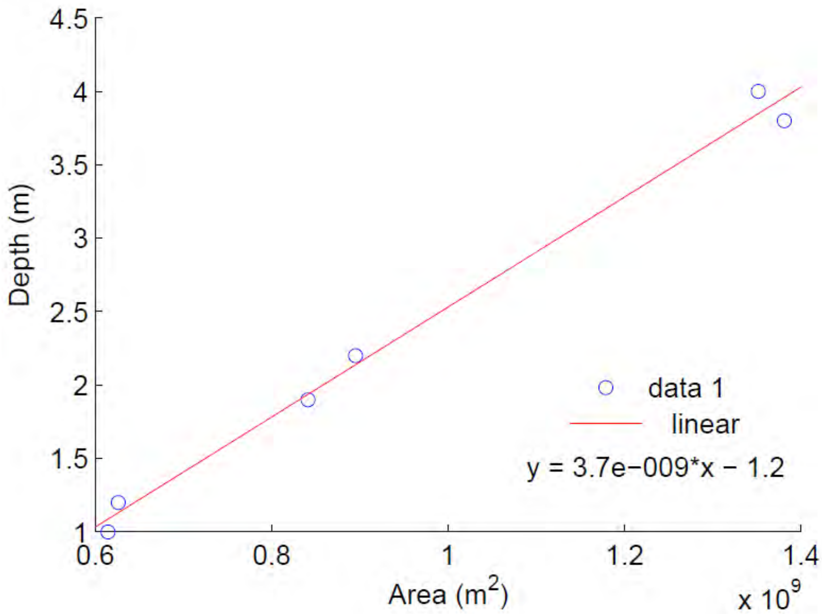

Figure 2. Relationship between measured depth of lake in the middle Mahakam area and area of open water inundation from PALSAR images.

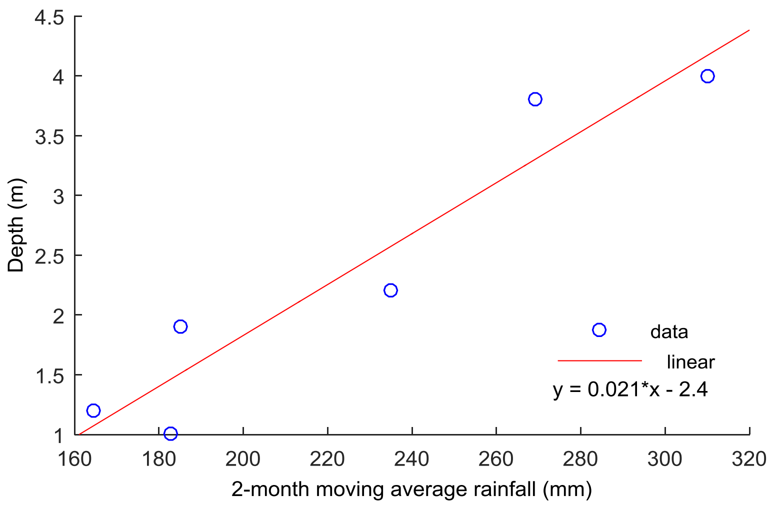

Figure 3. Relationship between measured depth of lake and rainfall (2-month moving average).

RESULTS AND DISCUSSIONS

The lake extent of the Kapuas and Mahakam floodplain lakes are highly dynamics. **Figure 4 and 5** show the extent of floodplain lakes in the Mahakam and those of the Kapuas during dry period (green) overlaid on top of that during high water period.

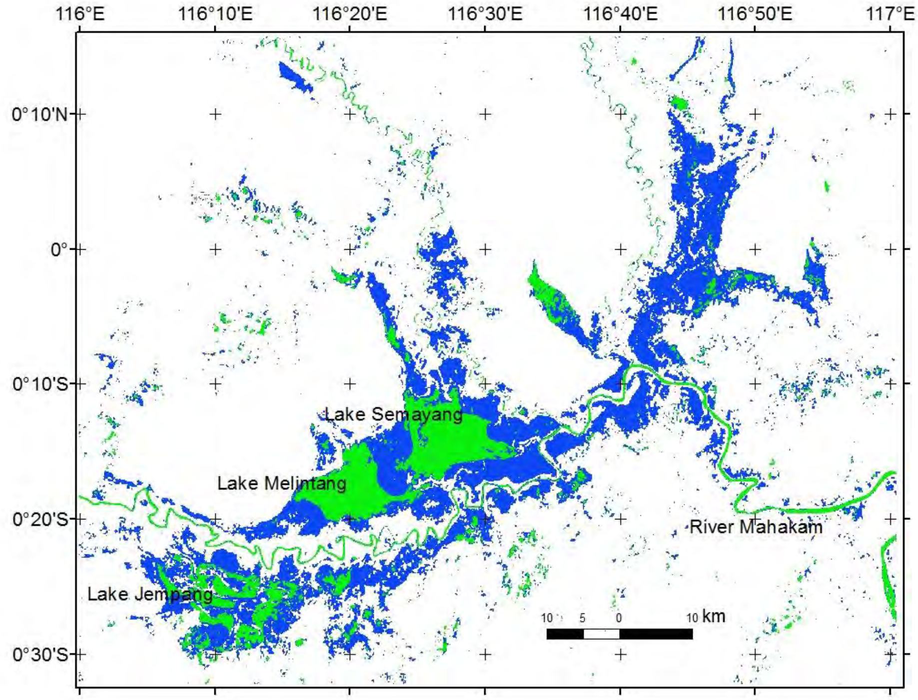

Figure 4. Extent of lakes in the Mahakam during dry period (green) overlaid on top of that during high water period on 5 April 2009 (blue).

Estimates of total volume of lakes in the Mahakam lakes area are shown in **Table 1**. The highest estimated total volume of water the Mahakam lakes is about 6.5 billion m^3 during the PALSAR data acquisition on 12 May 2010. The highest estimated total volume of water in the Kapuas lakes is about 3 billion m^3 during the PALSAR data acquisition on 8 April 2009 (**Table 2**). Considering the extent of flooding under vegetation cover, the maximum total volume of water stored in these wetlands can be twice as much as the abovementioned values. Note that stream network was not removed during the flood count assessment, which renders the area of inundation to be somewhat overestimated.

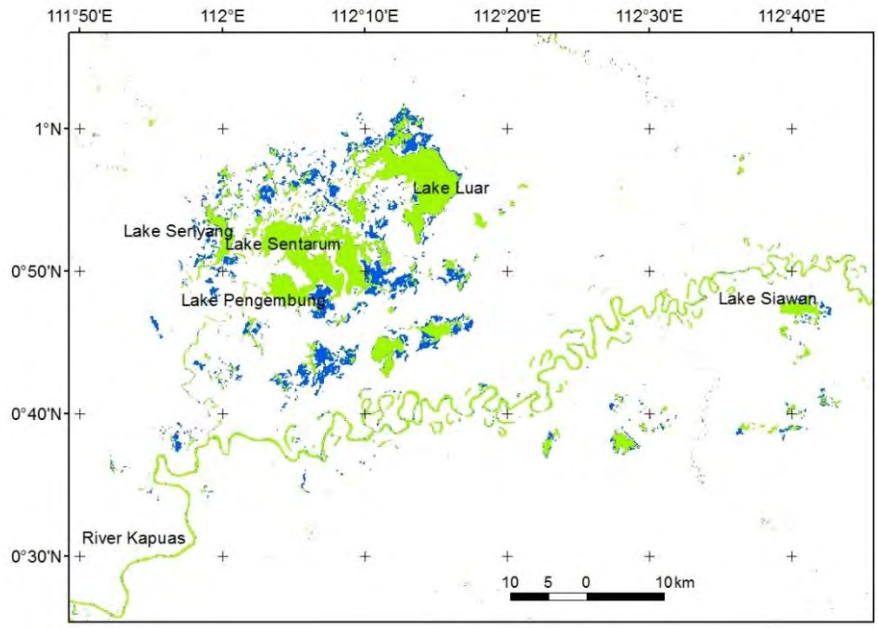

Figure 5. Extent of lakes in the middle Kapuas area during a relatively dry period (green) overlaid on top of that during wet period (blue).

Table 1. Estimates of total volume of lakes in the Mahakam lowlands derived from flooded pixels of PALSAR images.

PALSARdate	Image no	Flooded pixel	Area (m2)	Depth (m)	Vol (m3)
19/Mar/07	0	78441	4.41E+08	0.43	1.91E+08
4/May/07	1	264498	1.49E+09	4.30	6.4E+09
4/Aug/07	2	111896	6.29E+08	1.13	7.11E+08
19/Sep/07	3	103972	5.85E+08	0.96	5.64E+08
4/Nov/07	4	105421	5.93E+08	0.99	5.89E+08
20/Dec/07	5	87947	4.95E+08	0.63	3.12E+08
4/Feb/08	6	82759	4.66E+08	0.52	2.43E+08
21/Mar/08	7	125363	7.05E+08	1.41	9.94E+08
6/May/08	8	245561	1.38E+09	3.91	5.4E+09
21/Jun/08	9	159131	8.95E+08	2.11	1.89E+09
6/Aug/08	10	109242	6.14E+08	1.07	6.6E+08
21/Sep/08	11	111309	6.26E+08	1.12	6.99E+08
22/Dec/08	12	240312	1.35E+09	3.80	5.14E+09
9/May/09	13	149549	8.41E+08	1.91	1.61E+09
24/Sep/09	14	145948	8.21E+08	1.84	1.51E+09
9/Feb/10	15	245934	1.38E+09	3.92	5.42E+09
27/Mar/10	16	96125	5.41E+08	0.80	4.33E+08
12/May/10	17	266648	1.5E+09	4.35	6.52E+09
27/Jun/10	18	137079	7.71E+08	1.65	1.27E+09
27/Sep/10	19	96914	5.45E+08	0.82	4.45E+08

Table 2. Estimates of total volume of lakes in the Kapuas lowlands derived from flooded pixels of PALSAR images.

PALSARdate	Image no	Flooded pixel	Area (m^2)	depth (m)	Vol (m^3)
2/16/2007	0	90238	5.E+08	3.58	1.81E+09
5/19/2007	1	90107	5.E+08	4.19	2.13E+09
7/4/2007	2	92744	5.E+08	1.60	8.36E+08
8/19/2007	3	83070	5.E+08	1.47	6.86E+08
10/4/2007	4	81590	5.E+08	2.07	9.50E+08
1/4/2008	5	131906	7.E+08	2.21	1.64E+09
4/5/2008	6	133101	7.E+08	2.73	2.04E+09
5/21/2008	7	85980	5.E+08	4.57	2.21E+09
7/6/2008	8	75295	4.E+08	4.27	1.81E+09
10/6/2008	9	94211	5.E+08	3.54	1.88E+09
11/21/2008	10	116585	7.E+08	2.45	1.61E+09
2/21/2009	11	104589	6.E+08	2.06	1.21E+09
4/8/2009	12	102519	6.E+08	5.12	2.95E+09
7/9/2009	13	76651	4.E+08	2.50	1.08E+09
10/9/2009	14	79288	4.E+08	0.01	3.02E+06
2/24/2010	15	126777	7.E+08	2.87	2.05E+09
4/11/2010	16	115874	7.E+08	2.64	1.72E+09
5/27/2010	17	119436	7.E+08	3.63	2.44E+09
7/12/2010	18	130571	7.E+08	3.03	2.23E+09
10/12/2010	19	177314	1.E+09	2.63	2.62E+09

CONCLUSIONS

An estimate of total volume of lakes is derived from total area of flooded pixels and lake's depth. Within the study period, the highest estimated total volume of water in the Mahakam lakes is 6.5 billion m3 during the PALSAR data acquisition on 4 May 2007, while that of the Kapuas is about 3 billion m3 during the PALSAR data acquisition on 8 April 2009.

ACKNOWLEDGEMENT

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SELF ORGANIZING MAP (SOM) AS CLUSTER MODELLING TOOL OF ALGAL BLOOMS RISK IN MANINJAU LAKE

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ABSTRACT

Maninjau Lake is a vital water resource for West Sumatera Indonesia providing a home to aquatic species and has been used for hydropower plant, irrigation, tourism and fisheries. At the same time, Maninjau Lake suffered a catastrophic eutrophication by algal blooms for several years. It caused mass death of fish and reduce the water quality. The process of algal blooms mechanism in a lake is very complex with uncertainty in space and time. This study uses Self Organizing Map (SOM) to cluster of the water quality with uncertainty condition. SOM has advantages for information extraction without prior knowledge (unsupervised) and the efficiency of pattern classification, clustering and visualization. The input layer on-site monitoring data of water quality from 2013 to 2014 in 8 stations in Maninjau Lake were used in rainy and dry season.Findings indicate that the higher status of eutrophication, the lower accuracy that was achieved and most severe blooms outbreaks occured in rainy season.

Keywords: algal blooms, lake Maninjau, risk uncertainty, *Self Organizing Map.*

INTRODUCTION

The study of algal blooms is important because it provides indication to assess water quality in ecosystem especially in Maninjau Lake. Maninjau Lake is a volcanic lake in West Sumatera - Indonesia, providing a home to aquatic species and has been used for hydropower plant, irrigation, tourism and fisheries. The lake suffered a catastrophic eutrophication, algal blooming of *Mycrocystis aeruginosa* and hundreds ton of fish were killed (Syandri, 2000). Several researches found that those tragedies caused by cage aquaculture activity that has been increased rapidly. Cage aquaculture activity have an impact of organic materials load and increase nutrient content that stimulate algal growth. The trophic state index of Maninjau Lake tended to increase, it was mesotrophic between 2001 and 2007 and eutrophic between 2008 and 2014 (Sulastri et al., 2015). In 2011, Maninjau Lake was classified as a hypereutrophic lake (Tanjung, 2013) that caused taste and odor problems, oxygen depletion, and fish kills. The condition gets worse and mass death of fish happened again in 2013. The number of mass death of fish was about eight tons in Lake Maninjau (loss: IDR 200 Million) and fish kill happened again in 2014 with about 747,38 tons (loss: IDR 22,42 Billion) (Lukman et al., 2015).

The advance of computational technology has helped numerical algal blooms models (Hu et al.,2008). The validation of result from model application rise a problem because of slight change in parameters and add number water quality data lead to a quite different result. It is important to characterize and classify the spatial and temporal pattern of algal blooms to monitor water quality data in Maninjau Lake. Studies about algal blooms remain a significant challenge to researcher. Moreover, the study of algal blooms is a difficult task because of uncertainty condition and influenced by complex of biotic and abiotic factor and there has been little previous research conducted about algal blooms risk.

Machine learning technique such as Artificial Neural Network (ANN) has been used to solve the complexity of algal blooms process. There are two types of ANN, namely supervised and unsupervised method. SOM is one of unsupervised ANN method. The advantages of it are the efficiency of pattern, classification, clustering and visualization. SOM is used to classify blooms status with water quality data. Fuzzy Risk (FR) is used to analyse blooms risk after result of SOM is obtained.

This paper describes about SOM to present the classify and visualize of water quality data in 8 sites across a large spatial-temporal scale. The specific studies was to evaluate the cluster analysis of algal blooms data.

METHODS

Data Description

Water quality data and phytoplankton data from 8 permanent monitoring sites in Maninjau Lake (**Table 1**) from 2013 to 2014 (dry and rainy season) were collected from previous researches that have been conducted by the Research Center for Limnology, Indonesian Institute of Sciences. For each site, five parameters of water quality were taken, including chlorophyll *a* (Chl-*a*), water temperature (T), Dissolved Oxygen (DO), Concentration of Total Nitrogen (TN) and Total Phosphorus (TP).

Table 1. The Location of 8 Stations in Maninjau Lake

No	Sampling Area	Latitude	Longitude
1	Mukomuko	0°17'10.6" S	100°09'13.8" E
2	Pandan	0°22'29.1" S	100°13'13.6" E
3	Rambay	0°16'14.5" S	100°09'43.5" E
4	M. Tanjung	0°15'17.4" S	100°11'1.4" E
5	Lubuk Anyir	0°16'16.4" S	100°12'52.0" E
6	Lubuk Kandang	0°17'02.8" S	100°13'26.8" E
7	Bancah	0°19'04.3" S	100°13'27.7" E
8	Banda Gadang	0°20'14.3" S	100°13'10.2" E

Self Organizing Map (SOM) to classify bloom status

For each pattern x one neuron n will "win" (which means that w_n is the weights vector more similar to x) and this winning neuron will have its weights adjusted so that it will have a stronger response to the input the next time it sees it (which means that the distance between x and w_n will be smaller. The training algorithm can be summarized as follows (Kohonen,2001):

- Initialize the weights of each neuron. Initialize t= 0, t is the current time-step (iteration of the loop)
- Randomly pick an input x from the dataset . Determine the winning neuron i as the neuron such that

$$\underset{i}{\operatorname{argmin}} \|x - w_i\|$$

(*w* = Weights between every nodes data which is 0<w<1)

- Adapt the weights of each neuron n according to the following rule

$$w_n = w_n + \eta(t)h(i)(x - w_n)$$

- Increment t by 1. if $t < t_{max}$ go to step 3

$\eta(t)$ is called *learning rate* and $h(i)$ is called ***neighborhood function*** which has high values for i and the neurons close to i on the lattice (a Gaussian centered on i is a good example of neighborhood function). When t increases η decreases and h decreases its spread. This way at each training step the weights of the neurons close to the winning one are adjusted to have a stronger response to the current pattern. After the training process, the locations of the neurons become ordered and a meaningful coordinate system for the input features is created on the lattice.

```
Import modules
Input data samples
print 'size of data set:

Initialize weights
//Training data
For 0 to X number of training epochs
Select a sample from the input data set
Find the "winning" neuron for the sample input
Adjust the weights of nearby neurons
```

Figure 1. Algorithm module for SOM

Fuzzy Risk (FR) to analyze algal blooms risk

Fuzzy risk calculates the possibility and probability risk by interior-outer set model (IOSM). IOSM was applied to calculate the probability and possibility risk of the various bloom statuses. The possibility–probability risk calculated using the IOSM is referred to as fuzzy risk. IOSM was applied to calculate the possibility–probability risks of the various bloom statuses. Let X={xi | i=1, 2,…, n} represents the observed records of bloom status evaluated by the SOM network, where xi ∈ R (real number set) and n was the number of records. Since X represented the bloom status that was normalized into [0, 1], the universe of X was [0, 1], and was donated as U. Let u1, u2,…, uj,…, um represent discrete points with a given step length Δ, and use the same U to represent the discourse domain,we had U = { u_j | j=1, 2,…, m}. From an information distribution point of view, observation xi can allocate its information with a value of qij to point uj, as expressed by the following equation (Chen,2014) :

$$q_{ij} = \begin{cases} 1 - |x_i - u_j|/\Delta & \text{if } |x_i - u_j| \le \Delta \\ 0 & \text{else} \end{cases} \tag{1}$$

where xi is the bloom status value, u_j is a controlled point, and Δ is the step length of the controlled point. Define an interval Ij as the following:

$$I_j = \left[u_j - \frac{\Delta}{2}, u_j + \frac{\Delta}{2}\right] \qquad j = 1, 2, \ldots m. \tag{2}$$

For the purpose of computation, the definition of the interior set and outer set of Ij is as follows:

Interior set: $X_{in-j} = x \cap I_j$, i.e. a set composed of all elements contained within I_j.

Outer set: $X_{out-j} = \overline{X_{in-j}}$, i.e. a set composed of all elements not contained within I_j.

∀ xi ∊ X, if ∀ xi ∊ Xin - j, it loses information by gaining at 1 − qij to other interval, denoted as qij −; if ∀ xi ∊ Xout - j, it gives information by gaining at qij, denoted as qij +. So for Ij with information gain at qij, the possibilities can be formulated as follows:

$$q_{ij}^{-} = \begin{cases} 1 - q_{ij} & x_i \in X_{in-j} \\ 0 & x_i \in X_{out-j} \end{cases} \tag{3}$$

$$q_{ij}^{+} = \begin{cases} q_{ij} & x_i \in X_{out-j} \\ 0 & x_i \in X_{in-j} \end{cases}. \tag{4}$$

With IOSM method, the possibility–probability distribution of different bloom statuses was estimated for each specific site. Although the fuzzy risks can show the uncertainty of bloom occurrence, sometimes the composite risk that transforms the fuzzy risks into crisp risks was required.
The risk can be calculated by the alpha-cut fuzzy approach:

1. the higher the value of α, the lower the degree of uncertainty
2. the lower the value of α, the higher the degree of uncertainty, resulting in lower probability serviceability.

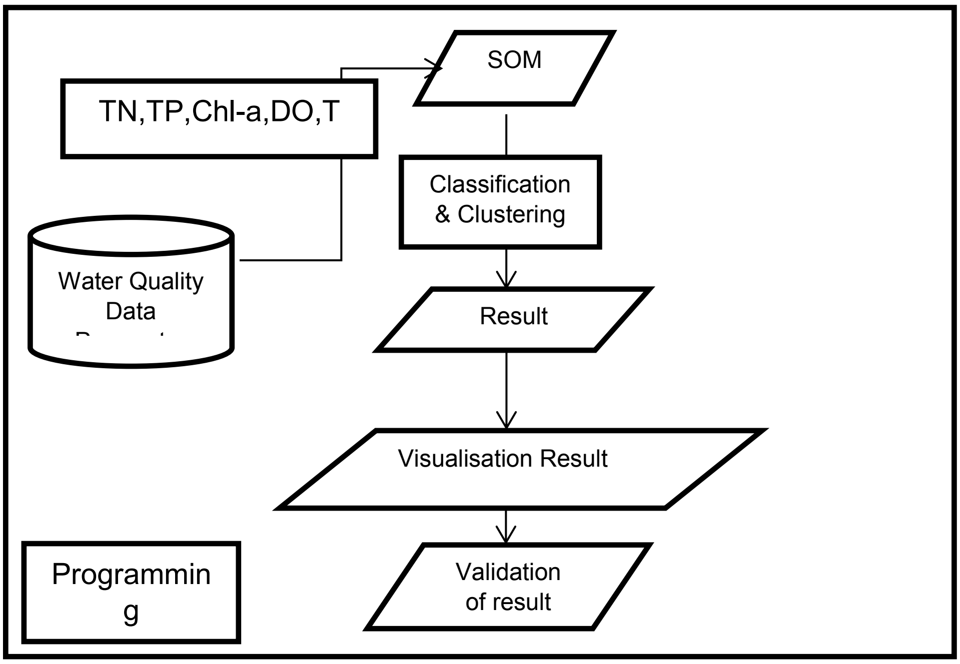

Figure 2. Data flow diagram

RESULTS AND DISCUSSIONS

Based on location of stations, algal blooms risk map was divided into 5 regions: I (Mukomuko and Rambay), II (M. Tanjung), III (Lubuk Anyir and Lubuk Kandang), IV (Bancah), and V (Banda Gadang and Pandan) as shown in **Fig 3**.

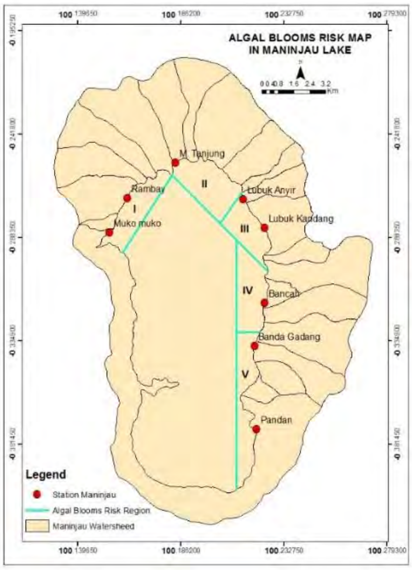

Figure 3. Algal blooms risk map in Maninjau Lake

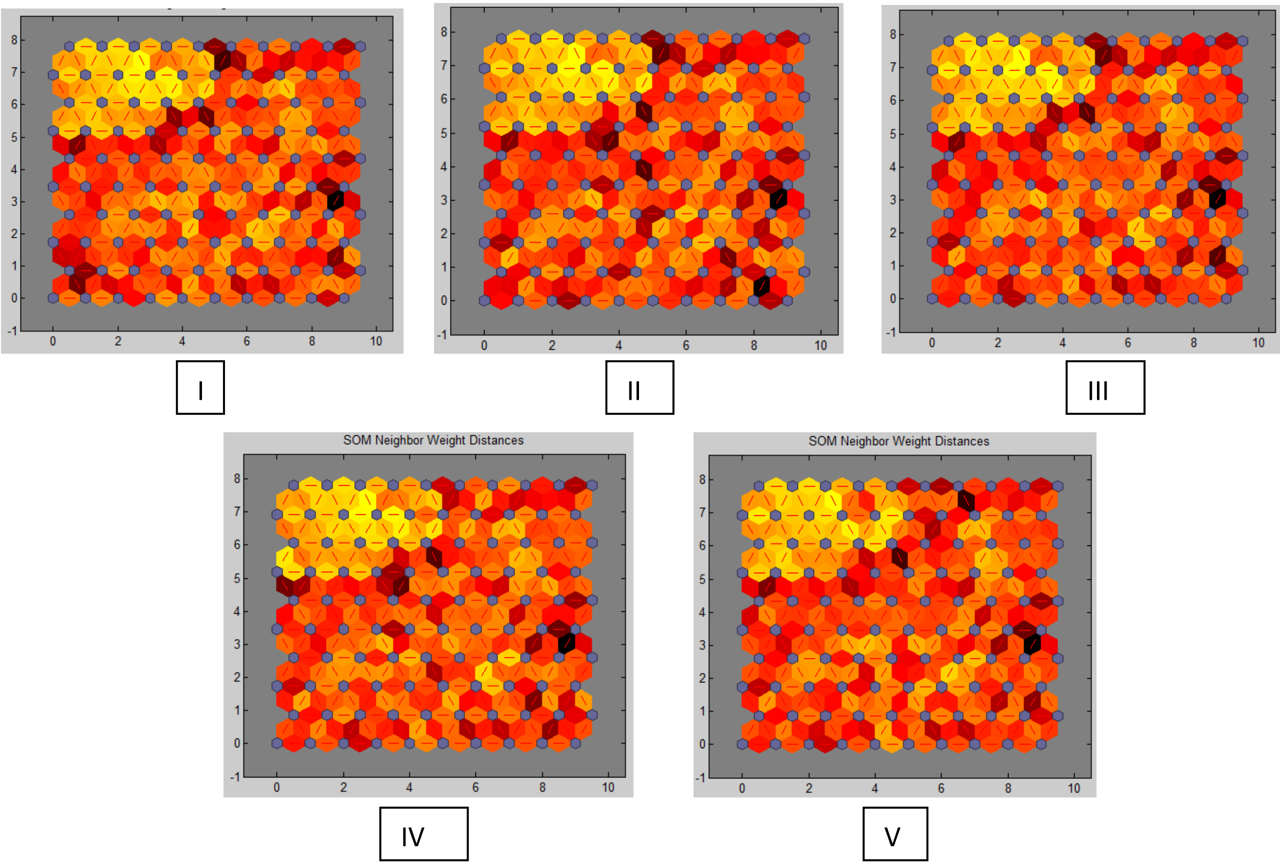

Figure 4. SOM Nearest Neighbour Distance Result 2013-2014 for (I) TN, (II) TP, (III) chlorophyll *a*, (IV) Temperature, (V) DO

As shown in **Fig 4**, the blue hexagons represent the neurons. The red lines connect neighbouring neurons. The colours in the regions containing the red lines indicate the distances between neurons. The darker colours represent larger distances, and the lighter colours represent smaller distances. A band of dark segments crosses from the lower - center region to the upper-right region. The SOM network appears to have clustered data into two distinct groups.

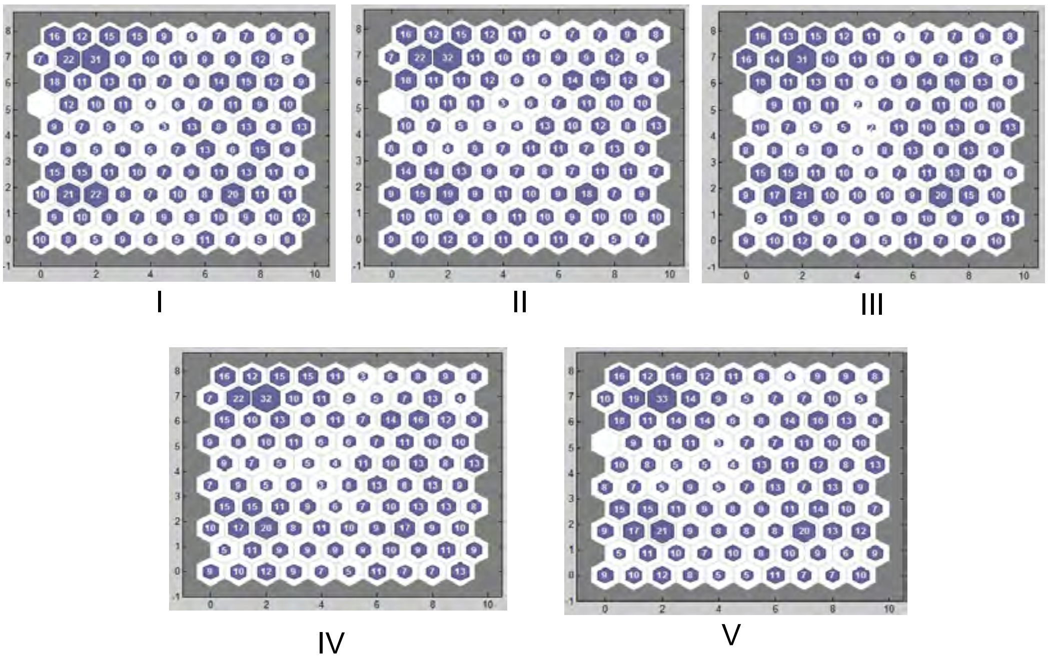

Figure 5. SOM Plot hits Result 2013-2014 for (I) TN, (II) TP, (III) chlorophyll *a*, (V) Temperature, (VI) DO

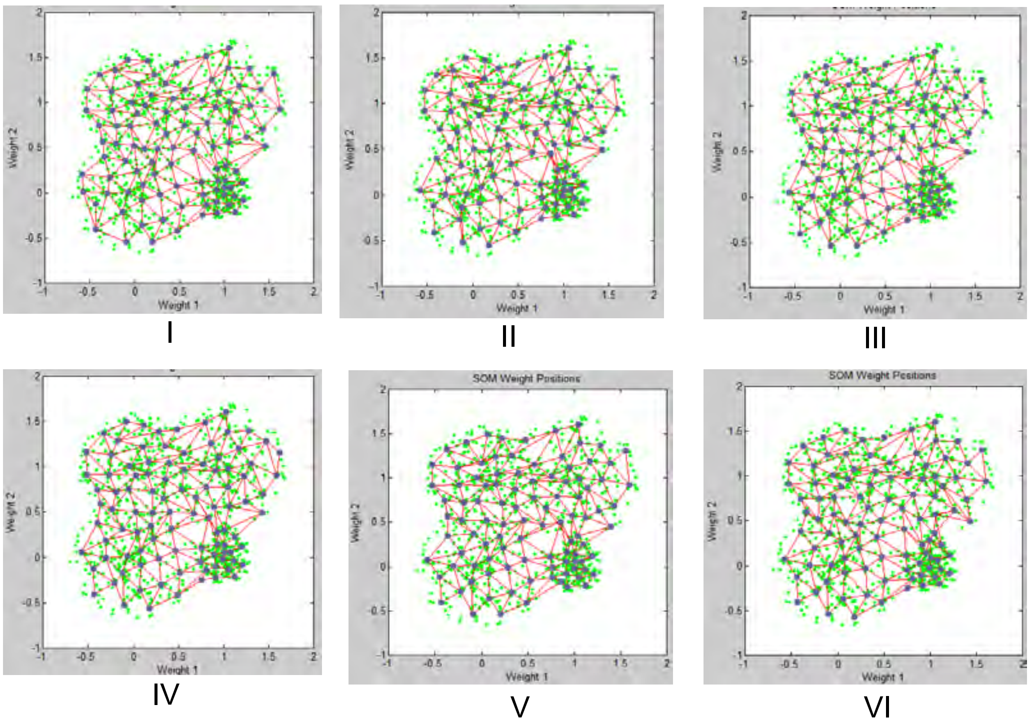

Figure 6. SOM Weight Point Position Result 2013-2014 for (I) TN, (II) TP, (III) chlorophyll *a*, (IV) Temperature, (V) DO

Table 2. Characteristic values of water quality factors for different bloom statuses

Bloom Status	Characteristic Values	Chl-a (µg/L)	T (°C)	TN (mg/L)	TP (mg/L)	DO (mg/L)
No Bloom	Std. Deviation	1.9593	0.2645	0.0338	0.0078	0.2646
Light Bloom	Std. Deviation	2.5669	0.2646	0.0234	0.0036	0.1732
Moderate Bloom	Std. Deviation	0.2306	0.0577	0.0387	0.0072	0.3500
Severe Bloom	Std. Deviation	5.6736	0.3109	0.6834	0.0344	0.2872

Table 2 shows that the more serious the bloom status, the higher the concentration of chlorophyll *a*, TN, and TP. These conditions represent the fact that algal blooms sometimes are natural phenomena, but their frequency, duration and intensity are increased by nutrient pollution. Algae can multiply quickly in waterways with an overabundance of nitrogen and phosphorus (Wetzel, 2001). Furthermore, Wetzel (2001) said that algal blooms tend to increase when the water is warm, but the T mean values in **Table 2** decreased with the higher bloom status and T median values were fluctuate.

DO concentration in **Table 2** increase aligned with the bloom status. According to ESA (2008), algae produce oxygen during the daylight hours as a by-product of photosynthesis. This is usually a major source of oxygen in lake. In darkness, however, all plants consume oxygen, including algae. Algae blooms in natural water bodies normally produce much more oxygen in the daylight than they consume during the night, but some situations reduce the amount of oxygen a bloom produces without reducing its night time oxygen consumption. Trace minerals or nutrients needed by the algae are occasionally used up, causing some or even all, of the bloom to die back temporarily. The resulting bacterial decomposition and loss of normal oxygen production can lead to oxygen depletions and fish kills.

The status for Algal blooms was classified into four categories : No bloom, light bloom, moderate bloom and severe bloom. The existence of fish cages in Maninjau Lake is a major factor of anthropogenic influence that contribute to water quality. It contributes to nutrient supply in water body. Algae tend to grow very quickly under high nutrient availability. Therefore, these location of cages were classified as moderate and severe bloom. Hypoxic or very low oxygen condition may result when algae die and decompose stripping water of dissolved oxygen, leading to fish kills and degrading the aesthetic and recreational value of the lake (ESA, 2008). One of fish killed incident was happened on August, 2014 with the loss of 350 tons of fish in Mukomuko. That was the fifth tragedy in 2014, previous tragedy of fish killed was happened on January (twice), March and in early August 2014 (Maulana, 2014).

Table 2, Chl-*a* content in Maninjau Lake was in the range of 11.95 to 27.40 µg/L. According to Wetzel (2001), Maninjau Lake was classified as eutrophic because the content of Chl-a was more than 11 µg/L. Temporal variation analysis showed that most severe bloom outbreaks in rainy season than dry season. This can cause more nutrient runoff into water bodies. Several locations in Maninjau Lake area surrounded by agriculture lands, hotel, restaurant and residential area. Anthropogenic factors can dramatically increase the concentration of nutrients in water bodies, a phenomenon known as "cultural eutrophication" (Hasler, 1974). In Maninjau Lake, human-induced pollution and accelerating eutrophication through the impacts of runoff from residential and agricultural areas which carries fertilizer, pesticides, detergent wastes, effluents from hotel and restaurant. The water quality of inflows from the southeast area is better than that from the north. Therefore, more effort should be taken to manage moderate and severe blooms in the north area of the lake.

CONCLUSIONS

SOM was successfully used to search for suitable membership and clustering from the data. The method has proved to be a promising modeling tool for algal bloom risk in Maninjau Lake. The Result of algal bloom risk is depended on complexity of data. One of the deficiencies in this model is lack of data. It must be decision-makers with deeper insight and a more comprehensive overview of algal bloom risk and uncertainty, which is helpful for practices for monitoring algal bloom. For more details about fuzzy risk in eutrophication lake Maninjau will be present in the future.

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A LAND COVER MAP ACCURACY METRIC FOR HYDROLOGICAL STUDIES

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ABSTRACT

Land cover (LC) has a significant impact on rainfall-runoff dynamics of a watershed, so LC maps are often incorporated into hydrological models to simulate how changes in climate or land management will affect water quantity/water quality within the watershed. The accuracy of a LC map can thus affect the accuracy of hydrological modelling results. However, because LC maps are not typically produced specifically for hydrological studies, the conventional LC map accuracy metrics may not be the most relevant. In this study, we proposed a new metric for LC map accuracy assessment, calculated as the root-mean-square-deviation (RMSD) of the mapped (i.e. estimated) and "ground truth" runoff curve numbers (CN) at randomly-sampled locations. The new metric, CN-RMSD, assesses the accuracy of the direct runoff estimates derived from the LC map, and its benefit over the traditional LC accuracy assessment metrics is that it more heavily weights LC classification errors that cause greater errors in estimated runoff. Ground truth CN data can be collected much in the same way as ground truth data is collected for the traditional accuracy metrics, although a soil map can improve the accuracy of the ground truth CN values. Some potential applications of CN-RMSD, e.g. for LC map selection and LC map fusion, are also discussed.

Keywords: hydrological modelling, land cover accuracy assessment, rainfall-runoff, remote sensing, SCS curve number

INTRODUCTION

Hydrological models are often used to estimate the water quality and/or water quantity of lakes and rivers under different climate and land/water management scenarios (Thirel et al., 2015). In terms of watershed land management, land cover (LC) conditions have a significant impact on hydrological processes (e.g. rainfall runoff and infiltration), so many hydrological models incorporate LC maps as input datasets. For this reason, the accuracy of a LC map can also affect the accuracy of hydrological modelling results (Cotter, Chaubey, Costello, Soerens, & Nelson, 2004). LC maps are typically produced by classifying pixels in a satellite or aerial image into different LC classes using an image classification algorithm (Jensen, 2005), and the LC map's accuracy is then calculated by comparing the "classified" LC type with the "ground-truth" LC type at a number of randomly-sampled pixel locations (Congalton, 2009). Ground truth LC data for this accuracy assessment is either obtained in-situ (through a field survey) or remotely (by visual image interpretation). Accuracy assessment is an important research topic for both LC map producers and LC map users, and although we just briefly introduce the topic here, readers can refer to some recent studies for a better understanding of various issues related to accuracy assessment (Castilla, 2016; Congalton, 2009; Johnson, 2015; Olofsson et al., 2014).

Several conventional LC map accuracy metrics exist, with the most common being overall accuracy (# of correctly classified sample pixels / total # of sample pixels) (Congalton, 1991). However, the existing metrics do not take into account that some types of classification errors are more problematic than others when it comes to simulating hydrological processes. As an example, consider two cases: In Case 1, a pixel in a LC map is classified as "built-up/impervious area" but in truth contains "forest", and in Case 2, a pixel is classified as "built-up/impervious area" but in truth contains "bare soil". Of these two cases, Case 1 is the more serious error due to the greater difference in runoff rates of impervious and forested lands (Soil Conservation Service, 1986).

Due to the limitation of the existing LC map accuracy metrics, the objective of this study was to develop a new metric more relevant to hydrological processes. This new metric is based on the well-known U.S. Soil Conservation Service runoff curve number (CN) approach for calculation of direct runoff (i.e. surface and immediate subsurface runoff), which takes into account the LC and soil properties of the land (Soil Conservation Service, 1986). Before describing the new metric, we first briefly introduce the

CN. CN is related to the maximum potential soil moisture retention of the land (S), and the CN calculation method was developed by the USDA from an empirical analysis of rainfall (P) and runoff (Q) measurements at field test sites. S and CN values were calculated using the measured values of P and Q and an estimate of the initial abstraction (I_a), i.e. the amount of rainfall that could be retained in the soil or vegetation before runoff begins (assumed to be = 0.2S) (Soil Conservation Service, 1986). *CN* is given by:

$$Q = \frac{(P - Ia)^2}{P - Ia + S} = \frac{(P - 0.2S)^2}{P - 0.8S} \qquad P > Ia$$

and

$$CN = \frac{1000}{10 + S}$$

Higher CN values indicate higher potential runoff rates (see **Table 1** for some examples for different LC/soil types**)**. A spatially-explicit CN map can be produced by overlaying a LC map and a soil map using Geographic Information Systems (GIS) software. The CN is the foundation of many hydrology algorithms, including those in most simulation models developed by the U.S. Department of Agriculture for hydrology, soil erosion, and nonpoint water quality estimation (Garen & Moore, 2005).

Table 1. Runoff Curve Number (CN) values of four common types of land cover (LC), adapted from the Table 2-2 of Soil Conservation Service (1986). Higher CN values indicate higher runoff potential.

	Hydrologic Soil Group (HSG)			
Land cover (LC)	A	□	C	D
Built-up/impervious area	98	98	98	98
Bare soil	77	86	91	94
Pasture, grassland, or range (>75% ground vegetation cover)	39	61	74	80
Forest (litter and brush covering the soil)	30	55	70	77

Because of the importance of the CN for various types of hydrological analysis, our proposed LC map accuracy metric is calculated as the root-mean-square-deviation (RMSD) of the mapped (i.e. predicted, or estimated) and ground truth (i.e. actual) CN values at randomly-sampled pixel locations. This new metric, CN-RMSD, assesses the accuracy of the direct runoff estimates derived from a LC map, making it a better indicator of the LC map's suitability for studies related to rainfall-runoff dynamics. To our knowledge, CN-RMSD is the first LC map accuracy metric developed specifically for hydrological applications. In the remainder of this paper, we provide a step-by-step approach to calculating CN-RMSD (Methods section) and identify some possible ways in which the new metric can be used in practice (Results and Discussions section).

METHODS

There are seven main steps for calculating CN-RMSD, and they can be performed using many free (e.g. QGIS) or commercial (e.g. ESRI ArcGIS) GIS software packages:

1. Obtain or create a LC map of a study area watershed;
2. Overlay the LC map onto a hydrologic soil group (HSG) map of the study area (more information related to HSGs given below after the main steps);
3. Generate a CN map of the study area using the LC map, the HSG map, and the lookup table provided in Soil Conservation Service (1986);
4. Randomly generate *n* sample points within the study area;
5. Extract the "mapped CN values" at these sample point locations from the CN map;
6. Identify the "ground truth CN values" at these sample point locations. A field survey or visual image interpretation can be conducted to identify the ground truth LC. The HSG map can be used to identify the ground truth soil properties (although the HSG map is unlikely to be 100% accurate, it is usually the best reference data available); and
7. Calculate the RMSD of the mapped (CN_{mapped}) and ground truth CN (CN_{GT}) values at these *n* sample point locations. CN-RMSD is calculated as:

$$\text{CN-RMSD} = \sqrt{\frac{\Sigma(CN_{mapped} - CN_{GT})^2}{n}}$$

Regarding the HSG map (step 2), soils can be generally classified into one of four HSGs – '*A*' ("sand, loamy sand, or sandy loam"), '*B*' ("silt loam or loam"), '*C*' ("sandy clay loam"), or '*D*' ("clay loam, silty clay loam, sandy clay, silty clay, or clay") – based on the minimum infiltration rate of the soil (Soil Conservation Service, 1986). A lookup table for identifying the HSG of many different soil types has also been provided by the U.S. Soil Conservation Service (1986). If a reliable soil map is not available for a watershed, the entire watershed area can alternatively simply be assigned to the dominant HSG of the watershed based on the hydrologist's knowledge of the typical soil conditions of the area. For easier understanding of the CN map generation process, a CN lookup table for a few selected LC classes is shown below in **Table 1**, and a LC map and its corresponding CN map are shown in **Fig. 1** to allow for a visual comparison. Regarding the appropriate number of sample points needed for calculating CN-RMSD (i.e. value of *n* in step 4), although no hard rules exist, for conventional LC map accuracy assessments a good "rule of thumb" is to collect a minimum of 50 samples for each LC class (Jensen, 2005), so this same rule of thumb could probably also be applicable for accuracy assessments based on CN-RMSD.

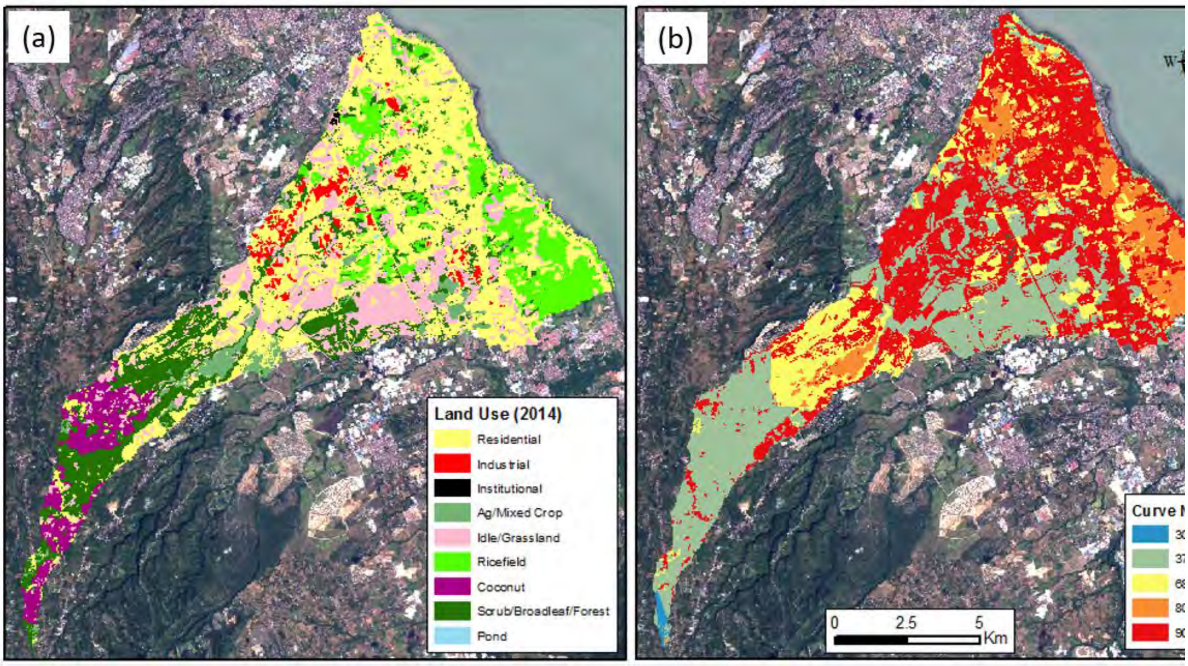

Figure 2. Land use/land cover map of the Silang-Santa Rosa sub-watershed in The Philippines (a) and the corresponding CN map (b) [soil map not shown for illustration simplicity]. LC classes with greater impervious surface area (e.g. "Residential" and "Industrial") appear red in the CN map (high CN values), while LC classes with greater vegetation cover (e.g. "Scrub/broadleaf forest" and "Coconut") appear green or yellow (very low CN values) depending on the hydrologic soil group of the underlying land.

RESULTS AND DISCUSSIONS

In this section, we discuss some ways in which the proposed metric, CN-RMSD, could be used in practice for hydrological studies.

If multiple LC maps exist for a watershed of interest, a commonly occurrence nowadays with the growing number of global/regional/national LC maps available, there are a few ways in which the CN-RMSD metric can be useful. As one example, CN-RMSD values could be calculated for each of the available LC maps, and the map with the lowest CN-RMSD value could be selected as the most appropriate map to use for hydrological analysis. Alternatively, CN-RMSD could be utilized for fusing, or combining, the CN_{mapped} values derived from multiple LC maps (i.e. CN_{mapped_1}, CN_{mapped_2}, …). As a simple example, if CN-RMSD is calculated locally pixel-by-pixel, e.g. based on the nearest 10 sample points with CN_{GT} information as shown in **Fig. 2**, then the most locally-accurate CN map can be identified at each pixel location. All of the most locally-accurate CN_{mapped} values could then be combined to produce a "fused" CN map with higher accuracy (lower CN-RMSD). Aside from this simple example, various other methods for geographic data fusion exist, including geographically-weighted regression based fusion methods (See et al., 2015) and machine-learning based fusion methods (Johnson, Scheyvens, & Shivakoti, 2014). For all of the map fusion methods, the different LC maps would first need to be resampled to a common spatial resolution and coordinate system.

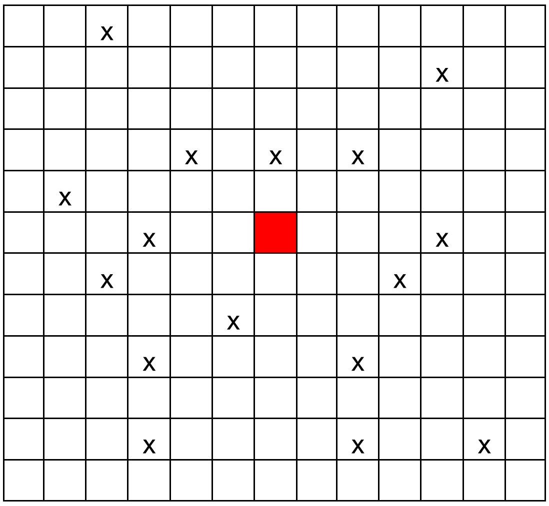

Figure 2. Simple approach for fusing multiple CN maps based on local CN-RMSD calculations. The red cell indicates the pixel for which the local calculation is being performed, and cells with “x” indicate sample pixels containing ground truth CN information. The 10 nearest sample pixels (shown in red) could be used to calculate CN-RMSD locally, and the map with the lowest CN-RMSD value could be identified as the most accurate at the red pixel location. [Note: we use the nearest 10 sample points for demonstration purposes only].

In addition to its usage to select or combine information from multiple LC maps, CN-RMSD could also be used to help better understand sources of uncertainty in a hydrological model’s results, which may be affected by various other factors including errors in the precipitation data, errors in the digital elevation model, and errors in water level or streamflow data. Finally, CN-RMSD may be helpful for the calibration of hydrological models with parameters related to CN. For hydrological model calibration, it is useful to have an idea before-hand of the realistic range of values of different model parameters (to avoid setting parameter values that are physically unrealistic or impossible), so CN-RMSD could be used to define a realistic range of values for the CN parameter(s) in a hydrological model. Several commonly-used hydrological models have CN parameters (e.g. The Soil and Water Assessment Tool (Neitsch, Arnold, Kiniry, & Williams, 2011)).

CONCLUSIONS

In this study, a new land cover (LC) map accuracy metric was developed with hydrological studies in mind. The metric is calculated as the root-mean-square deviation (RMSD) of the mapped (i.e. estimated) and ground truth runoff curve numbers (CN_{mapped} and CN_{GT}, respectively) at randomly-sampled locations in the LC map. Unlike conventional LC map accuracy metrics, the new metric, CN-RMSD, more heavily penalizes LC classification errors that cause greater errors in predicted runoff, making it a better indicator of a LC map’s suitability for hydrological analysis. Some potential uses of CN-RMSD for LC map selection, map fusion, and uncertainty analysis are also discussed.

ACKNOWLEDGEMENT

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INVESTIGATION ON RELATIONSHIP BETWEEN LAND COVER AND WATER QUALITY CHANGES IN LAGUNA DE BAY, THE PHILIPPINES, OVER THE 2007-2015 PERIODS

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ABSTRACT

In this study, we assessed the relationship between land cover change and changes in water quality in the Laguna de Bay area of the Philippines. Land cover changes occurring between 2007 and 2015 were mapped using a combination of optical (Landsat-7/-8) and synthetic aperture radar (ALOS Palsar-1/-2) satellite imagery, and time-series water quality data from five different stations situated in the Laguna lake were obtained from the Lake Laguna Development Authority. To study the effects of land cover changes on water quality at these different stations, the lake and its surrounding watershed area was first subdivided into five non-overlapping zones based on the generation of Thiessen polygons. Then, in each of these five zones, regression modelling was performed to assess the correlation between the changes in land cover (annual changes of "built-up" land cover type in ha.) and the change in water quality parameters. In future work, we plan to use the regression modelling results to predict some potential impacts of future land cover changes in each zone as well as in in the entire Laguna de Bay area. We also explore other explanatory factors of the lake water quality changes (e.g. other types of land conversions, changes in agricultural and industrial practices).

Keywords: land cover change, water quality, watershed, eutrophication, ecosystem services

INTRODUCTION

While they provide numerous ecosystem services, including water resources, flood control, ecosystem, and habitats for biodiversity, lakes are increasingly threatened by human activities such as the intensified use of surface waters; the exploitation of shoreline properties; and the pollution from domestic, agricultural, and industrial activities (ILEC, 2016). One of the most widespread environmental problems of lakes is water quality degradation, which can affect the health of humans and the environment (UNEP, 2001).

Runoff from intensive land-use areas such as urban developments and agricultural fields are a major source of nutrient pollution, leading to lake water quality degradation (Trolle et al., 2014; Wu, Long, Liu, & Ma, 2013; Xu & Zhang, 2016). For example, high levels of nitrogen (N) and phosphorus (P) are found in runoff from agricultural lands due to the applications of fertilizers, pesticides, etc., which are then transported to rivers during storms (Ahearn et al., 2005; Fisher, Breeze, Boynton, & Williams, 2006). Runoff from urban areas is also high in pollutants (Johnes, 1996; L. B. Johnson, Richards, Host, & Arthur, 1997). The change in land cover from vegetated areas to built-up areas contributes to this by increasing runoff.

In the Laguna de Bay area of the Philippines, land-use and land cover has changed significantly in the last few decades, and serious water degradation has been observed. Algal blooms frequently occur, for which nitrogen is considered as the main factor (Santos-Borja & Nepomuceno, 2004). Land conversion and land-use intensification are still occurring rapidly in many areas around the lake, so in this study we assessed the relationship between recent land cover changes and changes in water quality (Total N concentration). Unlike other previous studies that qualitatively described urbanization and industrialization as the cause of water degradation, this study quantified their impacts on the lake water quality by examining historical data.

METHODS

Study area

Laguna de Bay, located 15 km southeast of Metro Manila, is the largest lake in the Philippines (**Figure 1**), and its basin is one of the most important economic bases in the country (Laguna Lake Development Authority, 2016). The total area of the lake, including its watershed area, is approximately 3,813.2 km^2 (Lasco & Espaldon, 2005), and the surface area of the lake is 900 km^2 with the water volume of 2.19 billion m^3 and an average depth of 2.5-meters (Tongson & Faraon, 2012). There are 66 local governments in the lake basin where about six million people reside (Santos-Borja & Nepomuceno, 2004).

Figure 1. Laguna de Bay, Philippines (Santos-Borja & Nepomuceno, 2004)

Land cover change in the basin

Due to urbanization and industrialization, there has been a significant land conversion in the basin in the past few decades. Vegetated areas were converted to built-up areas for residential, industrial, and commercial purposes (**Figure 2**). This change is obvious particularly in the western part of the lake basin where woodlands and croplands/grasslands were altered for the other economic activities.

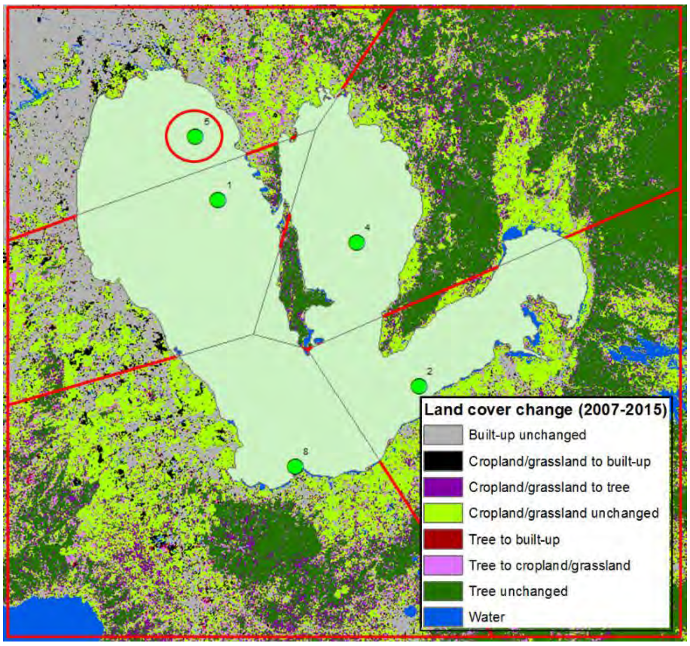

Figure 2. Land cover changes between 2007 and 2015 in the Laguna de Bay area. Points in light green in the lake indicates the location of five sampling stations for lake water quality. The lake and its watershed are divided into five zones according to the stations. The point with red circle is Station V whose data were used for this study.

Regression analysis
The general form of the empirical watershed model (Ryding & Rast, 1989) that this study employed is:

$$Y = a_0 + a_1 X_1$$

where Y = average annual nutrient load to a waterbody;
X_1 = area (ha) of watershed with land use 1; and
a_0, a_1 = coefficients.

Time-series water quality data from five monitoring stations (i.e. Stations I, II, IV, V, and VIII) situated in the lake were obtained from Laguna Lake Development Authority. Land cover changes between 2007 and 2015 were mapped using a combination of optical (Landsat-7/-8) and synthetic aperture radar (ALOS Palsar-1/-2) satellite imagery (for further information, see Johnson et al. (in review). To study the effects of localized land cover changes on water quality, the lake and its surrounding watershed area were subdivided into non-overlapping zones based on the generation of Thiessen polygons (Figure 2). In each zone, regression modelling was performed to assess the correlation between the changes in land cover (annual changes of "built-up" land cover type in ha.) and the change in water quality parameters. Only Station V data was used finally because the other stations did not have data for a long enough timeframe to coincide with our land cover change data. For the same reason, N data was used as a water quality parameter for the analysis.

RESULTS AND DISCUSSIONS
The regression analysis shows a relatively strong correlation (R^2 = 0.731) between the change in built-up area near Station V and the change in mean annual N concentrations of Station V (Figure 3). This indicates that lake water quality (total N) has been decreasing at a near-linear rate with the increase in built-up area (in ha.). If we assume that the built-up area increases at a similar rate in the future, we can extrapolate that N concentrations would increase over the next decade to 2.8 in 2025. To prevent the lake water quality from deteriorating, measures should be taken not only to conserve existing vegetated areas, but also to mitigate runoff from built-up areas if vegetated areas are converted. Such runoff-mitigation measures include tree planting, water-permeable paving, and vegetated roofs. In the future, we plan to expand our study to consider additional water quality parameters, other causal factors of water quality degradation (e.g. other types of land conversions, changes in agricultural and industrial practices), and alternative approaches for monitoring water quality (e.g. using satellite remote sensing technology).

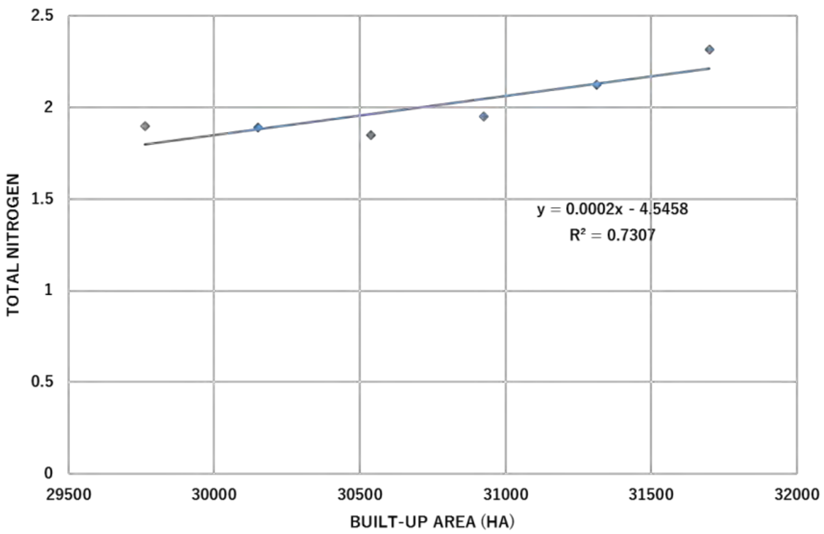

Figure 3. Relationship between land cover change and lake water quality at Station V

CONCLUSIONS
This study examined the relationship between the changes in land cover of the Lake Laguna basin and those in the lake water quality. The regression analysis indicates that there is a positive correlation between the change in built-up area and change in N concentrations, suggesting that as vegetated

areas (e.g. croplands, forests) become built-up areas for other uses such as residences, the mean annual N concentrations of the Laguna de Bay increase. To prevent further degradation of the lake water quality, measures to alleaviate runoff from built-up areas (e.g. tree planting, water-permeable paving) are necessary. Given the projected future land cover of the basin, the estimated regression model could project the additional degradation or improvement of the lake water quality.

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ASSESSMENT OF HYDROLOGIC ALTERATION WITHIN ECOSYSTEM IN A SAHALIAN SHALLOW LAKE: LAKE GUIERS, SENEGAL

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ABSTRACT

In this study, daily streamflow data of 35 years records and water quality data were investigated to determine Lake Guiers hydrologic alteration within its ecosystem. The Range of Variability Approach (RVA) was used to quantify the modification of the Indicators of Hydrologic Alteration (IHA) and the trophic State Indices (TSIs) was calculated to characterize the eutrophication level. Results show that the flow pattern at Lake Guiers is reversed from the pre-impact with high alteration on most of indicators. These changes on flow have greater impacts on the lake ecological functioning and on water quality. The trophic State Indices (TSIs) of Nitrogen (N) and Phosphorus (P) indicate respectively a eutrophic and hypereutrophic state. Lake Guiers hydrological alteration endanger its ecological integrity. Its restoration requires more than ever to reconcile economic needs and ecological requirements.

Keywords: Environmental flow, hydrologic alteration, indicator, Lake Guiers, Senegal, streamflow

INTRODUCTION

River flow regimes are considered to be the primary driving force of the river ecosystem (Poff et al., 1997). The integrity and stability of river ecosystems is largely dependent on the natural dynamic change characteristics of the streamflow (Poff et al., 1997). The development and management of water resources by humans has altered the natural flow of rivers around the world (Richter et al,.1997). Taking the example of Senegal River Basin (SRB), the downstream flow regime has been widely affected when the Senegal River Development Organization (OMVS), a regional cooperative management body of the Senegal River built along the river two dams (Diama 1985 and Manatali 1987) and structures (sluices, dikes, irrigation systems) in order to meet economic and social development needs for water resources.

In Lake Guiers, one component of the Senegalese River system, several studies have been carried out on first-order impacts in hydrology resulting from dam's operation. Water quality and environmental hazards in general are among the focus of research in the last twenty years. Bouvy et al., (2006) describes the phytoplankton/environment relationships and provides valuable information on algal strategies in a shallow tropical lake like Lake Guiers. Seasonal variations of zooplankton communities and their interactions with phytoplankton and environmental parameters has been investigated by Ka et al. , (2011). They find out the existence of seasonality in zooplankton communities and confirm the importance of using biological indicators such as phyto- and zooplankton to monitor Lake Guiers water quality. Sané, et al., (2013); Varis & Jussila, (2002) focused on Lake Guiers's eutrophication level and conclude that its management has to be revised because of changes in water quality and ecosystem and increasing pressure on its water resources. Berger et al., (2006) point out seasonal dynamics that will constitute an increasing challenge in Lake Guiers.

The impact of dams and the multipurpose use and water quality challenge in Lake Guiers has been investigated by Cogels et al., (1997; 2001). They describe the water quality effects on the management of the lake, with special emphasis on salinity and eutrophication. Recently by remote sensing tools (Diop et al., 2008; Merem & Twumasi, 2008) assess water quality. They compared the FUB-predicted image and study results with those from earlier studies and revealed good correlation.

As we can notice a large number of studies carried out have been focusing on water quality, hydro-biology, invasive aquatic plants, while limited research in view streamflow pattern (magnitude, duration, frequency, timing, and rate of change). Assessment of these streamflow characteristics is essential for understanding and predicting the biological impact of both natural and altered flow regimes on riverine biota (Zuo & Liang, 2015). In Lake Guiers this assessment is particularly important since 2013, the Lake Guiers authority has undertaken a wide project that aim to "restore the ecological and economic functions of the Lake". The main actions planned are: dredging channel, rehabilitating dyke, constructing water supply network and a crossing structure. How are the physical components expected to change after the re-planned development and what is the expected effect on ecological condition?

Accordingly, researchers have developed and applied methods to quantify indicators and to assess alteration in a flow regime through time. A great number of methods has been suggested for this purpose. The 33 Indicators of Hydrologic Alteration (IHA) (Richter et al., 1996) are intended to represent each of the major facets of the flow regime (Olden & Poff, 2003). As one set of proposed hydrologic indices assessment, the Streamflow Analysis and Assessment Software (SAAS) 4.0 (Metcalfe et al., 2013) was developed based on/focusing on hydrology-based environmental flow methods. It calculates hydrological indicators through time with respect to a reference condition, and relate hydrological alteration to changes in ecological condition (Metcalfe & Schmidt, 2014). The Range of Variability Approach (RVA) was established to evaluate the hydrologic alteration caused by hydraulic control structures (Richter et al., 1997, 1998). In this study, we focus on changes in the hydrologic regime and its potential impacts on ecosystem caused by dam's operation. To assess this particular impact, time series of daily mean discharge for Ngnith station (water treatment plant) were evaluated using the Indicators of Hydrologic Alterations (IHA) (Richter et al., 1996; 1998) and RVA associated SAAS (Metcalfe et al., 2013). Comparison of pre- and post-dams periods allows evaluation of their effects on hydrology and ecosystem. The ability to assess the condition of lake and river ecosystems, evaluate sensitivity to alteration, and identify potential changes to the ecosystem resulting from different development and redevelopment options is important to inform decision maker. In this perspective, this study focuses on variables of a flow regime strongly associated with ecological condition and, therefore, most suited to serve as indicators of hydrologic alteration. It aims to quantify and assess Lake Guiers hydrologic alteration arising from in-stream development. This assessment will inform a decision-making process and the implementation of a post-alteration monitoring program; and build knowledge that can inform future policy and management directions by allowing the analysis of information collected in a standard way across sites consistent with an adaptive management approach.

Study Area

Lake Guiers is an important fresh water reserve for Senegal. Its water is used for irrigating crops and drinking water resource for urban centres, including Dakar, the capital city, as well as for continental fishing and livestock breeding. It is located in the north of Senegal on the right bank of the Senegal River, between latitudes 16'23 N and 15'55 N, and longitudes 16'12 W and 16'04 W. It lies on the downstream of the Ferlo hydrological Basin **(Fig 1).**

Hydrology

The lake is 53.5 km long and up to 7 km wide, with a surface area of 274 square kilometers (measured and calculated with Google earth Pro and GIS). Its maximum depth is 4m and average depth is 2 m. Like most of the sahelian lakes, it is classified as a ''shallow lake''.

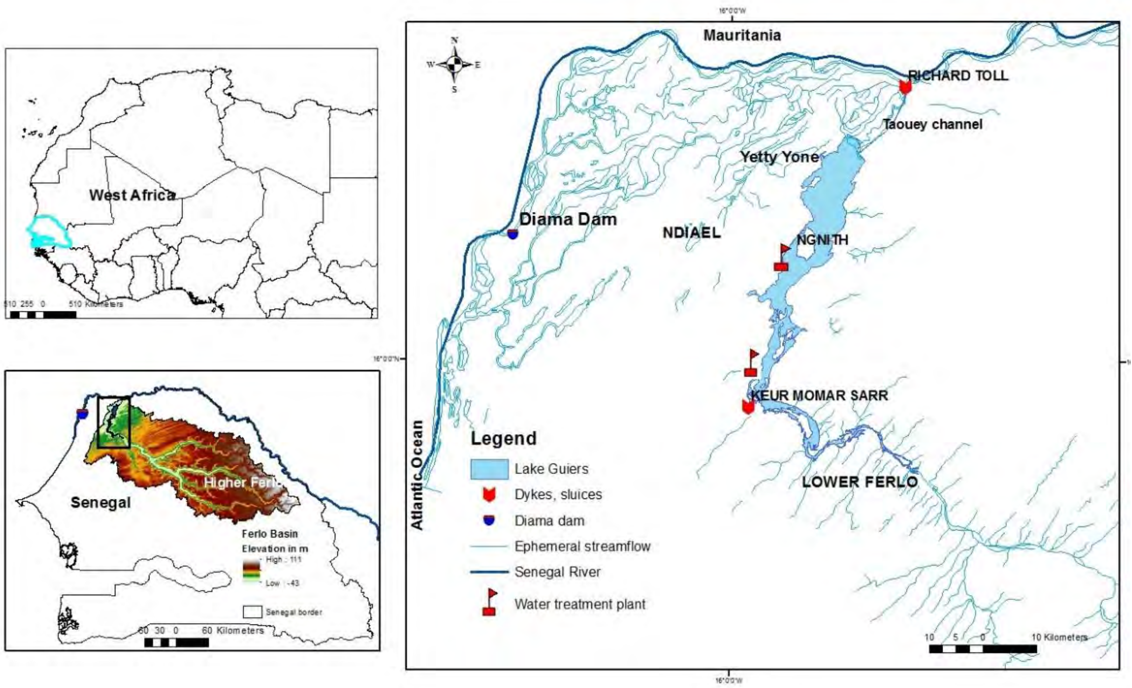


Figure 1. Study area: Lake Guiers within its hydrologic Basin and the main hydraulic infrastructures.

Lake Guiers hydrological system is composed of the following hydrological units (**Fig.1):**

- Taouey canal: It connects Lake Guiers to the Senegal River at Richard Toll city. Originally Taouey was a winding stream of 26 Kilometers, rectified by a canal long to 17 kilometers. It supplies 88% of the total water into Lake Guiers from Senegal River (Cogels, Fraboulet-Jussila, et al., 2001) .
- Yetty Yone: Situated on west of Lake Guiers, it is a 28 kilometers hydraulic axis which supplies the Ndiael depression.
- Ndiael: it is a depression designated as wetland area by the RAMSAR convention in 1977. The great expanse that is the core of the Ndiael covers 10,000 hectares. The site is listed on the Montreux record (endangered sites) since 1990.
- Lower Ferlo: Located in the southern part of the lake, it is complemented by the Ferlo valley. A dyke built in Keur Momar Sarr regulates the outflow from the lake into the lower Ferlo region.

Climate

The climate in the basin of Lake Guiers is similar to much of the Sahel and characterized by two main seasons: a dry season that lasts nine months from October to June, and a rainy season of three months (July–August-September). Total annual rainfall is generally low, but highly variable among years. In the basin, the average of total annual rainfall from 1982-2012 is estimated to 225 mm. The mean annual temperature oscillates around 27.6°C and fluctuates between a maximum average of 30.6°C in the month of June and a minimum of 23°C in the month of January **(Fig.2).**

Lake Guiers hydrological functioning before and after dam's construction

Before the construction of dams, Senegal River used to be a typical rainfall runoff river (Henny, 2012).The river's flow regime depends mostly, on rain that falls in the upper basin in Guinea (about 2,000 mm/year). In the river, this creates a high-water period or flood stage between July and October, and a low-water period between November and May to June (Cogels et al., 1997). Furthermore, sea water intrusion up to 250 kilometers inland occurs in Senegal River during four or five months per year due to low flow rates and a very slight slope (Cogels et al., 1997).

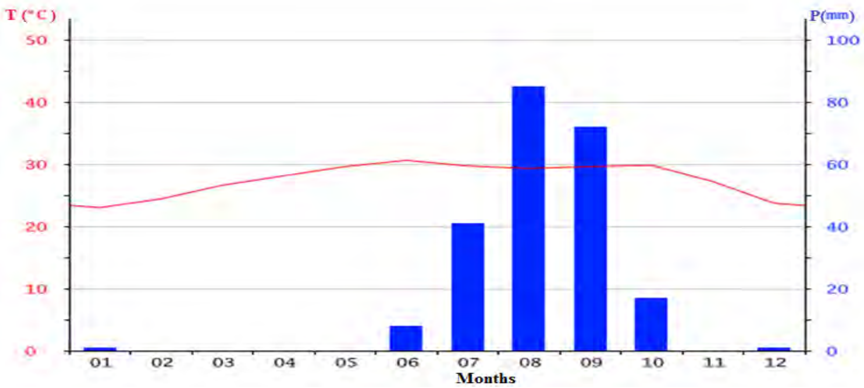


Figure 2. Climate graph (Precipitation and Temperature) 1982-2012, Lake Guiers Area, Senegal. Data source: (http://de.climate-data.org; average 1982-2012).

In Lake Guiers, the hydrology depended on these situations described above. During high water period the lake was filled once a year from the Senegal River and the damming up of the northern region and the closing of the southern and western outflows made it into the largest water reservoir which can be used extensively as a stable freshwater source throughout the dry season (Cogels et al., 1997). Under the combined effect of insufficient filling (during drought years in the whole basin), increased pumping for irrigation, and evaporation (2.2 meters per year), the level of the lake in certain years went below the threshold levels. Extreme conditions were reached during water year 1983- 1984 when the lake was almost completely dried up (Cogels et al., 1997).

In order to meet economic and social development needs for water resources, OMVS has undertaken the construction of Diama and Manantali Dams along the Senegal River. The Diama Dam is located 30 kilometers upstream of the city of Saint Louis. It was built in 1985 in order to stop the dry season intrusion of seawater along the river bed and to irrigate 375,000 hectares of former flood plain for production of two crops per year, especially for rice production (Cogels, Fraboulet-Jussila, et al., 2001).The second dam, the Manantali, was completed in 1987 and is located in Mali 1,200 kilometers

upstream from the Senegal River outlet. Its storage capacity is 12.8 km^3. It was built on the river, which supplies approximately 60% of the annual flow of the Senegal River in a reservoir.
Since 1986, the operation of the Diama Dam has prevented any seawater intrusion upstream and fresh water is available all the year at the Taouey - Lake Junction (Cogels et al., 1997). Since 1992, the steady and continuous operation of the Manantali Dam and the regulation of the river have changed the hydrological conditions in the lower valley and the delta region. There is now a constant supply of fresh water, sufficient to fill the lake several times a year. From 1986 to 1991, as before 1986, the lake was filled only once a year during the annual flood. However, water levels became clearly higher than before 1986 with an average levels of 0.8 m, compared with 0.4 m prior to 1986 (Cogels et al., 1997). Since 1992, the partial regulation of water flow by the Manantali Dam has further altered the hydrological regime of the Lake Guiers, which may now be filled several times a year. The annual average level has reached 1.5 m and its annual range is not greater than 0.96 m. Since 2002, the annual average level has reached 1.9 and the range of water level in the Lake is between 1.9 and 2.5 m.

METHODS

The daily flow data were used to analyse the variation of the flow regime at Ngnith station (water treatment plant). We collected observed water level data from 1976 to 2011, a total of 35 years of hydrological data, provided by Lake Guiers Authority (OLAG). Discharge has been calculated from daily water level using Manning- Strickler equation:

$Q= K*RH * i$ **(1)**
Q: Discharge in m/s
K: Roughness coefficient
RH: Hydraulic flow radius
i: Flow slope in m/m

A literature review allowed us to determine the following variables in the flow calculation: hydraulic flow radius (RH) = 7 m; the flow slope in Ngnith station (i) m / m = 0.001; and the roughness coefficient (K) = 35.
The stream flow data from 1976 to 2011 was divided into pre-impact period (1976–1986) and post-impact period (1987–2011), representing the stream flow under natural conditions (before dams) and changeable conditions (after dams), respectively. To address hydrologic regime alteration, we investigated stream flow through Stream flow Analysis and Assessment Software (SAAS) 4.0 developed by Metcalfe et al., (2013).
SAAS is a tool based on/focusing on hydrology-based environmental flow methods. Comparison of pre- and post-dam's periods allows evaluation of the dam's effects on hydrology and ecosystem. **Table 1** shows input data and time periods used for the analysis.
To determine the flow regime target, the Range of Variability Approach (RVA) (Richter et al., 1997) was used to evaluate the hydrological alterations. The RVA was formulated to quantify the modification of the Indicator of Hydrologic Alteration (IHA) by comparing the frequencies within three fixed intervals. The RVA is a milestone in the hydrologic alteration assessment and has been widely used (e.g.: (Chen, 2012); (Irwin & Freeman, 2002); (Shiau & Wu, 2004); (Zuo & Liang, 2015)). Richter et al., (1998) used the degree of hydrologic alteration as a measure to quantify a deviation of the post impact flow regime from the pre-impact one. The degree of alteration D is defined as:

$D = [(Post-Pre) / (Pre)]*100\%.$ **(2)**

Where "Post" is the median flow of the post-impact period, "Pre" is the median flow of the pre-impact period. Richter et al., (1998) further suggested that the value of D ranging between 0 and 33% represents little or no alteration (i.e. low alteration); 33-67% represents moderate alteration, and 67-100% represents high alteration. In order to characterize water quality alteration, we use monthly water quality data from 2008 to 2010 provided by Direction de la Gestion et de la Planification des Ressources en Eau du Sénégal (DGPRE), a national management body of Senegalese water resources. These data were observed in 7 sites in Lake Guiers from nord to south (Richerd Toll, Mbane, Téméye, Syer, Gnith, Keur Momar Sarr, and Lower Ferlo). However, in this study the focus in water quality analysis is primarily on salinity and eutrophication.

To characterise the trophic state in Lake Guiers, we calculate the Trophic State Indices (TSIs) of Secchi Disque (SD), Nitrogen (N) and Phosphorus (P) by using Environmental Protection Agency (EPA)'s nutrient criteria technical guidance manual (Gibson et al., 2000).

The results were interpreted according to EPA's criteria. It suggested that the value of TSI <40 represents oligotrophic state. The value of TSI ranging between 50 and 60 represents a eutrophic state and the value of TSI>60 represents a hypertrophic state.

Table 1. Input data and time periods used for streamflow analysis

	Input data and time periods	
Months	Before impact (dams)	After impact (dams)
Flow time interval	Daily	Daily
Drainage Area	273 Km^2	273 Km^2
Annual analysis period	January 1 to December 31	January 1 to December 31
Total period of record (POR) (for Seasonal Analysis)	12 years	26 years
Number of data values loaded	4380	9490
Number of data values loaded	4380	9490
Season 1	180 days (Jan 1 to June 29)	180 days (Jan 1 to June 29)
Season 2	185 days (June 30 to Dec 31)	185 days (June 30 to Dec 31)

RESULTS AND DISCUSSIONS

Indicator of Hydrologic Alteration

Streamflow

The operation of Diama and Manatali Dams has significantly modified the flow regime of Lake Guiers over the past 30 years. The annual flow increased by more than 269% at Ngnith station. **Table 1** shows a summary record of stream flow statistics. The maximum flow during pre-impact (15.6 m^3/s) is far less than in post impact (30.7 m^3/s). It can be noticed that zero flow days, decreased drastically between the pre- and post-impact periods, from 1041 to 153 days and has been eliminated since 1991.

Table 2. Stream flow statistics in Lake Guiers before and after dams construction

Streamflow statistics	Before dams construction	After dams construction	Unit
Maximum	15.6 (27 Sept-1981)	30.7 (01-Nov-2007)	m^3/s
Minimum	0 (Multiple Date)	0 (Multiple Date)	m^3/s
Mean	4	15.1	m^3/s
Standard Deviation	4.1	6.2	m^3/s
Coefficient of variation (SD/Mean)	1	0.4	m^3/s
Median	3	17.1	m^3/s
Upper quartile	6.9	19.8	m^3/s
Lower quartile	0.1	11.2	m^3/s
Relative Dispersion (IQR/mean)	2.2	0.5	m^3/s
Number of zero flow days	1041	153	---

The flow pattern in Lake Guiers is reversed from the pre-dam. Significantly greater median flows occurred almost during all twelve months (increases of 14 m^3/s), which were the typical high flow that occurred in September - October during the pre-dam period **(Fig.3).**

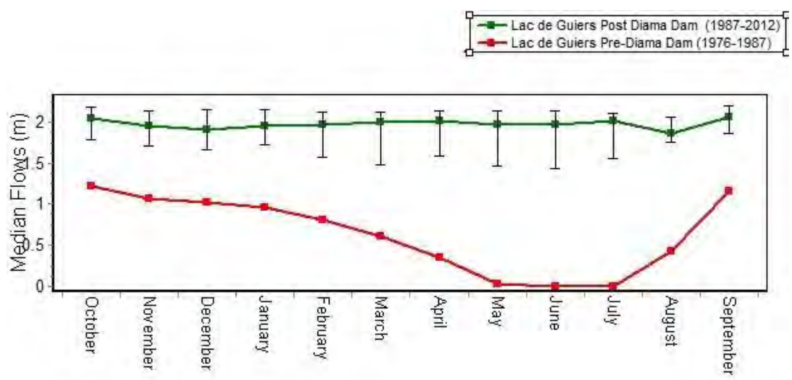
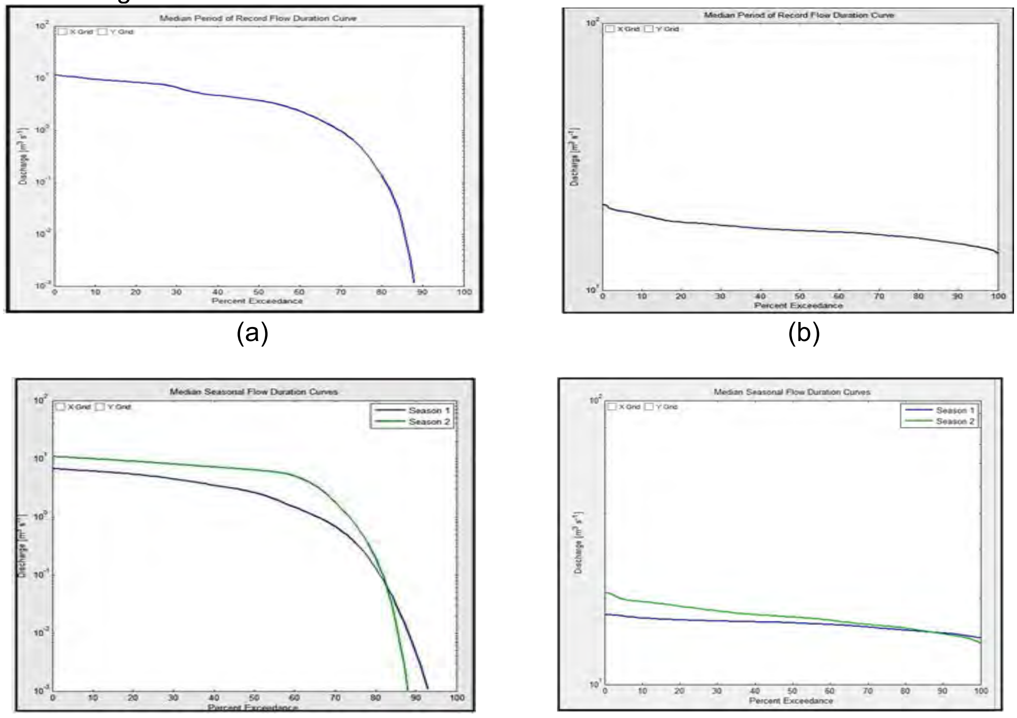


Figure 3. Monthly alteration with RVA in Lake Guiers 1976-2011

Flow duration

A flow-duration curve (FDC) represents the relationship between the magnitude and frequency of daily, weekly, monthly (or some other time interval) of stream flow for a particular river basin, providing an estimate of the percentage of time a given stream flow was equaled or exceeded over a historical period (Vogel & Fennessey, 1994). **Fig.4** compares annual and seasonal median of FDCs at Lake Guiers using two different periods of record (pre- and post impact). The FDC for these two periods are significantly different. For instance, i.e. in pre-impact period the highest Q = 11.4 m^3/s and the percentage of exceedance equal to 0.01%; and the lowest Q= 0.00m3/s and the percentage of exceedance equal to 99.9%. For Post impact, the highest Q = 21 m^3/s and the percentage of exceedance equal to 0.01%; the lowest Q = 13.7 m^3/s and the percent exceedance equal to 99.9%. Comparable changes are also observed on seasonal median FDCs.



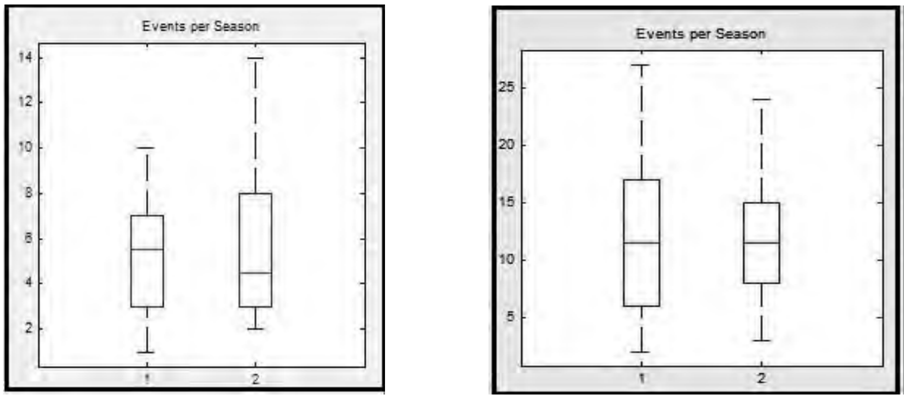
(a) (b)

(c) (d)

Figure 4. Annual (a) and (b) and seasonal median (c) and (d) FDCs at Lake Guiers before impact (a, c) and after impact (b, d)

Base flow index (BFI)

Base flow is defined as the stream flow portion generated by persistent slowly varying sources (i.e. groundwater, lakes, and wetlands) between precipitation events (Dingman, 1994). SAAS separates base flow from stream flow using a recursive digital filtering as described by Nathan & McMahon, (1990). The filter parameter recommended by Nathan and McMahon of 0.9 is used in the SAAS daily stream flow and base flow separation analysis with three filter passes. Base flow separation technique was used to estimate Base flow Index (BFI). Base flow index (BFI) is the ratio of the base flow to the total stream flow. The value ranges from 0 to 1. Therefore, a BFI of 0.5 indicates that 50% of total stream flow can be attributed to base flow for the respective time period (i.e. period of record, month or season). In Lake Guiers, before the dam's operation BFI for the entire period of record was 0.73 which is less than after dam operation (BFI= 0.92). This implies that 73.9 % of total stream flow can be attributed to base flow for the respective time period. In the post impact period it's 92.6% that can be attributed to base flow. Before and after impact periods, base flow constitutes the highest part on total stream flow. High and low flow.

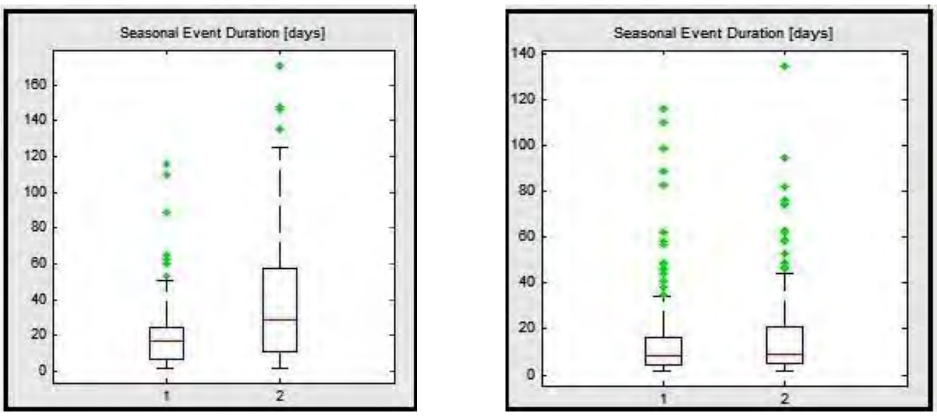


(a) (b)

Figure 5. Seasonal High Flow Frequency

This figure show the seasonal High flow frequency on pre-impact (a) and post impact (b). For pre-impact, the total events equal to 133 and the number of year = 12. During season 1, the 25 % ile = 3; Median = 5.5 and 75% ile= 7; during season 2, the 25 % ile = 3; Median = 4.5 and 75% ile= 8. For post-impact period, the total events equal to 655 and the number of year = 26. During the season 1, the 25 % ile = 6; Median = 11.5 and 75% ile= 17 and during season 2, the 25 % ile = 6; Median = 11.5 and 75% ile= 15.

Fig. 5 shows extreme hydrologic event (high and low flow). The extreme low flow during 1976- 1986 was more than twice the average number during 1987-2011 at Ngnith station. By using the high flow events, we explore the frequency and duration of those events on seasonal basis **Fig. 5 and 6**. The frequency refers to how often a flow above a given magnitude recurs over some specified time interval. The duration is the period of time associated with a specific flow condition. Duration can be defined relative to a particular flow event or a composite expressed over a specified time period (Richter et al., 1996).



(a) (b)

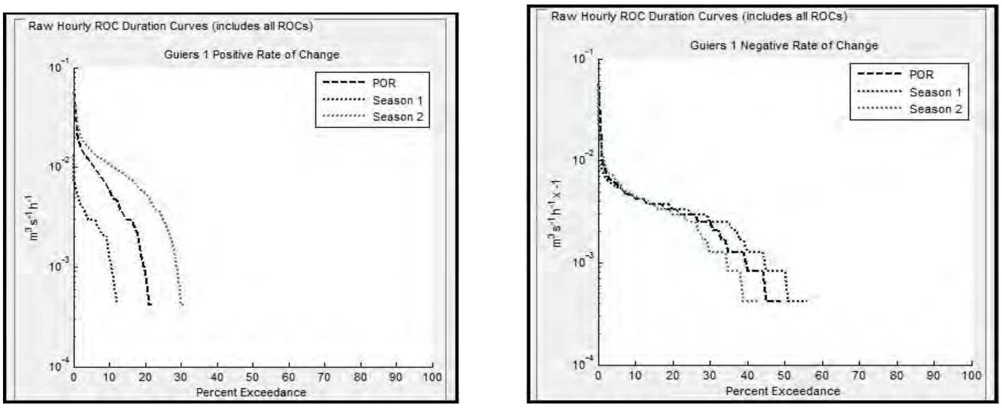
Figure 6. Seasonal High Flow duration

This figure show the seasonal High flow duration on pre-impact (a) and post impact (b). For pre-impact, the total events equal to 133 (S1 = 63; S2 =70). During season 1, the 25 % ile = 7; Median = 17 and 75% ile= 24.75 and during season 2, the 25 % ile = 11; Median = 29 and 75% ile= 57. For post-impact period, the total events equal to 655 (S1= 339; S2=316) and during the season 1, the 25 % ile = 4; Median = 8 and 75% ile= 16 and during season 2, the 25 % ile = 5; Median = 9 and 75% ile= 21.

While seasonal high flow frequency has increased by 109% during season 1 and 130% during season 2, high flow duration has decreased to (-53 %) during season 1 and, (- 69%) during season 2 in Lake Guiers **(Table 3)**.

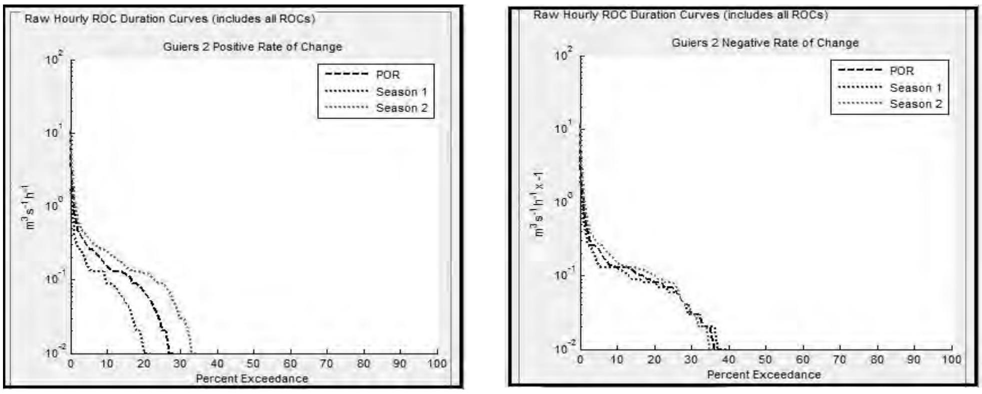
Rate of change (ROC)

Rate of change represents the change between stream flow data points. **Fig. 7 and 8** show POR and seasonal raw rate of change. Its duration curves was created using the unfiltered rates of change (i.e. all rates including low flows) (Metcalfe & Schmidt, 2014). For daily input data, these hourly rates are calculated by dividing the daily rates of change by 24, assuming a linear rate of change throughout each day. Raw ROC curves terminate at less than 100 percentage of exceedance because the percent exceedance is calculated using all rates (i.e. positive, negative and zero) (Metcalfe & Schmidt, 2014). In Lake Guiers, for pre-impact the POR ROC duration curves show that 21% of the time the rates are positive and 49% of the time they are negative, implying that 2% of POR rates are zero. Compared to post impact period ROC duration curves show that 27% of the time the rates are positive and 36% of the time they are negative, implying that 1% of POR rates are zero.



(a) (b)

Figure 7. POR and seasonal raw rate of change on pre-impact period. It shows the positive POR and seasonal raw rate of change (a) and negative POR and seasonal raw rate of change (b) on pre-impact period



(a) (b)

Figure 8. POR and seasonal raw rate of change on pre-impact period. It shows the positive POR and seasonal raw rate of change (a) and negative POR and seasonal raw rate of change (b) during post-impact period.

Trends in hydrologic indicator

The Mann-Kendall non-parametric trend test is used to statistically assess whether there is an upward or downward monotonic trend in a variable. The temporal variability (summarized annually) of a variety of hydrologic metrics (annual median stream flow, annual median base flow, and annual number of high flow events) were tested **(Fig. 9).** The Mann-Kendall τb (tau-b) test statistic, similar to the correlation coefficient in regression analysis, and the associated p-value used to test the zero-slope hypothesis (at 95% confidence a p-value of 0.05 or less allows the zero-slope hypothesis to be rejected). During post impact period, the stream flow shows an increased trend of 93% with 95% confidence. In addition, base flow and number of high flow events show respectively trends 91% and 42%. They are statistically significant. However, temporal trend was not detected in the annual median rate of change.

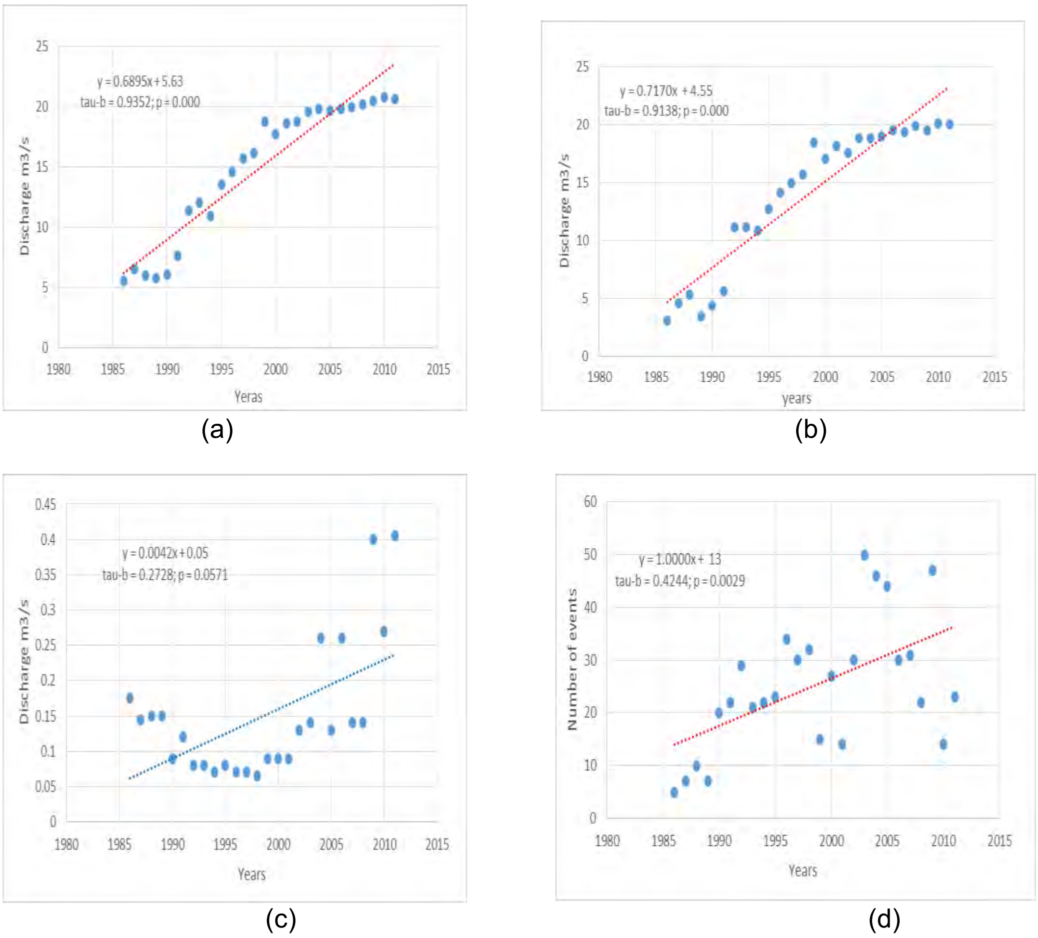


Figure 9. Temporal variability of hydrologic metric. It shows trends in stream flow (a), base flow (b) rate of change (c) and number of high flow events (d) during post impact period in Lake Guiers. Trend lines are shown in red if the slope of the line is significantly different from a slope of zero (i.e. temporal trend detected) with 95% confidence.

Hydrologic alteration magnitude

The median flow was used to quantify a deviation of the post impact flow regime from the pre-impact ones for Lake Guiers. The results show that the reservoir was strongly affected by the construction and operation of Diama and Mananatli Dams **(Table 3).** The hydrologic regime of Lake Guiers has been altered over the past 30 years. Annual flow increased more than 100% at Ngnith station. Monthly flows for May in dry season and monthly flows for October in flood season were selected to analyse monthly water condition alterations, which indicated magnitude alteration in Lake Guiers reservoir. Median monthly flows for May, the driest month, at Lake Guiers increased up to 100 %, (**Table 3).** Median monthly flows for October, the month in which, the flood pick occurs, account for 33.3% of the total annual flows. The increasing trend of flow is obvious. During all months, flow increased and the largest monthly alterations occurred during the dry season.

Table 3 Hydrologic alteration at Ngnith station, Lake Guiers, *1976-2011.*

Indicator of Hydrologic Alteration	Pre-Impact	Post-Impact	RVA (target) Lower	Upper	Deviation % (Magnitude)	Class
Stream flow						
Mean	04.0	15.1			269	H
Maximum	15.6	30.7			96.3	H
Zero Flow Days	1041	153			-85.3	H
POR BFI	0.7	0.9			25.5	L
Seasonal BFI						
Season 1	0.8	0.9			18.9	L
Season 2	0.7	0.9			27.5	L
Monthly High flow frequency (median)						
January	2	2	0.5	3	0	L
February	1	2	0	3	100	H
March	1	1.5	0	4	50	M
April	0	2	0	4	-	-
May	0.5	1	0	3	100	H
June	0	2	0	3	-	-
July	0	2	0	4	-	-
August	1	2	1	3	100	H
September	1	1.5	0	2	50	M
October	1.5	2	1	2	33.3	M
November	1	1	0	3	0	L
December	0.5	2	0	3	300	H
POR High Flow Frequency(median)	10.5	23	7.5	31	119	H
Seasonnal High Flow Frequency (median)						
Season 1	5.5	11.5	3	17	109	H
Season 2	5	11.5	3	15	130	H
POR High Flow Duration(median)	20	9	4	43	-55	M
Seasonnal High Flowduration(median)						
Season 1	17	8	4	24.7	-52.9	M
Season 2	29	9	5	56.7	-68.9	H

RVA lower and upper targets are 25th and 75th percentiles value of pre and post impact hydrologic parameters. L, M, H represent Low, Moderate and High alterations respectively.

Water quality alteration indicator
Secchi disque (water transparency)
Variation in Secchi disque (water transparency) are quite low between 54 cm to 86 cm (coefficient of variation= 24%) with an average of 66 cm **(Fig. 10). T**hroughout the study period, Secchi values remained less than 100 cm. However, they seem to draw a slight difference from year to year and show a seasonal trend. In addition, the fluctuations in water transparency seem to follow water volume variation in the lake. The increase in lake's water volume resulted in a decrease of transparency and vice versa.

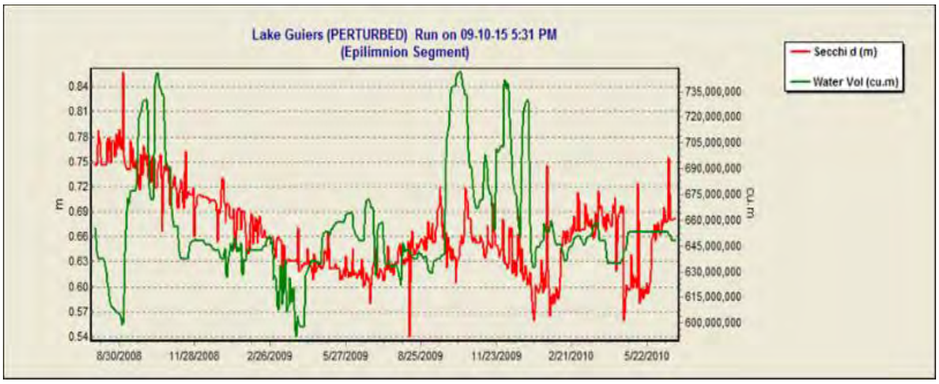


Figure 10. Water transparency with water volume in Lake Guiers,2008-2010

Salinity
The results of surveys between 2008 and 2010 indicates an average salinity in Lake Guiers of 199ppt (392 µS /cm) with a maximum of 257 ppt (506 µS /cm) and a minimum of 124 ppt (244 µS /cm). **Fig. 11** shows the evolution of the salinity during this period, superimposed with water volume in the lake. We can notice that the salinity increases when lake's water volume is low and decrease when lake's water volume is high.

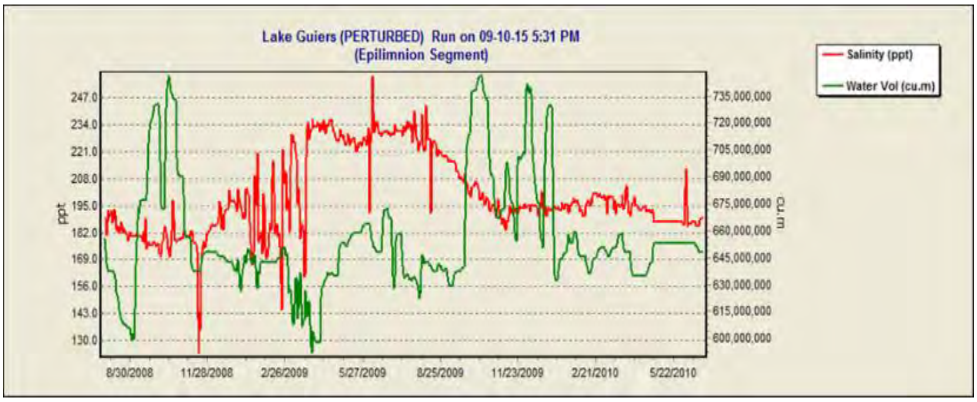


Figure 11. Evolution of salinity in Lake Guiers with water volume 2008-2010.

In addition, there is a spatial and temporal distribution of salinity into the lake. The results show a north - south gradient of salinity. The measurements observed from Richard Toll increase significantly as we move towards Keur Momar Sarr. They are even more (10 times higher) towards lower Ferlo
They also indicates a seasonal trends of salinity. Higher concentrations were noticed in August 2009 **(Figure 11).**
The main source of salt concentration into the Lake is an inappropriate discharge outlet in lower Ferlo and a high evaporation rate. The irrigated crop drainage water discharged into the northern part of the lake is the second main source of salts accumulation. It accounts for 56% of the salt influx (Cogels, 2001).

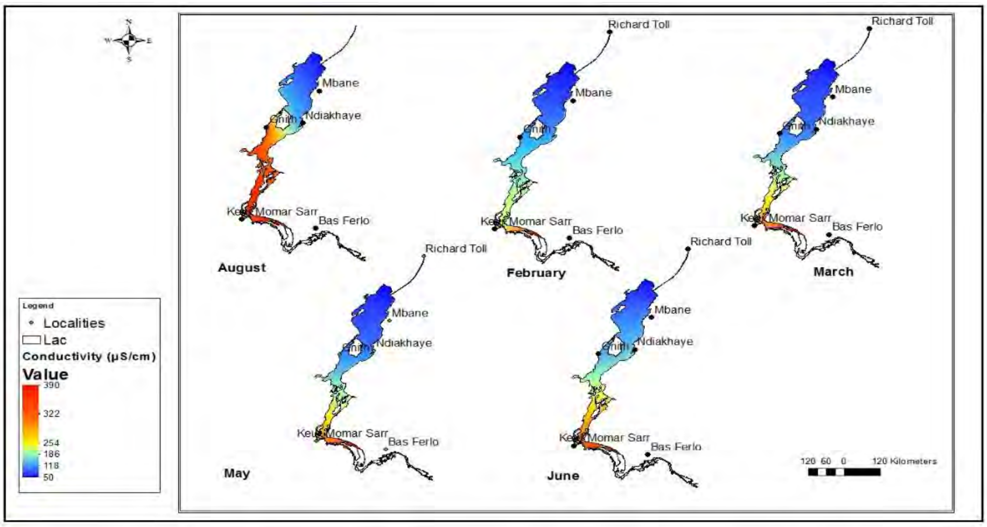


Figure 12. Spatial and temporal distribution of salinity in Lake Guiers 2008-2010

Nutrients concentration

Results of nutrient surveys between 2008 and 2010 show stabilized concentrations not exceeding 1 mg / L.

Total Nitrogen (N) during the study period ranged from 0.74 to 0.90 mg/L with an average of 0.75 mg / L. Total Phosphorus (P) ranged from 0.15 to 0.27 Mg/L with an average of 0.19 mg/L **(Fig. 13).**

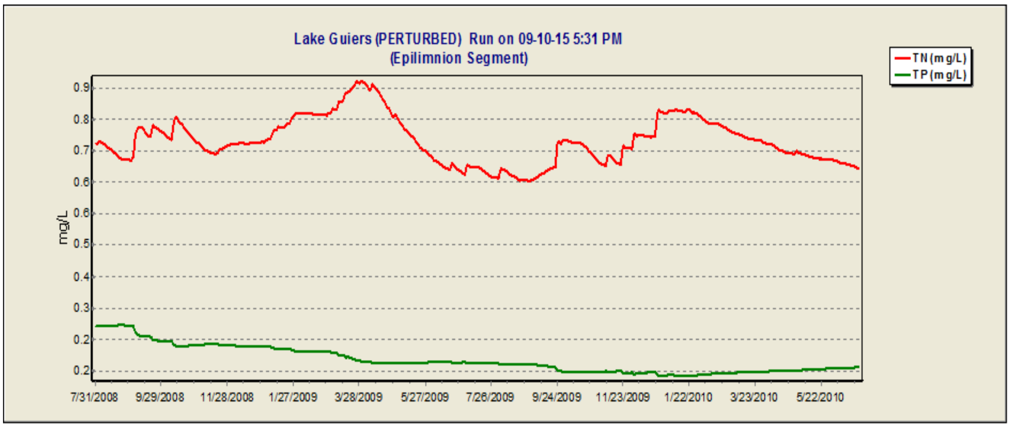


Figure 13. Evolution of Nitrogen (N) and Phosphorus (P) in Lake Guiers, 2008-2010.

In addition, **Fig. 14** show during the study period, Total Ammonia ($NH3$ & $NH4^+$ (mg/L)) varying between 0.1 mg/L and 0.09 mg/L with an average of 0.1 mg/L. Nitrates ($NO3$ (mg/L)) range from 0.7mg/L to 0.5 mg/L. Concerning pH, it varies between 8.5 and 6.3. However, no correlation was found between NH3 and pH.

These results did not reflect the spatial tendency of the nutrients which change from the Taouey canal, the northern part of the lake towards the south and Ferlo

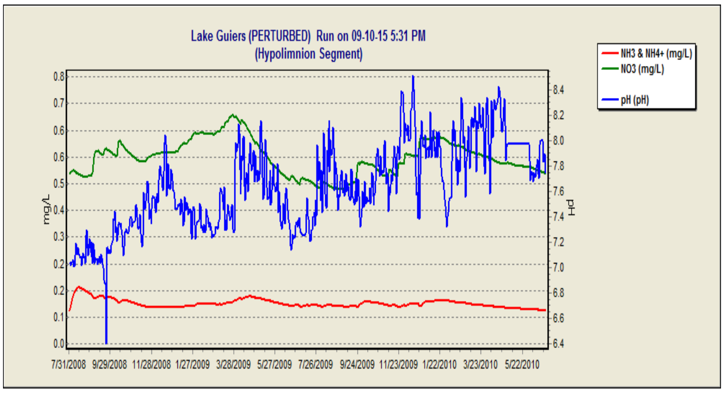


Figure 14. Evolution of ammonia with pH in Lake Guiers, 2008-2010.

Trophic State Indices (TSIs) in Lake Guiers

Throughout the study period, the low measured water transparencies reveal a TSI of Secchi disque of 65.91, which would indicate a hypertrophic state. Total N measured show a TSI of 50.22 indicating a eutrophic state. Finally, total P measured indicate a TSI of 79.57 which would indicate a hypertrophic state.

DISCUSSIONS

Lake Guiers hydrologic alteration

Key ecosystem components that have important functions in determining the integrity of river ecosystems include hydrologic regime, sediment regime, water quality, thermal regime, and biologic components. However, this study focuses on hydrologic regime and water quality factors that most strongly shape the ecological condition of river systems and that are often of greatest importance to the health of valued ecosystem components. Components of flow regimes considered important for maintaining the ecological condition of riverine ecosystems are described in Table 4, while important characteristics commonly used to define their pattern are (magnitude, duration, frequency, timing, and rate of change).

Table 4. Environmental flow components important for maintaining the integrity of aquatic ecosystems

Flow component	Description	Ecological function
Overbank flows	Infrequent, high flow events that exceed the normal channel.	These flows shape and redistribute physical habitats, purge invasive species, provide lateral connectivity between the channel and the active floodplain, provide life-cycle cues for various species, and facilitate exchange of nutrients, sediments and woody debris.
High flow pulses	Short-duration, in-channel, high flow events.	These flows maintain physical habitat by flushing silt and fines and preventing the encroachment of riparian vegetation into the channel, providing lateral connectivity to oxbows and providing life-cycle cues for various species.
Low flows	Normal flow conditions between high flow events sustained through the release of surface and groundwater storage.	These flows maintain water tables for riparian vegetation (lateral connectivity), provide longitudinal connectivity, and provide a range of suitable habitat conditions that maintain the diversity of the natural biological community.
Subsistence flows	Infrequent, naturally occurring low flow events of long duration (occurring over seasons).	These flows maintain sufficient water quality and provide sufficient habitat and connectivity to prevent direct mortality of aquatic species and ensure survival of organism populations capable of recolonising the river system once normal base flow returns.

In Lake Guiers, flow regimes pattern considered important for maintaining the ecological condition of riverine ecosystems have been investigated. Results show that hydrology in Lake Guiers depend in natural conditions on the filling and discharge phases following the rhythm of floods and low flows of the Senegal River. These hydrologic events played an important role in regulating the structure and function of the lake and flood plains. Low flows are necessary for many processes in riverine ecosystem functioning. If the low flow situation reaches extremely low levels, however, ecological communities are impaired. Low frequency but high intensity events, such as severe floods or droughts that used to occur in Lake Guiers had long lasting effects on the structure and function of lotic ecosystems. Extreme low flows may be necessary to dry out floodplain areas and enable certain species of plants to regenerate. On the other hand, water chemistry and dissolved oxygen availability can become highly stressful to many organisms during extreme low flow (Chícharo et al., 2009).

Since 1986, in-stream developments along Senegal River and Lake Guiers has changed the distribution of flow magnitude, duration, frequency, seasonality, and rates of flow increase and recession. The steady and continuous operation of dams and its regulation have changed the hydrological conditions. These new conditions have favored a few years after the proliferation of invasive aquatic plants.

Faye et al., (2016) show that aquatic plants has settled on a surface area of 7,458ha in Lake Guiers from 1988-2010. This has led to a decrease of 2,339 ha on open water and 4,021 ha on flood plains area.

Lake Guiers's water salinity

During the study period, results indicates an average salinity in Lake Guiers of 199ppt (392 µS/cm) with north / south gradient. This result is supported by studies carried out in September 2004 by DHI water and environment and TROPIS under the Long-Term Water Project (Projet Eau Long Terme). They showed a salinity gradient of about 30 µS/cm in Taouey channel entry until about 550 µS/cm to Keur Momar Sarr dyke and a strong rise about 992 µS/cm in lower Ferlo.

Studies carried out before Diama dams showed large variations in salinity in Lake Guiers. Indeed, the salts concentration from the Senegal River was relatively low with a salinity of 20-50 µS/cm (Carl Bro International c / o in Sané et al., (2013). However, it gradually increased in the Taouey before becoming constant in northern part of the lake. Then it increased again in lower Ferlo due to high evaporation rate and increase of dissolved salts in water.

The large variations in salinity (from 1972 until 1985) were therefore due to the intrusion of seawater. After Diama dam, the oscillations were due to the opening and closing of the valves at Richard Toll. The Lake was still subject to relatively large salinity oscillations until 1992.

These continuous variations were probably due to salt discharges stored in Lake Guiers's sediments. Since 1992 with Lake Guiers water level regulation (between 1.90 m and 2.50 m), annual variations in salinity are limited to minor seasonal variations

However, Sané et al.,(2013).noted that the water salinity in Lake Guiers did not show a significant difference between 2002 and 2003 with respectively average value of 180.5 and 178.4 µS / cm. However, a significant increase occurred in 2004 and 2005 with respectively an average of salinity of 220.6 and 207.0 µS / cm. This is probably due to water level elevation and a low water renewal.

Eutrophication level in Lake Guiers

Nutrient surveys during the study period show stabilized concentrations not exceeding 1 mg /. These results do not reflect those obtained previously. According to (Cogels et ,al., 2001) eutrophication is already a serious problem in Lake Guiers. Total N and nitrates are quite higher into the lake. They are even higher in the Taouey canal. However, they tend to decrease and stabilize in the central and southern parts of Lake Guiers. Mean concentrations of nitrogen (N) range from 1 to 2.5 mg/L in the lake and Ferlo, whereas in the Taouey they are estimated to be 6.5 mg/L (Cogels, et al., 2001). The Taouey channel provides significant amount of phosphorus (24%) and nitrogen (25%) into the lake, especially during the rainy season (Cogels, et al., 2001). This could probably be attributed to agricultural activities around the lake. (Faye et al., 2016) indicates that irrigated agriculture is currently the most common activities in the area. The irrigated areas comprise a large-scale irrigation field and peri-urban irrigated horticulture. About 20,063 hectares of land are now cultivated around Lake Guiers.

In this study, the TSIs of N (50.22) and P (79.57) would indicate a eutrophic and hypertrophic state, respectively. These results are likely due to over-use of nutrients by algae and plants. (Sané et al., 2013-3) also describe a eutrophic state from 2002 to 2004 and hypertrophic since 2005, based on chlorophyll estimation. According to them, their production has tripled in 2005.

CONCLUSIONS

Daily streamflow data of 35 years records and water quality data were investigated to determine Lake Guiers hydrologic alteration within its ecosystem. Comparison of pre- and post-dam's periods allows evaluation of their effects on hydrology and ecosystem. The results show that dams and sluices profoundly affect the hydrologic conditions in the Lake Guiers. They reduced high monthly variability of discharges, increased the range of daily discharges, altered the timing of high and low flows, and changed the timing of the yearly maximum and minimum flows.

Hydrologic features demonstrated obvious changes during the post-impact period. The flow magnitude was smaller and the frequency of low flow events decreased during all the year; and the maximum flows and minimum flows increased. The number of high flow events presented increasing trend. Annual median rate of change appeared as a decreasing trend. Base flow remains low both in pre- and post impact. The trophic State Indices (TSIs) of Nitrogen (N) and Phosphorus (P) indicated respectively a eutrophic and hypereutrophic state. These new features in hydrology regime resulting to in stream development lead to changes to the ecosystem. The flood plain ecosystems have been mostly affected. After 1986, Diama dam blocked seawater intrusion. The water into the Lake is now fresh year-round, creating ecological conditions favoring the proliferation of freshwater plants (Typhas australis, Pistia startioles, Salvinia molesta and various alga species). Recent studies show that invasive plants currently occupy 7,458 hectares in Lake Guiers. These are very invasive and eutrophication has begun at some places in the Lake. Downstream of the Diama dam, perturbations in the functioning of ecosystems takes the form of an increase in salinity and/or a drying-up during part of the year (Ndiael wetlands) due to the reduction of flooding or the destruction of water inflow channels during construction of hydrologic infrastructures (dikes, irrigated areas).

With the permanent standing freshwater, aquatic plants developed to excess and now prevent access to the water at some places. The Typha australis constitutes a refuge and a spawning area for fish. However, the abundance of vegetation also constitutes an obstacle for fishing. In addition, infrastructure installations represent obstacles for fish migration to spawning areas.

Lake Guiers's hydrological alteration endanger its ecological integrity. Each aquatic ecosystem requires a certain amount of water to maintain its ecological integrity. These environmental water requirements can be defined as the quantity and quality of water required to protect the structure, function, and species composition of that ecosystem. Therefore, to ensure ecologically sustainable development, we propose the following recommendation: After an alteration in the flow regime, a hydrometric monitoring program should be implemented to provide a thorough assessment of the degree of alteration. This would include measurement of continuous discharge using a data recording frequency that adequately captures the pattern of flow in the altered flow regime.

Continuous discharge measurements of inflows to the structure should also be estimated using back-calculations or measured directly. This will be particularly important where there are no upstream alterations, providing an indication of the natural variability in streamflow during the assessment period of interest. We also encourage the implementation of best management practices on water resources and landscapes to reduce non-point sources of phosphorus transport in the Lake. Also, we recommend that water resources manager work with municipalities to protect the lake shorelines and floodplains in order to better accommodate their natural processes as well as to improve resilience to flooding and to improve water quality. Finally, water resources managers should increase public education and provide resources for local residents regarding impacts of fertilizer use on water quality and the benefits of vegetated buffers.

ACKNOWLEDGEMENT

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RELATIONSHIP BETWEEN SPECTRAL OPTICAL PROPERTIES AND OPTICALLY ACTIVE SUBSTANCES (SUSPENDED MATTER) IN LAKE MANINJAU

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ABSTRACT

Light conditions in water are very important for primary production. Optical properties play a major role in the ecological structure and functioning of lakes. This study aims to investigate the relationship between spectral optical properties with optically active substances (transparency, suspended solid and volatile suspended solid concentration). The study has been conducted at eight stations during the month of May and August 2015 in Lake Maninjau. The attenuation coefficient of light is influenced by secchi depth. The shallowest Secchi depth was found in Koto Gadang (1.65 m) with attenuation coefficient of 0.764. For each station, suspended solid concentration ranges 0.83 – 3 mg/L and VSS value ranges 0.75 – 2.38 mg/L. The attenuation coefficient and depth correlated with VSS concentration. The concentration of organic suspended matter has a strong influence on the rate of attenuation of light into the lake.

Keywords: attenuation coefficient, depth, suspended solid, volatile suspended solid.

INTRODUCTION

Lake Maninjau is located in the district of Tanjung Raya, Agam, West Sumatra, and the position is located between 0°19'41"N 100°11'18"E. Maninjau is a caldera lake formed by a volcanic-tectonic activity, is situated at an altitude of 461.5 m above sea level and a maximum depth of 165.5 m (Merina, 2014). People use the lake for their daily needs, hydropower and floating net. Intensive activity will greatly affect water quality both in physics, chemistry and biology. Water quality in physics of the lake can be seen from the optical properties of water. Color changing in water of lake indicate optical properties water that is impact to water quality in lake. The optically active substances (OAS: suspended particles and dissolved organic matter) determine the penetration of light to the water. Matter suspended in water consist of live organic material (phytoplankton), dead organic (detritus) and inorganic material (Reinart, 2004).

Studies on the optical properties of water have been done by some researchers in the sub-tropical region like in the Lake Peipsi, Estonia (Reinart et al., 2004), Lake Verevi, Estonia (Reinart et al., 2005), Lake Taupo, New Zealand (Belzile et al., 2004). As for the tropics, this study has not been done in detail. In this paper, the authors analyze the optical characteristics of lakes in the tropics, a preliminary case study on Lake Maninjau. Related to this, the composition of a water body will affect the content of the transmitted light, absorbed, or scattered from the signal propagation. It shows that the behavior of light is strongly influenced by the nature of the medium that is passed or the characteristics of the water column. Based on this, the knowledge of the attenuation of light can be used to determine the characteristics of the water column and bio-optical modeling of the lake.

METHODS

Survey has been conducted in Lake Maninjau at 8 stations with 84 samples. Sampling sites are shown in Figure 1. Selection of sampling sites based on the results of previous studies (Lukman, et al 2014; Suryono 2016). Transparency score is obtained by measuring water transparency using a Secchi disc. The intensity of sunlight on the surface of the lake was measured by using a lux meter. Light intensity is measured in Maninjau just the intensity on the surface of the lake. Light attenuation coefficient was calculated using the following equation (William, 1980):

$$K = \frac{1.1}{z_S^{0.73}}$$

z_s states secchi depth at each sampling point on the lake, K states attenuation coefficient of light.

The concentration of suspended solid matter is measured by filtering water samples as much as 250-800 ml with Whatman GF/A filter with known the empty weights. The filtrate is then heated in an oven at 105 °C and weighed. Furthermore, the filtrate is heated to a temperature of 550 °C for 1 hour. The sample is weighed and the concentration obtained was suspended organic matter or known as volatile suspended solid (VSS) . The calculation of the concentration of Total Suspended Solid (TSS) and VSS according to the procedure in standard method book of APHA-AWWA 2012 (page: 2-66 and 2- 67).

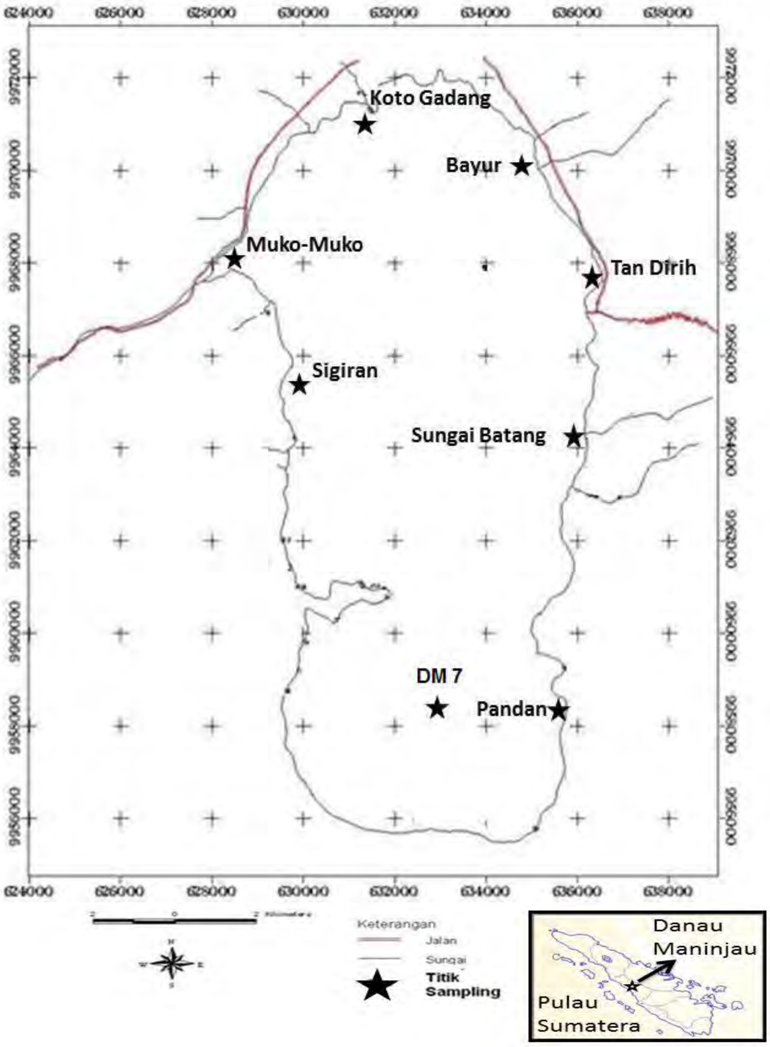

Figure 1. Sampling Location in Lake Maninjau (Souce of Map : Research Center for Limnology LIPI)

RESULTS AND DISCUSSIONS

The weather at the time of sampling are relatively flat at sunny - cloudy, so the Secchi depth has been measured value does not differ much between May and August, with the value range 1.65 - 2.2 m. Besides the weather condition (sunny-cloudy), Secchi depth is closely related to the process of light absorption in the waters affected by biomass in lake. The greatest value of sechi depth is in the blue-green wavelength region (Markager & Vincent, 2000). From Figure 2 it can be seen that in August slightly higher than in May. The average of Secchi depth to its lowest in Koto Gadang station with a depth of 1.65 m.

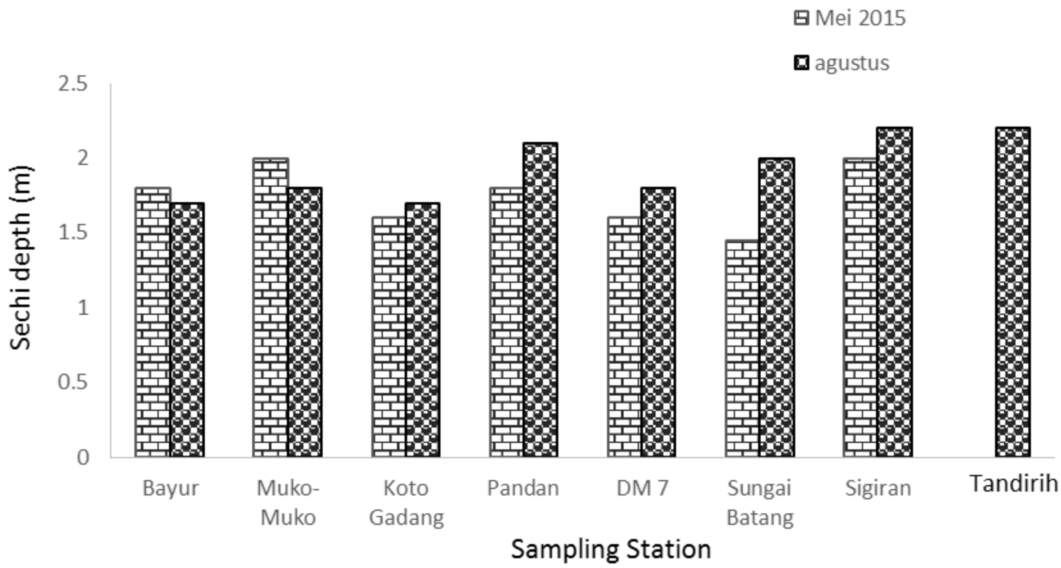

Figure 2. Secchi Secchi depth profile in Lake Maninjau 2015

The transparency level of the waters of lake indicates a period which sunlight can be absorbed by the lake to sustainability photosynthesis process. The deeper the Secchi depth means more sunlight energy is absorbed by the lake and vice versa. Decreased energy of sunlight entering the lake is indicated by the light attenuation coefficient.

Figure 3 shows the relationship between Secchi depth with the light attenuation coefficient (K), which regression value is 0.99. The Secchi depth inversely with K, if the Secchi depth increasingly in the light attenuation rate will be smaller. Attenuation of light shows the accumulation of the loss of light energy due to absorption or scattering of light straight into in the lake. Light attenuation coefficient value that indicates an incoming light energy to the surface of the lake was not up to the deepest part of the lake, it will have an effect on the rate of photosynthesis in the lake and aquatic primary production. The average of Secchi depth in Koto Gadang is the shallowest, it is 1.68 m, the value of K = 0.764 m^{-1} while in Tandirih, which the average of Secchi depth is 2.2 m, it is the deepest, the value of K = 0.619 m^{-1} (**Figure 4**).

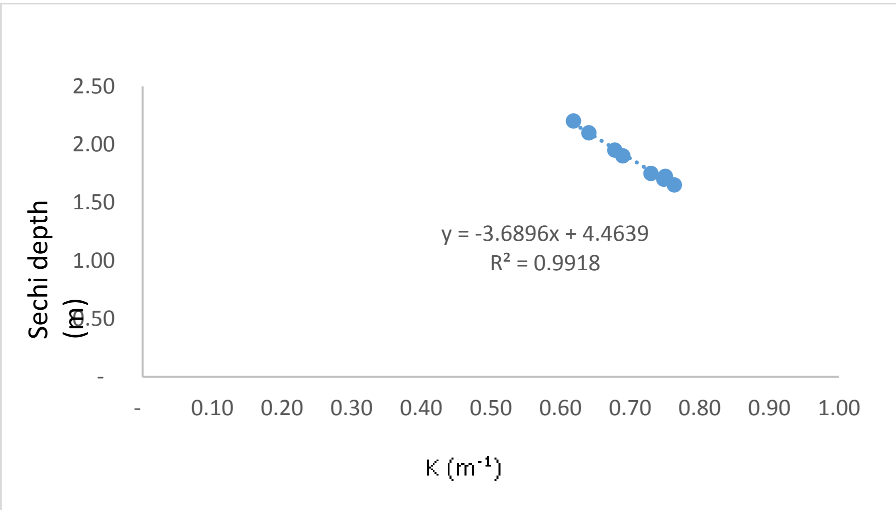

Figure 3. Relationship between Depth and Attenuation coefficient (K)

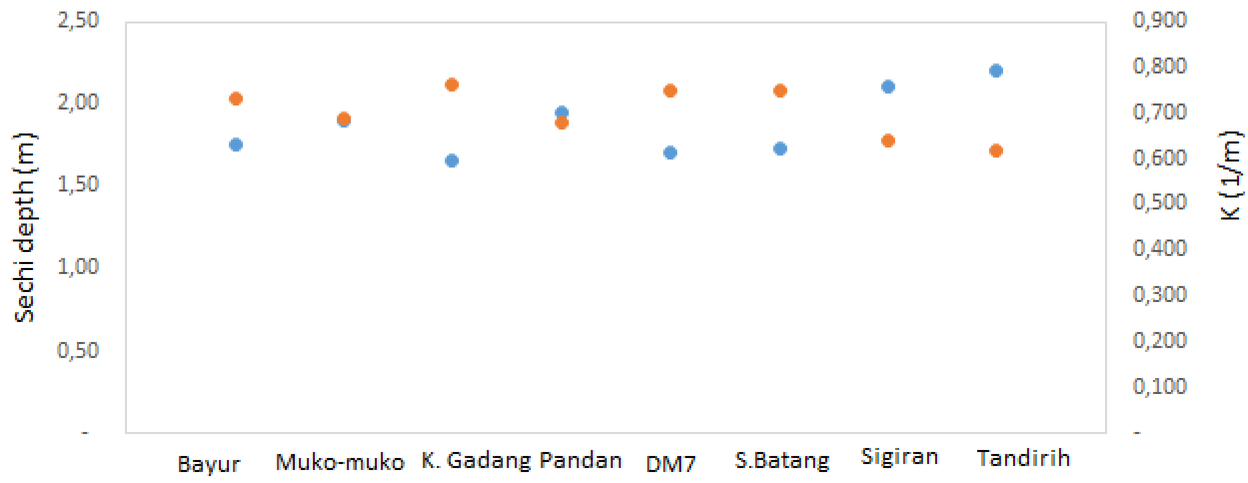

Figure 4. Relationship between Secchi Depth and Attenuation coefficient (K)

The amount of light energy that goes into a body of water can be seen from the amount of value the intensity of sunlight coming into the medium. Tandirih with a value of 107 500 lux intensity, depth of 2.2 m while koto Gadang with a depth of 1.65 m Secchi 60500 lux light intensity value (Figure 5). The light intensity at Pandan station and Sungai Batang amounted to 23 000 lux while Secchi depth of 1.95 m and 1.73 m. This suggests there are other factors that contribute to low levels of brightness on Koto Gadang Due to the intensity of light at the surface is quite large with a large attenuation coefficient so that the intensity of light coming into the lake is reduced in the appeal on the surface of the lake. Factors that led to the decline in energy of light into the lake called optically active substance such as the value of suspended matter, chlorophyll and yellow substance concentration.

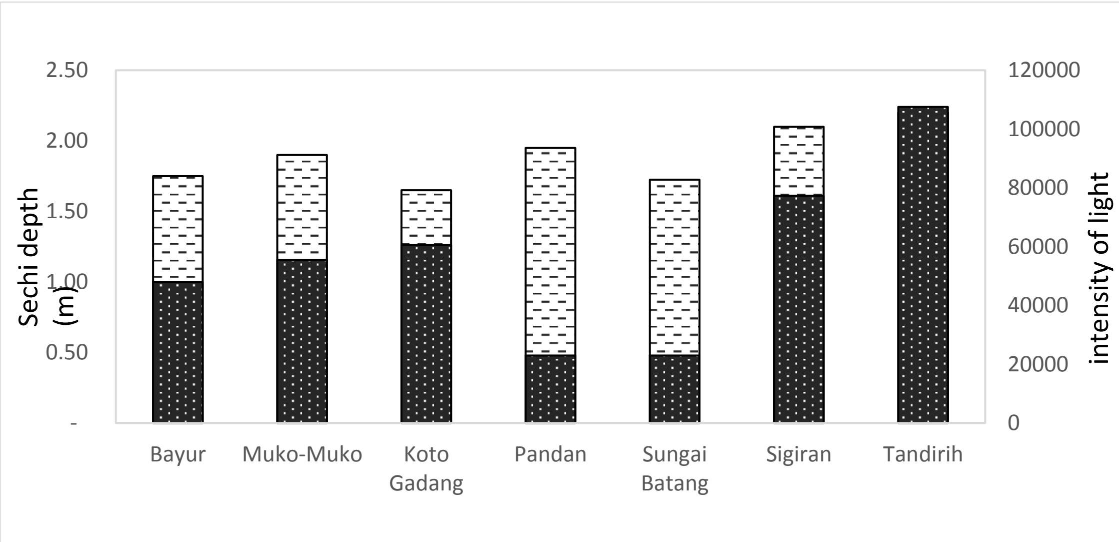

Figure 5. Relationship between Depth and Light intensity

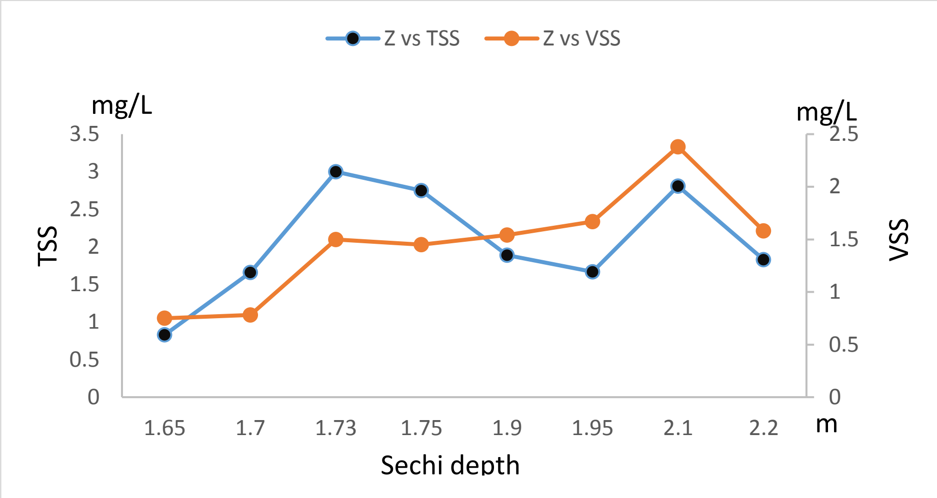

Figure 6. Relationship between Total Suspended Solid (TSS), volatile suspended solid (VSS),and Secchi depth (Z)

The average of concentration of suspended matter in Koto Gadang is 0.83 mg/L, the concentration of organic matter is 0.75 mg/L with a Secchi depth of 1.65 m. Sigiran station at a Secchi depth of 2.2 m has the highest suspended matter (2.81 mg/L) and organic matter 2.38 mg/L. The number of floating net cages is very high in Sigiran. The residue from feed and fish feces cause the high content of the suspended solids and organic matter that settle in the waters. High TSS concentrations can be caused by the high number of biomass and suspended solids that are characteristic of eutrophic lakes (Reinart, 2004). The concentration of suspended solids and organic matter in Tandirih and Sungai Batang sequentially is 1.83 mg/L and 1:58 mg/L, 3 mg/L and 1.5 mg/L. VSS values indicate the amount of concentration of organic matter that is in the water. This value is usually correlated with yellow substance concentration which will be greater in shallow areas (Davies-Colley and Vant 1987).

CONCLUSIONS

The results showed an interesting correlation between the optical properties of the spectra and optically active substances in the lake. The rate of light transmission to the lake decreases exponentially with increasing depth which is indicated by the coefficient of light attenuation. The amount of light intensity on the surface indicates the Secchi depth. Secchi depth is also strongly correlated with organic substances present in the lake but not absolute because many other factors that affect the organic content in Lake.

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LAND USE CHANGE ANALYSIS AT SENTARUM CATCHMENT AREA, WEST KALIMANTAN-INDONESIA

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ABSTRACT
Lake Sentarum (800 km^2) is one of 15 national priority lakes in Indonesia. As a floodplain lake, it has various seasonal changes those affect in the extents area and the depth between rainy and dry seasons. Lake Sentarum as included in the list of Ramsar sites, is the largest and the most important part of the wetland ecosystem in Asia since 1994. Sentarum catchment area (4000 km^2) is directly adjacent to the national boundary of Malaysia. Currently, Indonesian government is improving the economy in border areas. The economic growth will trigger the land demand for residential areas and cultivation. Therefore, it is important to identify land use changes that will have impacts on hydrological characteristics and floodplain ecosystem of the lake. Meanwhile, the land use changes in the catchment arise quickly, especially in forests loss and development of oil palm plantations. The purpose of this study is to analyze the land use changes in Sentarum catchment area. The identification of land use changes was using classification based on data utilized such as Landsat-5 (2001) and Landsat-8 (2013). Analysis of land use changes used cross tabulation methods to compare both of land use data series. Results of the analysis showed the land use in 2013 was still dominated by forests with area of 2,320 km^2 (56.6%) after decrease of 143 km^2 for 12 years, while settlement area still only 4.9 km^2 (0.1%) which was a result of increase of 3.8 km^2. Major changes occurred in the development of oil palm plantations which covers 280 km^2 and the majority comes from the area originally covered by forests (140 km^2).
Keywords: Lake Sentarum, land use, catchment area, classifications, landsat

INTRODUCTION

Land is the basic material of an environment, which is defined by a number of natural characteristics, namely climate, soil geology, topography, hydrology and biology (Aldrich, 1981 in Lo, 1995). Also, land cover depicting the artificial construction of vegetation and land surface (Burley, 1961 in Lo, 1995). Construction is entirely visible directly from remote sensing imagery. Three classes of data in general are included in land cover: physical structures built by man, biotic phenomena such as natural vegetation, crops and animal life and the type of development. The spatial and temporal distribution of land use is important parameters to correct their characteristics. Numerous applications rely on information about land use classification levels, from hydrologic and climate models to techniques aimed at optimizing best management practices in agricultural watersheds. Remote sensing techniques can be used to obtain the spatial distribution of the land use content over large areas, reducing expensive and time-consuming field measurements.

Land use associated with human activities in certain areas, land cover information can be recognized directly by using the appropriate remote sensing technique. Moreover, information about human activities on the land cannot always be interpreted directly from the closure of the land (Lillesand and Kiefer, 1993). Land use changes include a shift towards the use of land to different land use (conversion) or intensification on existing land use. In general, changes in land use will influence: (a) the characteristics of the river flow, (b) the amount of surface runoff, (c) the nature of the relevant regional hydrological (Mayer and Turner, 1994, Ferry, 2007). The various of land use and land cover data needs is exceedingly broad. Land use and land cover existing data are needed for equalization of tax assessments in many states. Land use and land cover data also are needed by federal, state, and local agencies for water- resource inventory, flood control, water-supply planning, and waste-water treatment. Many federal agencies need current comprehensive inventories of existing activities on public lands combined with the existing and changing uses of adjacent private lands to improve the management of public lands (Anderson *et al*, 1976).

Nowadays, it is widely-known that land-use changes can be accurately monitored at a global, regional and local scale using satellite remote sensing imagery. One of the most commonly used satellite sensors for such purposes is the Thematic Mapper (TM) on board of Landsat series satellite platforms. The spatial and temporal resolution, the availability, the coverage and the overall quality of the Landsat data, provide a useful informational background for detailed land-use change studies.

Lake Sentarum is one of the 15 national priority lakes in Indonesia for the conservation period 2010-2014, based on the National Conference of Indonesia Lake II in Bali in 2009 on the sustainable management of the lake (Soeprobowati, 2015). Lake Sentarum is one of the lake exposures to floods since 1994 designated as a conservation and sustainable use of wetlands (Ramsar site) in Indonesia via the UNESCO convention (Giesen, 1996; Ashari et al, 2002). The Ramsar Convention is an agreement among member states to commit to maintaining the ecological processes of wetlands of international importance and seeks to manage wetlands in the region wisely with the principle of sustainable utilization. Common problems in Sentarum National Park are the change in land use in the watershed, riparian damage and water contamination originating from anthropogenic activities (Ministry of Environment of the Republic of Indonesia, 2011). Another problem, which is the exploitation of the fisheries sector, is mainly done in the dry season. Catching fish is done on a permanent puddle in the national park area. This puddle should be protected as a refuge for species of water at a time when dry. The purpose of this study is to analyze the land use changes in Sentarum catchment area. The analysis also identified patterns of changes to build the model projections of land use.

METHODS

Study Area

Lake Sentarum was located in 111° 35' 42.598" – 112° 31' 12.317" E and 0° 38' 20.249 - 01° 22' 0.861" N. Administratively, this lake are in Kapuas Hulu District, West Kalimantan Province (Sub-District of Batang Lupar, Badau, Embau, Bunut Hilir, Suhaid, Selimbau and Semitau). There are two National Parks in the Sentarum watershed, namely Lake Sentarum National Park and Betung Kerihun National Park which is located in upstream area. In 2016, both of National Parks combined into one management. **Figure 1** shows location of study area.

Sentarum catchment area is wet tropical climate type. According to Schmidt and Ferguson classification, it is Type A with Q values ranged from 50% to 84.3%. The range of annual rainfall is 2,307 – 4,616 mm, temperatures during the day is 29 ^{0}C – 36 ^{0}C and at night the temperature range between 12 ^{0}C – 29 ^{0}C. Dry season occurs between July to September, the monthly rainfall about 100 mm. Topography around Lake Sentarum mostly flat with a slope of less than 5%, is surrounded by hills that can reach 400 meters above sea level. Vegetation in highland area has different habitat types with lowland forest vegetation in the vicinity which is always flooded. But in general, this area is a basin and catchment area unit Kapuas River.

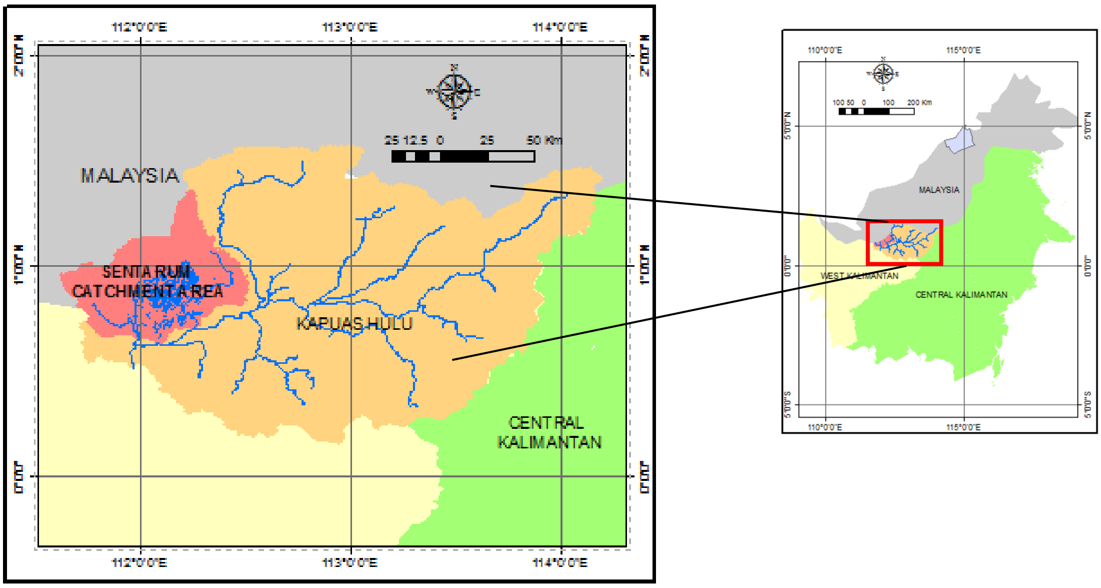

Figure 1. Study area in Sentarum watershed

Image Classification

Analysis of land use is divided into two parts: land use change analysis (change detection) and land-use change prediction models. For the analysis and simulation of the dynamics of change in land use, data required include; distribution of land use at some period, biophysical parameters and socio-economic variables were considered as potentially important factors of land use patterns. These factors describe the demographic situation, soil, geomorphology, climate and infrastructure.

Land use analysis generally begins with the processing of satellite imagery as the basis data. Image processing consists of two parts: pre-processing and image classification. Pre-processing the image consists of a process for preparing image data for subsequent analysis which tries to correct or compensate for systematic errors, like as atmospheric, radiometric and spatial error. The image classification method is used supervised classification and the training sample area is derived from ground check data which is collected by Camera GPS, reference data from Lake Sentarum was collected by boat and in the upstream area by vehicle.
Any supervised classification does not complete until an assessment of its accuracy has been performed, an appropriate technique of accuracy assessment needs to be performed. Accuracy assessment can be defined as a comparison of a map produced from remotely sensed data with another map from some other source or base on ground check data. How closely the new map produced from the remotely-sensed data matches to the source map is important analysis (Sense man *et al*,, 1995). Kappa coefficients were used to estimate the similarity between the two maps. Values > 80% are categorized as the same, 60% -80% of high similarity, almost the same 40% - 60% and < 40% do not have a common (Landis and Koch, 1977).
Comparing the results of classification by cross tabulation is used to analyze changes in the research area of land, land use change on two series of maps will be detected by comparison of pre-classification. Cross tabulation is done in a series of land use in 1991 and 2013. Comparisons will observe changes in each pixel (Lunetta and Elvidge, 1999). **Figure 2** shows flow chart of the study. The result of the study are rate and distribution of land use changes, and then compared with interview data the pattern of land use change in Sentarum catchment area also delivered.

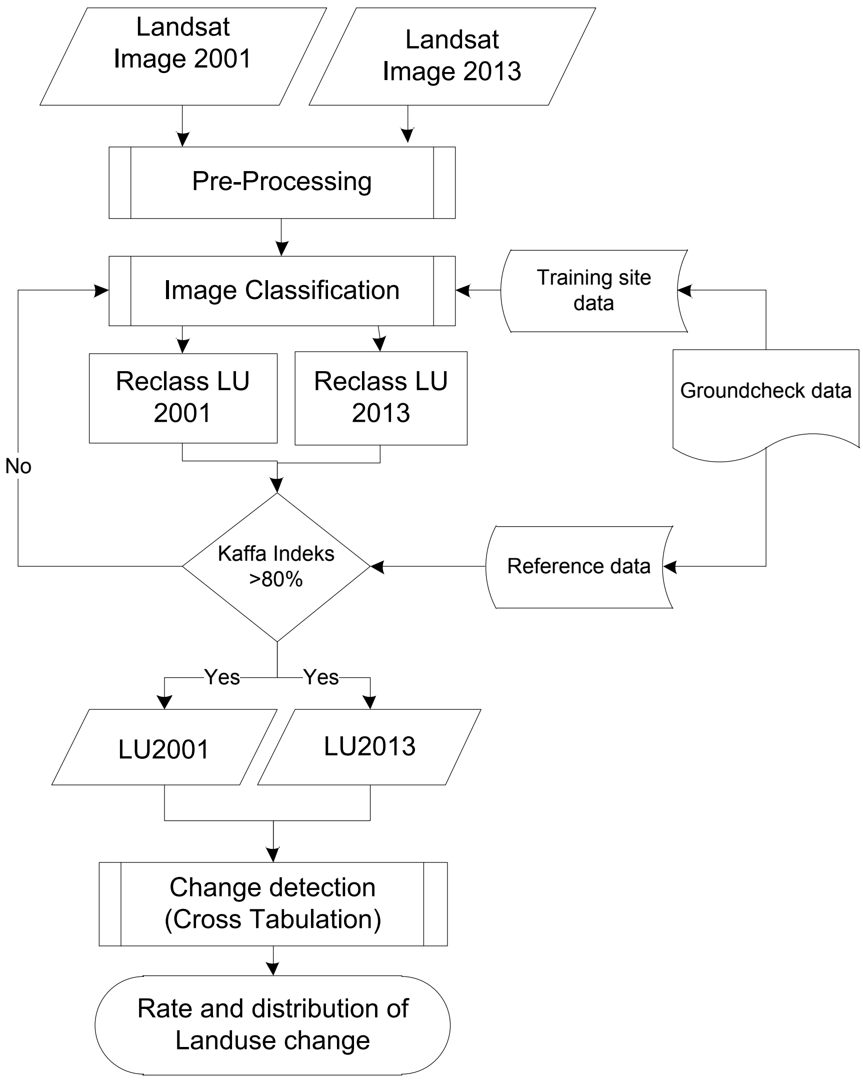

Figure 2. Flow chart of landuse change in Sentarum Watershed

RESULTS AND DISCUSSIONS

The first step in this research is data collection, Landsat image and ground check data field. Landsat image is derived from USGS and ground check data retrieval using GPS Camera and conducted interviews with people in the field. A time sequence of multi-spectral Landsat 7 ETM+ images was used to identify spatial/temporal changes in the vegetative cover of Sentarum watershed. The Landsat 5 and Landsat 8 create images with 30 m × 30 m pixel size. The satellite orbital profile operates on a 16-day cycle, with each image covering a swath 183 km wide. The results of retrieval data is plotted by GIS applications and is used classification process (**Figure 3**). Results of the land use identification in the Sentarum watershed are shown in **Figure 4**. There are eleven land use class that are; forest, rubber tree, paddy, bush, dry agriculture, settlement, oil palm, grass, barren and water.

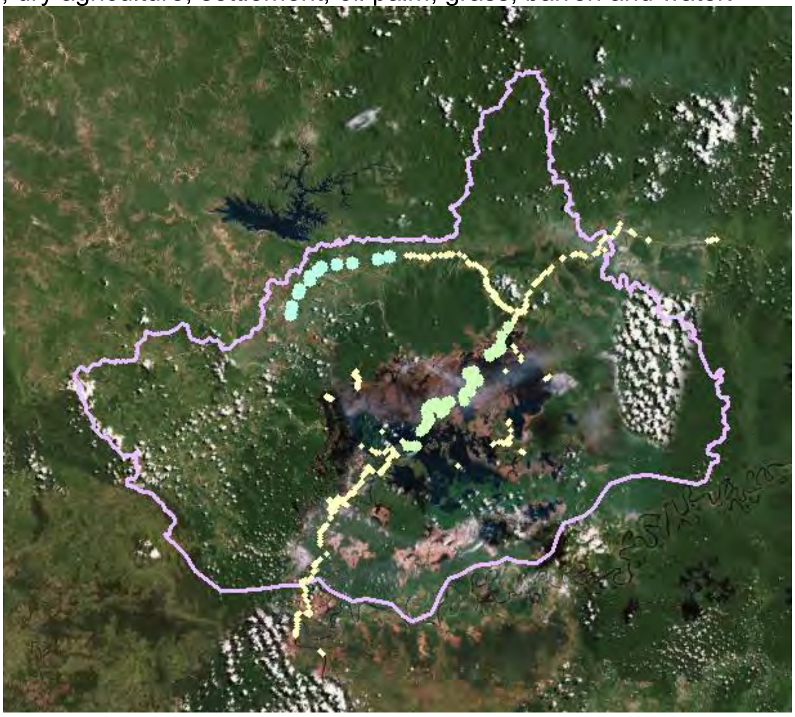

Figure 3. Reference data for landuse classification

Figure 4. Land use class in Sentarum Watershed

In this study, the identification of land use used supervised classification, and visualization was made also in natural color composite bands. The Landsat 5 in 2001 used composition of the band 542, while the Landsat 8 in 2013 using the composition of the band 752. From the appearance of the second series of Landsat imagery found striking differences mainly in the west and northwest visible openings are expected to oil palm plantations. **Figure 5** shows the RGB Composite band Landsat imagery in the Sentarum watershed. Composite band also shows the distribution of the water body of the lake is a lake of flood exposure, there is some vast lake and found also lakes with an area of only a few hectares.

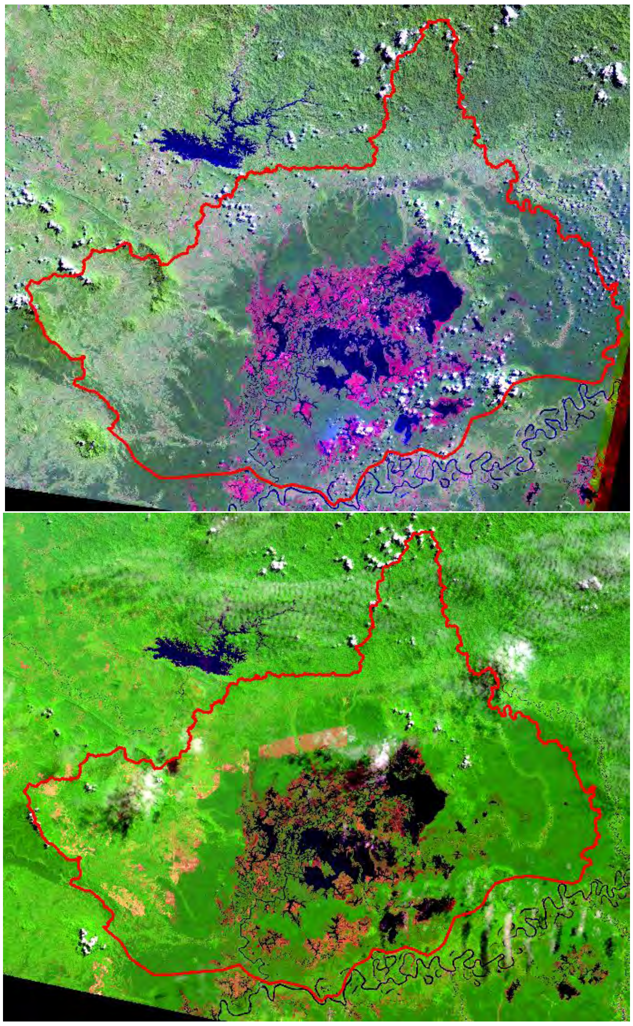

Figure 5. RGB composite band image, 542 for Landsat TM 2001 and 752 for Landsat 8 2013 (Red line: Catchment boundary).

Classification of land use in the Sentarum watershed performed on Landsat-8 imagery in 2013. Training sample reference data obtained from the results of field trips during the year 2015 - 2016. The results of image classification in 2013 are shown in **Figure 6**, which gained 11 land use classes. Based on the kappa index classification results are included in the same category, which shows a match with the reference data is 85%. The results also show the use of forest classification is still quite wide reaching 56.6% of the total area (2,316 km^2), and shrubs 14.6% (596 km^2). Plantations in the watershed Sentarum is Perennials such as: rubber, fruits and oil palm, in 2013 the area of oil palm plantations has reached 6.7% of the total watershed area (275 km^2). Location of oil palm plantations mostly found in the northwestern part of the watershed, or more precisely on Sub-catchment Seriang River that flows into Lake Sentarum.

The results of the classification of Landsat 5 in 2001 shows the forest area reached 60% of the total watershed area (2459.7 km^2), most of the forest is included in the Lake Sentarum National Park and Betung Kerihun National Park. An area of shrubbery was 20% (837 km^2) resulting in a vast reduction in both classes, the forest is reduced 133 km^2, while the area of plantations in 2001 was only 6% (263 km^2) which is a rubber plants and fruits, oil palm plantations have not found on land use in 2001. Timber industry, such as plywood, timber, furniture, paper pulp rapidly evolving in the 1980-1990s led to a large number of natural forest in Borneo to be cut down (Velasquez and Shimizu 2001; Butler 2005; Engel and Palmer 2008). The area of the body of water is 8% (328.2 km^2), decreased compared with the area in 2013, which reached 9.6% (392 km^2). It is common condition on the lake-type flood exposure. **Figure 7** shows a map of the watershed land use Sentarum 2001.

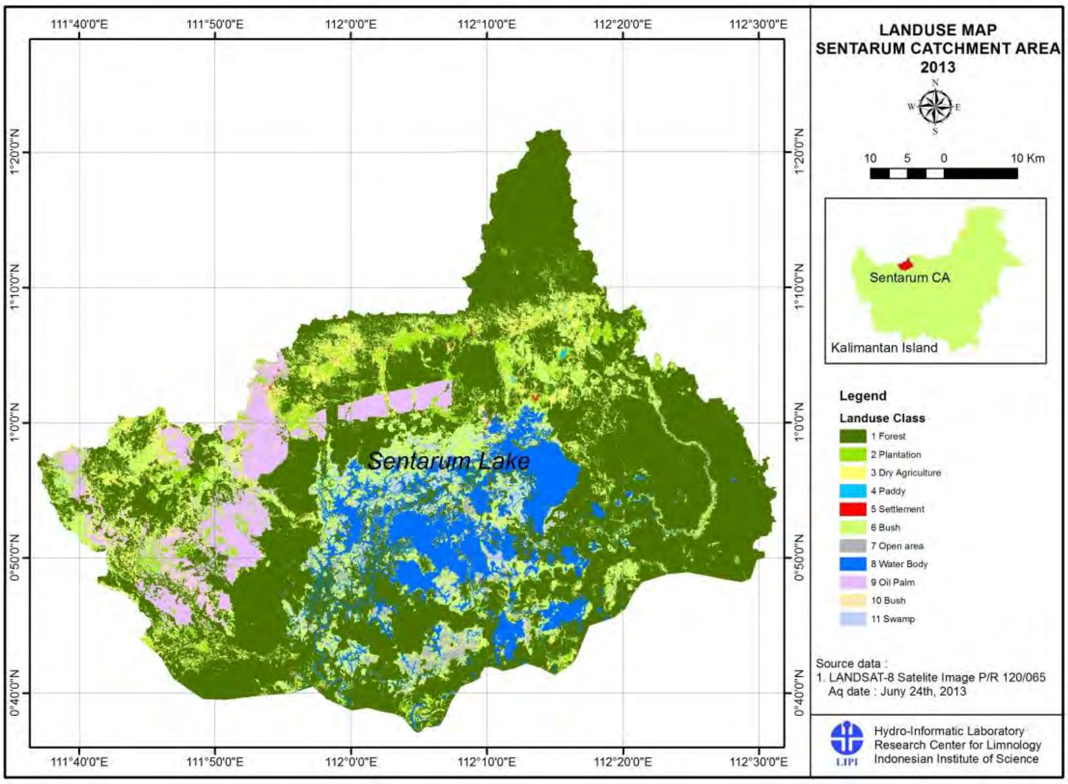

Figure 6. Land use Sentarum Catchment Area 2013

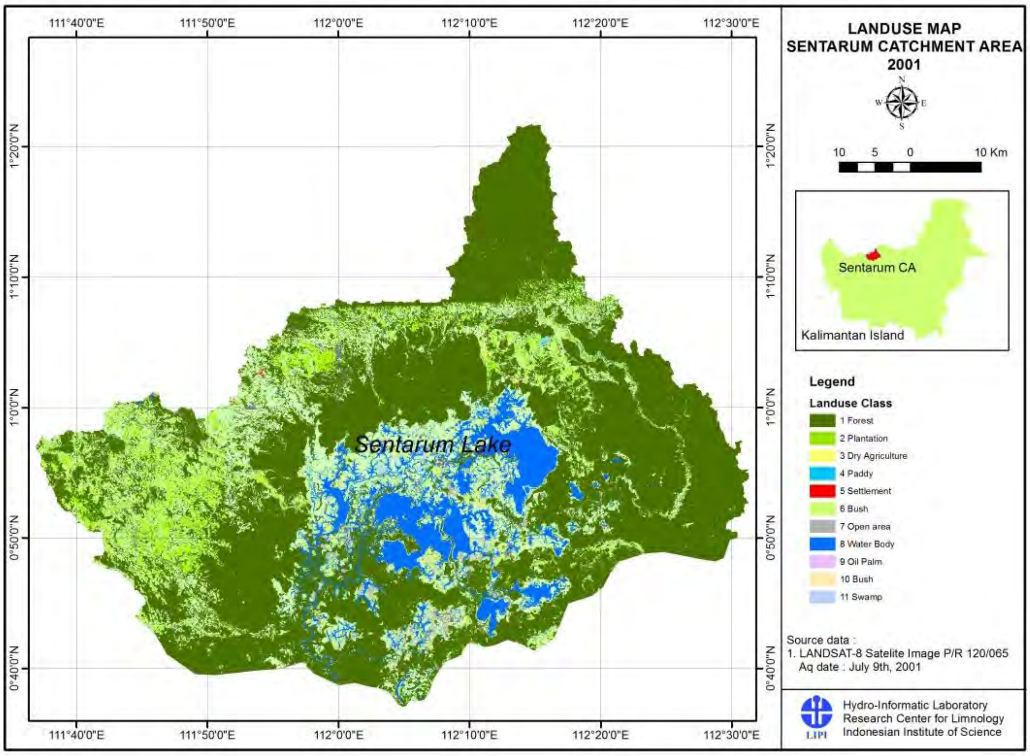

Figure 7. Land use map of Sentarum Catchment Area (2001)

Rate of land use change in Sentarum watershed were shown in more detail in **Table 1**, where the shrub was missing approximately 240 km^2. Based on the analysis of cross tabs on some of the region grows into a forest but in other areas of forests are converted into a thicket. Great changes found in palm oil plantations cover, where for 10 years of oil palm plantations increased 275 km^2, while the cover of lading for 10 years farmland increased by 126 km^2. Field observations in the form of agricultural fields were conducted, such as: upland rice, pepper, and some cassava. The patterns of land use change in each class are shown in **Table 2**.

Tabel 1. Rate of Land use changes in Sentarum Catchment area

		Landuse 2013		Landuse 2001		Changes (Km^2)
ID	Landuse	Area(Km^2)	%	Area(Km^2)	%	
1	Forest	2316.5	56.6	2459.7	60.1	-143.2
2	Plantation	179.5	4.4	253.5	6.2	-74.0
3	Dry Agriculture	128.2	3.1	2.2	0.1	126.0
4	Paddy	1.0	0.0	1.1	0.0	0.0
5	Settlement	4.9	0.1	1.1	0.0	3.8
6	Bush	596.1	14.6	837.0	20.5	-240.9
7	Open area/barren	41.4	1.0	18.3	0.4	23.0
8	Water	392.5	9.6	328.2	8.0	64.3
9	Oil palm	275.0	6.7	0.0	0.0	275.0
10	Grass	65.1	1.6	19.8	0.5	45.3
11	Swamp	91.1	2.2	170.5	4.2	-79.4
	Total	4091.4	100.0	4091.4	100.0	

Tabel 2. Cross tabulation on land use 2001 and 2013

	Landuse Class	Landuse 2001											Total Area
		1	2	3	4	5	6	7	8	9	10	11	
Landuse 2013	1. Forest	1952.74	69.56	0.21	0.09		264.42	2.93	12.56		4.76	9.26	2316.52
	2. Plantation	83.88	25.13	0.67	0.29		63.96	2.08	0.72		0.90	1.88	179.51
	3. Dry Agriculture	34.60	27.59	0.60	0.11		61.22	2.64	0.28		0.39	0.78	128.21
	4. Paddy Field	0.09	0.21	0.01	0.49		0.20	0.02				0.02	1.05
	5. Settlement	1.23	0.32	0.12	0.01	1.10	1.39	0.38	0.01		0.01	0.31	4.87
	6. Bush	185.00	80.66	0.49	0.08		223.00	4.11	12.79		5.93	84.06	596.12
	7. Open Area	4.29	0.19	0.01			9.62	0.55	1.51		2.54	22.66	41.36
	8. Water Area	25.80	0.36				58.05	0.28	289.67		2.22	16.12	392.49
	9. Oil Palm	140.94	42.28				87.34	3.23	0.16			1.06	275.01
	10. Grass	23.75	7.13	0.09	0.00		23.54	1.62	1.17		1.55	6.21	65.07
	11. Swamp	7.36	0.08				44.26	0.48	9.31		1.47	28.18	91.15
	Total Area	2459.69	253.51	2.19	1.07	1.10	837.00	18.33	328.19	0.00	19.76	170.54	4091.36

Gogo rice is a traditional activity of the Dayak people, where they burn back into the forest areas that have been planted with rice, they will always move from one place to another. The pattern of land use changes in the Sentarum watershed was shown in **Figure 8**. This pattern was obtained from the crosstab analysis and interviews with people in the study site. Shifting cultivation is mainly found in highland forests. In a system of shifting cultivation, the main crops cultivated are gogo rice (Setiawan, 2010). Shifting cultivation is a system that builds on people's experiences in preparing the land and land practiced hereditary (Febriani, 2016). Shifting cultivation is an old traditional way of farming. The relationship between the local communities with traditional knowledge of forest resources is often referred to as local wisdom (Zakaria 1994 in Sardjono, 2004). Land use with the traditional pattern known as the cultivation where the Dayak community in these activities is a major source of meeting the needs of the family. This fact was expressed also by all Dayak tribes that are in parts of Kalimantan/ Borneo inland (Dove, 1988). The practice of shifting cultivation has a strong correlation with the damage to the forest ecosystem. Shifting cultivation has impacts that may affect farming and forest ecosystems. Drastically reduced soil fertility, traces farming area has become scrub or grasslands. When the rainy season, many layers of topsoil are eroded and washed away, thus decreasing soil fertility conditions (Febriani, 2016). But according to Setiawan (2010) in the last 300 years, this system has little effect on the destruction of forests, the tropical forests, the largest content of phosphorus stored in the trees, so to release it by forest fires. Nutrients released into the soil can be used for growing upland rice, until absorbed, then cultivators opening a new forest, while the long-abandoned land (fallow) to become the back woods (for 20-25 years). Land clearing sequence, causing the formation of the mosaics of land with a succession of ages and diverse biodiversity. This process is often coupled with agroforestry (forest gardens multicultural), where the fields to be abandoned planted with various trees useful that can be integrated on forest ecosystems, especially rubber and fruits.

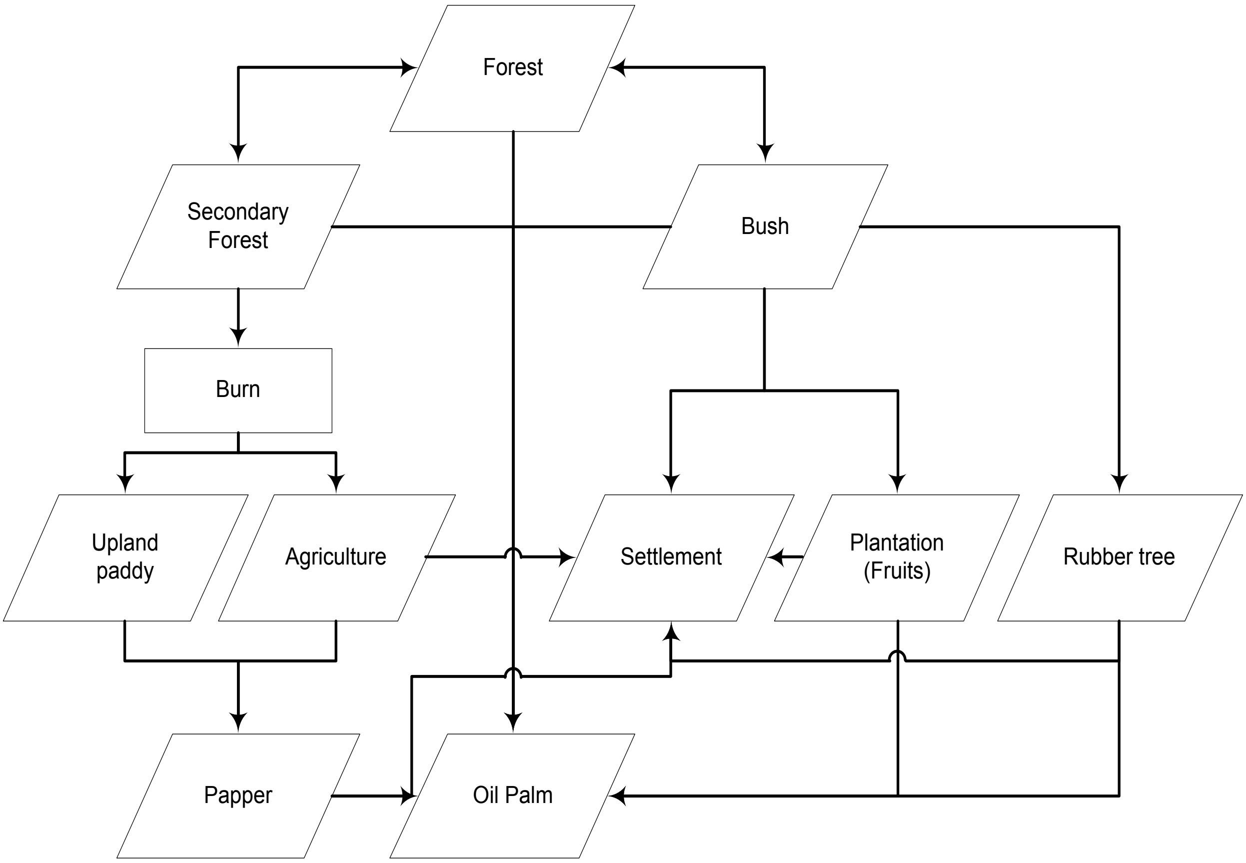

Figure 8. Landuse changes pattern in Sentarum Catchment area

In the present state of shifting cultivation becomes more complicated due to forest area reduced due to other causes, in the river basin itself area reduced Sentarum 145 km^2 largely converted into oil palm plantations and shrubs. So, the Dayak people who do shifting agriculture become difficult because the land has changed function. Another influential factor is the migration of the population into the territory Sentarum watershed triggered by the acceleration of development in the boundary region by the government. This leads to the changing dynamics of land, creation of infrastructure such as road networks, as well as consideration of labor and land availability.

External trigger factor that plays a big role in land use changes dynamics in the Sentarum watershed, as influential as well in various places in Indonesia, are the needs of industry and exports of palm oil and paper. This request triggers the issuance of policies specific forestry and land use that supports the development of two of these commodities through land conversion is realized through the forest. Cultivation right policy for industrial forest plantation and exploitation permits.

CONCLUSIONS

Lake Sentarum Ecosystem have anthropogenic pressure by land use changes, such as; deforestation (-143 Km^2) Expansion of oil palm (+275 Km^2), urban growth. The results from land use change analysis should support the development economic plan and settlement problem, and still pay attention in conservation for biodiversity in Sentarum catchment.

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A CASE STUDY ON SIMPLE FLOODS OBSERVATION AND MAPPING SYSTEM BY IMAGE INFORMATION

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ABSTRACT

In the Philippines, flood disasters are increasing. And the governments and many donors are trying to mitigate it by introducing monitoring stations. However, many systems cannot work well to protect the regional community. The local people did not react well for the warnings. Why does this happen? The warnings issued by the authorities said to be quite general. This is due to limited monitoring systems. In addition, people treated floods as a part of normal life. To tackle the difficulty, we started our researches with LLDA (Laguna Lake Development Authority) from 2013. Simple web cameras have been installed to four rivers just for visual surveillance. This study analysed the effectiveness of the simple floods monitoring and mapping system to improve the economic resilience of the local community and provided some policy recommendations to the local governments and donor organizations to increase the people's response to the floods. For river systems, we have installed some monitoring stations with smartphones. For disaster management team, we have provided smartphones with a special application for mappings and photo images. The method of the effectiveness evaluation on the simple monitoring system is including number of images, maps and warnings from the authorities and other social issues including security of the town, traffic jam, and illegal waste disposal. And we examined technical sustainability of the system under bad internet environments. We had a series of discussions with the target LGUs (Local Government Units), LLDA, private companies including Japanese factories and other stakeholders. We have found that the system can never be effective without education and community's involvement. We found that the simple observation system can increase people's involvement.

Keywords: Flood around Laguna Lake, Web camera monitoring, Early warning, Waste management, Problem Mapping by smartphone

INTRODUCTION

Background

This paper aims to investigate the possible flood risk management by focusing on simple floods observation and mapping system by smartphones. The most important aspect of the web camera monitoring system is easiness to show potential risks to local people. Everybody can easily watch river flow condition via web site. When the local authority issues a flood warning, people try to see present conditions of the river side. It is dangerous situation but people want to see the real condition by themselves. This system provides a real view of the potential risk area via web site and at the same time, the hazard map on the same web pages will guide the people to evacuation spots. (See **Figure-1**). However, the cost of the CCTV camera is quite high and unable to cover all the risk area. In Japan, there are some simple water level monitoring system (See Figure 2). It has only simple water sensor, which detects just high, middle and low water level. It has a red light with siren alarm. This system can be an independent alarming system since it can automatically alarm the surrounding community in case of risky situation. This is why our simple web camera system has been widely appreciated recently. To install this system, the collaboration between local authority and community is essential.

Figure 1. CCTV Camera in Nagaoka City, Japan

Figure 2 Simple Water level sensor with alarm, installed by Unimation Inc., Japan

Floods are natural and inevitable, and large cities like Metro Manila cannot be protected from all flooding. However, some floods are extreme and others are not extreme. We aim to minimize their risk to people, property, industry and infrastructure by empowering community capacity. There are so many measurements to reduce flood risk such as construction of dikes, protection of river banks and rehabilitation of river system, however, we focus on community awareness since it is the most effective way to reduce food risks to the community itself. We are developing supporting education system and awareness programs for communities in flood prone areas, in collaboration with local government units (LGUs), Laguna Lake Development Authority (LLDA) and University of the Philippines Los Baños (UPLB). The flood prone area lacks flood prevention infrastructure. Furthermore, residents are economically vulnerable to flood as they have limited options for relocation, improvement of their housing, or insurance methods. Although the community had an evacuation plan in the event of typhoon, the absence of reliable property security systems prevented the community from mobilizing quickly enough to avoid injuries and loss of valuable assets. Prior to the intervention, residents would rely on the word-of-mouth to determine if river levels were high enough to warrant evacuation. And the community people receive frequent warnings from the government authority and they were insensible to the warnings.

Research question and Significance of the Study

The impact of flood is heavily depending upon the floating dangerous matter such as woods and solid wastes. And the quality of flood water is another course of damages of the floods. The flood waste risks

we observed in the Philippines are related to the risk of Tsunami in terms of secondary risks caused by floating matters. "Metro Manila's dump sites are dangerous, exposed, and generate potentially toxic liquids called "leachate." As these toxins flow along the surface and seep into the earth, they risk poisoning the surface and groundwater that are used for drinking, aquatic life, and the environment." (ADB 2004) And now, urbanization is all around the Lake Laguna. Up to now, we identified the following facts;
i) Flood is a part of their life.
ii) Flood water was clean and it was not so dangerous.
iii) Flood brings solid wastes, foul-smelling and dark color.
iv) water color of the flood was changed.
v) In case of evacuation, people cannot leave their house since they have to protect their property.
In the Philippines, the number of river basins where flood control works have been implemented is increasing year by year. However, they had serious damages caused by flood disasters every year, especially in rapidly developing areas.

PREVIOUS STUDY

Lessons learned from the East Japan Great Disaster in 2011 (EJGD)

In this chapter, we will examine lessons learned from EJGD in the field floods disaster. There are some differences between Tsunami and Floods, but we have learned the most important factor to activate people's response to the warnings. The warning system was mostly perfect. It includes web based information, mobile e-mail notification, warning siren and loud speaker systems. However, more than half of the people at the risk area recognized the warning via TV news. Based on lessons learned from the EJGD, the Japanese government plans to take the revised approaches while issuing a warning:

- the information should be clear and timely, emphasize crucial messages, and encourage evacuation. (Easy to understand, but reaction of the people still unknown)
- Issue the first warning quickly and revise it according to observed data. (Technical improvement, it takes much costs and time.)
- Provide tsunami height predictions qualitatively instead of numerically, considering the uncertainty of tsunami estimates. (Easy to understand, but reaction of the people still unknown)

However, these small improvements are not yet perfect. The messages to encourage people to escape the Tsunami risk were modified practically. But, no matter how advanced technology becomes, the guiding principle is that people should take the initiative to escape or tackle the potential risks on their own. While warnings must be delivered to everyone at risk, only half of the affected residents actually received the information following the EJGD.

Lessons learned from the Thai Floods in 2011

Flood protection is important in the industrial zones because of the risk of large scale damage to industry and private property. Dikes were constructed downstream of the Chao Phraya together with a number of pumping stations. In June 2011, heavy rainfall occurred in many locations throughout the month caused by the influence of the active southwest monsoon. Moreover, during late June 2011, Thailand was dominated by the remnant of tropical depression "Haima" led to heavy rainfall in several areas especially in the northern part where flash floods and landslides was reported. In July 2011, downpour rain continued in many areas in addition to tropical depression "Nock-Ten" moved into the area of Nan province on 31 July 2011 before weakening to low pressure cell covering the northern part. This brought heavy rain to several areas resulted in widespread flooding in north and northeast parts.
However, associated with high tide, severe flood and extensive damage was extended to most areas of northern, eastern and western Bangkok and its vicinity. The rainfall amount of Thailand since 1 January to 31 October 2011 was 1822.4 millimetres, about 28 percent above normal. Seasonal rainfall from May to October in 2011 was above normal of 20 – 60% in northern part, but of 10 - 40% with below normal in some areas in central part.
We must understand the man-made causes of floods as well. The most common man-made causes of flood in Thailand are deforestation, uncoordinated urban development, over-abstraction of groundwater, and destruction of flood embankments (Hoang 2011). One of large man-made reasons is deforestation. Forest area was reduced from 166,000 km2 in 1942 to 106,000 km2 in 1983 and to 92,000 km2 in 1995. But, the entire region is usually flooded during the monsoon season, part of the ecological cycle that causes Thai people to adapt their lifestyles accordingly. Boats become the vehicle of transport and become a necessity for the rice harvest. Their houses in the Central Plains sit atop stilts. In addition, we must understand a common phrase used in Thailand, "Mai pen rai", which translates to 'it's nothing' in English, and it sums up the Thai philosophy fairly well (Plocher 2011). During our survey in Vietnam, we heard the last floods in Thailand in 2011 will be forgotten instantly. But people in Central Vietnam are always preparing the coming floods. We believed that a popular water puppet show in central

Vietnam could be a hint for their good awareness for flood risks. We understand that visualization of flood can motivate people to take positive actions for floods. This difference should be revealed in the coming surveys.

Flood Disaster Related Project by Major Donors

We recognized various flood projects in the Philippines since they had continuous flood disasters. Those projects can be classified by the Donors as Table-1. Bilateral donors including JICA, US, Spanish, Australia, UK and Canada are commonly to improve the monitoring and furcating systems for the floods. Multilateral donors including World Bank, ADB and UNDP are working together with some bilateral donors and providing necessary funds to the government agencies in the Philippines.

Table-1 Flood related projects in the Philippines

Project name and related organization in the Philippines	Donor
Disaster Risk Reduction and Management (DRRM) Capacity Enhancement, Office of Civil Defense (OCD). (2012-2015)	JICA
A Simple and Community Friendly Independent Floods Observation System for the Laguna Lake district and National Capital Region, The University of the Philippines Los Baños (UPLB), Laguna Lake Development Authority (LLDA) (2013-2016)	JICA
ASEAN – US Cooperation on Disaster Management, ICS(Incident Command System) Phase 2 (2009-2012)	US State Department, USAID
Program for Enhancement of Emergency Response (PEER) Phase 3	USAID, Office of U.S. Foreign Disaster Assistance (OFDA)
Establishment of Reconstruction Monitoring and Evaluation System (RMES)	World Bank, US State Department, USAID
Climate Change Adaptation Project Study to establish impact of climate change in the agriculture sector in two pilot areas (Bicol Region and Region 2), Department of Environment and Natural Resources (DENR)	Spanish Government, World Bank
Integrated Disaster Risk Management Framework – Disaster Risk Profiling and Development of Risk Models	ADB
Hazards Mapping and Assessment for Effective Community-based Disaster Management (READY), DENR, Department of Science and Technology (DOST)	UNDP, AusAID,
Greater Metro Manila Area Risk Analysis Project	AusAid, UNDP
Building Community Resilience and Strengthening Local Government Capacities for Recovery and Disaster Risk Management	UNDP, CIDA
Flood Early Warning System in Metro Manila, Philippines, Center for Disaster Preparedness, University of Philippines (2012-)	Christian Aid UK Government

(Source: Adopted by the author from the various website information.)

The PAGASA Rainfall Warning System (RWS) under UNDP is in operational mode since its launching on June 20, 2012. The initial color coding: YELLOW, ORANGE, RED was used based on the color coding scheme of the Community-Based Flood Early Warning System (CBFEWS) under the UNDP project. These colors are generally associated with awareness, preparedness and emergency respectively. JICA started to improve the Office of Civil Defense (OCD) capacity in responding to disaster risks. Before this, OCD's main function was just to recover the damages of the disaster. And JICA has also started our new project, "A Simple and Community Friendly Independent Floods Observation System for the Laguna Lake district and National Capital Region in the Republic of Philippines." The uniqueness of this simple system for flood observation is to observe river systems by using smartphone camera, powered by solar panel.

All projects are providing training program since the importance of risk perception in shaping people's behavior is essential. Slovic (1987) emphasized the role of risk perception by indicating that the public relies on risk perception to evaluate hazard situation. Risk perception can influence both the design and operational aspects of disaster risk management. Accordingly, perception could be viewed as a process of transforming inputs (e.g. flood warning) to output (e.g. public mitigation response). People who

perceive that they are vulnerable are more likely to respond to warnings and undertake protective measures. Thus, understandings of the people's risk perception will influence the effectiveness of the flood management strategy.
The continuous floods in the surrounding Metro Manila and Laguna basin became a new challenge to have sustainable growth. Simple measures can be taken beforehand to strengthen the resilience of communities, to save lives, to secure livelihoods and to prevent the loss of investments and development gains. When a natural hazard threatens a nation, public facilities and private businesses alike have to protect their assets, their workforce, and their supply and distribution chains in order for society and the economy to keep functioning.

Participatory Mapping

Nowadays, all the donors and government agencies have introduced this mapping operations with the collaborations of the local community. The Participatory Mapping is the most popular and effective methods to ensure the effectiveness of the floods preparation operation. In order to minimize the increasing potential hazards and rising vulnerability, flood disaster risk managers need to first identify who and what are exposed to floods disaster risks. Basic data for flood disaster risk management are sometimes limited, unobtainable, incomplete, inaccurate, outdated, contradictory, or expensive. Disaster risk managers, especially those in local governments, therefore face many barriers to accessing and utilizing up-to-date and accurate hazard and risk data (Chapman 2013). In Nagaoka city, we have recognized similar activities and they have developed it on the web site.

How to activate local people: A case of Shiga prefecture, Japan

In Japan, all the measures are based upon "Disaster Countermeasure Basic Act" in 1961. All the local governments including prefecture and city government are responsible to manage flood risks under the act. The Central Disaster Management Council was to formulate the overall policy for DRM and to function as the national coordinating body for disaster management. (Government of Japan 2015) Direct communications from the local governments are very limited and only official announcement via official home pages is the main measures to the community. Recently, Takashima and Kusatsu city introduced daily e-mail services including Typhoon, flood risks and other community problems including unexpected witness the bear in the community and fire accidents. Especially, Takashima city government is quite actively announced all the problems and events directly informing to the registered readers of the e-mail, called "Real time Takashima". The basic idea is to include warning information into their daily life.

METHODS

Basic Idea for the effective monitoring

To expand the monitoring points, it is necessary to reduce the cost of the monitoring station. The Nagaoka City Crisis Management and Disaster Prevention Headquarters introduced some simple systems to do so. The system has a different idea. A large number of cameras have been installed to various rivers just for visual surveillance. It reduced the numerical monitoring items such as river heights and water flow velocity.
The basic idea for people's action can be illustrated as follows. (See **Figure 3**) The community people can understand the warnings from the authority, but it does not always bring action of the people. But, if they can compare the photos between regular and present photos, then they can easily understand the present situation.

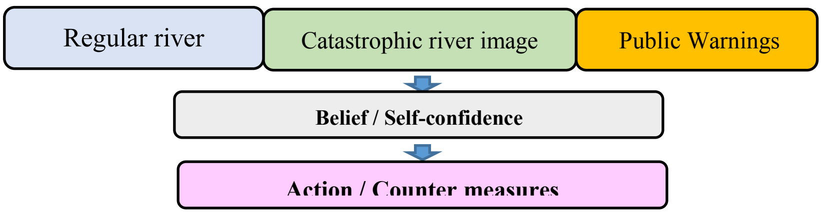
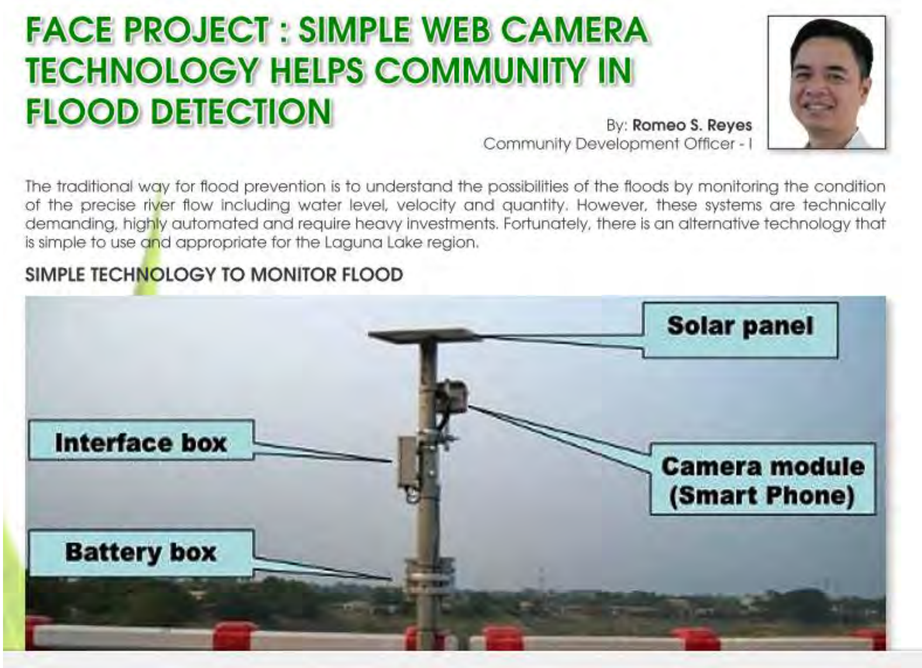


Figure 3 Impact of Photos to action

On the contrary, we can observe traditional limited expensive monitoring systems in the surrounding area of the Philippines. In Banaba, Metro Manila, they are trying to establish an accurate flood prediction and early-warning system with funding and support from Christian Aid and UK Government. University scientists trained residents to monitor and collect information related to flooding, particularly river height, speed of river rise, and meteorological information such as rainfall. This approach is a typical traditional expensive method and takes much funds and time to install. Obviously, the local communities are economically vulnerable to disasters as they have limited options for relocation, improvement of their housing, or other financial insurance methods.

FACE project

We conducted field surveys from 2014 both in Nagaoka city, Japan and surrounding rural area of Lake Laguna and Metro Manila in the Philippines to compare the effectiveness of the flood monitoring system. Our target was Santa Rosa and Calamba city in Laguna and Tanay, Angono and Taytay city in Rizal provinces. We have interviewed city officials of the flood prevention sections in the local government. And we have checked their preparedness by using check lists including floods hazard maps, training programs, communication systems, periodical evacuation drills, food and clean water stocks and any records of the previous floods. After that, we have started the Flood Awareness and Community Empowerment (FACE) project under JICA grassroots project in the Philippines from October 2014 to October 2016. The report below described FACE project under the authority of LLDA. (See **Figure 4**)



FACE PROJECT : SIMPLE WEB CAMERA TECHNOLOGY HELPS COMMUNITY IN FLOOD DETECTION

By: Romeo S. Reyes
Community Development Officer - I

The traditional way for flood prevention is to understand the possibilities of the floods by monitoring the condition of the precise river flow including water level, velocity and quantity. However, these systems are technically demanding, highly automated and require heavy investments. Fortunately, there is an alternative technology that is simple to use and appropriate for the Laguna Lake region.

SIMPLE TECHNOLOGY TO MONITOR FLOOD

Figure 4 Simple Web Camera on FACE project
Source: LLDA, Laguna de Bay Environment Monitor 2013-2014

RESULTS AND DISCUSSIONS

The flood warning systems were able to reduce economic damages and loss of life by providing lead time for people to take protective measures. But it is not perfect still needs some improvement to activate people's response to the warnings. All the donors are trying to introduce new sophisticated technologies to improve these system, especially early warning system. Using warning systems to trigger community response is the key to flood disaster management. Nowadays, the speed of the floods are increasing because of the rapid urbanization. No matter how advanced technology becomes, the guiding principle is that people should take the initiative to understand the potential risks of the flood on their own. Warning information has the limitations of the forecasting technology. Inaccurate or inappropriate warning information could mislead or delay evacuation and increase the loss of lives. Disaster risk communication must be practiced regularly, so that people are able to better understand the flood warning system.

Findings from the FACE project

There were several findings from the pilot project, FACE project in the Philippines. One of the important finding was to identify the very regional risks such as intensive rains. (See **Figure 5**).

Figure 5 Simple Web Camera on FACE project
Source: LLDA, Laguna de Bay Environment Monitor 2013-2014

A comparison between CCTV and Smartphone camera

We can summarize the characteristics of the two system, CCTV and smartphone as follows (See **Table 1**).

Table 1. A Comparison between CCTV and Smartphone Camera System

	CCTV Camera	Smartphone
1.Basic equipment	➢ CCTV camera with communication and power supply lines. ➢ For night vision, additional lights and/or Infrared camera required ➢ Movie record available.	➢ Smartphone with Solar panel. ➢ Photo only (interval shots) ➢ For night vision, additional lights required
2.Costs of Instalments	US$300,000 to 500,000	US$20,000 to 30,000
3. Advantage	➢ Clearer visions ➢ Movie ➢ Widely spread established technology	➢ Cheaper installation and O/M costs ➢ Easier and quicker installation works and O/M ➢ No power and no communication lines
4. Dis-advantages	➢ Higher installation and O/M costs ➢ Limitation caused by power and communication lines ➢ No function caused by no power and disruption of power and communication line	➢ Mobile communication available area only ➢ Interval of images depend upon the speed of communication system (3G or 4G) ➢ No internet availability in case of huge disaster
5. Other expected monitoring functions	➢ Town security ➢ Illegal dumping monitoring (in the act)	➢ Town security (Limited) ➢ Illegal dumping monitoring

Source: Prepared by the author

The flood warning systems were able to reduce economic damages and loss of life by providing lead time for people to take protective measures. But it is not perfect still needs some improvement to activate people's response to the warnings. Using smartphones images to trigger community response is the key to flood disaster management. Nowadays, the speed of the floods is increasing because of the rapid urbanization. No matter how advanced technology becomes, the guiding principle is that people should take the initiative to understand the potential risks of the flood on their own.

CONCLUSIONS

Conclusions

The flood warning systems were able to reduce economic damages and loss of life by providing lead time for people to take protective measures. But it is not perfect still needs some improvement to activate people's response to the warnings. Most donors are trying to introduce new sophisticated technologies to improve these system, especially early warning system with expensive devices. Using warning systems to trigger community response is the key to flood disaster management. Nowadays, the speed of the floods are increasing because of the rapid urbanization. An effective floods warning system always requires continuous public education about the purpose of the system. As we saw a case of Shiga prefecture, Japan, daily communication with the community is the most important issue. A system can never be totally effective without education, no matter how expensive or sophisticated. We found that the simple web camera observation system can reduce the setup time, costs dramatically and increase the people's involvement. This simple method can be much more practical for poor communities.

Remaining Issues

From this survey, we found out some useful findings such as the cultural aspects to understand the preparedness of the flood risk. This implies that flood warnings should be tailored to the characteristics of the target people. That is why the participatory mapping was introduced to ensure the effectiveness of floods preparedness.

A conclusion drawn from this research focused on industrial area is the importance of joint risk education initiative among communities, industries and local government. When it comes to the formulation and implementation of floods management strategies, identification of the local risks are essential. Factors influencing the decision of risk management can be; the possibility to evaluate prior floods accurately. Factors influencing the decision of a local adaptation strategy of the floods risks can be; cultural differences, history and better knowledge of the prior and neighboring flood experiences.

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DEVELOPMENT OF SPATIAL PREDICTION MODEL TO IMPROVE LAKE WATER QUALITY MANAGEMENT IN KLANG VALLEY, MALAYSIA

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ABSTRACT

Water quality of a lentic system is highly dependent on the intensities of land use activities of its surrounding area. Hence, integrated management approach is obligatory in order to sustainably manage lake water quality. Due to complex nature of lake with its ability to absorb pollutant over a long period of time, it is quite an arduous task to comprehend types and strengths of pressures that influence the water quality status. Therefore, by using management support tool, lake managers are able to determine drivers that significantly affecting lake water quality conditions. The existing traditional evaluation practice of lake water quality that is based on quick assessment with paucity on seasonal succession and land use transition will never be accurate. The major hurdle of limited information and data scarcity also strongly affect effective strategies to overcome water quality deterioration which escalates with time. In addition, relying on water quality monitoring alone based on a few fixed parameters may not be sufficient to analyze lake water quality status. Currently, the significance contribution of the vicinity of land use activities and spatial distributions that are affecting lake water quality are still minimally studied. Thus, the aim of this paper is to illustrate the design framework of the developed similarity based water quality prediction model. The developed spatial model incorporates the physical, social and water quality variables within 1km buffer radius of selected lakes. The expected model output is a guideline comprises of index indicating lake water quality status to facilitate proximity-scale planning strategies between land use activities and lake waterbody, especially in identifying vulnerable areas with high risk of pollution impact, for highly developed or urbanized area.

Keywords: GIS, integrated management, lake water quality, similarity index, spatial modelling.

INTRODUCTION

The lentic nature of lakes has caused it to act like a sink or sponge absorbing all the pollutants which accumulate without any symptom being noticed at early stage and escalating over period of time causing symptoms to only appear at later stage (WLC, 2007 and ILEC, 2005). In addition, lake ecosystem is also unable to operate in self-sustaining ways because of interferences or damages over a period of time exceedings their capacity for self-repair (WLC, 2007 and ILEC, 2005). Land use activities, changes of land cover, rapid urbanization, socio-economic demands and growth of population density, and climate have been identified and proven as imminent factors in contributing to the degree of severity of lake water quality, and eventually impacting the aquatic ecosystem well-being (Dai et al., 2017; Elliot et al., 2016; Zessner et al., 2016). In addition, the shape and size of a lake basin or watershed have also been acknowledged to highly affecting lake water quality and ecosystem within it (Lytras, 2007). However, the geomorphology of lake which play a major role in determining the water quality condition is always kept in sideline. Lake area, lake volume, maximum and average depth are parameters that are related with nutrient cycling, (Matisoff et al., 2017; Erol and Randhir, 2013; Lytras, 2007) seldom included in pollution impact measurement.

The deeper lakes are characterised by thicker surface layer which determines the photosynthetically available irradiance, the efficiency of nutrient cycling and the vertical distribution of organisms (Lytras, 2007). On the other hand, smaller and shallow lakes are strongly affected by wind-induced sediment re-suspension which results to significant changes in the water chemistry and geochemical cycles (Lytras, 2007). Mean depth is also an important factor for controlling productivity while the size of lake is related to the depth of thermocline (Lytras, 2007). Moreover, the shape of the lake can be associated with bottom dynamic conditions (ILEC, 2005; Lytras, 2007). The slope of littoral zone has a great influence on the biomass and the distribution of submerged macrophytes communities (ILEC, 2005; Lytras, 2007). A gently sloped littoral allows the deposition of fine materials and can modulate the wave action in favour of establishment of aquatic macrophytes (Dunalska et al., 2015; Erol and Randhir, 2013).

The fragmented approach of lakes and their various values being governed and managed did not allow comprehensive understanding of the hydrological and ecological dynamics of the lakes and the manner they changed over time and prevented the development of sustainable management regimes based on long term trends and requirements (WLC, 2007 and ILEC, 2005). Most importantly is the lack of coordination and integration of data between stakeholders that has prevented the values of these lakes to be adequately quantified (Dunalska et al., 2015; Kibena et al., 2014; Duggan, 2012; Evers, 2008), as a consequence of which planners and managers have little understanding of the full value of lake importance.

Deficiency in the aspect of legal framework governing Malaysian lakes also leads to an unnoticeable exceedance to the assimilative capacity of the lakes. The closest to legislative proposals is merely a series of guidelines including National Water Resources Policy, Integrated Lake Basin Management (ILBM) and Strategic Planning of Sustainable Management of Lake developed by Ministry of Natural Resources in 2007. Thus, key reason of why sustainable management of lake water quality facing a great challenge to achieve effective implementation and ILBM principle is yet to fully realize.

Another major obstacle is the extemporary approach taken by lake managers of “wait until it turns bad” towards lake water quality leads to severe deterioration of resources within the lake ecosystem, causing high cost of restoration on both financial and time (Chea et al., 2016; Dunalska et al., 2015; Aglanu, 2014; Duggan, 2012). Because of its lentic nature, it will take years for lake to being restored back to its original condition (WLC, 2007 and ILEC, 2005). Even if only a segmented issue such as water quality or sedimentation or algae bloom is to be regarded, the fact that lakes are close ecosystems means that a comprehensive analysis is necessary so as to include all the activities and landscape patterns within lake watershed concerned (Lin et al., 2015; Niswonger et al., 2014).

Thus, the major reason on why a continuous and regular monitoring of lake water quality for both dry and wet season is compulsory. Long term regular monitoring provides trends and sufficient data to be analyzed in order to fathom the dominant pollution sources either point sources or non-point sources, how much nutrients coming in from the catchment activities, what are the prominent stressors (or drivers), how strong the impacts of watershed activities influence water quality status and which land use types profoundly affect lake water body (Lin et al., 2015; Liu et al., 2015; Leon-Munoz et al., 2013). Without a complete data and information, lake managers and watersheds stakeholders would not be able to comprehend or have an absolute understanding on how the driving factors would impact the water quality status which is the theoretical principle of Driver-Pressure-State-Impact-Response (DPSIR) in achieving sustainable integrated watershed-waterbodies management (Tsuzuki, 2015).

The concern of how lake water quality being managed is due to the fact that health status of lake water quality especially natural and recreational lakes has significant impact on the public well-being, property values and the number of tourist visits (Tuttle and Heintzelman, 2014; Larsona et al., 2013). A clean and pristine lake is one of the key indicator on measuring the sustainable development and the quality of life of a community (Tuttle and Heintzelman, 2014; Larsona et al., 2013). In addition, natural and recreational lakes are also a tangible reflection of the quality of life in a given community (Tallis et al., 2015). A major contributing factor of amenity and aesthetic values of a community livelihood especially in urban areas. Studies by Dunalska et al., 2015; Kandulu et al., 2014 and Larsona et al., 2013 have shown that there is a significant correlation to reductions in stress, lowered blood pressure, and apparent physical health to the length of stay and frequency of visits to recreational parks and being with nature.

It is also important to be aware that most changes happened in lake water quality is unobservable to the naked eye. Low dissolved oxygen, high total coliform, increase of water acidity of alkalinity, high concentration heavy metals such as lead, mercury, zinc and copper, and high nutrients loads can never be detected through visible eye view. Only when high pollutants concentrations combine with other factors causing algal blooms, fish kills, appearance of colour or turbid water, will physical evidence to be noticed. The severity of pollutants concentrations in lake water quality can only be determined through measurement with specific scientific equipment. Furthermore, the value of pollutants reading must comply with standard water quality index before the actual condition of lake water quality is known. The main reason why referring to the available standard developed specifically for river or industrial effluent is not accurate, which is a common practice at the moment in Malaysia because lake water quality standard is at development stage. The current practice is for lake managers or researchers to follow Water Quality Index (WQI) developed by Department of Environment (DOE) Malaysia intended to assess industrial discharge into rivers and streams, and/or either combining it with Carlson 1977 Trophic State Index. In addition, pathogenic indicators such as *E. Coli* and Total Coliform are missing in both standard, which is quite inapt as pathogenic parameters is important in permitting body contact recreational activities with lake water and its pointing towards any possible leakages of sewer or wastewater treatment pipeline within close vicinity of lake areas.

Therefore, the aim of this paper is to illustrate on the model development framework of spatial based water quality prediction model as a supporting tool to be used intently by lake managers, and generally by relevant stakeholders in implementing sustainable lake water quality management. The model facilitates understanding of parameters that affect lake water quality, the quantitative relationships between all the variables, and integrates all the leading drivers within designated surrounding activities of lake environment, to measure alteration in lake water quality and forecast the water quality changes with the changes of the identified variables. In addition, they may information to support sustainable planning and lake restoration, on which funding decisions are made, providing prioritization on financial allocation in order to avoid unnecessary surplus towards any particular lake.

Overview of Water Quality Modeling

Looking at a global scale, there are many types of prediction model developed or commercially used to manage lake water quality, controlling pollution, managing the lake ecosystem, ecology and economic assessment. Some of these models were developed to suit the geographical and lake morphological condition of a particular country such as China, Turkey, New Zealand, USA, Canada, Switzerland, Denmark and Japan. However, rest of the world rely heavily on the commercially developed model by adopting or adapting the model input to suit their targeted environmental goals. Most of the water quality models developed focuses on eutrophication issues, nutrient fluxes due to agricultural activities, sedimentation loads, and urban expansion of land areas in the lake shoreline or fringes (Nyamrumbu and Magadza, 2016; Xue et al., 2015; Zou et al., 2014;). Integration between land-use activities, socio-economic demand, hydrological factors, pollution sources and lake morphology, being calculated in one database to assess current water quality status or forecasting the impacts on lake water quality is usually non-existence.

At the regional level of ASEAN countries, Laguna De Bay of Philippines (Barbosa et al., 2007) and Tonle Sap of Cambodia (Chea et al., 2016) are good examples of regional success in developing specific model that meet the countries' lakes need instead of just relying on using commercial model. The purpose of developing water quality prediction model that tailored to the Malaysia's need is to help us to better reflect on our understanding of lake water quality interactions and their behavior, and we can improve from the current traditional management practice, including cost saving on medium to long term scale. In a long run, we would be able to share knowledge gained from our own experiences with other lake managers at regional and global scale.

GIS infrastructure existed in every government agencies and department is the major reason of choosing ARC-GIS as a platform of model set-up, with minimal financial implication in contrast to commercially existed model such as PAMOLARE, InfoWorks, CENSIS and MIKE. The system also catered to standardize water quality parameter monitored by all lake managers, hence providing a guideline on selecting suitable types of water quality parameter in regular monitoring. This is crucial in promoting effective implementation of Integrated Lake Basin Management which has been introduced to Malaysia since 2007 but has taken a slow ride in implementation scale. GIS is also chosen because of its ability to store, retrieve, manage and analyse spatially and temporally varied data (Kim et al., 2012). The system provides the best platform to integrate both spatial and non-spatial data into decision support system. Its ability to perform interpolation and extrapolation at large spatial scales also play huge advantages (Liu et al., 2015; Lee and Chung, 2007).

Once the lake managers and stakeholders are enlightened about the medium to long term hazards of lake mismanagement to the whole lake ecosystem health and well-being, they likely would form a strong pressure groups to facilitate effective implementation of established policies and strategic planning. Through this model they would also be able to make a responsive and affirmative decision.

METHODS

Previous studies of model development in Malaysia mainly focusing on sustainable rivers management only. A handful of studies on model development with regards to lake are only concentrating on nutrient response model for shallow tropical lake (Sharip et al., 2012), eutrophication (Ishak, 2012) and water quality assessment of urban recreational lake which omit the watershed and surrounding land use factors (Oyekanmi et al., 2014). Recent studies (Sharip et al., 2016; Sharip and Yanagawa, 2016; Ali et al., 2013) deliberated on the subject of water demand issues, assessment of spatial water quality dynamics, and lake ecosystem dynamics in response to nutrients fluxes respectively, using the application of commercial software. Most of the existing studies on lakes in Malaysia for the past five years only concentrated on pollution determination especially sedimentation, runoff, nutrient fluxes and eutrophication; including their impact on aquatic ecosystem. The variables of population density, expansion of development and urbanization close to lake water, prospect of changes in land use activities within lake watershed and how it has affected the lake water quality are the common missing link and minimally studied.

Conceptual Framework

Similarity based modelling is adopted in this particular research due to severe data limitation in water quality parameter and lake geomorphology. The principle of similarity based modelling is introducing similarity measure between a series of given or known values of an element with similar options (Chen, 2009; Wegerich, 2004 and Duch, 2000). The theory is to postulates water quality status of other lakes using similarity index quantified based from lake with comprehensive series of data.

The currently developed model is only focusing on spatial distribution of three major independent variables which are the social factor, the water quality parameter and the physical factors as illustrated in **Figure 1**. This similarity based model is complimenting the non-spatial factors that consists of established guidelines, policy and strategic planning by serving as management or decision support tool.

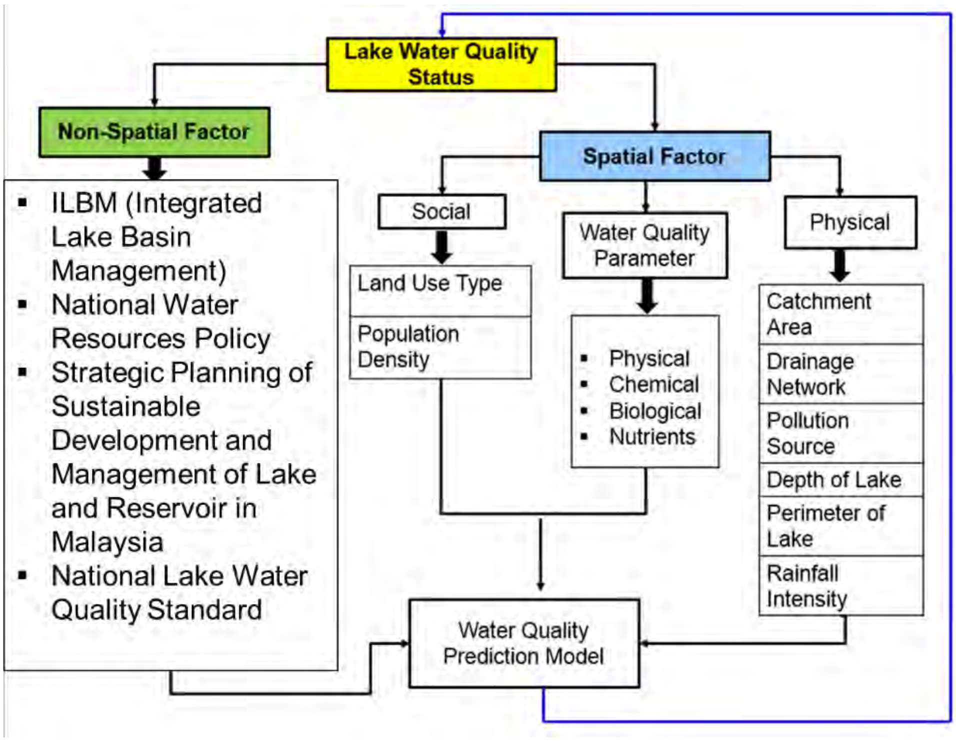

Figure 1. Conceptual Framework of the developed Spatial Prediction Model.

Model Design and Structure

A geodatabase was developed to integrate the rainfall, population density, water quality, catchment area, land-use types, pollution sources and drainage network in one platform. Arc-GIS 10.3 software is used in model development. The percentages of built up area, rainfall distribution and population density was calculated within specified range of 1km buffer (Wardropper et al,2015, Liu et al., 2015, Dunalska et al, 2015, Kibena et al, 2014) radius surrounding the selected lakes. The 1km buffer was clipped with land use map of the lakes and served as modeling database. The rainfall data and river basin network for this study were obtained from National Hydraulic Research Institute of Malaysia (NAHRIM). The 2013 land use map was acquired from Department of Town and Rural Planning, and 2010 population density data were obtained from Department of Statistic. Seventeen water quality parameters were selected based on systematic literature review of previous researches from 2000 to 2016 which are; pH, temperature, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Dissolved Oxygen (DO), Total Phosphorus, Total Nitrogen, Ammonia, *E. Coli*, Total Coliform, Turbidity, Suspended Solids, Chlorophyll a, Nitrate, Nitrite. Correlations between land use types and water quality were tested using Pearson's correlation coefficient or Principal Component Analysis (PCA) with statistical significances at $p<0.01$ using SPSS to measure the association between the independent variables.

In order to measure the status of lake water quality and variables that affecting it, an equation based from y=mx+c is formed (equation 1).

$$LWQI=f\ (S+W+P) \qquad (1)$$

LWQI = Lake Water Quality Index;
f = Coefficient; S = Social Factor; W = Water Quality Factor and P = Physical Factor

Lake Putrajaya because of its comprehensive long-term water quality data has been selected as based model to develop the similarity index. 5 years data set of lake water quality from 2010 to 2015 obtained from Perbadanan Putrajaya was calculated to produce range of values, categorizing each range of values in classes of bad, poor, medium, good and excellent. 85 recreational lakes in Selangor and 8 recreational lakes in Kuala Lumpur were selected in prediction model development. Those with missing or incomplete data, interpolation technique is applied using spatial analyst tool. Secondary data of selected recreational lakes in Selangor and Kuala Lumpur is engaged to calibrate and validate the developed similarity based water quality prediction model. In addition, for measurement of model sensitivity, sampling of lake water of selected lakes was conducted and the measured data will be run using the developed model. This is to ensure the model achieves its key objective of development as well as to gauge the uncertainties factor and percentage of accuracy.

RESULTS AND DISCUSSIONS
The expected result from this research is a spatial water quality prediction model to predict water quality status with changes of variables within the specified 1 km buffer, as well as displaying current status of the lake water quality. A range of numerical values in index form categorizing the lake water quality status from bad, poor, good and excellent, served as guideline for lake managers to determine their lakes water quality status. The similarity index is also presented in visualization form depending on water quality status (**Figure 2**).

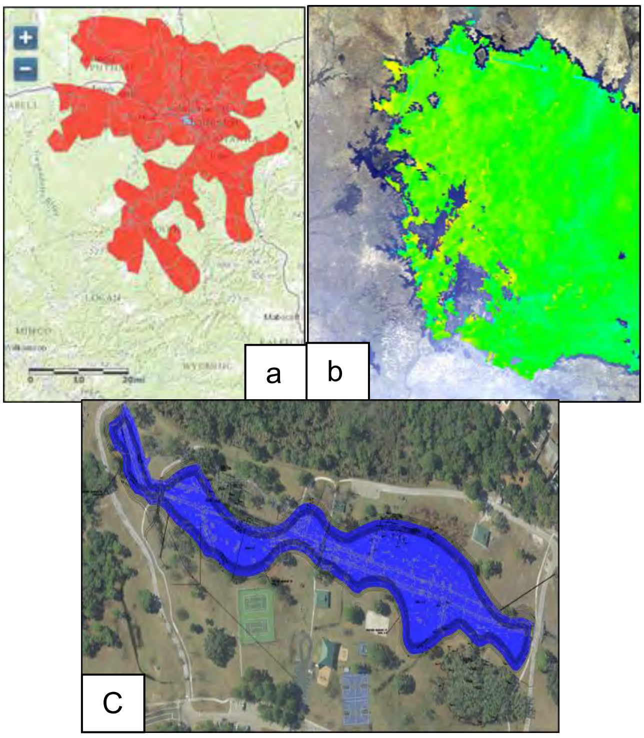

Figure 2. The example of expected visualisation output of the developed model based from the calculated index, indicating lake water quality status a) poor; b) medium; c) good (images used are just as an example, source: Google Image)

The sparse data availability especially water quality data during model development is seriously considered during model development. It is generally very difficult if not impossible, to acquire enough data sets to sufficiently calibrate and validate a model as the basis of effective decision making. Uncertainty will occur in calibration process due to data deficiencies, which lead to significant interpretations among parameters. Lin, P. et al., 2015, Xue et al., 2015, and Zou et al., 2014 have contemplated that water quality model developed through the traditional trial and error calibration and validation process will encounter great uncertainties in both simulations and predictions, especially with scarcity of data. The targeted output of this research is not only about water quality prediction, but also to demonstrate the major advantages of applying GIS spatial analysis technique as a cost-effective and user-friendly tool in sustainable water quality research and management to promote effective ILBM implementation with diverse kind of disparity and limitations. It is also expected that model output can be emulated in other lakes serving different role such as flood mitigation, irrigation and water supply, but potentially facing risk of water quality impairment with any changes of land use activities within lake areas.

CONCLUSIONS

The developed water quality model is for the lake water quality managers to meet the water quality targets and reversing deterioration trend. The approach of similarity based technique is to predict a range of possibilities in water quality response to external drivers which include quantifying the spatial variability and to produce an effective management tool that, in spite of severe data limitations, would be able to assists lake managers to establish water quality monitoring regime within a period of time. The model is useful in decision making, for it helps to understand the features and behaviours of lake water and its surrounding environment relationship. It also allows policy makers and stakeholders to assess the effects exerted by activities based on distance, hence using proximity as a basis of sustainable planning. It helps them to better relate to the lake water quality problems directly and indirectly affecting them, which eventually facilitates the process of developing a shared vision for the watershed and lake waterbody. Moreover, the model also acts as communication tool that bridge barriers and gap between lake managers and key stakeholders to make good decision with regards to lake and its ecosystem.

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Topic 7. Biodiversity and conservation

HABITATS CHARACTERIZATION FOR IHAN (*Neolissochilus* sp.) CONSERVATION PLANNING AROUND LAKE TOBA, NORTH SUMATERA, INDONESIA

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ABSTRACT

Lake Toba is home for some Indonesian native fishes including the endemic species. Ihan (Neolissochilus sp.) is a local name for a fish inhabiting Lake Toba and rivers in North Sumatera which has high economic and sociocultural value. However, the population of ihan in the wild has declined because of several factors such as overfishing and habitat degradation. Conservation program for ihan is required to prevent them from extinction. Our previous study has identified ihan (N. cf sumatranus) from some rivers surrounding Lake Toba. The present study aimed to physically and chemically characterize some ihan habitats potentially developed as conservation areas. Tulas, Bonandolok, and Boho rivers in Samosir District and Binangara River in Dairi District were selected. Habitat mapping and measurement of the physical and chemical parameters were conducted at the locations. Mapping was done by Geographic Information System (GIS) and direct measurement in the field. Water quality was measured by Water Quality Checker and laboratory analysis. Based on the physical conditions and water quality data, the four rivers support the growth and development of ihan. However, Bonandolok River is the most suitable site for conservation because two thirds of the sub-catchment areas are dominated by natural forests. Still, the riparian zone of Bonandolok River needs to be restored with some vegetation preferable for ihan. The existing local wisdom in Bonandolok related to ihan capture will play a role in the conservation program and sustainable utilization of ihan.

Keywords: *Neolissochilus*, Lake Toba, habitat characteristics, conservation area

INTRODUCTION

Indonesia is one of the world mega biodiversity countries with high fish species diversity. There are approximately 1218 freshwater fish species, of which 1700 are native species and 630 of them are endemic (Hubert et al., 2015). Ihan or ikan batak is one of the native fish species with high economic and sociocultural value. The fish inhabiting Lake Toba and rivers surrounding it. Genera of *Tor* and *Neolissochilus* are known as ihan by the local people. The fishes are sold with a high price in the local market reaching up to approximately Rp 300,000/kg.

According to the published reports, the population of *Tor* and *Neolissochilus* are declining in the wild because of overexploitation, habitat degradation, water pollution, and the introduction of exotic species (Kottelat et al., 1993; Haryono & Tjakrawidjaja, 2006). Therefore, some efforts need to be made to protect the fish from extinction which can be conducted ex situ and in situ. The in situ approach may include local wisdom which exists in the community and developing the conservation area (Maskur, 2002).

Krismono and Sarnita (2013) reported that there are 19 locations scattered around Lake Toba which have been categorized as conservation areas. However, Lukman (2013) mentioned that those locations were established for fish restocking managed by Department of Marine and Fisheries. Some of those areas were not suitable for conservation sites because of several activities which may harmfully impact the environment or fish habitats such as the cage aquaculture, port, and tourism (Lukman, 2013). Nasution et al., (2013) mentioned that the 19 locations have been reevaluated and only 11 locations meet the criteria for conservation areas. Nevertheless, those potential locations have not been thoroughly studied.

Selection of potential habitats for conservation area should be based on the bioecological characteristic of the fish. Habitat quality and land use change greatly influence the presence and abundance of fish and other aquatic biota in the river (Diana et al., 2006). Our study aimed to physicochemically and morphologically characterize some rivers as recommended by Nasution et al., (2013) for developing ihan conservation areas around Lake Toba. Four rivers from two Districts were selected and the study included the geographic information system (GIS), remote sensing, and measurement in the field. The GIS has been widely used as a rapid, objective, and cost-effective tool to map fish habitat for conservation and restoration project (Fisher and Toepfer, 1998; Lunetta et al., 1997).

METHODS

Habitat mapping and water physicochemical measurement

Four rivers inhabited by ihan were selected for characterization (**Fig. 1**). Three rivers (Tulas, Bondandolok, and Boho) are located in Samosir District and one river (Bonandolok) is in Dairi District. Except for Bonandolok River, the three rivers are among the proposed conservation areas around Lake Toba (Nasution et al., 2013). We added in Bonandolok River because our previous study showed ihan was captured in this river. Habitat mapping and physicochemical measurement were done at the locations during the dry season (June 2016) (**Table 1**). The coordinates of Lake Toba are 98^{o} 28' 8.194" E - 98^{o} 12' 36.65" E and 2^{0} 55' 23.828" N - 2^{0} 11' 22.795" N.

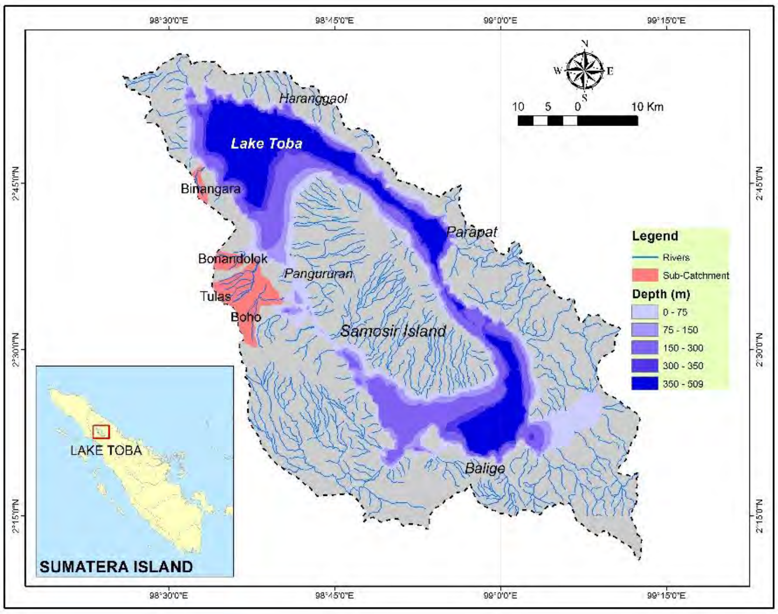


Figure 1. Location of the selected rivers for habitats characterization

Remote sensing and GIS (spatial and 3D analysis) were conducted to determine the conservation zone. The parameters to be analyzed are shown in **Table 1**. Remote sensing was used to identify the riparian vegetation condition in river segment. The digit on screen method based on the visualization of satellite images (SPOT 6 and SPOT 7 2014-2015) was used for the identification procedure. The satellite images were also used to classify the land use in each potential sub-catchment for conservation areas. Pre-processing including atmospheric correction, geometric and composite of the RGB band on natural color composite were conducted to obtain better visualization on the satellite image. The green color in the image exhibits vegetation and the reddish color exhibits settlement area.

Morphometric parameters are important for describing the physical condition of ihan habitat. Digital elevation model (DEM) SRTM 30m was performed for subcatchment morphometry. This dataset can be accessed here http://dds.cr.usgs.gov/srtm/version2_1/SRTM30//srtm30 (Farr et al., 2007). Digital elevation model data was analyzed with GIS application ArcGIS 10.2 and 3D Analyse tools to obtain slope and river network in sub-catchments. Habitat characterization was analyzed using GIS application combined with a visual map of Indonesia 1:50,000 published by Geospatial information Agency. The analysis was integrated with DEM and land use map was classified using ALOS 6 and ALOS 7 satellite images.

The hydrological condition observed in this study was discharged and flow velocity of the rivers segment selected for the conservation areas. Discharge volume influences the thermal and hydrologic stability of habitat characteristics (Gordon et al. 1992). The flow velocity was measured using a current meter and discharge was measured using the velocity-area method. Water quality is important to sustain fish growth and in relation to the land use at sub-catchment area. Water quality parameters were measured in the field using Water Quality Checker YSI Professional Plus (USA) and by laboratory analysis.

Table 1. Measurement methods of different parameters.

No	Parameter	Measurement method
1	Subcatchment area	GIS
2	Length and width of river	GIS and on site measurement
3	River gradient and subcatchment	GIS
4	Discharge and flow velocity	On site measurement
5	Riverbed and riparian vegetation	On site measurement and sampling
6	Water quality (temperature, pH, dissolved oxygen, conductivity, turbidity, oxidation reduction potential, total nitrogen, total phosphate, total suspended solid)	On site measurement with Water Quality Checker (WQC) dan and laboratory analysis

RESULTS AND DISCUSSIONS

Sub-catchment characterization

Land use in subcatchment area of the river has an important role in fish habitat preservation. Human activities on the land use may influence stream ecosystem and water quality (Diana et al., 2006). We characterized the types of land use in sub-catchments of selected rivers which were obtained from SPOT-6 and SPOT-7 satellite image.

We defined the borders of selected rivers using Automatic Watershed Delineation (AWD) to get morphometric calculations, slope, and shape of sub-catchments. **Figure 2** shows the results of AWD as sub-catchment polygon of the selected rivers. There are three sub-catchments mutually bounded, ie Tulas, Bonandolok, and Boho which have similar watershed characteristics compared to Binangara sub-catchment. The three sub-catchments have similar soil type composition as well as the shape and slope.

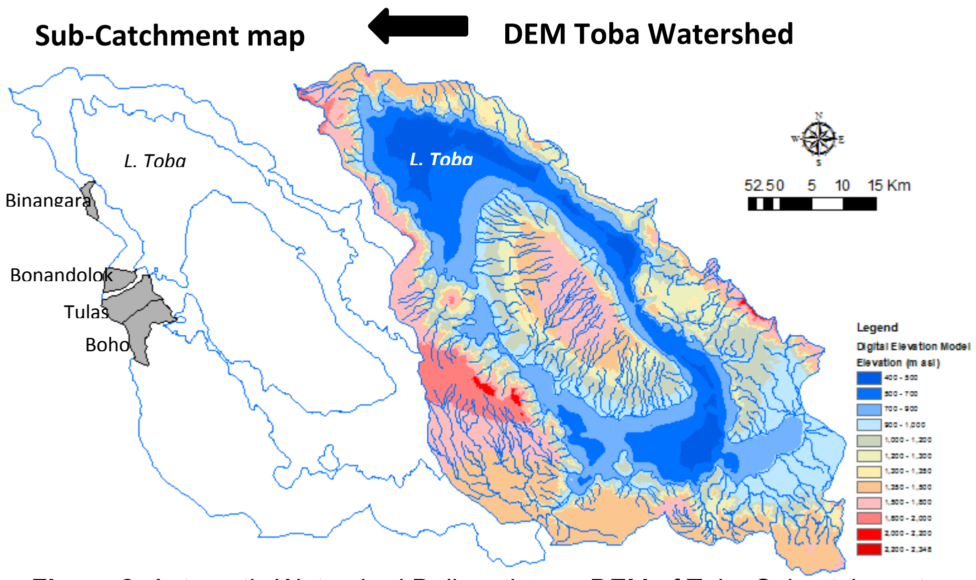


Figure 2. Automatic Watershed Delineation on DEM of Toba Subcatchment.

Physical Characteristics of the selected rivers

Binangara River

The river is located in the west part of the lake at Dairi District. The point of measurement and observation were at one of the pools situated along the river. The averages of width and depth are 8 m and 0.6 m, respectively. The water flows continuously with slow velocity (0.17 m/s) and discharge of 0.6 m^3/s. A waterfall is formed in the upstream. The river was dominated by igneous rock sized of 10 cm – 0.5 m. Some banyan trees (*Ficus* sp.) grow in the riparian zone. Paddy field and bushes were found in the location adjacent to ihan habitat (**Fig. 3B**). The overall land use of Binangara subcatchment was dominated by natural forest (92%) (**Fig. 3**). The distance from the river mouth to the upstream is 1 km and a steep part was formed close to the upstream (**Fig. 3C**).

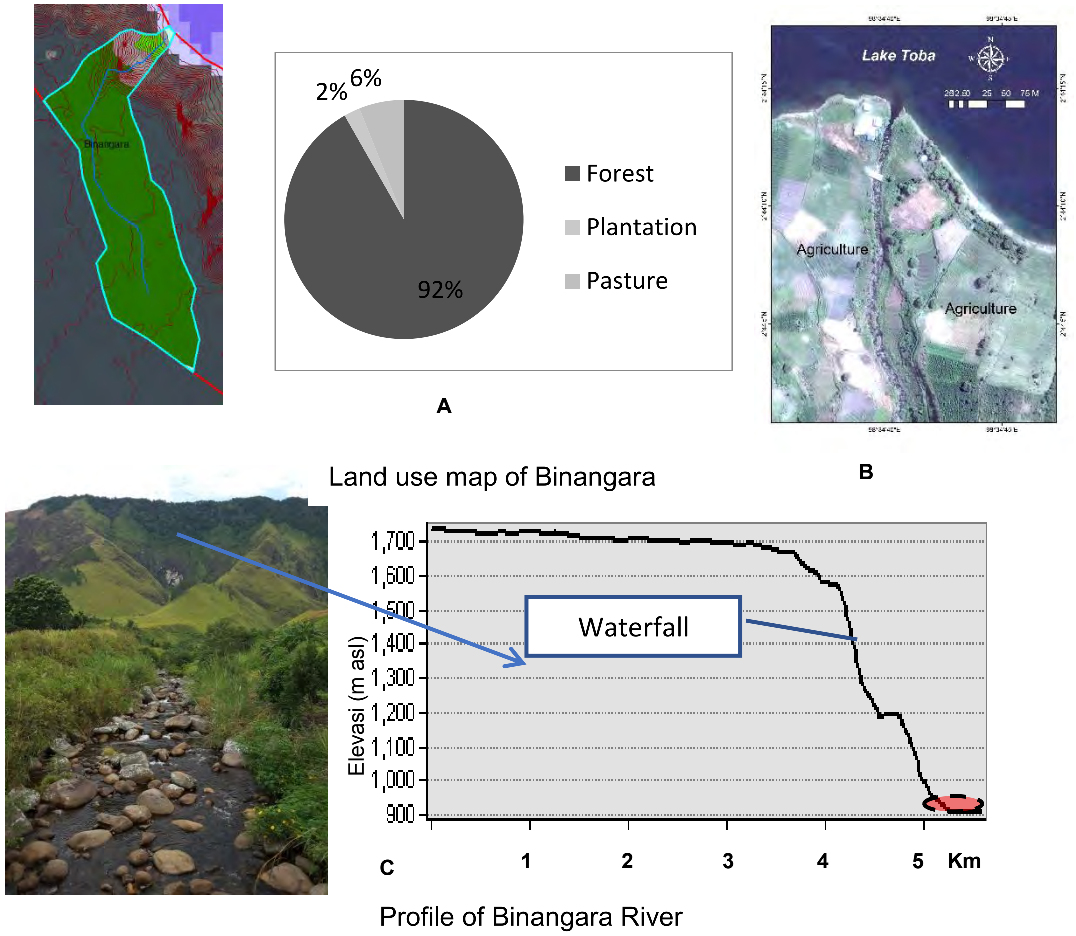
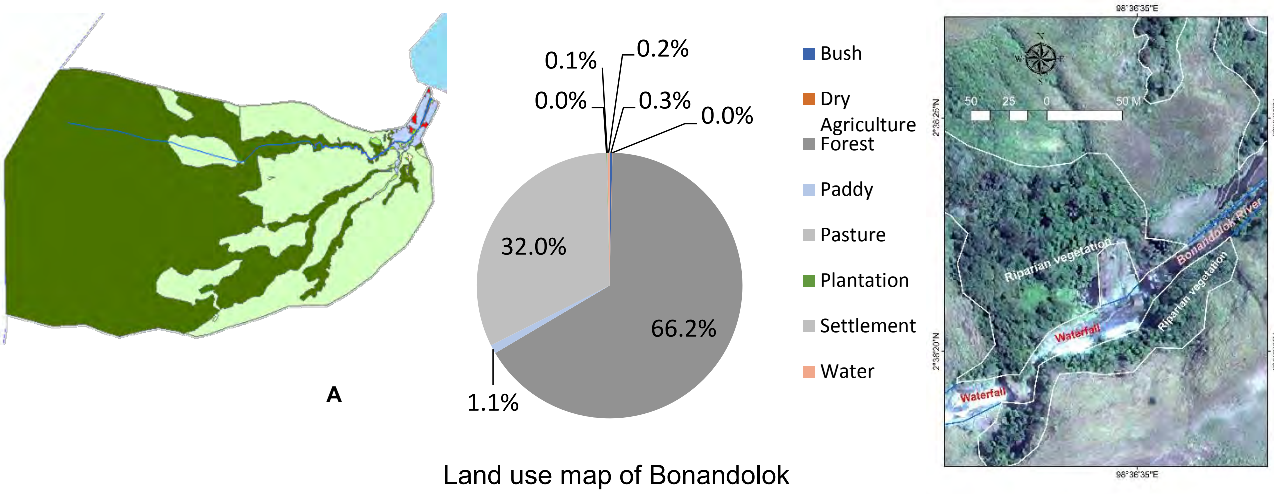


Figure 3. Land use map (A, B) and profile of Binangara River (C). Red color in the graph (C) is ihan habitat. Land cover of sub-catchment area is dominated by forest. River bed is dominated by boulder and sand.

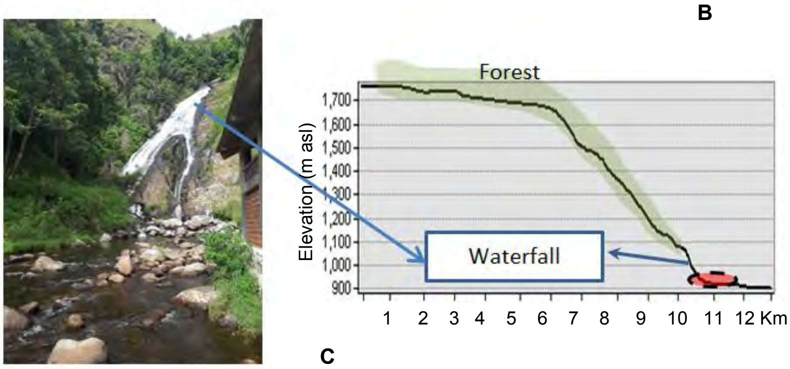
Bonandolok River

Bonandolok River flows continuously with river bed dominated by gravel or boulder, lumps, and igneous rock. A waterfall named Sitapigagan is situated in the upstream. The averages of width and depth of the river were 9 m and 0.4 m, respectively. The river flows slowly and continuously with high gradient reached to 0.12 m/s and discharge of 0.7 m^3/s. The composition of land use and morphology of the subcatchment are shown in **Figure 4**. Overall, 66% of Bonandolok subcatchment was covered by the forest which is predominantly located in the upstream and the remaining was covered by industrial plantation. The percentage of forest area already exceeded the minimum area of forest by government regulation No. 104 in 2015 (30%). The satellite image showed that the vegetation buffer at the side of Bonandolok River was 10-22 m. Riparian vegetation with 10-30 m forested buffer is able to maintain stream temperatures which are important to certain fish species (Osborne and Kovacic, 1993). The types of land use adjacent to fish habitat were pasture and agriculture.



Land use map of Bonandolok

B



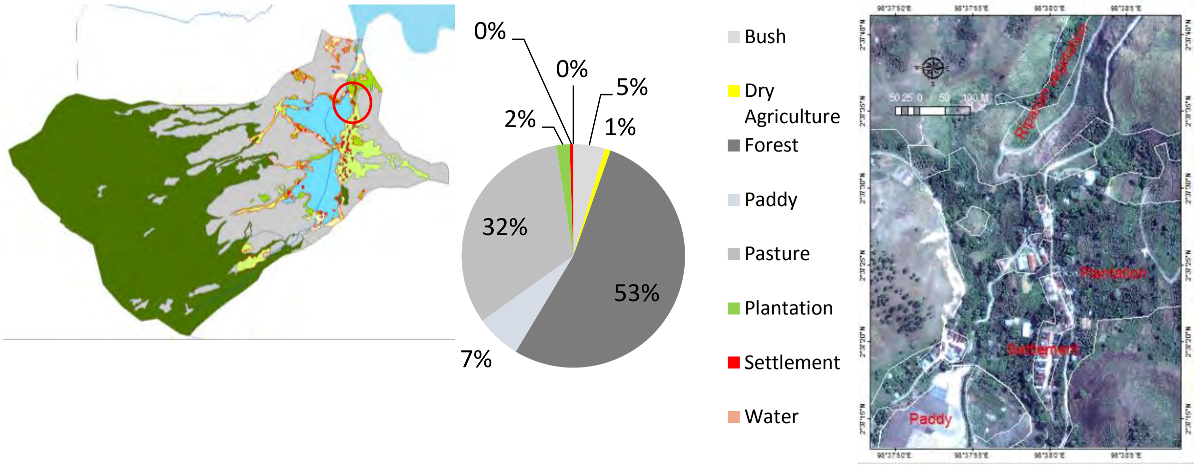
C

Profile of Bonandolok River

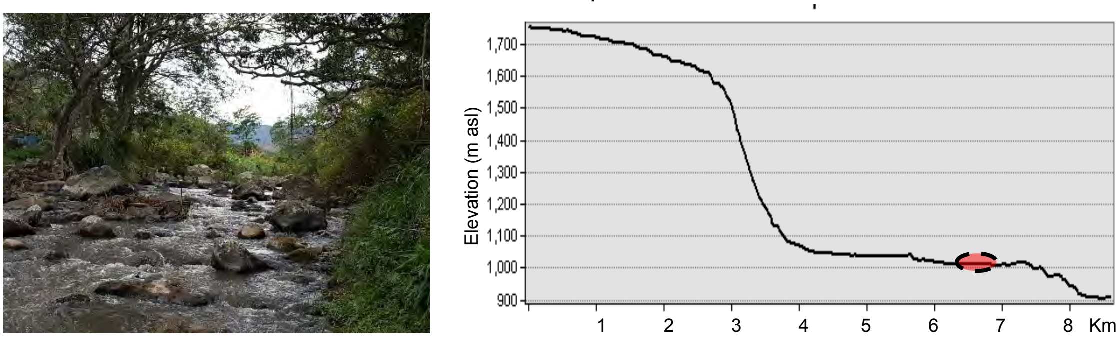
Figure 4. Land use map (A,B) and profile of Bonan Dolok River (C). Red color in the graph is ihan habitat. Land use of sub-catchment area is dominated by forest. River bed is dominated by boulder. A pool was formed between the waterfall and the main river.

Tulas River

The river is located in the west part of the Lake Toba with points measured in the area next to the church of Tulas Village. The width of the river was 5.1 m with depth average of 0.3 m. The river flows continuously with the high gradient shown by strong flow with a velocity of 0.9 m/s and discharge of 0.6 m^3/s. The river was dominated by igneous rock with the size of 10 cm – 0.5 m. Main river segment has moderate flow with slope gradient in the middle of the segment (**Fig. 5**). The riparian vegetation at the side of the river was dominated by banyan trees. Based on the satellite image, the vegetation buffer at the side of Tulas River was 5-10 m. Subcatchment area surrounding the ihan habitat was dominated by paddy field, coffee plantation, and settlement area. However, overall land use in the subcatchment was dominated by the forest (**Fig. 5**). Tulas River is among the list of rivers proposed for fish conservation zone (Nasution et al., 2013). However, subcatchment of Tulas has been further developed into settlement and agriculture areas.



A: Land use map of Tulas

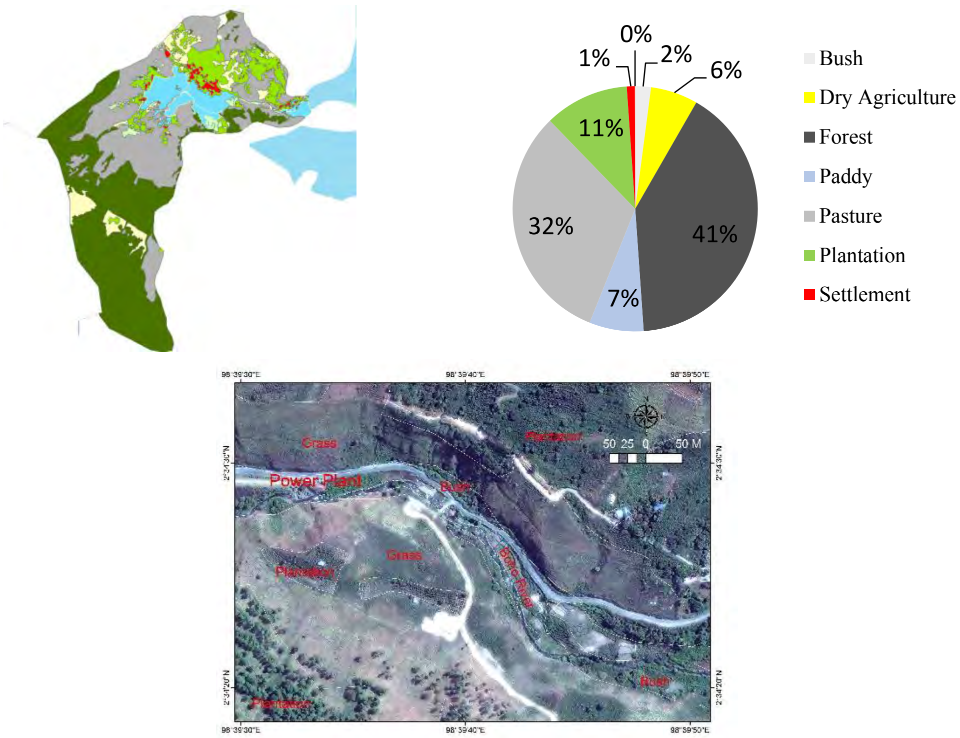


B: Profile of Tulas River

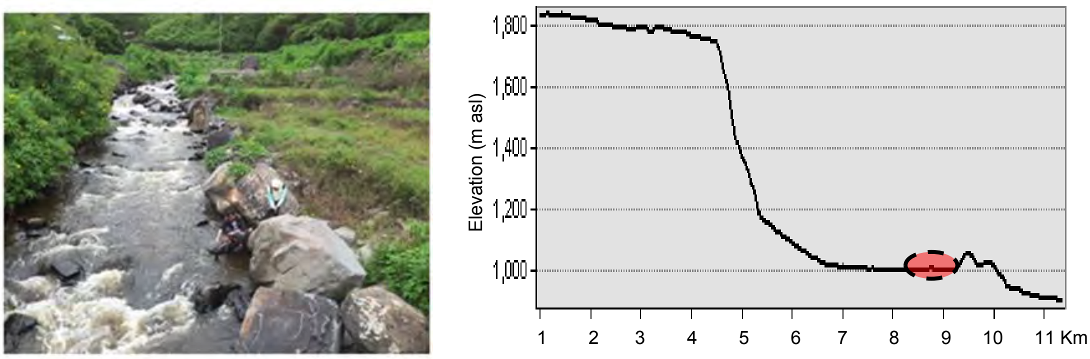
Figure 5. Land use and profile of Tulas River. Red color in the graph is ihan habitat. Land use of subcatchment area is dominated by forest. River bed is dominated by ignaeous rock.

Boho River

The river is situated at the west part of Lake Toba. Points measured were approximately 1.5 km from the bridge at river mouth to the office of Boho Village head community. The width and depth of the river were 5.6 m and 30 cm, respectively. The river flows continuously with high gradient reached to 0.3 m/s and discharge of 0.3 m^3/s. The river bed was dominated by igneous rock with the size of 20 cm – 1.5 m. The riparian vegetation dominates the river edge and banyan trees were found in some area of the riparian zone. Other areas of the riparian zone were used for settlement and agriculture. Overall land use in sub-catchment is mostly dominated by forest (41%), followed by pasture (32%), agriculture which includes paddy field, and coffee plantation (24%), and settlement (1%) (**Fig 6**).



A: Land use map of Boho



B: Profile of Boho River

Figure 6. Land use map (A) and profile of Boho River (B). Red color in the graph is ihan habitat. Land use of sub-catchment area is dominated by forest, however very large areas are used for pasture and agriculture.

Water quality

The results of measurement on water quality parameters of the selected inlets are summarized in **Table 2**. In general, the water conditions of the four rivers support the growth and development of ihan. Temperatures of selected rivers were between 19.9 – 29^{0}C and the lowest temperature was found in Bonandolok River (19.9^{0}C). Dissolved oxygen (DO) concentrations were between 8.2 – 8.9 mg/L and the highest was in Tulas River which has rapid water flow and cascade. The pH of the selected rivers ranged between 7- 8.

Table 2. Physical condition and water quality of the selected rivers.

No	Parameters	Binangara	Bonan Dolok	Tulas	Boho
	Physical				
1	Sub-catchment area (ha)	809.9	2487.5	1229.1	2737.7
2	Type of the rivers	Continue	Continue	Continue	Continue
3	Length of main river (km)	6.04	9.3	6.5	16.3
4	Width of river (m)	8	9	5.1	5.6
5	Depth of river (m)	0.6	0.4	0.3	0.3
6	Gradient of river (%)	11.9	18.5	25.3	14.1
7	Gradient of sub-catchment (%)	14.7	24.9	35.8	17.8
8	Discharge (m^3/s)	0.6	0.7	0.6	0.3
9	Flow velocity (m/s)	0.17	0.12	0.9	0.3
10	Riverbed	Boulder, sand, gravel	Boulder, gravel	Sand, gravel	Boulder, gravel
11	Predominate morphology	Water fall	Waterfall	-	-
12	Dominancy of land use at the upstream	Forest	Forest	Forest	Agriculture
13	Distance to settlement (km)	6	2	0,3	1
14	Riparian vegetation	Agriculture	Forest	forest	Settlement and Road
15	Local Wisdom	-	exist	-	-
Water quality					
16	Temperature (^{0}C)	23.47	19.95	24.14	23.51
17	DO (mg/l)	8.29	8.26	8.9	8.8
18	pH	7.48	7.61	7.18	7.68
19	Conductivity (m/cm)	0.037	0.043	0.065	-
20	Turbidity (NTU)	2.78	4.4	-	15.6
21	ORP (mv)	113	108	172	107
22	Total Suspended solid (TSS) (mg/L))	2.1	2	20.5	14.6
23	Total N (mg/L)	0.149	0.465	0.362	0.355
24	Total P (mg/L)	0.083	0.084	0.122	0.081

Mahseer of *Tor* and *Neolissochilus* or Tambra of *Tor* sp. live in the same water condition. Hoàng et al., (2015) reported that the water condition where *Neolissochilus stracheyi* lives were 17-26^{0}C, pH 6.5−7.66, DO 79−88.6% (7.49-8.4 mg/L), conductivity 10–34 µS/cm and flow velocity 0.17−0.77 m/s, while Tor lives in rivers where temperatures were 21−26^{0}C, pH 7−7.66, DO 79−80.6% (7.49-7.64 mg/L), conductivity 32−34 µS/cm and flow velocity 0.20−0.77 m/s. Tambra of *Tor* sp. inhabit water with a temperature between 25-26^{0}C, pH between 6-7, and DO 5.8-8.5 mg/L (Haryono & Subagja, 2008).

Genera *Tor* and *Neolissochilus* live in rapid flow and clear water. Haryono and Subagja (2008) characterized tambra (*Tor* sp.) habitat according to their size. Adult fish inhabits deep pools, slow to moderate water flow, 15-20 m width, >1.5 m depth, river beds composed of sand and gravel. Fry lives in moderate to rapid water flow, 15-20 m width, < 1 m depth, riverbed composed of rocks with diameter more than 50 cm, sand and gravel. Juvenile inhabits river bank with sand-river bed and calm or slow flow.

Water clarity is the most important factor for the living organism which provides food source for the fish including tambra or mahseer (Desai (2003) in Haryono & Tjakrawidjaya, 2009). Generally, sampling locations of the selected rivers have clear water except for Boho River, slow to strong flow, riverbeds consist of boulder and sand, and upstream which are predominantly covered by natural forests except in Boho River.

In sub catchment of Boho River, the land along the river is used as settlement and agriculture areas. The upstream of Boho River is dominated by production forest which is managed for the timber industry. Higher turbidity in Boho River (**Table 2**) was the result of input from domestic and agricultural activities to the water. Although the turbidity value was still in the recommended limit for fish (Wardoyo,1994), the tendency of high anthropogenic pressure along Boho River would constrain the development of conservation area in Boho River. Land use changes adjacent to the streams may have severe effects on the lifecycle of fish such as loss of breeding, feeding, and resting sites (Paul and Meyer 2001). In addition, the flow of Boho River is also used for hydroelectric power generation. Boho River may not be suitable for the conservation area.

According to Syahroma and colleagues (2013), Binangara River is one of the potential areas for fish conservation site. However, there are some agricultural activities in the upstream (**Fig. 4B**) which may become a problem when developing the conservation area in this river. Moreover, further study on the water flow condition of Binangara River is needed because some has observed no water flow during the dry season. Continous water flow is required for fish conservation area. Land-use disturbances in watersheds can negatively affect the stream water chemistry and aquatic biota (Morgan and Phillipp, 1986). Farming activities which release the nutrients and pesticides to adjacent water bodies can lead to eutrophication. In freshwater systems, it affects fish and fisheries by changing the availability and type of food for the fishes (Richardson, 2001). The TSS value of Tulas River was the highest among the four rivers (**Table 2**) which was the result of agricultural activities in the riparian zone and other subcatchment area. Much effort needs to be made to develop Tulas, Binangara, and Boho River into a conservation area, such as replacing chemical fertilizer with the organic one and pesticide banning for agricultural activities.

Subcatchment of Bonandolok River showed less agricultural or plantation activities compared to other selected rivers. Moreover, the percentage of forest area in Bonandolok was greater than the other river sub catchments. The quality of riparian vegetation is important for the fish because it has an effect on the light and water temperature, as well as to provide the food and habitat (Zalewski et al., 2001). Genera *Tor* and *Neolissochilus* feed on some fallen fruits from the riparian zone, insects, mollusks, and plant matter (Khaironizam et al., 2015; Roberts & Khaironizam, 2008). According to the local people around Lake Toba, fruit from *Ficus* sp. is favored by ihan. Ficus trees were found in the riparian zone of the selected rivers. Preserved riparian vegetation buffer was observed only in Bonandolok (**Table 2**). Some vegetation preferable for ihan such as *Ficus* sp. should be planted in the riparian zone of Bonandolok River. Bonandolok River and its surrounding have physical characteristics which support for the development of ihan conservation areas such as a strong water flow and preserved riparian vegetation.

In addition, the village community living near Bonandolok River implements a local wisdom to preserve the nature. One of the local wisdom roles is for managing ihan captured in the river. The local people have conducted some rituals near the river before doing some activities in or surrounding the river. The existing local wisdom could be one of the strengths which should be retained as a part of ihan captured management.

CONCLUSIONS

Based on the physicochemical characteristics on the selected habitats, Bonandolok River is potential for the development of ihan habitat conservation area. More than two-thirds of the subcatchment is natural forests. The existing local wisdom in the Bonandolok village might be a keypoint for the fishery management and conservation. The sub-catchment areas of Tulas and Boho River have been changed into the agriculture and settlement areas. However, it is still possible to develop Tulas and Boho Rivers as ecotourism site with some infrastructures restoration. Further study on the biological characterization is required to get a comprehensive description of the selected rivers.

ACKNOWLEDGEMENTS

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AVIFAUNAL AND RIPARIAN VEGETATION COMPOSITION IN AND AROUND THE MUSEUM LAKE IN GOVERNMENT ZOOLOGICAL GARDEN THIRUVANANTHAPURAM, KERALA INDIA

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ABSTRACT

This study considers with species composition, diversity and IUCN threat status of avifaunal population along with earmarked riparian vegetation in and around the lentic ecosystem inside the Government Zoological Garden, Thiruvananthapuram Kerala. Of the total 60 bird species identified during the study period June 2013 to June 2015, 88% (S=53) are resident breeders and 23% (S=14) are winter migrants. The order Passeriformes shows an exceptional gradient of species diversity with 26 species (43%). 17% (S=8) of the total 46 plant species belongs to the family Poaceae followed by Araceae and Lecythidacaea. Nesting ground of Oriental darter (Anhinga melanogaster), a near threatened species enlisted in the IUCN Red List ignites the indispensability of biodiversity conservation and effective resource management. The Thiruvananthapuram zoo which is located in the heart of the city acts as a buffering zone for the captured, exhibited and native avian fauna. The maximum number of bird species was observed in winter season as compared to the summer and monsoon. Highest numbers of birds were recorded during the month of November(n=423) and lowest in August (n=193) which may be due to the availability of food and favourable climatic conditions for nesting, roosting and boosting for most of the bird species in the winter season. This watery ecosystem and the surrounding vegetation is an abode of diverse fauna which emancipates the global concept of conservation and ecological duty, even if it is being landscaped at the heart of the overcrowding city. The distribution of birds shows the status of this aquatic ecosystem.

Keywords: Avifauna, Kerala, Oriental darter, Riparian Vegetation, Zoological garden.

INTRODUCTION

India which shares 2.4% of the world's land area covers 8.1% of the global species diversity that makes our country one of the 12 mega biodiversity countries of the world (Praveen et al., 2016). A recent report recorded 1263 species of avifauna i.e., 12.5% (Praveen et al., 2016) of that of the worlds is in India. Kerala records a total of 500 species of birds of which 17 of them are endemic to Western Ghats and 25 of them are included under IUCN threatened categories and 32 are categorized under Near-Threatened whereas, 443 are listed under the schedules of Indian Wildlife (Protection) Act and 71 are listed under the appendices of CITES (Praveen, 2015). Ecologically, birds are of tremendous importance because of their key roles as pollinator and agents of seed dispersal (Bibi and Ali, 2013). Urbanisation (Czech et al., 2000), habitat loss (Blair and Launer, 1997; Marzsluff and Ewing, 2001) and pollution (Lovett et al., 2009) are the major causes of biodiversity loss. The loss of natural habitats due to various pressures in urban areas has increased the emphasis upon the capacity of zoos and parks in contributing towards the conservation of biodiversity of native fauna (Kuruvilla, 2014). Therefore, understanding the diversity and structure of bird communities is essential to define the importance of avian conservation in those areas (Kattan & Franco, 2004). Lakes, rivers and riparian vegetation provide favourable conditions to birds for their habitat for feeding, roosting, nesting and breeding (Ali, 1969; Vyas & Singh, 2004; Bijukumar, 2006; Rias et al., 2011; Singh and Laura, 2012). Riparian ecosystems have been found to be among the most productive and valuable wildlife habitats wherever they occur (Hubbard, 1977; Schrupp, 1978). There is a dazzling array of freshwater wetlands- inland water bodies in India yet to be explored in terms of its biodiversity. These studies on biodiversity will help in the management of those lakes and also helps in the biodiversity conservation.

In this context, a study was carried out to obtain some preliminary checklist of bird community and their relation to the riparian vegetation around the Museum Lake in Thiruvananthapuram Zoo. Moreover, the feeding habits of the birds are assigned as described by Ali and Ripley (2007). This information is required for proper planning of management towards sustainability of the ecosystem as a whole.

METHODS

The Thiruvananthapuram museum and zoo is one of the oldest of its kind in India located at the heart of the city (08˚30' N, 076˚57'E). The lake is extended over an area of 2 acres. A total of 60 bird species were identified during the study period from June 2013 to June 2015. Field studies were carried out mainly during the early morning hours from 7.00 am to 9.30 am when the birds were most active. Identification of birds was done by both sight and sound, direct observations were done periodically and spot identification was done based on standard field guides such as, Ali and Ripley, (2007) Grimmet et al., (2011) and Kazmierczak, (2000). Plant taxa were identified in the field and photographs were taken for further identification and closer examination following Gamble (2011). The scientific and common names follow Manakadan & Pittie (2002). The feeding habits of the birds were assigned as described by Ali and Ripley (2007).

RESULTS AND DISCUSSIONS

Avifaunal Diversity

During the study period, a total of 60 bird species belonging to 33 families and 14 orders were recorded around the Museum Lake. Among them, 51 of the birds recorded were included in the Schedule I and IV of the Wildlife Protection Act 1972. 53 bird species in them are resident breeders, 14 of them are winter migrants. List of Bird species observed around the Museum Lake is given in **Table.1** and the percentage of Order of species is shown in **Figure.1**.

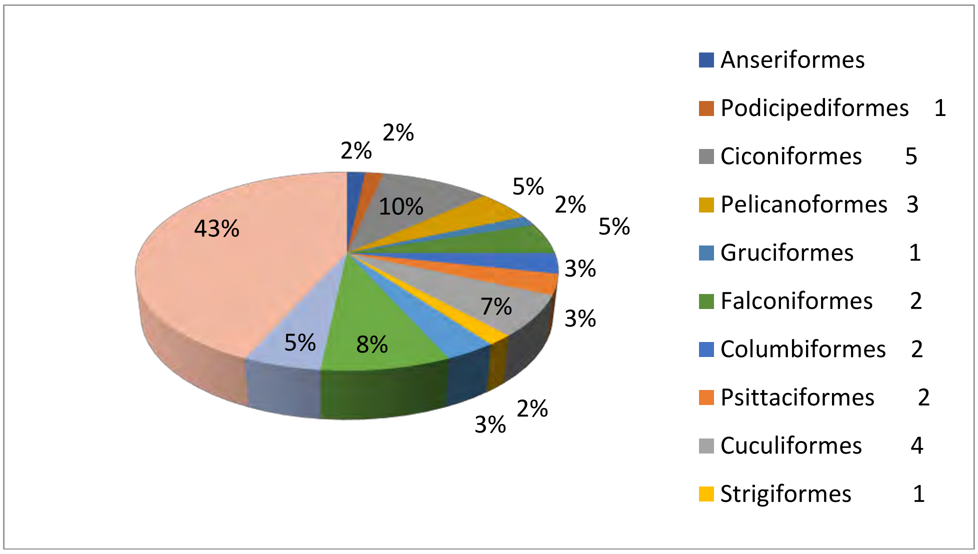

Figure 1. Order-wise percentage of birds observed around Museum Lake.

Table 1. List of Avifauna Recorded in and around the Museum Lake, Thiruvananthapuram.

Sl. No	Classification	Common Name (BLI)	IUCN Status	Breeding Resident	Non-Breeding Resident	Winter Migrant	Summer Migrant	Passage Migrant	Category in WPA
1	Order: Anseriformes Family: Anatidae *Dendrocygna javanica* (Horsfield, 1821)	Lesser Whistling-duck	LC	X		X			Schedule IV
2	Order: Podicipediformes Family: Podicipedidae *Tachybaptus ruficollis* (Pallas, 1764)	Little Grebe	LC	X		X			Schedule IV
3	Order: Ciconiiformes Family: Ciconiidae *Anastomus oscitans* (Boddaert,1783)	Asian Openbill Stork	LC			X			Schedule IV
4	Family: Ardeidae *Nycticorax nycticorax* (Linnaeus, 1758)	Black-crowned Night-heron	LC	X					Schedule IV
5	*Ardeola grayii* (Sykes, 1832)	Indian Pond-heron	LC	X					Schedule IV
6	*Bubulcus ibis* (Linnaeus, 1758)	Cattle Egret	LC	X		X			Schedule IV
7	*Mesophoyx intermedia* (Wagler, 1829)	Intermediate Egret	LC	X		X			Schedule IV
8	*Egretta garzetta* (Linnaeus, 1766)	Little Egret	LC	X		X			Schedule IV
9	Order: Pelicaniformes Family: Annhingidae *Anhinga melanogaster* (Pennant, 1769)	Oriental Darter	NT	X					
10	Family: Phalacocoracidae *Phalacrocorax niger* (Vieillot, 1817)	Little Cormorant	LC	X					Schedule IV
11	*Phalacrocorax fuscicollis* (Stephens, 1826)	Indian Cormorant	LC	X					Schedule IV
12	Order: Falconiformes Family: Accipitridae								

	Milvus migrans (Boddaert, 1783)	Black Kite	LC	X	X		Schedule I
13	*Haliastur indus* (Boddaert, 1783)	Brahminy Kite	LC	X			Schedule I
14	*Accipiter badius* (Gmelin,1788)	Shikra	LC	X			Schedule I
15	Order: Gruiformes Family: Rallidae *Amaurornis phoenicurus* (Pennant, 1769)	White-breasted Waterhen	LC	X			Schedule IV
16	Order: Columbiformes Family: Columbidae *Columba livia* Gmelin, 1789	Blue Rock Pigeon	LC	X			
17	*Treron pompadora* (Gmelin, 1789)	Pompadour Green-pigeon	LC	X			Schedule IV
18	Order: Psittaciformes Family: Psittacidae *Psittacula krameri* (Scopoli, 1769)	Rose-ringed Parakeet	LC	X			Schedule IV
19	*Psittacula cyanocephala* (Linnaeus, 1766)	Plum-headed Parakeet	LC	X			Schedule IV
20	Order: Cuculiformes Family: Cuculidae *Cuculus varius* (Vahl, 1797)	Common Hawk-cuckoo	LC	X			Schedule IV
21	*Cuculus micropterus* Gould, 1837	Indian Cuckoo	LC	X		X	Schedule IV
22	*Eudynamys scolopaceus* (Linnaeus, 1758)	Asian Koel	LC	X			Schedule IV
23	*Centropus sinensis* (Stephens, 1815)	Greater Coucal	LC	X			Schedule IV
24	Order: Strigiformes Family: Strigidae *Glaucidium radiatum* (Tickell, 1833)	Jungle Owlet	LC	X			Schedule IV
25	Order: Apodiformes Family: Apodide *Cypsiurus balasiensis* (Gray, 1829)	Asian Palm-swift	LC	X			

26	*Apus affinis affinis* (Gray, 1829)	House Swift	LC	X		
27	Order: Coraciiformes					
	Family: Alcedinidae					
	Ceryle rudis (Linnaeus, 1758)	Pied Kingfisher	LC	X		Schedule IV
28	*Pelargopsis capensis* (Linnaeus, 1766)	Stork-billed Kingfisher	LC	X		Schedule IV
29	*Halcyon smyrnensis* (Linnaeus, 1758)	White-throated Kingfisher	LC	X		Schedule IV
30	*Alcedo atthis* (Linnaeus, 1758)	Common Kingfisher	LC	X		Schedule IV
31	Family: Meropidae					
	Merops orientalis (Latham, 1802)	Little Green Bee eater	LC	X		
32	Order: Piciformes					
	Family: Ramphactidae	White-cheeked Barbet				
	Megalaima viridis (Boddaert, 1783)		LC	X		Schedule IV
33	*Megalaima haemacephala* (Müller, 1776)	Coppersmith Barbet	LC	X		Schedule IV
34	Family: Picidae					
	Dinopium benghalense (Linnaeus, 1758)	Black-rumped Flameback	LC	X		Schedule IV
35	Order: Passeriformes					
	Family: Aegithinidae					
	Aegithina tiphia (Linnaeus, 1758)	Common Iora	LC	X		Schedule IV
36	Family: Campephagidae	Large Cuckooshrike				Schedule IV
	Coracina macei (Lesson, 1830)		LC	X		
37	Family: Oriolidae	Eurasian Golden Oriole				
	Oriolus oriolus (Linnaeus, 1758)		LC		X	Schedule IV
38	*Oriolus xanthornus* (Linnaeus, 1758)	Black-hooded Oriole	LC	X		Schedule IV
39	Family: Dicruridae					
	Dicrurus macrocercus (Vieillot, 1817)	Black Drongo	LC	X		Schedule IV
40	Family: Monarchidae					
	Terpsiphone paradisi (Linnaeus, 1758)	Asian Paradise-flycatcher	LC	X		Schedule IV

41	Family: Corvidae *Dendrocitta vagabunda* (Latham, 1790)	Rufous Treepie	LC	X		Schedule IV
42	*Corvus splendens* Vieillot, 1817	House Crow	LC	X		
43	*Corvus levaillantii* Lesson, 1831	Jungle Crow	LC	X		
44	Family: Pycnonotidae *Pycnonotus jocosus* (Linnaeus, 1758)	Red-whiskered Bulbul	LC	X		Schedule IV
45	Family: Cisticolidae *Orthotomus sutorius* (Pennant, 1769)	Common Tailorbird	LC	X		
46	Family: Phylloscopidae *Phylloscopus trochiloides* (Blyth,1843)	Greenish Leaf Warbler	LC		X	Schedule IV
47	Family: Leiothricnidae *Turdoides affinis* (Jerdon, 1845)	Yellow-billed Babbler	LC	X		Schedule IV
48	Family: Sturnidae *Acridotheres tristi* (Linnaeus, 1766)	Common Myna	LC	X		Schedule IV
49	*Acridotheres fuscus* (Wagler, 1827)	Jungle Myna	LC	X		Schedule IV
50	*Sturnia malabarica* (Gmelin, JF, 1789)	Chestnut-tailed Starling	LC	X	X	Schedule IV
51	*Sturnus roseus* (Linnaeus, 1758)	Rosy Starling	LC		X	Schedule IV
52	Family: Muscicapidae *Copsychus saularis* (Linnaeus, 1758)	Oriental Magpie-robin	LC	X		Schedule IV
53	*Muscicapa dauurica* Pallas, 1811	Asian Brown Flycatcher	LC		X	Schedule IV

54	Family: Irenidae *Chloropsis aurifrons* (Temminck, 1829)	Golden-fronted Leafbird	LC	X		
55	Family: Dicaeidae *Dicaeum erythrorhynchos* (Latham, 1790)	Pale-billed Flowerpecker	LC	X		Schedule IV
56	Family: Nectarinidae *Nectarinia zeylonica* (Linnaeus, 1766)	Purple-rumped Sunbird	LC	X		Schedule IV
57	*Nectarinia lotenia* (Linnaeus, 1766)	Long-billed Sunbird	LC	X		Schedule IV
58	Family: Motacillidae *Dendronanthus indicus* (Gmelin, 1789)	Forest Wagtail	LC		X	Schedule IV
59	*Motacilla maderaspatensis* Gmelin, JF, 1789	White-browed Wagtail	LC	X		Schedule IV
60	*Motacilla cinerea* Tunstall, 1771	Grey Wagtail	LC		X	Schedule IV

(LC: Least Concern; NT: Near Threatened)

A maximum number of bird species was observed in winter season as compared to the summer and monsoon. Highest numbers of birds were recorded during the month of November and lowest in July and August. This may be due to the availability of food and favourable climatic conditions for nesting; roosting and boosting for most of the bird species in the winter season (Bhat et al., 2009; Singh and Laura, 2012). Moreover, the water body which is abundant in fish species like Grass Carp (*Ctenopahryngodon idella*), Rohu (*Labeo rohita*), Catla (*Catla catla*) and Tilapia (*Oreochromis mossambica*) provides food resources for the birds. The presence of some of the exclusive piscivores like Oriental Darter and Cormorants were conspicuous due to their good numbers and ideal feeding condition for these birds. Similar observation was also made by Vyas and Singh (2004).The abundance of birds from the Museum Lake is given in (**Fig. 2**).

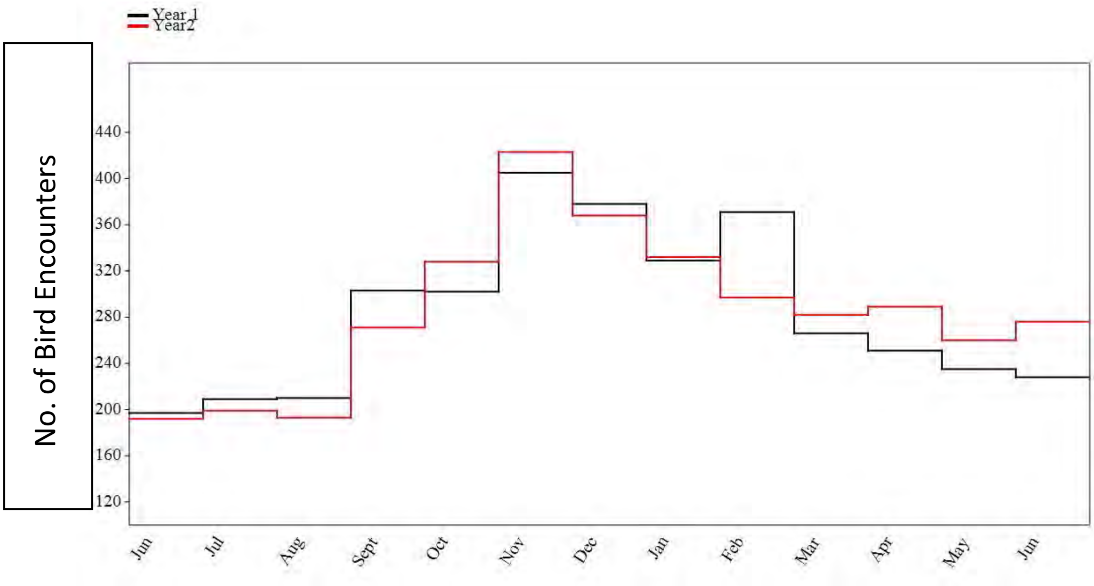

Figure 2. The abundance of avifauna recorded from Museum Lake during the study period.

The distribution of birds reflects the status of the aquatic ecosystem and the surrounding vegetation. A good number of birds are insectivores followed by piscivores and frugivores (**Fig.3**). Increased number of insectivores birds are related to the increased phytophagus insects from the riparian vegetation. Lovejoy et al., (1986) observed the influence of these phytophagus insects on the bird diversity. A similar observation was made by Rathore and Sharma (2000). Moreover, the waterbirds recorded from the lake showed an increase in number especially with the Oriental Darter (*Anhinga melanogaster*) (**Fig: 4**) a bird enlisted in the Red Data Book of IUCN as a RET species. The Museum Lake within the zoo provides a potential habitat for the bird. A significant sighting of Asian Openbill Stork (*Anastomus oscitans*) a migratory bird shows importance of this critical habitat and the availability of necessary resources from this water body. The resources obtained from this area makes them resident breeder and migratory ones.

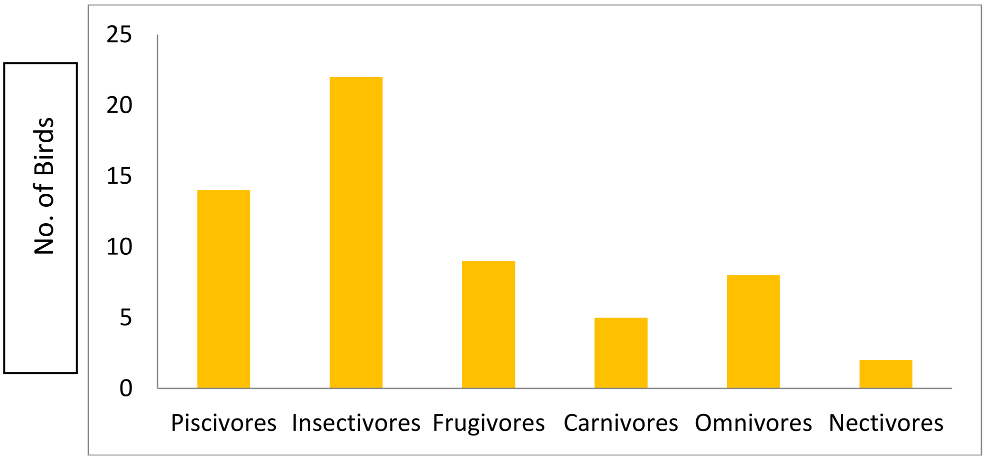

Figure 3. Feeding Guilds of the avifauna around the Museum Lake.

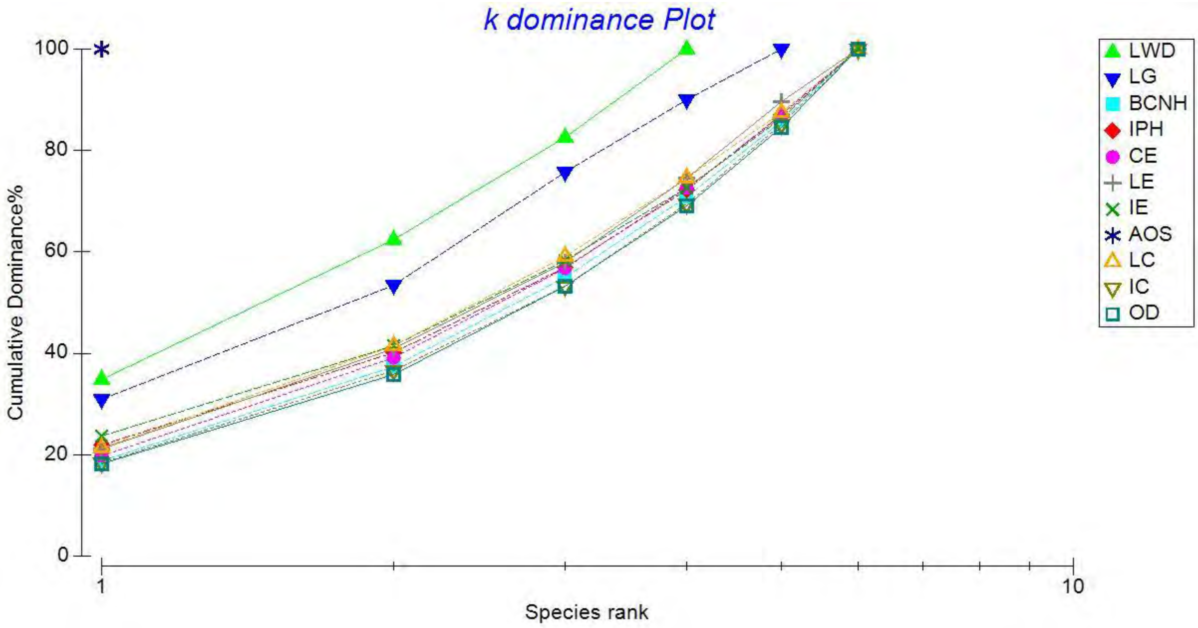

Figure 4. k dominance plot showing the waterbird diversity from Museum Lake for the study period. (LWD; Lesser Whistling Duck; LG: Little Grebe; BCNH: Black Crowned Night-Heron; IPH: Indian Pond-Heron; CE: Cattle Egret; LE: Little Egret; IE: Intermediate Egret; AOS: Asian Openbill Stork; LC: Little Cormorant; IC: Indian Cormorant; OD: Oriental Darter).

Riparian Vegetation

Riparian communities with diverse vegetation are best for promoting bird diversity (Schell and King). Among the tree species, rain tree- *Samanea saman* (Fabaceae) and Bamboo varieties like *Bambusa bambos var. gigantea, B. multiplex, B. ventricosa, B. vulgaris, Dendrocalamus giganteus, D. membraneus, D. strictus* and *Gigantochloa nigrociliata* (Poaceae) were common. Hydrophytes were represented insignificant with *Pistia sp* and *Lemna minor* only. These plant varieties are providing cool and comfort zone for the birds and making it a haven for them. For the nectar feeding birds, seasonal flowering varieties like *Pongamia pinnata, Pteocarpus marsupium* and *Peltophorum peltocarpum* are attracting them. The shrub and herbaceous varieties like *Quisqualis indiaca, Heliconia angusta, H. restrata, Etlingera elatior, Alternanthera philoxeroides* and *Ipomea* were common there. The rain tree *Samanea saman* provides landing and roosting place for many bird species especially for the Asian Openbill Storks.

Table 2. List of Plants associated with the Museum Lake.

Family	Botanical Name/Authority	Indigenous/ Exotic	IUCN Status
Annonaceae	*Monodora myristica* (Gaertn.) Dunal	Exotic	NE
	Polyalthia longifolia (Sonner) Thw	Indigenous	NE
Menispermaceae	*Coscinium fenestratum* (Gaertn.) Colebr	Indigenous	NE
Sterculiaceae	*Gauzuma ulmifolia* Lam.	Exotic	NE
Eleocarpaceae	*Muntingia calbura* L.	Exotic	NE
Oxalidaceae	*Averroha carumbula* L.	Exotic	NE

Anacardiaceae	*Mangifera indica* L.	Indigenous	NE
Leguminosae Pappilionaceae	*Pongamia pinnata* (L.) Pierre	Indigenous	LC
	Pterocarpus marsupium Roxb.	Indigenous	V
Mimosaceae	*Albezzia saman* (Jacq.) Merr.	Exotic	NE
	Adenanthera pavonia L.	Exotic	NE
Caesalpiniaceae	*Leucaena leucocephala* (Lam.) de Wit.	Exotic	LC
Combretaceae	*Quisqualis indica* (L.) DeFilipps	Exotic	NE
	Terminalia catappa L.	Exotic	NE
Lecythidaceae	*Barringtonia asiatica* (L.) Kurz	Exotic	LC
	Barringtonia racemosa (L.) Spreng	Indigenous	NE
	Careya arborea Roxb.	Exotic	NE
	Cauropita gynensis Aubl.	Exotic	NE
Lythraceae	*Lagestromia flos – reginae* Retz.	Exotic	NE
Caricaceae	*Carica papaya* L.	Exotic	NE
Bignoniaceae	*Millingtonia hortensis* L.f.	Exotic	NE
	Spathodea campanulata P. Beauv.	Exotic	NE
	Tecoma stans (L.) Juss.ex Kunth	Exotic	NE
Verbinaceae	*Citharexylum spinosum* L.	Exotic	NE
Amaranthaceae	*Alernanthera philoxeroides* Griseb.	Exotic	NE
Euphorbiaceae	*Dryptes conferiflora* (Hook.f.) Pax & K. Hoffm.	Indigenous	NE
	Sauropus androgynus (L.) Merr	Indigenous	NE
Ulmaceae	*Trema orientalis* (L.) Blume	Exotic	NE
Moraceae	*Antiaris toxicaria* Lesch	Exotic	NE
	Artocarpus heterophyllus Lam.	Exotic	NE
	Artocarpus hirsutus Lam.	Indigenous	NE
Zingiberaceae	*Etlingera elatior* (Jack) R.M. S	Exotic	NE
Musaceae	*Heliconia angustata* Vell.	Exotic	NE
	Heliconia rostrata Ruiz & Pav.	Exotic	NE
Araceae	*Epipremnum aureum* (Linden and Andre) G.S. Bunting	Exotic	NE
	Epipremnum pinnatum (L.) Engl.	Exotic	NE
	Lemna minor L.	Exotic	LC
	Pistia sp	Exotic	LC
Poaceae	*Bambusa bambos* var. *gigantea* (Bahadur) Bennet & R.C. Gaur	Exotic	NE
	B. multiplex (Lour.) Raeusch.ex Schult	Exotic	NE
	B. ventricosa McClure.	Exotic	NE
	B. vulgaris Schrad.ex J.C. Wendl	Exotic	NE
	Dendrocalamus giganteus Munro	Exotic	LC
	D. membraneus Munro	Exotic	NE
	D. strictus (Roxb.) Nees	Exotic	NE
	Gigantochloa nigrociliata (Buse) Kurz	Exotic	NE

CONCLUSIONS

The study reveals better role of conservation areas as habitat for the avifauna. The Thiruvananthapuram zoo which is located at the heart of the city acts as a buffering zone for the captured, exhibited and native avian fauna. As urbanization is making depletion of the natural habitats, this *ex situ* conserved area well nourished with exotic and indigenous floras and perennial water body inside could provide shelter for the winged beauties. The increasing population of Oriental Darters enlisted in the IUCN Red List ignites the necessity of biodiversity conservation and effective resource management of conditions to birds for their habitat for feeding, roosting, nesting and breeding and there is an urgent need to study on the biodiversity of those unexplored water bodies which ensures the conservation of diverse flora and fauna of the Museum Lake. The study emphasises that lakes, rivers and riparian vegetation provide favourable conditions to the birds for their feeding, roosting, nesting and breeding.

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FISH DIVERSITY OF THE SINGKARAK LAKE, INDONESIA: PRESENT STATUS AND CONSERVATION NEEDS

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ABSTRACT

Singkarak Lake is one of the priority lake in Indonesia which needs to be restored in terms of fish production and source of income for many fishermen living. This study has been conducted from January to April 2016. This study aimed to reveal the existing of fish species and their composition along with diversity and conservation needs. The results of present investigation reveal the occurrence of fish belonging to 5 orders, 9 families, 16 genera and 19 species. Among the collected species, order Cypriniformes was the most dominant consist of 42.10%, followed by order Perciformes 21.05%, order Siluformes 10.52%, and order Tetraodontiformes and Synbranchiformes 5.26%, respectivelly. Among 19 species, bilih fish (Mystacoleucus padangensis) is endemik species in Singkarak Lake. Now, this species has been introduced to Lake Toba and grow well in this lake. This species has economic value to society around Singkarak Lake. The bilih status is endangered now, due to over fishing by gillnet and liftnet. Furthermore, needs to be conservation regarding the mess size and the total fishing gear used in Singkarak Lake.

Keywords: Singkarak Lake, fish, diversity, conservation, economic value

INTRODUCTION

West Sumatera Province has total area 42297.3 km^2, which has natural conditions with plateau mountains. The 15% of that area was used for agriculture. These Province has five major lakes i.e. *Maninjau* Lake (9,950 ha), *Singkarak* Lake (11,220 ha), *Diatas* Lake (3,500 ha), *Dibawah* Lake (1,400 ha), and *Talang* Lake (500 ha) (Suryono et al., 2008).

Singkarak Lake is one of the fifteen lakes priorities in Indonesia which needs to be saved from over exploitation (Ministry of the Environment, 2011). This lake has a surface area of 11,200 ha and the average depth of 136 m. Singkarak Lake is a tectonic lake originate from the tectonic eruptions that occurred during the quarter. The elevation of lake is 360.86 to 362.20 above sea level. Singkarak Lake is located in *Solok* and *Tanah Datar,* West-Sumatera Province. The water sources of lake come from *Sumpur* River, *Paninggaha*n River, *Baing* River, *Muara Pingai* River, *Saning Bakar* River, and *Sumani* River with the area 129,000 hectares (Syandri, 1996). The Singkarak Lake water naturally flow into *Ombilin* River, and ended to estuary of east coast of Sumatera Island. Since the year of 1998, Singkarak Lake water flowed through PLTA (hydropower) tunnel of Singkarak with the diameter 3.4 meters along the 17 km from January to October 2013. The discharge ranged from 17.02 to 52.66 m^3/sec to turn the turbine to produce electricity energy with 175 MW (PT. PLN Bukittinggi Power Sector, 2013). Singkarak Lake was also used for capture fisheries, aquaculture, tourism, and irrigation. The number of fish species found in Singkarak Lake was 19 species, and the most dominant populations is *bilih* (Syandri et al., 2013). Recently, the populations of *bilih* in Singkarak Lake has declined and become an endangered species characterized by the size of smaller fish was an average of 6.5 cm (Purnomo & Sunarno, 2009). Syandri et al., (2011) reported that the total length of *bilih* ranged from 6 -7 cm. Furthermore, Syandri et al., (2013) states that the size of female of *bilih* ranged from 60-69 mm and male of *bilih* ranged from 50-59 mm. There is no species caught on the size less than 50mm and bigger than 109 mm. The size of *bilih* published by the researchers was smaller than the size of fish caught in the years of 1996, which ranged from 10-15 cm (Syandri & Effendie., 1997, Syandri et al., 2001). Based on the data, it is important to do an analysis the diversity of fish species and conservation need to *bilih* fingerlings in Lake Singkarak.

METHODS

Study area and duration

The study was conducted in Singkarak Lake with geographical position S: 00°32′01"-00°42′32" and E: 100°28′28"-100°36′08", include the area of *Sumpur*, *Paninggahan* and *Sumani* sub-district of *Tanah*

Datar and *Solok* district West-Sumatera. Observation was conducted for four months from January to April 2016.

Sampling framework

Fish was collected at three stations named *Sumpur*, *Paninggahan*, and *Sumani* sub-district. Fish samples were obtained from local fishermen caught using different type of fishing gear such as gill nets, lift net, traps nets, and fishing pole. All fishing gears were operated at the same spot within the area of 0.5 km. It is to ensure that the maximum species was found in this study site. Gill net and lift nets were set up in the late afternoon and left overnight, then its check in the morning. The fish samples were transferred to laboratory for taxonomic study. Fish specimen were preserved with 10% formalin solution and put in separate specimen jars as according to the size of species. The small size fish were directly placed in 10% formalin solution while, preservation for the big size of fish by giving an incision in their abdomen.

Fish Identification

The meristic and morphometric characteristic of fish were measured, and identified with the standard keys books as according to Weber and de Beaufort, (1913; 1916; 1922 and Kottelat et al., (1993).
The data was collected from Singkarak Lake, and the species status based on IUCN red list.

The composition of daily catch by lift net was calculated by the following equation (Akiyama, 1997)

The composition of fish catches = $\frac{\text{The number of fish catches (individual) species to i}}{\text{Total fish catch (individual)}}\ x\ 100\%$

Total daily fish catch = $\frac{\text{Total fish catch (individual)}}{\text{Fishing Trip}}$x 100%

Primary catch

The percentage of the main catch was calculated by using the following equations.

MR = $\frac{\Sigma MC}{\Sigma TNG}$ x 100%

Where: MR = The number of main catches;
Σ MC = The total number of main catches;
ΣTNG = The total catches

RESULTS AND DISCUSSIONS

The composition of fish fauna

Fish composition and their status in Singkarak Lake, Indonesia were given in **Table 1**. The total of fish *belonging to 5 orders, 9 families, 16 genera and 19 species.* The family of Cyprinidae was dominant catches which are consist of 42.10% from total catch. Other families were Bagridae (10.52%), Osphronemidae (10.52%), Channidae (10.52%), Tetrodontidae (5.26%), Anabantidae (5.26%), Mastacembelidae (5.26%), Chiclidae (5.26%), and Gobiidae (5.26%), respectively (**Figure 1**). Aryani (2015) found the order of Cypriniformes in Kampar Kanan river were 13 species (36.11%), include *Cyprinus carpio, Leptobarbus hoeveni, Oreochromis niloticus* and *Osphronemus gourami.* Fish composition in Kampar Kiri River was also dominated by the order of Cypriniformes as many as 35 species (40.7%) (Simanjuntak et al., 2006). According to Kottelat et al., (1993) the species belong to the family Cyprinidae is the largest freshwater fish species in worldwide; except Australia, Madagascar, New Zealand, and South America. In Koilsagar reservoir Mahbubnagar district Telangana India found that the order Cypriniformes were 13 species (43.33%) (Laxmappa et al., 2015). In Betwa river Madhya Pradesh India, the order Cypriniformes were 29 species (56.86%) (Vyas et al., 2012), then in the Narmada river, Western Zone found that 28 species (54.90%) (Bakawale & Kanhere., 2013).

Based on IUCN status, nine species (47.36%) were not evaluated, eight species (42.10%) were least concern, and two species (10.52%) were deficient data (**Table 1**). At *Lima Puluh Kota* river, from 43 species were identified. Based on the IUCN status, 20 species (46.51%) were categorized NOT Evaluated, 18 species (41.86%) were categorized LEAST Concern, 4 species (9.30%) were categorized *Data Deficient*, and one species (2.32%) was categorized *Near Threatened* (NT) (Statistic data Fisheries *Lima Puluh Kota* Regency, 2013).

The utility of each fish species is diverse such as for consumption, bait, larvivous fish, medicinal value, ornamental fishes, and biological agents. In the point of tropical food level, fish species living in Singkarak Lake consist of herbivores, carnivores, omnivores, and planktivores (Syandri et al., 2011).

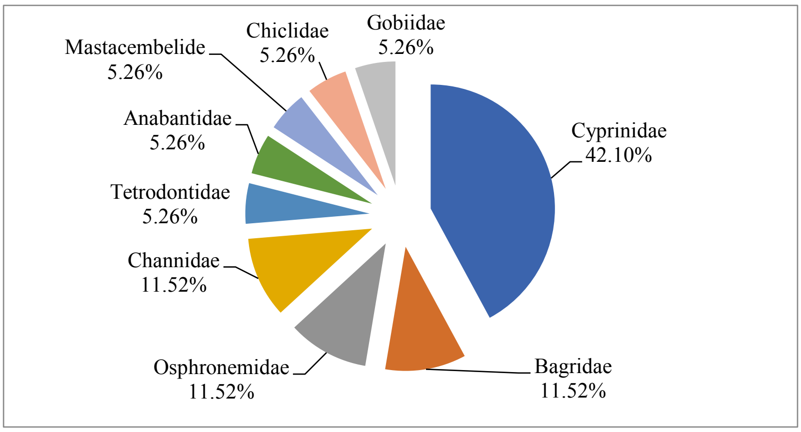
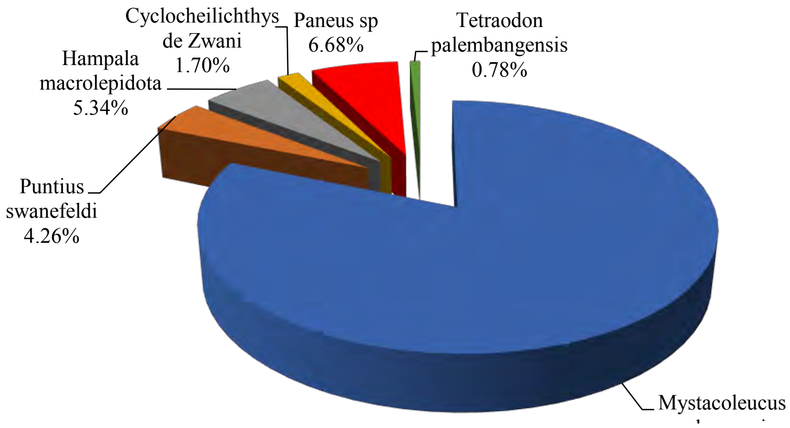


Figure 1. The percentage of fish family in Singkarak Lake, Indonesia

The composition of fish caught by lift net

The main purpose of lift net operated in Singkarak Lake is to catch *bilih* fish. However, based on the fish resources species identification, from 21 trip catches of fish was obtained 10,926 individual which are consist of *Mystacoleucus padangensis* (81.17%), *Puntius swanefeldi* (4.26%), *Hampala macrolepidota* (5.34%), *Cyclocheilichthys dezwani* (1.70%), *Penaeus* sp (6.68%), and *Tetraodon palembangensis* (0.70%), respectively (Figure 2). Furthermore, composition based on the growth of *bilih* caught by lift net, there were larvae (24.56%), juvenile (32.93%), and broodstock (47.33%), respectively (**Figure 3**).



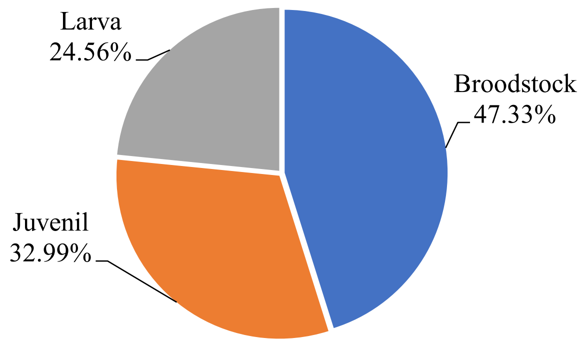


Figure 3. Composition of *Bilih* based on the growth stages caught by lift net

The different size of *Bilih* caught by lift net or light fishing was due to very small mess size of nets (0.1 – 0.2 cm) for monofilament net, and (0.5 cm) for multifilament nets (0.5 cm) operated for fishing. It means that mesh size of the gears used for fishing was not selective. Selective fishing gear means that net of the gear used for fishing is suitable for fish size, did not injure and kill other fish size (Sudirman et al., 2011). The selective of lift net is very important for implementation of sustainable fishing activities *of Bilih* fish in Singkarak Lake. According to Syandri et al., (2011) there are three points strategies to implement the sustainability of *Bilih* fish fisheries in Singkarak Lake; (1) Management of fishing gear through publishing a rule that gillnet used for fishing in mesh size of 1.0 inches, (2) Fish habitat management through implementation of fisheries co-management, and (3) The management of fish populations through development of fish hatchery and fish restocking. The improvement of selective fishing gear is one of the efforts to implement the friendly environment lift net in Singkarak Lake, It is expected that the fish catch have been on the decent size. At least currently fish on the size is the first ripe gonads (Length at first maturity / LFM).

Table 1. The status and utility of fish fauna in Singkarak Lake

Order	Family	Scientific Name	Local Name	English Name	Fish utility	Price/kg (IDR)	IUCN Red List Status
Cypriniformes	Cyprinidae	*Mystacoleucus padangensis*	Bilih	-	FD, MD, BT	40.000	NE
Cypriniformes	Cyprinidae	*Osteochilus brachmoides*	Nilem	Bonylip barb	FD, BA	25.000	LC
Cypriniformes	Cyprinidae	*Osteochilis vittatus*	Asang	Bonylip barb	FD, BA	30.000	LC
Cypriniformes	Cyprinidae	*Cyclocheilichthys de Zwani*	Turiq	-	FD	30.000	LC
Cypriniformes	Cyprinidae	*Hampala mocrolepidota*	Sasau	Hampala barb	FD, OF	50.000	LC
Cypriniformes	Cyprinidae	*Tor douronensis*	Garing	Semah mahseer	FD, OF	50.000	NE
Cypriniformes	Cyprinidae	*Puntius shwanefeldi*	Kapiek	Tinfoil barb	FD, OF	25.000	NE
Cypriniformes	Cyprinidae	*Puntius belinka*	Balingkah	-	FD	25.000	NE
Cypriniformes	Gobiidae	*Psilotris sp*	Rinuk	-	FD	50.000	NE
Siluformes	Bagridae	*Hemibagrus nemurus*	Baung	Asian redtail catfish	FD	50.000	LC
Siluformes	Bagridae	*Clarias batrachus*	Kalang	Phillipine catfish	FD	50.000	NE
Tetraodontiformes	Tetraodontidae	*Tetraodon palembangensis*	Jabui	-	FD, OF	30.000	DD
Perciformes	Osphronemidae	*Osphronemus gurami*	Kalui	Giannt gourami	FD	35.000	NE
Perciformes	Osphronemidae	*Trichogaster trichopterus*	Sepat	Sneskin Gourami	FD, OF	30.000	LC
Perciformes	Anabantidae	*Anabas testudeneus*	Puyu	Climbing perch	FD, LV	35.000	DD
Perciformes	Mastacembelidae	*Mastacembelus unicolor*	Tilan	-	FD	35.000	NE
Perciformes	Channidae	*Channa striata*	Bakok	Striped snakehead	FD, MD	40.000	LC
Perciformes	Channidae	*Channa lucius*	Bujuk	snakehead	FD, OF	40.000	LC
Cypriniodontiformes	Chiclidae	*Oreochromis niloticus*	Nila	Nile tilapia	FD	20.000	NE

FD = *Food fish;* BT = bait; OF =*Ornamental fishes*; LV =*Larvivous fish;* MD=*Medicinal value;* BA= *Biological agents*
IUCN Red List Status: NE = *Not Evaluated*; LC = *Least Concern*; DD = *Data Deficient*; NT = *Near threatened*

CONCLUSIONS

Among 19 species of fish in Singkarak Lake, *bilih* (*Mystacoleucus padanggensis*) was the most dominant population, and categorized as endemik species in Singkarak Lake. This species has economic value to society around Singkarak Lake. The fish status is endangered now, due to over fishing by gillnet and liftnet, local name *Bagan*. Furthermore, It needs to be conservation regarding the mess size and the total fishing gear used in Singkarak lake.

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THE FISH COMMUNITIES OF ABKHAZIAN LAKES

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ABSTRACT

The aim of this work was to assess the fish community's status of the Abkhazian lakes with different anthropogenic pressing. In the work following tasks have been: a study of the species composition of the lake's fish fauna, assessment of species diversity of fish communities with the aid of standard indexes, analysis of the environmental groups of fish communities in lakes. The material was collected by fishing on lakes using fishnet with length of 3 m and a mesh size of 5 mm. Assessment of species diversity indices was carried out by Margalef-, Menhinik- and Shannon-indexes. The study as a part of the fish communities of lakes Skurcha, Ritsa, Mayak found 16 fish species of four units (Gasterosteiformes, Cephaloformes, Cypriniformes, Perciformes). Skurcha's fish communities to the following types by their feeding regime: 60% of benthophages, planktophages (30%) and 10% of detritophages. Lake Mayak is fully represented by benthophages. The Lake Ritsa is represented by planktophages (60%) and benthophages (40%). Skurcha had freshwater (46%), brackish water (36), and marine fish (18%). Lake Mayak is fully represented by freshwater species. The Lake Ritsa is represented by brackish water species. Skurcha had rheophilic (60%) and limnophilic fish (40%). Lake Ritsa is fully represented by rheophilic fish while Lake Mayak fish communities contain of limnophilic fish (100%). By habitat types, fish communities of the lakes of Skurcha and Ritsa represented by demersal (50%) and pelagic species (50%). Only demersal species (100%) live in the Lake Ritsa.

Keywords: Abkhazian lakes, Caucasus lakes, ichthyofauna, Lake Ritsa.

INTRODUCTION

Abkhazia is a partially recognised state on the eastern coast of the Black Sea and the south-western flank of the Caucasus. It covers near 9000 square kilometres. In Abkhazia, there are more than 50 lakes. The largest of them are Lake Ritsa and Amtkel. The aim of this work was to assess the fish community of Lake Ritsa, Skurcha and Lake Mayak. Most of the lakes of Abkhazia are underexplored and unexplored as a result of military events from 1992 to 2008. In this regard, the study of ichthyofauna of lakes of Abkhazia is a particularly relevant scientific task. Study of the ichthyofauna is an important aspect of the study of aquatic ecosystems and assessment of its ecological status. Fish make a significant contribution to the function and energy balance of aquatic ecosystems due to participation in trophic relationships, and often being on the end of food networks. Data about fish fauna can be used for monitoring purposes. Anthropogenic impact leads to the transition of the fish fauna of certain regions in an unstable and depressive state.

Currently to achieve our aim the following tasks were:

1. The study of species composition of ichthyofauna of the lakes.
2. Assessment of species diversity of the ichthyofauna using conventional indexes.
3. Analysis of ecological groups of ichthyofauna of the lakes.

Ritsa is a mountain lake in Abkhazia. It located in Ritsa Nature Reserve on 950 m above the sea-level. Lake surrounded by mixed mountain forests and subalpine meadows. Mountains with heights of 2200 to 3500 m surround the lake. The lake has a tectonic origin. Ritsa is an oligotrophic freshwater lake. Area – 1,27 km², length – 2,5 km, width - from 270 to 870 meters. The average depth is 63 m, maximum - 131 m. Power supply are rains and snow (Elanidze, 1983) .

Lake Skurcha is located on the left bank of the river Kodor in Ochamchira district of Abkhazia. From the Black Sea it separates narrow coastal strip in widths since 100 to 200 meters. Skurcha is an artificial origin lake, which was formed from the quarry. The area is 140 hectares with depth of 26 meters. In the lower layers of the lake there is a very high concentration of hydrogen sulphide. The lake receives water from the river Kodor and connected by channel with the Black Sea. Skurcha is an mesotrophic brackish water lake (Elanidze, 1983).

Lake Mayak is located in the south-western part of the city of Sukhum. Mayak is an artificial origin lake. The area is 10 hectares with depth of 3.5 meters. Mayak is a mesotrophic freshwater lake. The lake has a low value of recreation for the local population. On the banks of the lake marked the illegal dumping of household and organic waste (Elanidze, 1983).

METHODS

In the 2015-2016 years the staff of Kazan University and Abkhazian Academy of Sciences investigated the fish fauna of the three lakes in Abkhazia. Ichthyologic material has been collected by fishing with a whitebait-scraper with a length of 6 m and mesh step of 5 mm and a fishing net. It was determined the species composition of fish (Veselov, 1977) and sorted by species. The average number of each species was counted on the basis of quantitative indicators of catches. The structure of the fish community was described by calculating the share of each species in the catches. To assess the status of fish communities, we calculated the Margalef and Menhinick indexes of species richness and Shannon index of species diversity (Magurran,2004).

RESULTS AND DISCUSSIONS

We revealed 16 species in the composition of ichthyocenosis of studied lakes (**Table 1**). Most of them belongs to the order of Cypriniformes (nine species), four species of Perciformes, one species – Mugiliformes, two - Gasterosteiformes.

Table 1. The list of ichthyofauna species.

Species	Lake Skurcha	Lake Ritsa	Lake Mayak
Alburnus alburnus	+		
Barbus ciscaucasicus		+	
Barbus tauricus escherichii		+	
Cobitis taenia	+		
Gambusia affinis			+
Gasterosteus aculeatus	+		
Gobio gobio		+	
Mugil cephalus	+		
Mullus barbatus	+		
Neogobius melanostomus	+		+
Parablennius sanguinolentus	+		
Phoxinus percnurus	+		
Phoxinus phoxinus colchicus		+	
Proterorhinus marmoratus	+		
Romanogobio ciscaucasicus		+	
Syngnathus typhle	+		

The ichthyofauna of Lake Skurcha is the most diverse and is represented by 10 species of order Mugiliformes, Gasterosteiformes, Cypriniformes and Perciformes. The ichtyofauna of the Lake Ritsa is represented by five species from order Cypriniformes. The ichthyofauna of the Lake Mayak is presented by two species of order Cyprinodontiformes and Perciformes (**Table 2**).

Table 2. The number of taxonomic groups of of ichthyofauna

Lake	Class	Orders	Families	Species
Skurcha	Osteichthyes	4	8	10
Ritsa	Osteichthyes	1	1	5
Mayak	Osteichthyes	2	2	2

The highest values of diversity parameters obtained in Lake Skurcha. The lowest indexes of species diversity of the ichthyofauna was observed in Lake Mayak (**Fig.1**). It can rather be explained by the high eutrophication of the reservoir and its contaminant organic and household waste. The Lake Ritsa has the highest indicator values of species diversity (**Fig.2**).

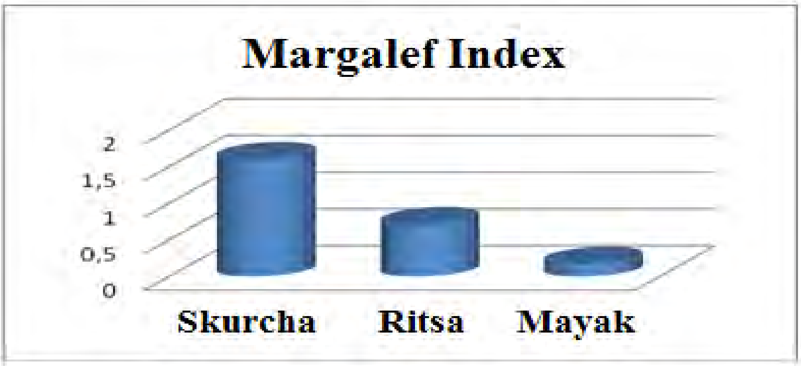

Figure 1. Biodiversity parameters in some of the lakes

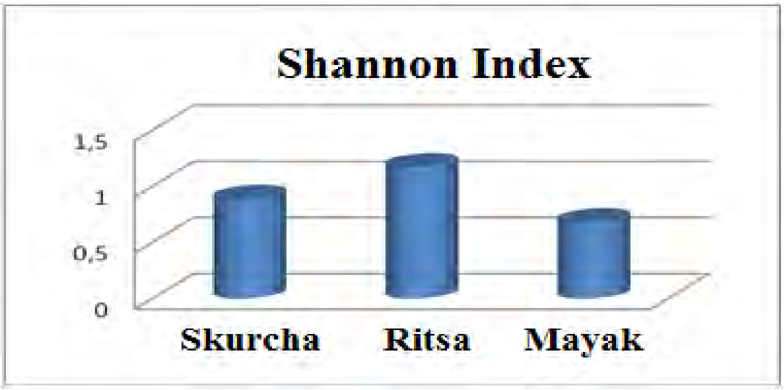

Figure 2. Shannon index in some of the lakes

We can divide (Ilmast, 2005) Skurcha's fish communities to the following types by their feeding regime: 60% of benthophages, planktophages (30%) and 10% of detritophages. Lake Mayak is fully represented by benthophages. The Lake Ritsa is represented by planktophages (60%) and benthophages (40%). Skurcha had freshwater (46%), brackish water (36) and marine fish (18%). Lake Mayak is fully represented by freshwater species. The Lake Ritsa is represented by brackish water species. Skurcha had rheophilic (60%) and limnophilic fish (40%). Lake Ritsa is fully represented by rheophilic fish while Lake Mayak fish communities contain of limnophilic fish (100%). By habitat types, fish communities of the lakes of Skurcha and Ritsa represented by demersal (50%) and pelagic species (50%). Only demersal species (100%) live in the L. Ritsa.

CONCLUSIONS

The ichthyofauna of Lake Skurcha is the most diverse and is represented by 10 species of order Mugiliformes, Gasterosteiformes, Cypriniformes and Perciformes. The ichtyofauna of the Lake Ritsa is represented by five species from order Cypriniformes.The ichthyofauna of the Lake Mayak is presented by two species of order cyprinodontiformes and perciformes. The highest values of diversity parameters obtained in Skurcha lake. The lowest indexes of species diversity of the ichthyofauna was observed in lake Mayak. It can rather be explained by the high eutrophication of the reservoir and its contaminant organic and household waste. The lake Ritsa has the highest indicator values of species diversity. The fish communities of investigated lakes are significantly different from each other by environmental groups and biodiversity. This is related with different ecological and limnological conditions.

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EFFECT OF SEASONAL CHANGES ON SPATIAL DISTRIBUTION OF BACTERIAL PATHOGENS IN TILAPIA (*Oreochromis niloticus*) IN LAKE BATUR

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ABSTRACT

The aquaculture production of tilapia in Lake Batur is decreasing due to infection of some potentially pathogenic bacteria. Bacterial infection happens when the tilapia immune system weakens which may cause by the changing of water quality during the dry season. Diseases by pathogenic bacteria damage the skin, flesh, gills and internal organs. The spread of bacterial diseases in fish are fast and can lead to a high mortality. The economic loss from bacterial disease is quite large. Lesions in the flesh of infected fish reduce the quality which lower fish price in the market. The aim of the research was to determine the seasonal distribution of pathogenic bacteria presented in tilapia samples collected from farming locations in Lake Batur. Tilapia (Oreochromis niloticus) samples were collected from five floating net cages (FNC) in Lake Batur. Three fish were collected from each station with fish sized ranged from 100-200 g. Identification of bacteria was conducted by Gram staining method while the observation of colors and shapes of the cells were performed using a microscope at 1000 magnification. Finally, the bacteria were inoculated using a streak plate technique on SSA (Salmonella Shigella Agar), EMBA (Eosin Methylene Blue Agar) and TCBS (Thiosulphate Citrate Bilesalt Sucrose). The results showed that the seasonal change affects the spatial distribution of pathogenic bacteria in tilapia. The types of pathogenic bacteria in the dry season aremore varied than in the rainy season. In the dry season, there are 5 types of potentially pathogenic bacteria that cause the disease namely Aeromonas, Streptococcus, Salmonella sp., Shigella sp., and E. coli. While in the rainy season, Pseudomonas alcaligenes and Aeromonas salmonicida are the types of pathogenic bacteria which infected the Tilapia.

Keywords: *Oreochromis niloticus*, seasonal change, spatial distribution, potential bacteria pathogenic

INTRODUCTION

Seasonal changes which leads to changes in water quality is one of the factors causing disease problems in fish farming. Generally, the quality of water in the dry season is relatively low. The decrease in water quality causes the bacteria to grow rapidly and the number of species increases. According to Hambali et al. (2005), the number and type of pathogenic bacteria in tilapia are more varied in the dry season compared to the rainy season. The decrease in water quality makes the fish stress, and weaken the immune system making it more susceptible to disease causing high mortality and large economic loss. Another disadvantage is the decrease of fish meat quality because of ulcers or injury which is not preferred by consumers. This lowers the selling price of the fish.

Diseases caused by pathogenic bacteria can result in the death of approximately 50% - 100% (Frerichs, 1984). While the research by Barnes et al. (2003) stated that one of the bacterial infectious diseases which are found in Floating Net Cages (FNC), particularly in those cultivating tilapia (*Oreochromis niloticus*), is infection by *Streptococcus.* Pathogenic bacteria cause damage to the skin, flesh, gills and internal organs. The spread of bacterial diseases in fish are generally very fast and may lead to a very high mortality in infected fish. Results of research by Supriyono and Wiwit (2011) showed that the performance of a bacterial disease found in tilapia farmed in fish net in Riam Kanan River consisted of some types of bacteria which are *Aeromonas hydrophila*, *Bordetella* sp., *Streptococcus* sp., *Acinetobacter* sp., *Pasteurella* sp., *Pseudomonas* sp., *Actinobacillus* sp., *Citrobacter* sp. and *Enterobacter* sp. The prevalence of the outbreaks ranges between 90-95%.

A fish farming system with Floating Net Cage (FNC) in waters such as lake is one of the activities in the fisheries sector, which has high economic value. Fish farming activities using FNC system at Lake Batur has been familiar since the 1990s. In 2014, there were about 560 FNC managed by 950 fish farmers. Each FNC consists of 9 plots extending in several places, namely Desa Kedisan and Toya Bungkah, also Trunyan, Buahan, and Songan. All these places are located on the edge of Lake Batur (Trobos, 2014). The fish farming activities have increased the economic growth for the local community.

The death of tilapia caused by pathogenic bacteria in Lake Batur has long been identified, but the publication of official data on the identification of potentially pathogenic bacteria which infects tilapia is not yet available. Losses caused by the bacterial infection are highly influential on the development of fish farming in Lake Batur. Therefore, it is necessary to conduct a research on the effects of seasonal change on the partial distribution of potentially pathogenic bacteria in tilapia fish farming locations in Lake Batur, Bali, Indonesia.

METHODS

Fish Sampling

The study was conducted in August 2014. Samples were collected directly from the tilapia fish farming in Floating Net Cage (FNC) of Lake Batur. Three fish which shows clinical symptoms such as an ulcer on the body or swim weakly were collected from each station with sized ranged from 100 -200 g. Measurement of water quality parameter included pH, Dissolved Oxygen (DO), temperature, salinity, and turbidity. Data of bacteria during rainy season obtained from Fish Quarantine and Inspection Agency Class I of Denpasar Bali, in March 2014 that taking samples of Tilapia in Lake Batur.

Isolation and Identification of Bacteria

Organs of tilapia used for isolation were the head, stomach, intestines and tails. Sections were weighed as much as 10 grams and put into 90 ml of sterile distilled water, then homogenized using vortex for 3-5 minutes. The media used for bacterial growth was NA (Nutrient Agar). Pour plate methods and the dilution test tube up to 10^4 were used to inoculate the bacteria. After 24 hours incubation, the total abundance of bacterial colonies was enumerated using Total Plate Count and dilution techniques.

Identification includes morphological observation of bacterial cells inoculated in the NA by Gram staining reaction test, using 2% crystal violet, lugol, acetone alcohol, and saffranin 0.25%. The Gram-positive and the Gram-negative bacteria are differentiated at the end of staining. The colors and shapes of cells were observed using a microscope Binocular Olympus CX-21 at a magnification of 1,000 x.

The determination of typical bacteria presented in the body of the fish were performed by inoculating the bacteria isolated from NA on media SSA (Salmonella Shigella Agar), EMBA (Eosin Methylene Blue Agar), and TCBS (Thiosulphate Citrate Bilesalt Sucrose). A red color of inoculant in the SSA media indicates *Salmonella* sp. and a yellow color indicates *Shigella* sp. A metallic green in EMBA media indicates *E. coli*. The color of TCBS media turned into yellow when *Vibrio* sp. was grown.

RESULTS AND DISCUSSIONS

Waters Quality Parameters

Differences in the water quality of the five stations during the dry and rainy seasons were shown in **Table 1**. Water quality parameters that change was the temperature, pH, DO, and turbidity. Temperature indirectly influences the solubility of CO_2 used for photosynthesis and O_2 solubility used for respiration by fish and other aquatic animals. O_2 solubility decreases with the increasing of water temperature. Temperatures in the dry season were 23.4 to 25.7°C, meanwhile it decreased in the rainy season from 22.2 to 25°C. Tilapia can grow optimally at temperatures of 25-33°C, however temperature below 25°C may hamper Tilapia (**Table 1**).

Table 1. Water Quality Parameters in Dry and Rainy Seasons

Water Quality Parameters	Dry Season					Rainy Season				
	Station					Station				
	1	2	3	4	5	1	2	3	4	5
Temperatur (ºC)	23,4	23,9	25	25,7	24,3	22,2	23,2	25	25	24
pH	8,6	8,56	8,55	8,6	8,61	7,53	7,82	7,11	7,61	7,82
DO	9,2	8,5	9,3	7,2	9,1	7,2	7,7	6,73	7,2	6,43
Turbidity (NTU)	3,1	2,44	3,2	2,15	3,7	5,13	4,33	4,45	3,39	5,2

According to Cahyono (2000), the optimal pH range for tilapia (*O. niloticus*) is 7-8, however tilapia tolerates pH between 5-11. Afriyanto and Liviawati (2006) explain that the decrease in pH harm fish metabolism. The changes in pH value also affect the levels of CO_2 in the water, the higher the pH value, the lower level of freeCO_2. Conversely, the lower the pH value, the higher level of free CO_2.

In the rainy season, the normal water pH for fish to live is equal to 7.11 to 7.81. The pH value increases during the dry season of 8.55 to 8.61. At such pH conditions, the bacterial growth is increasing. Boyd (1979) explains that the growth of bacteria would be better off in normal pH until relatively alkaline.

The level of turbidity shows the optical characteristic of water which is determined by the amount of light absorbed and emitted by the materials contained in the water. Turbidity is caused by the presence of organic and non-organic material that are suspended and dissolved in water, as well as plankton and other microorganisms. The maximum standard of turbidity for aquaculture is 5 NTU (Boyd, 1979). Turbidity in Lake Batur in the dry season ranged from 2.15 to 3.7 NTU and 3.39 to 5.13 NTU in the rainy season. In the rainy season, the turbidity level was higher than standard values due to the input of colloids, organic and non-organic materials from the river mouth, as well as the erosion of the land. Turbidity value above 5 NTU can disrupt fish osmoregulation system, hamper light penetration into the water. High turbidity values will influence the dissolved oxygen because inhibit photosynthesis process (Effendi, 2003). As a result of water quality degradation, the fish are easily stressed and are susceptible to disease and bacteria are more pathogenic.

Isolation of Bacteria

After incubation for 24 hours at 37° C, the colonies of bacteria with various quantities were visible. The total amount of bacterial colonies grown on NA media varied from 1.10^5 to 45.10^5 CFU/mL. The result of the calculation showed that the lowest average number of bacterial colonies was at Station 2 (2.10^5 CFU/mL), while the highest was at Station 5 ($21. 10^5$ CFU/mL) (**Figure 1**).

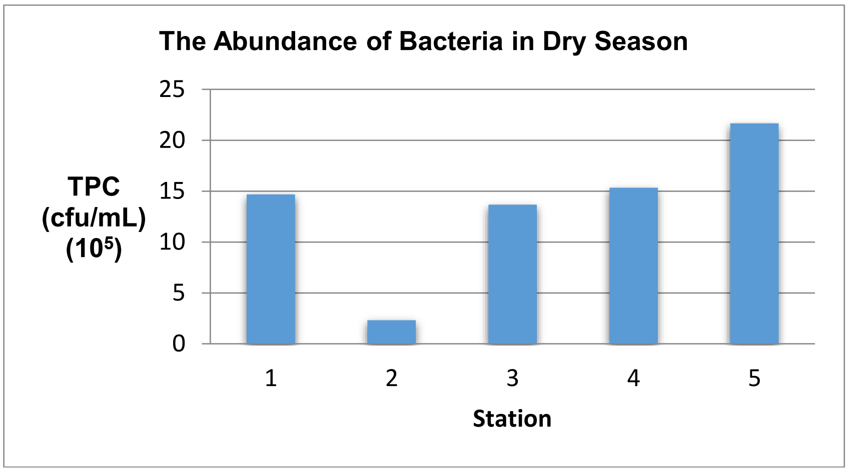

Figure 1. Abundance of Bacteria in Dry Season

The Gram staining results showed that the Gram-positive and Gram-negative bacteria were dominated by rod-shaped and coccus shapes. At Stations 1, 3, and 5, the bacteria were Gram negative with rod-shaped. The Gram-negative bacteria with coccus shape were found at Station 4. Gram-positive bacteria with streptococcus shape were found at Station 2 and 4 (**Table 2**). The results from selective media showed *Salmonella* were positive in fish samples found in Station 3 (sample 2 and 3) and Station 5 (sample 1 and 2). Meanwhile, *Shigella* were found in Station 3 (sample 1 and 3) as well as Station 5 (sample 1 and 2). *E. coli* were found in Station 3 (sample 1) and Station 5 (samples 1 and 2). The results on media SSA and EMBA are presented in **Figure 2.**

Table 2. Gram-Staining Results at Station 1-5

Station	Fish sample	Form	Gram	Bacteria
1	1	Rod-shaped	Negative	-
	2	Rod-shaped	Negative	*Aeromonas*
	3	Rod-shaped	Negative	-
2	1	Streptococcus	Positive	*Streptococcus*
	2	Rod-shaped	Negative	-
3	1	Rod-shaped	Negative	*Shigella, E. coli*
	2	Rod-shaped	Negative	*Salmonella*
	3	Rod-shaped	Negative	*Salmonella, Shigella*
4	1	Rod-shaped, coccus	Negative	-
	2	Streptococcus	Positive	*Streptococcus*
	3	Coccus	Negative	-
5	1	Rod-shaped	Negative	*Salmonella, Shigella, E. coli*
	2	Rod-shaped	Negative	*Salmonella, Shigella, E. coli*
	3	Rod-shaped	Negative	-

(b)

Figure 2. Bacterial colonies on the selective media (a) SSA (Salmonella Shigella Agar) (b) EMBA (Eosin Methylene Blue Agar)

Effect of Seasonal Changes on the Distribution of Pathogenic Bacteria in Tilapia

Changes in water quality due to the seasonal change affect changes in the quality the fish on sampling sites in Lake Batur. It affected the spatial distribution of pathogenic bacteria. This type of bacteria increased in the dry season due to a decrease in water quality. The spatial distribution of pathogen bacteria in tilapia during the dry and rainy seasons were shown in five Floating Net Cage (FNC) locations in Lake Batur.

Five types of bacteria isolated from fish cultured in Floating Net Cage (FNC) in Lake Batur during the dry season (August 2014) were identified as *Aeromonas*, *Streptococcus*, *Salmonella*, *Shigella* and *E. coli*. Based on the recapitulation data of monitoring results by Fish Quarantine and Inspection Agency Class I of Denpasar Bali, two types of bacteria on tilapia were obtained during the rainy season (March 2014), namely *Pseudomonas alcaligenes* and *Aeromonas salmonicida* (**Table 3**).

Table 3. Types of Bacteria in Dry Season and Rainy Season

	Season	**Bacteria**
1.	Dry Season (August 2014) *Rainfall 64 mm	 *Aeromonas* sp. *Streptococcus* sp. *Salmonella* sp. *Shigella* sp. *E. coli*
2.	Rainy Season (March 2014) *Rainfall 210 mm	 *Pseudomonas alcaligenes* *Aeromonas salmonicida*

*Data Indonesian Agency for Meteorology, Climatological and Geophysics, 2014

Descriptively, it seems that there is a tendency that the distribution of pathogenic bacteria in the dry season is more varied than in the rainy season. This is a result of changes in water quality in the dry season, which is generally relatively poor or decreased compared to the rainy season. This is supported by Hambali, et al. (2005) which found seven species of bacteria in the dry season and four species of bacteria in the rainy season that cause disease to tilapia in FNC of Cirata reservoir. Concentration of organic matter increases in the dry season, affecting the bacterial diversity. High fluctuations on water quality in dry season makes the fish stress and susceptible to disease.

CONCLUSIONS

Seasonal change affects the spatial distribution of pathogenic bacteria on tilapia in Lake Batur.

The type of pathogenic bacteria in the dry season is more varied than in the rainy season. In the dry season, there are five types of pathogenic bacteria that can potentially cause disease, such as *Aeromonas*, *Streptococcus* sp., *Salmonella* sp., *Shigella* sp., and *E. coli*; while in the rainy season, there are two types of pathogenic bacteria, such as *Pseudomonas alcaligenes* and *Aeromonas salmonicida.*

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Fish Quarantine and Inspection Agency Class Iof Denpasar Bali.

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FLUCTUATING ASYMMETRY USING GEOMETRIC MORPHOMETRICS IN *Glossogobius giuris* (HAMILTON, 1822) FROM LAGUNA LAKE, PHILIPPINES

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ABSTRACT

White goby, Glossogobius giuris, is a native and an economically important fish which is of declining population in Laguna Lake, Philippines. The study investigated fluctuating asymmetry in fish samples (n=118) obtained from two predominantly agricultural sites (Bay and Santa Cruz, Laguna) in the East Bay of the lake and from a reference site, where gobies were reared in concrete tanks. Nineteen anatomical landmarks were digitized on fish images and were subjected to an advanced tool for shape asymmetry (Symmetry and Asymmetry in Geometric Data (SAGE) version 1.04). Procrustes two-way mixed model ANOVA revealed significant levels of both directional and fluctuating asymmetries (FA) among populations and between sexes. Fluctuating asymmetry, the small, random differences between the left and right sides of a bilaterally symmetrical organism, is widely reported as a measure of developmental stability and as an early-warning tool in monitoring the health of aquatic ecosystems. Overall FA variations based from two major principal components were higher in wild than in reared population. FA levels detected may imply that deviations from perfect symmetry could be attributed to environmental stress. Findings may indicate the contributory effects of environmental conditions associated with anthropogenic pressures on the developmental instability of goby populations.

Keywords: environmental stress, fluctuating asymmetry, geometric morphometrics, Laguna Lake, white goby

INTRODUCTION

Laguna Lake is the largest freshwater lake in the Philippines and is a vital natural resource providing various ecosystem services like fisheries and aquaculture production, navigation, hydroelectric power generation, temporary storage of floodwater, source of irrigation and domestic water, and recreation (Lasco and Espaldon, 2005). However, through the years, the lake has become a huge sink for discharge from industries and residential areas in the western bay whereas fertilizer and pesticides runoff from agricultural land uses in the eastern bay. Fish production in the lake and its river tributaries declined due to pollution and contributory factors such as destructive harvesting and introduction of exotic species ((Lasco and Espaldon, 2005).

Several studies have shown that biomarkers, functional measures of exposure to various stressors (Adams et al., 2001), are useful tools in monitoring biotic 'health' and therefore give an indirect measure of possible environmental pollution or degradation (Sole et al., 2006; Richardson et al., 2010). Fluctuating asymmetry (FA), small, random differences which occur between the left and right sides of a bilaterally symmetrical organism due to subtle variations in the developmental environment (Palmer and Strobeck, 2003), is a potential biomarker of stress within populations. It is widely used as a measure of developmental stability (DS) or developmental instability (DI) (Godet et al., 2012) where DI can be viewed as the sensitivity of a developing system to random perturbations (Knierim et al., 2007). Developmental instability results from internal (genetic) or external (environmental) stressors that disturb the development of structures along their normal developmental pathway in a given environment and produce developmental "noise" (Palmer, 1994). The presence of stress during ontogeny may reduce the efficiency of normal developmental processes, this being reflected by an increase in the level of FA (Ambo-Rappe et al., 2008). Significantly increased levels of FA in a population may indicate that individuals are having more difficulty maintaining precise development, resulting in negative effects on the population over time (Markow, 1995). Several studies have shown positive relationships between environmental stress and FA level in different fish species (Franco et al., 2002; Romanov and Kovalev, 2004; Marques et al., 2005; Ozsoy et al., 2012; Hermita et al., 2013; Mabrouk et al., 2014; Pojas and Tabugo, 2015).

White goby, *Glossogobius giuris*, (locally known as "*biyang puti*"), is one of the native fish species thriving in Laguna Lake and is reported to be of declining status. It is considered as commercially important and has a potential for aquaculture. It has a unique feature of having a fused pelvic fin at the antero-ventral portion of the body that serves as a suction-like disc and dwells at the bottom substrate or attaches into rocks. Much of the researches on *G. giuris* in the Philippines focused on body shape variation within and among populations using landmark-based geometric morphometrics (Nacua et al., 2010; Dorado et al., 2012; Unito-Ceniza et al., 2012). Geometric morphometry is an advanced tool in determining shape variation. In this technique, data are recorded in the form of coordinates of landmark points (Rohlf and Marcus, 1993), which are morphological points of specimens that are of biological interest (Richtsmeier et al., 2002).

The present study investigated fluctuating asymmetry in reared (8 to 12 months) and wild white goby populations using landmark-based geometric morphometrics. The technique and analyses of FA is simple, non-lethal, cost-effective, has broad application across biological systems and stressors, and can be associated with life history traits and fitness (Lens et al., 2002; Lens and Eggermont, 2008). With these features of FA, it may be used as an early warning tool for monitoring the Laguna Lake's ecological status.

METHODS

Study area

Laguna Lake (also known as Laguna de Bay), situated within latitudes of 13º 55' to 14º 50' N and longitudes of 120º 50' to 121º 45' E in Luzon Island, Philippines (**Fig 1**), occupies a total land area (administrative jurisdiction) of 3,880 km^2 (LLDA, 2013). Its morphometric features include a total surface water area of approximately 900 km^2, shoreline of 220 km, average depth of 2.5 m, maximum water holding capacity of about 2.9 billion m^3 and watershed area of 3,820 km^2 (Lasco and Espaldon, 2005). The lake is divided into three distinct bays: the West, Central, and East bays that converge towards the south resembling a large pre-historic bird's footprint. The study focused in the East Bay of the lake, where the main landuse is agricultural, limiting to Bay and Santa Cruz in Laguna province.

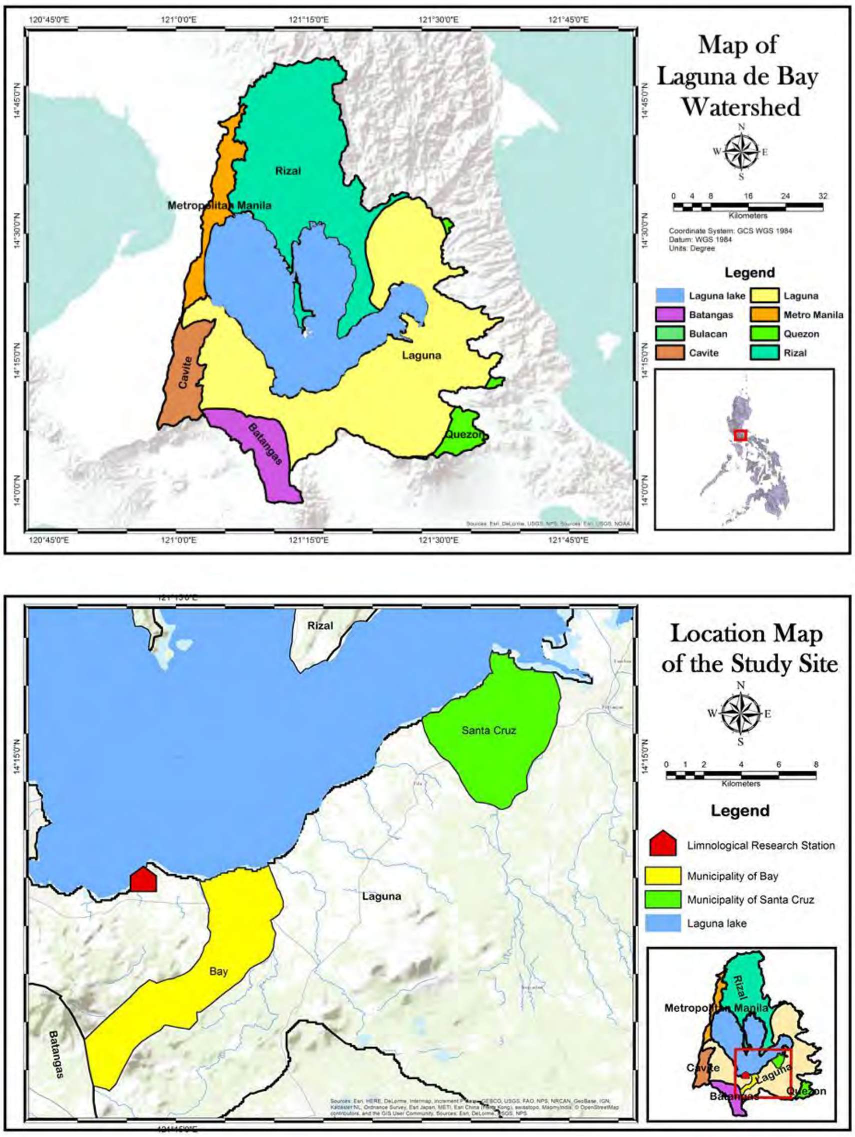

Figure 1. Map of study area (top) and location of study sites (bottom).

Fish sample collection

Wild populations of *G. giuris* were obtained from the East Bay of Laguna Lake, particularly in Bay and Santa Cruz, whereas reference population was obtained from the University of the Philippines, Limnological Research Station (UPLB-LRS) (**Fig 1**). Samples were collected with the aid of fishermen, using gill nets, fyke nets and cover pots, from June to October 2015 (coinciding with wet season). Reference samples were those caught from the lake, reared in concrete rectangular tanks for 8 to 12 months at UPLB-LRS, and fed with shrimps bought from the local fish market.

Image acquisition and landmark selection

Both left and right sides of 118 fish samples from three sites (Reference, n=31; Bay, n=42; Santa Cruz, n=45) were photographed using a Sony DSC-W290, 12.1 megapixels, camera. The samples were positioned with fins teased in order to show their natural position in swimming.

A total of 19 anatomical landmarks with both evolutionary and functional significance were selected and were based from previous studies on body shape variations in *G. giuris* (Nacua et al., 2010; Dorado et al., 2012). Location and description of anatomical landmarks are shown in Figure 2.

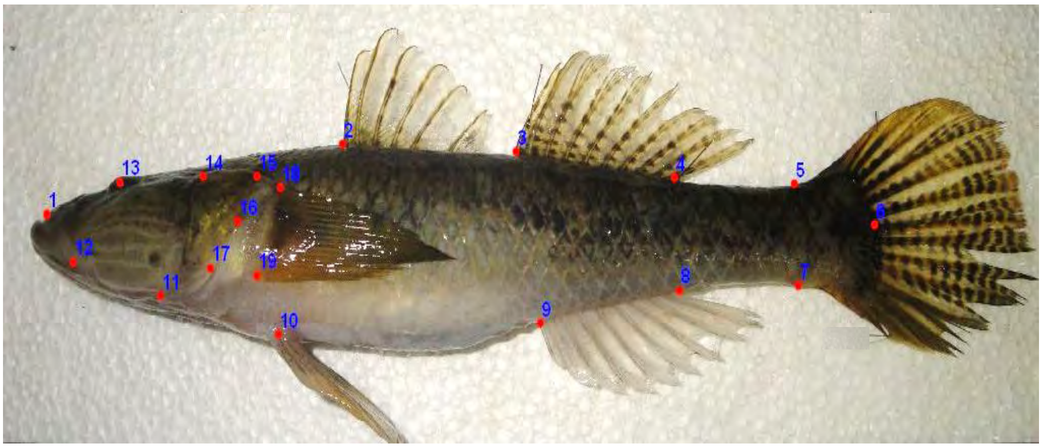

Figure 2. Location and description of anatomical landmarks in white goby, *G. giuris*, used in fluctuating asymmetry analysis. 1) snout tip, 2) anterior insertion of first dorsal fin, 3) anterior insertion of second dorsal fin, 4) posterior insertion of second dorsal fin, 5) point of maximum curvature of the peduncle, 6) posterior body extremity, 7) point of maximum curvature of the peduncle, 8) posterior insertion of anal fin, 9) anterior insertion of anal fin, 10) anterior insertion of the pelvic fin, 11) insertion of the operculum at the lateral profile, 12) posterior extremity of premaxilla, 13) center of the eye, 14 – 17) contour of gill cover, 18) superior insertion of pectoral fin, 19) inferior insertion of pectoral fin.

Image digitization and fluctuating asymmetry analyis

Captured images were digitized using TPS Dig version 2.12 (tpsDig2) (Rohlf, 2008) where landmark points were plotted to obtain the 2D (“x” and “y”) coordinates of the corresponding morphological landmark points.

Fluctuating asymmetries among populations and between sexes were determined by subjecting the paired landmark coordinates to Procrustes ANOVA following the method of Klingenberg et al. (2002) and using Symmetry and Asymmetry in Geometric Data (SAGE) software version 1.04 (Marquez, 2007). The software (SAGE) analyzed the x and y coordinates of the landmarks per individual, using a configuration protocol for both lateral sides of the goby. Procrustes superimposition analysis was performed with the original and mirrored configurations of the right and left lateral sides simultaneously to produce an overall mean shape (Savriama and Klingenberg, 2011). Procrustes two-way mixed model ANOVA with three replicates was used to quantify shape asymmetry. Fisher's exact test (F-test) determined the significance of null hypothesis of no difference between variance products *(XY)* in both left and right sides. Effects can be interpreted as follows (Savriama and Klingenberg, 2011): The main effect, *sides,* indicates the variation between sides and presence of directional asymmetry (DA) while the effect, *individuals,* refers to the variation of individuals. The mixed effect, *individual-by-side-interaction,* refers to the failure of the individuals to be the same between sides (left and right) and represents fluctuating asymmetry (FA). The measurement error, replications within *sides by individuals*, is a random effect. Deformation grids were generated through Principal Component Analysis (PCA) in order to visualize patterns in shape variability.

RESULTS AND DISCUSSIONS

Procrustes ANOVA of white goby populations (**Table 1**) revealed highly significant (P<0.01) F values for both *sides* and *individuals-by-sides interaction* in all sites. Thus, results can be interpreted that deviations from perfect symmetry were present among *G. giuris* populations in all sites and these were significantly due to directional (DA) (P<0.01) and fluctuating asymmetries (FA) (P<0.01). However, it seemed that asymmetry was largely due to FA in two study sites (Reference and Santa Cruz).

Table 1. Procrustes ANOVA results of white goby, *G. giuris,* populations from three sites.

Effects	SS	df	MS	F
Reference Site (n=31)				
Individuals	0.104	1020	0.0001	1.185**
Sides (DA)	0.016	34	0.0005	5.620**
Individuals x sides (FA)	0.088	1020	0.0001	7.969**
Measurement error	0.046	4216	0.0000	--
Bay (n=42)				
Individuals	0.209	1394	0.0002	1.123*
Sides (DA)	0.029	34	0.0009	6.578**
Individuals x sides (FA)	0.186	1394	0.0001	4.273**
Measurement error	0.178	5712	0.0000	--
Santa Cruz (n=45)				
Individuals	0.169	1496	0.0001	1.411**
Sides (DA)	0.019	34	0.0006	7.121**
Individuals x sides	0.119	1496	0.0001	11.852**
Measurement error	0.041	6120	0.0000	--

DA - directional asymmetry; FA - fluctuating asymmetry; ** - highly significant, P < 0.01;
* - significant, P < 0.05. Significance was tested with 99 permutations.

Directional asymmetry is a tendency for a trait to be consistently developed in different manners on the left and right body sides (Klingenberg, 2015). The difference between left and right sides may be large or small, but the average left–right difference varies from zero. DA may have a genetic basis (Palmer, 1994) or may arise due to differential use (left vs. right handedness). Few studies clearly demonstrated the influence of genetic stress on developmental stability (Blanco et al., 1990; Batterham et al., 1996; Brakefield and Breuker, 1996 *as cited by* Fessehaye et al., 2007). A meta-analysis by Vøllestad et al. (1999) showed that heterozygosity explained only a very small (1%) amount of variation in FA, and most investigators appear to agree that there is very little additive genetic variation for FA in most characters (Fessehaye et al., 2007).

Meanwhile, fluctuating asymmetry denotes small differences between the left and right sides due to random imprecisions in developmental processes (Klingenberg, 2003). It is symmetrically distributed about a mean of zero and a stochastic component of phenotypic variation (Graham et al., 2010). When one partitions total phenotypic variation into genetic and environmental components, FA is part of the environmental component (Falconer 1996 *as cited by* Graham et al., 2010). FA is widely associated with developmental instability, which results from internal (mainly genetic) or external stressors (environmental) that disturb the development of structures along their normal developmental pathway in a given environment and produce developmental "noise" (Palmer, 1994). Because the left and right sides of the same organism share the same genome and usually nearly the same environment, organs on the left and right sides can be expected to share the same target phenotype (assuming that there is no directional asymmetry) and therefore differ only by developmental instability (Godet et al., 2012).

In the present study, FA detected in *G. giuris* from all sites may reflect the inability of individuals to maintain homeostasis during development (Møller and Swaddle, 1997) due to the presence of stressors. Environmental stress can give rise to decreased developmental stability of individuals, which may result in reduced performance of fitness components (Møller and Swaddle, 1997). Stress causes a reduction in the efficient use of energy, causing a reduction in developmental homeostasis, and finally reducing long-term, total inclusive fitness (Escos et al., 2000).

Notably higher FA than DA was also revealed by Procrustes ANOVA results between sexes of *G. giuris* except in Bay male (**Table 2**). In localized trait asymmetry analysis, high number of characters exhibiting trait FA

supported these high F values of FA. Bay males had the least number of trait FA, with only 5 out of 16 characters. All populations showed significant FA in three traits: snout tip, center of the eye, and superior insertion of pectoral fin. Differences in the levels of FA among characters may indicate the variation on the ability of traits to buffer developmental noise and achieve homeostasis (Graham, 2010). Similarly, Angeles et al. (2014) found significant differences in FA mostly in the mouth, eyes and operculum part of females, while in the operculum and pectoral region of males. These were associated with stress in food competition and water turbidity which might have affected visibility and respiration (Angeles et al., 2014).
Principal component analysis (PCA) on the tangent coordinates derived from Procrustes analysis assists to examine the variability of landmark points in tangent space. Table 3 shows the percent variations or level of variability in the data among *G. giuris* populations. Based on the percentage of overall variation explained by two major principal components (PC 1 and PC 2), Bay *G. giuris* population exhibited the highest variation (54.72%) followed by Santa Cruz (49.77%) and Reference Site (41.77%). It could be observed that higher overall variation was detected in wild populations (Bay and Santa Cruz) than reared population (Reference).

Table 2. Procrustes ANOVA results between sexes of white goby, *G. giuris,* populations from three sites.

Effects	SS	df	MS	F
Reference Site				
Female (n=15)				
Sides (DA)	0.009	34	0.0003	2.732**
Individuals x sides (FA)	0.045	476	0.0001	12.017**
Male (n=16)				
Sides (DA)	0.009	34	0.0003	3.075**
Individuals x sides (FA)	0.048	510	0.0001	11.526**
Bay				
Female (n=23)				
Sides (DA)	0.009	34	0.0003	2.713**
Individuals x sides (FA)	0.078	748	0.0001	13.846**
Male (n=19)				
Sides (DA)	0.022	34	0.0007	3.805**
Individuals x sides (FA)	0.105	612	0.0002	2.866**
Santa Cruz				
Female (n=26)				
Sides (DA)	0.016	34	0.0005	6.117**
Individuals x sides (FA)	0.066	850	0.0001	11.293**
Male (n=19)				
Sides (DA)	0.005	34	0.0002	1.753**
Individuals x sides (FA)	0.053	612	0.0001	13.190**

DA - directional asymmetry; FA - fluctuating asymmetry; ** - highly significant, $P < 0.01$. Significance was tested with 99 permutations.

Table 3. Variations based on two major principal components in *G. giuris* populations from three sites.

Site	PC 1 (%)	PC 2 (%)	Overall (%)
Reference (n=31)	27.24	14.53	41.77
Bay (n=42)	37.21	17.51	54.72
Santa Cruz (n=45)	32.29	17.48	49.77

Principal component analysis implied deformation for *individual x side* interaction or fluctuating asymmetry of *G. giuris* populations in the three study sites are shown in Figure 3. In the Reference population (**Fig 3A**), PC 1 (27.24%) shows slight compression along the anterior end (head region) due to minimal movement at landmarks 1, 13, 14, 15, 18 and, along the posterior trunk region (at landmark 8). In contrast, slight expansion along the anterior trunk and caudal peduncle region (posterior end) are shown. PC 2 (14.53%) displays minimal expansion along the anterior end (head region) while slight compression along the posterior end (tail region).

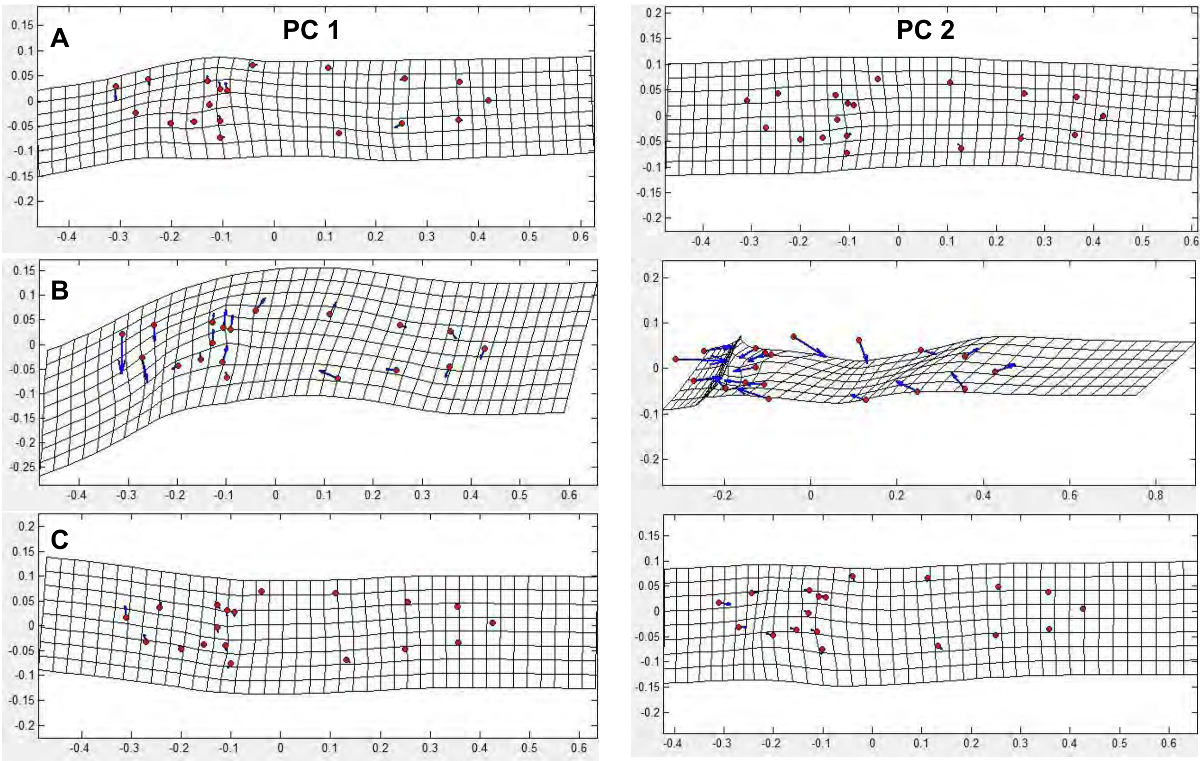

Figure 3. PCA implied deformation for *individual x side interaction* (fluctuating asymmetry), as explained by two principal components (PC1, left; PC2 right) of *G. giuris* populations from three sites: A) Reference, B) Bay, C) Santa Cruz. Red dots represent landmark points whereas blue arrows represent magnitude and direction of variation.

Extreme deformation or warping can be observed in Bay population (**Fig 3B**). Warps are prominent at the head region (anterior end) in PC1, which accounts 37.21% of the total variation among samples. Notable magnitude and direction of fluctuation are depicted by longer blue arrows pointing downward primarily at landmarks 1, 12 and 13. Warping is also influenced by upward movement at the opercular region (landmarks 14, 15) and pectoral fin insertion (landmarks 18, 19). These magnitude and direction of vectors have caused compression from the posterior toward the trunk region, and a strong downward shift along the anterior region. Although PC 2 only accounts 17.51% of the variation, magnitude and direction of vectors as shown by arrows were greater. Compression was intense or extreme at the head region, as shown by longer arrows that tend to meet. Displacement of landmarks from the grids is evident. Deformation grids for FA of Santa Cruz population were similar to Reference population with slight compression at the opercular region (PC 1, 32.29%). However, vectors along the head region, particularly at landmarks 1 and 2, tend to move upward. For PC 2 (17.48%), slight compression along the anterior end could be observed. Overall, most variations were detected at the head region or anterior end across populations, although these were more notable in wild populations (Bay and Santa Cruz). These configurations were able to show the dynamics in overall shape changes in *G. giuris* populations from the three sites. According to Beasley et al. (2013), studies that used geometric morphometric approaches to FA in shape and size were more sensitive to changes in environmental quality compared to linear and meristic measures and thus showed larger effects on FA.

Fluctuating asymmetry is a useful indicator of stress, not because it is more sensitive to stress than phenotypic modification, but because it reveals the average individual's robustness and stability in the face of stress (Graham et al., 2010). Stress is any environmental factor that causes a reduction in the efficient use of energy, causing a reduction in developmental homeostasis, and finally reducing long-term, total inclusive fitness (Escos et al., 2000). Furthermore, while the general definition of a stressor encompasses any biotic or abiotic factor that interferes with an individual's energy allocation toward its reproduction and development, novel, anthropogenic stressors may have stronger effects on FA levels because they more actively interfere with developmental pathways (Parsons, 2005) and more directly limit the mass and energy available compared to naturally occurring stressors, against which adaptive responses are expected to have evolved (Graham et al., 2010).

Detected fluctuating asymmetry in the Reference population of this study could be explained that artificial environmental conditions can affect morphology, physiology and behavior of fishes (Kihslinger and Nevitt, 2006). This could be attributed to both the restrictions to their ecological requirements (Barber, 2007) and the lack of natural physical, chemical or biological stimuli, which would trigger mechanisms of their life history strategies (Patterson et al., 2004). *Glossogobius giuris* dwells at the bottom substrate (sandy or muddy substrate) and attaches into rocks in the wild whereas at the bottom of concrete tanks with attached algae in reference population. It is carnivorous and cannibalistic in nature feeding on various types of fishes, crustaceans, insects and molluscs (Rao and Rao, 2002; Achakzai et al., 2015). The carnivorous habit of *G. giuris* is well evidenced by its large head with a large mouth and strong sharp teeth (Nacua et al., 2010). Juveniles feed on crustaceans as their major food while adults of this species prefer fish (Islam, 2004). Reared population in the present study was only fed with thawed small shrimps purchased from the local market. Similar sizes of individuals were maintained in each tank to avoid cannibalism. Food diversity and natural behavior of catching for prey were therefore limited. Moreover, FA could be sensitive to different levels of individual density in captive conditions (Leary and Allendorf, 1989).

Results of this study could imply that wild *G. giuris* populations experienced more developmental perturbations or more stressed due to exposure to various stressors. The east bay area of the lake is predominantly agriculture wherein the use of pesticides for intensive farming along the lakeshore is widespread. Agricultural activities are non-point sources of water pollution. Excessive use of fertilizer results in eutrophication in many aquatic habitats because precipitation carries dissolved nutrients (nitrogen and phosphorus compounds) into river tributaries and lakes. Water used to flush irrigated land to get rid of excess salt in the soil carries a heavy load of salt that degrades the water body. Agriculture dominates the existing landuse categories in Bay, in which nine barangays are considered agricultural lands while five are coastal areas. Santa Cruz, ideally situated on a plain land area, has 13 agricultural barangays and eight coastal barangays. Based from Key Informant Interviews (KII) and Focus Group Discussion (FGD) with individual rice and vegetable farmers/growers, farmers' associations from selected barangays and Municipal Agriculture Office (MAO) technicians, herbicides were applied once to twice per cropping at a rate of half to one liter per hectare whereas insecticides were applied once to thrice per cropping with the same rate of application in Bay and Santa Cruz. However, spray loading or application per hectare of both herbicides and insecticides was greater in Santa Cruz (10 to 16 tank loads) than in Bay (4 to 6 tank loads), in which a tank load is equivalent to 16 L. Pesticides can enter water through surface runoff, leaching, and/or erosion. Moreover, drift, evaporation, and wind erosion can carry pesticide residues into the atmosphere that can lead to contamination of surface waters via precipitation (Dubus et al., 2000). Whether they are dissolved in water or carried by sediment, pesticides that are carried off-site can contaminate surface waters (Hamers et al., 2001). Pesticides runoff can persist for days in the environment but their action on tissues of non-target organisms such as fishes and other aquatic fauna may last for weeks (Assis et al., 2012). Furthermore, solid and liquid domestic wastes from coastal barangays along the lakeshore could contribute to the water quality of the lake.

These results support previous studies in fish at individual and population levels of bilateral asymmetry which have been shown to relate positively to a wide range of stresses such as acidification (Øxnevad et al., 2002), toxic chemicals or heavy metals (Franco et al., 2002; Estes et al., 2006; Romanov and Kovalev, 2004). Stress such as chemical pollutants including metals or pesticides can cause developmental perturbations that can notably induce an increase of the FA level in invertebrates (Chang et al., 2007).

CONCLUSIONS

Patterns of asymmetry in body shape are present both in reared and wild *G. giuris* populations and seemed to be largely attributed to fluctuating asymmetry. Significant levels of fluctuating asymmetry across populations may indicate that individuals' developmental homeostasis is disturbed. Developmental instability in *G. giuris* populations could be possibly attributed to stressors environmental in origin such as artificial environmental conditions in reared whereas agricultural chemicals and wastes associated with other anthropogenic pressures in wild populations.

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EARLY DETECTION OF ICHTHYOFAUNA ALIEN SPECIES AT GAJAH MUNGKUR RESERVOIR, WONOGIRI, CENTRAL JAVA, INDONESIA

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ABSTRACT
Alien species is one of the threats to the ecosystem. Alien fish species could lead to the extinction of native species and ecosystem disturbance. Distribution through human activities allows alien species spread easily. Early detection of alien fish species provides information about the types and existence of alien fish species. This research was held at Gajah Mungkur Reservoir, Wonogiri in July 2015 to August 2015. A collection of data held by direct sampling and observations of angler's catches in 7 locations. Results showed 5 of 19 species were alien fish species. Cyprinus carpio, Clarias gariepinus, Pterygoplichthys pardalis, Pangasanodon hypophthalmus, *and* Oreochromis niloticus *were observed as alien species.* Pterygoplichthys pardalis *is a forbidden species to enter the territory of Indonesia based on the Regulation of Minister of Maritime Affairs and Fisheries Number 41 The Year 2014. The alien species have been detected in Gajah Mungkur Reservoir and need urgent treatment to control the alien species.*
Keywords: alien species, detection, threat, reservoir.

INTRODUCTION
Gajah Mungkur is one of the vastest (90km^2) artificial lake in Java Island (Whitten, Soeriaatmadja, & Afiff, 1996). This reservoir is one of the headwaters of Bengawan Solo River, the longest river on Java Island (Utami & Trilaksana, 2015). This reservoir functions as a provider of clean water, flood mitigation control, and provide mainly the fishery products in the province of Central Java. Various non-indigenous fish species Sutchi catfish *Pangasianodon hypophthalmus* and Tilapia *Oreochromis niloticus* deliberately introduced in the Gajah Mungkur to take advantage (Riverine into Lacustrine) of ecological niches created after the construction of the dam is completed (Department of Fisheries Wonogiri, 2015; Utami & Trilaksana, 2015).
In addition to the introduction, the development of technology facilitates the spread of alien species as a demand of ornamental fish and various other tourist activities such as recreational fishing (Rahardjo, 2011. The distribution of alien fish species tends to be difficult to find and are often detected when it has become invasive. Alien fish species could become invasive and lead to the extinction of native species and ecosystem disturbance (Grabowska & Witkowski, 2010). Distribution through human activities allows alien species to spread easily. Early detection of alien fish species provides information about the types and existence of alien fish species (Koehn & MacKenzie, 2004; Leunda, 2010). The availability of information about potential impacts and the existence of alien fish species makes it possible to understand the worst possible of an alien fish species impact and as the basis for management of alien fish species in Gajah Mungkur Reservoir.

METHODS
The Collection of data conducted in July 2015 - August 2015 at Gajah Mungkur Reservoir (**Figure 1**). The station set intentionally at seven locations by considering human activity and floating aquaculture cages in the Gajah Mungkur Reservoir. A collection of data included direct observation and the angler's catch.
Direct observation conducted with 4 hours fishing effort for each sampling in seven locations. Sampling method conducted with two (2) modified *net trap* and two (2) *modified hooks & line* for each sampling. Specification of the modified *net trap* is using 2-5cm mesh size and for the modified *hook & line* is using five (5) hooks size #12 (IGFA standart) and one (1) hook size #5 (IGFA standart). The fish identified based on (Kottelat, Whitten, Kartikasari, & Wirjoatmodjo, 1993) and justified with present taxonomic at *fishbase.org*. Each sample of fish species fixed in 90% alcohol.

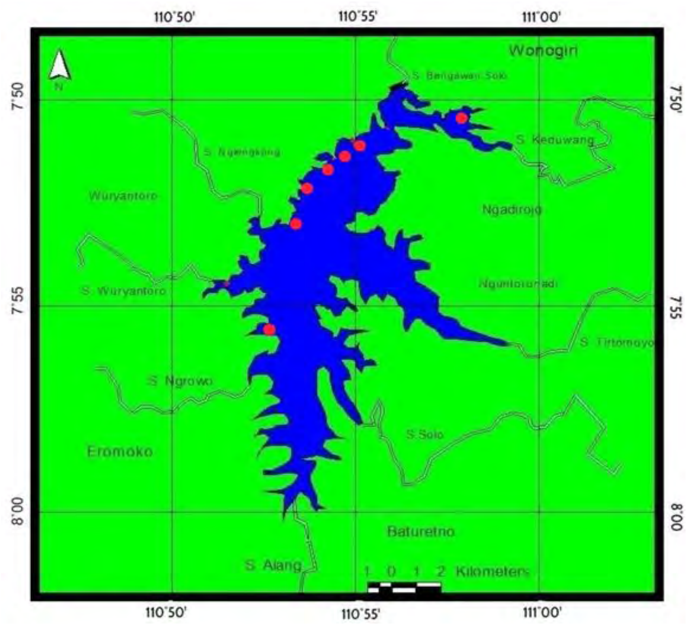

Figure 1. Sampling Sites at Gajah Mungkur Reservoir
Source : Private Maps

RESULTS AND DISCUSSIONS

The community of fish in the Gajah Mungkur reservoir commonly by freshwater fish that was once a community of fish in the Bengawan Solo River. Establishment of the reservoir resulted in a transformation of the type of waters (riverine) turned into a type of artificial lake waters (lacustrine). Some stream-river fish (Stream catfish, *Acrochordonichthys* sp.; *Glyptothorax* sp.) tend to be difficult to find because of the modification of types waters (Adjie, 2009; Sriwidodo, Budiharjo, & Sugiyarto, 2013). The composition of the fish community structure and the list of fish in the Gajah Mungkur can more clearly in the **Table. 1**. The collection of data showed five (5) species of fish alien species, Tilapia *Oreochromis niloticus*, Catfish Sutchi *Pangasianodon hypophthalmu*s, Amazon Sailfin Catfish *Pterygoplichthys pardalis*, African Catfish *Clarias gariepinus*, and Carp *Cyprinus carpio*. The catches dominated by Tilapia which almost found throughout the sampling locations. This shows the introduction carried out in 1981 was a success. Tilapia were recorded in some previous studies (Purnomo, 2000; Adjie, 2009; Sriwidodo, Budiharjo, & Sugiyarto, 2013) indicate that these fish are able to survive until today. It tends to be the same with the *Pangasianodon hypophthalmu*s. This fish also deliberately introduced in 2002 and is still found in some previous studies (Purnomo, 2000; Adjie, 2009) found in this study.

Pterygoplichthys pardalis suspected accidentally released in Gajah Mungkur Reservoir. This fish found only in location 1 and never recorded in the list of introduced fish in Wonogiri District Fisheries Office. *Clarias gariepinus* were found in two locations (2 & 6) and suspected released inadvertently from aquaculture ponds (interview). *Cyprinus carpio* ecorded in the list of introduced fish in Wonogiri District Fisheries office, but in a previous research by other author (Purnomo, 2000; Adjie, 2009; Sriwidodo, Budiharjo, & Sugiyarto, 2013) never recorded and only one individual was found in this sampling. Based on Regulation of Minister of Maritime Affairs and Fisheries Number 41 The Year 2014, *Pterygoplichthys pardalis* is a forbidden species to enter the territory of Indonesia.

Tabel 1. List of species and location of fishes at Gajah Mungkur Reservoir

No	Scientific Name	Family	Location							Total
			1	2	3	4	5	6	7	
1	*Barbonymus balleroides*	Cyprinidae	66	2		36	5	25	15	149
2	*Barbonymus gonionotus*	Cyprinidae	8	2		5		2		17
3	*Channa striata*	Channidae					1			1
4	*Clarias gariepinus**	Clariidae		1				3		4
5	*Cyprinus carpio**	Cyprinidae	1							1
6	*Hamibagrus nemurus*	Bagridae	16	1		4		3	2	26
7	*Hampala macrolepidota*	Cyprinidae	3				1			4
8	*Pterygoplichthys pardalis**	Loricariidae	1							1
9	*Labiobarbus leptocheilus*	Cyprinidae	30	14		11	2	2		59
10	*Mystacoleucus marginatus*	Cyprinidae	2	4					4	10
11	*Mystus singaringan*	Bagridae	9		8	6		2		25
12	*Mystus nigriceps*	Bagridae	9			4		2	1	16
13	*Nemacheillus* sp.	Balitoridae		1						1
14	*Oreochromis niloticus**	Cichlidae	170	10		120	5	52	25	382
15	*Osteochilus vittatus*	Cyprinidae	6	1						7
16	*Oxyeleotris marmorata*	Gobiidae		2		1				3
17	*Pangasianodon hypophthalmus**	Pangasiidae	13		3	1	2			19
18	*Rasbora argyrotaenia*	Cyprinidae	3							3
19	*Trichopodus trichopterus*	Osphronomidae	7							7
Total	19	10	344	38	11	188	16	91	47	735

Asteriks (*) indicate the alien fish species at Gajah Mungkur Reservoir.

CONCLUSIONS

Observed five alien species, Tilapia *Oreochromis niloticus*, Sutchi Catfish *Pangasianodon hypophthalmus,* Amazon Sailfin Catfish *Pterygoplichthys pardalis,* African Catfish *Clarias gariepinus,* and Carp *Cyprinus carpio. Pterygoplichthys pardalis* is a forbidden species to enter the territory of Indonesia based on the Regulation of Minister of Maritime Affairs and Fisheries Number 41 The Year 2014.

ACKNOWLEDGEMENT

This research is a part of preliminary study of potential impacts of alien fish species at Gajah Mungkur Reservoir, Wonogiri. Participation at World Lake Conference funded by the Bogor Agricultural University and supported by the Wonogiri District Governance.

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FECUNDITY OF THREE SPOT GOURAMI (*Trichopodus trichopterus* PALLAS) IN LAKE LANAO, LANAO DEL SUR

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ABSTRACT

The study aimed to assess the fecundity of T. trichopterus and determine its relationship to body length, body weight, egg diameter, and gonadosomatic index (GSI). A total of fifty-five (55) samples (24 males and 31 females) of non-native three spot gourami (T. trichopterus) were collected from Lake Lanao, Lanao del Sur in February 2016. The collection represents the first documentation of this species in Wato, Lanao del Sur. The correlation coefficient analysis of each parameter of the said species was obtained through Pearson-Product moment correlation. Result showed that there was a very high positive and significant correlation between body length and body weight in male (r = 0.967, P = 0.01) and female (r = 0.952, P = 0.01) T. trichopterus. The fecundity showed a high positive and significant relationship with both body length (r = 0.857, P = 0.01) and body weight (r = 0.939, P = 0.01). Egg diameter showed low positive and no significant relationship with body length (r = 0.344, P = 0.05), body weight (r = 0.369, P = 0.05) and fecundity (r = 0.405, P = 0.05). The fecundity showed a moderate positive correlation with GSI (r = 0.599, P = 0.01). The findings of this study showed that T. trichopterus has a relatively high fecundity compared to other studies.

Keywords: fecundity, Lake Lanao, *Trichopodus trichopterus.*

INTRODUCTION

Ancient lakes are usually home to endemic fish species flocks and contain the highest known density of fish species in the world (Goulden, 2001). Lake Lanao is one of the world's 15 ancient lakes, located in the province of Lanao del Sur, Philippines particularly in southern island of Mindanao (Ismail *et al.,* 2013). Jordan and Richardson (1965) stated that a large number of cyprinids species is found in the Philippine lakes and rivers. The endemic cyprinids of Lake Lanao consisted of five genera and 18 (or more) species. However, in the finding of Ismail *et al.* (2013) the poor dispersal capacity, low fecundity and small populations of many of the endemics make them vulnerable to extinction that at least two endemic cyprinids remain in Lake Lanao. The ecological health of Lake Lanao has been categorized in an alarming stage. However, no updated studies have been done. The often cited reasons were the unstable peace and order condition in the area (Naga, 2010). Ever since, the lake plays vital roles in socio-economic and religious lives of the Meranaos (lake dwellers). Lake Lanao serves as source of water for ablution and domestic use, as transport route and, most importantly, as source of freshwater fishes and shellfishes for local consumption (Rosaragon, 2001).

According to a landing survey of Ismail *et al.* (2013) in the landing sites of Marawi City, Ganassi and Lumbatan, one of the 10 introduced species is the *Trichopodus trichopterus.* The survey indicated that there is a decline number of *T. trichopterus* since year 1963-2008. A market survey that was conducted which serves as basis for comparison of the lake's fisheries production showed an evident that all the endemic and introduced species in Lake Lanao are in a precarious situation (Rosagaron, 2001).

The objective of this study is to present the fecundity of one of the genus of the family Osphronemidae, the *T. trichopterus,* commonly known as the Three Spot Gourami. Rosagaron (2001) stated the introduction of *T. trichopterus* was brought into the Philippines in 1938 from Bangkok, Thailand and was later stocked into the lake. In the meantime, the future of the *T. trichopterus* in Lake Lanao is uncertain but there is hope that they will survive. The concerns for Lake Lanao are diverse and aimed at increasing fisheries production, utilization of the lake water for various purposes, and conservation/preservation of its commercial endemic finfishes and watershed (Rosagaron, 2001). Through understanding reproductive behavior, sex ratio, and fecundity of fishes is not only important for elucidating the basic biology of the fishes but it can also help in their management, conservation and aquaculture of fish species.

METHODS

Collection of Samples

Fifty-five (55) individuals of *T. trichopterus* from Wato, Lanao del Sur (**Fig.1**) were randomly collected using gill nets having mesh size of 3.5 cm with the help of local fisherman. The samples collected were identified based on the description found in www.fishbase.org (Froese and Pauly, 2007) and randomly assigned a specimen number without determining their sexes. The samples were carried using an ice box to the Biology Department's Research laboratory for the measurements of its length, weight, egg diameter and fecundity.

Figure 1. Map of Wato, Lanao del Sur, showing the location of Lake Lanao in the Philippines (Inset)

Measurement of the Specimen and Sex Determination

Body length of each specimen was obtained by measuring from its anterior tip of the snout to the tip of its caudal fin with the aid of transparent ruler having 0-150 mm scale. Body weight of each specimen was also obtained using digital weighing scale. Sexing of the sample was done by opening its abdomen through cutting with a pair of scissors, a pair of forceps and a scalpel to expose the gonads. The gonads of the male and female *T. trichpoterus* can be easily distinguished. The ripe ovaries are larger in size, yellowish in color and lobular in shape while the testes are smaller, whitish and elongated.

Fecundity Estimation

The fecundity of ripe gonads was estimated gravimetrically (Mirzaei *et al.*, 2013).The gonads were preserved in Gilson's fluid (17 ml Nitric acid, 4 ml Glacial Acetic acid, 20g Mercuric Chloride, 70 ml 95 % Ethanol, 900 ml Distilled water). Mercuric chloride was dissolved first before adding other ingredients. Three subsamples were taken from the anterior, middle and posterior parts of the ovary. Samples were weighed and average numbers of eggs in each subsample were directly counted. Actual counting of eggs was done by spreading the egg uniformly on a petri plate (10 cm diameter) and using a dissecting pointer together with the aid of magnifying glass to avoid error in continuous counting. The plate was divided into sixteen equal sized wedges. Eggs within each wedge were counted to estimate the total number of eggs.

The Absolute fecundity (F) and Relative fecundity (R) were obtained using the following equations (Mirzaei *et al.*, 2013): $F_1 = n_1 \times G/g_1$, $F_2 = n_2 \times G/g_2$, $F_3 = n_3 \times G/g_3$; $F = (F_1 + F_2 + F_3)/3$; where F= absolute fecundity, n= average number of eggs in each subsample, g= subsample weight (g), and G= Ovarian dry weight (g). Relative fecundity was calculated by the following equation: R =F/TW, where: R= relative fecundity, F= absolute fecundity, and TW= Total body weight (g).

Determination of Egg Diameter

In each female sample, a number of fifty (50) eggs were randomly chosen from the total number of eggs to determine the egg diameter. A compound microscope with a calibrated micrometer eyepiece was used in measuring egg diameter. The stage micrometer was laid over the hole of the microscope stage and was focused on the 10x objectives into place to get the calibration and estimate the diameter of the field of view.

Gonadosomatic Index

Gonadosomatic index (GSI) was determined by using the equation (Mirzaei *et al*., 2013): GSI =Weight of gonads/Body weight x 100.

Statistical Analysis

Pearson Product-moment correlation coefficient was used to measure the strength of the degree of linear relationship between two variables (i.e., fecundity-weight and fecundity-length), and denoted by r. That is, r measures the extent to which the points cluster about a straight line {(x, y); 1, 2,, n) in a random sample, one is able to draw certain conclusion concerning r.

Below is the formula that was used in computing correlation coefficient, r, where; n is the number of sample; x is the weight in gram of the sample, y is the length in mm of the sample.

$$r = \frac{n(\Sigma xy) - (\Sigma x)(\Sigma y)}{\sqrt{[n\Sigma x^2 - (\Sigma x)^2][n\Sigma y^2 - (\Sigma y)^2]}}$$

Interpretation of the correlation value followed the classification of Deauna (1982) as follows:
An r value of 0.00 indicates no correlation
An r from ± 0.01 to ± 0.30 indicates very little correlation
An r from ± 0.31 to ± 0.50 indicates low positive correlation
An r from ± 0.51 to ± 0.70 indicates a moderate positive correlation
An r from ± 0.71 to ± 0.90 indicates a high positive correlation
An r from ± 0.91 to ± 0.99 indicates very high positive correlation
An r value of 1.00 indicates perfect correlation
Statistical analyses of the data were carried out with SPSS software package by Dr. Sonny M. Magno, an expert statistician from Mindanao State University - Institute of Science Education – Science High School.

RESULTS AND DISCUSSION

Body Length - Body Weight Correlation of T. trichopterus

The body length and body weight of the twenty-four (24) male and thirty-one (31) female samples of *T. trichopterus* ranged from 58 mm to 115 mm and 3.01 to 19.97 g respectively. The largest fish recorded was from the male group having a length of 115 mm long weighing 19.97 g. The smallest fish recorded was from the female group having a length of 58 mm long weighing 3.18 g. Figure 2 shows the result of length-weight correlation analysis. The correlation coefficient for males was 0.967. There was a very high positive relationship that was significant at 0.01 level. This suggests that as the length increases there is an increase in weight. Table 1 shows the body lengths (TL) in millimeters with corresponding weights for male and female samples.

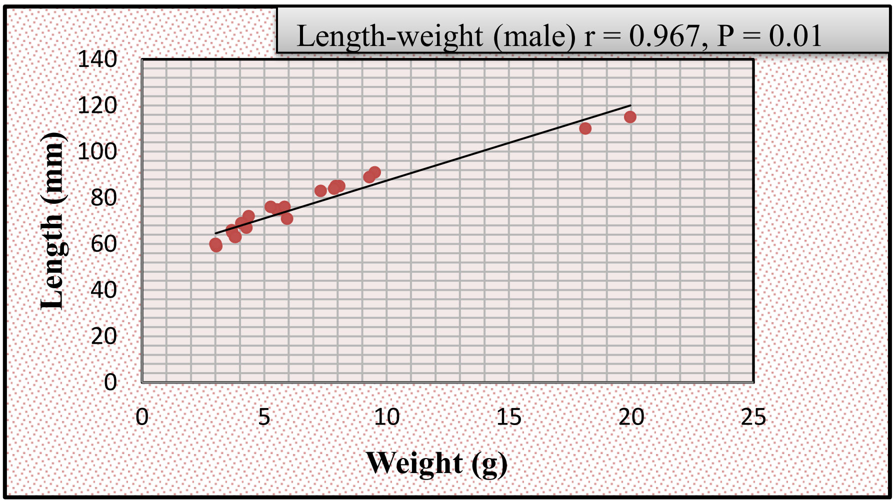

Figure 2. A scatter chart showing the body length (TL) - body weight relationship of male *T. trichopterus*

Table 1. Data of female *T. trichopterus* with its corresponding body length, body weight, egg diameter, absolute fecundity, relative fecundity and gonadosomatic index (GSI)

Specimen No.	Total Length (mm)	Body Weight (g)	Egg Diameter (mm)	Absolute fecundity (F)	Relative Fecundity (R)	GSI (%)
3	96	13.001	0.695	6179.40	47525	7.39
5	90	9.564	0.700	4476.13	46826	7.44
31	90	9.673	0.646	4110.56	42531	7.04
34	90	10.162	0.650	4917.32	48423	7.58
32	87	8.346	0.638	4028.08	48324	6.84
37	87	8.317	0.648	4069.37	49020	7.11
53	86	8.019	0.569	3627.41	45330	6.49
6	84	8.555	0.705	4187.74	49021	8.10
35	84	8.128	0.653	3696.69	45529	6.65
36	84	7.791	0.644	3596.01	46227	6.29
33	81	6.722	0.657	3317.02	49419	5.95
10	79	6.801	0.656	4137.15	60814	6.60
11	79	6.761	0.621	3485.01	51618	6.21
13	76	5.612	0.627	3156.52	56317	6.77
39	75	7.241	0.657	3327.22	46028	5.66
41	74	5.732	0.629	3481.81	60813	8.03
48	74	7.211	0.623	3486.31	48423	6.52
19	71	5.222	0.663	3128.52	59915	6.70
42	71	5.172	0.627	3067.12	59316	6.38
17	70	4.182	0.602	2928.03	7019	5.74
20	70	3.983	0.667	2859.13	7186	5.03
28	70	4.322	0.654	2977.82	68410	6.48
27	69	4.242	0.616	2980.72	7038	6.37
22	68	3.723	0.668	2749.93	7405	4.84
44	68	4.812	0.634	3040.22	63212	6.24
45	68	4.312	0.698	3053.72	7087	6.73
55	66	4.163	0.661	2888.03	69411	5.05
23	63	3.443	0.574	2860.73	8322	4.07
50	62	3.253	0.604	2623.83	8073	3.69
49	59	3.963	0.682	3071.82	7764	7.83
52	58	3.183	0.545	2835.73	892	3.15

The correlation coefficient *r* of 0.952 obtained for the females **(Fig.3 and Table 1)** indicates a very high and significant positive relationship between body length and body weight. This means that there is a corresponding increase of length as the weight increases.

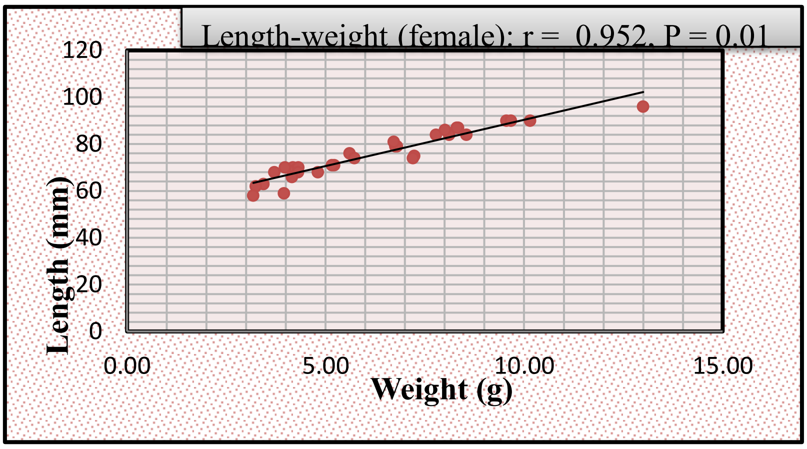

Figure 3. A scatter chart showing the body length (TL) - body weight relationship of female *T. trichopterus*

Fecundity - Body Length and Body Weight Relationship

Thirty-one female samples of *T. trichopterus* were enumerated for the study of fecundity and they were found to range between 2623.8 to 6179.4 ova. The lowest count was from the sample, having a length of 58 mm and weight of 3.18 g; while the highest was from sample having a length of 96 mm and weight of 13.00 g (**Table1**). Fecundity and body length was found to have a high positive and significant correlation (r = 0.857) at 0.01 level (**Fig.4**). This means that as the body length increases, the fecundity of the species is more likely to increase.

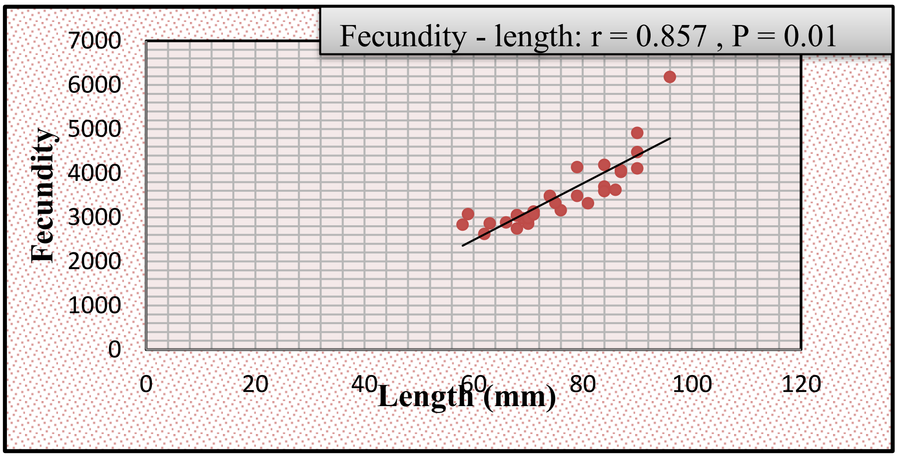

Figure 4. A scatter chart showing the fecundity - body length (TL) relationship of female *T. trichopterus*

Fecundity and body weight was found to have a very high positive and significant correlation (r = 0. 939) at 0.01 level (**Fig.5** and **Table 1**).

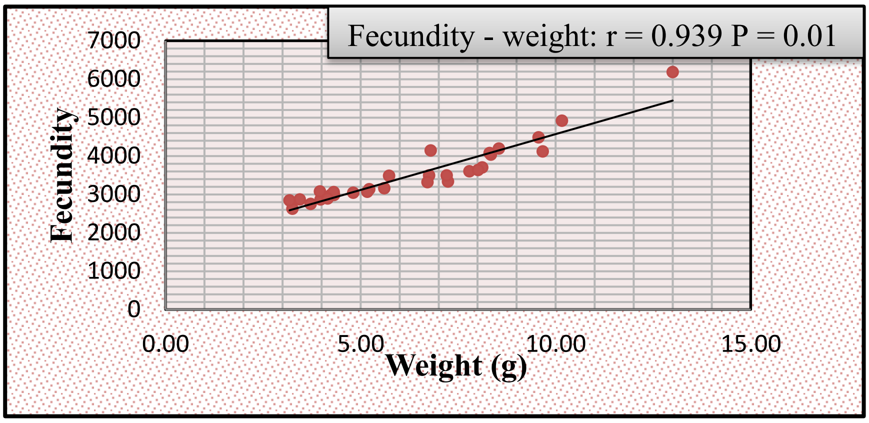

Figure 5. A scatter chart showing the fecundity - body weight relationship of female *T. trichopterus*

Egg Diameter - Body Length, Body Weight and Fecundity Relationship

From each of the thirty-one samples, fifty ova were randomly taken from each subsample. The diameter of a total of 2200 ova was measured using the calibrated micrometer. The diameter of the ova (**Table1**) ranged from 0.5450 mm to 0.7046 mm with a mean of 0.6424 and standard deviation of 0.3788.

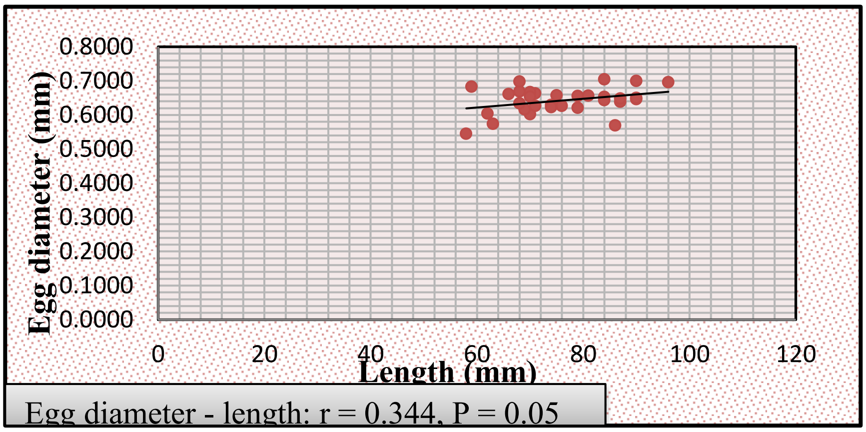

Figure 6. A scatter chart showing the egg diameter - body length (TL) relationship of female *T. trichopterus*

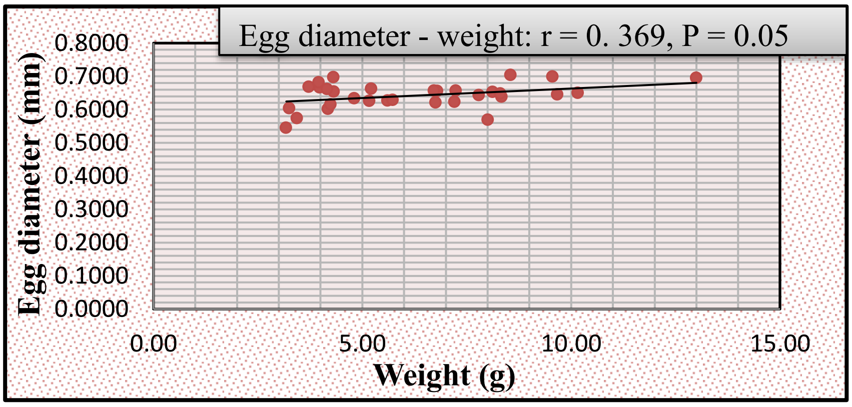

Figure 7. A scatter chart showing the egg diameter - body weight relationship of female *T. trichopterus*

The egg diameter of female *T. trichopterus* had a low and no significant correlation with body weight and body length **(Fig.6 & 7**). The results indicate that body length and body weight do not influence the egg diameter. The result also shows that there is a low positive and no significant (r = 0.405, P = 0.05) correlation between egg diameter and fecundity (**Fig.8**). This implies that fecundity does not influence egg diameter.

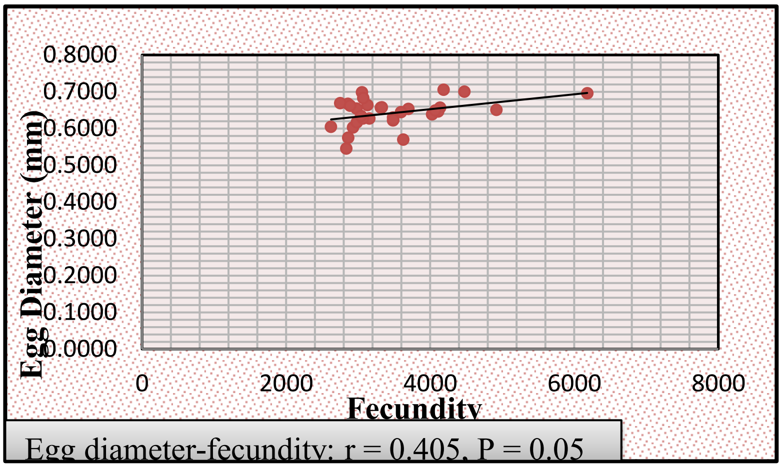

Figure 8. A scatter chart graph showing the egg diameter - fecundity relationship of female *T. trichopterus*

The results show that correlation between the egg diameter and three parameters are very weak. According to Sangcaan (2014), this simply implies that there is a little relationship which might be due to other variable such as environmental factors aside from the fecundity, length and weight which are affecting the diameter of the egg.

Degani (2001) stated that the habitats affected by seasonal rains influence the standing water where the fish breed. There is no detailed description of conditions in natural habitats; however, extensive study has been made regarding the adaptation to growth and reproduction under artificial conditions. Bindu *et al*. (2014) concludes that changes in salinity and conductivity levels from underground water affects hormone control reproduction and is in agreement with what was found regarding the hormone most involved in the sexual behavior of three spot gourami males.

T. trichopterus is a tropical fish and multiple spawner (Degani, 1990). The sexual behavior of *T. trichopterus* is a very important factor in preparing the female for spawning. During courtship and nest building, the ovary develops sensitivity to hormones, both growth hormone and steroid (Degani, 1991).

Fecundity - GSI Relationship

The weight gonads of each fish sample was divided by its body weight then multiplied by 100 to obtain the GSI. In this study, the GSI recorded (**Table1**) for females ranged from 3.15 to 8.10 with a mean of 0.629. The fecundity has a mean of 3494.9748 and standard deviation of 752.66. The value of *r* between the fecundity and GSI which was 0.599 indicated that there is a moderate positive and significant correlation (**Fig.9**). This means that as fecundity increases, GSI tends to increase.

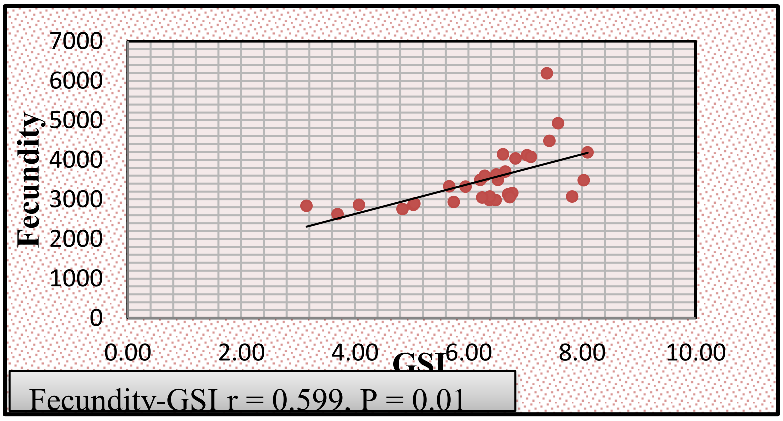

Figure 9. A scatter chart showing the fecundity - GSI relationship of female *T. trichopterus*

Absolute fecundity is the number of ripe eggs produced by a female in one spawning season or year and relative fecundity is the number of eggs produced in a season per unit somatic weight of the fish (i.e., eggs/gram), and is useful if it is shown that the fecundity of a fish is proportional to its weight, which is not uncommon. Bindu *et al.* (2014), stated that there was not much variation in the behavior, spawning and larval rearing of blue and gold populations of *T. trichopterus.* They are easy to breed. Experiments by Pollak *et al.* (1981) and personal experience suggests that multiple mating can take place. Egg production in *T. trichopterus* is prodigious and probably does not severely limit the frequency of mating. Both males and females are clearly capable of mating with as little as 24 hours separating successive spawning. *T. trichopterus* is a tropical fish that exists in a habitat having a relatively constant temperature range in this habitat. This fish reproduces all year round in the 23°C - 31°C temperature range. In this habitat, water is highly affected by rain (Degani & Levy, 2013). In the study of Bindu *et al.* (2014), spawning fecundity of *T. trichopterus,* was higher after breeding and early development spawning occurred simultaneously and the male fertilized the eggs. The eggs were lighter and the male picked up those eggs that sink and those that have floated outside the nest in its mouth and placed into the nest.

Some of the complications of fecundity data are the relationship between the fecundity and (i) fertility (ii) frequency of spawning (iii) parental care (iv) egg size (v) population density and (vi) environmental factors (Bagenal, 1978). In addition, fish can exhibit atresia (oocyte degeneration) in response to poor nutritional state. Pollution increases the level of atresia and has been shown experimentally (Lawrence, 2013). Benjamin *et al.* (2010) stated that there is a negative impact of polluted area on the liver weights, fish size, and reproductive traits (gonadal weight and number of mature eggs, adjusted for fish size). The cyprinid fauna of Lake Lanao, Mindanao presents a widely acknowledged but controversial example of adaptive radiation. The declining fecundity of cyprinid species might be because of the increasing pollution and over exploitation by the people around the lake.

The result of this present study shows that *T. trichopterus* has a relatively high fecundity compared to the study of Pethiyagoda (1991) on the same species found in Sri Lanka with a relative fecundity of 300-400 up to 1000 and Richter (1988) also on the same species in Neptune City of United States with absolute fecundity of 1000-4000. Ecological factors affect the biological and the reproduction characteristics of fish population, and so these kinds of investigations should be carried out periodically.

The finding of this study is contradictory to the declining fecundity of Lake Lanao cyprinids. One possible reason is that *T. trichopterus* is known to be very tolerant of wide ranges of environmental conditions including varying pH, temperature and dissolved oxygen levels (Priest, 2002).

CONCLUSIONS

Based on the results, it can be concluded that as weight of *T. trichopterus* increases the length increases. As the body length and body weight increase, the fecundity of the species is likely to increase. Body length, body weight and fecundity do not influence the egg diameter. Fecundity is more or less directly proportional to GSI (gonadosomatic index). Finally, the fecundity of *T. trichopterus* collected in Wato, Lanao del Sur is relatively high compared to the study of (Pethiyagoda, 1991) and (Ritcher, 1988).

ACKNOWLEDGEMENT

We would like to thank and appreciate Dr. Cesar A. de la Seña and Dr. Sherwin S. Nacua for their excellent advice during the preparation of this study. Deep thanks also to the Mindanao State University, Biology Department, CNSM, for allowing us to use the fish laboratory room and materials for the study.

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GUT CONTENT ANALYSIS OF *Puntius tumba* TAKEN FROM SELECTED RIVERS OF LANAO DEL SUR, PHILIPPINES

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ABSTRACT

Gut content analysis of Puntius tumba, one of the two remaining endemic cyprinids in Lake Lanao, was carried out to gather additional information that could be used for any planned scheme to develop appropriate culture techniques for the prevention of the extinction of this fish. The guts from 60 samples of P. tumba taken from the river along Ramain, Saguiaran, and Marantao were examined and analyzed. With the use of stereomicroscope, macroscopic gut contents were identified. Data on gut contents were subjected to frequency of occurrence and were analyzed by points (volumetric) method. Costello's method was used to determine whether the fish species is a generalists or specialists. The body length and the gut length measurement were analyzed and plotted in Microsoft Excel to determine whether there is a correlation between the length measurements. Body length is plotted as the x values and the gut length as the y values. Macrophytes are found to be the most frequent gut contents consumed by P. tumba. The least in frequency of occurrence are bivalve juveniles. The gut contents with the highest volume percentage are macrophytes and the least are fine sand grains, bivalve juveniles, and detritus. Other food items found include gastropod fragments, bivalve fragments, and gastropod juveniles. Costello's method indicated that P. tumba is a generalist fish species. In addition, only a slight correlation was determined between gut length and body length of P. tumba.

Keywords: *Puntius tumba*, gut content analysis, endemic to Lake Lanao, Costello's method, generalist

INTRODUCTION

Puntius tumba is a species of cyprinid fish endemic to Mindanao, Philippines where it is found in Lake Lanao and associated water systems. This species can reach a length of 12.8 centimeters (5.0 in). Lake Lanao, as one of the ancient lakes of the world, is the deepest and second lake in the Philippines. It is located in the island of Mindanao in the province of Lanao del Sur. Based on historical surveys, most of the 18 endemic cyprinid species in Lake Lanao are now believed to be extinct. *Puntius lindog* and *Puntius tumba* are the only two endemic species recorded in 2008 (Ismael et al., 2014), accounting for 0.01 % and 0.04 %, respectively, of the total weight harvested. The rest are no longer seen in the Marawi City market today. Several significant historical fish market and landing surveys have been conducted in the region of Lake Lanao (Villaluz, 1966; Sanguila et al., 1975; Escudero et al., 1980; Escudero and Demoral, 1983; Escudero, 1994) showing an alarming decline in the number of endemic species and one of those species is *Puntius tumba*. The study of gut content analysis and feeding habits of fishes are a continuous exercise because it provides information for successful fisheries Management. With paucity of information on gut content analysis of *Puntius tumba,* this study is aimed to determine the gut content of *Puntius tumba* in Lake Lanao to be used for any planned scheme to develop appropriate culture techniques for the prevention of the extinction of this fish.

METHODS

Collection and Identification of Sample

Freshwater samples of *Puntius tumba* were taken from the rivers located in Ramain at 8˚0'4 N and 124°20'51 E, Marantao at 7°57'39 N and 124°11'56 E, and Saguiaran at 8°1'0 N and 124°13'51 E , using gillnets, traps and hooks. These three places are where *Puntius tumba* species are reported to occur and they are the best places to conduct the research. A series of collection or sampling was done from February 7 to 10, 2016. Twenty individuals of *Puntius tumb*a from each site were collected and then stored immediately inside an icebox prior to further examination.

The collected samples were brought to Biology Department of Mindanao State University for the identification and verification of the fish. The samples were identified based on meristic characteristics and other morphological features as indicated in Fish base and were further verified by Prof. Escudero, a retired professor from College of Fisheries, Mindanao State University-Marawi. Counting of the samples' scales for the meristic characteristics of the species was made possible with the expertise and aid of Dr. Alicante, professor from Biology Department College of Natural Sciences and Mathematics, Mindanao State University-Marawi.

Dissection and Preservation

The fish samples were washed first in flowing water carefully to remove any dirt on their bodies. They were then put in the tray and their lengths were measured. Each fish sample was dissected viscerally from mouth to anus to expose the internal organs. The whole process was done very carefully so as to ensure that the gut is intact and to prevent disintegration of the gut contents. The gut is a tubular structure beginning at the mouth and ending at the anus. After the careful dissection, the whole gut was preserved in petri dish containing 5% of buffered formalin solution so as to harden the soft wall of the gut.

Analysis and Identification of Gut Contents

After dissecting the alimentary system, different components of the stomachs were recorded. They were split open by a pair of scissors, blade, forceps, and scalpel and emptied in a petri dish for examination. The food items were identified, counted, scaled, and enumerated. Each food item was scaled from 0 to 16 by points as described in the study of Zacharia (2004). Contents were placed in vials and transferred to a slide for examination and observation. The grouping was based on the information obtained in Fish base. After identifying the contents, they were placed again in vials for storage and future use.

Data Analysis

Data on gut contents were subjected to frequency of occurrence analysis as described in the study of Agbabiaka (2012), Ahlbeck et al. (2012), Badamasi (2014), and Bob-manuel (2011) and were analyzed by points (volumetric) method (Zacharia, 2004).

The used formulas to get the frequency of occurrence and volume percentage are written below:

Points (Volumetric) method = $\frac{Number\ of\ points\ allocated\ to\ component\ \alpha}{Total\ points\ allocated\ to\ sub\ sample} x\ 100$

Frequency of the occurrence (FO) = $\frac{Total\ number\ of\ gut\ \ with\ a\ particular\ food\ item}{Total\ number\ of\ gut\ with\ food}\ x\ 100$

Costello's method

In determining whether the fish species is a generalists or specialists, Costello's method (Lima-Junior, 2001; Eya et al., 2011) was used. The method consists of a scatter plot of percentage volume values in the y axis and frequency of occurrence in the x axis. Points located near 1% of occurrence and 1% of volume showed that the predator consumed different preys in low quantity. On the other hand, points located near 100% of occurrence and 100% volume show that the predator is a specialist for a given prey. Hence, in this study the prey items in the diet of the fish species were plotted in a graph so as to determine whether the fish in this study is a generalists or specialists (Amundsen et al., 1996).

Gut and Body Length Correlation

The body length and the gut length measurement were analyzed and plotted in Microsoft EXCEL to determine whether there is a correlation between the two length measurements. Body length is plotted as the x values and gut length as the y values. There is a correlation if the coefficient R^2 is above 0.5 or nearing to 1.0 but if the coefficient R^2 is below 0.5; there is no correlation.

Documentation

Photo documentation was done throughout the research using a digital camera (Kodak EASYSHARE).

RESULTS AND DISCUSSIONS

Identification of the Gut Contents Found

The observed gut contents from the gut of *P. tumba* were grouped into eight (8) categories, namely: gastropod juveniles, gastropod fragments, bivalve juveniles, bivalve fragments, macrophytes, water insect appendages, and fine sand grains. The rest of the gut contents were classified as unidentified or detritus since most of the gut contents were nearly digested completely.

Frequency of Occurrence of the Gut Contents

The frequencies of occurrence of gut contents in the gut of *Puntius tumba* are shown in Table 1. The examination of the gut samples taken from Ramain showed that the most frequent gut contents were detritus and macrophytes, which formed 70% and 65%, respectively followed by bivalve fragments and gastropod fragments (45%), water insect appendages (40%), bivalve juveniles (30%), and fine sand grains (25%). The least frequent gut content with a value of 20% was recorded for gastropod juveniles.The result supports the findings of several workers who reported gut contents in cyprinids species. In the study of Petr (2000), he found out that cyprinids such as *Puntius tumba* thrive in the benthopelagic freshwater environment of lake such as Lake Lanao. Arimoro and Orogun (2010) found that detritus appear to be taken in automatically along with the food items associated with them, when the fish feeds on the bottom.

Table 1. The percentage frequency of occurrence of the contents found in the gut of 20 *P. tumba* samples taken from Ramain, Saguiaran, and Marantao.

GUT CONTENTS	RAMAIN No. of Gut containing the item	%	SAGUIARAN No. of Gut containing the item	%	MARANTAO No. of Gut containing the item	%
Animals						
Gastropod juveniles	4	20	1	5	5	25
Gastropod fragments	9	45	2	10	4	20
Bivalve juveniles	6	30	1	5	2	10
Bivalve fragments	9	45	2	10	4	20
Water insect appendages	8	40	4	20	2	10
Plants						
Macrophytes	13	65	10	50	17	85
Other materials						
Detritus	14	70	8	40	6	30
Fine sand grains	5	25	8	40	3	15

From Saguiaran, the most frequent gut contents were macrophytes with the value of 50% followed in rank by detritus and fine sand grains which have the same value of 40%, and water insect appendages (20%) . Next were bivalve fragments and gastropod fragments, which formed 10%, and with the value of 5%, both gastropod juveniles and bivalve juveniles were the least in frequency of occurrence.
From Marantao, the most frequent gut contents were macrophytes (85%), detritus (30%), and gastropod juveniles (25%). Next were gastropod fragments and bivalve fragments having the same value of 20% and fine sand grains (15%). The least in frequency of occurrence with a value of 10% were water insect appendages and bivalve juveniles.

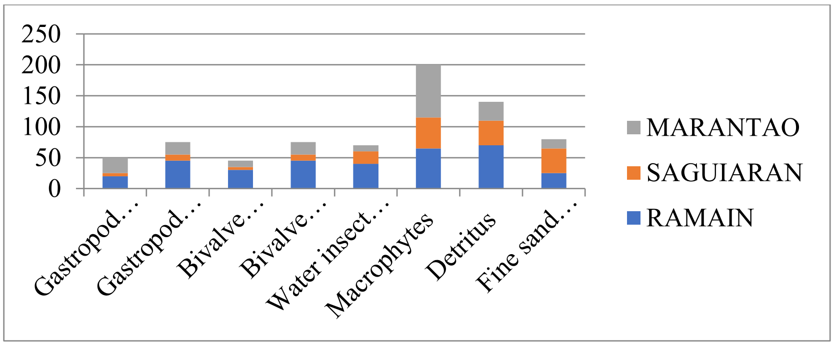

Figure 1. The total percentage composition of the contents found in the gut of *Puntius tumba* from the three selected areas.

Combining the results obtained from Ramain, Saguiran, and Marantao, the most frequent gut contents were macrophytes followed in rank by detritus, fine sand, gastropod fragments and bivalve fragments, water insect appendages, gastropod juveniles, and least was the bivalve juveniles as shown in **Figure 1**.
This result supported the study of Petr (2000) who found out that the reason why cyprinids frequently feed on macrophytes is because it is the most preferential fish habitat where they spawn and nest their eggs. Some cyprinids tend to thrive in the deeper limits of the littoral zone where they pick up the food items such as the gastropods and bivalve.
Point (Volumetric) Method
Results of the Point (Volumetric) Method of the 8 gut contents found in the gut of *P. tumba* from the 3 municipalities were shown in **Figures 2a, 2b, and 2c**.

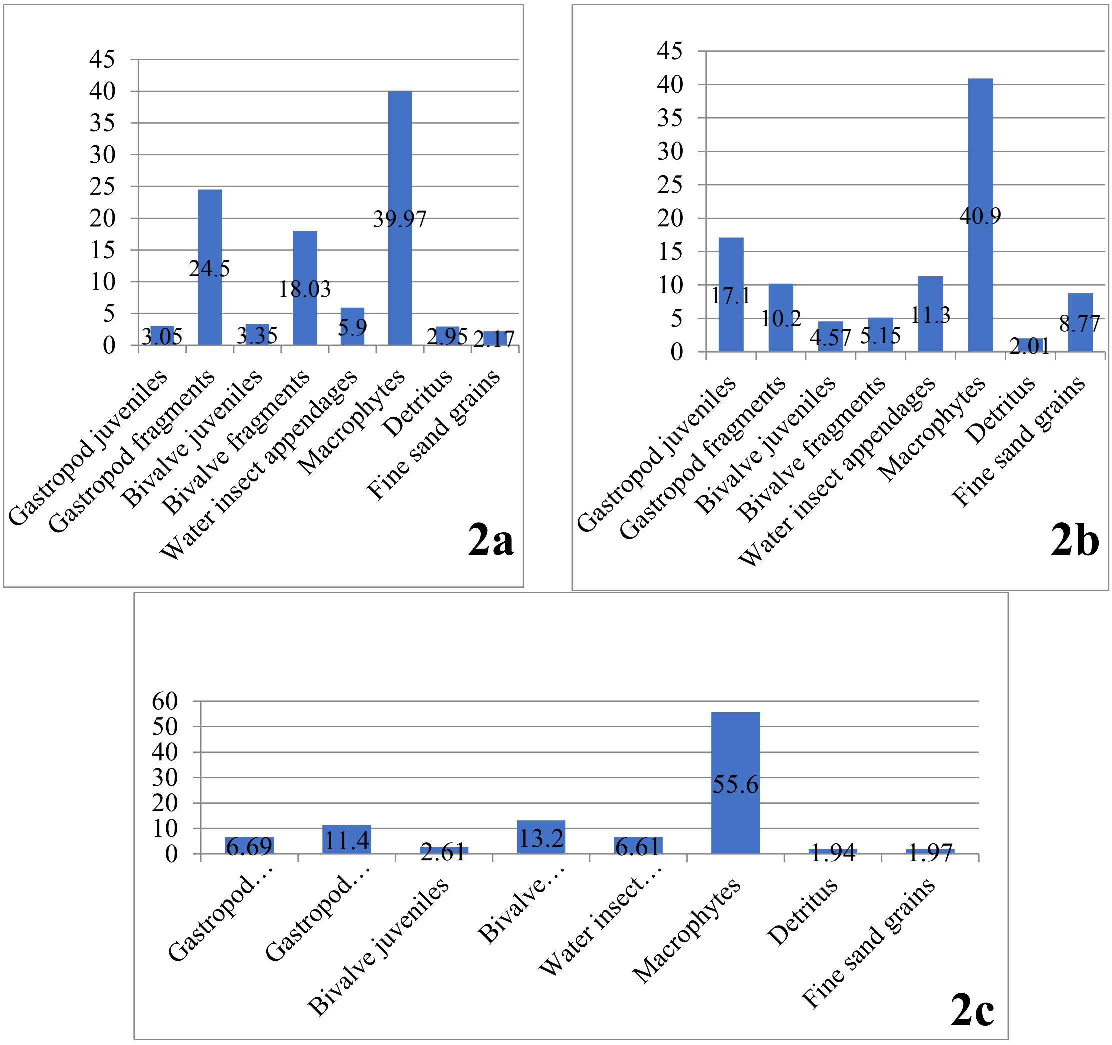

Figure 2. Volume percentage per content found in the gut of *P. tumba* collected from Ramain (2a), Saguiaran (2b) and Marantao (2c).

In Ramain (**Fig. 2a**), the most consumed gut contents were macrophytes (39.97%), gastropod fragments (24.58%), and bivalve fragments (18.03%). Next in rank were water insect appendages (5.90%), bivalve juveniles (3.35%), gastropod juveniles (3.05%), and detritus (2.95%). The least consumed gut content was fine sand grains with the value of 2.17%.

In Saguiaran (**Fig. 2b**), macrophytes and gastropod juvenile were the most consumed gut contents with the value of 40.9% and 17.1%, respectively. Bivalve fragments, bivalve juveniles, and detritus were the least consumed gut contents with the value of 5.15%, 4.57%, 2.01%, respectively.

In Marantao (**Fig. 2c**), the most consumed gut contents were macrophytes (55.6%), bivalve fragments (13.2%), and gastropod fragments (11.4%). Next in rank were gastropod juveniles (6.69%), water insect appendages (6.61%), bivalve juveniles (2.61%), and fine sand grains (1.97%). The least in the list was detritus with a value of 1.94%. Lumping Figures **2a, 2b, and 2c**, macrophytes were the most consumed gut content found in the gut of *P. tumba* followed by gastropod fragments, bivalve fragments, and gastropod juveniles as illustrated in Figure 3. Water insect appendages, fine sand grains, bivalve juveniles, and detritus have the lowest percentage being recorded and observed in the gut of *P. tumba.* This result again is in concordance with the study of Petr (2000) who found out that macrophytes are the most abundant food source of cyprinids and they are benthopelagic species.

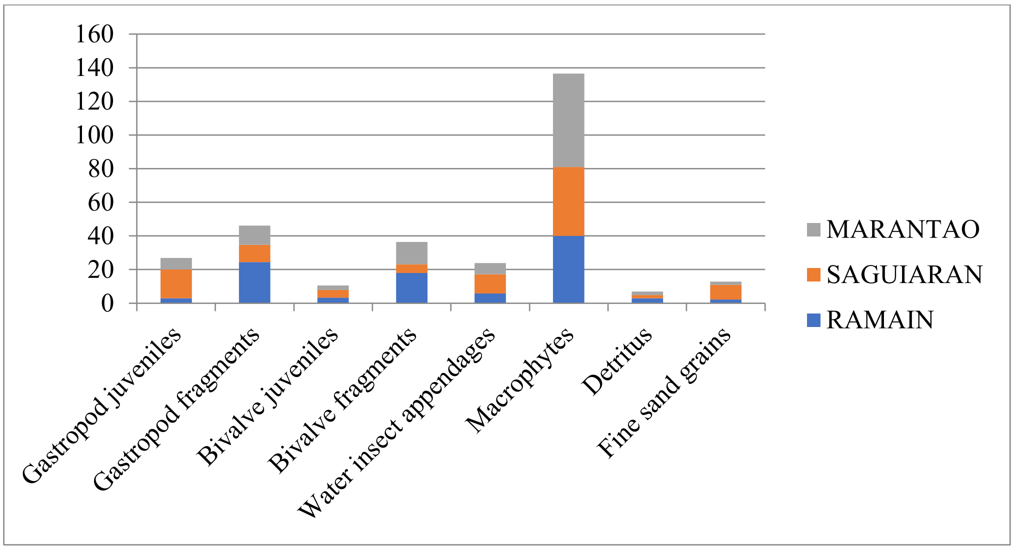

Figure 3. Combined volume percentage per content found in the gut of *P. tumba* collected from Ramain, Saguiaran, and Marantao

Costello's method

The Costello's method was used to determine whether *P. tumba* is a generalist or specialist. **Figures 4 a**, **b, and c** showed the scatter plot utilizing the frequency of occurrence which is the x-axis and volume of each food item as the y-axis.

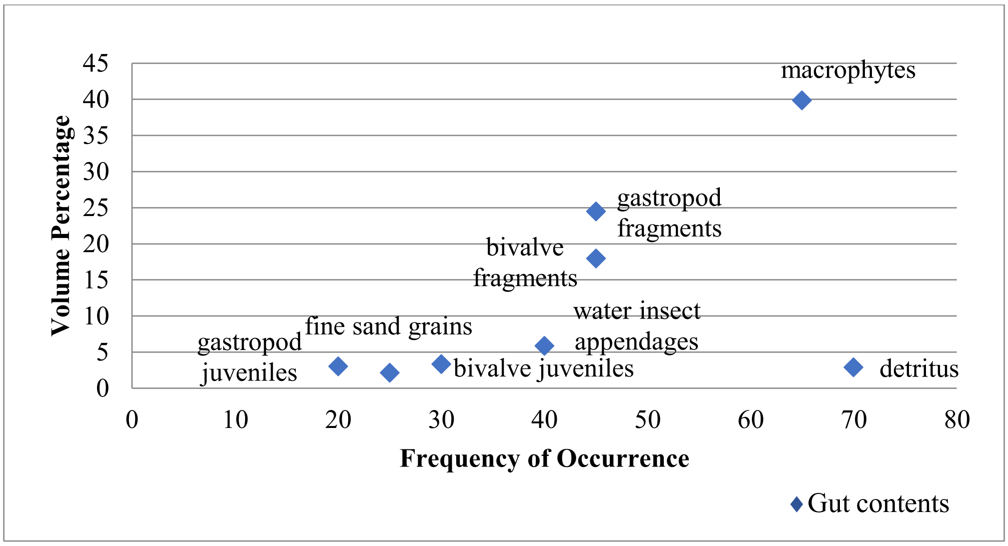

Figure 4a. A graphical representation of the contents found in the gut of *P. tumba* taken from Ramain based on Costello's method.

In Ramain (**Fig. 4a**), the points of gastropod fragments, bivalve fragments, water insect appendages, gastropod juveniles, bivalve juveniles, detritus, and fine sand grains were located below 35% and macrophytes were below 45% for volume percentage while only the points of detritus and macrophytes were plotted 70% and 65%, respectively for frequency of occurrence. Most of the gut contents had low quantity both in volume percentage and frequency of occurrence. Therefore, *P. tumba* is categorized as generalist based on Costello's method.

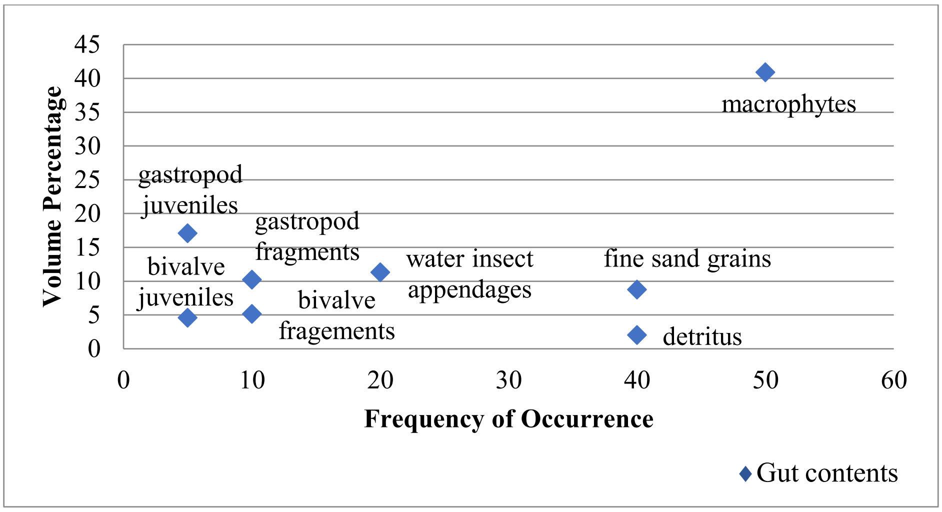

Figure 4b. A graphical representation of the contents found in the gut of *P. tumba* taken from Saguiaran based on Costello's method.

The result from Saguiaran (**Fig. 4b** above) showed that the points for macrophytes, gastropod juveniles, water insect appendages, gastropod fragments, fine sand grains, bivalve fragments, bivalve juveniles, and detritus were located below 45% for volume percentage while only the points of macrophytes was plotted 50% for frequency of occurrence. The result shows *P. tumba* is a generalist based on Costello'smethod.
In Marantao (**Fig. 4c**), the points of gastropod fragments, bivalve fragments, gastropod juveniles, water insect appendages, bivalve juveniles, fine sand grains, and detritus were plotted below 20% for volume percentage and only macrophytes was plotted above 80% of frequency of occurrence. The result suggests *P. tumba* is a generalist based on Costello's method.

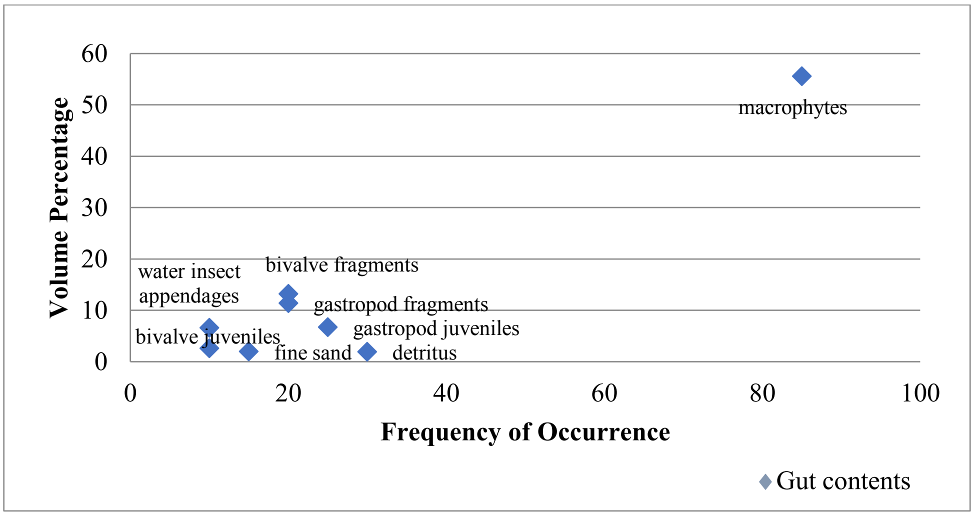

Figure 4c. A graphical representation of the contents found in the gut of *P. tumba* taken from Marantao based on Costello's method.

Gathering all the data obtained from three selected areas, the points of most of the gut contents of *Puntius tumba* were located below 35% of volume percentage and below 50% of frequency of occurrence. Since most of the gut contents had low quantity in terms of volume percentage and frequency of occurrence, *P. tumba* is classified as a generalist based on Costello's method.

Body length and gut length correlation
Figures 5a, b, and c showed the correlation between body length and gut length of *P. tumba* obtained from the three selected areas.
Sixty (60) samples were measured as to body length and gut length. Data collected for the body length from Ramain samples ranged from 92cm to 132cm with a gut length ranging from 95cm to 207cm. For the body length of data collected from Saguiaran ranged from 91cm to 134cm with a gut length ranging from 110cm to

213cm. Ranging from 96cm to 133cm was the body length for Marantao samples with a gut length of 104cm to 240cm.

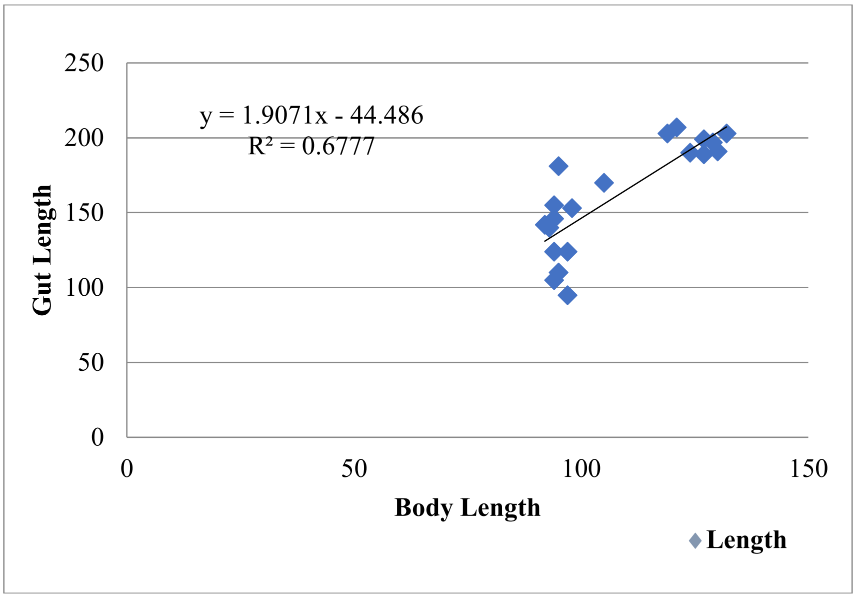

Figure 5a. Correlation between body length to gut length of *P. tumba* taken from Ramain

Figure 5a above showed the gut to body correlation in *P. tumba* taken from Ramain. The value of R^2 was 0.677 and it showed a slight correlation. The correlation equation generalization was Y= 1.9071x-44.486 where X is the body length and Y is the gut length.
Figure 5b showed the gut to body correlation in *P. tumba* taken from Saguiaran. The coefficient R^2 has the value of 0.774 and it showed a slight correlation. The correlation equation generalization was Y= 1.9275x-52.038 where X is the body length and Y is the gut length.

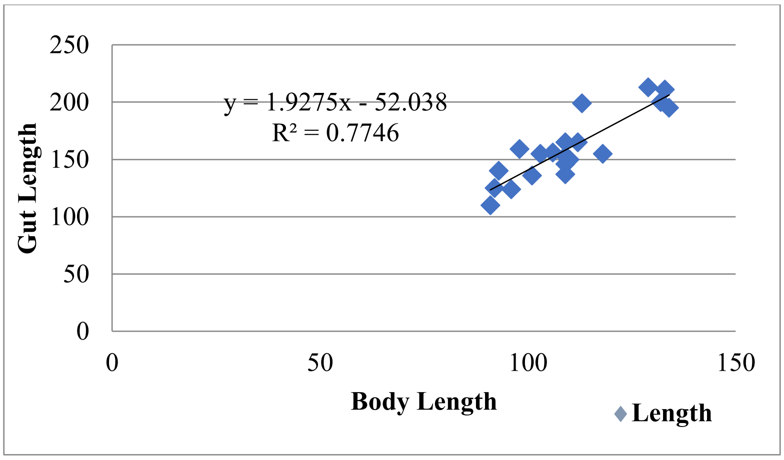

Figure 5b. Correlation between body length to gut length of *P. tumba* taken from Saguiaran

Figure 5c revealed a slight correlation between gut length and body length of *P. tumba* since the coefficient R^2 had the value of 0.505 where Y is equal to 2.290x-87.88.
Lumping all the obtained data, **Figure 6** below illustrated the gut to body length correlation in *P. tumba* obtained from the three selected areas. The plot showed a slight correlation since the value of R^2 was equal to 0.628. The body length Y was equal to 2.007x- 57.42. The relationship between body length and gut length for the samples taken from Ramain, Saguiaran, and Marantao was significant as illustrated in **Figure 7**. As the fish increases in size the gut length also increases in size.

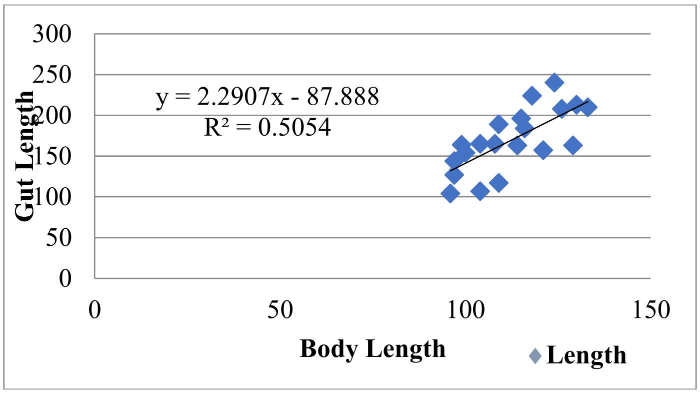

Figure 5c. Correlation between body length to gut length in *P. tumba* taken from Marantao

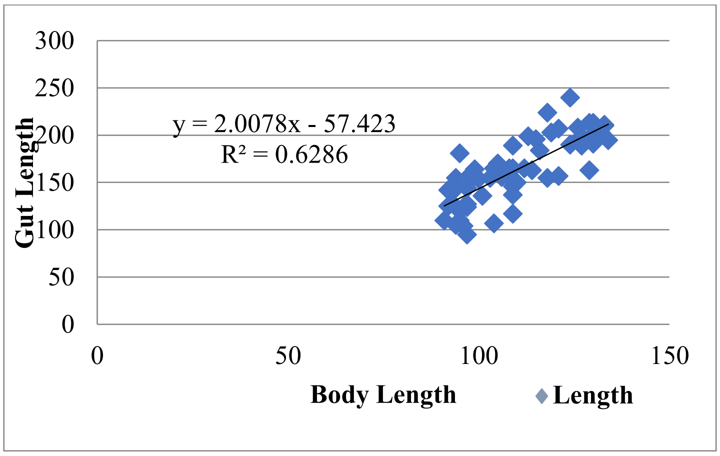

Figure 6. The total correlation between body lengths to gut lengths taken from three selected areas

Food Diet

Dissected guts of *Puntius tumba* samples taken from three selected areas namely, Ramain, Saguiaran, and Marantao, revealed that this fish feeds on both plants and animals such as gastropods, bivalves, and water insect appendages. Other materials such as detritus and fine sand grains were also found and observed in their gut. Apparently, these fine sand grains are accidentally swallowed by the fish while feeding on detritus and algae (Arimoro and Orogun, 2010). Their low percentage and occasional occurrence presumably point to this conclusion. Almost all of the food items obtained from the gut had undergone complete digestion. In this study *P. tumba* is proved to be omnivorous which feed on both plants and animals which is in agreement with the findings of Aba-Conding (1998), who reported *P. tumba* was an omnivore. As illustrated in **Figures 4a, b, and c** by Costello's method, *Puntius tumba* is a generalist since most of the gut contents were located below 35% of percentage volume and below 50% of frequency of occurrence. In general, generalist animals such as *P. tumba* appear to be more successful than specialists, as they can take advantage of a wider range of circumstances. *P. tumba* being generalist is probably the reason why until now it survives because it is not selective or choosy when it comes on the food it consumes. When food resources become scarce, it can divert to another food resources. The downsides of generalist according to Deus and Petrere-Junior (2003) are stress and competition — because they compete in crowded biological niches, generalists have to elbow other generalists out of the way to survive on a fixed amount of nutrients. The examination of the gut samples taken from Ramain showed that most frequent gut contents were detritus and macrophytes while gastropod juveniles were the least frequent. In terms of percentage volume, macrophytes were the most consumed gut contents and fine sand grains were the least consumed one. Results from Saguiaran revealed that macrophytes were the most frequent and consumed contents in the gut of *P. tumba* in terms of the frequency of occurrence and percentage volume. Gastropod juveniles appeared to be the least frequent content in terms of the frequency of occurrence while detritus were the least consumed one in terms of the percentage volume. A similar result was observed in Marantao where in terms of frequency of occurrence and percentage volume, macrophytes ranked as the first. The least was bivalve juveniles and water insect appendages for the frequency of occurrence while detritus were the least for the percentage volume. In general, collected *P. tumba* samples taken from three selected areas were observed and found to share almost the same food resources mainly on plants such as macrophytes, which is in line with the study by Petr (2000) who stated that the reason why most cyprinids frequently feed on macrophytes is because macrophytes use to be the most preferential fish habitat and they are abundant as food source. Body length and gut length for the *Puntius tumba* were notably the same in the three selected areas. There is a slight correlation between body length and gut length of *P. tumba*. As the fish increase in size, the gut length also increases.

CONCLUSIONS

The study was carried out to determine the gut content of *Puntius tumba* in three selected areas. The gut contents of *Puntius tumba* showed that they feed on a wide variety of food items ranging from animals and plants as well as detritus and fine sand grains, thus, it is omnivorous and a generalist.

Puntius tumba feeds on both plants and animals such as water insect appendages, gastropods, and bivalves. There is a positive slight correlation between the body length and gut length. As the fish grows, the gut length also increases.

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EFFECTS OF QUALITY AND QUANTITY OF WATER ON MACROINVERTEBRATES IN TEMPORARY STREAM AT HARIPHUNCHAI EDUCATION CENTRE, THAILAND

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ABSTRACT

A temporary stream that delivers water to a reservoir in Hariphunchai Education Centre, Lamphun Province, was subjected to study the effects of the quality and quantity of water on the macroinvertebrates from October 2015 to September 2016. Four study sites were selected and monitored. The study showed that the average flow of water discharge into the reservoir was 0.03 m^3/s. In November 2015, the water level in the stream began to decrease. The flow stopped towards the end of the month and became a small pool which dried out consequently. The stream began to flow again in late June 2016. The measurements of water qualities are as follow: pH ranged from 6.31 to 8.10, Dissolved Oxygen was 0.35–8.2 mg/L. Water temperatures ranged 22.0–37.0°C. Total Dissolved Solid was 62.0–312.0 mg/L. Conductivity was 117.0–576.0 µS/cm. Concentrations of NH_3, NO^-_3, and PO_4 in the water were under the Thailand standard for surface water quality. Macroinvertebrates found belonged to 11 orders and 33 families. The first study site was the most abundant in Chironomidae and Beatidae. In the second study site, Ceratopogonidae and Chironomidae were found as the dominant groups, while in the third study site, the most dominant taxa were Chironomidae in October 2016. But, in November 2016, this study site became dried out. The fourth study site showed that the most abundant family was Chironomidae. The changes in discharge for 10 months caused the stream to dry out especially in the downstream area. This caused many macroinvertebrate taxa to disappear when the stream became a pool. Chironomidae and Caratopogonidae were the only well adapted group to this condition. Finally, all aquatic macroinvertebrates disappeared when the stream completely dried.

Keywords: Reservoir, Temporary stream, Macroinvertebrates, Water Discharge, Hariphunchai

INTRODUCTION

Water is an important resource for establishment the new campus of Chiang Mai University in Lamphun province. The aquatic environmental information of water input is important for solving the water shortage in the new campus area. This research was about the aquatic ecosystems in the Hariphunchai Education Centre related to quality and quantity of stream flowing into the campus reservoir. There were several streams flowing into the reservoir, but in the dry season there was only one stream that continue to flow into the reservoir. These streams were temporary streams, which flowed during the flood season and stopped flowing during the dry season (McDonough *et al.*, 2011).

Temporary streams are channels that dry and stop flowing during some portion of the year. This type of stream is the interface between aquatic and terrestrial ecosystems. They are abundant, widely distributed, and play an important role for the organisms, and as a regulator of freshwater ecosystem (Comin and Williams,1994). Temporary stream imposes a special set of problems upon their inhabitants. The most obvious of these is the cycle of flood and drought conditions. In temporary streams, there are three phases (Williams and Hynes, 1976). The first phase is the period where the stream flows. The second is the pool phase where the flow has ceased and isolated pools remain. The third is the dry phase where the column disappeared to become a terrestrial ecosystem. These changes of phase can be expressed into the pattern and level of stream water discharge.

Discharge is the most critical flow-related variable when assessing habitat conditions for fish and benthic organisms in the streams with flows of up to 0.14 m^3/s, while velocity is more important in the streams and rivers with greater flows (Plafkin *et al.*, 1989). Measurement of discharge and stage is important in situations where water management is a priority concern. For example, state legislation in Florida required the South Florida Water Management District (SFWMD) to establish the minimum flows and levels for Lake Okeechobee (SFWMD, 2000). A basic step in planning of stream and riparian restoration is to obtain information on the hydrology of the project area (USEPA, 1993).

The purpose of biological monitoring is to continuously assess both water quality and quantity based on the presence of living organisms such as macroinvertebrates. The abundance and diversity of macroinvertebrates can indicate the overall stream quality (Karr and Chu, 1999). Macroinvertebrates include aquatic insects, crustaceans, and mollusks that live in various stream habitats and derive their oxygen from water (Rosenberg and Resh, 1993). These insects and crustaceans are impacted by all the stresses that occur in a stream environment, both man-made and natural (Nelson and Roline, 1996). The basic principle of the study on macroinvertebrates for biomonitoring is that some species are more sensitive to pollution and disturbance than the others. The species that are very sensitive to pollution will not be able to survive in degraded waters, while those which are tolerant to pollution will be the dominant and are usually found in the degraded aquatic ecosystems.

The reservoir in campus faces the problem of water shortage in the dry season. Thus, this study focuses on the physical, chemical, biological, and the changes of the amount of water in the streams that flow into the reservoir, including the changes in the diversity of macroinvertebrates in each season. The result of this study can be used as a database of aquatic ecosystem in campus that can be applied for the planning and management of the aquatic ecosystems of Hariphunchai Education Centre, Lamphun Province. Therefore, an appropriate management will produce a sustainable reservoir.

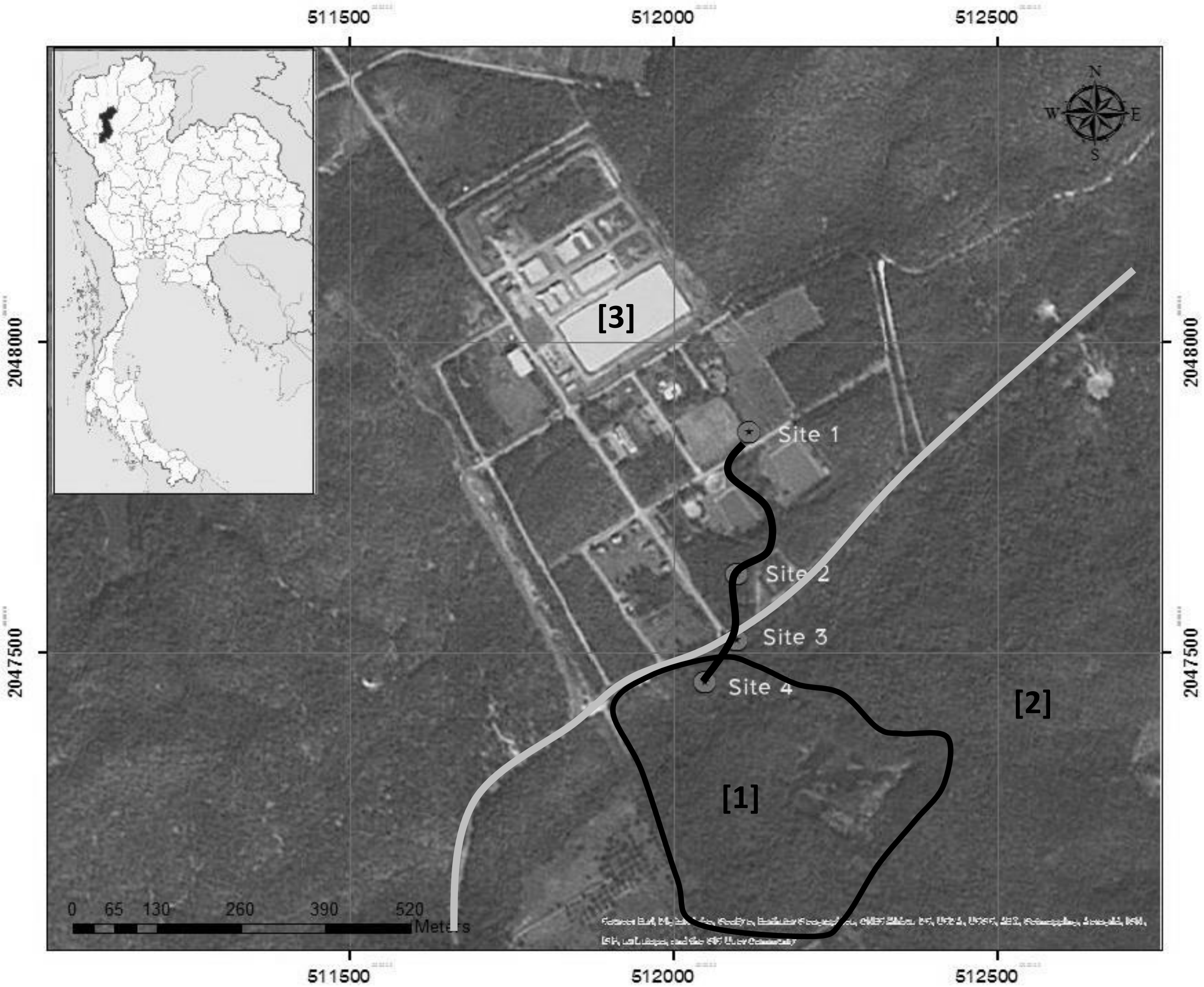

Figure 1. Location of the study sites on a temporary stream in Hariphuchai Education Centre,

Lamphun Province, Thailand. Site 1 (18°31'16.37"N, 99°6'53.25"E, Altitude 374 m), Site 2 (18°31'8.92"N, 99°6'52.63"E, Altitude 373 m), Site 3 (18°31'5.47"N, 99°6'52.60"E, Altitude 371 m), located in Lamphun Agriculture Extension and Development Centre[3], and Site 4 (18°31'3.26"N,99° 6'50.96"E, Altitude 370 m), located in the reservoir [1] of Hariphunchai Education Centre[2]. (Source: Google Map)

METHODS

The study was carried on a temporary stream in Lamphun Agriculture Extension and Development Centre for Sites 1, 2, and 3, and in Hariphunchai Education Centre, Lamphun Province for Site 4 (**Figure 1**). This stream has an irregular hydrological regime, with severe droughts in the dry period and floods in the rainy season. The stream was also exploited for agricultural irrigation. The wet phase or rainy period occurs from June to September. On the other hand, the rainfall amount decreases during the dry phase (late October to May). This event causes some part of stream to dry or becoming a series of isolated pools.

Macroinvertebrate communities along the stream were sampled monthly from October 2015 to September 2016 from all four sites using a bottom kick net (500 µm mesh). The samples were taken from an area of 3 m^2 in 5 minutes, included all possible microhabitats at each site. In some areas where large stones were present, the sample was taken after these were discarded. All macroinvertebrate samples were fixed in 70% ethyl alcohol, the samples were then sorted and identified to the lowest possible taxon (families and order) (McCafferty, 1981) and counted under a stereomicroscope in the laboratory.

Temperature, Conductivity (EC), Total Dissolved Solid (TDS), and pH were measured in the field using a portable multiparameter analyser (Consort C533). On each site, a 500-ml water sample was collected, filtered (Whatman Cat No 1001 090), and analysed in the laboratory for N-nitrate (Cadmium reduction method), Ortho-phosphate (ascorbic acid method), and Ammonium (Nesslerization technique) by spectrophotometer (HACH DR-2000). Using Azide Modification of Iodometric method the Dissolved Oxygen (DO) and Biochemical Oxygen Demand (BOD) were analysed (APHA, AWHA, WPCF, 1998)

The discharges of stream were calculated using velocity-area method. Discharge is computed as the product of the area and velocity. The measurement is made by subdividing a stream cross section into segments (sometimes referred to as partial areas, sections, subareas, verticals, stations, profiles, panels, or ensembles), and by measuring the depth and velocity vertically within each segment. The total discharge is the sum of the products of the partial areas of the stream cross section and their respective average velocities. This computation is classically expressed by the equation (Horner et al., 1994)

$$Q = \sum_{i=1}^{n} a_i \, v_i$$

Where Q: total discharge, (m^3/s)

a: cross-section area, (m^2), for the ith segment of the n segments into which the cross section is divided,

v: corresponding mean velocity, (m/s) of the flow normal to the ith segment, or vertical.

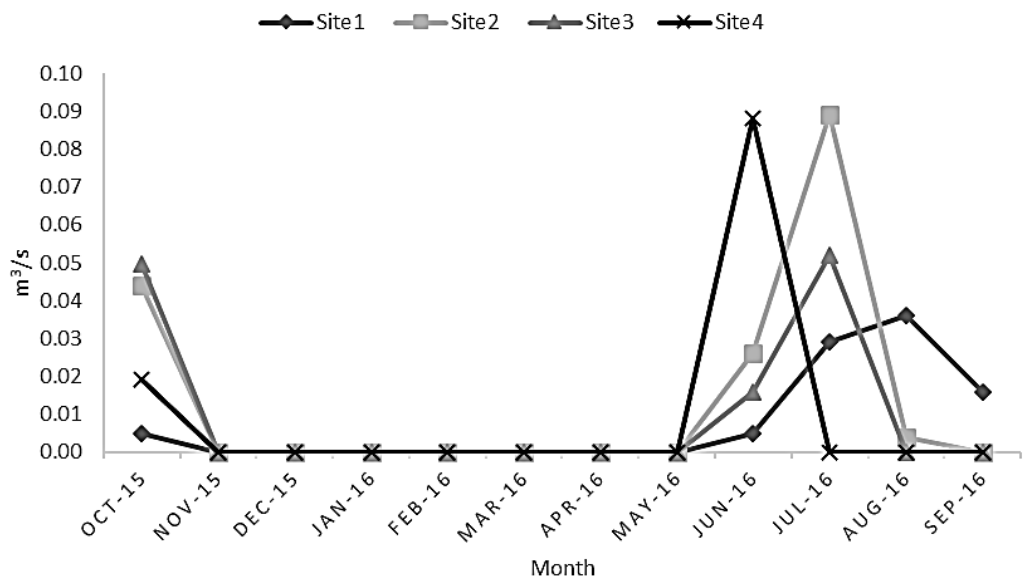

Figure 2. Amount of water discharge of temporary stream at each site

Table 1. Characteristics of stream water at each site and each month.

	Oct-15	Nov-15	Dec-15	Jan-16	Feb-16	Mar-16	Apr-16	May-16	Jun-16	Jul-16	Aug-16	Sep-16
Site 1	Lothic	Lenthic	Lenthic	Lenthic	Lenthic	Lenthic	Lenthic	Lenthic	Lothic	Lothic	Lothic	Lothic
Site 2	Lothic	Lenthic	Lenthic	Lenthic	Lenthic	Lenthic	Lenthic	Lenthic	Lothic	Lothic	Lothic	Lenthic
Site 3	Lothic	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Lothic	Lothic	Lenthic	Lenthic
Site 4	Lothic	Dry	Dry	Dry	Dry	Dry	Dry	Dry	Lothic	Lenthic	Lenthic	Lenthic

RESULTS AND DISCUSSIONS

The water qualities monitored were DO, BOD, pH, nitrate, ortho-phosphate, and ammonia. Their values were categorized as fairly good based on Thailand Standard for surface water, except DO. The average value of DO in Site 2 was the lowest due to its slow flow that sometimes it became still water (**Table 2**). This stream was classified as Type 4 **"**Fairly clean fresh surface water resource suitable for consumption, but requires special treatment before using" (National Environmental Board, 1992**).** The water discharge shown were of two periods: wet phase and dry phase. Wet phase starts in June which is the start of the rainy season in Thailand, during which the amount of water is abundant in the stream with strong current in all study sites. The average of water discharge flowing into the reservoir was approximately 0.03 m^3/s. In August, we were unable to measure the values of water discharge in the Sites 2, 3, and 4 because the stream changed from lotic to lentic ecosystem. In late September, the amount of water gradually decreased until mid-November, where the water flow stopped. That was the change to the dry phase that lasted from November to May (**Figure 2**).

Table 2. Physico-chemical characteristics of the study sites.

Site	Air temperature (°C)	Water temperature (°C)	TDS (mg/L)	Conductivity (µS/cm)	pH
S1	30.25 ± 0.62^{a}	28.69 ± 0.65^{ab}	167.86 ± 4.72^{a}	316.72 ± 8.96^{a}	7.38 ± 0.05^{b}
S2	29.46 ± 0.64^{a}	26.88 ± 0.46^{a}	238.00 ± 9.66^{b}	446.89 ± 17.79^{b}	6.84 ± 0.02^{a}
S3	29.00 ± 1.13^{a}	27.33 ± 0.69^{a}	176.60 ± 17.86^{a}	332.27 ± 33.50^{a}	6.98 ± 0.08^{a}
S4	28.60 ± 0.77^{a}	30.80 ± 0.82^{b}	181.33 ± 14.17^{a}	340.87 ± 26.48^{a}	7.31 ± 0.06^{b}

Site	DO (mg/L)	BOD (mg/L)	Nitrate (mg/L)	Ortho-phosphate (mg/L)	Ammonia (mg/L)
S1	5.8 ± 0.25^{c}	1.8 ± 0.14^{b}	0.83 ± 0.05^{a}	0.29 ± 0.04^{a}	0.30 ± 0.02^{a}
S2	2.3 ± 0.23^{a}	1.3 ± 0.11^{a}	0.90 ± 0.05^{a}	0.28 ± 0.02^{a}	0.42 ± 0.04^{a}
S3	3.9 ± 0.55^{b}	3.0 ± 0.11^{a}	1.03 ± 0.07^{a}	0.23 ± 0.03^{a}	0.35 ± 0.06^{a}
S4	5.0 ± 0.66^{bc}	4.0 ± 0.13^{a}	0.91 ± 0.05^{a}	0.29 ± 0.03^{a}	0.38 ± 0.06^{a}

*The mean difference is significant at the 0.05 level

A difference in the quality and quantity of water can cause the difference in the macroinvertebrate communities. In Site 1 Chironomidae and Beatidae were found to be the most abundant. In Site 2 Ceratopogonidae and Chironomidae were found to be the dominant groups, while Site 3showed that the most abundant taxa was Chironomidae. In Site 4, it was found that Chironomidae and Culicidae were the dominant groups (**Table 4**). In this temporary stream the Diptera (Chironomidae, Ceratopogonidae and Culicidae) were the dominant groups, while Odonata (Libellulidae and Gomphidae) and Ephemeroptera (Baetidae) were the second and the third dominant groups (**Table 4**). These three macroinvertebrate orders were tolerant groups, that can adapt to the discharge changes in the stream. Dipterans can adapt to survive in standing water, so the stream was a suitable habitat for these insects. For these macroinvertebrates, the samples S211 and S212 from Site 2 showed the highest Shannon's diversity and Evenness indexes (**Table 3**) This is due to the fact that a wetland is located behind this site, where the water gradually fills into Site 2 the entire period. So, almost a full year Site 2 has a pool where Diptera was found during sample collection (**Table 4**).

Table 3. Shannon's diversity and Evenness indexes of macroinvertebrates in each site and month. *S1 = Site 1, S2 = Site 2, S3 = Site 3, S4 = Site 4, 01 = January, 02 = February,03 = March, 04 = April, 05 = May, 06 = June, 07 = July,08 = August,09 = September,10 = October, 11 = November, 12 = December.

Sample	Diversity index	Evenness Index	Sample	Diversity index	Evenness index
S101	1.461	0.815	**S206**	1.568	0.806
S102	1.800	0.866	**S207**	0.243	0.221
S103	0.704	0.438	**S208**	0	0
S104	0.514	0.371	**S209**	0.600	0.546
S105	1.415	0.879	**S210**	0.750	0.466
S106	0.443	0.213	**S211**	1.703	0.775
S107	0.918	0.662	**S212**	1.730	0.832
S108	1.227	0.630	**S306**	0.067	0.096
S109	1.117	0.694	**S307**	1.146	0.64
S110	0.240	0.173	**S308**	1.416	0.645
S111	1.689	0.868	**S309**	1.352	0.615
S112	0.823	0.511	**S310**	1.315	0.548
S201	1.699	0.873	**S406**	0.736	0.531
S202	1.239	0.637	**S407**	1.172	0.509
S203	0.637	0.918	**S408**	1.076	0.601
S204	0.346	0.250	**S409**	1.583	0.884
S205	0.260	0.236	**S410**	1.222	0.759

Table 4 Proportion of number of individuals, taxa, and Shannon's diversity index in each site.

Family	Site 1	Site 2	Site 3	Site 4	Total
Athericidae	3	-	1	-	**4**
Atyidae	19	10	1	12	**42**
Baetidae	152	8	6	27	**193**
Caenidae	28	-	2	-	**30**
Caratopogonidae	1	112	6	-	**119**
Chironomidae	496	105	195	696	**1492**
Coenagrionidae	1	6	3	5	**15**
Corixidae	1	-	1	2	**4**
Culicidae	5	3	1	172	**181**
Cyclestheriidae	7	-	1	3	**11**
Dytiscidae	-	3	-	-	**3**
Filopaludina	1	-	-	-	**1**
Gerridae	11	7	4	3	**25**
Gomphidae	43	3	6	3	**55**
Halipidae	3	-	-	-	**3**
Helodidea	-	2	-	-	**2**
Hydrophilidae	-	2	3	28	**33**
Hydropsychidae	3	-	-	1	**4**
Isolapotamidae	9	-	-	-	**9**
Lampyridae	1	3	-	-	**4**
Libellulidae	14	28	27	21	**90**
Lymnaeidae	5	-	-	-	**5**
Naucoridae	-	-	-	13	**13**
Nepidae	2	-	-	-	**2**
Palaemonidae	19	1	-	8	**28**
Planorbidae	18	19	10	3	**50**
Protoneuridae	-	2	1	-	**3**
Stratiomyidae	-	-	7	4	**11**
Tabanidae	-	1	1	-	**2**
Thiaridae	13	49	1	-	**63**
Unknown1(Coleoptera)	-	3	-	6	**9**
Unknown2(Coleoptera)	-	1	-	-	**1**
Viviparidae	-	1	-	1	**2**

Total	**855**	**369**	**277**	**1008**	
Taxa number	**23**	**21**	**19**	**18**	**2509**
Diversity index	**1.583**	**2.004**	**1.293**	**1.156**	
Evenness index	**0.505**	**0.685**	**0.439**	**0.400**	

CONCLUSIONS
A temporary stream in Hariphunchai Education Centre flowed from June to October 2016 after which the stream became isolated pools that finally completely dried. The macroinvertebrates that survived in this condition were Diptera, Odonata, and Ephemeroptera. The quality of stream was not different among sites, except DO in Site 2 was different from the other sites. Sites 1 and 2 showed higher diversity than Sites 3 and 4, because the water in the upstream dried slower than in the downstream. The well adapted macroinvertebrate families in this stream were Chironomidae and Ceratopogonidae.

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THE COMPOSITION OF A BENTHIC MACROINVERTEBRATE COMMUNITY IN HANJALUTUNG OXBOW-LAKE: AN ANALYSIS

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ABSTRACT

Benthic macroinvertebrates play important role in the ecosystem of a lake, in the food chain system, nutrient cycle, and in the state of water quality. This preliminary research project was explored the composition of a benthic macroinvertebrate community in the Hanjalutung Oxbow-lake, in Central Kalimantan and the relationship to physical and chemical water quality parameters. The study was conducted in Hanjalutung, a shallow oxbow lake located in Palangkaraya, Central Kalimantan, Indonesia. In addition, we also conducted sampling at Rungan River, which is the source of input for Hanjalutung. A total of 14 taxa of benthic macroinvertebrates was determined during the research. The study showed that the values of Shannon-Wiener diversity index were ranged from low to moderate, the evenness index was in low to high, and the total abundance in each location ranged between 18-960 individuals/ m^2. The water quality showed in normal range and 60% of taxa were characterized by pH, DO, and TDS. Five others were characterized by temperature. It can be concluded from this research that Hanjalutung oxbow lake has lack of benthic macroinvertebrates both in diversity and abundance in dry season, which are composed by groups of Insects and Oligochaetes, and dominated by Insects groups. This research can be used as basic information on lake management.

Keywords: oxbow lake, hanjalutung, macroinvertebrate, kalimantan

INTRODUCTION

The oxbow lake is an ecosystem which has an important role as a habitat for biodiversity. These lakes are naturally formed when a meandering river is separated due to erosion. These horshoe-shaped lakes can be separated from the main water course either permanently or non-permanently. Glińska-Lewczuk (2009) divided the oxbow lake into three types based on morphology and connectivity aspects of hydrology: open lotic oxbow, semi-open semi-lotic, and closed-lentic oxbow lake, as can be seen in Figure 1 (Obolewski, 2011). Based on that type, Lake Hanjalutung has a simple form morphologically and is a *closed lentic type* in the dry season because it is disconnected to the river during the dry season. However, it changes to a *semi-open semi lotic,* or even an *open lotic* type during the wet season with inflows stream from Rungan River. Water from the river flows through one or both sides. From those conditions, the Hanjalutung oxbow lake can be categorized as a floodplain also. Some type of oxbow lakes can be seen in **Figure 1**. The pattern of dark on the figure 1 shows the habitat of macroinvertebrates in different types of oxbow lakes based on connectivity to the main river. Therefore, the distribution of macroinvertebrates in the habitat needs to understand.

Palangkaraya city has many oxbow lakes with a total lake area of ±13.63 km^2. One of them is Hanjalutung, in the Petuk Katimpun Village, Jekan Raya District, Province of Central Kalimantan (Local government unpublished report, 2009). There are two other oxbow lakes, namely, Lake Burung and Lake Rangas in Petuk Katimpun. Hanjalutung is temporarily disconnected from the main river, Rungan River, especially during the dry season. When it comes to the wet season, the water flows into the lake through one or both sides.

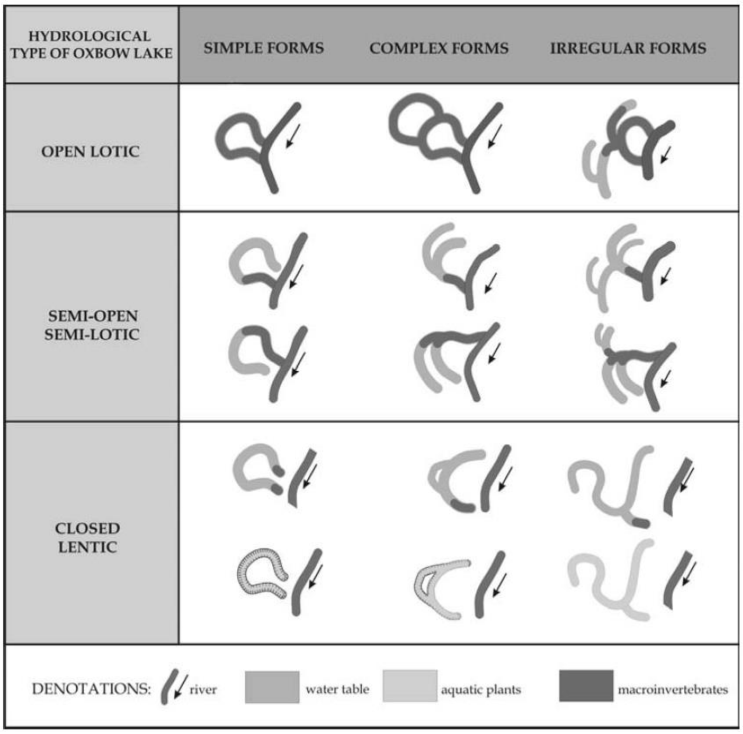

Figure 1. Oxbow lake types (Glińska-Lewczuk, 2009 in Obolewski, 2011)

Hanjalutung oxbow lake has important values ecologically and economical. For example, provides benefits for society in the fishery. Productivity of the fishery in Petuk Katimpun village ranged between 2-5 kgs daily, with daily average of production is 3,92 kgs and daily average of income gained of Rp 45129 (Susila, 2012).
Ecologically, the oxbow lake is a habitat for biodiversity, such as for benthic macroinvertebrates. These aquatic organisms are often used to study the condition of the freshwater ecosystem. They confer significant roles in the lake ecosystem, for example, as a part of the food chain system, and nutrient cycles, and they give an indication of the ecosystem and/or water quality (Yule and Sen, 2004). Benthic macroinvertebrates are one of food source for fish population; this community lives on the bottom, with the size ranging between 200 - 500 µm. They include both epifauna and infauna (Sudarso and Wardiatno, 2015; Odum, 1993; Rosernberg and Resh, 1993). Their community consists of group of worms, mollusks, crustaceans, and Insects/ Insects larvae. Informations or documentations of macroinvertebrates in the Oxbow Lake Hanjalutung in Palangkaraya are limited, therefore this preliminary research aims to explore the community and to investigate the water quality condition.

MATERIALS AND METHODS

This research project used a survey method. The survey was conducted in Hanjalutung oxbow lake, Palangkaraya, Central Kalimantan. The aim of this research was to explore macroinvertebrates along the lake so the location chosen was purposive. Five locations were chosen; four were on the inside and one on the outside of the lake (in the Rungan river near the inlet) (**Figure 2**). An oxbow lake shape is like a horseshoe or almost a U-shape. Due to the shape, two locations were chosen near the U-end-site of the lake (A and D). These were assumed to connected to the river during rainy season because of flooding. However, this research was conducted in the dry season in only one leg connected to the river. Two other locations were in the middle, near the curved-site (sites C and B).

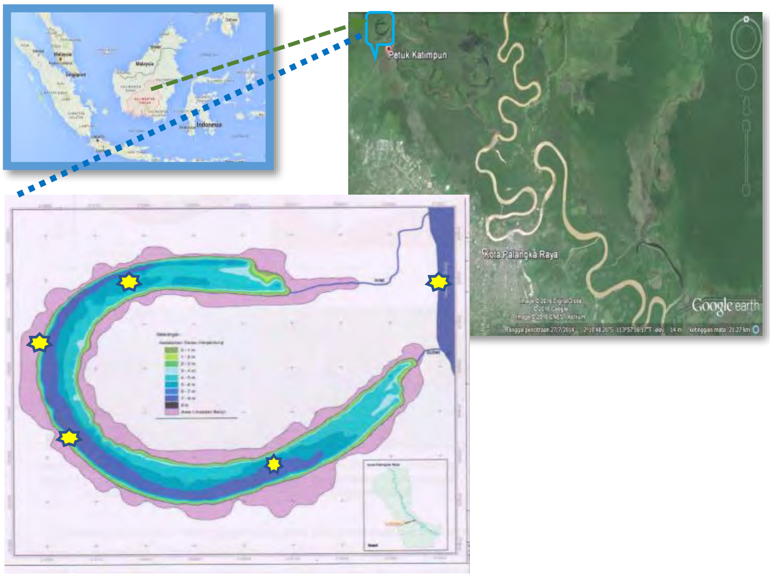

Figure 2. The Hanjalutung Oxbow Lake

Macroinvertebrates were collected using the Ekman grab tool, with three repetitions at each location as a composite sample. Sediments containing macroinvertebrates were filtered, stored in a plastic bag and preserved in 10% formaldehyde. The samples were then sorted and identified in the laboratory. Sorting and identification were done using microscopes. To identify all groups, the books of identification were used (Epler, 2001; Kathman and Brinkhurst, 1999; Merrit and Cummins, 1995; Yule and Sen, 2004). Groups of Oligochaeta and Diptera larvae were mounted by using CMCP 10 before they were identified (Kathman and Brinkhurst, 1999).

The analysis of macroinvertebrates included the number of taxa, abundance, diversity index (H), evenness index (E), and feeding behaviour. The relationship between macroinvertebrates with water quality was assessed by Canonical Correspondence Analysis (CCA). Diversity index, Evenness index, and CCA were analyzed using the MVSP program. The abundance was determined using the formulation below:

1. Abundance: shows the composition of species in the community:

$$\text{Abundance} = \frac{\text{Number of individu}}{\text{m2}}$$

2. Shanon- Wiener diversity index (H)

The index is used to determine the diversity of the ecosystem. The value ranged between 0 to 5. Here's the formulation (Fachrul, 2007): $\mathrm{H} = -\sum \mathrm{Pi} \ln \mathrm{Pi}$

3. Evenness Index (E)

Rated E ranged from 0-1, where the value is 1 illustrates a state in which all species are spreading fairly to prevail. Here's the formula for calculating the evenness index (Astuti and Satria, 2009): $\mathrm{E} = \frac{\mathrm{H}'}{\ln \mathrm{S}}$

RESULTS AND DISCUSSIONS

Number of Taxa, Diversity and Evenness Index

A total 14 taxa were found in Hanjalutung oxbow lake consisting of groups Arthropods and Annelida. The classifications of benthic macroinvertebrates can be observed in **Table 1**. Thirteen were classified at the genus level and one was at the family level. Benthic macroinvertebrates were collected from four locations from the lake and one from a segment of the Rungan River. Insects were the most common found, with about 11 taxa. They are represented in four orders: Diptera, Hemiptera, Trichoptera and Ephemeroptera. Diptera consists of two families, Chironomidae and Ceratopogonidae. Chironomidae was the most varied. Hemiptera had only one family, Corixidae, it was the most abundant in the lake. Trichoptera consists of three taxa and only one taxa in Ephemeroptera. Annelida was represented by a group of Oligochaetes. It consists of two families, Naididae and Tubificidae.

Table1. The Classification of Benthic Macroinvertebrates

Phylum Arthropods
Class Insects
Order Hemiptera
Family Corixidae
Genus *Micronecta*
Order Trichoptera
Family Ecnomidae
Genus *Ecnomus*
Order Ephemeroptera
Family Caenidae
Genus *Caenis*
Order Diptera
Family Chironomidae
Genus *Clinotanypus*,
Genus *Cryptochironomous,*
Genus *Goeldichironomous,*
Genus *Kiefferulus,*
Genus *Parachironomous,*
Genus *Polypedilum,*
Genus *Tanytarsus*
Phylum Annelids
Class Oligochaeta
Order Tubificida
Family Naididae
Genus *Nais*
Family Tubificidae
Genus *Aulodrilus*

The number of taxa ranged between 1 and 7 in each location. The Location D yielded the most with seven taxa, location E had six taxa, while B had only one taxa (**Figure 3**). The total number of taxa in the lake was 12 and in the Rungan river the total number was six (**Table 2**).

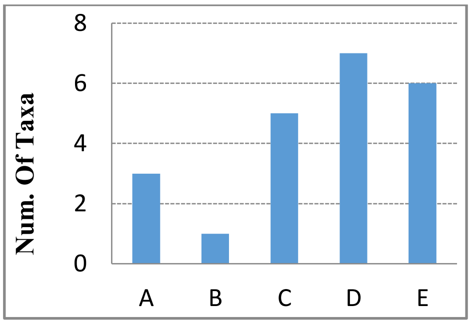

Figure 3. The number of taxa in each location. A-D in lake, E in River

The diversity of benthic macroinvertebrates in Lake Hanjalutung was analyzed by Shanon-Wiener diversity index. It ranged from 0 to 2.439 ± STD 0,97 (the analysis using log base 2). The diversity indexes in five locations, A-E were: 1,053; 0; 2,12; 1,96; and 2,439. The evenness index shows that benthic macroinvertebrates were distributed from among the less to homogeny (E = 0- 0.944 ± STD 0,39). Based on the result, it can be summarised that Hanjalutung was low in diversity. The connectivity between the lake and the river had probably been one of the reasons. Similarly, a previous study showed that, when the diversity of benthic macroinvertebrate in the river was high recorded, so does with the lake (Trichkova *et al*, 2013). However, our research showed that, benthic macroinvertebrates both in the lake and the river were in low diversity.

Abundance, Composition, and Functional Feeding Group

Total abundance of the community ranged between 18-960 indv/ m^2. It varied from each location. Location D was the most abundant, with about 960 indv/m^2 while location B was the lowest, with 18 indv/m^2. In location E, we found 54 indv/m^2. From those findings, the abundance of Arthropods (Insects) was 84% and Annelida (Oligochaetes) was 16%. Most Insects families were found in Hanjalutung: Chironomidae (42%) and Corixidae (56%). Chironomidae was distributed among the four locations A,C,D, and E; Corixidae was distributed in three locations C, D, and E (**Figure 4**). The three other families of Insects were found : Ecnomidae, found in two locations (D and E), Caenidae and Ceratopogonidae, only found in location D. Three benthic macroinvertebrates dominated : *Micronecta* (795 indv / m^2); *Tanytarsus* (380 indv / m^2), and *Aulodrilus* sp (226 indv / m^2), but they were not distributed well among all locations.

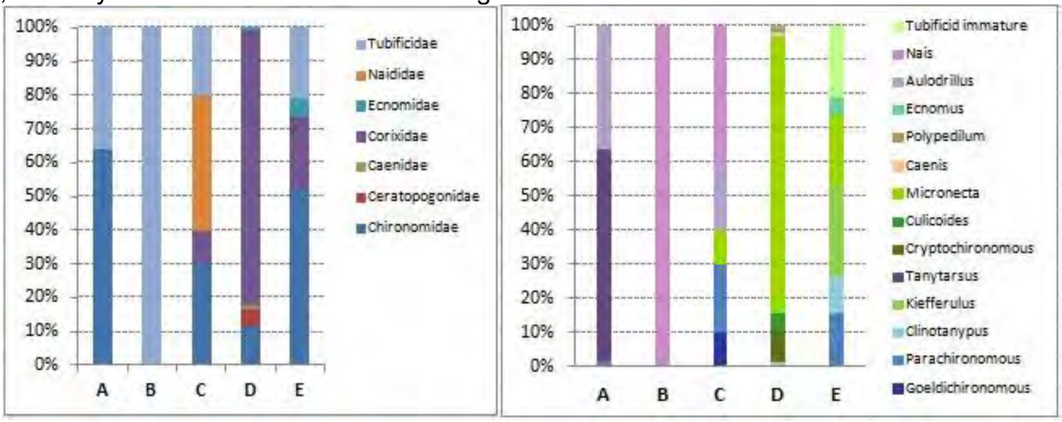

Figure 4. Families (left) and taxa (right) Compotition of Benthic Macroinvertebrates

Generally, insects dominated almost in all locations. This group was more abundant and varied probably because there are many vegetations. The vegetation function as habitat for adult insects. They provide food and shelter for insects. Eventhough they more in composition compared to Oligochaetes, benthic macroinvertebrates were low in diversity and abundace compared to those from other lake in Indonesia.

At the location A, benthic macroinvertebrates represented mostly Chironomidae, especially *Tanytarsus*. There were also Oligochaetes (*Aulodrilus*). Location A was the leg of the lake, which during the rainy season flooded with the water from the Rungan river. When the research was conducted, there has only a little water in this location. The location C was in the curve of the lake and was the only location where Oligochaetes (both Tubificidae and Naididae) were found, with the number of Naididae: Tubificidae = 2: 1. At this location there was a fishery-cage called keramba. At the location B, located between the locations A and C, benthic macroinvertebrates were only represented by one taxa, which *Nais.* It is located between the location A and C.

At location D, there were seven kinds of benthic macroinvertebrates and all of those were within the insects group. It was dominated by *Micronecta*. In contrast to the other locations, we did not find any Oligochaetes here. It became the only location without Oligochaetes. A and D were located in the leg of the Oxbow-lake, opposite each other. B was in the curved-shape, and E was in the river. As the inlet which is the nearest location to the main river, A and D have a different condition not only in abundance but also in number of families or taxa. We assumed this was a transition zone between river and oxbow lake. This difference needs to be investigated, in terms of the hydrological connectivity and flooding.

The presence of vegetation or riparian might have also influenced the abundance of benthic macroinvertebrates indirectly through the habitat. As shown in previous study in peatland that the abundance of vegetation is an important factor affecting the habitat of this community (Passuni and Fonken, 2014). We knew that the oxbow lake is in peatland area which is surrounded by swamp vegetation either trees or shrub. The relationship between macroinvertebrates community and vegetation needs to be studied further.

We also collected data from additional locations between C and D but we did not find any benthic macroinvertebrates. This is probably because of the succession process, the process of reforming of the litter is ongoing in this patch so the substrate was unsuitable for benthic macroinvertebrate to live in. Hanjalutung might also act as a floodplain lake during the rainy season. Local people said that the lake area was increasing due to water flow from the Rungan river. This increase has probably changed the condition of the substrate in the bottom.

We grouped the benthic macroinvertebrates based on the functional feeding to understand the feeding behaviour of the community. We used the following literature as a reference to grouping (Merrit and Cummins (1996), Zilli (2008), Mandaville (2002), Heino (2000 and 2008), Sudarso and Wardiatno (2015). Those functional feeding groups can be observed in **Table 2**.

Table 2. Distribution and Functional Feeding Group of Benthic Macroinvertebrates

Num	Taxa	Oxbow lake	Rungan River	FFG*
1	*Goeldichironomous*	+		CO
2	*Parachironomous*	+	+	PD
3	*Clinotanypus*	+	+	PD
4	*Kiefferulus*		+	CO
5	*Tanytarsus*	+		CO
6	*Cryptochironomous*	+		PD
7	*Polypedilum*	+		SH
8	*Cullicoides*	+	+	PD
9	*Micronecta*	+		PD
10	*Caenis*	+		CO
11	*Ecnomus*	+	+	CO
12	*Aulodrilus*	+		CO
13	*Nais*	+		CO
14	*Tubificid* immature	+	+	CO

Noted: CO = collector, PD= predator, SH= Shredder

From the table above, it can be seen that most of them were in the group of Predator, with about 58,26%. All of the predators were Insects and belonged to three families: Chironomidae (*Parachironomous, Clinotanypus, Cryptochironomous*), Ceratopogonidae (*Cullicoides*), and Corixidae (*Micronecta*). There were also a small number of Collectors (41,13%) and Shredders (0,59%). Predators get food by eating other organisms. Meanwhile, collectors get food from fine-sized particles or FPOM. The presence of predators can be indicated from the water clarity. Predators will be present not only because of the abundance of the prey but also the environmental factors. They can see prey clearly if the water clarity is good (Adeyemi in Orwa et al, 2014). In Lake Hanjalutung the average water clarity by the secchi depth measurement was about 30,26 cms. When we compared benthic macroinvertebrates from the lake and the river, the composition of the lake sites represented 13 taxa with 1618 individuals/m^2, while in the river site were only 6 taxa with 57 individuals/m^2, and 4 of these taxa live in both lake and river. It seems that the lake has more macroinvertebrates in number than the river. In this case, we ignored the number of locations in each.

CCA of Benthic Macroinvertebrates – Water quality

According to water quality parameters assessment, some of it were recorded in low range: pH and DO (in 3 locations). The low of pH may be because the Hanjalutung oxbow lake is located in peatland area. Meanwhile the low of DO, in previous research showed that it can be caused by the result of decomposition, but in this case, it can not be clearly described because the temperature was in normal ranged. However, the water quality parameters were recorded in normal ranged (**Table 3**).

Table 3. The Water Quality Parameters

Num	Locations	Temp (°C)	DO (mg/L)	pH	TDS (gr/L)
1	A	29,47	8,88	5,38	0,006
2	B	26,65	7,78	4,99	0,007
3	C	26,49	3,61	5,14	0,007
4	D	28,80	5,32	4,92	0,007
5	E	28,60	5,50	5,80	0,009

Based on the results of CCA between water quality parameters and benthic macroinvertebrates, it can be observed that pH, DO, and TDS were closer to the axis 1, while the temperature parameters were closer to the axis 2. There were nine taxa were characterized by pH, DO, and TDS, which included *Clinotanypus, Tanytarsus, Polypedilum, Cryptochironomous, Cullicoides, Micronecta, Caenis, Ecnomus, and Aulodrilus*. While five other taxa were characterized by temperature parameters: *Goeldichironomus, Parachironomous, Kiefferelus, Nais, and Tubificid* immature. From graph result in **Figure 5**, it can be seen that location B and C were closer to the axis 2, but tend to be negatively correlated to axis 2, position far from the center of the axis. It means that in this case, the higher temperature might tend to lower the abundance of those benthic macroinvertebrates. Meanwhile locations A, D, and E, were closer to axis 1 and have a positive correlation to axis 1.We used CCA analysis only to see the tendency towards the environmental factors of benthic macroinvertebrate, however, we did not determine the correlation between these parameters and benthic macroinvetebrates.

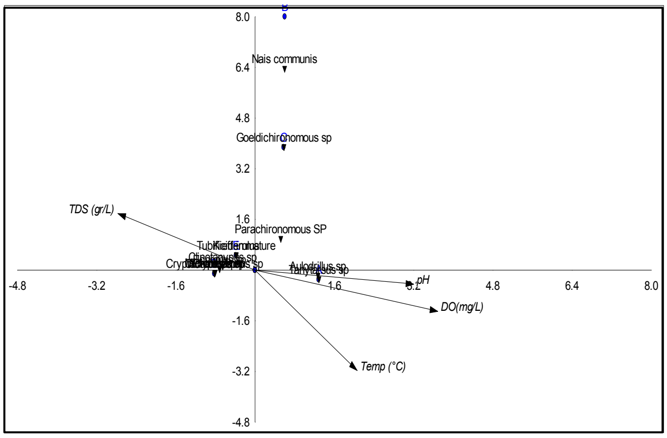

Figure 5. Scatter Plot Graph of CCA Between Macroinvertebrates and Water Quality

CONCLUSIONS

It can be concluded from this research that generally, the hanjalutung oxbow lake has lack of benthic macroinvertebrates in dry season. Nevertheless, we highlight, the insect groups have potential as a food source of fish populations due to the higher composition compares to the other group. However, our research was preliminary and only conducted in dry season. We predict that in different season might be more benthic macroinvertebrates will be recorded. We suggest to exploring benthic macroinvertebrates in the rainy season in further research and more water quality parameters used as variables.

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PHYTOPLANKTON COMMUNITY AT LITTORAL ZONES OF LAKE MATANO IN RELATIONSHIP TO WATER QUALITY

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ABSTRACT

Research on phytoplankton in Lake Matano has been carried out, however observations of phytoplankton in the littoral zone have not been done, even though the role of the littoral zone is important. This study aimed to find out the composition and abundance of phytoplankton at littoral zone of Lake Matano in relationship to the water quality. Observations were made in April and August 2015 at six locations in littoral zone of Lake Matano. Water samples were taken 10 - 20 L at surface water and Secchi depth, filtered using a plankton net no. 25, and preserved with Lugol 1%. Water quality parameters measured were temperature, pH, dissolved oxygen, conductivity, and turbidity. Phytoplankton abundance was calculated using the Sedgwick Rafter method. Phytoplankton community structure was analyzed by Diversity Index (H'), Evenness Index (E) and Simpson Dominance Index (D).There were five phyla and 57 species of phytoplankton found in Lake Matano, comprised of Chlorophyta (16 species), Dinophyta (2 species),Bacillariophyta (34 species), Chrysophyta (1 species), and Cyanophyta (6 species). The abundance of phytoplankton in April and August 2015 ranged between 198 – 1.281 x 10^4 individual/L, dominated by Peridinium inconspicuum *and* P. Cinctum. *Diversity Index ranged from 0.719 to 2.632 indicates low to moderate community stability. Evenness Index ranged from 0.065 to 0.216 which indicated low uniformity among species. Dominance Index ranged from (0.216 to 0.749), species dominance occured in some observed locations at Lake Matano, especially in April 2015. Dissolved oxygen, pH, temperature and conductivity influenced the existence of phytoplankton on the surface area especially in April 2015.*

Keywords: abundance, composition, Matano, phytoplankton, water quality.

INTRODUCTION

Phytoplankton response to the environment changes can be seen from the changes in species diversity and abundance. Diversity will be low if a community is dominated by one or a few species of phytoplankton. This occurres due to environmental disturbances in the waters, so that only certain species are able to adapt the environmental changes for survival. This condition is usually accompanied by the high abundance of phytoplankton which is usually found in eutrophic waters, while the low abundance of phytoplankton found in oligotrophic waters. Low diversity of phytoplankton is an indicator of oligotrophic waters. Light penetration, temperature, nutrient enrichment, toxic substances, mixing of water, parasites, herbivores and heterotrophic microorganism activities influence phytoplankton growth (Reynolds, 1984). The continuous light and temperature contribute substantially to the phytoplankton community (Kolayli & Sahin, 2007). Biomass and diversity of algae and animals are higher in the littoral zone than in the pelagic, so it is important to understand what drives littoral productivity. Littoral zones are also characterised by having high inputs of allochthonous carbon from fringing vegetation (France 1995).

Lake Matano is located in the Malili Lakes Complex (South Sulawesi) and is the deepest lake compared with Lake Mahalona, Lake Towuti, Lake Lantoa, and Lake Masapi. Lake Matano is categorized as tectonic and ancient lake (Haffner *et al*, 2001); ultraoligotrofik lake by a low rate of carbon fixation (Crowe *et al*, 2008) and based on the trophic status of a single parameter or composite parameters (Nomosatryo *et al*, 2014). The lake is also categorized as oligotrophic based on total nitrogen and total phosphorus content at a depth of over 100 m (Sabo *et al* , 2008) and based on phytoplankton abundance (Sulawesty, 1994).

Several studies on phytoplankton in Lake Matano have been carried out, such as by Sulawesty (1994) concerning planktonology character, Sabo *et al* (2008) regarding factorsaffecting to the composition and relative abundance of plankton, and Snook (2009) about limiting factors of the abundance and composition of pelagic phytoplankton. But observations of phytoplankton in the littoral zone of the lake Matano has not been done, even though the role of the littoral zone are important. Most of the fish in Lake Matano live in the littoral zone. A study on the habitat of *Telmatherina sarasinorum* showedthat fish prefers shading places provided by any trees existing on the lake sides as spawning sites, the fish was not observed to spawn in places covered by dense cobbles and open waters exposed directly to sunlight (Nilawati *et al*, 2010). Herder *et al* (2012) showed that flowerhorns (*Amphilophus*) were found from the shoreline out to >13 m depth, eggs deposited on the surface of stones and schools of immature individuals found mostly in the shallow lake habitats. Observations on 2010 showed that breeding pairs and numerous juveniles recorded at the southern shore of Lake Matano at Salona Beach (Southern Soroako) (Herder *et al*, 2012). This study is aimed to understand phytoplankton community structure and its relationship to water quality at littoral zones of Lake Matano.

METHODS

Sampling Site

Lake Matano is located in South Sulawesi between 2°28'90" Sand 121°17'90" E.Lake Matano is one of the deepest lakes in the world with a maximum depth of ~ 590 m, and an altitude of 380 m above sea level. The maximum area of the lakes is 16,408 ha (Nomosatryo et al, 2012; Hafner *et al*, 2001).

Phytoplankton Analysis

Phytoplankton data were collected in April and August 2015 at several littoral zones of Lake Matano (Figure 1), a description of the sampling locations are presented in **Table 1**. Phytoplankton sample was collected with a Van Dorn bottle in surface waters and in the Secchi depth by filtering 10 - 20 L through a plankton net no. 25 (53 µm mesh size), and preservedwith Lugol 1%. Phytoplankton species was identifiedaccording to Prescott (1951), Scott & Prescott (1961), Prescott (1962), Mizuno (1970), Vyverman (1996), Gell, *et al* (1999) and Bellinger & Sigee (2010) using an inverted microscope with a magnification of 400x. Phytoplankton abundance was calculated using the Sedgwick Rafter method (APHA, 2012). Phytoplankton community structure was analyzed by Diversity Index (H'), Evenness Index (E) and Simpson Dominance Index (D) (Odum, 1971).

Water Quality Parameters

Water quality parameters data were collected at Secchi depth and surface water in several littoral zones of Lake Matano. Water temperature, pH, dissolved oxygen (DO), conductivity, and turbidity were collected using a water quality checker YSI, while water transparency was examined by the measurement of the Secchi depth. Multivariate analysis was used to determine the grouping of phytoplankton at sampling sites based on the condition of the water quality using software Multivariate Statistical Package (MVSP V 3.1).

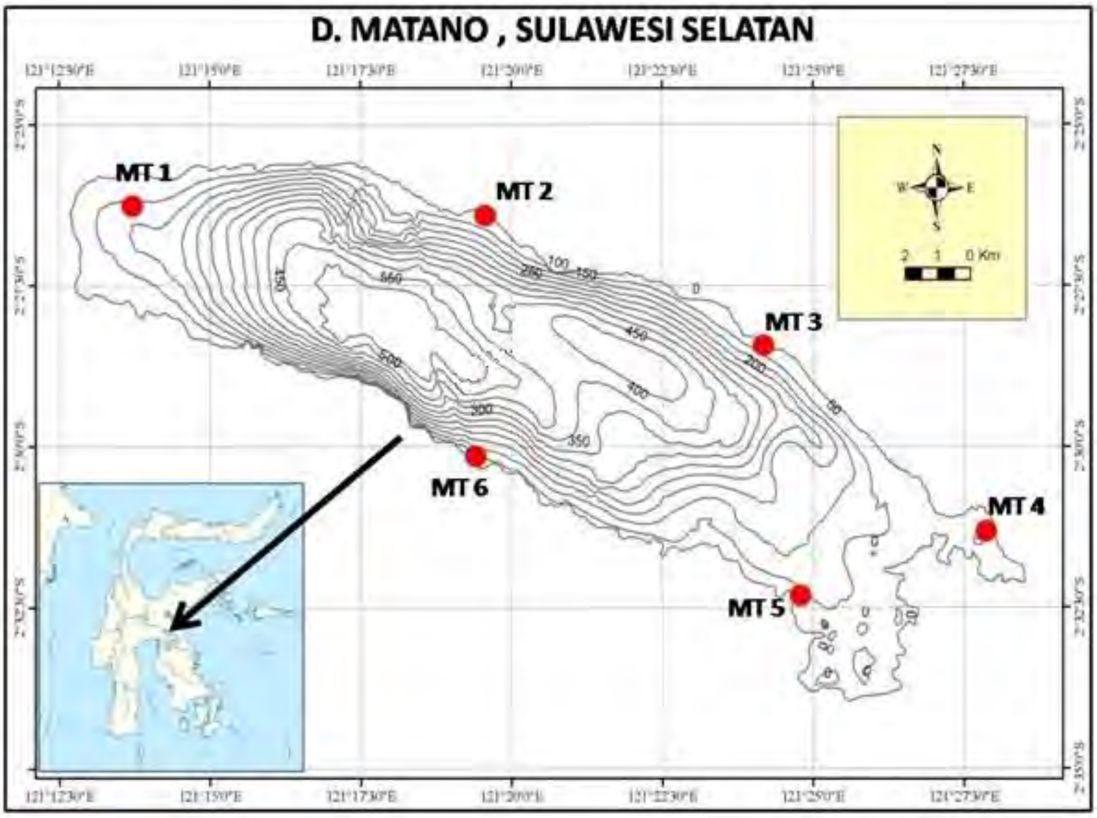


Figure 1. Sampling position at Lake Matano (Source : Haffner *et al*, 2001)

Table 1. Description of Sampling Sites at Lake Matano

Code	Location	Position	Habitat description
MT. 1	Elawa	121°13'28.7" E 02°25'52.2" S	Lake Matano inlet form Lawa River. Sampling site area is still forested, until 2 meters depth the substrate was rocky gravel, at the depth of 5 and 10 meters dominated by sand, disturbance from anthropogenic activities (settlements) are very minimal .
MT. 2	Nuha	121°19'28.06" E 02°26'23.1" S	The location is close to Nuha Village, a fisherman village, boat docks, a boat crossing from the village of Nuha to Sorowako or vice versa. Around the village there are natural vegetation cover (forest) , until 2 meters depth the type of basic substrate was small gravel, a depth of 5 and 10 meters is sand.
MT. 3	Tanah Merah	121°23'58.5" E 02°28'21.2" S	Location named Tanah Merah, around the lake they found the native vegetation (forest), there are several former landslide, anthropogenic activities are still very minimal, from 0 to 1 meter the susbtrates were rocky gravel and hardpan (hard ground), substrate from 2 meters to 10 meters is sand .
MT. 4	Petea	112°27'55.4" E 02°31'16.8" S	Location named Petea, more open area, there is a former forest clearing in order to be converted into plantation areas. Formerly a former area of nickel tailings disposal, from a depth of 0 to 2 meters the base substrates were fine mud and sand, depth of 5-10 meters is sand . There are swamps.
MT. 5	Pantai Impian	121°24'46.1" E 02°32'23.9" S	Location named Pantai Impian, the natural vegetation is still there, the location of settlements populatins and settlements workers of PT Vale and close to Sorowako Village, berth of the fishing boats, from 0-2 meters the base substrate were gravel and pebble stone, depth of 5 to 10 meters is sand.
MT. 6	Pantai Kupu-Kupu (*Bubble Beach*)	121°19'27.7" E 02°30'11.2" S	Location named Pantai Kupu-Kupu or Bubble Beach, habitat around the site still dominated by native vegetation, on the basis habitat often encountered gas bubbles are suspected of H2S, a depth of 0-2 meters is dominated by gravel, 5 and 10 meter depth of the base substrate is sand

RESULTS AND DISCUSSIONS

There were five phyla and 57 species of phytoplankton found in Lake Matano, comprised of Chlorophyta (16 species), Dinophyta (2 species), Bacillariophyta (34 species), Chrysophyta (1 species), and Cyanophyta (6 species) (**Table 2**). This result is quite different than the observations by Sulawesty (1994), but almost the same as Haffner *et al*. (2001), Sabo *et al*. (2008) and Snook (2009). Bacillariophyta were the dominant type/group reaching up to 59.65% of the total taxa (**Table 2**). Bramburger *et al*. (in press a) *in* Bramburger *et al*. (2008) demonstrated that the planktonic diatom community of Lake Matano may be considered depauperate, with only 31 of the lake's 191 observed taxa reported from the plankton. Meanwhile, the total taxa richness of diatoms (include benthic diatom) found at Lake Matano is 140, 22% of which are endemic species (Bramburger *et al*, 2004 *in* Bramburger *et al*, 2008). Complex interactions between nutrient limitation and metal toxicity may influence plankton community dynamics within Lake Matano (Sabo et al., 2008). In Malili Lakes, stochastic processes related to biogeography and colonization have had little influence on the diatom flora of the lakes, and deterministic processes related to competition, selection, speciation, and adaptive radiation, functioning on very small spatial scales, have contributed greatly to the diversity, community structure, and endemismof the system (Bramburger *et al*, 2008).

Centric diatoms were not found in Lake Matano at April and August 2015, Bramburger *et al*. (2008) also reported that centric diatoms are absence both in the pelagic zoneand in the littoral zones around the Lake Matano. Meanwhile, centric diatoms are found in other lakes on the island of Sulawesi, Sabo *et al*. (2008) explained that the absence of these cosmopolitan planktonic groups supports the conclusion that Lake Matano's water chemistry is playing an important role in regulating both the composition and biomass of the phytoplankton community.

Table 2. Species composition of phytoplankton at Lake Matano in April and August 2015

SPECIES COMPOSITION OF PHYTOPLANKTON				
CHLOROPHYTA	**DINOPHYTA**	**BACILLARYOPHYTA**	**CHRYSOPHYTA**	**CYANOPHYTA**
Closteriopsis longissima	*Peridinium inconspicuum*	*Achnanthes* sp.	*Chrysosphaerella* sp.	*Chroococcus* sp.
Cosmarium contractum	*Peridinium cinctum*	*Achnanthes longipes*		*Merismopedia* sp.
Cosmarium lundellii		*Amphiprora alata*		*Aphanothece* sp.
Cosmarium maculatum		*Amphora ovalis*		*Oscillatoria* sp.
Crucigenia apiculata		*Cymbella aspera*		*Spirulina* sp.
Kirchneriella lunaris		*Cymbella ehrenbergii*		*Spirulina subsalsa*
Pediastrum duplex		*Cymbella gracile*		
Scenedesmus sp.		*Fragilaria* sp.		
Spondylosium nitens		*Frustulia rhomboides*		
Staurastrum prionotum		*Gomphonema*		
Staurastrum gracile		*Gomphonema affine*		
Staurastrum limneticum		*Gyrosigma* sp.		
Staurastrum sebaldi		*Gyrosigma attenuatum*		
Staurastrum thienemannii		*Nitzschia* sp.		
Staurastrum xanthium		*Navicula* sp.		
Ulothrix		*Navicula cryptocephala*		
		Navicula lanceolata		
		Navicula pupula		
		Navicula radiasa		
		Navicula rhyncocephala		
		Navicula viridis		
		Pleurosigma fasciola		
		Rhapolodia sp.		
		Rhapolodia gibba		
		Surirella sp.		
		Surirella elegans		
		Surirella excellens		
		Surirella pseudovalis		
		Surirella robusta		
		Surirella wolterecki		
		Synedra ulna		
		Pinnularia viridis		
		Tabellaria sp.		
		Unidentification Sp 1		

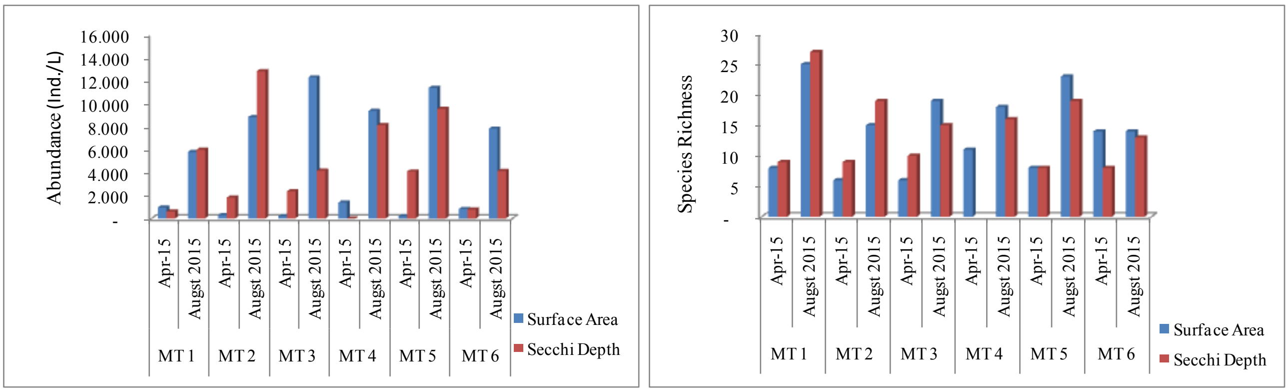


Figure 2. Phytoplankton abundance and species richness at Lake Matano in April and August 2015

The abundance of phytoplankton in April and August 2015 ranged between 1.98 x 10^2– 1.281 x 10^4 individual/Liter (**Figure 2**), where Dinophyta was higher than the others, i.e. *Peridinium inconspicuum* and *Peridinium cinctum*. Figure 4 shows that the percentage abundance of Dinophyta is the highest compared to other groups on each observation, with a value of 61.05 to 96.38%. Pollingher (1988) *in* Queimalinos *et al*. (2002) mentioned that dinoflagellates are also favored in oligotrophic environments due to their feeding mode and their movement capacity, since they can screen the whole water column for nutrients through vertical migration.This is evidenced also by Queimalinos *et al*. (2002) in his research on the lake Andean (ultraoligotrophic lake) in Argentina, where he obtained the same results with the results of Pollingher, obviously this is also related to the presence of a source of food which is phytoplankton such as cyanobacteria, cilliata, and other dinoflagellates. Sellers & Markland (1983) also mentioned that the oligotrophic lake with neutral to alkaline and nutrient poor characteristic Dinoflagellata especially *Peridinium* and *Ceratium*. Lake Matano is a nutrient poor lake (Sabo et al., 2008) with a neutral to alkaline pH (Nomosatryo *et al*., 2014) and (**Figure 5**). Although the abundance of phytoplankton was high in Lake Matano, it was dominated by *Peridinium* which is an unpalatable species and is not that well suited as a food source. Sabo *et al*. (2008) mention that the phytoplankton assemblage of Lake Matano largely consists of unpalatable species, such as *Peridinium* and *Tribonema* cf. sp., and therefore Lake Matano does not have the capacity to sustain a significant zooplankton community.Diversity Index ranged from 0.719 to 2.632 indicates low to moderate community stability (**Figure 3**). Evenness Index ranged from 0.065 to 0.216, this value is close to zero means the uniformity among species in a community is lower, and there is usually a species that dominates. Dominance Index (0.216 to 0.749) indicates that species dominance occurred in some locations of observation at Lake Matano, i.e. *Peridinium inconspicuum* and *Peridinium cinctum* from Dinoflagellata (**Figure 4**).

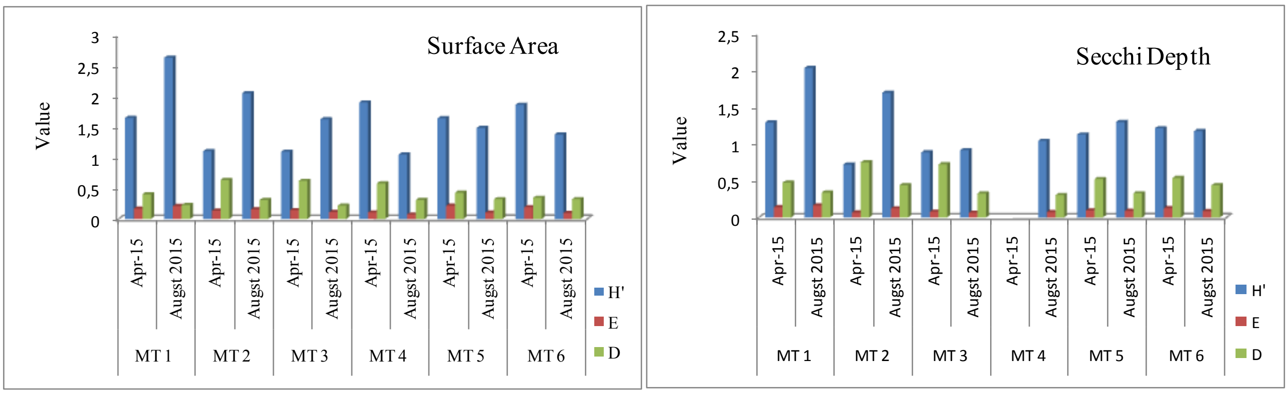
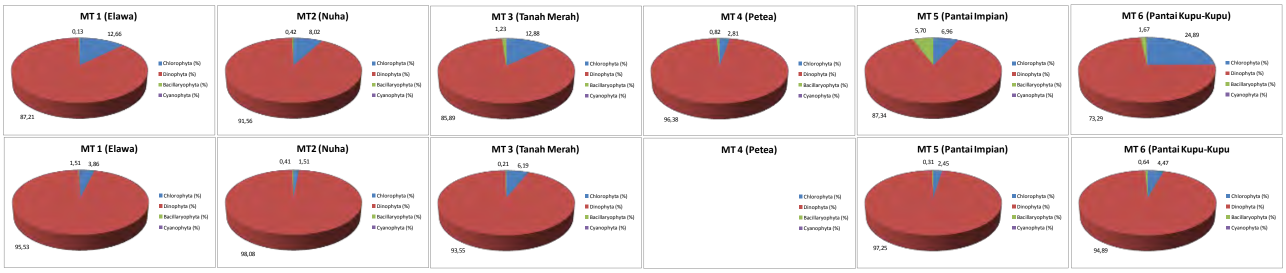
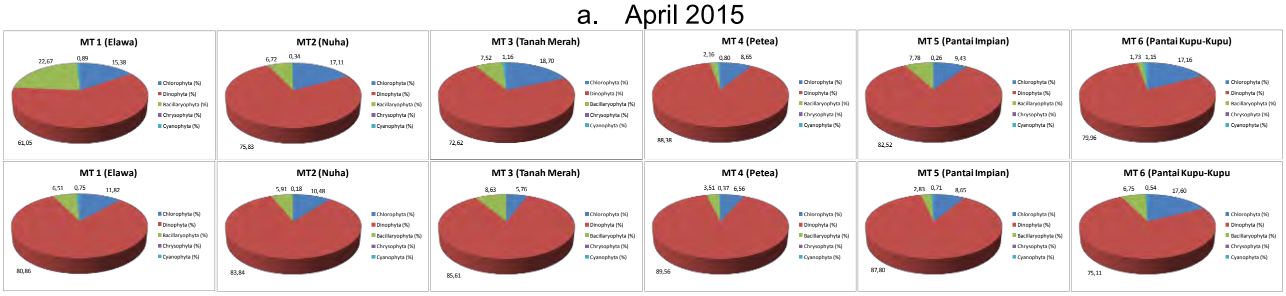


Figure 3. Diversity Index (H'), Evenness Index (E) and Simpson Dominance Index (D) at Lake Matano in April and August 2015



a. April 2015



b. August 2015

Figure 4. Phytoplankton division percentage at surface area (upper) and Secchi depth area (below) at Lake Matano in April 2015 (a) and August 2015 (b)

Matano lake water quality conditions in April and August 2015 can be seen in **Figure 5**. Temperatures ranged from 26.6ºC – 30.5ºC, this result is similar to observations by Nomosatryo *et al*. (2012), Nomosatryo *et al*. (2014) and Snook (2009), which ranged 27.3 - 29.62ºC. Water temperatures tend to be higher in April compared to August 2015, however the phytoplankton abundance and taxa richness were higher in August compared to April 2015 (**Figure 3 and 5**). Schabhiittl *et al* (2013) mentioned that the growth and diversity of phytoplankton are also affected by changes in seasonal temperatures and increased water temperature. Temperature is one of the major determining factors that affect the rate of growth of phytoplankton, nutrient stoichiometry and spatial and temporal distribution in freshwater. Changes in the availability of light and nutrients accompanying climate change, qualitatively affect the species composition and diversity at the level of primary producers, which in turn can have an impact on higher trophic levels (Vincent, 2009).
The pH values ranged from 8.23 to 9.61 indicating that D. Matano is alkaline waters. Alkaline nature is also the same as mentioned by Nomosatryo (2014) and Snook (2009). Dissolved Oxygen value ranged between 6.44 – 7.76 mg/L, this value shows aerobic condition and still support phytoplankton life. Nomosatryo *et al*. (2014) mentioned that the aerobic condition in Lake Matano is found to a depth of 95 m, while the state is completely anaerobic starting from a depth of 100 m to the bottom. Conductivity value of Lake Matano was high ranging between 0.134 – 0.177 mS/cm. Snook (2009) mentioned that conductivity in Lake Matano was high reflecting high ground water input.

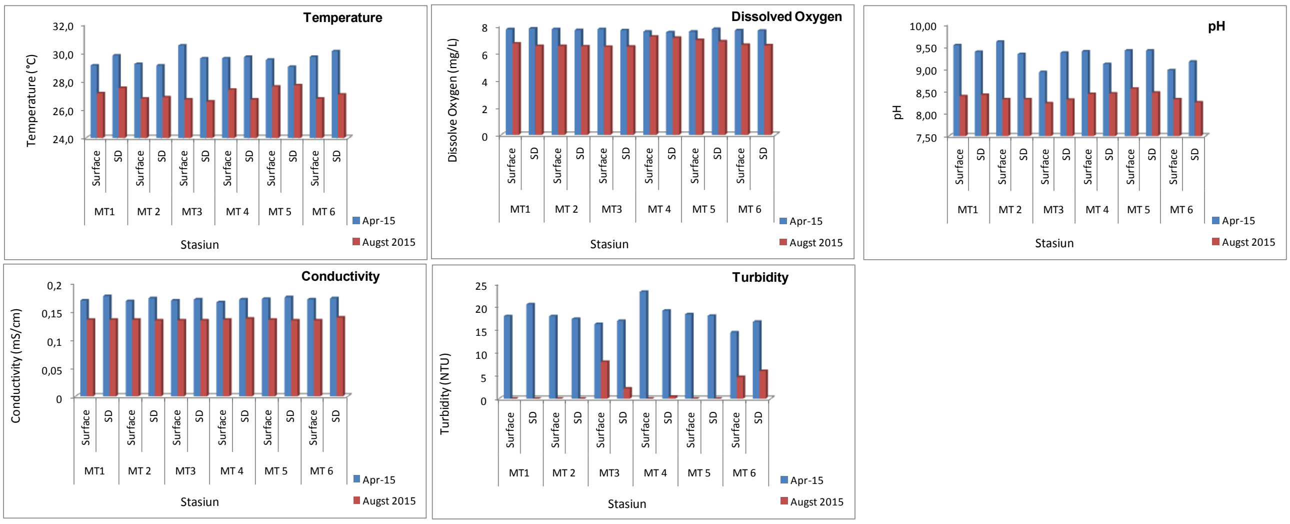
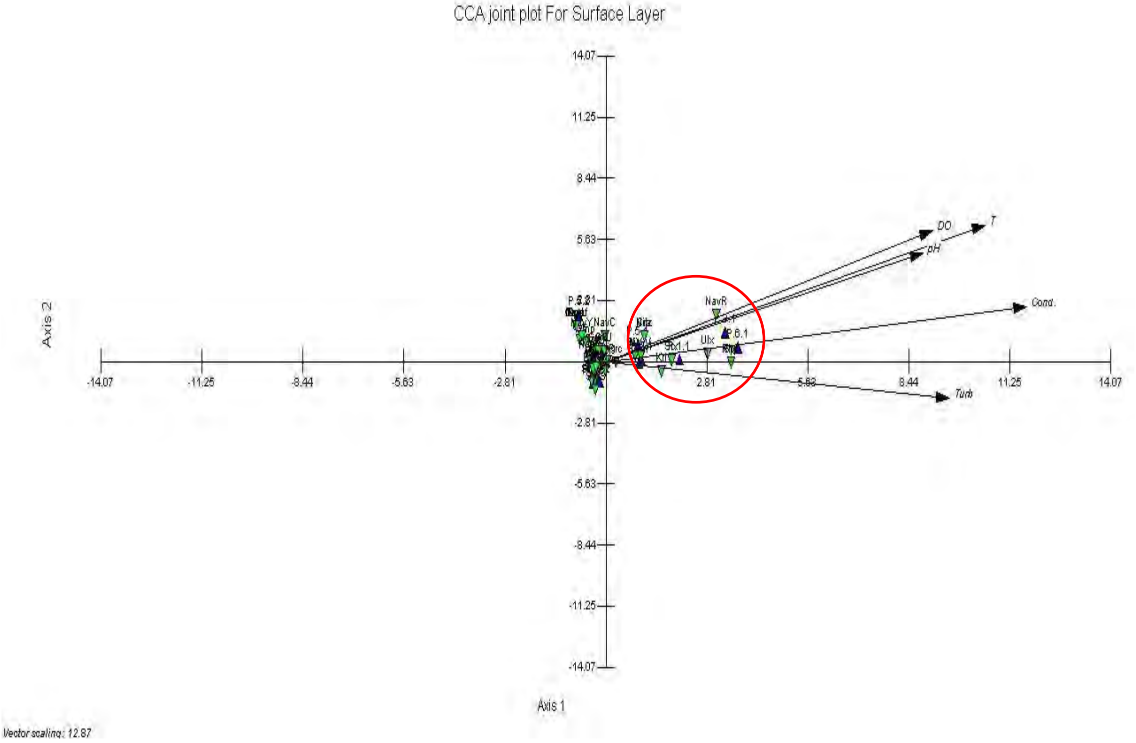
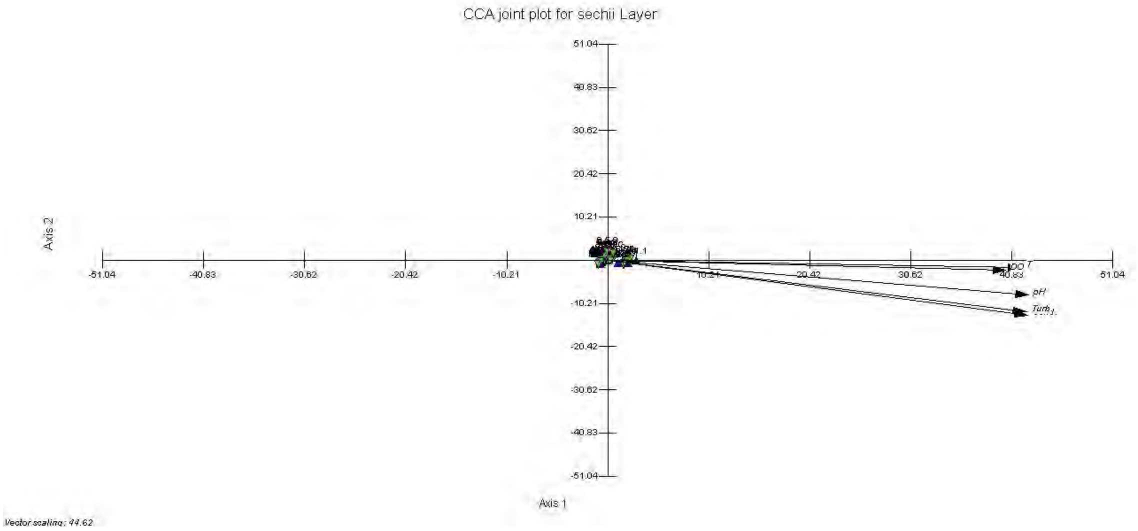


Figure 5. Value of temperature, DO, pH, conductivity, and turbidity at Lake Matano in April 2015 and August 2015

The result of CCA ordination in Lake Matano is shown in **Figure 6**. In general, water quality parameters affected the abundance of phytoplankton in the surface waters of Lake Matano. Dissolved oxygen, pH, temperature and conductivity influenced the existence of phytoplankton on the surface area especially in April 2015. At a Secchi depth, it can be seen that the abundance of phytoplankton tends to converge in the whole observation, this indicates that there are no circumstances that characterize the area. Similarly, with water quality parameters, there is a little effect on the abundance of phytoplankton at a Secchi depth.



a. Surface Area



b. Secchi depth

Figure 6. CCA ordination at surface area (a) and Secchi depth (b)

CONCLUSIONS

- There were five phyla and 57 species of phytoplankton found in Lake Matano, comprised of Chlorophyta (16 species), Dinophyta (2 species), Bacillariophyta (34 species), Chrysophyta (1 species), and Cyanophyta (6 species).
- The abundance of phytoplankton in April and August 2015 ranged between 1.98 x 10^2– 1.281 x 10^4ind/L, where Dinophyta was higher than other species, i.e. *Peridinium inconspicuum* and *Peridinium cinctum*.
- Phytoplankton abundance and taxa richness were inversely proportional to the temperature, when temperatures was high (April 2015) the abundance and taxa richness were low, when the temperature was low (August 2015) the abundance and taxa richness were high.
- Dissolved oxygen, pH and temperature influenced the existence of *Ulothrix*, *Navicula radiosa* and *Nitzschia*, while conductivity impacted on the *Spirulina* on the surface area in April 2015.

ACKNOWLEDGEMENT

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EVALUATION OF GENETIC RELATIONSHIP AMONG SELECT SIX FISH SPECIES USING THE PARTIAL FRAGMENT OF MITOCHONDRIAL CYTOCHROME C OXIDASE SUBUNIT-1GENE (CO1)

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ABSTRACT

In modern conservation and sustainable management approaches of species, it is important to have knowledge about biodiversity, population structures and dynamics. In the present study, the genetic relationship among select fish species in Lubuk Lampam floodplain region was investigated, utilising partial fragment of mitochondrial Cytochrome C Oxidase Subunit-1gene (CO1). The aim of the study was (1) to reveal genetically relevant relationship of fish species in the Lubuk Lampam floodplain and (2) to find more pronounced substructures on the fine scale analysis. Tissue samples from 10 specimens of fish species were collected during several field trips in 2012 at sample sites across Lubuk Lampam floodplain Ogan Komering Ilir regency South Sumatra Province. The results showed different species that are deviated relatively new from a similar ancestor. The molecular marker, a 570 bp region of the mitchondrial cyctochrome c oxidase I gene (COI) has been successfully found to be species-specific, and was also more variable between species than within species. In summary, the present study represents an important step understanding evolution relationship for teleost fish living in tropical peat swamp in Sumatra. Producing of a COI sequences from the Lubuk Lampam system also assist to the global DNA barcoding library.

Keywords: Phylogeny, Lubuk Lampam and species assignment

INTRODUCTION

In modern conservation and sustainable management approaches of species, it is important to have knowledge about biodiversity, population structures and dynamics. Moreover, the detection of genetic variation at the species, population and within population level is of great importance for sustainable aquaculture practices. Especially in freshwater species, direct measurements about connectivity and differentiation are difficult to obtain, which is why indirect measures with the help of phylogeographic and population genetic approaches can be very helpful and necessary.

Genetic variation at species level helps to identify the taxonomic units and to determine the species distinctiveness. Variation at the population level can provide an idea about different genetic classes, the genetic diversity among them and their evolutionary relationship with wild relatives. The genetic variability within population is extremely useful to gather the information on individual identity, breeding pattern, degree of relatedness and disturbances of genetic variation among them (Schierwater et al. 1994). In order to evaluate biodiversity correctly it is important to clarify species boundaries, integrities, and phylogenetic relationships (Frankham et al., 2002).

The genetic tools available to date, vary from mitochondrial or plasmid DNA, to nucleus DNA, sequence based to length or single nucleotide polymorphism markers, and differ in the ways of possible analyses and information gain, all afflicted with different advantages and disadvantages (Timm et al., 2012). Mitochondrial sequence markers are widely used for phylogenetics of fish (e.g., Kochzius et al., 2003; Santini & Polacco 2006; Timm et al., 2008). As certain regions show high variability and the procedure for amplification and sequencing is comparably easy (Timm et al., 2012). Sequencing of the mitochondrial cytochrome-*c* oxidase subunit 1 (*COI*) gene fragment in animals has become one of the most widely used and effective tools for species identification and discovery. This approach, known as DNA barcoding, has been shown to provide unprecedented accuracy for the identification of various taxonomic groups of fish (Kochzius, 2009)

Not much is known about connectivity of freshwater populations in the Indonesia floodplain in general and especially for fish, despite the fact that such information is important to understand evolutionary and ecological processes in the centre of biodiversity. Data on connectivity are also urgently required to design effective conservation strategies for these living freshwater resources.

In the present study, the genetic relationship among select fish species in Lubuk Lampam floodplain region was investigated, utilising partial fragment of mitochondrial Cytochrome C Oxidase Subunit-1gene (CO1). This study aims (1) to reveal genetically relevant relationship of fish species in the Lubuk Lampam floodplain and (2) to find more pronounced substructures on the fine scale analysis.

METHODS

Sampling

Tissue samples from 10 specimens of fish species were collected during several field trips in 2012 at sample sites across Lubuk Lampam floodplain Ogan Komering Ilir regency South Sumatra Province. A small piece of tissue was cut off from each specimen. Tissue samples were preserved in 96% of ethanol and later stored at 4^0C.

DNA extraction, amplification and DNA sequencing

Genomic DNA was isolated from the muscle tissue using extraction kits from GENEAID, following the manufacturers' protocols. A fragment of around 550 bp from the mitochondrial Cytochrome C Oxidase Subunit-1gene (CO1) was amplified by polymerase chain reaction (PCR) using the primers Fish-COI-F (5'-ACT TCA AAC TTC CAY AAA GAY aty GG-3) and COI-Fish-R (5'-TAG ACT TCT GGG TGG CCR AAR Aay CA-3 ') (Ivanova et al., 2007). Polymerase chain reaction (PCR) was carried out in a total volume of 50 µL. PCRs contained 5 µL DNA samples, 16 µL double distillate water, 2 µL of each primer and 25 µL of PCR ready mixture solution (KAPPA). The following temperature profile was used for the PCR, an initial denaturation phase at 95°C for 10 min, followed by 35 cycles at 94°C for 1 min, 48°C for 1 min and 72°C for 1.5 min and ended with a final extension at 72°C for 7 min. The PCR products were purified using the The GenepHlow™ Gel/PCR Kit (GENEAID), following the manufacturer's protocol. Both strands of the purified DNA were automatically sequenced in both directions at First Base, Singapore (www.firstbase.com).

Genetic diversity DNA extraction, amplification and DNA sequencing

All sequences were edited with the program sequence navigator (version 7.0.1; Applied Biosystems) (Hall, 1999) and checked manually by eye. The sequences were translated to amino acids in order to exclude mistakes in sequencing and to verify if a functional mitochondrial DNA sequence was obtained and not a nuclear pseudogene. A multiple sequences alignment was obtained by using clustal w (Thompson *et al*. 1997) as implemented in the software bioedit (version 7.0.4.1; Hall 1999). Phenetic reconstruction was done using a distance based method, Neighbor-Joining (NJ), carried out in MEGA5 software (Tamura *et al.,* 2007) with the K2P model of substitution. Support for nodes in NJ analyses was assessed using non-parametric bootstrapping with 100 full heuristic pseudo-replicates. For comparative purposes, we used the several sequences of the freshwater fish species in Genbank (Accession Number view in figure) to root the tree.

RESULTS AND DISCUSSIONS

Information on the evolutionary relationships of genetic lineages can be obtained from DNA sequences through the reconstruction of phylogenies (Freeland, 2005). At the beginning, DNA was isolated from 20 specimens but amplification of the 501-bp target DNA fragment was successful only for 8 samples (voucher), despite multiple attempts to amplify DNA. The positioning of organisms on a tree is generally based on their genetic similarity to one another. This is illustrated in Figure 1, which shows a phylogeny tree showing the inferred evolutionary relationships among some fish species, genus and family. Organisms of different species of the same genus will be close to each other on the tree, different genera, such as *Barbichthys* and *Belodontichthys* (**Fig 1**), futher distance on the phylogeny tree.

The tree reflects how much genetic change has occurred and therefore roughly how much time has passed, since lineages split from one other, because branch lengths reflect the evolutionary distance between two points on a tree. Phylogenetic analyses have been invaluable in evolutionary biology, trees are appropriate for taxonomic groups at the species level and beyond, which have experienced a period of reproductive isolation long enough to allow for the fixation of different alleles (Freeland, 2005).

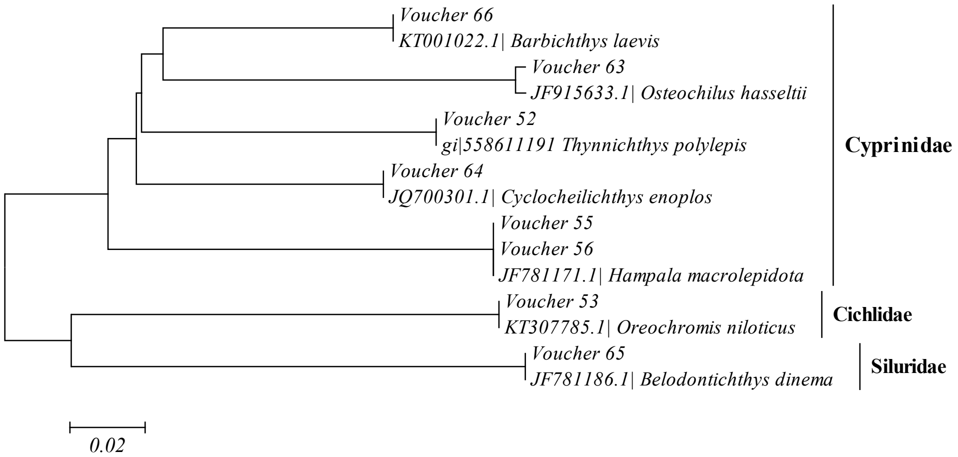

Fig. 1. A phylogeny of 15 fish species based on the partial fragment of mitochondrial Cytochrome C Oxidase Subunit-1gene DNA gene. First species names, then family names, are shown to the right of the tree.

One way in which we can measure the genetic similarly of two individuals is by estimating the genetic distance between them. There are many different ways in which this can be done, one of most common being Nei's (1972) genetic distance, D. The primer pair Fish-COI-F and COI-Fish-R used in this study was found to produce different number of base pairs with an average 570 bp.

The molecular marker, a 570 bp region of the mitchondrial cyctochrome c oxidase I gene (COI) has been successfully found to be species-specific, and was also an average of 18 times more variable between species (7.05-7.93 per cent) than within species (0.27-0.43 per cent) (**Table 1;** Herbert et al., 2004b). This suggests the existence of a separate gene pool for these species. Similar results were obtained when genetic distance calculated for other fish species (Lakra et al., 2007). However, low levels of genetic diversity among species or impoverishment of genome variability could be a threat for the future survival of the species (Sengupta & Homechaudhuri, 2012).

Table 1. Pairwise distance between fish species studied

		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Voucher_52														
2	gi|558611191_Thynnichthys_polylepis	0,000													
3	Voucher_64	0,146	0,146												
4	JQ700301.1|_Cyclocheilichthys_enoplos	0,146	0,146	0,000											
5	Voucher_66	0,145	0,145	0,134	0,134										
6	KT001022.1|_Barbichthys_laevis	0,145	0,145	0,134	0,134	0,000									
7	Voucher_63	0,178	0,178	0,171	0,171	0,159	0,159								
8	JF915633.1|_Osteochilus_hasseltii	0,183	0,183	0,167	0,167	0,156	0,156	0,005							
9	Voucher_55	0,188	0,188	0,171	0,171	0,177	0,177	0,221	0,221						
10	Voucher_56	0,188	0,188	0,171	0,171	0,177	0,177	0,221	0,221	0,000					
11	JF781171.1|_Hampala_macrolepidota	0,188	0,188	0,171	0,171	0,177	0,177	0,221	0,221	0,000	0,000				
12	Voucher_53	0,246	0,246	0,241	0,241	0,236	0,236	0,246	0,249	0,273	0,273	0,273			
13	KT307785.1|_Oreochromis_niloticus	0,246	0,246	0,241	0,241	0,236	0,236	0,246	0,249	0,273	0,273	0,273	0,000		
14	Voucher_65	0,255	0,255	0,239	0,239	0,244	0,244	0,283	0,286	0,256	0,256	0,256	0,234	0,234	
15	JF781186.1|_Belodontichthys_dinema	0,255	0,255	0,239	0,239	0,244	0,244	0,283	0,286	0,256	0,256	0,256	0,234	0,234	0,000

CONCLUSIONS

The molecular marker, a 570 bp region of the mitchondrial cyctochrome c oxidase I gene (COI) has been successfully found to be species-specific, and was also more variable between species than within species. In summary, the present study represents an important step understanding evolution relationship for teleost fish living in tropical peat swamp in Sumatra. Producing of a COI sequences from the Lubuk Lampam system also assist to the global DNA barcoding library.

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BIODIVERSITY AND CONSERVATION OF ENDEMIC FISH SPECIES IN SOME LAKES OF SULAWESI

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ABSTRACT

The diversity of freshwater fish in Indonesia is the second highest after Brazil. Biodiversity include diversity of ecosystem, species and genetic. There are 1300 of fish species found in Indonesian inland waters and in lakes of Sulawesi there are 68 species (52 endemic). The high fish diversity in inland water of Sulawesi could decline and even extinct because of over exploitation, water pollution, habitats degradation, species invasion, and water flow modification. The distribution of fish endemic species in several lakes of Sulawesi show that in Lake Matano has 14 endemic fish species, in Lake Towuti, there are 21 endemic fish species, and Lake Poso, there are eight (8) endemic fish species. There is one native fish species Anguilla marmorata *found in Lake Poso. The act of protection to endemic and native species will be discussed on manuscript.*

Keywords: Distribution, endemic, native, lakes, Sulawesi

INTRODUCTION

The number of lakes in Indonesia is approximately 1575 consists of 840 large lake and 735 small lake (Ministry of Environment and Forestry, 2014) has many type of lakes such as tectonic lake that the basin formed from earthquake activity; volcanic lake originated from volcanic activity; floodplain; and the karst (limestone lake). The profile and dimensions of some Indonesian lakes was presented in **Figure 1**.This figure, show that there are three ancient lakes named Lake Matano, LakeTowuti located at Malili Complex, South Sulawesi) and Lake Poso (located in Central Sulawesi). The age of those lake is estimated 4-12 million years (Fernando, 1984 in Whitten et al. 1997). Lakes in Malili Complex give an attention in the world because of its uniqueness, so it should be conserved. Those lakes are oligotrophic and save as either a high biodiversity of plankton, fish, shrimp, crabs, and molluscs.

In Malili Complex, there are three lakes connected each other or in a cascade stage, the uppermost is Lake Matano in the District of Nuha, and then Lake Mahalona and the lowermost is Lake Towuti in the District of Towuti. Those lake was established by the Ministry of Forestry and Environment of Republic Indonesia as a Natural Recreation Park (Anonymous, 1990). Lake Towuti conditions is classified as a natural waters and oligotrophic lake (Haffner et al. 2001). However, the conditions of lake need to be maintained continually in order to anticipate the threat of the damage as found in some other Indonesian Lake.

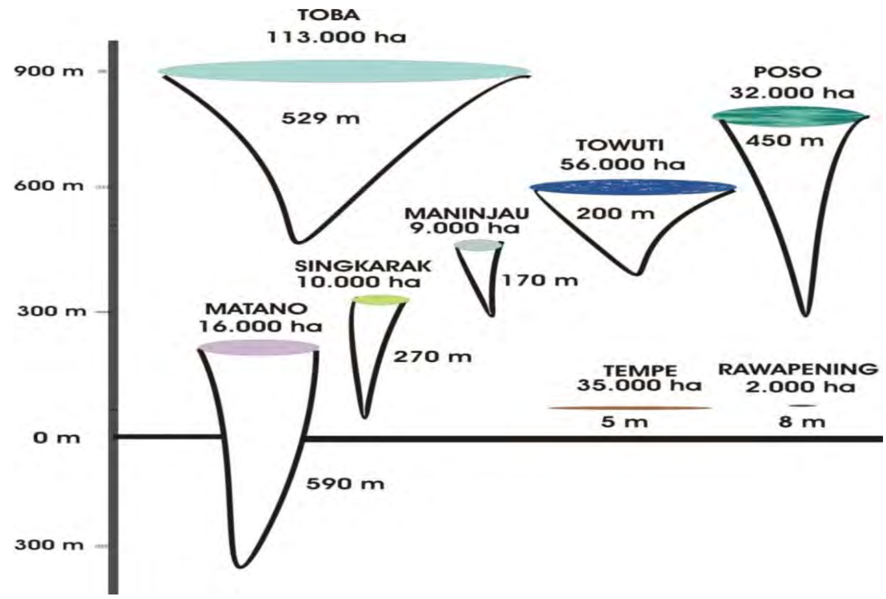

Figure 1. The profile and dimensions of some lakes in Indonesia (Source: P. Hehanussa)

Besides having endemic fish resources as economic potential, Lake Towuti and Matano is also used for hydroelectric power plant, source for ornamental fish, consumption fish, animal feed sources, transportation, ecotourism and for domestic use (Nasution, 2006). This manuscript explains biodiversity and conservation of ichthyofauna on ancient lake.

ENDEMIC FISH IN ANCIENT LAKES

In Indonesia, there are about 4834 kinds of fish (http://www.fishbase.org). Freshwater fish of Sulawesi was recognized many endemic species. Lake Matano, Lake Towuti in South Sulawesi, and Lake Poso are known as the heart of Sulawesi because the biggest and the ancient lake in this island preserves a great amount of endemic species (Mac Kinnon, 1994). Whitten et al. (1987); according to Kottelat (1990) and Soeroto (1995), that Sulawesi have 69 freshwater fish species where 52 species (77%) are endemic. Counted were 15 *Telmatherina* species live in lakes at Malili Complex, all of them are endemic species (Kottelat et al. 1993).

Some of fish have recorded in the IUCN list as a threatened species. Red List Threatened Species in 2003, namely: *Oryzias marmoratus, O. matanensis, O. nigrimas, O. ortognatus, O. profundicola*, *Dermogenys megarrhamphus, D. weberi, Nomorhamphus celebensis, Paratherina cyanea, P. labiosa, P. striata, P. wolterecki, Telmatherina abendanoni, T. celebensis, T. lagidesi, T. bonti, Glossogobius intermedius, G. matanensis, Tominanga aurea, T. sanguicauda, Mugilogobius latifrons, Stupidogobius flavipinnis, Tamanka sarasinorum*, and *Weberogobius amadi.*

According to Wirjoatmodjo et al. (2003), there are 29 fish species in Lake Towuti from 13 families which is sampling from 12 locations. From 29 species, there are 19 endemic fish species which are presented in **Table 1**, along with the status of IUCN (IUCN, 2003 and Froese and Pauly, 2004). All of these endemic fishes are caught by the people around the lake for consumption (Nasution, 2006).

Table 1. Endemic Fish Species in ancient lake

No	Familia	Species	Local name	Lake Matano	Lake Towuti	Lake Poso
1	Hemirhamphidae	*Dermogenysmegarrhamphus*	Dui-dui	-	Endemic	-
2	Hemirhamphidae	*Nomorhamphustowoeti*	-	-	Endemic, VU	-
3	Hemirhamphidae	*N. cf brembachi*		Endemic	-	-
4	Oryziidae	*Oryzias matanensis*	Padi	Endemic, VU	-	-
5	Oryziidae	*O. marmoratus*	Padi	-	Endemic, VU	-
6	Oryziidae	*O. profundicola*	Padi	-	Endemic, VU	-
7	Oryziidae	*O. nigrimas*		-	-	Endemic, VU
8	Oryziidae	*O. orthognathus*		-	-	Endemic, VU
9	Telmatherinidae	*Telmatherinaantoniae*	Opudi	Endemic, VU	-	-
10	Telmatherinidae	*T. prognatha*	Opudi	Endemic, VU		
11	Telmatherinidae	*T. opudi*	Opudi	Endemic, VU		
12	Telmatherinidae	*T. sarasinorum*	Opudi	Endemic, VU		
13	Telmatherinidae	*T. obscura*	Opudi	Endemic, VU		
14	Telmatherinidae	*T. abendanoni*	Opudi	Endemic, VU		
15	Telmatherinidae	*T. wahjui*	Opudi	Endemic, VU		
16	Telmatherinidae	*T. bonti* new record	Opudi	Endemic, VU	Endemic, VU	-
17	Telmatherinidae	*Telmatherina*sp. new sp.	Opudi	Endemic, VU	-	-
18	Telmatherinidae	*T. celebensis*	Pangkilangkasar/kuning	-	Endemic	-
19	Telmatherinidae	*T. bonti*	Pangkilang	-	Endemic	-

20	Telmatherinidae	*Paratherinastriata*	Bonti-bontibiru	-	Endemic	-
21	Telmatherinidae	*P. cyanea*	Bonti-bontisiripmerah	-	Endemic	-
22	Telmatherinidae	*P. labiosa*	Bonti-bonti	-	Endemic	-
23	Telmatherinidae	*P. woltereckі*	Bonti-bonti	-	Endemic	-
24	Telmatherinidae	*Paratherina*new sp.	Bonti-bonti	-	Endemic	-
25	Telmatherinidae	*Tominangasanguicauda*	Pangkilankasar/merah	-	Endemic	-
26	Telmatherinidae	*T. aurea*	Pangkilankasar/merah	-	Endemic	-
27	Gobiidae	*Mugilogobiuslatifrons*	-	Endemic	-	-
28	Gobiidae	*M. rexi*	-		Endemic	-
29	Gobiidae	*M. adeiae*	-	Endemic	-	-
30	Gobiidae	*M. lepidotus*	-	-	Endemic	-
31	Gobiidae	*M. sarasinorum*	-	-	-	Endemic
32	Gobiidae	*M. amadi*	-	-	-	Endemic
33	Gobiidae	*Mugilogobius*sp.	-	-	Endemic	-
34	Gobiidae	*Glossogobiusflavipinnis*	Boto-boto	-	Endemic	-
35	Gobiidae	*G. matanensis*	Butini	Endemic	Endemic	
36	Gobiidae	*G. intermedius*	Bungo	-	Endemic	-
37	Gobiidae	*G. giuris*	Anggori	-	Endemic	-
38	*Adrianichthyidae*	*Adrianichtthys kruyti*		-	-	Endemic
39	*drianichthyidae*	*Xenopoecillus poptae*		-	-	Endemic
40	*Adrianichthyidae*	*X. sarasinorum*		-	-	Endemic
41	*Adrianichthyidae*	*X. oophorus*		-	-	Endemic

Note: VU= vulnerable species

Small fish (*Paraterina, Telmatherina, Oryzias*, etc.) in Lake Towuti are called as “Pangkilang” fish and in Lake Matano called as “Opudi”. To catch these fishes, people use dip net (“bagan”). Hauled fish are dried and sold as dry fish, whereas big fish like “butini” (*Glossogobius*) is demersal fish, that catch by using seine or hook and line (“rawai”), they are sold as fresh or dried fish. Some of the endemic fishes especially *Telmatherina,* is a potential trade as ornamental fish because they have beautiful body color (**Figure 2**), among others of Telmatherinidae is *Telmatherina* like *T. celebensis* in Nasution and Sulistiono (2003) and *Paratherina* sp. There are 19 fish species found in Lake Towuti, 14 species found in Lake Matano, and eight found in Lake Poso (**Table 1**) (Wirjoatmodjo et al. 2003). *Telmatherina antoniae* dominates the fish population at Lake Matano, followed *Glossogobius matanensis.* At Lake Towuti, *Paratherina striata* dominate the lake followed by *Telmatherina celebensis* (Nasution, 2004 and Nasution, 2008). One species has been reported to be extinct, that is *Muglogobius amadi.* **Table 2** showed the function and problems of ancient lake in Indonesia.

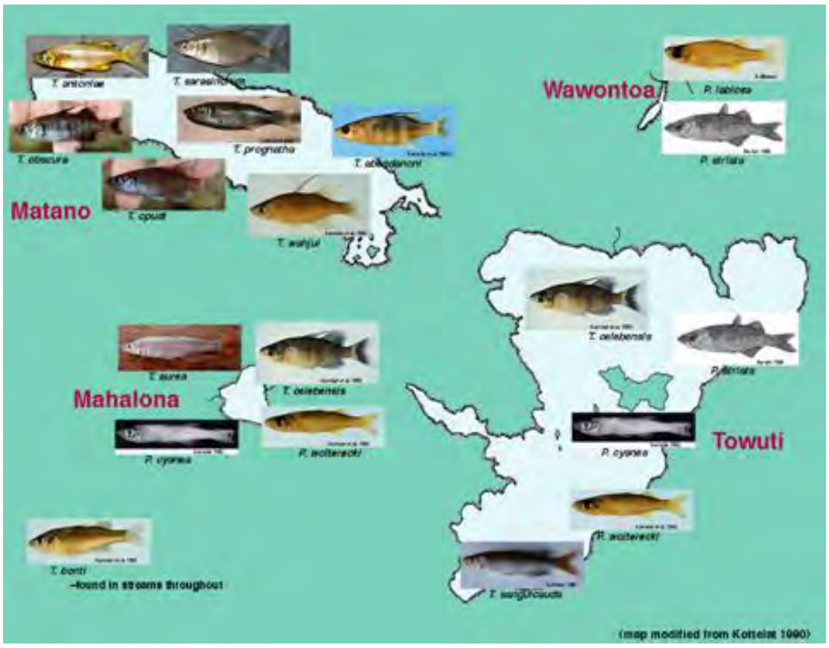

Figure 2. Ichthyofauna endemic of Lake Matano, Towuti, and Mahalona in South Sulawesi

Table 2. Function and problems of ancient lake in Indonesia

Lake	Fuctions	Problems/indication of damage
Poso	Source of water for domestic uses, agriculture, fisheries, hydroelectric power, tourism	Decreasing production of native fish (eel), nearly extinct the population of endemic fish species.
Matano	Source of water for domestic uses, tourism, fishing, rich of the endemic fish species (used for consumption and ornamental fish), the lake the world heritage designate.	Infected non-native fish species that threat endemic fish species, the potential threat of fish species is and sedimentation and pollution due to mining activities in water catchment areas
Towuti	Source of water for domestic uses, rich of endemic fish species used for consumption, ornamental fish and raw material for animal feed (Nasution, 2006), capture fisheries, and hydroelectric power	Infected not native fish species that threat the conservation of endemic species, sawmill, and sedimentation

Important Issues and Threats to Inland water fish Biodiversity

Some issues of inland waters degradation Biological diversity lost and declining such as:

1. The environmental degradation by soil erosion is caused by logging and bad land management;
2. The disposal of waste from the habitat, industries, mining and agriculture gave an impact on the water pollution of inland water;
3. Introducing of invasive/alien species;
4. Over exploitation of fish that caused not environmental friendly in fishing method;
5. Habitats destruction by sedimentation, decline in surface area and depth of lake;
6. Declining of the water quality because of pollution load from the river flow, water catchment areas, surrounding area and activities in the inland water such as fish aquaculture;
7. ~~A~~ The change of water flow;
8. The loss of the local wisdom in relation to inland water conservation.

CONSERVATION OF ICHTHYOFAUNA EFFORT

In development of conservation in the last decade (The 20th century)-has been lead into the understanding of conservation in the world to the use of biodiversity in conservation activity. Redford and Richter (1999) defines conservation is the effort to manage the benefits of natural resources (biosphere) in order to obtain the benefits that maximum and sustainable generation for now while retaining the potential to meet the needs and aspirations of future generations.

The conservation of the fish resources and their ecosystems has been set on the Government Republic Indonesia Regulation No. 60, 2007 on the chapter I articles 1 and 2. Fish resources conservation is defined as a refuge, preservation, and fish resources utilization including the ecosystem, sex and genetic to guarantee the existence, availability, of sustainability and to keep, maintain, enhance the quality and diversity of resources. Ecosystem conservation is an effort to protect, conserve and utilize the functions of ecosystems as habitat of fish resources in maintaining their life in the present and the future.

The activity of conservation is also part of sustainable development that having three dimensions, it was, economical sustainability, ecological compatibility and socio-politic acceptability (Hartoto, 2009). Sustainable development related to the inland waters is an integrated three dimensions those are the developments of inland water have to push economic growth; the developments socio politically acceptable and the developments have to consider ecological sustainability. In implementation of conservation activity should be based on the scientific information and combined with the local ecological wisdom, formulate the right policy in sustainable use of natural resources.

Participating of people is keyword in taking care of natural resources. The way is to give income alternative and utilization of the natural resources but do not bother the sustainability of resources. It is confessed that it is not easy to look for the alternative income, but the idea is that domestication of endemic fish species as ornamental fish commodity needs to be developed. The example of quite succeed in conservation of fish at some locations in Indonesia is hat entangling role of people such as management of “Bilih” fish (*Padangensis mystacoleucus*) in Lake Singkarak, conservation of “Semah” fish (*Tor* sp) in Pasaman-West Sumatra and Kerinci, and conservation of “Kancra” or “Dewa” fish (*Tor soro*) in Kuningan-West Java. Whereas, In West Kalimantan was assessed successfully in taking care of continuity of fish of Red Arawana (*Scleropages formosus*) through culture activity for ornamental fish trade. But, endemic fish from ancient lake has not cultivated yet, so still rely on fish catch from lake for animal protein source of local community. If they do not conduct an effort such as development of endemic fish domestication, then the endemic fish will have experience extinction.

THE SPATIAL ARRANGEMENT FOR UTILIZATION OF LAKE

The aquatic ecosystem in Sulawesi is generally a conservation area managed under Division of Conservation of Natural Resources, Ministry of forestry and environment. From several existing water bodies the high biological endemicity was found in three lake namely Lake Poso (Central Sulawesi), Matano and Towuti (South Sulawesi). As a conservation area, the status of those three Lakes are classified into National Tourism Park (NTP) Area.

The rules of management efforts of lake ecosystem were only focused on terrestrial are around the lake by zoning the utilization of terrestrial area, while management of water resources has not conducted yet.

NTP is a natural conservation area especially used for recreation and nature tourism. In fact, around the NTP areas is not t only used for tourism, but also used for economic activity such as mining activities, the opening of the forest, agriculture, and settlement development. The economic activities in the lake system are hydroelectric power station, smelting the ore of nickel industry, and fisheries.

The effort fishery resources preservation in those three lakes is to establish the conservation area include both water area or lake and terrestrial area around the lake. The changes of the region could change the ecosystem and needs the technological development to resolve the problem affecting of fish diversity. As an example, the logging activity around lake will affect the quality and quantity of the water and disturbing the endemic fish migration as opudi fish (*Telmatherina wahjuii*) in Lake Matano. The success of technology for example fish hatchery of lake system with a high endemicities biodiversity should be one level higher than the status of terrestrial area.

The study of extinction species included in CITES or Red data book (IUCN). Study of habitats done by the institutions related e.g. LIPI, University, fisheries research institutions who cooperate with some societies as underwriters/superintendentthe preservation of aquatic resources. The study relating to the function economical based on value to a species in domestic and for export activities.

The spatial arrangement based on bio-economi utilization

Some aspect of fishing arrangement includes: 1) number of species and characteristic a fishing gear, 2) spawning season, and 3) spawning site. Information from fisherman that there are various types of a gear used for fishing in Sulawesi. There are selective gill nets and hook and line and there is less selective fishing gear such as deep net, palawang, bungka toddo, and boso. Related to the economic sustainability a fishing gear which are not selective should be discussed together with the fisherman or if it is used, the fisherman had to follow the regulation published by local government.

From 17 species of fish found hat is in lakes and inland water of Sulawesi, only around 5 percent of the biological condition of fish was observed. This situation is a challenge to do activities of fishing based on fish resources sustainability. Several species have been known the habitat of reproduction and feeding habit. Some researchers reported that there was a group species have experienced of spawning with the peak season in March or April, September – November those species are known ~~to~~ the spawning peak more than twice a year. Based on the reproduction information, it is recommended to do fishing not in those peak seasons of spawning.

Spawning habitat of fish species has an appropriate requirements condition for species. There is species spawn in the aquatic plants (fitofil) substrate, stone (litofil), sand (psamofil), and shells (ostracofil). From the observation in Lake Matano and Towuti, there have been known that the spawning from group of *Telmatherina celebensis* and *T. bonti* related to aquatic plants (Nasution, 2000 and 2004). The spawning habitat of gobies group (*Glossogoius* spp.) suspected using sand or gravel as a substrate as a spwaning, meanwhile the *T. wahjuii* use sand for spawning.

Activities of forest logging and mining would have an impact on water turbidity. It will influence the hatching of *Telmatherina* eggs attached toaquatic plants and a stone substrate (Nasution, 2001). The construction of dam in Lake Poso also indicates that migration of catadromus specis (eel) is disturb (Muchsin et al. 2003). The condition of eco-biological has been known, therefore, it is suggested to the conservation areas an effort for preservation of germ plasm of endemic fish.

The implantation of lake conservation is needed local regulations published by local government Local regulation establish the zoning area for conservation and for fishing activity. The local legislation and policy should be established based on scientific and mutual agreement between. It is not easy to apply the local rule for local institution; therefore, it needs to develop co-management to implement fish endemic conservation.

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OCCURRENCE OF WATER-BORNE BACTERIAL PATHOGEN, *Aeromonas* sp., IN LAKE MATANO, INDONESIA

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ABSTRACT

Water-borne pathogens can be threatening substances if adequate surveillance is not routinely carried out. Pathogens in water can grow at a rapid rate if environmental factors permit. Aeromonas is one of the eminent water-borne pathogens which has a cosmopolitan distribution in various environmental settings including freshwater lake. This genus has also been associated with a variety of diseases and infections in humans and animals. Although the updates on this genus have increased and intensified, the research on this genus in Indonesian freshwater lakes is still sparse. We investigated the possible occurrence of the genus Aeromonas from water samples collected from Lake Matano, Indonesia. In August 2016, five sampling sites in Lake Matano were determined. The water samples were plated on M-Aeromonas media. After an incubation at 35^{0}C for 24 hours, colonies of interest were screened. Biochemical assay was performed following single colony isolation. Of five presumptive isolates, we managed to identify one candidate which showed remarkably similar biochemical features to those from our reference Aeromonas. MALDI TOF technique revealed that this candidate belongs to Aeromonas group. It is surprising that this Aeromonas isolate, STASATU, originated from a depth of 175 m. Even though its functional and ecological role is still unclear, this finding permits the notion that the genus Aeromonas is diverse in distribution.

Keywords: *Aeromonas* sp., Lake Matano, water-borne pathogen.

INTRODUCTION

The genus Aeromonas has been of interest to science since its first reported occurrence in 1891 (Ewing et al., 1961). The association of this genus with a variety of diseases and infections in humans and animals (e.g gastrointestinal tract syndromes, infections of soft tissue, eye and skin, respiratory and urogenital tract infections, blood-borne dyscrasias) makes it difficult not to simply ignore its existence. In the past, research on Aeromonas has identified and described outbreaks. For example, isolates of Aeromonas were identified from samples of dead fish seemingly killed by microbial infections in Yadkin and Catawba Rivers, North Carolina (Miler and Chapman, 1976). Identification of this genus was also done elsewhere in Sweden (Krovacek et al., 1995) and in China (Nielsen et al., 2001) from similar background settings. Additionally, Aeromonas was able to be recovered from broader ranges of environment which suggests that this genus shows a cosmopolitan distribution in the microbial biosphere (Janda and Abbott, 2010). It was reported that Aeromonas could successfully be recalled from diverse environmental samples such as faeces (Esteve et al., 2012), vertebrates (fish, birds, ticks, insects, amphibians), invertebrates, and water environment either in fresh or saline water (Janda and Abbott, 2010). With the advent of sequencing technology, the updates on this genus have increased and intensified.

In Indonesia, the research on Aeromonas is still sparse. The earliest reports associated with it date back to the 1980's, when a bacterial outbreak in Indonesia caused a notable effect on carp industries at that time (Hardjoutomo et al., 1981), while another study conducted by Japanese researcher also detected Aeromonas in water samples tested from Java, Kalimantan and Sumatra (Okuwaki et al., 1982). While most reports by Indonesians are not published in English, only nationally, research on Aeromonas in Indonesia has been ongoing. The monitoring and surveillance of Aeromonas in the surrounding environment, i.e lake in particular, through research is indispensable since it enables us to understand its behaviour and set up a better management plan to mitigate the worst outbreaks in the future.

In this study, we investigated the possible occurrence of the genus Aeromonas from water samples collected from Lake Matano, Indonesia. Of five presumptive isolates of interest, we managed to identify one candidate which showed remarkably similar features to those from our reference. It is surprising that this Aeromonas isolate, STASATU, originated from a depth of 175 m. Even though its functional and ecological role is still unclear, this finding permits the notion that the genus Aeromonas is diverse in distribution.

METHODS

Sample Collection

Lake Matano, a tectonic type lake, is located in South Sulawesi, Indonesia. It stretches from 2^{0}29'7" S to 121^{0}20'0" E. Water samples were collected from five designated stations throughout the lake (**Figure 1**). *In situ* measurements were done to record Dissolved Oxygen and pH level using Water Quality Checker (YSI, USA). Only in STASATU did we take water samples from the surface (0 meter) and the 175-m depth. We used the surface water for the remaining stations. ~300 ml of water was collected at each station and kept in a sterile container. This was intended for the microbiological analysis. Another ~300 ml of water was also sampled for chemical analysis (total phosphorus and total nitrogen). All water samples were stored in cool conditions (~4^{0}C) during transportation to the laboratory for further analysis.

Figure 1. Locations of sample collection.

The description of each station is summarized in **Table 1**. Station numbers 2, 4 and 5 were chosen because they are close to residential areas and were likely to have been influenced by anthropogenic activities. Stations 1 and 3 are seemingly away from direct contact with any anthropogenic influences.

Table 1. Description of the sampling stations

Station	GPS Coordinates (N, E)	Remarks
1 (STASATU)	-2.51027, 121.36531	North-western part
2 (DESANUHA)	-2.44968, 121.34013	Residential area
3 (STATENGAH)	-2.46671, 121.28385	South-eastern part
4 (DESAMATANO)	-2.46330, 121.24482	Residential area
5 (DESASOROWAKO)	-2.52350, 121.36472	Residential area

Bacterial isolation and biochemical assay

Water samples were subsampled aseptically by dispensing 150 µL and spreading on to M Aeromonas media (Himedia, India). The plates were incubated at 34-35^{0}C for 24 hr. Each had duplication. The colonies which appeared were screened according to the instructions in media usage. One representative colony was selected from each sample and underwent single colony isolation. The pure isolates were then maintained on NA (Nutrient Agar) for further analysis. NA (1 L) was composed of 5 g peptone, 3 g beef extract, 15 g agar. The incubation was at 34-35^{0}C for 24 hours. We used HiIMViC KB001 (Himedia, India) kit to reveal biochemical features for all isolates. The preparation of inoculum, inoculation of the kit and incubation (at 35-36^{0}C for 24 hours) were administered according to the instructions for use. The results were tabulated by marking the positive reaction with 1 and negative with 0. The determination of positive-negative result referred to the interpretation chart given in the instruction sheet (Himedia). Our reference Aeromonas culture was *Aeromonas hydrophila* B464 attained from InaCC (Indonesia Culture Collection) LIPI.

Bacterial identification

Prior to bacterial identification, isolates of interest were determined by a dendrogram generated using R software. Dendextend packages (Galili, 2015) were chosen to provide the Euclidean weighing upon biochemical features for all isolates. Isolate performing the closest features to those from reference Aeromonas was then identified using MALDI TOF (Matrix Assisted Laser Desorption Ionization Time of Flight) technique.

RESULTS AND DISCUSSIONS

Five isolates of interest from five sampling sites were determined based on their morphological features (i.e yellow colonies on M Aeromonas media). Single colony isolation was done simultaneously to obtain pure culture. Prior to bacterial identification using MALDI TOF technique, all isolates were biochemically checked for their features in utilizing eight types of carbohydrate (glucose, adonitol, arabinose, lactose, sorbitol, mannitol, rhamnose, and sucrose). A dendrogram generated from R shows their similarities based on biochemical test result (**Figure 2**).

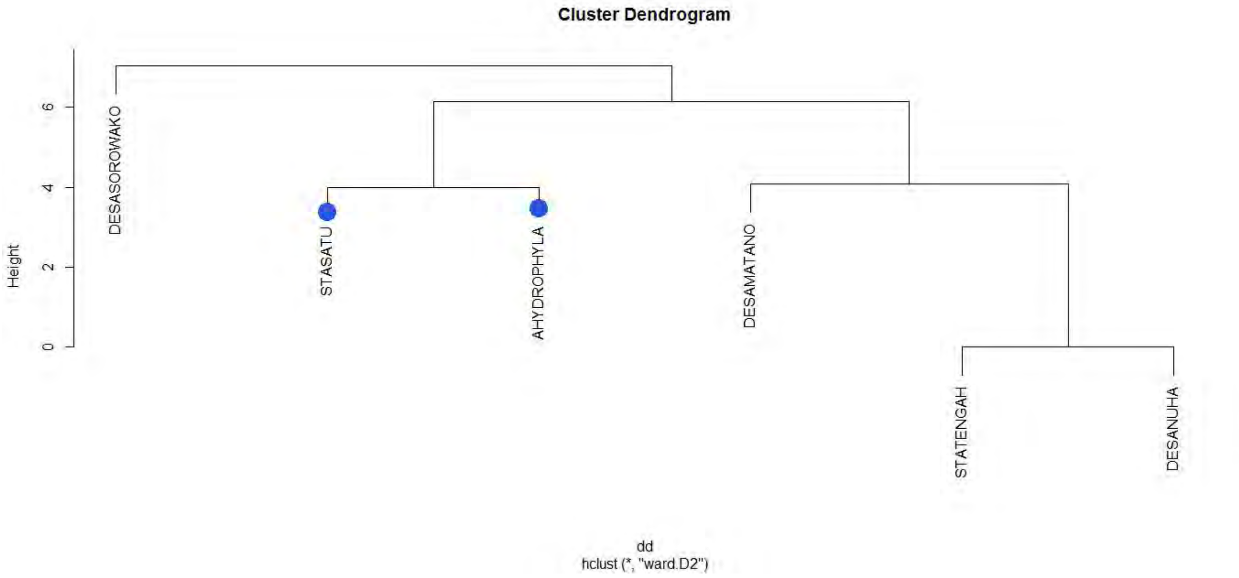

Figure 2. Cluster dendrogram of five isolates (blue dots highlight the cluster of interest)

According to **Figure 2**, isolate from STASATU clusters together with reference Aeromonas, *Aeromonas hydrophila*, whereas four other isolates cluster within different clades. This also means that STASATU isolate has more common biochemical features with those of the reference as compared to those from other isolates. STATENGAH isolate shares more similar biochemical features with those from DESANUHA isolate but not necessarily similar with the features of DESAMATANO isolate. While DESASOROWAKO isolate is grouped separately since this isolate is likely to possess relatively more dissimilar features among all.

The reference Aeromonas and STASATU isolates were able to utilize glucose, mannitol and sucrose. However, other isolates could metabolise different other carbohydrate sources. Isolates from DESANUHA and STATENGAH were able to take up glucose and arabinose but did not show the ability to use mannitol and sucrose. All isolates were shown to give positive reactions on Citrate utilization.

Since the dendrogram clustering revealed that STASATU isolate exhibited more similar features to those from the reference, bacterial identification was specifically done for this isolate using the MALDI TOF technique (Singhal et al., 2015). This technique is quite common to analyse fragile biomolecules that tend to get fragmented easily. In contrast to 16S rRNA sequencing method, the MALDI TOF technique does not require the cells to be DNA extracted and screened on gel electrophoresis, which can save time.

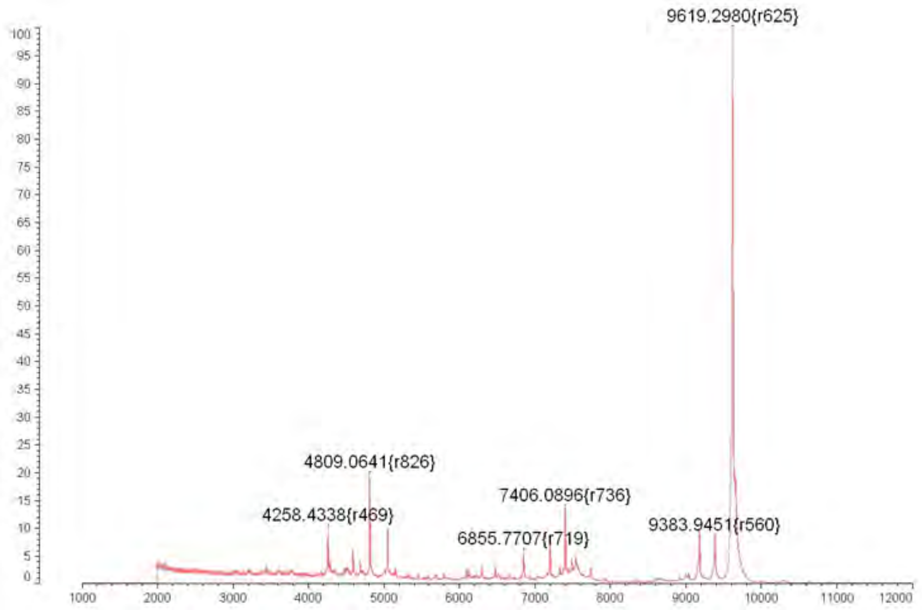

Figure 3. Spectral ionization of STASATU bacterial cells

Figure 3 shows the spectra taken from MALDI TOF ionisation of STASATU isolate. After being compared to the database, the pattern of the spectra is 88% identical to *Aeromonas sobria.*

Aeromonads are among the eminent pathogens widely distributed in various environmental settings (Janda and Abbott, 2010). The members of this genus can be detected either in an aquatic environment (Beaz-Hidalgo et al., 2015) or a terrestrial habitat (Hayase et al., 2000). Others can also be found in vegetables (Mcmahon and Wilson, 2001), food (Stratev and Odeyemi, 2016) and faeces (Waldridge et al., 2011). While most isolates of Aeromonads can be predominantly attained from the surface water of aquatic habitats (Hazen et al., 1978; Rhodes and Kator, 1994), here, we show evidence that this genus could also be recovered from a depth of 175 m in a freshwater lake. The likelihood of this finding was underestimated because we initially expected to identify Aeromonads in the water samples taken from the sampling sites near the residential areas (Nuha, Matano and Sorowako). This is because the water quality of these sites might be biochemically influenced by anthropogenic activities rather than autochthonous effects. Even though we observed yellowish Aeromonad-like colonies on the plates from residential area-related water samples, interestingly, the biochemical test and the dendrogram clustering revealed that STASATU isolate was the only isolate sharing similar features as those from the reference *Aeromonas hydrophila*. This result suggests that the failure to see the expected clustering may have been due to a need for more Aeromonas reference.
The water quality analysis of five sampling sites (**Table 2**) shows that the amount of total nitrogen (TN) of STASATU was 1.09 mg/L while those from other four sites ranged from 0.1 - 0.2 mg/L. Total phosphorous (TP) of STASATU was < 0.1 mg/L however TP from other sites varied around ~ 0.01 mg/L. This result may suggest that STASATU site favors a suitable niche for the growth of Aeromonads since nitrogen, as one of the essential nutrients for most heterotrophs, is available in a greater amount as compared to those from other sites. Even though Aeromonad existence is evident in Lake Matano, a further investigation needs to be carried out since its ecological and/or functional roles in this habitat remain unclear.

Table 2. Water quality parameters

Station	DO (mg/L)	pH	Total Phosphorus (mg/L)	Total Nitrogen (mg/L)
1 (STASATU) at 175 m depth	1.55	7.6	< 0.010	1.0972
2 (DESANUHA)	7.68	7.96	< 0.010	0.2167
3 (STATENGAH)	7.62	7.7	0.012	0.1715
4 (DESAMATANO)	7.71	8.06	0.016	0.1569
5 (DESASOROWAKO)	7.70	8.06	0.011	0.2590

CONCLUSIONS

An isolate of *Aeromonas* sp. was successfully recovered and confirmed from 175 m depth water sample. Even though Aeromonads can be commonly isolated from the surface water of freshwater lake, this study demonstrated that this group could also be found at such depth. Further investigation may help reveal its ecological and functional roles and address the question whether these bacteria are solely tourists.

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Topic 8. Ecotechnology and ecohydrology

LAKE RESTORATION IN INDONESIA: A RISK BASED ECOHYDROLOGY APPROACH

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ABSTRACT

Lakes are the last frontier in the survival and resilience of our society in that they provide us with more than just precious fresh water resources and other ecosystem services, but the health of lake's ecosystem would reflect how we value our present civilization and future wealth of our descendants. What may commonly be misperceived is that lakes in many respects are not part of rivers, e.g. their unshared features like longer retention time, different geological histories, and many lakes have no rivers and the presence of thermocline as well. 15 lakes in Indonesia have been considered to have acquired their critical stage and they suffered from a range of direct and indirect anthropogenic as well as the aggravating climate change impacts. Attempts to address some ecosystem deterioration in a number of lakes in Indonesia by introducing ecohydrological and ecotechnological measures will be described in this paper. This paper will eventually highlight the restoration within the light of risk and future uncertainties impacts reduction at the center of our sustainable lake management, in which ecohydrology remains at the core of seamless reconciliation between development and aquatic environmental conservation efforts.

Keywords: lake restoration, ecohydrology

INTRODUCTION

Indonesia is the fifth largest country in the world with fresh water resources (3,221 billion m^3/year), blessed with an extraordinary number of multi origin (tectonic, volcano-tectonic, oxbow, and enclosed) lakes, amounting to 840 lakes (covering 685,000 ha), 735 ponds and 162 reservoirs (National Committee on Wetland Ecosystem Management, 2004). Lake Toba (North Sumatra) is the largest (110,260 ha and 505 m deep), Lake Matano is the deepest (600 m) and Lake Sentarum (West Kalimantan, 126.000 ha) is richest with 10 months wet, 2 months dry 266 fish species, 18 are endemic (Haryani, 2013).

Such a huge volume of some selected lakes in Indonesia are presented in this **Table 1,** in which the ecosystem of the lake should be should be managed seriously in order to meet the needs of the people and the environment for their services

Table 1. Basic information of some selected lakes in Indonesia (Ministry of Environment, 2012)

No	Lake	Area (km^2)	Max Depth (m)	Volume (billion m^3)	Category volume
1	Batur	15,9	88	820	Medium
2	Bratan	3,85	22	49	Small
3	Buyan	3,9	87	160	Medium
4	Kerinci	46	97	1600	Medium
5	Limboto	56	2,5	159.566	Large
6	Maninjau	97,9	169	10.400	Large
7	Matano	164,1	590	55.015	Large
8	Ranau	125,9	229	21.950	Large
9	Rawa Pening	25	14	52	Small
10	Singkarak	107,8	268	16.100	Large
11	Tamblingan	1,9	90	27	Small

In entering the 21st century, there exist increasingly complex problems of the lakes whereby the function is decreasing over time due to both increasing utilization of the resources of the lake and in line with population growth. The overall lake ecosystem in the catchment area, water bodies and in the riparian are heavily affected by human activities. Lakes ecosystem suffers from heavy pollution, siltation, ecosystem deterioration and fish killed. Sewage, sludge, garbage, and even toxic pollutants are all dumped into the inland water ecosystem. These have resulted in the decline in the carrying capacity of the ecosystem to support the productivity of water. The water crisis is not only from water scarcity, but also from a lack of access to affordable clean water. During the First National Conference of Indonesian Lakes in 2009, an important agreement by 9 line Ministries: Environment, Home Affairs, Public Works, Agriculture, Energy and Mineral Resources, Research and

Technology, Maritime and Fisheries Affairs, Culture and Tourism, and Forestry has been achieved to Sustainably Managed the lakes. The Bali Agreement has stipulated 7 programs for 15 priority lakes: lake ecosystem management; thorough science, technology and impact based analysis in the use of lake resources; the development of lake monitoring, evaluation and information systems; preparation of adaptation and mitigation measures on the impact of environmental changes to the lakes; capacity building, regulation and coordination; improvement of community participation; and sustainable funding.
The 15 National Priority Lakes (NPL) have been chosen based on 6 criteria:

1. Lake degradation: sedimentation, pollution, eutrophication, as well as the decreasing quality and quantity;
2. Lake Utilization: hydropower, agriculture, fisheries, raw water, religious and cultural values, tourism (including the uniqueness of the lake, accessibility, infrastructure, and the surrounding communities);
3. Commitment of Local Government and the community in the management of the lake (Master Plan, Legislation, the Management Board);
4. Strategic value/uniqueness of Lake: how strategic is its function in the national interest;
5. Biodiversity (endemic fish communities, birds, and flora diversities);
6. Disaster and climate change risks.

These 15 national priority lakes are 4 lakes in Sumatra (Lake Toba, Maninjau, Singkarak, Kerinci), 5 lakes in Sulawesi (Tondano, Limboto, Poso, Tempe, Matano), 2 lakes in Kalimantan (cascading Mahakam Semayang-Melintang-Jempang, Sentarum), 1 lake in Papua (Sentani), 1 lake in Banten (Rawa Danau), 1 lake in Bali (Batur), and 1 lake in Central Java (Rawapening).
Inescapable use of lake water for hydropower energy plants has been done in 9 large lakes of 15 priority lakes such as Lake Toba, Maninjau Lake, Lake Kerinci, and Lake Singkarak, These 15 priority lakes are also of tourism value, given their natural beauty. There are still many other lakes apart from the 15 lakes that give incomparable natural beauty, and these will be the next and to be rescued in the next batch of our national priority lakes.
Lakes in Indonesia are global heritage that must be restored and protected to enhance their life-supporting ecosystem services, including those associated with their linkages to other aquatic ecosystems. Therefore, the management and sustainable use require a wise and adequate scientific foundation, including the likely interdisciplinary adaptation and mitigation efforts and the active societal role in maintaining the inland water conservation in Indonesia as well. Hence, a reformed management of the lakes in Indonesia is inescapable in order to comply with the sustainable use of different end users like clean and drinking water supply, transportation, fishery and agriculture, industrial use, waste disposal, energy generation, natural habitat for fauna and flora, climate regulator and cultural activities. Yet, referring back to the agreed 6 criteria to select any inclusion of a lake into the 15 NPL, the disaster and climate change risks is likely the least known aspect. It is therefore the strategic intention of this paper to highlight the disaster and climate change risks factor to be incorporated in the future selection and restoration of the NPL, in which ecohydrology will be at the heart of the approach. An example of how this has been attempted in Limboto Lake (North Sulawesi) is presented. This will be preceded by a review of the ecosystem of lake and the anthropogenic and climate change impacts. Finally, a paradigm shift and the need to develop a national rapid as well as long term preparedness capacity on lake resilience will be presented.

ECOSYSTEMS OF LAKE: UNIQUENESS AND THE ROLE AS HABITAT OF FRESH WATER FISH AND HUMAN LIFE SUPPORT

The unique lake ecosystem settings, which are not always be part of any river system, are typified by their water retention time, their geologic history, the presence of thermocline layer, their depths which could be much lower than the sea level and they formed crypto depressions.
Lake ecosystems are unique when compared with other water resources, especially river ecosystems. *First*, the lake's water retention time can reach yearly or even decades, while rivers and reservoirs are in days, weeks to months. This difference in retention time creates a very fundamental difference in preparing the management plans, especially when dealing with the prevention and control of pollution. *Second*, lake is not part of the river because it is formed through a different geological process. Many lakes do not have rivers that flow its water into the sea, and these are called enclosed lakes, such as Lake Batur, Bratan-Buyan-Tamblingan Lake complex in Bali, crater lake in Kelud and Galunggung volcanoes, lake Subsidence in limestone areas in the islands of Eastern Indonesia (all in Saparua Island, Kei Kecil, and Biak).
Third, and this is especially found in the lakes in Indonesia, *i.e.* the existence of thermocline layers in some lakes reaching the depths of greater than 100 m. Thermocline is a water layer with a very sharp water temperature drop (greater than 1^{o} C). The thermocline layer is between the warmer and relatively stable epilimnion layer and the cooler and homogeneous layer of the hypolimnion, all of which constitute the vertical lake temperature stratification. Examples are Lake Toba, Lake Poso and Lake Matano. The temperature profile at Lake Matano shows the presence of a thermocline with a water temperature difference between the surface

layer and those at a depth of 80 m to 270 m, and this goes further to the bottom of the lake at 590 m with no significant temperature difference. The surface temperature of 27.7° C decreases to 27.3° C at a depth of 80 m, then dropped to 25.6° C at a depth of 270 m. No visible temperature drop from this depth to the deepest base. The presence of small anomalies of the curve at 80 m and 120 m gives an indication that there are two strata of water columns leaving little marks on the temperature curve at the depth.

Fourth. The depth of a lake can be below the sea level or cryptodepression. For example, Lake Sentani with a lake base located 70 m below sea level. Matano Lake forms cryptodepression with a depth of 595 m or a lake bottom which is 203 m below sea level. Tolire Lake in Ternate is also a lake that is essentially 19.9 m below sea level, whose formation is related to the ancient Gamalama volcanic processes. Apart from the uniqueness mentioned above, each lake basically has a different behaviour or trait, due to their specific formation.

There are 10 classes (**Table 2**) of lake type/morphogenesis proposed by Hehanussa & Haryani (2009): tectonic lake (eg D. Matano), volcano-tectonic lake (eg D. Toba), caldera lake (eg D. Batur), subsidence lake (D Tolire), floodplain lake (D. Semayang) and oxbow lake (D. Teluk), strike slip fault lakes (eg D. Singkarak), dilutional lakes (eg D. Kei Kecil), estuary lakes (eg. Aiduna, Segara tillers), artificial lakes/reservoirs (eg Saguling reservoir), mine remnant/excavation/bottom (in Bangka Island). Such a morphogenetic classification should form the basis in the lake ecosystem management planning, whereby a lake should be treated differently, depending on the characteristics and condition of the lake.

Table 2. Indonesian lake morphogenesis (Hehanussa and Haryani, 2009)

No	Type/Lake Morphogenesis	Examples
1.	Tectonic lake	Lake Kerinci, Matano, Paniai
2.	Volcano-tectonic lake	Lake Toba, Maninjau, Tondano
3.	Caldera lake	Lake Batur, Bratan, Buyan
4.	Collapse/subsided lake	Lake Tolire
5.	Oxbow lake and floodplain	Lake Semayang, Melintang, Lake Teluk
6.	Faulted lake	Lake Singkarak, Ranau
7.	Dissolved lake	Lake Kei Kecil
8.	Estuarine lake	Lake Aiduna, Segara Anakan
9.	Artificial lake/reservoir	Saguling, Jatiluhur, Rawa Pening reservoirs
10.	Abandoned mining pit	Kolong in Bangka

The lakes in Indonesia also become the habitat of various freshwater fish. Even a place to live Indonesian native fish such as bada fish (*Rasbora argyrotaenia*) in lake Maninjau, West Sumatera, Telmatherina type only found in Malili Lake complex, *M. praecox* only found in Iritoi and Dabra Irian. Lake Sentarum area which is the site of Ramsar is a habitat for 250 species of fish such as native fish and highly commercial ornamental fish Arwana, botia, jelawat, belida, and semah. The volume of capture fisheries production in lakes throughout Indonesia in 2011 reached 56,006 tons with a value of more than Rp. 640 billion. The economic and nutrition values of the lake have been tremendous when added to the production of aquaculture the source of animal protein, mainly because of the large volume of water in the lake in Indonesian lakes. From the fishery point of view, the presence of eel populations living in Lake Poso has added another uniqueness of Indonesian lakes. There are five types of eels in the estuary of the bay forming the downstream of Poso River: *Anguilla marmorata, A. celebesensis, A. bicolor pacifica, A. interioris and A. borneensis*, of which eel of *Anguilla marmorata* is the dominant species in Lake Poso. The past production has once reached 41.5 tons in 1990 and this, however, has been continuously decreased due to: (i) overfishing, especially during the downstream or seaward eel migration to spawn, and (ii) the lake ecosystem degradation. Annual eel production decreased, in 2009 the eel production only about 6.49 ton, and the volume of eel catches in public waters since 2007 – 2011 decreased by 8.06%, and in the year 2010-2011 decreased by 51.52%. The recent development of hydropower downstream of Poso Lake will make the situation even worse to the eel population and may end up with the extinction of the eel population from the Lake Poso.

ANTHROPOGENIC AND CLIMATE CHANGE IMPACTS

The problems of the lake can be attributed to both natural phenomena and anthropogenic related activities, such as intensive exploitation in fishing and cultivation, the impact of water transport mechanization, and industrial, agricultural and domestic waste disposal, as well as the cumulative impact of land use change in the upstream and in watershed areas. Whole lake ecosystem consists of the catchment area of the lake ecosystem, the body of water and the affected lake border by direct human activities. The impacts are present in the decline of chemical and physical quality of the water, and the indirect impact is the decline in the carrying capacity of the ecosystem to support the aquatic productivity. Four limnological impacts have been identified by Haryani & Hehanusa (2002) when dealing the lake's ecosystem carrying capacity is surpassed: (a) reduction in fisheries productivity, (b) growth of weeds, (c) contamination of water resources and germplasm, (d) siltation of the lake leading to the limited use of the water for transportation during the dry season and, otherwise, flooding in the rainy season. These increasing threats and their impacts on the economy and the preservation of natural resources are described herewith.

The decline of fishery productivity in the lake includes pollution, siltation, overfishing and destruction of riparian areas. Pollution leads to a decrease in lake water quality and this may have gone beyond the tolerance of the aquatic organisms including fishes. Suspended solids in water could cause water turbidity and influence the fishery resources in spawning areas and in fishing areas. Pollution, turbidity, and siltation would also bring indirect effects on the life of fish with the loss of other aquatic organisms which form the food web like phytoplankton, zooplankton, benthos, etc. Siltation causes a decrease in the living space of fish, especially in wetland and will increase the water temperature. Eventually these will cumulatively destroy the special environment of the spawning area of the fish. Such a situation had happened in Lake Tempe, South Sulawesi, where fishery production in 1948 of 58,000 tons has decreased to 10,000-15,000 tons alone due to reducing depth and the shrinking lake by sedimentation.

In addition to providing the source of protein in lakes like Lake Tempe, South Sulawesi, other lakes in Kalimantan, Sulawesi and Papua are also habitat of germplasm of ornamental fish. Several endemic ornamental fish producers are lakes in Jambi, Malili Lake complex: Matano, Mahalona, and Towuti in South Sulawesi Province. Some well-known species from Papua include *Iriatherina werneri, Sclerophages jardini, Glossolepis, Chilaterina* and *Melanotaenia*. The high diversity of ornamental fish plays a direct role to the people's economy and local income sources. Human activity in the Poso river banks and surrounding tributaries causes the loss of habitat for elver eel, resulting in a decrease in the elver population of eels that will migrate back to Lake Poso.

Rapidly growing aquatic plants such as water hyacinth (*Eichornnia crassipes*) in some lakes, has made the lake becomes too fertile because of the input of nutrients from domestic waste as well as uncontrolled use fertilizer. If most of the surface of the lake is covered by plants, this will inhibit the penetration of sunlight into the water, resulting in disruption of the photosynthesis processes and lower the water productivity as well as disturbance to water transportation. Organic and non-organic pollution related to human activities such as domestic waste disposal, agricultural wastes, and industrial wastes from the surroundings

Rampant algae or algae blooming have disrupted the fish life as well as other biota in the lake and, naturally, will influence the scenic beauty of the lake. Algal blooming and mass mortality of fish in Lake Maninjau happens almost every year since 2001, partly due to natural processes of sulphuric outburst accompanied by a surge in activity aquaculture floating cage which exceeds the carrying capacity of the lake, have all made the accumulation of organic matter from the residu of the fish feed and trigger excessive growth of phytoplankton. This is also exacerbated by the changes in lake surface water flow due to the damming of outflows for hydropower purposes. This condition resulted in the decrease of water quality of the lake thus affecting the utilization of lake water as a source of drinking water, recreation, industrial purposes, tourism, and fisheries. Fish life in the lake is also disrupted because of the reduced levels of dissolved oxygen in the water due to the use of oxygen by bacteria for the decomposition of dead algae populations.

Heavy metal pollutants are extremely hazardous for human life that consume lake water well as the indirect effects from consuming the fish and other aquatic organisms that accumulate heavy metals. Silting in the lake sediments occur due to input both from the surrounding lakes (riparian zones Lakes) as well as river-borne erosion due to erosion in the watershed area. Erosion occurs naturally and as a result of human activities such as intensive logging and cultivation of land around the lake for agricultural land. Lake siltation has influenced the transportation activities through the lake, the fish habitat loss, disruption of the reproductive processes with the consequent decrease fisheries productivity, and can further trigger the growth or water weed emergence, and reduced the space for fish / aquatic mammals. Examples of these phenomena occurred in flood plain lakes of cascading Semayang – Jempang – Melintang, East Kalimantan, wherein the Mahakam dolphin mammal populations (*Orcaella brevirostris*) decreases because of continuously decreasing habitat, which in turn interfere their food web.

The climate change impact on the lake ecosystem can be grouped into four, namely: (i) impacts on the physical characteristics of the lake, (ii) impacts on lake chemical characteristics, (iii) impacts on lake biological characteristics, and (iv) impacts based on lake genes type. Climate change affects the ability of the lake as a productive resource for humans. Increasing air temperature, changes in the duration of dry season or the rainy season will affect the volume fluctuations in of the surface water of the lake. Rainfall system and patterns change in a season may potentially shift of lake connectivity. A lot of oxbow lakes in Kalimantan are connected with the river periodically or permanently depending on the seasons. The lakes are the shelter, the feeding place, and the reproduction site for the fish. When the connection with the river is cut off due to the long dry season, the ecosystem will be disrupted resulting in a decrease in fishery productivity. Example of this can be found in Kapuas Hulu District, in which 115 lakes with an area of 120,000 ha, mostly are flood related lakes or flood swamps connected to the river. Decrease in rainfall as a variable input of watershed components due to global climate irregularities will affect the input of river flow which will eventually affect the lake water level. The shift of precipitation (P) relative to evaporation (E) (P/E ratio) causes changes in the lake's water balance and lake water retention time, as well as depth and extent. Flood plain lake is particularly susceptible to P/E changes due to the relatively shallow depth in comparison with the size of the area to the volume (Ludwig & Moench, 2009).

The effects of climate change coincide with the increasing need for irrigation during the drought conditions, and the use of water by humans will lead to a 50% reduction in lake area. Increasing the temperature and speed of evaporation will affect the stratification of Lake Matano, Lake Toba and Lake Batur. The extent to which the effects of climate change and the rise in global temperatures on the shift of thermocline layers in Indonesian lakes still require more in-depth research. The impact of climate change on the lake's most basic chemical characteristics is the increasing frequency of heavy rains that increase the flow of water into lakes. This will lead to increasing rate of contaminants and sediments into the lake or river resulting in degradation of water quality. Water retention time in the lake affects the chemical composition of lake water as well as the process and duration of biogeochemical interactions with lake sediments and littoral regions. In lakes that typically have an anoxic lake floor, with longer water retention due to reduced precipitation will lead to phosphorus accumulation and eutrophication. This happened in Lake Maninjau which has a long water retention time of about 27 years and Lake Toba about 90 years (Haryani, 2013). The opposite situation occurs when the precipitation and inflows increases. This will be increase the nutrient and phytoplankton leaching that will decline in productivity of algae.

Further effect is to increase erosion of catchment areas and enrichment of soil nutrients entering the lake. Temperature changes will affect the function of ecosystems especially when interacting with chemical contamination. When warmer water is associated with excessive nutrients derived from agricultural fertilizers (brought to the lake by rain), eutrophication and explosive plankton growth in the surface of the lake will decrease dissolved oxygen in the waters, thus endangering the life of other organisms in the lake ecosystem. Small changes in lake water levels due to water balance shifts cause this environment to be vulnerable to climate change. Changes in connectivity between aquatic habitats due to lowering or rising water levels will affect the composition of aquatic biota species, especially fish communities, such as in the flood plain lakes and swamps in Kalimantan. The light and nutrient changes available due to climate change have a qualitative influence on composition and diversity at the primary producer level which in turn induces a higher trophic level. Changes in the lake also affect the composition of macrophyte community species in the littoral zone, which implicate birds, fish, and other biota that depend on the existence of the plants. Many fish species are sensitive to slight temperature changes, and an increase in temperature due to global warming is thought to cause a shift in the distribution of the geography of various taxa.

Climate change also affects the migration behaviour of some species of fish due to changes in rainfall and seasonal patterns that have implications for shifting lake connectivity to rivers that function as migratory pathways of the species, due to the disruption of fish migration paths from lake to river to sea or vice versa. Fish will ultimately have difficulty to feed or reproduce according to their migration purpose. The interruption of the migration processes will endanger the migratory fish species to extinction.

The impact of climate change to lake water conditions depends on the type of lake (volcanic, tectonic, and flooding), the ratio of the lake area to the area of the catchment area, and the height of the sea level. Possible impacts of climate change on lakes have been analyzed in two types of lakes: Lake Maninjau-West Sumatra as volcanotectonic lake and Semayang – Melintang Lakes in East Kalimantan as a flood plain lake (Haryani, 2009). The degradation of lake water quality induced by climatic changes is clearly of a magnitude that should be incorporated into long-term management strategies for all lakes, as demonstrated for the New Zealand lakes (Trolle et al.,2011).

LAKE RESILIENCE, DISASTER RISK REDUCTION AND ECOHYDROLOGY

A resilient system is one that tends to maintain a given state when subject to disturbance (Holling, 1973 *in* Carpenter and Cottingham, 1997). Lakes are routinely disturbed by many kinds of events. Inputs of solar radiation fluctuate from second to second. Pulses of chemical inputs occur with storms (at intervals of days to weeks). Fluctuations in climate affect seasonal phenologies and budgets of heat, water, and nutrients from year to year. Exceptionally large cohorts of fishes recruit every few years and restructure the food web for their lifetimes. Fires or other disturbances alter watershed vegetation at intervals of decades to centuries, thereby causing a pulse of nutrients to the lake and changing the water budget (through changes in evapotranspiration) as the vegetation regrows. Extreme changes in climate (with cycles of centuries) change hydrologic connections, water level, the shape of the lake, or even cause the lake to disappear for a period of time. In the normal dynamics of lakes, ecosystem processes are maintained despite moderate and continuous disturbances originating in the lake, its watershed, and its airshed (**Fig. 1**). This resilience involves several mechanisms, which have different ecosystem components and distinctive spatial locations, spatial extents, and return times (Holling, 1973 *in* Carpenter and Cottingham, 1997).

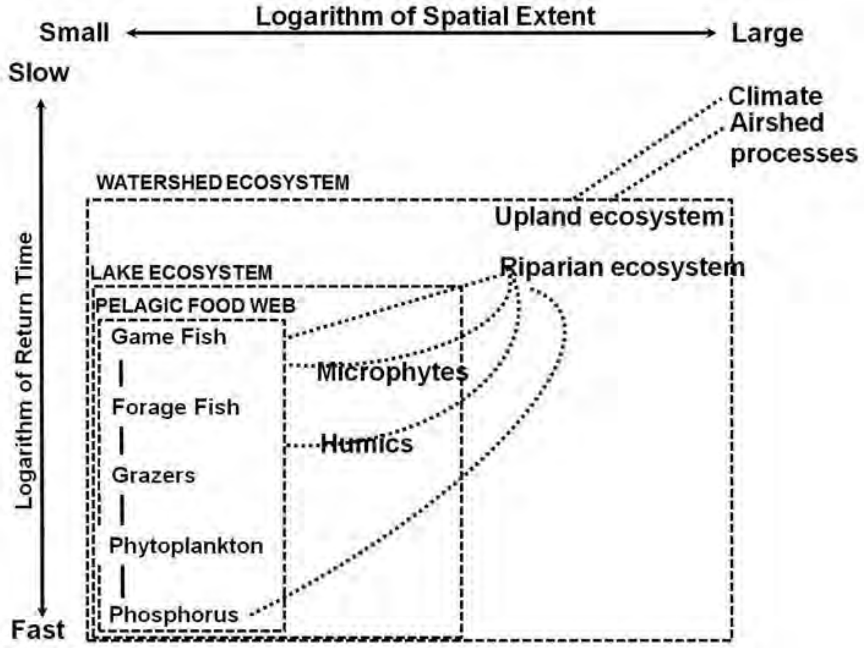

Figure. 1. Major interactions in the normal dynamics of lakes as a function of spatial extent (x-axis) and return time (y-axis). Boxes enclose 3 commonly-recognized subsystems: the watershed (largest box), lake (medium-size box), and pelagic zone (smallest box) (Holling, 1973 *in* Carpenter and Cottingham, 1997)

When talking about disaster risk reduction, there are several vocabularies we are dealing with, i.e.hazards, vulnerability and risks. *Vulnerability* refers to exposure of any system to physical and socio-ecological threats and inadequate capacity of the system to cope with the probable external *hazard* which threat the system. While *risk* is basically the entity which may be borne by the system which is proportional to the *hazard probability* and *the estimated lost*. The better the preparedness of the system, the smaller the risk. However, we will have to keep in mind that risk is decision maker's and analysts's perception and interpretation. This means, for example, although the risk is high, the decision maker or the person may ignore it and disaster could then happen.

The problems which are suffered by the lake ecosystem we are dealing with today is mainly due to "opposing" views between the so-called the "environmentalist" and "developmentalist", in a way that the two camps tend to stick themselves in their conventional believes and practices. The environmentalist tends to think and move their actions within the strict preservation and conservation terms, mainly due to the facts that degradation has impacted the severe consequences to the environment and their services. On the other hand, the developmentalist continues to pursue their economic benefit by neglecting the negative impacts of their unsustainable practices that eventually have created (ecological) disasters and environmental pollution. These two opposing camps can be united if both parties reconcile themselves in preparing for the future plausible jeopardizing impacts in the forms of disasters, pollution, and other forms decreasing environmental services as well as diminishing natural resources. The two parties can meet their interest when they mutually are talking in risk language, the ecosystem risk assessment. Ecosystem risk is the thing that will be shared by the conflicting parties, in that:

- The developmentalist will reduce the probabilities of the disaster events and the pollution, while they can still enjoy the growth and economic benefit, and
- The environmentalist will be confident that the ecosystem services will not be jeopardized and the ecological integrity remains intact

This paper proposes ecohydrology to be placed within the framework of Lake Resilience. Risk assessment is the instrument that will be beneficial for both development purposes and environmental conservation. Risk is a major factor in dealing with resilience.

There are three components when we are talking about Lake Resilience: Lake's ecosystem integrity, (Lake Disaster) Risk Management, and Climate Change (CC) (**Fig. 2**). *Lake's ecosystem integrity* deals with intactness, completeness and integration. Ecosystem Integrity is a framework of precaution of ecological risks, preserving the power of nature, long-term development basis for human life, protection of processes and structures being precautional for self-regulation. *Lake disaster risk management* is an analytical-to-application process that can be integrated and leveraged to help achieve lake resilience. The *climate change framework* builds the resilience to withstand impact of climate change, including but not limited to lake's ecosystem change and diminishing aquatic resources. These three elemental constitutions will finally form the Lake Resilience, that is about being prepared for a host of unforeseen shocks and stresses, far beyond those attributable to climate change. Ecohydrology will then be positioned in this Lake Resilience framework in that it is the common field shared by the previous three major components (ecosystem integrity, Disaster Risk Reduction-DRR, and CC) and a powerful tool towards building the Lake Resilience. It is proposed that in the future, ecohydrology will not be only dealing with ecosystem integrity, but also to address the disaster risk reduction and the adverse impacts of climate change. This is our common and emerging challenge to jointly build the resilience of our previous lakes. An initial effort to attempt restoring the Lake Limboto, North Sulawesi, by implementing ecohydrology has been described elsewhere by Chrismadha *et al*. (2007, 2011). With the forest area in Limboto catchment 14.893 ha (16,37% of the total catchment), this is far below the minimum of 30%. Forest degradation aggravates the soil erodibility to become critical land covering 26.097 ha (12.573 ha in the forest and 13.524 ha outside). Erosion rate in Limboto catchment is 9.902.588,12 ton/yr or on average 108,81 ton/ha/yr and the sedimentation in Lake Limboto is 0,438 mm/yr. These have ultimately changed the depths as well as the surface area of the lake (**Fig. 3**).

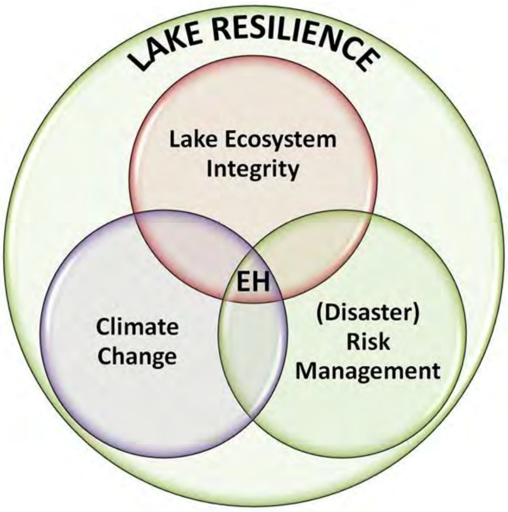

Figure. 2. Lake resilience framework which integrate the lake ecosystem integrity, Lake Risk Management and Climate Change. Ecohydrology is the compromising and solution to address and improve the lake resilience.

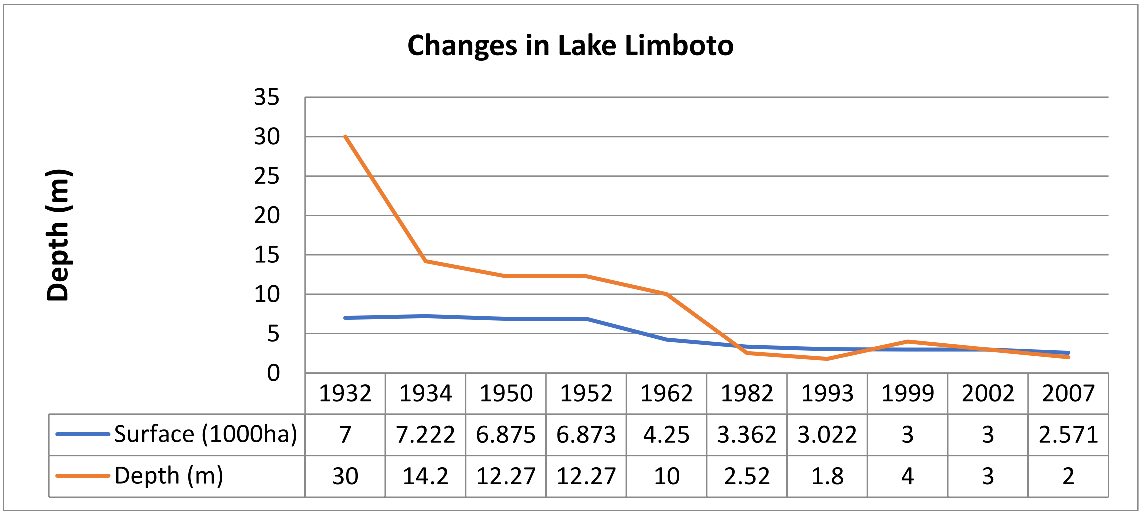

Figure. 3. Diminishing depths and surface area over time (1932 – 2002) in Lake Limboto, North Sulawesi (data after Chrismadha et al, 2007)

Since the main problem of the lake is sedimentation, the most current morphometry status was taken to be the first consideration, followed by the hydro-climatological conditions as well as the biotic community and productivity and anthropogenic activities surround the lake area. Chrismadha et al. (2007) mentioned that more than 1000 ha emerging lands has to be removed. A 'cut and fill' method is suggested for the most efficient land removal, as it particularly avoids the needs of dumping area and transportation cost. In this case, land cutting is directed to form some bays which retain the hydrological function, while the uptaken soil dumps out next to the bays to form some extended inlake piled up lands that can be functional for both settlement or agricultural area. This is to find a balance between preservation and utilization of the ecosystem to generate livelihoods for people without compromising environmental values. It is and ecohydrological approach which integrates rehabilitation of the lake hydrology and habitat functions to restore Lake Limboto in a more effective and efficient way.

CONCLUDING REMARKS

Given the critical status of many of our lakes, notably the National 15 Priority Lakes, it follows that a paradigm shift is inevitable, due to the serious impacts of lake degradation and the extremely poor ecosystem services which we have had benefited in the past. The paradigm shift moves forward our conventional framework from Lake Conservation through Lake Risk Reduction to finally Lake Resilience. In disseminating the need to conserve our lakes while sustainably use them, we should develop scenarios of the likely escalating ecological disasters and the disrupting ecosystem services in the endangered lakes. We would foresee that ecohydrology will play its role as part of the risk management. We should then develop the capacity and the culture of preparedness by building and installing environmental EWS (Early Warning System) to safeguard aquatic environmental services and livelihood, as well as a tool to identify which related terrestrial environment that should be restored. It should be emphasized that Ecohydrology be positioned as part of disaster preparedness tool. We should further plan and strengthen the institutional development to accommodate the paradigm shift along with the continued and consistent public awareness.

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ECO-FRIENDLY LARGE-SCALE TESTS TO REDUCE PHOSPHORUS IN RIVER WATER BY ELUTING IRON ION SYSTEM

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ABSTRACT

A large-scale demonstration tests were performed. The purpose was to confirm a reduction in phosphorus in river water using technology of eluting iron ion bodies and to suppress generation of phytoplankton and water purification in the rivers flowing into The Lake Kasumigaura, Ibaraki Prefecture, Japan. The system consisted three processing 25 m^3 tanks as $10m^3$, $10m^3$ and $5m^3$ were developed based on a system of rolling dram cartridge in order to elute iron ions, Fe^{2+} continuously. The flow rate of treatment water was 100-300m^3/day and the volume 384kg of eluting iron ion bodies were referred from a middle scale demonstration test of $3m^3$ single processing tank and laboratory column tests. The reduction rate of PO_4-P of treatment raw water recorded 31-47% relative to the flow rate. This ensured the authors achieved the targeted value of reduction over 30% of PO_4-P through the series of tests. These tests found that it is important a deposition process to reduce PO_4-P and TP under gentle velocity of treatment flow. DO and pH of the treated water to be discharged into the river was a value that fully satisfies the environmental regulations. Through the results, the authors aim to develop a more cost-effective system construction through effective iron ion elution.

Keywords: eluting iron ions, large scale tests, phosphorus reduction, phytoplankton, water purification

INTRODUCTION

The water quality of ponds and lakes has deteriorated due to the phenomenon of eutrophication. An outbreak of phytoplankton has resulted as part of this process. In order to improve the water quality of these park ponds and dam lakes, the authors have been working on technology to elute iron ions (Fukuda, N. et al., 2014, 2015). **Fig. 1** shows an example of field tests on the improvement of water quality in a dam lake through a floating system which elutes iron ions.

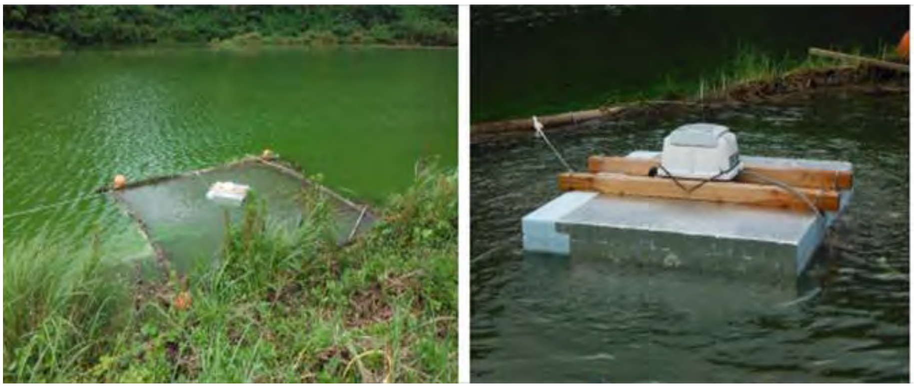


Figure 1. Field tests on water quality improvement in dam lake by eluting iron ions (Fukuda, N., et al., 2014, 2015)

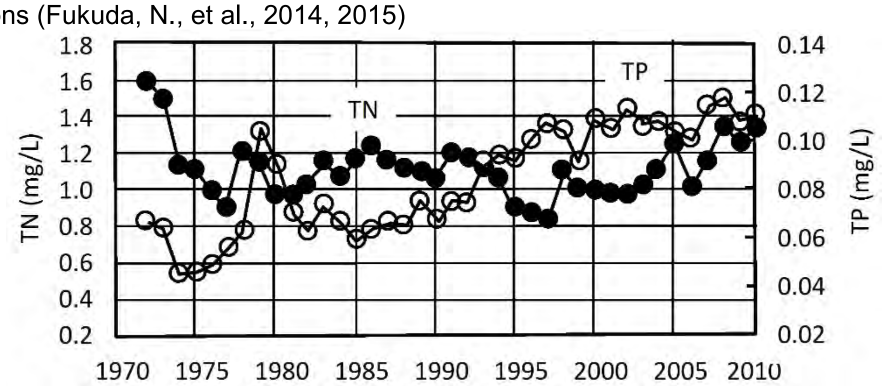


Figure 2. Changes of annual average of TN and TP in the Lake Kasumigaura

The phenomenon of eutrophication by phytoplankton has also long been a problem in the Lake Kasumigaura. **Fig. 2** shows the increase trend of annual average of TP and TN in the Lake Kasumigaura from 1972 to 2010 (Ibaraki Kasumigaura Environmental Science Center, 2012). Through the decrease of PO_4-P by eluting iron ions, Fe^{2+} could suppress generation of phytoplankton in the rivers flowing into the Lake Kasumigaura. To confirm this effect, the authors have been conducting laboratory and field tests for eutrophic ponds and lake of dam. Fe^{2+} can be generated by submerging iron ion eluting bodies (hereafter, D-material) in water. Based on the results, middle scale demonstration test using the $3m^3$ water treatment tank that was conducted from 2013 to 2014 (Fukuda, N., 2015) and large-scale demonstration tests using three water treatment tanks of $25m^3$ was conducted from 2015 up to now. The results of decrease effect of PO_4-P and TP during large scale demonstration tests under flow rate from 100 to 300 m^3/day are mainly reported in the paper.

METHODS

Principle 1. How to elute iron ions

Fig. 3 shows how to elute iron ions in water. When metallic iron and carbon are attached together underwater, local current is generated by a difference in electro-negativity that occurs between both materials. From this mechanism, metallic iron ions will be eluted into the water (Patented technology by Sugimoto)

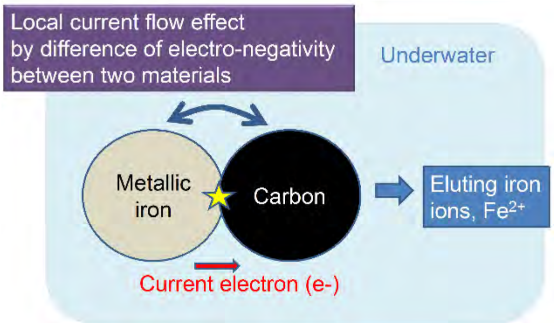


Figure 3. Mechanism of eluting iron ion by attaching metallic iron and carbon in the water.

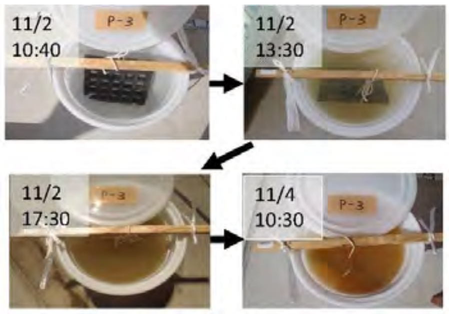


Figure 4. Eluted Fe^{2+} is immediately changed to ferric hydroxide $Fe(OH)_3$ (Fukuda, N. et al., 2013)

Principle 2 How to decrease phosphorus in water

Equation (1) shows how the mechanism decreases dissolved phosphorous (PO_4-P) in the water. Iron ions (Fe^{2+}) are eluted from D-material composed of iron and carbon particles. Fe^{2+} is changed to ferric hydroxide $Fe(OH)_3$.as shown in **Fig. 4**. $Fe(OH)_3$ and PO_4^{3-} form a chemical adsorbent (suspended state). The chemical adsorbent, $Fe(OH)_3 \equiv PO_4^{3-}$ will be deposited to bottom of water as shown in Equation (1). The concentration of PO_4-P and TP will be reduced from the process. Therefore, it will be effective in reducing the nutrients required for phytoplankton growth.

$$Fe^{2+} \rightarrow Fe(OH)_3 \rightarrow Fe(OH)_3 \equiv PO_4^{3-} \qquad (1)$$

RESULTS AND DISCUSSIONS

Bucket test under non-flow condition

Fig. 5 shows an effective reduction of PO_4-P of dam water during bucket test. This first involved placing 100g of D-material into 10L water bucket. The concentration of dissolved phosphorus was then reduced to 10% in 7 days.

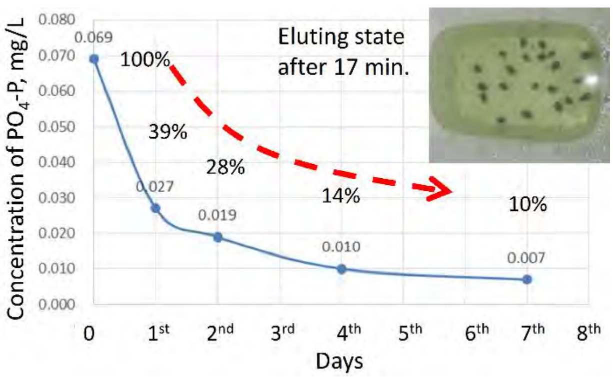


Figure 5. Reduction of dissolved phosphorous (PO_4-P) of dam lake water by eluting iron ions

Column test under flow condition

To determine appropriate testing conditions for large scale demonstration tests under flow condition, a series of column tests were conducted using the setup of apparatus as shown in **Fig. 6**. The diameter and length of the column are 19 mm and 100 mm respectively, and 17.9 g of D-material was encapsulated within the column. **Fig. 7** shows the relation of concentrations between PO_4-P, D-Fe and flow rate from 0.033 to 0.385 mL/s. Initial concentration of PO_4-P was adjusted to 1.0 mg/L. By eluting Fe^{2+} concentration of PO_4-P was decreased immediately to 70% under 0.1 mL/s as shown in **Fig. 7**. The results show immediate reaction effect just after flowing water or solution.

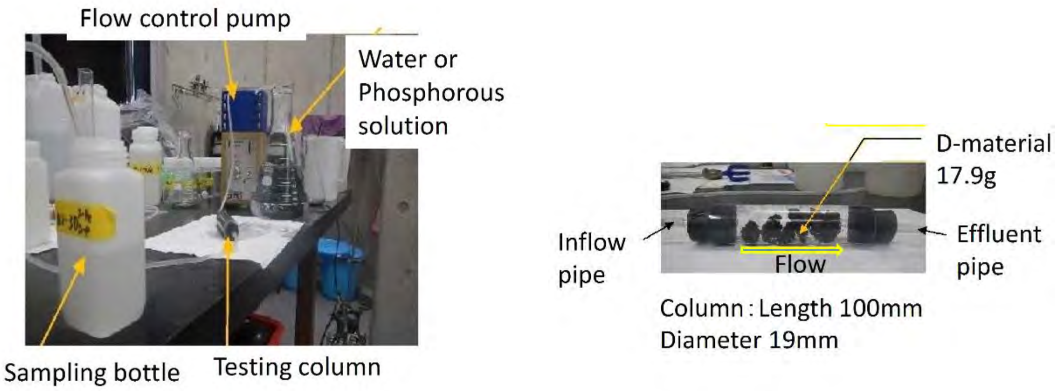
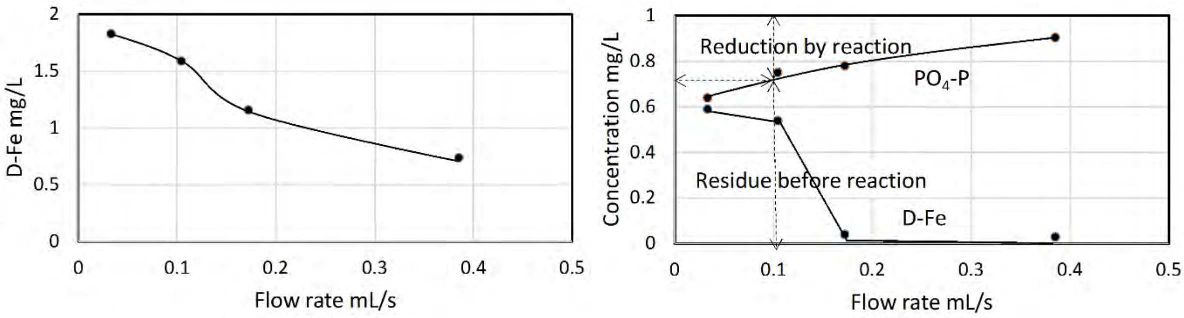


Figure 6. Setup of column test and column capsuled Iron Ion eluting bodies (D-material)



(a) Case-1 Tap water (b) Case-2 1.0 mg/L PO_4-P solution

Figure 7. Concentration of D-Fe and PO_4-P under flow condition by column tests (Fukuda, N., 2015)

Configuration of demonstration tests

To confirm the effect of phosphorous reduction in river water, middle and large-scale demonstration tests were conducted from 2013. **Fig. 8** shows plan view of large scale demonstration testing site of the iron ion eluting apparatus and the existing water purification facility to reduce BOD managed by Tsuchiura City. Raw water pumped up from settling tank of existing facility was treated through iron ion eluting apparatus (**Fig. 9**) and discharged to bio-module tank of the existing facility.

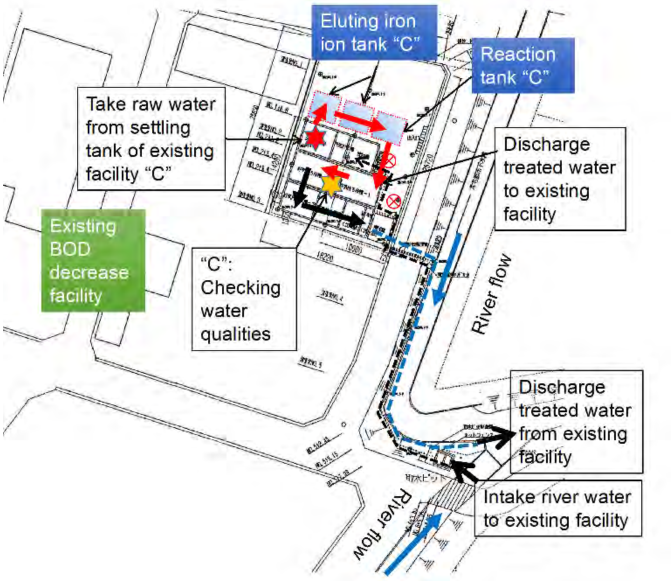


Figure 8. Plan view of Iron ion eluting aparatus and existing bio-module facility to reduce BOD

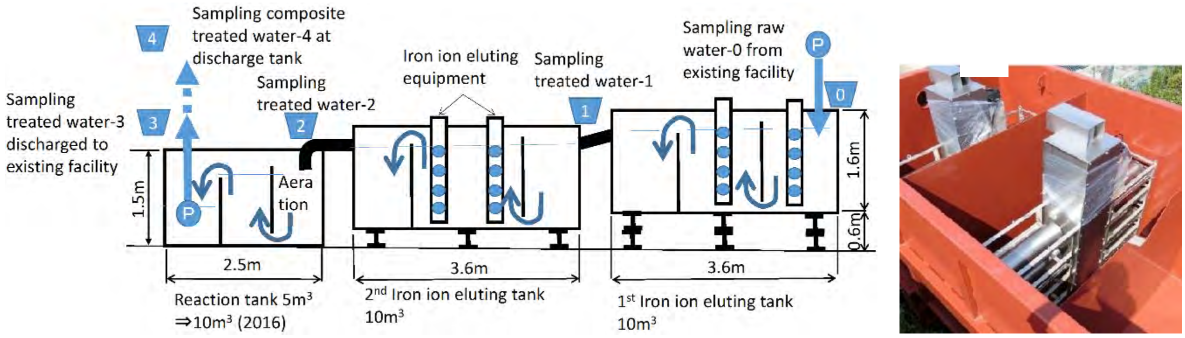


Figure 9. Overall composition of apparatus and iron ion eluting equipment

Determination of specification of iron ion eluting equipment

At first required volume of D-material under practical treatment flow rate was analysed from column tests shown in **Fig. 7**. Reduction rate of PO_4-P was planned to 30% then the flow rate was set at 0.1 mL/s (Q_{col30}, 0.00864 m^3/day). The design flow rate of 30% reduction treatment Q_{d30} was set 175 m^3/day, half flow rate of existing facility. The mass of D-material was 17.9g (M_{col}, 0.0179kg) in the column tests, thus required total mass M_{dreq30} of D-material can be calculated from a proportional relationship as Equation (2).

$$M_{dreq30} = (Q_{d30} \times M_{col}) / Q_{col30} = (175 \times 0.0179) / 0.00864 = 362.1 \text{ kg} \qquad (2)$$

Therefore D-material mass of one set of equipment was determined 96 kg; consisting of 8 rolling drams as shown in **Fig. 9**. And total mass of D-material was 384 kg for four sets of equipment. The flow rates of large scale demonstration tests were determined from 100 to 300 m^3/day in case of 2015.

Results of large scale demonstration tests

Fig. 10 shows representative results of concentration decreases of TP and PO_4-P by eluting iron ions under a flow rate of 200m^3/day. **Fig. 11** shows decrease of TP and PO_4-P through the treatment process by iron ion eluting systems under each flow rate. Concentrations of TP from treatment water 1 to 3 were around 0.8 – 0.7 mg/L and were gently decreased through the treatment process. However Concentration of composite treatment water 4 in existing water purification facility remarkably decreased to around 0.4 mg/L. This result means that the suspension of the chemical adsorbent, $Fe(OH)_3 \equiv PO_4^{3-}$ suggests that it is deposited to the bottom of the tank in the existing facility under low velocity of flow. On the other hand, concentration of PO_4-P was decreased through treatments 1 to 3 by eluting iron ions, and the concentration of composite treatment water 4 was in the same order of treatment water 3.

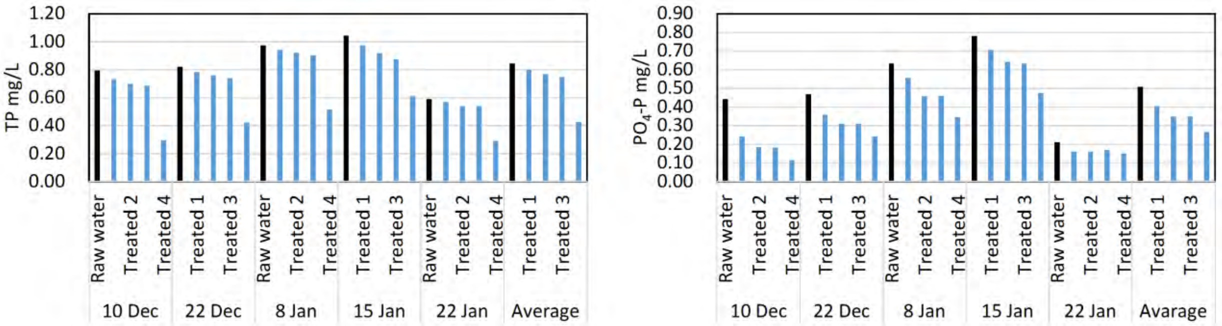


Figure 10. Decrease effect of concentrations of TP and PO_4-P by eluting iron ion under 200m^3/day

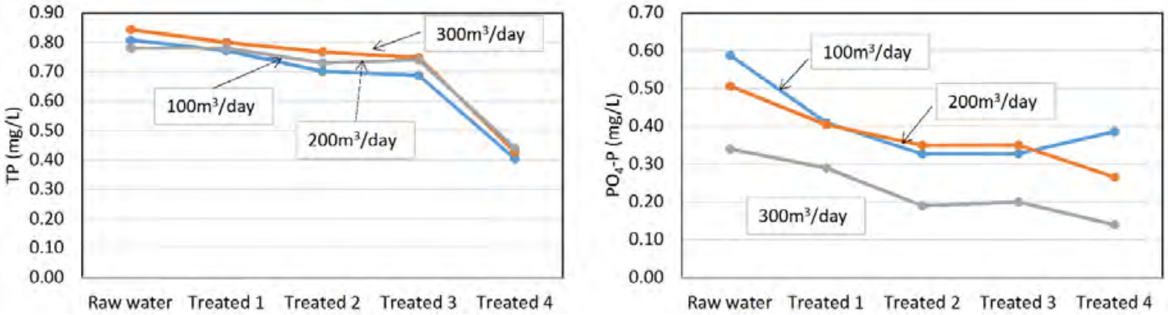


Figure 11. Annual average concentration of TP and PO_4-P of raw water and treated water in each flow rate

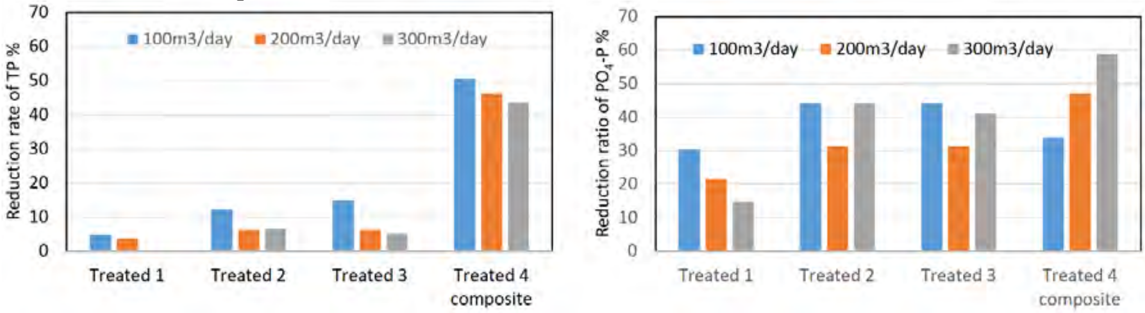


Figure 12. Reduction ratios of annual avarage of TP and PO_4-P through the treatment in each flow rate

Fig. 12 shows reduction ratios of annual average of TP and PO_4-P through the treatment processes. Because the difference in the number of iron ion eluting equipment sets between 2 sets in 1st tank and 4 sets total in 2nd tank, reduction ratios of treatment water 1 were smaller than treated water 2. PO_4-P reduction ratios were 44~31% at the maximum flow rate of 300m^3/day. The result achieved the original target of 30%, creating an immediate and satisfactory effect under those flow conditions. However, TP reduction ratios in treated water 3 were 14.8 ~ 5.1%, lower than the target of 30%, so the solution to facilitate sediment process is under study at present. Because the suspension of the chemical adsorbent, $Fe(OH)_3 \equiv PO_4^{3-}$ will easily re-elute under poor oxygen environment, therefore stable reduction of TP is necessary by sedimentation in the system.
Confirmation of environmental load. To confirm of environmental load of discharged water to rivers, pH and DO values were checked for safety as shown in **Fig. 13**. Values of pH ranged from 7.3 to 8.1 (average 7.8), which were within living environmental standard from 6.5 to 8.5. Values of DO ranged from 7.0 to 9.5 mg/L, indicating that the system did not cause undue stress to the river environment.

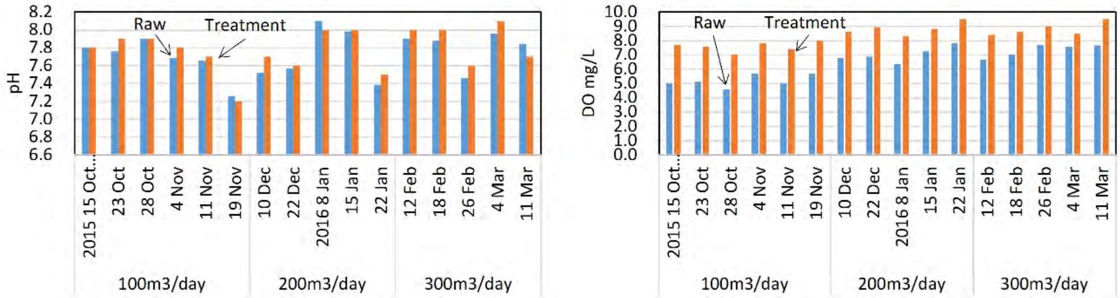


Figure 13. pH and DO values of discharged water treated by iron ion elution system

CONCLUSIONS

The water quality of ponds and lakes has deteriorated due to the phenomenon of eutrophication. An outbreak of phytoplankton has resulted as a part of this process. In order to improve the water quality of park ponds and dam lakes by applving eluting iron ion method, the authors have been challenges through laboratory and field experiments for many years. The phenomenon of eutrophication by phytoplankton has also long been a problem in the Lake Kasumigaura. The technologies for effective and economically efficient to reduce phosphorous have been challenges for many years. Therefore, the authors proposed the method to decrease of PO_4-P by eluting iron ions, Fe^{2+} could be suppressed of generation phytoplankton in the rivers flowing into the Lake Kasumigaura.

The followings are the results from the series of large scale demonstration tests that carried out from October 2015 to March 2016.

- Under the flow condition such as in rivers, by continuously eluting iron ions to reduce the nutrient source PO_4-P and TP for phytoplankton, laboratory tests, mid-scale field tests and large-scale field tests were taken with improved equipment.
- The reduction ratios of PO_4-P were 44 ~ 31% at the flow rate of 300m^3/day. The result achieved the original target of 30%, showing the technology has an immediate effect.
- Also, the reduction ratio of the existing water purification facility was 33 ~ 59%. The result may be caused by the deposition effect of suspended bodies as a result of the decreased flow velocity.
- The TP reduction ratio in treated water 3 was 14.8 ~ 5.1%, which is lower than the goal of 30%, so the solution to facilitate sediment is under study at present.
- The eco-friendliness of the system which decreases phosphorous by eluting iron ions is confirmed by environmental loads as evidenced by pH and DO values though the series of field tests.

Based on above results under flow rate from 100 to 300 m^3/day, additional demonstration tests using an increased flow rate from 400 to 550m^3/day are in process to develop the practicality of the system. The authors will show the results at the next opportunity.

ACKNOWLEDGEMENT

The project received supports and advises from Environmental Management Division and Kasumigaura Environmental Science Center of Ibaraki Prefecture and Tsuchiura City managing existing water purification facility. In addition, engineers from each company made great efforts to assist on the project. The authors express appreciation for this exceptional support.

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RESTORING INDONESIAN LAKE BUFFER ZONES USING NATIVE PLANT SPECIES

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ABSTRACT

Lake buffer zones are essential area to protect freshwater from pollutants originating from the catchment area. Empirical research projects on the restoration of lake buffer zones' function as pollutants trappers have been undertaken in some sub-tropical countries with mixed results. Most projects agreed that vegetated lake buffer zones significantly reduce pollutants depending on the width of buffer area and vegetation types. In tropical country including Indonesia, empirical research projects attempted to measure buffer zones effectiveness in reducing pollutants are still limited. Existing regulations only consider buffer sizes; meanwhile few research projects on plant species that are capable in trapping pollutants have been exposed. This paper aims to explore potential plants for restoring buffer zone functions. Nitrogen accumulator plants were chosen, as Nitrogen is one of major pollutant sources on some Indonesian lakes. The exploration on Nitrogen accumulator plants was carried out to gather information on the species. All collected plants were then sorted into species distributed and native to Indonesia. Result from World Agroforestry Database explained that there are 125 Nitrogen accumulator plants, 45 of which are distributed in Indonesia and 22 of them are native. The native plants consist of timber sources from genus Acacia, Albizia, Casuarina, Dalbergia, Dipterocarpus and Intsia; food sources such as Cajanus cajan, Gnetum gnemon and Sesbania grandiflora; medicine sources like Cajanus cajan, Erythrina variegate, Flemingia macrophylla, Peltophorum pterocarpum and fodder such as Flemingia macrophylla and Sesbania grandiflora.

Keywords: Indonesia, lake buffer zones, native plant species, rehabilitation

INTRODUCTION

Lake buffer zones are essential area adjacent to the lakes which provide numerous ecosystem services. They function as shoreline stabilization, water quality protection, flood attenuation and wildlife habitat (Buffler, 2005; Fischer & Fischenich, 2000). In water quality protection, vegetated buffers play important roles on filtering sediment, sediment-bound and soluble nutrients, pesticides, microbes (Buffler, 2005). Vegetation can capture pollutants by slowing down runoff through stems and leaf litter which automatically filtering pollutants (BRPC, 2003). As water retention is extended longer, plants have more chances to absorb nutrients and pollutants and transform them into less harmful forms (BRPC, 2003). Pollutants are usually coming from the catchment area (BRPC, 2003).

Empirical research projects on the restoration of lake buffer zones' function as pollutants trappers have been undertaken in some sub-tropical countries with mixed results. Fischer and Fischenich (2000) analysed results from various research and summarised them into four main functions of buffer zones with different width and species composition. The authors explained that for stream stabilisation, the buffer can be between ten to twenty meters, while from five to thirty meters buffer width planted with grass, herbaceous, shrubs and trees is recommended for water quality protection. Buffer sizes for flood attenuation and riparian habitat are wider than the previous functions that are 20-150 m and 30->500 m respectively. Buffler (2005) focusing on buffer functions as water quality protection illustrated matrixes on buffer width for each contaminant types such as sediment, pesticides, phosphorus, pathogens and nitrogen. For Nitrogen filtering, the buffer width recommended was from three meters planted with grass and it was claimed to reduce 65% of N contaminant (Chaubey et. al., (1994) in Buffler, (2005)). Most projects above agreed that vegetated lake buffer zones significantly reduce pollutants depending on the width of buffer area and vegetation types.

In tropical country including Indonesia, empirical research projects attempted to measure buffer zones effectiveness in reducing pollutants are still limited publicly. The earliest and most straightforward publication is Presidential Decree Number 32 Year 1992 on Protected Area Management. The decree considers buffer sizes for beach, rivers, lake, reservoirs and springs. For lake and reservoirs, the obligated buffers are from 50 to 100 m from the highest tide. The buffers aim to protect lakes from activities harming the sustainability of lake function. However, at least five lake buffers have suffered from serious degradation indicated by massive residential occupation, intensive cultivation, fertilizer use, waste disposal and pollution exceeding lake capacity (MoEF, 2016).

Since 2009, nine ministries have agreed to rehabilitate damaged or threatened lakes throughout the country, particularly 15 lakes that were categorised as high priority (MoEF, 2016). Various efforts have been undertaken, from zoning lakes, calculating lake carrying capacity, remediating lake water, researching lake social economy, eliminating sediment and algae and establishing coordination forum for each lake. However, lake degradation is still happening and the status of 15 lakes has very little improvement. In 2016, the Ministry of Environment and Forestry suggested several programs, one of which was tree planting along buffer zones, called green belt.

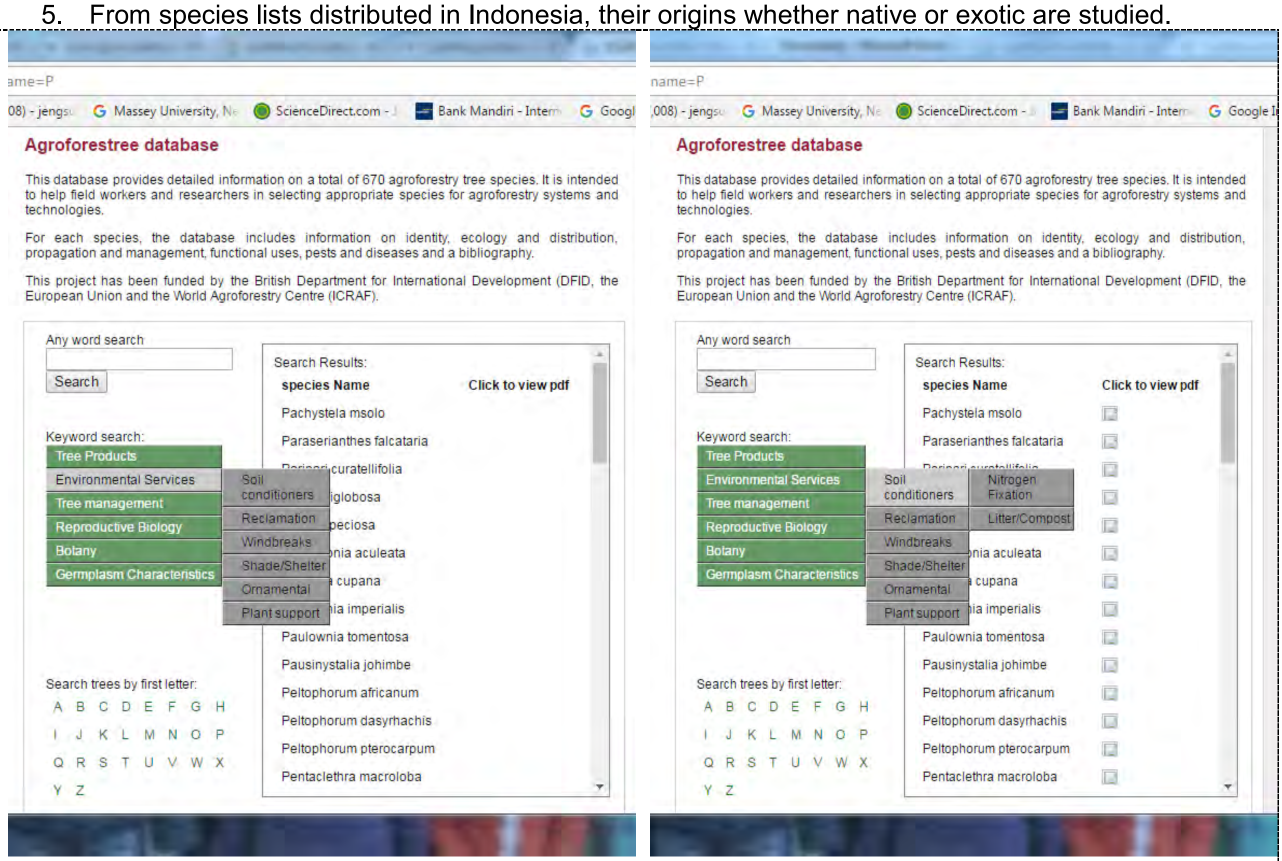
Besides planting trees for riparian has been recommended by many research in other countries, Indonesia's mega biodiversity provides many options for plant selection. MoF (1994) in BAPPENAS (2003) claimed that there were 38,000 flowering plant species in Indonesia, 55% of which was endemic. Later in 2010, Kartawinata mentioned that from 30.000 species, 60% have been described (Kartawinata, 2010). The latest is from Widjaja et. al. (2014) updating the number . They said that there were 1,500 algae, 80,000 cryptogram, 595 lichens, 2,197 ferns and 30,000-40,000 flowering plants. All those numbers show how rich biodiversity in Indonesia is. On the other hand, few research projects on plant species that are capable in trapping pollutants have been exposed. Therefore, the aim of this paper is to explore potential native plants for restoring lake buffer zone functions, particularly on filtering Nitrogen.

METHODS

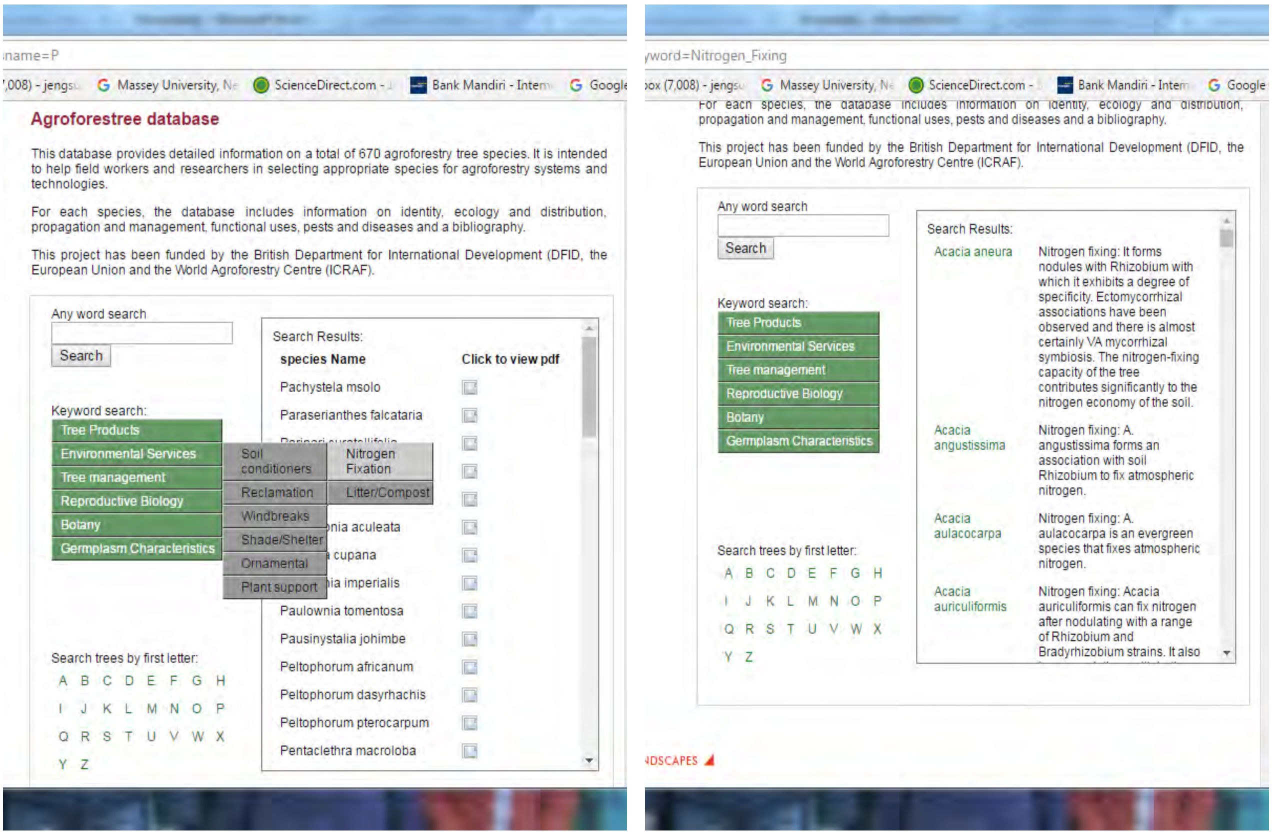
Indonesia prioritizes 15 lakes for conservation and rehabilitation, 13 of which are experiencing severe eutrophication. They are Toba, Singkarak, Kerinci, Rawa, Batur, Tondano, Limboto, Mahakam (Semayang, Melintang, Jempang), Sentarum, Sentani, Maninjau, Rawapening and Tempe (MoEF, 2016). The last three are at the top rank of eutrophication. Nitrogen is one of main pollutants in those lakes, therefore plants which are able to fix Nitrogen are chosen.

Almost all information was gathered from *World Agroforestry Database* through their website http://www.worldagroforestry.org/treedb/index.php (Orwa C., A. Mutua, Kindt R., Jamnadass R., & S. Anthony, 2009). The database provides 670 tree species commonly used in agroforests. Steps to explore potential species as follows:

1. On the web page, Environmental Services was clicked/chosen (**Fig. 1.a.**)
2. Within Environmental Services, choose menu Soil conditioners (**Fig. 1.b.**)
3. Within menu Soil conditioners, choose menu Nitrogen Fixation (**Fig. 1.c.** and **1.d.**)
4. Distribution areas of all Nitrogen Fixing species were recorded then were differentiated into Indonesia and non-Indonesia.
5. From species lists distributed in Indonesia, their origins whether native or exotic are studied.



a. b.



c. d.

Figure 1. Sequences in data exploration.

For species that is familiar to the writer but according to the database, distribution area is outside Indonesia, further investigation was done using information provided by E-Prosea (PROSEA) and other sources.

RESULTS AND DISCUSSIONS

The results show that there are 125 species in the Agroforestry Database which have capability in fixing Nitrogen (**Table 1.**). They are dominated by Fabaceae (103 species ≈ 82.4%). The other are 5 species from Casuarinaceae, 4 species from Betulaceae, 2 species Moraceae, and a species from Apocynaceae, Dipterocarpaceae, Eleagnaceae, Ginkgoaceae, Gnetaceae. Guttiferae, Magnoliaceae, Meliaceae, Sapotaceae, Ulmaceae and Verbenaceae.

Table 1. N-fixing plant species from Agroforestree Database

No	Species	Fam	No	Species	Fam	No	Species	Fam
1	*Rauvolfia vomitoria*	Apo	43	*Albizia anthelmintica*	Fab	85	*Cupressus torulosa*	Fab
2	*Alnus acuminata*	Bet	44	*Albizia chinensis*	Fab	86	*Dalbergia latifolia*	Fab
3	*Alnus japonica*	Bet	45	*Albizia coriaria*	Fab	87	*Dalbergia sissoo*	Fab
4	*Alnus nepalensis*	Bet	46	*Albizia ferruginea*	Fab	88	*Dichrostachys cinerea*	Fab
5	*Alnus rubra*	Bet	47	*Albizia gummifera*	Fab	89	*Erythrina abyssinica*	Fab
6	*Casuarina cunninghamiana*	Cas	48	*Albizia julibrissin*	Fab	90	*Erythrina berteroana*	Fab
7	*Casuarina equisetifolia*	Cas	49	*Albizia lebbeck*	Fab	91	*Erythrina caffra*	Fab
8	*Casuarina glauca*	Cas	50	*Albizia odoratissima*	Fab	92	*Erythrina edulis*	Fab
9	*Casuarina junghuhniana*	Cas	51	*Albizia procera*	Fab	93	*Erythrina poeppigiana*	Fab
10	*Casuarina oligodon*	Cas	52	*Albizia saman*	Fab	94	*Erythrina sandwicensis*	Fab

11	*Dipterocarpus grandiflorus*	Dip	53	*Albizia versicolor*	Fab	95	*Erythrina variegata*	Fab
12	*Hippophae rhamnoides*	Ele	54	*Albizia zyga*	Fab	96	*Flemingia macrophylla*	Fab
13	*Hardwickia binata*	Fab	55	*Calliandra calothyrsus*	Fab	97	*Gliricidia sepium*	Fab
14	*Intsia bijuga*	Fab	56	*Entada abyssinica*	Fab	98	*Millettia thonningii*	Fab
15	*Parkinsonia aculeata*	Fab	57	*Enterolobium cyclocarpum*	Fab	99	*Myroxylon balsamum*	Fab
16	*Peltophorum pterocarpum*	Fab	58	*Inga edulis*	Fab	100	*Olneya tesota*	Fab
17	*Piliostigma malabaricum*	Fab	59	*Inga vera*	Fab	101	*Ougeinia dalbergioides*	Fab
18	*Schizolobium parahybum*	Fab	60	*Leucaena collinsii*	Fab	102	*Pongamia pinnata*	Fab
19	*Senna atomaria*	Fab	61	*Leucaena diversifolia*	Fab	103	*Pterocarpus angolensis*	Fab
20	*Acacia aneura*	Fab	62	*Leucaena esculenta*	Fab	104	*Pterocarpus erinaceus*	Fab
21	*Acacia angustissima*	Fab	63	*Leucaena leucocephala*	Fab	105	*Pterocarpus indicus*	Fab
22	*Acacia aulacocarpa*	Fab	64	*Leucaena pallida*	Fab	106	*Pterocarpus rotundifolius*	Fab
23	*Acacia auriculiformis*	Fab	65	*Leucaena trichandra*	Fab	107	*Pterocarpus santalinoides*	Fab
24	*Acacia cincinnata*	Fab	66	*Mimosa scabrella*	Fab	108	*Pterocarpus soyauxii*	Fab
25	*Acacia crassicarpa*	Fab	67	*Paraserianthes falcataria*	Fab	109	*Robinia pseudoacacia*	Fab
26	*Acacia ferruginea*	Fab	68	*Pentaclethra macroloba*	Fab	110	*Sesbania bispinosa*	Fab
27	*Acacia karroo*	Fab	69	*Pentaclethra macrophylla*	Fab	111	*Sesbania grandiflora*	Fab
28	*Acacia koa*	Fab	70	*Pithecellobium dulce*	Fab	112	*Sesbania macrantha*	Fab
29	*Acacia lahai*	Fab	71	*Prosopis africana*	Fab	113	*Tephrosia candida*	Fab
30	*Acacia leptocarpa*	Fab	72	*Prosopis alba*	Fab	114	*Tephrosia vogelii*	Fab
31	*Acacia leucophloea*	Fab	73	*Prosopis chilensis*	Fab	115	*Tipuana tipu*	Fab
32	*Acacia mangium*	Fab	74	*Prosopis cineraria*	Fab	116	*Ginkgo biloba*	Gink
33	*Acacia mearnsii*	Fab	75	*Prosopis glandulosa*	Fab	117	*Gnetum gnemon*	Gnet
34	*Acacia melanoxylon*	Fab	76	*Prosopis juliflora*	Fab	118	*Mesua ferrea*	Gutt
35	*Acacia pachycarpa*	Fab	77	*Prosopis tamarugo*	Fab	119	*Michelia champaca*	Mag
36	*Acacia pennatula*	Fab	78	*Pseudosamanea guachapele*	Fab	120	*Lovoa trichilioides*	Mel
37	*Acacia saligna*	Fab	79	*Andira inermis*	Fab	121	*Musanga cecropioides*	Mor
38	*Acacia senegal*	Fab	80	*Ateleia herbert-smithii*	Fab	122	*Myrianthus arboreus*	Mor
39	*Acacia sieberiana*	Fab	81	*Cajanus cajan*	Fab	123	*Madhuca latifolia*	Sapo
40	*Acacia tortilis*	Fab	82	*Chamaecytisus palmensis*	Fab	124	*Celtis australis*	Ulm
41	*Acacia xanthophloea*	Fab	83	*Crotalaria juncea*	Fab	125	*Vitex doniana*	Verb
42	*Adenthera pavonina*	Fab	84	*Crotalaria micans*	Fab			

Fam: Family
Apo: Apocynaceae
Bet: Betulaceae
Cas: Casuarinaceae
Dip: Dipterocarpaceae
Ele: Eleagnaceae
Fab: Fabaceae
Gink: Ginkgoaceae
Gnet: Gnetaceae
Gutt: Guttiferae
Mag: Magnoliaceae
Mel: Meliaceae
Sapo: Sapotaceae
Ulm: Ulmaceae
Verb: Verbenaceae

Among 125 species, 45 are reported in Indonesia and 22 of which are native (**Fig.2**) The 45 are also dominated by Fabaceae (36 ≈ 80%) with still having 4 species from Family Casuarinaceae, 2 from Betulaceae, and a species from Dipterocarpaceae, Gnetaceae, and Magnoliaceae. Fabaceae (17 ≈ 77.3%) were also dominant within 22 native species with still having 3 species from Family Casuarinaceae, and a species from Dipterocarpaceae and Gnetaceae (**Table 2.**).

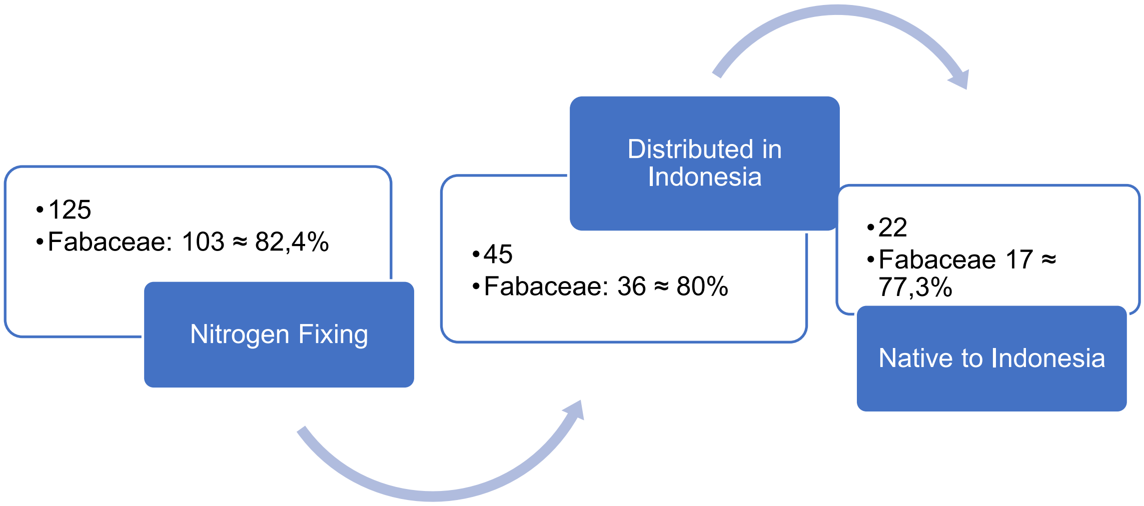


Figure 2. The number of N-fixing species from Agroforestree Database

Table 2. Indonesian native N-fixing plant species and suitability for the 15 priority lakes

No	Scientific name	Indonesian name	Family	Suitability for the 15 priority lakes[a]
1	*Intsia bijuga*	merbau asam	Fabaceae	Maninjau, Singkarak, Limboto, Poso, Tempe, Matano, Kaskade Mahakam, Sentarum, Sentani, Rawapening
2	*Peltophorum pterocarpum*	soga jambal/soga	Fabaceae	all
3	*Piliostigma malabaricum*		Fabaceae	Maninjau, Singkarak, Limboto, Poso, Tempe, Matano, Kaskade Mahakam, Sentarum, Sentani, Rawapening
4	*Acacia aulacocarpa*		Fabaceae	all except Batur
5	*Acacia auriculiformis*	akasia	Fabaceae	Maninjau, Singkarak, Limboto, Poso, Tempe, Matano, Kaskade Mahakam, Sentarum, Sentani, Rawapening
6	*Acacia crassicarpa*		Fabaceae	Singkarak, Limboto, Tempe, Matano, Kaskade Mahakam, Sentani
7	*Acacia leucophloea*	pilang	Fabaceae	all except Toba and Batur
8	*Acacia mangium*	mangge hutan	Fabaceae	all except Toba and Batur
9	*Albizia chinensis*	sengon	Fabaceae	all
10	*Albizia lebbeck*	tekik	Fabaceae	all
11	*Albizia procera*	weru, ki hiyang	Fabaceae	all
12	*Paraserianthes falcataria*	sengon laut, jeungjing	Fabaceae	all
13	*Cajanus cajan*	kacang Bali, kacang gude	Fabaceae	all
14	*Dalbergia latifolia*	sonokeling/brits	Fabaceae	all
15	*Erythrina variegata*	dadap ayam	Fabaceae	all
16	*Flemingia macrophylla*	pok-kepokan, hahapaan	Fabaceae	all
17	*Sesbania grandiflora*	turi	Fabaceae	all except Batur
18	*Casuarina equisetifolia*	aru, cemara laut	Casuarinaceae	all
19	*Casuarina junghuhniana*	kasuari, cemara gunung	Casuarinaceae	Toba, Kerinci, Tondano, Rawadanau and Batur
20	*Casuarina oligodon*	kilu	Casuarinaceae	Toba, Kerinci, Tondano and Batur catchment
21	*Dipterocarpus grandiflorus*	keruing	Dipterocarpaceae	Maninjau, Singkarak, Limboto, Poso, Tempe, Matano, Kaskade Mahakam, Sentarum, Sentani, Rawapening

22	*Gnetum gnemon*	melinjo	Gnetaceae	all

[a]The Government of Indonesia has prioritized 15 lakes for rehabilitation: Toba, Maninjau, Singkarak, Kerinci, Tondano, Limboto, Poso, Tempe, Matano, Cascade Mahakam, Sentarum, Sentani, Rawadanau, Batur and Rawapening

Products

The Database provides information not only tree products but also environmental services. Regarding tree products, the 22 native species have various products such as food, fodder, medicine, fibres, timber, tannin/dyestuff and apiculture (Orwa C., et al., 2009). Almost all natives (21) are timber sources except *Flemingia macrophylla* as it is a shrub with height 1-4 m.

Food sources consist of eight species: *Intsia bijuga, Piliostigma malabaricum, Acacia leucophloea, Acacia mangium, Albizia procera, Cajanus cajan, Sesbania grandiflora* and *Gnetum gnemon.* The last three are well-known and widely used in some area in Indonesia. However, *Cajanus cajan* (pigeonpea) is still minor important legume crops compared to peanuts and soybean (Mula & Saxena, 2010). In Java, Bali, Madura, and Sulawesi, pigeonpea is usually intercropped with other food crops, only in Flores Island, the monocrop pigeonpea between 150-195 days period was found. The main product of pigeonpea is seeds which are used to make *tempe* (Indonesian traditional food made from fermented soybean) and ketchup (Mula & Saxena, 2010). The other uses are for different side dishes in West and Central Java which use fresh pods or seeds (Mula & Saxena, 2010). As the used parts are the fresh ones, the need for mature dry grain and the importance of pigeonpea in Indonesian dietary are difficult to estimate (Mula & Saxena, 2010). However, Haliza et. al. (2007) founded that Pigeonpea can be a potential soybean substitute for tempe production in the country.

The most popular species among those above three is *Gnetum gnemon* which is also called melinjo (**Fig. 3**). The seeds are raw material for an important and famous cracker called *emping* (**Fig. 3**), which is produced mostly in Java and northern Sumatera (Orwa et al, 2009). From 2009 to 2013, the production was relatively stable around 220s T/year, but the next following year, there has been a slight by 10% decrease in melinjo production, from 220 to 197.6 T (Dirjen Hortikultura, 2015). Although almost all provinces in the country cultivate the species (except west Sulawesi and Gorontalo because no information has been available), 75% production in 2014 were from Java. Besides the seeds, melinjo young leaves, flowers and fruits are consumed as vegetables.

Source: Crawford (n.d.) Source: Aryanto (2011)

Figure 3. *Gnetum gnemon* flower (left) and *emping* (right).

Sesbania grandiflora, which is also named *turi* in Indonesia, is another species that has been known particularly in Java. Flowers of *turi* are the most widely consumed compare to leaves, seeds, pods and flowers which are also edible. In 2015, ten trees can earn IDR 10,000-20,000/day (Seputar Pertanian, 2015). In Java, the boiled/steamed flowers together with other vegetables were used in pecel (traditional Javanese dish consisting of steamed vegetables served with peanut sauce (made from fried peanut, chili, garlic, *Kaempferia galanga*, tamarind, palm sugar and salt) (**Fig. 4**).

Source: (http://bungahias.net/turi-putih/) Source: Retno (2014)

Figure 4. *Sesbania grandiflora* flower (left) and *pecel* (right)

Site suitability

Almost all species have a wide range of altitude distribution, for example *Cajanus cajan* and *Flemingia macrophylla* which are suitable for elevation 0-2000 m above sea level (asl). There are also two species for high altitude i.e. *Casuarina junghuhniana* (550-3100 m asl) and *Casuarina oligodon* (1500-1800 m asl). Only five species have elevation limitation up to 450 and 600 m asl. They are *Acacia crassicarpa* (maximum 450 m asl)*, Dipterocarpus grandiflorus, Instia bijuga, Peltophorum pterocarpum, and Piliostigma malabaricum*.

Lakes in Indonesia are spread throughout islands, from low elevation to relatively high. Among 840 big and small lakes in the country, 521 of them sizing more than ten hectares and hundreds of them are in Sumatera and Kalimantan. Among 15 National Priority Lakes, only Batur Lake in Bali and Toba Lake in North Sumatera which are located on high elevation, 1050 m asl and 900-200 m asl respectively, while the other are below 1000 m asl (MoE, 2011).

Ministry of Environment and Forestry of Republic Indonesia (2016) stated that good lake buffer zones should be free from buildings, land management, fertilizers and waste. Only structures for lake protection are allowed. If tree planting is included in rehabilitation programs; almost all species in this paper can be used for particularly the 15 lakes. Even *Casuarina junghuhniana* (550-3100 m asl) and *Casuarina oligodon* (1500-1800 m asl) are still suitable for planting program in Batur and Lake Toba.

CONCLUSIONS

There are 22 potential native species for rehablitation lake buffer zones in Indonesia which have both production and environmental functions. Almost all species can be used in 15 national priority lakes as they can grow on a wide range of elevation. *Casuarina junghuhniana* and *Casuarina oligodon* which have higher elevation distribution still can be planted in Batur Lake and Lake Toba.

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ECOHYDROLOGY MANAGEMENT OF LAKE AND WETLAND IN PUTRAJAYA URBAN ECOSYSTEM

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ABSTRACT

Putrajaya has successfully implemented the creative ecohydrology concept of 'ecosystem exploitation' to achieve the targeted 'hydrological quantity and quality' of water in its urban drainage system by constructing a 600 ha of Lake and Wetland. The appropriately managed and conserved constructed wetland leads to the evidently functioning ecosystem services that benefit to the wellbeing of the communities. It has not only produced the high quality of water, help in flood mitigation but also creates amazingly numerous benefit such as functioning as breeding grounds, nurseries and homes to numerous flora and fauna. The diverse aquatic organism that has been amazingly improving since it was created 15 years ago, represents a good sign of a balance ecosystem. In addition, the lake has now supporting the healthy lifestyle and become a renowned venue to community, national and international high-profile events, though an attraction for domestic and international tourism as well. In 2015 and 2016 various management innovative applications has been applied in order to achieve healthy, balance ecosystem the expected conservation status. Among all an innovative method of algae removal through the non-destructive micro-bubble technology, a study of Economic Assessment of Ecosystem Services and the integration of Putrajaya Lake Model and catchment management models becomes the long-term initiative towards conserving the Putrajaya Lake and wetland resources. Another innovative management effort that are taking place is the formation of the Lake Network. In January 2016, three other ASEAN countries members were invited to join the International Seminar of Lakes in Putrajaya. The idea for Lake Network were than agreed as prospective way forward to encourage information and experience exchanges among members. Such fairly similar lake environment in the region provide a good platform for this kind of relationship.

Keywords: eco-hydrology, Putrajaya Lake and Wetland, integrated lake management, catchment

INTRODUCTION

It was decided by the Malaysian Government that administrative function of Federal Government should be moved to a new area prompted by the dire need to balance and disperse development to areas outside of the congested capital city of Malaysia, Kuala Lumpur. The move would improve the efficiency of the government services to the public, the urban environment and its quality of life, as well as easing the pressure on the overstretched infrastructure of Kuala Lumpur. In the early 90s a site was chosen for the new administrative city. It was located 20 km south of Kuala Lumpur and 25 km north of Kuala Lumpur International Airport (KLIA). Subsequently a Master Plan was prepared for the new administrative city called Putrajaya.

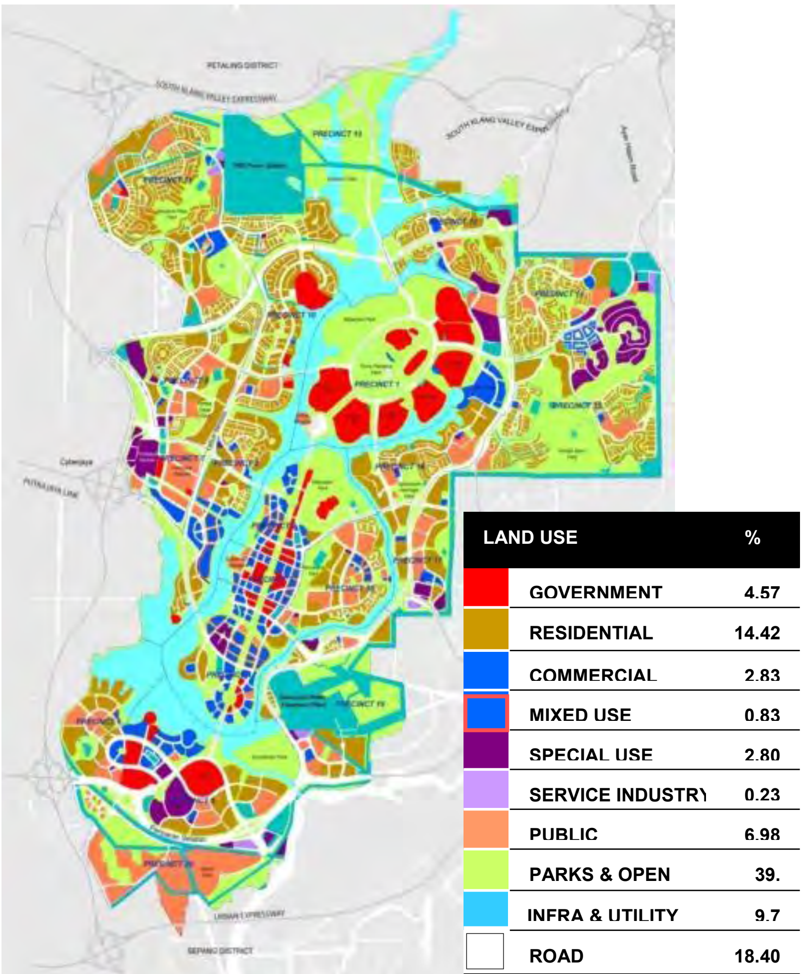

Figure 1. Putrajaya Masterplan

A Garden City, the unique of Master Plan (**Figure 1**) is its vast open spaces and water bodies which constitute of nearly 40% of the total city. Putrajaya has been planned with high environmental design standards and now after 20 years, it still stands as a development hard to surpass.

One of the main challenges of developing a modern city is managing its storm water, especially in the tropical areas where rainfall is high. As a solution to the surface runoff management, Putrajaya has successfully implemented the ecohydrological concept of ‘ecosystem exploitation’ to achieve the targeted ‘hydrological quantity and quality’ of water in its drainage system. This is possible by the construction of the Putrajaya Lake and Wetland.

PUTRAJAYA LAKE AND WETLAND (PLW)

The development of PLW was started in 1996 and the lake was fully inundated in 2002. The 650 hectares’ man-made lake and constructed wetland with 38km of water front created along the lake are the very basic key feature of the master plan. Putrajaya Wetland is the first man-made wetlands in Malaysia and the largest constructed freshwater wetlands in the tropics. The wetland system is about 200 hectares, comprises of five arms with 23 cells, namely Upper West (UW), Upper North (UN), Upper East (UE), Lower East (LW) and Upper Bisa (UB). It is as illustrated in **Figure 2**. They straddle the water courses of Chuau river, Bisa river and three other tributaries.

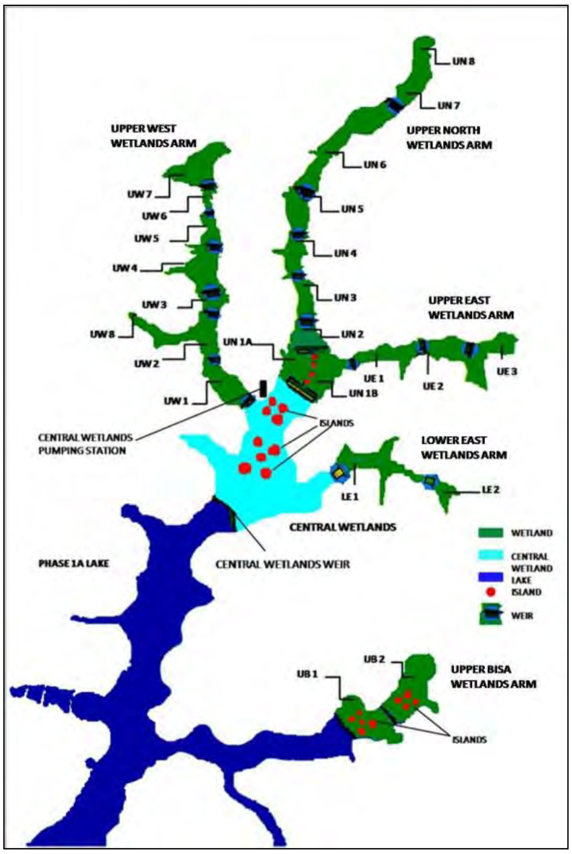

Figure 2. Putrajaya Wetland system

All the arms (except for Upper Bisa) eventually discharge to Central Wetland, which make up 24 cells in total, before the water flows down into Putrajaya Lake. Although all cells are functioning in the same manner, they differ in size, depths, plant communities and pollutant loads that it is designed to handle. Their primary function is to filter, absorbing the nutrients and cleansing the surface runoff from its catchment, ensuring that the water quality is improved before entering the lake at downstream area meets the standard that suitable for water body contact activities. To achieve this, the wetland has been planted with more than 20 species of wetland plants that enable to treat and act as a natural filtration system.

The filtered water from Putrajaya Wetland flows down into an urban lake, the Putrajaya Lake. The lake is about 400 hectares of surface area and it contains nearly 25 million cubic meters of clean freshwater with its depth is in the range of 2 to 14 meters. 60% of the source of the water is from the wetland and the remaining 40% comes from the surface runoff of surrounding land directly flows into the lake.

THE MANAGEMENT OF PUTRAJAYA LAKE AND WETLAND

According to Zalewski et al.,1997, Ecohydrology is a scientific concept applied to environmental problem-solving. It quantifies and explain the relationships between hydrological processes and biotic dynamics at a catchment scale. The concept is based upon the assumption that sustainable development of water resources is dependent on the ability to restore and maintain evolutionarily established process of water and nutrient circulation and energy flows at the basin scale.

Putrajaya Lake Catchment

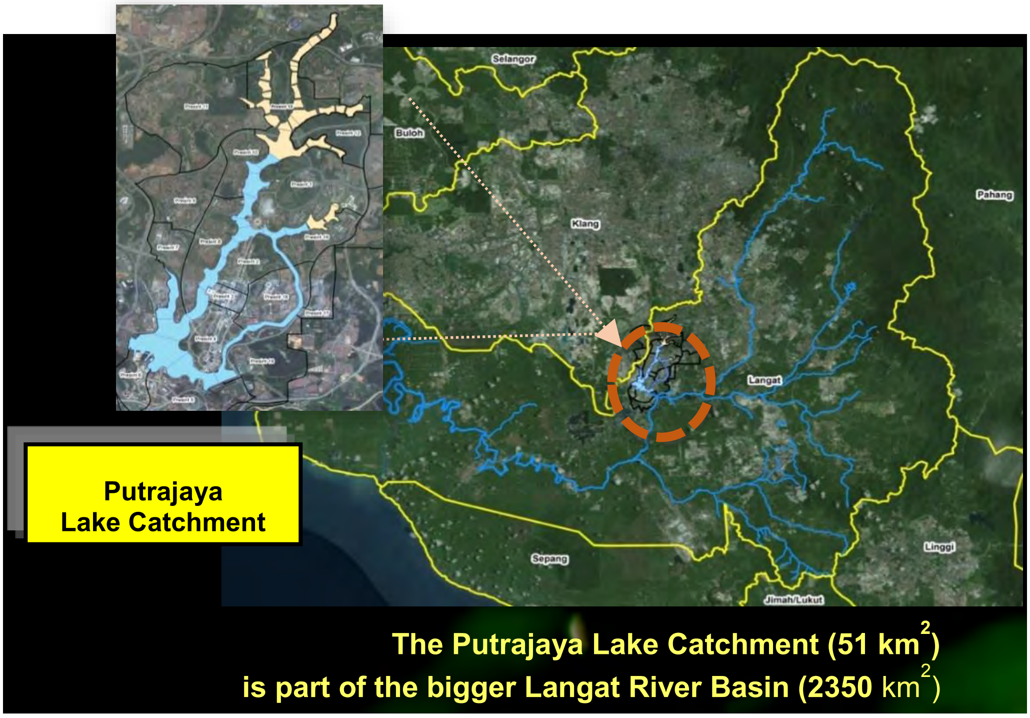

Figure 3. Putrajaya Lake Catchment lies within the bigger Sungai Langat Basin

Putrajaya Lake Catchment consists of 51 km square lies within the bigger Sungai Langat Basin of 2350 km square. **Figure 3** illustrates the inter-relation Putrajaya Lake Catchment and the bigger Langat River Basin. To control the quality of the surface runoff, considerations were given to the possible source of all pollutant in the catchment areas (watershed) of the lake and wetland. The catchment's stakeholders, activities as well as the possible source of pollutant were scrutinised and identified. This is part of the strategic planning exercises for implementing the ecohydrology concept for the Integrated Putrajaya Lake and Wetland Basin Management.

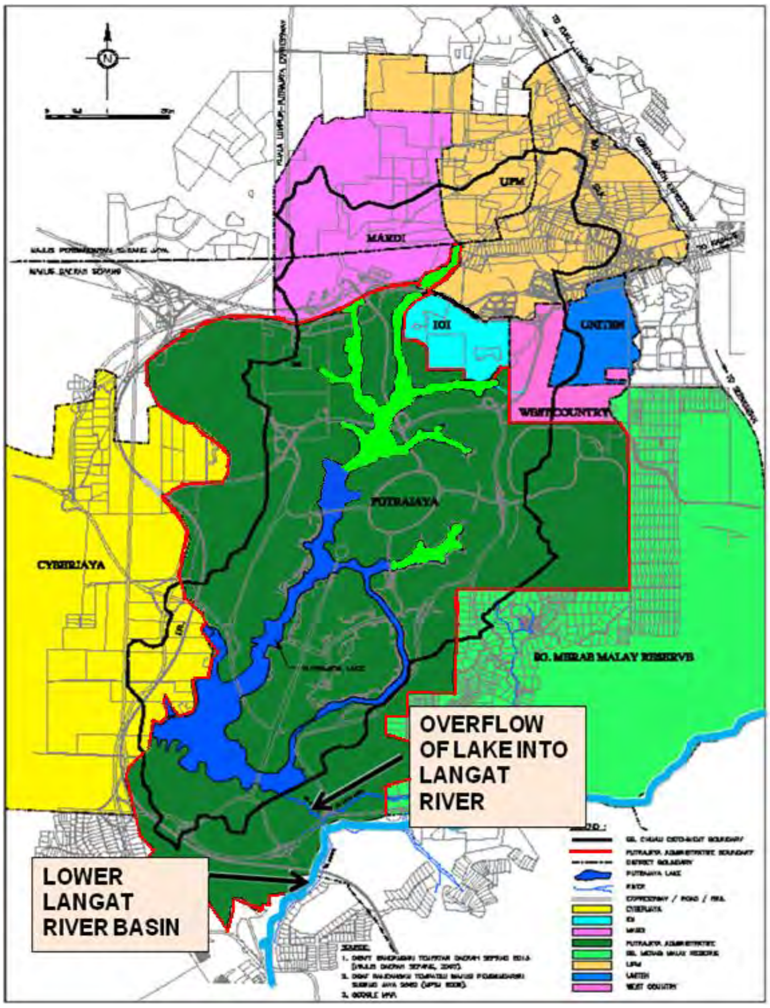

Figure 4. Layout of Putrajaya Lake Catchment and its stakeholder's boundaries

The extent of the catchment's areas lies within three (3) different municipalities: Areas under the jurisdiction of PPj, Sepang District Council and Subang Jaya Municipal Council (**Figure 4**). Roughly 70 % of the Putrajaya Lake Catchment is in Putrajaya and the remaining 30% lies in Selangor. There are nine main stakeholders of different entities including individual ownership. Various types of uncontrolled activities in the catchment areas will expose Putrajaya Lake to the runoff pollution. Therefore, it is very crucial to ensure all the stakeholders being aware of the importance of the Putrajaya Lake and Wetland from the planning stage, even though, every one of them is having their own need and reasons.

Routine and Schedule Maintenance, Monitoring Activities, Ecosystem Assessment and Management Measure

The main activities of Putrajaya Lake and Wetland operation are amongst others comprising of routine and schedule maintenance activities, regular monitoring and survey exercises, and diversity assessment. Monitoring activities for the lake and wetland system include water quality and biological aspects, hydrology, sedimentation survey and dam integrity monitoring. Diversity assessment activities are carried out and include terrestrial fauna survey of birds, insects, reptiles, mammals and amphibians. Development of biodiversity profiles, enhancement and establishment of a balance habitat for communities is also undertaken at regular intervals.

Surveillance and evaluation of plants growth, fish species determination and population control are done which also ensure conformation to “zero threat” from mosquitoes breeding within the wetland systems.

Table 1 shows the main management activities of Putrajaya Lake and Wetland, comprising of routine and schedule maintenance activities, regular monitoring and survey exercises, diversity assessment and also the management measures which are human disturbance to ensure the development and sustainability of the healthy ecosystem within the catchment. Whereas **Table 2** shows the findings of the monitoring exercise that has been carried out.

All the maintenance programs are of minimal disturbance to the system except some activities that required *'intervention'*. '*Intervention activities'* are considered as *'management measures'*. The management measure works that need to do is based on the result from the monitoring exercise and also the ecosystem assessment exercise.

Example of *'management measures'* carried out are plant harvesting, transplanting, and replacement of plants, replanting, and desilting of wetland cells. Fish management is done on regular basis by fish stocking (juvenile) exercise and elimination process for population control of invasive aquatic species. Whereas the lake system refitting including desilting works, harvesting and replanting of wetland plants is done periodically whenever necessary.

Table 1. The management activities of Putrajaya Lake and Wetland

Activities	Details Scope of Work
Maintenance Activities	• Up-keeping and cleaning; • Maintenance of structures and facilities (weir, jetty, pontoon, lake shorelines, dam) • Management of plants in nursery/cells; • Prunning/Trimming/Thinning of ZII plants; • Manual weeding • Plants Pest & Disease Control
Monitoring Exercises	• Physico-chemical and biological of water • Hydrological monitoring • Rainfall and weather monitoring • Dam safety monitoring
Ecosystem (Diversity) Assessment	• Terrestrial Fauna survey including birds, insects, reptiles, mammals and amphibians; • Surveillance & Evaluation of Plants Growth; • Fish
Management Measures	• Habitat Enhancement – for birds, fish • Ensuring the health of aquatic life; • Fish Stocking; • Elimination of unwanted species of fish • Protection of rare and endangered bird species; • Refitting – Desilting / Plant Harvesting / Replanting • An integrated system of the wetlands and lake management

Table 2. Number of species of different fauna found at Putrajaya Lake and Wetland

Species	**EIA Report**	**Baseline data (year)**	**2010**	**2015**	**Inventory until 2015**
	No of species				
Phytoplankton	-	100 (2006)	140	106	202
Zooplankton	-	42 (2006)	61	51	111
Macrobenthos	-	09 (2006)	16	16	20
Fish	10	17 (2008)	16	11	55
Birds	34	80 (2007)	147	119	187
Insects	-	21 (2007)	21	924	1421
Amphibians	-	2 (2007)	5	8	13
Reptiles	-	5 (2007)	15	8	21
Mammals	24	7	8	9	17

Communities and Stakeholders Participation

The responsibility of maintenance and taking care of the city ecosystem does not fall on authorities alone. It needs involvement of its citizen, the communities, visitors and workers to care and love the 'built-up nature' of Putrajaya. In this regard, PPj had started on programs with active participation from the communities through Local Agenda 21 (LA 21) initiatives.

The spirit of partnership (initiated by LA 21) between local authority, community and private organisation/NGOs to undertake the responsibility that normally lies with the government will ensure sustainability and a strong sense of belonging from the residents.

There is also the management activity with the concept of Environment, Ecosystem and Educational Programs (3EP) that is being implemented on regular basis all year round. 3EP activities are designed and implemented to create awareness, sense of belonging and ownership especially amongst young people who live within the catchment areas. A series of awareness programs (awareness camp, dialogue, workshops, etc.) are conducted periodically with school children, universities and college students.

Figure 5. 3EP activities which involves school and university students conducted at Putrajaya Lake and Wetland

The 'know your ecosystem' program is part of 3EP that is a field-based learning through actual monitoring of water quality, survey of vertebrates and invertebrates, know-what are the biological indicators of a healthy ecosystem. During the programs, students are being taught how to collect sample, assess and interpret the data. Discussion also take place to discuss on how they, the small citizen can help the management to sustain the good ecosystem

Communities and stakeholders are also involved for inventory, record and data collection as well as for surveys purposes. All the activities conducted with the communities are part of the Healthy Communities, Healthy Ecosystem (HCHE) programs where presentations, discussions and dialogs are carried out in every part of the city.

Public participation exercise also been carried out through Intellectual Discourse where we share ideas and thought among the participants and experts. These activities are jointly organized by PPj with other government agencies, stakeholders, private sector and NGOs. Series of PLW seminar, workshops, colloquiums, consultative forums are among activities that has been conducted so far.

Figure 6. Public participation activities are carried out all year round involving all walks of life

ECOSYSTEM SERVICES INTEGRATED INTO DEVELOPMENT AND OPERATION
Ecosystem services are the beneficial outcomes, for the natural environment or people, that result from ecosystem functions. Since these valuable ecosystem services are often invisible in the national and local accounts and budgets, the policy makers and market forces often fail to adequately consider the value of these goods and services. Therefore, development co-operation should integrate biodiversity and ecosystem services into development plans and programmes, and mainstream biodiversity into all aspects of development co-operation. The important link of this need is the water within the catchment. The blue and green concept, ie the blue water and green flora, ought to inter-related and should be promoted in any urban ecosystem.
The ecosystem services provided by PLW has not only produced the high quality of water, help in flood mitigation but also creates amazingly a lot of benefit and healthy lifestyle to the communities and wellbeing. The constructed wetland acts as breeding grounds, nurseries and homes to numerous flora and fauna. The diversity of aquatic organism shows a good sign of a healthy and balance ecosystem. The number of species for phytoplankton, zooplankton, macro benthos, insects, amphibians, fish and birds, that has been monitored since the last 15 years is amazingly improving for such a built-up city area. In addition, the lake has now become a renowned venue to community, national and international high-profile events, though an attraction for domestic and international tourism as well.
The 'ecosystem services' provided by the PLW is in line with the achievable outcome of the project such as:
- ✓ Improved high water quality: suitable for water body contact activities;
- ✓ Venue for national and international water sports events: more than 30 events in a year;
- ✓ Location for recreational activities (lake cruising, fishing, bird watching etc);
- ✓ A popular and beautiful tourist attraction and destination;
- ✓ Habitat creations that involved the ability to enhance the ecosystem - more or less towards natural surroundings;
- ✓ Successful and unique flood mitigation system;
- ✓ Utilising the water for irrigation (landscape area);
- ✓ The centre of reference for the best managed ecosystem of lakes and wetlands practices in this region; and
- ✓ Finally, the ecosystem contributes to the 'well-being' of the people of Putrajaya and its visitors.

The urban ecosystem development approach in Putrajaya is also in line with the one recommended by the Millennium Ecosystem Assessment 2005 that suggested the overall outlook of 'ecosystem services'.

THE IMPACT AND OUTCOME
PLW contributes to environmental conservation, economic development and nation-building by:
- ✓ Establishing the understanding and the ability of creating and maintaining acceptable ecosystem in the urban surroundings by applying the integrated management of lake and wetland;
- ✓ Contributing significantly to the government's efforts to promote eco-tourism in Malaysia;
- ✓ Innovative creation of various activities, functions and programs to get the involvement of communities, stakeholders and the public participation in our integrated management approach;
- ✓ Enhancing awareness of the city's ecosystem services and its values to be enjoyed together especially among Malaysians and the younger generation;
- ✓ Introducing the rich bio-diversity of Malaysia's flora in the city/urban area to the rest of the world; and
- ✓ Providing an opportunity to professionals in various fields to appreciate and get acquainted to the concept of ecosystem management in their business.

SUSTAINABILITY MANAGEMENT EFFORTS
In 2015 and 2016, various management innovative applications have been applied in order to achieve healthy, balance ecosystem the expected conservation status.
Economic Assessment Ecosystem Services Study
Economic Assessment of Ecosystem Services is hardly being done on water body such as lakes. In 2015, PPj has won a grant from UNESCO-IHP Jakarta, through Malaysia Fund in Trust (MFIT) to implement the Economic Assessment of Putrajaya Lake and Wetland Ecosystem Services study. The economic assessment will enable understanding and resolve the delicate balance of water for livelihoods and water for maintaining the resource base. The assessment includes ecosystem functions and ecosystem services. Ecosystem functions are the physical, chemical, and biological processes or attributes that contribute to self-maintenance of an ecosystem. On the other hand, ecosystem services are the beneficial outcomes, for the natural environment or people that result from ecosystem functions. These services are resource provision services, regulating services, cultural services and supporting services.

As for the man-made Putrajaya Lake and Wetland, over time, is turning into a more natural setting and enhancing its own ecosystem services. Therefore, many aspects of its ecosystem services need to be assessed in terms of its economic values.

There are numbers of assessment methods used in this study. This included the Direct Market Value (DMV) and the Benefit Transfer Method (BTM) was applied for 10 different ecosystem services, in which the actual assessment was done elsewhere. All those values were then being transferred to the benefit for Putrajaya Lake. Finally, the Contingent Valuation Method (CVM), Travel Cost Method (TCM) and Hedonic Pricing Method (HPM) were also applied to determine the conservation, recreational and aesthetic value.

In this study, DMV was applied for the benefit of Cruise Tasik Putrajaya ridership, the value for water supply and the value of fish. DVM was estimated using the market price of measured item. The total of DMV from three aspects revealed a value of RM48,205,100.00 (USD11,315,751.17).

On the other hand, the BTM value for 10 different ecosystem services economic value done elsewhere creating the value of RM223,568,845.00 (USD52,480.949.53).

While for the CVM and TCM, field survey and data collection works was done for around Putrajaya areas. Number of respondent for both CVM and TCM surveys are 793 each. For the HPM, information for houses along the shorelines and various house types has been studied. All data for CVM, TCM and HPM were analysed by using the specified statistical software.

Obviously, the conservation management efforts have raised the value of the ecosystem services to USD1,381,296,965.96 (RM5,888,325,075.00). his value will justify for a sustainable fund for its operation, maintenance and management from various beneficial organisations. The economic value of each assessment applied in this research is tabulated in Table 3

Table 3. Findings of the ecosystem services economic assessment research done at Putrajaya Lake and Wetland

NO	ITEM	ECOSYSTEM SERVICES	VALUATION TECHNIQUES	VALUE (RM)	USD
1.0	**DIRECT MARKET VALUE**				
1.1	Selling the lake water for drinking- Water Rent	Provisional	Direct value	19,162,500.00	4,495,139.25
1.2	Use of the cruise Tasik Putrajaya boating service	Cultural	Direct Value	24,176,000.00	5,671,206.08
1.3	Fish harvest	Provisional/ Cultural	Direct Market Price	4,866,600.00	1,141,607.03
Sub Total DIRECT MARKET VALUE				**48,205,100.00**	**11,315,751.17**
2.0	**BENEFIT TRANSFER METHOD**				
2.1	Water quality Improvement	Regulating	Waste Treatment	2,363,334.00	554,390.89
2.2	Local climate influence	Regulating	Climate regulating	6,167,416.00	1,446,752.45
2.3	Nuisance prevention	Regulating	Disturbance moderation	37,737,511.00	8,852,465.33
2.4	Reduce flow energy	Regulating	Regulating of water flows	70,849,460.00	16,619,866.33
2.5	Slowing down the flow	Regulating	Erosion Prevention	32,947,653.00	7,728,860.44
2.6	Retention time control	Regulating	Nutrients Cycling	21,649,148.00	5,078,457.14
2.7	Pest or disease control	Regulating	Biological control	11,980,965.00	2,810,494.77
2.8	Breeding ground	Habitat	Nursery Service	16,265,297.00	3,815,513.37
2.9	Genetic materials and resources	Habitat	Genetic Diversity	14,761,357.00	3,462,719.13
2.10	Education and research	cultural	Inspiration	8,846,704.00	2,075,259.82
Sub Total BENEFIT TRANSFER METHOD				**223,568,845.00**	**52,480,949.53**
3.0	**INDIRECT VALUE – SURVEY**				

NO	ITEM	ECOSYSTEM SERVICES	VALUATION TECHNIQUES	VALUE (RM)	USD
3.1	Willingness to pay – Conservation efforts ILBM	Regulating/ Cultural	CVM – Contingent Valuation Method	1,027,356,375.00	241,163,468.31
3.2	Events – Recreation in lake	Provisional/ Cultural	TCM – Travel Cost Method	2,254,018,125.00	529,112,235.92
3.3	Aesthetics – Lake front house price	Provisional	Hedonic Pricing Model	2,331,176,630.00	547,224,561.03
Sub Total INDIRECT VALUE - SURVEY				**5,612,551,130.00**	**1,117,500,165.26**
TOTAL ESTIMATION – 31 OCTOBER 2015				**5,884,325,075.00**	**1,381,296,965.96**

Algae Removal exercise

With the high temperature of tropical climate, the shallow lake experiencing very active metabolism of its aquatic organisms. The algae growth in the last 15 years has shown that such lake need to be improved by removing it's organic and overflow of excessive nutrients. PPj has introduced an innovative method of Algae Removal System (ARS), that involves the main process of micro-bubble generating device and principle of floating by spraying of zeta-potential micro-bubble complex to cohere with algae of negative zeta and colloidal matter quickly to float and will be removed on the surface of water. Water quality sampling shows clear improvement of the turbidity, ammoniacal nitrogen, nitrate and chlorophyll-a. This practical technology has proven to be applicable for tropical lakes. Figure 8 shows some images of how the machine looks like. While Figure 9 indicates the locations of Algae Removal System (ARS) Operational Sites. **Table 4 and 5** detail out the Removal Efficiency (%) of Algae and Nutrient Removal Technology and also the weight in kilograms of algae been removed at selected sites at Putrajaya Lake.

Figure 8. The Algae Removal System (ARS) 'non-destructive micro-bubble technology' machine

Figure 9. Location of Algae Removal System (ARS) Operational sites.
(A= Inlet P10, GPT 33,
B= Inlet P1Taman Botani,
C= Inlet P9 Puspanita Puri; and
D= Inlet P3, GPT 02-03

Table 4. Removal Efficiency (%) of Algae and Nutrient at selected sites, Putrajaya.

Location (sampling date)	Parameter	Unit	Before (a)	After (b)	% Removal Efficiency (a-b)/a
Inlet P10 GPT 33 (27-Jul-16)	Turbidity	NTU	18.7	17.9	4.28
	NH_3N	mg/l	0.1	0.06	40.00
	Nitrate	mg/l	1.54	1.41	8.44
	Chlorophyll-*a*	µg/l	<0.5	<0.5	0.00
Inlet P1 Taman Botani (17-Aug-16)	Turbidity	NTU	17.3	18.0	- 4.05
	NH_3N	mg/l	0.08	0.01	87.50
	Nitrate	mg/l	0.6	0.26	56.67
	Chlorophyll-*a*	µg/l	19	16.1	15.26
Inlet P1 Taman Botani (17-Aug-16)	Turbidity	NTU	17.3	18.0	- 4.05
	NH_3N	mg/l	0.08	0.01	87.50
	Nitrate	mg/l	0.6	0.26	56.67
	Chlorophyll-*a*	µg/l	19	16.1	15.26
Inlet P9 Puspanita Puri (22-Aug-16)	Turbidity	NTU	16.3	15.0	7.98
	NH_3N	mg/l	0.03	0.01	66.67
	Nitrate	mg/l	<0.01	<0.01	0.00
	Chlorophyll-*a*	µg/l	5.8	<0.5	100.00
Inlet P3 GPT 02-03 (24-Aug-16)	Turbidity	NTU	16.0	15.2	5.00
	NH_3N	mg/l	0.05	0.05	0.00
	Nitrate	mg/l	1.44	0.06	95.83
	Chlorophyll-*a*	µg/l	<0.5	<0.5	0.00

Table 5: Total amount (kg) of removal sludge at selected operational sites at Putrajaya Lake

Location	Total Number of operation days	Weight (kg)
Inlet P10 - GPT 33	29	610
Inlet P1 - Taman Botani	2	65
Inlet P9 - Puspanita Puri	1	25
Inlet P3 - GPT 02-03	5	29

Eco-hydrological modelling

Recent global approach of managing lakes through the application of eco-hydrological modelling has enable scientists and engineers to better understand lake characteristics under changing environment and supports effective decision-making. The integration of Putrajaya Lake Model and Catchment Management Models through a collaborative effort with the National Hydraulic Research Institute of Malaysia becomes the long-term initiative towards conserving the Putrajaya Lake and wetland resources. Figure 10 (a) and (b) show Bathymetry of Putrajaya Lake and also possible spread of pollutant under high wind events.

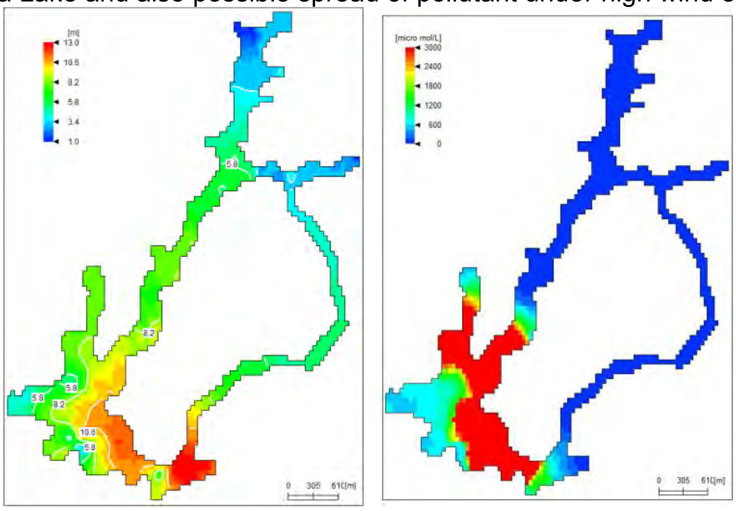

Figure 10. (a) Bathymetry of Putrajaya Lake (b) Spread of pollutant under high wind events

The numerical simulation provided a good match with the monitoring data (Sharip *et. al*. 2016). The model was able to provide the lake water quality characterisation under different scenarios. By linking with the catchment, the model is useful to enhance the management efforts to maintain the lake water quality by demonstrating the impact of the point source discharges to the water bodies.

Formation of Lake Network

Another innovative management effort that are taking place is the formation of the Lake Network. In January 2016, the lake managers and researcher from three other ASEAN countries members representing Lake Lanao in the Philippines, Rawa Pening Lake in Indonesia and the Lake of Prince of Songkla of Thailand were invited to join the International Seminar of Lakes in Putrajaya. Some of the photographs taken during the seminar are showed at Figure 11.

The idea for ASEAN Lake Network were than agreed as prospective way forward to encourage information and experience exchanges among members. Such fairly similar lake environment in the region provide a good platform for this kind of relationship.

Creating a regional platform will certainly provide opportunities to exchange information and improve ideas of managing our natural resources especially related to water and management of pollution. Together we will learn the better way of getting everybody involve in the concept of ecohydrology and the integrated manner our lakes and wetlands should be managed. Another important thing is that it will create the excitement among the young scientists, managers and engineers to understand our different culture and way of life while at the same time taking care of our lakes and wetlands.

Figure 11. Photographs taken during seminar on lake and wetland, Putrajaya

CONCLUSIONS

The application of an innovative ideas of ecohydrology management concept had enabled to bringing back ‘the lost nature’ into the urban surrounding with sustainability as the primary aim. This creative ecohydrology approach presents Malaysians with a new experience where nature and technology come together to benefit the communities. The creation of the lake and wetland as the basis of its biodiversity enhancement is aimed to boost the healthy and balance urban ecosystem within the area. The city now provides an environment that is conducive to quality urban living and pursuit of economic activities. The economic value of the ecosystem services and conservation is worth of USD1,381,296,965.96 (RM5,888,325,075.00). With the continuous management effort together with the latest initiatives comprising the Algae Removal System (ARS) ‘non-destructive micro-bubble technology’, eco-hydrology lake modelling and formation of Lake Network, it is hoped to showcase Putrajaya Lake and Wetland as the best of Malaysian expertise in creating and maintaining an urban ecosystem suitable for modern living and benefiting its communities. This innovative project is able to support ecosystem-friendly city that will become a global city and hopefully to achieve a Global Reference Site of UNESCO-IHP Ecohydrology Programme in the near future.

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INTEGRATED MULTI TROPHIC AQUACULTURE AS SAFE ENVIRONMENT FOR FISH PRODUCTION IN SMALL RESERVOIRS

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ABSTRACT

*Integrated Multi Trophic Aquaculture (IMTA) is a technique of aquaculture in which the organisms of varying trophic levels are cultured to maximize the system's energy and nutrient utilization efficiency. IMTA systems have been implemented as an effort to utilize the water from small reservoirs. This study assessed the growth of duckweeds (*Lemna perpussila*), catfish (*Clarias sp.*), tilapia (*Oreochromis niloticus*), and the water quality of IMTA system. Application of the IMTA systems by utilizing the two treatments in different small reservoirs was conducted from April to August 2016 at Enrekang Botanical Gardens, South Sulawesi. First small reservoir located inside the botanical garden was a fish pond with a volume of 20x25x1.5 m^3. Catfish with an average total length of 5.6 cm and an average weight around 1.34 g were cultured in a net (2x5x1 m^3 with stocking density of 180 fish/m^2.* L. perpussila *was grown in two nets of the same size as that for catfish and placed on both sides of the catfish nets. Tilapia with an average total length of 6.93 cm and an average weight of 6.10 g were cultured outside the net, with stocking density of 2,000 fish. The second reservoir located outside the botanical garden was a new pond consisting of two units (30x30x1.5 m^3 and 20x40x1.5 m^3 respectively). Catfish with a length of 4.9 cm an average weight of 0.84 g were reared in a 4 x4x1m^3 net, with stocking density of 188 fish/m^2. Tilapia with an average total length of 6.5 cm and an average weight of 5.3 g were cultured with the density of 2,000 fish separately in another small reservoir having water connection to catfish reservoir. The feed was administered as much as 5% of the total weight per day, while tilapia was fed with* Lemna.*The results showed that the Specific Growth Rate (SGR) of catfish and tilapia reached 3.53--4.02%/day and 2.06--2.60%/day respectively.* L. perpussila *grew well and it could be used as feed source for tilapia. The water quality observed in IMTA systems was considered appropriate to support the life of fish. Elimination rate of TN and TP was 14.76--15.63% and 35.00--52.00% respectively. This suggested that IMTA system can promote a safe environment for aquaculture with high efficiency. To conclude, IMTA can be recommended for wider implementation to conserve water resource and inland water ecosystem.*

Keywords: aquaculture, feed efficiency, IMTA, small reservoir

INTRODUCTION

Enrekang Massenrempulu Botanical Garden with an approximate area of 300 ha is located in the Batumila village Maiwa district, which is about 22 km south of the Enrekang city in the province of South Sulawesi This botanical garden is one of the best botanical gardens among 7 (seven) botanical gardens in Indonesia. These gardens are situated in the tropical (Wallaceae) region and are intended for education, environment conservation, and tourism. In the botanical gardens, there are many unused ponds or reservoirs. The idea is to utilize these reservoirs to be beneficial to the society such as setting them up for aquaculture. However, two major problems resulted from aquaculture activity are the production of waste and the high cost of feed. Therefore, our main goals is to minimize the waste and feed cost. In this context, the integrated multi trophic aquaculture (IMTA) can be an alternative solution. Originally, multitrophic refers to the explicit incorporation of species from different trophic positions or nutritional levels in the same system (Soto, 2009). It can also be defined as a technique in fish culture which integrates some biotic components in a system of aquaculture based on the trophic levels to maximize the energy in the system and increase the efficiency level of nutrient utilization.

IMTA's history started from a system of marine aquaculture in the 1990s. Shawn Robinson, a researcher from the Department of Fisheries and Oceans in Canada and his friend, Thierry Chopin, a professor from the University of New Brunswick, cultivated salmon, shellfish, and seaweed which were integrated in a bay of New Brunswick. The settling wastes generated from the maintenance of salmon were utilized by clams which were also the basic biota to be the source of nutrients, while the particles on the surface of the water were used by the seaweed as the nutrient to grow. Three commodities together provide economic value
(http://www.theecologist.org/News/news_analysis/340409/can_salmon_farming_be_suistanabel.html).

Integrated aquaculture has been widely practiced by small households in freshwater environments, mainly in Asia (Soto, 2009). The concept of IMTA, developed through an ecological approach to manage the structure of the food chain in micro-aquatic ecosystem pond, primarily directed to the utilization of wastes from aquaculture activity mainly by other suitable organisms. It can be seen from the economic aspect and the capability improvement of environmental quality. Aquaculture waste is actually a manifestation of metabolic inefficiency of fish feed given. It was generally known that the average fish is only able to convert a maximum of 40% of feed into the body (Chrismadha, 2014), while the rest is discharged into the water system in the form of organic matter and nutrients. Efforts on using this waste to improve feed efficiency and increase productivity of the water column have been carried out at the Research Center for Limnology-LIPI. The use of *Lemna perpussila* in carp culture proved to control the degradation of water quality due to the fish waste itself. Elimination of nutrients in the water exceeded 70% whereas theTotal Suspended Solid (TSS) eliminated was more than 85% (Chrismadha, 2014), Other trials also demonstrated the ability of lemna as an alternative of feed source in aquaculture of tilapia and catfish. For each trial, lemna replaced up to 50% of artificial feed without a significant reduction in the growth rate (Chrismadha, 2014). The IMTA concept is extremely flexible. It can be applied to open-water and land-based systems, marine and freshwater systems (Barrington et al., 2009) and its capability enables the development of aquaculture in closed system which can reduce water requirements up to ~85% (Chrismadha, 2014). The objective of this study was to obtain the growth of catfish (*Clarias* sp.) and tilapia (*Oreochromis niloticus*), the production of Lemna with an optimum water quality in the IMTA system of small reservoirs.

METHODS
The research was conducted during April-August 2016 in the Enrekang Botanical Garden, South Sulawesi. This study consisted of two experiments within different types of small reservoirs. First small reservoir located inside the botanical garden was a fish pond with a volume of 20x25x1.5 m^3. In this reservoir, the catfish were cultured in the net (2x5x1 m^3). The duckweeds (Lemna) planted inside the two nets of the same size as the catfish nets were placed on both sides of the catfish nets. Surrounding catfish nets and duckweed nets were installed plastic tarps to capture the wastes from the catfish and to limit the water from catfish culture which mixed directly with the water outside the net. The tilapia was cultured outside the net (**Figure 1**). The days of culture (DOC) were 114 days (**Table 1**)

Figure 1. Performance of system in 1st reservoir

The second reservoir located outsidebut near the botanical garden was a new pond consisting of two units (30x30x1.5 m^3 and 20x40x1.5 m^3 respectively). Catfish were cultured in the net (4x4x1m^3), of the first unit, while Tilapias were reared with the initial stock of 2,000 fish separately in the second unit, that connected to the catfish reservoir (**Figure 2**). The fish culture was conducted from June to August 2016, and the approximate days of culture (DOC) were 63 days. The stock fry, stocking density, average size of Catfish and Tilapia, and the days of culture (DOC) are shown in **Table 1**. The Catfish in the two reservoirs were fed with fish pellets as much as 5% of their body weight per day, while Tilapias were fed daily with 400 g (w/w) of duckweed grown in the system.

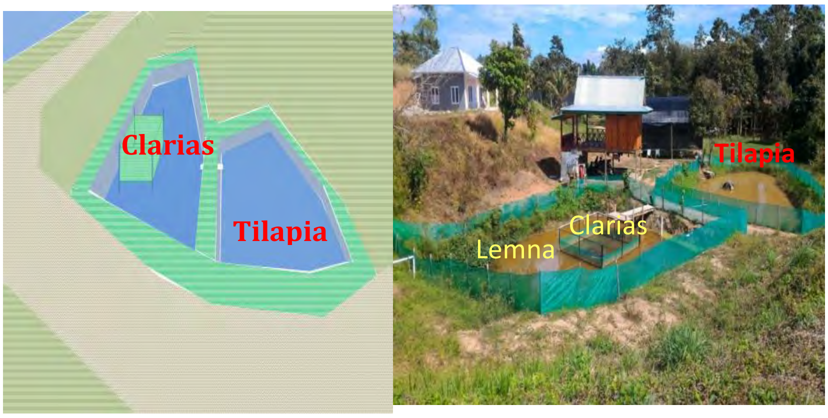

Figure 2. Setting up of the system in the 2nd reservoir

Table 1. Stock of fry, stocking density, the size, and DOC of fish in two reservoirs

Parameter	1st Reservoir		2nd Reservoir	
	Catfish	Tilapia	Catfish	Tilapia
Stock (fry)	1,800	2,000	3,000	2,000
stocking density (fry/m^2)	180	nd	188	3.0
average total length (cm)	5.6	6.93	4.9	6.5
average weight (g)	1.34	6.10	0.84	5.3
DOC (days)	114	114	63	63

nd = no data

The components of observation includedthe survival rate (SR/%) of *Clarias* sp. (in 30 days) only in the first reservoir, growth of fish, and lemna. Observation of fish growth was conducted by taking the sample of 30 fish of each species in all reservoirs and measuring their length and weight. Fish growth parameters were based on the length (growth rate of length/ GR-L) and weight (growth rate of weight/GR-W). Subsequently, the specific growth rate for length (SGR-L) and specific growth rate for weight (SGR-W) were calculated. Observation of survival rate is only done on catfish in the first reservoir. We did not observe this parameter for other reservoirs due to technical limitation.

Calculation of Survival Rate (SR)

$$\mathrm{SR} = \frac{\mathrm{Nt}}{\mathrm{No}} \text{ x } 100$$

SR = Survival Rate (in %)
Nt = The number of surviving fish after t period
No = The number of initial fish at t0

Calculation of Growth Rate (length, GR-L) and (weight, GR-W)

$$\mathrm{GR\!-L} = \frac{\mathrm{Xt} - \mathrm{Xo}}{\mathrm{DOC}}$$

GR-L = Growth Rate (length) in cm/day
Xt = average length after t period;
Xo= average length at t0;
DOC = Total days of culture

$$\mathrm{GR\!-W} = \frac{\mathrm{Xt} - \mathrm{Xo}}{\mathrm{DOC}}$$

GR-W = Growth Rate (weight) in g/day
Xt = average weight after t period;

Xo= average weigh at t0; DOC = Total days of culture

Calculation of Specific Growth Rate (SGR) which refers to the formula as follows (Eppley, 1977)

$$\mu = \frac{\ln x_t/x_o}{t}$$

μ = Specific Growth Rate (SGR); x_t = biomass after t period; x_0 = initial biomass; t = time of observation

Lemna growth was observed daily by calculating the biomass weight/m^2 in 5 m^2. Other observations covered organic components (Total Nitrogen/TN in mg/L), Total Phosphate/TP in mg/L), and Total Suspended Solid (TSS in mg/L). These were analyzed three times (April, May, August) in the Chemistry Laboratory of the Research Center for Limnology-LIPI. The parameters of water quality such as pH, dissolved oxygen (DO in mg/L), temperature (^{o}C), were observed in situ using Water Quality Checker [Horiba-Japan]. Sampling of those parameters was conducted inside and outside the nets of catfish. The elimination rate of nutrients (TN and TP) was calculated using the following formula:

$$\text{Elimination Rate of TN or TP (\%)} = \frac{Xt\text{-}Xc}{Xc} \times 100\%$$

Xc = Value of TN or TP in the Catfish net culture; Xt = Value of TN or TP in Tilapia net culture

RESULTS AND DISCUSSIONS

Survival rate and growth of fish

Fish survival rate and growth conditions onboth reservoirs are shown in **Table 2**. Survival rate of Catfish during 30 days of observation was 76% (Table 1). This value is higher than that from Marnani et al. (2011) which showed the SR of Catfish ranged 30–70%. Fish feed used was fish pellet. Generally, the common survival rate of Catfish ranges from 60% to 70%, and according to Sarma (2004), the survival rate of Catfish is considered good if the value is higher than 50%.

Table 2. Observations of Catfish and Tilapia in two reservoirs

Parameter	1st Reservoir		2nd Reservoir	
	Catfish	Tilapia	Catfish	Tilapia
SR (%-30days)	76	nd	nd	nd
GR-L (cm/day)	0.15	0.07	0.14	0.07
GR-W (g/day)	0.71	0.51	0.34	0.30
SGR-L (%/day)	1.24	0.65	1.41	0.79
SGR-W (%/day)	3.53	2.06	4.02	2.60

nd= No data

Growth conditions and growth parameters of catfish and tilapia in both reservoirs are summarized in **Table 1.** In the first reservoir after 114 days of culture, the average length of Catfish becomes 23.04 cm with GR-L of 0.153 cm/day and SGR-L of 1.24%/day. The average weight is 87.94 g with GR-W of 0.711 g/day and SGR-W is 3.53% per day. The average weight is 82.94 g. The average length of tilapia is 14.57 cm with GR-L of 12.07 cm/day and SGR-L of 0.65%/day). The average weight recorded is 64.04 g with GR-W of 0.51 g/day, and SGR-W of 2.06%/day (**Table 1, Figure 3**). In the second reservoir, after 63 days of culture, the average length of catfish is 13.47 cm with GR-L of 12.14 cm/day and SGR-L of 1.41%/day. The average weight of Catfish is 22.182 g with GR-W of 0.34 cm/dayand SGR-W of 4.02%/day. The average length of Tilapia is 11.34 cm with GR-L of 0.07 cm/day and SGR-L of 0.79%/day. The average weight of Tilapia is 25.52 g with GR-W of 0.30 g/day and SGR-W of 2.60%/day (**Table 2; Figure 4**).

Catfish and tilapia are fish for consumption and their body weight is the significant parameter for the growth. Therefore, it is reasonable that this paper focuses on the weight observation. In the first reservoir, the average weight of catfish is 82.94 g with SGR of 3.53%/day, while the average weight of tilapia is 64.04 g with SGR of 2.06%/day (**Table 2, Figure 3**). Whereas in the 2nd reservoir, the average weight of catfish is 22.18 g with SGR of 4.02%/day and the average weight of Tilapia is 25.52 g, with SGR of 2.60%/day (**Tabel 2, Figure 4**). SGR value of catfish in this study is relatively good. This suggests that catfish grow well in the IMTA system created. The results from Said et al. (2016) in an IMTA system set at Ligarmukti village in Bogor, the SGR of Catfish was 3.11%/day after DOC of 72 days. Research by Marnani et al. (2011) showed the SGR of catfish was 0.87-5.21%/day by various frequency of feeding and tank settings.

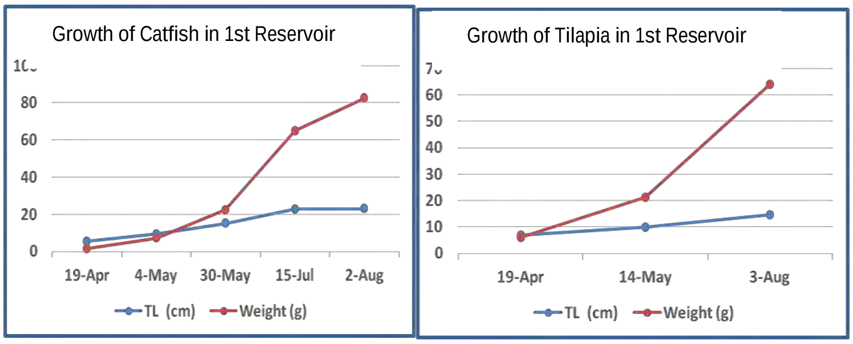

Figure 3. Average size of Catfish and Tilapia in the 1st reservoir during 114 days

Tilapia is a herbivorous fish that utilizes the biomass of duckweed as the food source. Tilapia has notable advantages, among others, they have a comprehensive response to food (Yuliati et al., 2003). In this research, the value of SGR (W) tilapia that ranges 2.06–2.60%/day is considered good. These results are similar to those from previous research by Said et al. (2016), that the SGR of tilapia was 2.70%/day which was fed with Lemna during 72 days of culture. Another study showed SGR of tilapia by feed pellets with recirculation system was in the range of 1.76–2.45%/day (Diansari et al., 2013).

Similarly to the SGR value, the average weight of tilapia in the first reservoir is 64.04 g with GR-W of 0.51 g/day (DOC-14 days), while in the second reservoir, the average weight is 25.52 g and GR-W is 0.30g/day after 63 days (**Table 2, Figure 3-4**). This result is higher than the research of Yuliati et al. (2003) that obtained the daily growth of tilapia after 8 weeks of 0.17g/day, (fed by pellets). This shows that in this study, tilapia can be grown using Lemna as feed.

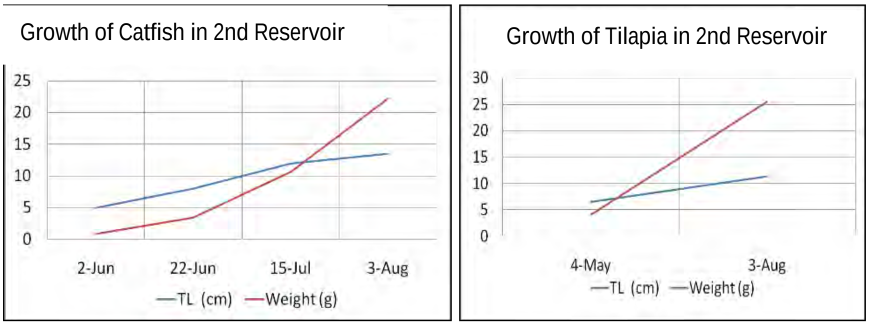

Figure 4. Average size of Catfish and Tilapia in the 2nd reservoir during 63 days

Growth of duckweed is observed per day and obtained the average amount of 400 gper 5 m^2 which is equivalent to 800g per10m^2 or as much as 0.8 kg/net per day. This result is lower than the output from Said et al (2016) in an IMTA system, in which the productivity of Lemna ranged 1.46–1.69 kgper10 m^2. This is presumably due to differences in the culture systems. In this research, the application net caused all wastes of Catfish might not be utilized by Lemna for growth. In Said et al. (2016), Lemna culture in ground pool was associated directly with the catfish pond. Therefore, it was assumed that the waste was captured by Lemna in relatively large amounts for growth.

This study used Lemna plants as feed for tilapia. *Lemna perpussila* is an aquatic plant that has a high protein content ~38.86% (Leng et al.,1995; Tavares et al., 2008) (**Table 3**) making it suitable as feed for herbivorous fish, as was done by Said et al. (2016). The protein content of *Lemna perpussila* is higher than of *Lemna minor* who has a protein content of 22.4--25.16% (Nophriani et al., 2014). Aside from being the source of feed, Lemna also serves as a water purifier. According to Chrismadha's study (2014), Lemna can eliminate the nutrient with a rate of more than 70%.

Table 3. The nutritional value of *Lemna perpusilla* Torr.

Contents/composition		**Composition of amino acid**			
Composition	**dry weight (%)**	**Composition**	**% of total protein**	**Composition**	**% of total protein**
water content	3.00	Lysin	3.7	Valin	5.8
Protein	38.86	Histidin	1.7	Methionin	1.5
Fat	3.80	Arginin	5.1	Isoleusin	4.3
Fiber	13.22	Aspartat	-	Leusin	7.8
Ash	16.00	Threosin	4.2	Triptophan	4.2
Calorie (kcal/100g)	325.70	Serin	-		

(Leng et al.,1995; Tavares et al., 2008)

Water quality

Fish growth are also influenced by external factors, such as temperature, pH, and more importantly, dissolved oxygen (DO). Water temperature affects processes in the body either directly or indirectly as much as the need for feed and fish activities (Brett, 1979). **Table 4** shows some key water quality parameters for fish farming. Values of pH, DO, and temperature in this research are within the range that meets the needs for the growth of fish and Lemna as stated by Alabaster & Lloyd (1982) for aquatic lives. It requires relatively neutral pH, high DO, and ambient temperature.

Table 4. Parameters of water quality measured

	1st reservoir		2nd reservoir	
Parameter	Catfish	Tilapia	Catfish	Tilapia
pH	7.18±0.53	6.84±0.33	7.13±0.19	6.72±1.17
DO (mg/L)	5.93±2.08	5.86±2.45	4.95±3.22	7.09±3.27
Temp (°C)	29.42±1.58	29.81±1.41	30.42±4.13	29.75±2.99
TN (mg/L)	1.49 ±0.75	1.27±0.12	0.96±0.05	0.81 ±0.11
TP (mg/L)	0.25 ±0.23	0.12±0.12	0.02±0.003	0.013 ±0.036
TSS (mg/L)	27.02±6.07	32.89 ±11.47	27.7±13.71	41.22±11.32

In both reservoirs, it is shown that the values of nutrient [Total nitrogen (TN) and Total phosphate (TP)] in the Catfish nets was higher than that of Tilapia's (**Table 3**). It means TN and TP have been reduced in Tilapia's system. Elimination rate of TN in both reservoirs ranged 14.76--5.63% and TP ranged 35.00-52.00% (**Table 5**). It also means that *Lemna perpussila* absorbs the nutrients from the Catfish's wastess for their growth. According to the results of Amalia (2014), *Lemna perpussila* is able to absorb nitrogen and phosphate from the excretion of catfish with the absorption capacity of nitrogen and phosphate is around 2.4 mg N g biomass^{-1} day^{-1} and 0.3 mg P g biomass^{-1} day^{-1} respectively. According to the research of Umaruddin et al. (2015), *Lemna perpussila* is a suitable agent for phytoremediation to improve the water quality in the fish cage of Cape Semarang. The value of Total Suspended Solid (TSS) in the Tilapia nets is higher than that of Catfish nets (**Table 4**), while according to Chrismadha (2014), it can be vice versa. This happened presumably because Tilapias were reared directly in the ground reservoir that made their movement stirred the bottom waters. Conversely, catfish were reared inside the nets slightly above the bottom of reservoir.

Table 5. The Elimination rate (%) of TN and TP

Parameter	Elimination rate (%)	
	1st Reservoir	2nd Reservoir
TN (mg/L)	14.76	15.63
TP (mg/L)	52.00	35.00

CONCLUSIONS

Catfish culture can be synchronized with the cultivation of Lemna to produce the biomass used to feed the Tilapias. Lemna can also reduce the water pollution from fish culture. It means that IMTA system is successfully able to promote a safe environment and high efficiency aquaculture. Therefore, IMTA can be a recommended alternative for wider implementation to conserve water resource and inland water ecosystem.

ACKNOWLEDGEMENT
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A NEW METHOD TO ESTIMATE CONCENTRATIONS OF PHOSPHOROUS, NITROGEN AND COD IN EUTROPHIC RIVERS

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ABSTRACT

A new method was proposed to estimate the concentration of total phosphorous (TP), total nitrogen (TN) and chemical oxygen demand (COD) in eutrophic river streams as an alternative to the conventional rating method (LQ method). The method was formulated and parameterized based on the water quality data obtained from a number of water samples collected from six rivers flowing into Lake Kasumigaura. For estimating TP and COD, the ratio of particulate phosphorous (PP) and particulate COD (PCOD) to the total constituents (PP/TP and PCOD/COD, respectively) was represented as a function of concentration of suspended sediments (SS). Furthermore, the ratio of constituent per unit weight of SS is represented by a function of SS with a correction factors depending on the ratio of particulate component to the total concentration (PP/TP and PCOD/COD). These equations are combined to calculate TP and COD from observed SS given as a single input variable. For TN, we proposed a method to estimate dissolved nitrogen (DN) from the monitored (or measured) Nitrate concentration (NO3-N) and particulate nitrogen (PN) from SS. The estimated concentrations of TP, TN and COD well agreed with those observed with the root mean square error (RMSE) less than that calculated from the rating method. We concluded that by using monitored SS, NO3-N and the flow rate, we can obtain reliable estimates of the concentration and load of TP, TN and COD in the eutrophic streams.

Keywords: COD, Estimates of Concentration, Suspended Sediment, Total Nitrogen, Total Phosphorous.

INTRODUCTION

Eutrophication of impounded water is a major environmental concern in Japan (Kim et al., 2012) as well as many other countries. For water quality management and mitigation of eutrophication, it is highly demanded to monitor the nutrient loading to the impounded water. Typically, periodical sampling and chemical analysis have been conducted in many streams to quantify the concentrations of phosphorus, COD and nitrogen that may affect the eutrophication of the effluent water body. Due to its time consuming and labor intensive works, automated water quality monitoring stations have been installed as an alternative to the conventional sampling method although the sampling method is still regarded as feasible approach for quantifying the nutrient load.

The most widely-used method for the loading estimation is called LQ method, which is based on the relationship between flow rate Q and nutrient load L. If a good correlation between Q and L is found, it is preferred to apply the LQ method, but in many examples the correlation is not acceptable beyond our expectation. Therefore, alternative method is highly demanded to better estimate the loading from inflowing streams.

In this study, we develop a new method to estimate concentrations (and loadings) of TP (total phosphorus), TN (total nitrogen) and COD (chemical oxygen demand) of stream water flowing in eutrophic rivers. For TP and COD, equations were formulated and parameterized based on SS (suspended sediments) concentration as input variable. For TN, in addition to SS concentration, we proposed a method to use measured NO_3-N (nitrate) concentration as input data. We finally show the comparison of the proposed method with the conventional LQ method.

STUDY AREA AND WATER QUALITY DATA

Introduction of study area

Our proposed method was applied to streams that are flowing to Lake Kasumigaura, which is located in the south east of Ibaraki prefecture (**Figure 1**). Lake Kasumigaura is the second largest lake in Japan which has water surface of 167.63 km^2 and catchment area of 2,156.7 km^2. It consists of two lakes, the West Lake and the North Lake. Both of them are regarded as eutrophic lakes. Figure 1 shows six rivers focused in this study, namely, Sakura River, Koise River, Ono River, Seimei River, Tomoe River, and Hokota River. The Sonobe River was excluded in this paper due to data limitation. The red point plotted on each river stream shows the observation site. The land use of the Koise and Sakura catchments is dominated by paddy fields and forests. Tomoe and Hokota catchment is characterized by high proportion of farmland and orchards. Urban areas occupy a large proportion in Tomoe and Ono catchments.

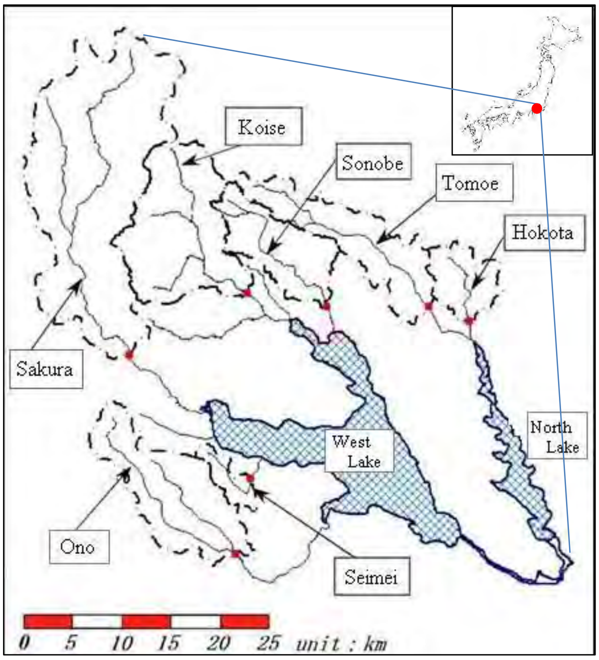

Figure 1. Kasumigaura Lake and inflowing river catchments.

Water quality data

The water quality data used in this study was collected by the local office of MLIT from 2006 to 2014. It includes data obtained during the flood season and non-flood season. Among them, data from 2006 to 2009 was used for developing the new method and calibrating parameters, and data from 2010 to 2014 was used for validation. The water quality components used in this study include suspended sediments (SS), total phosphorus (TP), particulate phosphorus (PP), total nitrogen (TN), particulate nitrogen (PN), dissolved nitrogen (DN), nitrate (NO_3-N), COD and particulate COD (PCOD) among others.

DEVELOPMENT OF ESTIMATION METHOD

Framework of the estimation method

We used SS concentration and flow rate as input to estimate loads of total phosphorus and COD. The load of total nitrogen was estimated from observed SS, nitrate (NO_3-N) and flow rate. The framework for estimating total phosphorus load and total COD load is shown in Figure 2.

The ratio between the particulate component (PP, PCOD) and total constituent (TP, COD) were found to be related to SS concentration. The ratio of particulate components to SS concentration are estimated from SS concentration with a correction factor □. Combining the results from these steps, the total nutrient concentration is estimated. Finally, nutrient loads are calculated from the concentration of SS and flow rate.

For nitrogen, the estimation procedure is shown in Figure 3. Firstly, concentration of dissolved nitrogen (DN) is estimated by using observed nitrate concentration (NO_3-N). Secondly, PN is calculated from SS concentration. Thirdly, by summing up the result from step one and two, the total nitrogen concentration (TN) can be estimated. Finally, same as TP and COD, nutrient loads are estimated by multiplying flow rate Q (mg/L) and the estimated nitrogen concentration.

As explained above, if functions g1, g2, g3, f1, f2 and f3 are determined, time series of concentrations and loads of TP, TN and COD are estimate only by inputting monitored time series of SS concentration, flow rate and nitrate concentration data.

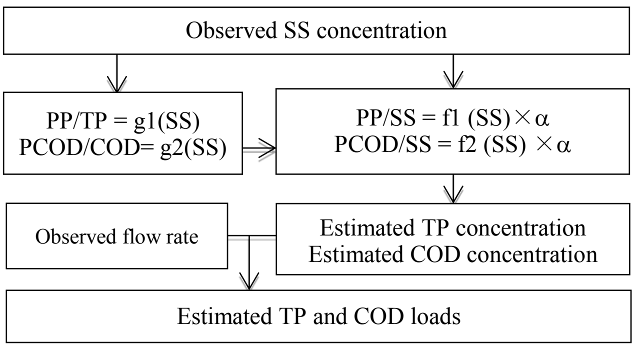

Figure 2. Framework of TP and COD estimation.

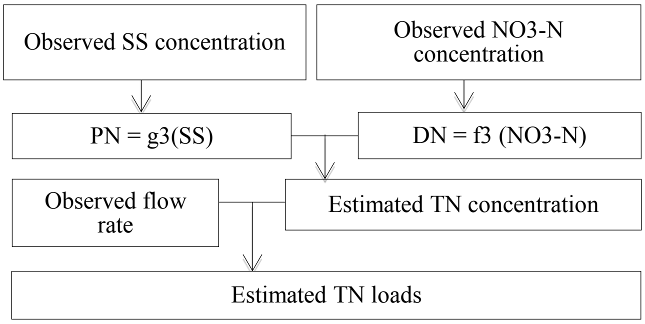

Figure 3. Framework of TN estimation.

Estimation method of TP and COD

The ratio between the concentration of nutrient in particulate and dissolved forms was formulated. Nutrient concentration C (mg/L) is equals to the sum of concentrations of nutrient in particulate form C_p (mg/L) and dissolved form C_d (mg/L), shown as Equation 1.

$$C = C_d + C_p \quad (1)$$

The concentration of suspended sediments is expressed as *SS* (mg/L). The amount of particulate form component contained in the unit amount of *SS* (= W_p) is expressed by Equation 2.

$$W_p = C_p / SS \quad (2)$$

In river water, if the adsorption and leaching is at an equilibrium state, or the actual amount of adsorption is small enough compared to the saturated adsorption amount of the particles, Equation 3 can be established.

$$W_p{}' = K_d C_d \quad (3)$$

where, K_d (mg/L) is the distribution coefficient. By equating the right hand side of Eqs. 2 and 3 and combining with Equation 1, the ratio between the concentration of particulate form and the total concentration is expressed as Equation 4. Nutrients in particulate form flow into the river from different kinds of sources, leading to complex interactive adsorption-desorption processes in actual situation of river water. So, a constant b is introduced to fit the actual data used in this study.

$$\frac{C_p}{C} = \frac{bK_d SS}{1 + K_d SS} \quad (4)$$

From data analysis, we found that both *PP/SS* and *PCOD/SS* show little correlation with *DP* or *DCOD*, while W_p is negatively correlated with *SS*. Therefore, we introduced Equation 5 to relate W_p with *SS* with a correction factor α to give better correlation between them by considering other factors. Here, we found that the correlation is affected by the ratio of C_p to C (Fig. 4). Thus, the equation linking W_p and *SS* takes the form given by Equation 5 through 7.

$$\frac{C_p}{SS} = f(SS) \times \alpha \quad (5)$$

$$f(SS) = F_1 - \frac{F_2 \times SS}{SS + F_3} \quad (6)$$

$$\alpha = \left(C_p / C\right)^A \quad (7)$$

where F_1, F_2, F_3 and A are the constants which are determined based on the observed data. C_p/C is calculated from Equation 4. Combining Eqs. 4 through 7 results in Equation 8.

$$C = SS \times \left(F_1 - \frac{F_2 \times SS}{SS + F_3}\right) \times \left(\frac{bK_d SS}{1 + K_d SS}\right)^{A-1} \quad (8)$$

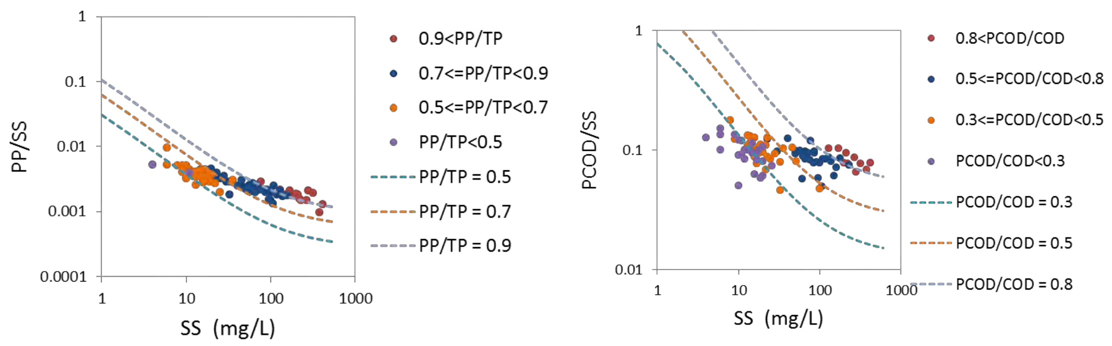

Figure 4. The relationship between W_p and *SS* (Ono river, Left: PP, right: PCOD).

Estimation method of TN

The low correlation between *PN* and *SS* prevented us to apply the same method used for *PP* and *PCOD*. In addition, most of nitrogen in the studied streams is in dissolved form, which is quite different from phosphorus or *COD*. Thus, we tried to establish a different method for *TN* estimation.

Since a large proportion of *DN* is nitrate, a strong correlation was observed between *DN* concentration and nitrate concentration. Therefore, if nitrate concentration is directly monitored, *DN* concentration is estimated from nitrate. The equation is established by applying linear regression as shown in Equation 9,

$$DN = a_1 NO_3 - N + a_2 \quad (9)$$

where a_1 and a_2 are constants; NO_3-*N* is the concentration of nitrate (mg/L).

Since the concentration of particulate nitrogen (*PN*) is not strongly correlated with *SS*, an alternative method for *PN* estimation was examined. We finally used a simple regression line to relate the concentrations of *PN* to *SS* (Equation 10).

$$PN = cSS \quad (10)$$

As a consequence, *TN* is estimated by combining Eqs. 9 and 10. As mentioned above, our data suggested that *PN* does not show a good correlation with *SS* as *PP* or *PCOD* does. Therefore, a further investigation is necessary to find factors that affect *PN* concentration for improving the estimation of *PN*.

RESULTS AND DISCUSSIONS

For *TP* and *COD* estimation, parameters appeared in each equation were calibrated to give a smallest RMSE. The calibrated parameters for each river are listed in **Table 1. Figures 5 and 6** show the results of fitting to Equation 4 and Equation 5, respectively. For the estimation of DN, observed nitrate concentration was used. As shown in Figures 7 through 12, good agreements were observed between the observed *TP*, *COD* and *TN* concentrations and those estimated from the proposed method.

Comparing with the results obtained from *LQ* method, it can be seen that the new method has greatly improved the estimation results. Table 2 listed the root mean square error (RMSE) of the estimation results from the proposed method as well as *LQ* method. It indicates that the new methods have improved the estimation results of *TN*, *COD* and *TP* about 54%, 64% and 32% respectively, relative to the result from *LQ* method.

Table 1. Parameters for nutrients estimation.

		Sakura	Koise	Tomoe	Hokota	Ono	Seimei
TP	b	0.93	0.92	0.93	0.97	0.97	0.96
	Kd	0.114	0.049	0.118	0.06	0.094	0.064
	A	2.4	1.7	1.7	1.4	2.1	2.2
	F1	1	1	1	1	1	1
	F2	0.9985	0.9982	0.9972	0.997	0.9988	0.9992
	F3	0.13	0.19	0.1	0.13	0.15	0.33
COD	b	0.92	0.97	0.9	0.89	0.95	0.95
	Kd	0.018	0.015	0.03	0.027	0.027	0.025
	A	1	1.2	1.3	1.1	1.4	1.7
	F1	10	10	10	10	10	10
	F2	9.94	9.92	9.89	9.9	9.93	9.95
	F3	0.3	0.5	0.6	0.6	0.7	1.4
DN	a1	0.9057	0.8186	0.9420	1.1106	0.9109	0.8011
	a2	0.5506	1.0345	0.6555	0.5608	0.7602	0.8088
	c	0.0042	0.0066	0.0138	0.0142	0.0060	0.0063

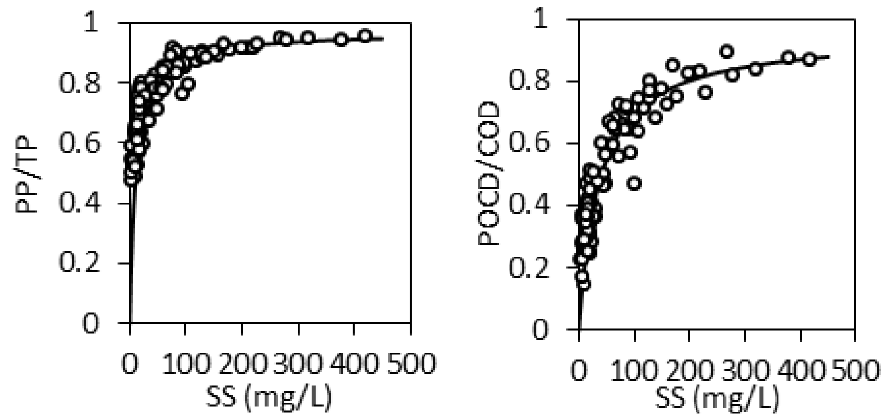

Figure 5. Relationship between Wp and SS concentration (Ono River).

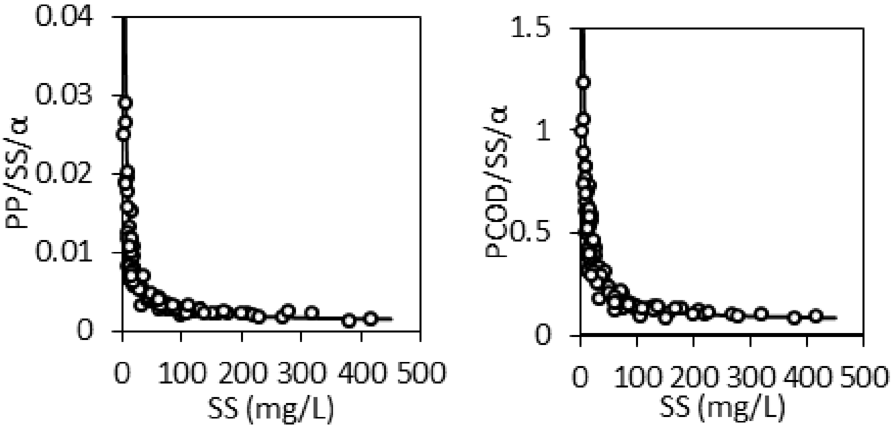

Figure 6. Relationship between Cp/SS/α and SS concentration (Ono River).

Table 2. Comparison of RMSE of the estimation results by the proposed method and LQ method.

	Sakura	Koise	Tomoe	Hokota	Ono	Seimei
			TP			
LQ	0.1273	0.1531	0.1048	0.2287	0.0950	0.1768
NEW	0.0585	0.0647	0.0445	0.1046	0.0362	0.1073
			COD			
LQ	4.7393	5.3306	4.5616	7.0308	4.9372	7.6862
NEW	1.8159	1.4906	1.6699	2.5287	1.4195	3.5233
			TN			
LQ	0.6097	0.6010	1.0229	2.0890	0.8713	0.9455
NEW	0.3202	0.5408	0.8300	1.5775	0.4803	0.5422

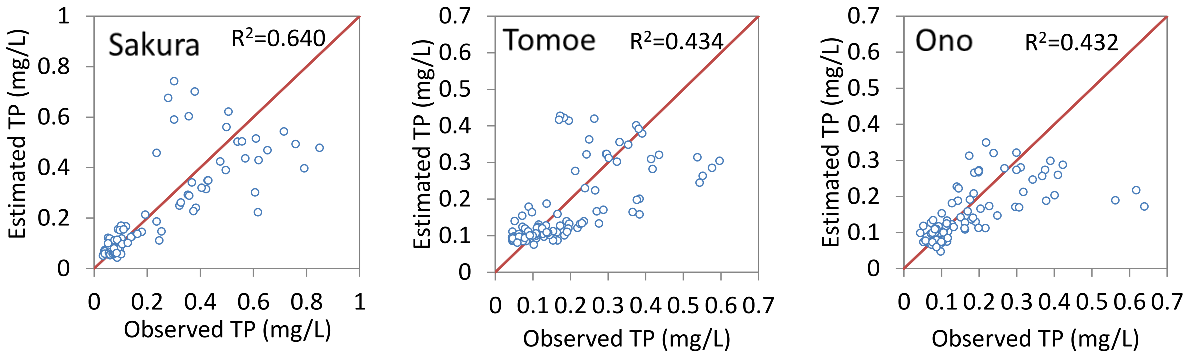

Figure 7. Comparison of observed TP concentration with that estimated by L-Q method.

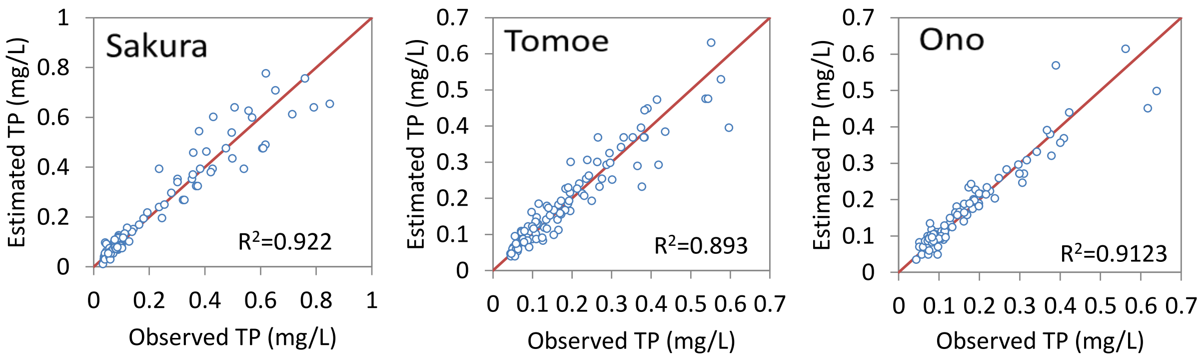

Figure 8. Comparison of observed TP concentration with that estimated by the new method.

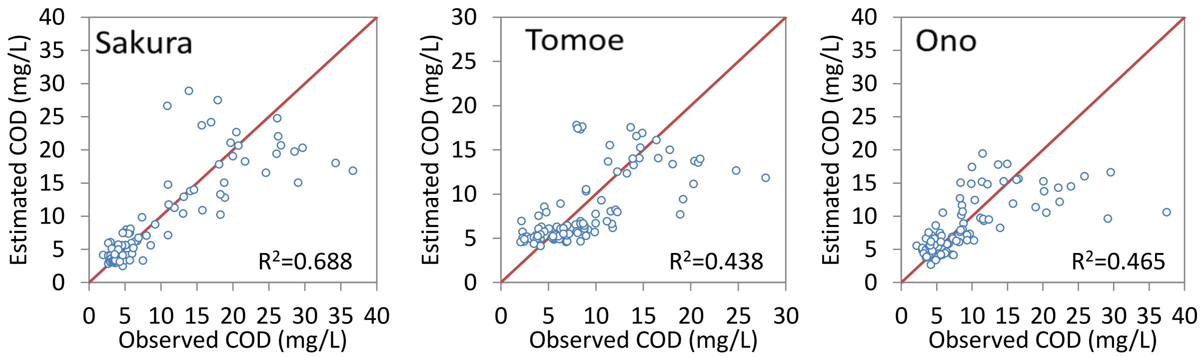

Figure 9. Comparison of observed COD concentration with that estimated by L-Q method.

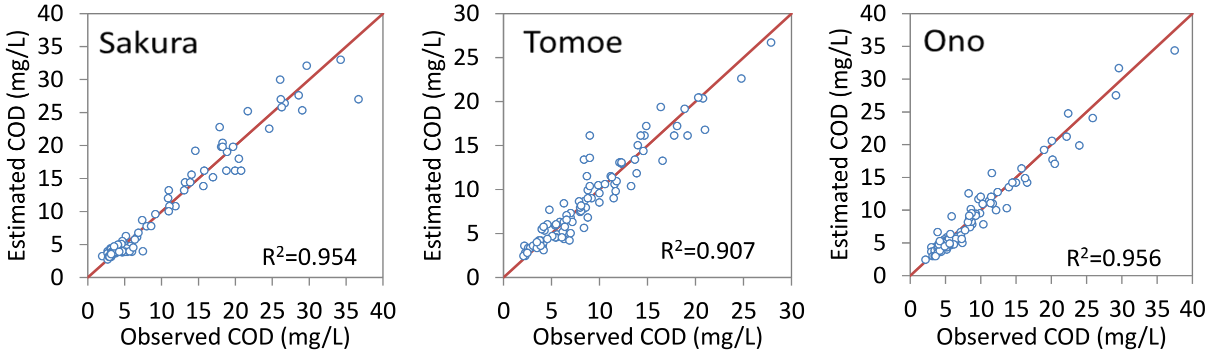

Figure 10. Comparison of observed COD concentration with that estimated by the new method.

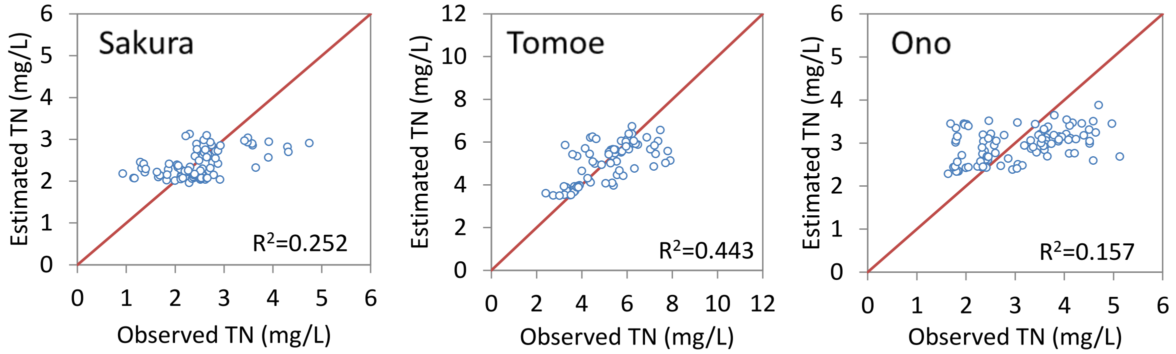

Figure 11. Comparison of observed TN concentration with that estimated by L-Q method.

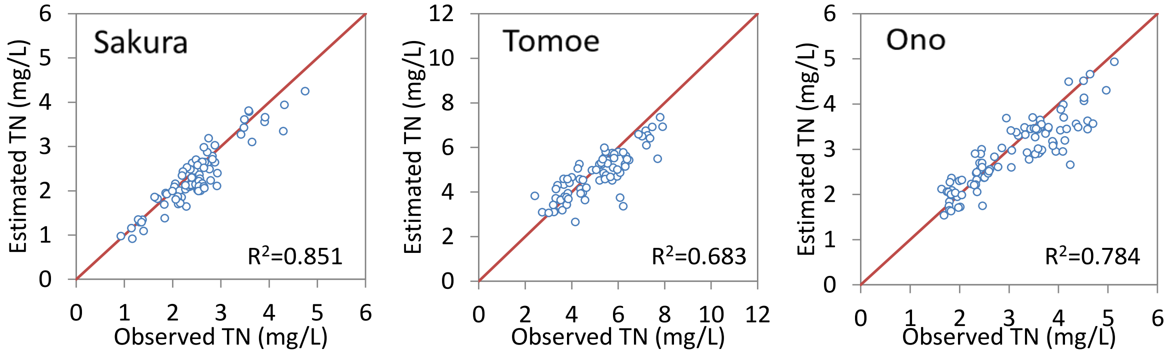

Figure 12. Comparison of observed TN concentration with that estimated by the new method.

CONCLUSIONS

A new method was developed to estimate concentrations and loads of *TP* (total phosphorus), *TN* (total nitrogen) and *COD* (chemical oxygen demand) in river streams flowing into Lake Kasumigaura. By applying this method, *TP* and *COD* concentrations are estimated solely from *SS* concentration. Besides, observed Nitrate concentration (NO_3-N) is necessary for estimating *TN* concentration. Further study is needed to monitor *SS* and NO_3-N for better estimation of *TP*, *TN* and *COD*.

ACKNOWLEDGEMENT

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MONOFILLAMENT GILLNET AS A CONTROL OF MIDAS CICHLID (*Amphilophus citrinellus*) AT IR. H. DJUANDA RESERVOIR, WEST JAVA-INDONESIA

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ABSTRACT

*Midas cichlid (*Amphilophus citrinellus*) is an invasive alien species in the Ir. H. Djuanda Reservoir. The presence of these fish is one of the factors leading to the decline of fish species diversity. The purpose of this study was to gain control techniques of Midas cichlid populations in the Ir. H. Djuanda Reservoir, West Java-Indonesia. The results showed for the control these population can be to do with catching using gillnet with mesh size of 3.8 cm (1.5 inch). The use of mesh sizes can catch fish on the size of the first length of maturity are 11.3-13.5 cm (average 12.4 cm) for male and 11.6-12.7 cm (average 12.0 cm) for female*. *Optimal length was caught with mesh size 3.2; 3.8; 4.4; 5.1 and 5.7 cm are 8.3; 9.9; 11.7; 13.3 and 14.8 cm respectively. Mesh size of 3.8 cm was also just catch fewer another importantce economic fish spesies. Gillnet installation can be done at the aquaculture location like zone 5 (Baras Barat). At the location of the aquaculture of a number of Midas cichlid caught was high and most have mature. Catching with mesh sizes and the exact location is expected to break the reproductive cycle of the fish.*

Keywords: control, Midas cichlid, gillnet selectivity, Ir. H. Djuanda Reservoir

INTRODUCTION

Ir. H. Djuanda Reservoir has area 8,300 ha and multipurpose reservoir with main fuction are irrigation and flood control, while other functions are drinking and industrial water sources, generated hydroelectric power, sport, tourism and fisheries. This reservoir has a high diversity of fish species, but now tend was decrease. Its caused by the introduction of alien species and pollution from anthropogenic activities (Tjahjo, 1994; Innal, 2012). Ir. H. Djuanda Reservoir is often carried out the stocking with exotic species (Krismono, 1989). The introduction of exotic fish species is not careful will cause harm both the environment and economically (Gozlan, 2009) and for capture fisheries at this reservoir (Tampubolon *et al*., 2005). it is caused by competition for feed utilization and habitat, predation, and the introduction of parasites and diseases (Rocha & Freire, 2009; Grabowska et al., 2010). The midas cichlid was dominant in Lake Panjalu and Kedung ombo Reservoir (Warsa & Purnomo, 2013).

Alien fish species in ecosystems will have an impact on native fish community structure, which in the end the exotic species can be dominant. It also occurred at the Lake Banyoles, Spain (Berthou & Amich, 2002). Hence the need for an effort to control the population of the invasive alien species. The technique can be used in an attempt eradication and control of invasive alien fish in a water body include fishing, habitat manipulation, use poison (chemistry) and the introduction of predators (biological) (Corfield et al., 2008). The purpose of this study was to known control techniques midas cichlid fish populations using gillnets in Ir. H. Djuanda Reservoir, West Java-Indonesia.

METHODS

Time and Location

The study was conducted in Ir. H. Djuanda in May, June, and July 2012. The fish sample was catch using monofilament gillnets with mesh sizes from 3.2 to 6.4 cm by 0.6 cm intervals (3.2; 3.8; 4.4; 5.1; 5.7 and 6.4 cm). Experimental fishing was conducted at Dam, Pelabuhan Biru and the aquaculture location (floating cages net) Zone 4 and zone 5 (Baras Barat) (**Figure 1**). Dam site is free of cage and deep near outlet. Pelabuhan Biru is capture area by local fisherman. Installation gillnet was conducted at 17.00 pm and lifted at 05.00 am. Mesh size used in the experiment were random. The fish are caught, after that measured using a board measuring with an accuracy of 0.1 cm. Observed maturity level of gonad based on Cassie methods (Effendi, 1979). Fish sample was preserved using formalin 10% and was identified by Kullander (2003), and the site Fishbase (Froese & Pauly, 2012).

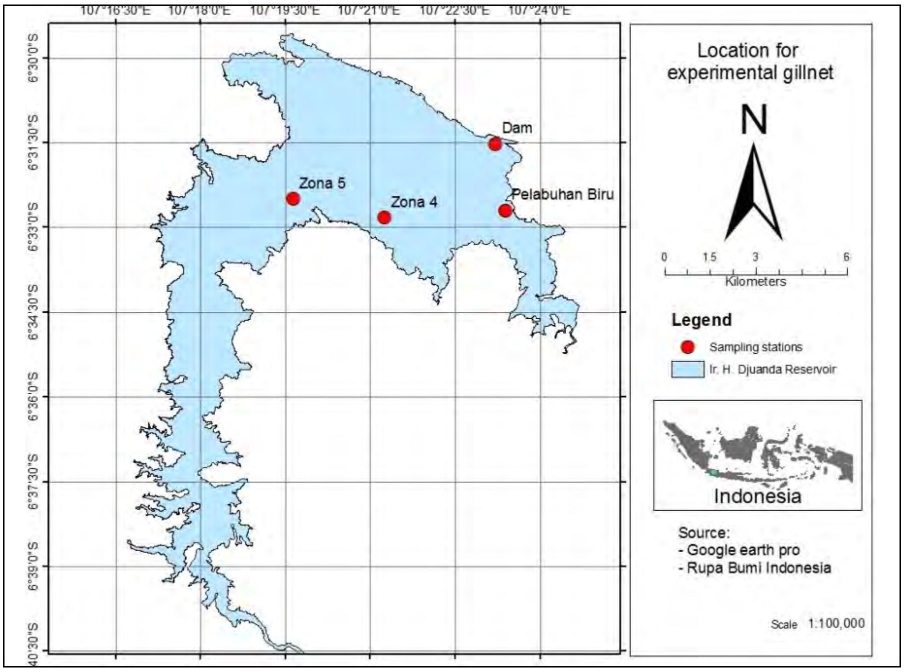

Figure 1. Location of experimental fishing using gillnet

Data analysis

Length frequency of fish sample was separated by mesh size and the location. Gillnet selectivity was analyzed using the indirect method. This method is used by Ozyurt & Avsar (2005) to determine the selectivity of gillnet for common carp (*Cyprinus carpio*) in Seyhan Dam Lake, Turkey. Estimating of selectivity parameters of by comparing the catch from two different mesh sizes, m_a and m_b (example 3.2 cm vs 3.8 cm; 3.8cm vs 4.4 and etc based on mesh size). cm for the same length class (Sparre & Venema, 1999). The natural logarithm of the number of each class, C_a and C_b for gillnets with different mesh sizes, m_a and m_b is linear to the length of the fish:

$$\ln (C_b/C_a) = a + bL$$

where:

L = lenght class of fish (cm)
a = intercept
b = Slope

The optimum length (Lm_a and Lm_b) for mesh sizes m_a and m_b

$$L_{ma} = -2[am_a/b(m_a + m_b)]$$

$$L_{mb} = -2[am_b/b(m_a + m_b)]$$

Selection factor (SF) and standard deviation (SD) of experimental gillnet using more than two mesh sizes use the following equation:

$$SF = -2 \sum \left[\left(\frac{ai}{bi}\right)(mi + mi + 1)\right] / \sum[m1 + mi + 1)^2]$$

$$SD = \{1/n - 1)\sum[2a(m_{i+1} - m_i)]/bi^2(m_i + m_{i+1})]\}^{1/2}$$

The probability of capture (P) of fish with a length (L) on gill nets with mesh sizes (m) was determined by the equation:

$$P = \exp[-(L-Lm)^2/(2SD)^2]$$

The optimum length (by probability of capture is 100%) for each mesh size is obtained:

$$Lm = SF \times m$$

Determination of length at first mature was estimated using logistic curve (King, 2007). The number of individual fish that have matured gonads (TKG III and above) was included. The logistic equation used is as follows:

$$P = 1/(1+\exp[-r(L-Lm)$$

Where:

P = The proportion of mature fish gonad (%)
Lm = Length at first maturity (cm)
L = Total length (cm)
r = Slope

Curve linear constant of a relationship between the proportion of fish mature with a number of examples of the same length class can be used to determine the value of r and Lc where r = -b and Lc = a/r. Logistic equation is also used by Hutubessy et al. (2005) to determine the length of the first mature of bony flyingfish (*Hirundichthys oxycephalus*) in Naku, Ambon Island.

RESULTS AND DISCUSSIONS

Gillnet is dominant fishing gear that was widely used by fishermen at Ir. H. Djuanda and contribute as much as 43% of total fish production (Kartamihardja, 1987). 17 species of fish was caught using gillnet experimental during the study namely Marble goby (*Oxyeleotris marmorata*), Spotted barb (*Puntius binotatus*), Mexican mojarra (*Cichlasoma urophthalmus*), Banded jewel cichlid (*Hemichromis elongatus*), Hampala barb (*Hampala macrolepidota*), *Parambassis siamensis*, Beardless barb (*Cyclocheilichthys Apogon*), Two spot catfish (*Mystus nigriceps*), *Puntius bramoides*, Jaguar guapote (*Parachromis managuensis*), Common carp (*Cyprinus carpio*), Mozambique tilapia (*Oreochromis mossambicus*), Nile tilapia (*Oreochromis niloticus*), Bonylip barb (*Osteochilus vittatus*), Midas cichlid (*Amphilopus citrinellus*), Striped catfish (*Pangasianodon hypophthalmus*) and Snakeskin gourami (*Trichopodus pectoralis*). The composition of the fish by the time of arrest is presented in **Figure 2**.

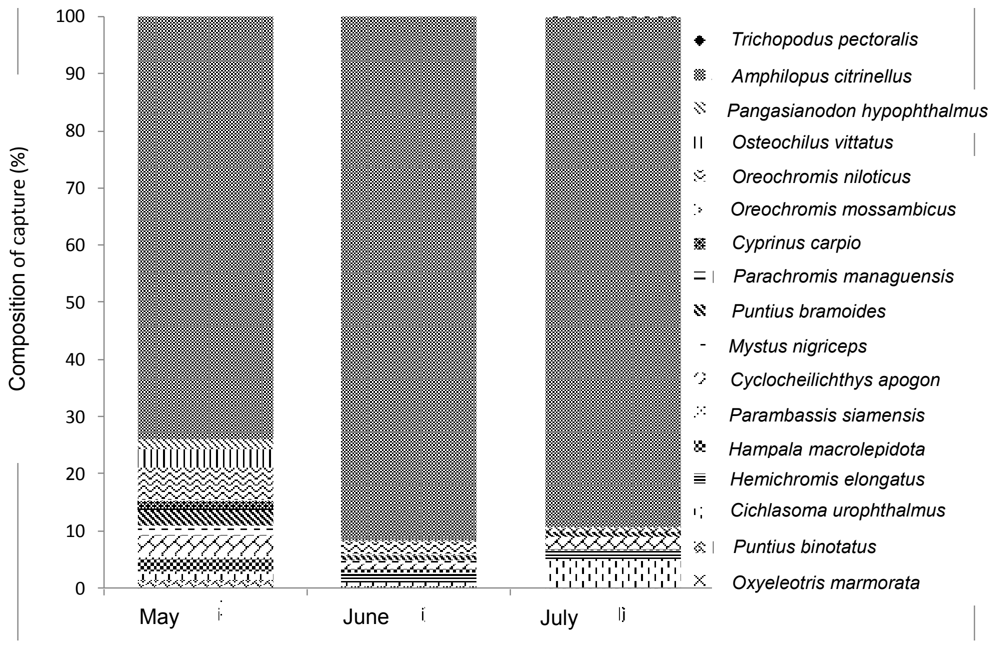

Figure 2. Catch composition of based on temporal

Midas cichlid is a dominant species that predominantly caught by 73.9 to 91.8% based on the month. Other dominant fish are Mexican mojarra and banded jewel cichlid is also an alien species. For economically important fish caught in considerable numbers include Nile tilapia and beardless barb.

Midas Cichlid were caught with gillnet at mesh size of 3.2; 3.8; 4.4; 5.1; 5.7 and 6.4 cm respectively has a total length around 7.2-12 cm; 8.1-16.6 cm; 9.5-15.2 cm; 11.5-15.6 cm; 13.5-17.5 cm, and 10.5-19.5 cm. The total length of Midas cichlid was caught for each mesh shown in **Table 1.**

Table 1. Total lenght distibution of Midas cichlid at Ir. H. Djuanda Reservoirs

Mid length *(cm)*	Mesh size (cm)					
	3.20	3.80	4.40	5.10	5.70	6.40
3.5						
4.5						
5.5						
6.5						
7.5	57					
8.5	91	76				
9.5	114	239	8			
10.5	74	173	61			2
11.5	16	52	74			1
12.5		9	34	25		2
13.5		2	16	17	3	1
14.5		1	2	8	7	1
15.5		1	1	2	4	13
16.5		1			1	9
17.5					1	5
18.5						1
19.5						1
20.5						
Total	352	561	179	60	16	36

The total length of Midas cichlid male was caught during the study around 6.0-19.5 cm for male and 6.5-17.0 cm for females. Number of Midas cichlid was caught in all mesh size experimental gillnet as shown in **Figure 3.**

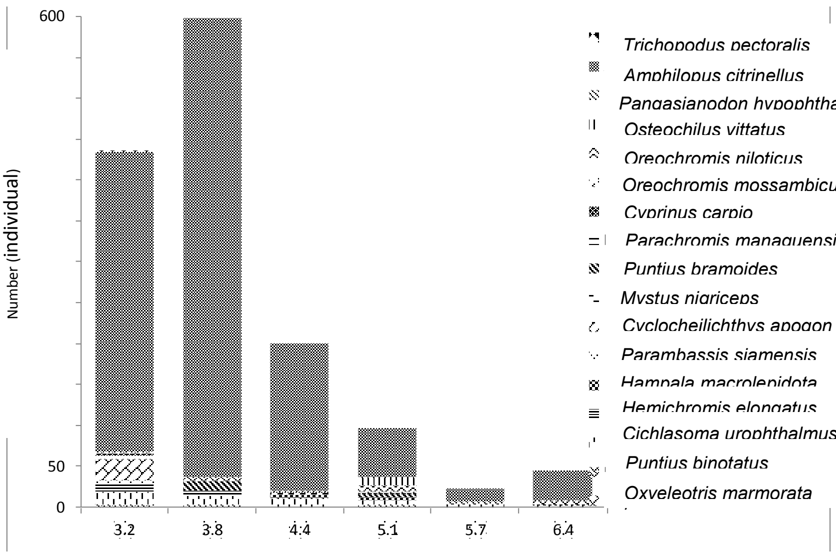

Figure 3. Catch composition of fish based on mesh size

The gillnet with mesh size of 3.2 cm and 3.8 cm gives catches were highest. Mesh size of 3.2 cm also catch other species with a considerable amount include beardless barb and two spot catfish is native species. For a mesh size of 3.8 cm, other species are also caught including Mexican mojarra and banded jewel cichlid. Both of these fishes are a fish species of potentially invasive alien species in the waters Ir. H. Djuanda.

Midas cichlid is also the dominant species was caught in all locations experimental gillnet with a percentage of 33.3-84.5% (**Figure 4**).

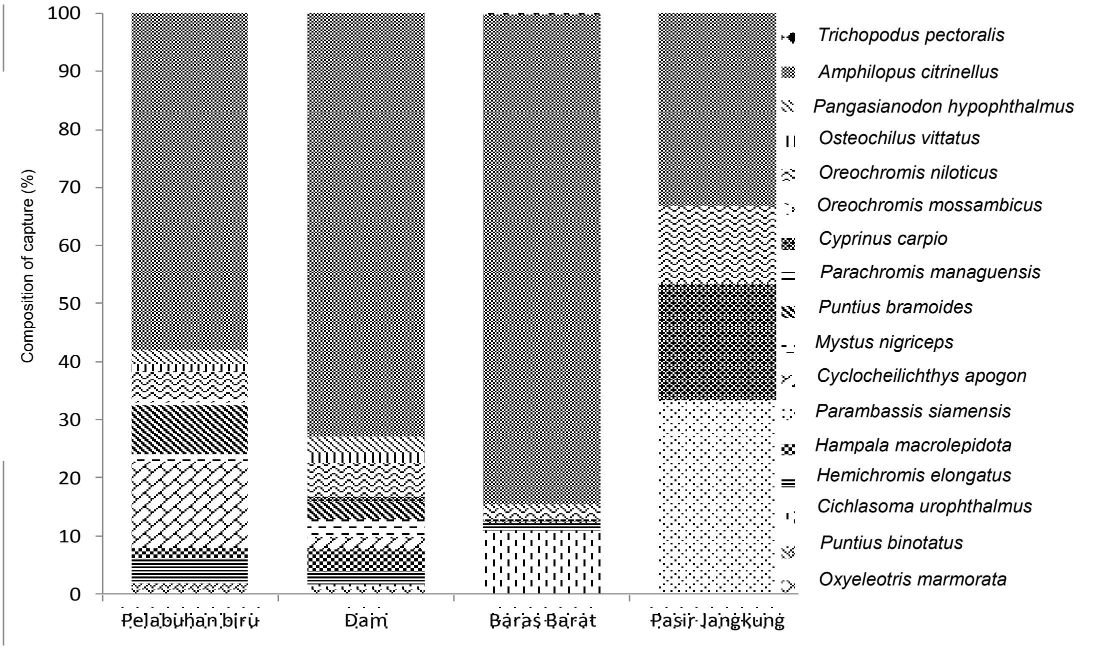

Figure 4. Catch composition of fish based on research stations

Zone 5 (Baras Barat) is located with highest catch of Midas cichlid. That is aquaculture location and perhaps the fish will be associated with aquaculture activity. Based on field study the fish using the loose feed as a food and using the cages as nursery ground.

Selectivity factors and standard deviation of gillnet with two mesh size combination shown at **Table 2**. Selectivity factors for gillnet with combination all mesh size 3,2; 3,8; 4,4; 5,1 dan 5,7 cm is 2,5987 with standar deviation is 1,0921.

Table 2. Regression constant and selectiviy parameters of gillnet for Midas cichlid

Mesh size (cm)		regression constants			Selectivity prameters			
m_a	m_b	a	b	r^2	Lm_a (cm)	Lm_b (cm)	SF	SD
3,2	3,8	-18,107	2,1653	0,9845	7,6	9,1	0,6621	0,8137
3,8	4,4	-21,100	1,9610	0,9306	9,9	11,7	0,9255	0,9620
4,4	5,1	-18,760	1,3960	0,9999	12,6	14,3	1,2033	1,0969
5,1	5,7	-15,228	1,0111	0,9322	14,2	15,9	1,6551	1,2865

The total length with the highest probability of capture for combination of mesh sizes of 3.2 and 3.8 cm is 7.6-9.1 cm. For a combination of mesh sizes of 3.8 and 4.4 cm is 9.9-11.7 cm; to a combination of mesh sizes from 4.4 to 5.1 cm is 12.6-14.3 cm while the combination of mesh sizes of 5.1 and 5.7 cm is 14.2-15.9 cm. Optimal total length was caught in the mesh of 3.2; 3.8; 4.4; 5.1 and 5.7 cm respectively 8.3; 9.9; 11.7; 13.3 and 14.8 cm (**Figure 5**)

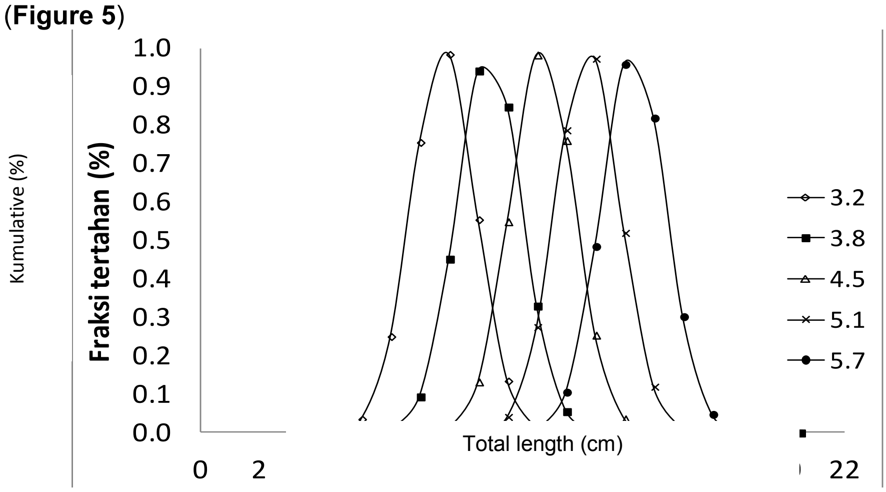

Figure 5. Selection curve of midas cichlid at Ir. H. Djuanda Reservoir

The length at first maturity ranged from 11.3 to 13.5 cm with an average of 12.4 cm for males, while for females ranged from 11.6 to 12.7 cm with an average of 12.0 cm (**Figure 6**).

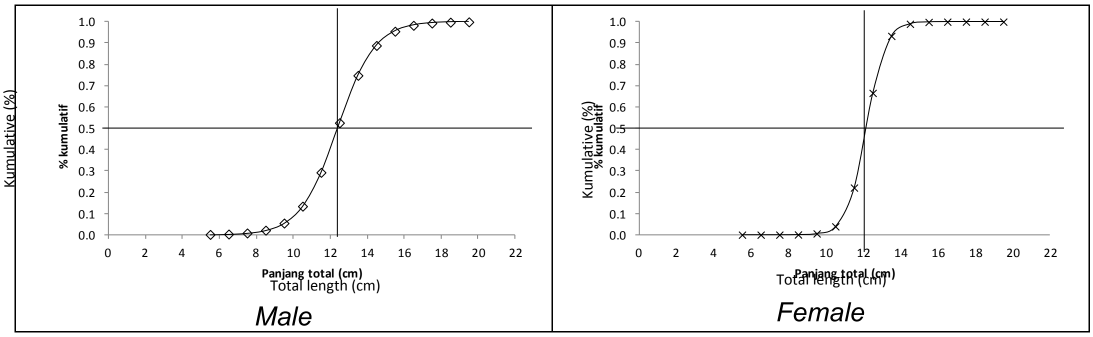

Figure 6. Length at first maturity (Lm) of midas cichlid

Total lenght of male with mature condition was caught around 11.0-19.5 cm and 10.0-17.0 cm for female. Its dominant capture in Zone 5 using gillnet with mesh size 4.4-5.7 cm.

Gillnet is a fishing gear with high selectivity and size of the fish was captured depending on the mesh size (Ozekinci, 2005). Control of invasive alien species can be done with gillnets. Control of alien fish populations in Lake Mizoro Ga Ike in Japan conducted by using net fishing and damage of spawning ground give the impact on the population decrease as much as 40-60% in 4 years (Abekura et al., 2004).
Similar results were obtained from studies Hedianto & Purnamaningtyas (2011) in which the dominant fish caught with gillnet in Ir. H. Djuanda is Midas cichlid. The dominant species was caught using gillnets in Ir. H. Djuanda was changes, in 1982-1989 dominant fish caught Hampala barb and *Mystacoleocus marginatus* (Krismono, 1989; Azizi & Sadili, 1994). Its a native species that has spread most widely in Ir. H. Djuanda Reservoir (Tjahjo & Umar, 1994), but now its existence was replaced by Midas cichlid. Midas cichlid is also the dominant fish species in some other waters, such as Situ Panjalu and Kedung Ombo (Purnomo, 2010; Warsa, 2011). Negatively impact of Midas cichlid dominance for fish communities in Reservoir Ir. H. Djuanda, namely a decrease in the diversity of fish species (Hedianto & Purnamaningtyas, 2011). Optimal length of Midas cichlid was caught in Ir. H. Djuanda in the mesh size of 3.2; 3.8 and 4.4 cm smaller than the size caught in Situ Panjalu namely 10; 11.5 and 14 cm (Warsa & Purnomo, 2013). The total length of the Midas cichlid biggest caught in Ir. H. Djuanda (19.5 cm) smaller than caught in Australian waters is 24 cm (Corfield et al., 2008). Selectivity factor of gillnet for midas cichlid at Ir. H. Djuanda also smaller in comparison with situ Panjalu is 3.0745. The total length was caught on two mesh sizes combination is 3.2 and 3.8 cm, and 3.8 and 4.4 cm fish Oskar in Ir. H. Djuanda smaller than in Situ Panjalu ie 10.7 and 12.8 and 11.2 cm and 13.3 cm (Warsa & Purnomo, 2013). Hamley (1975) states that the total length of fish caught is 20% longer or shorter than the optimum length. In theory, total length was caught on mesh sizes are presented in **Table 3**.

Table 3. Theoritically of total length at difference of mesh size

Mesh size (cm)	*Total length* (cm)
3,2	6,6-10,0
3,8	7,9-11,9
4,4	9,4-14,0
5,1	10,6-15,9
5,7	11,0-17,8

Research from Purnomo & Warsa (2013) showed that the size of the head girth, HG and the maximum girth, MG of Midas cichlid in Ir. H. Djuanda each ranging from 5.7 to 12.0 cm and 6.6 to 13.3 cm. The relationship between head circumference and weight to the total length (TL) of Midas cichlid is:

$$MG = 0{,}801\ TL + 0{,}296 \qquad R^2 = 0{,}920$$

$$HG = 0{,}788\ TL - 0{,}248 \qquad R^2 = 0{,}889$$

Head girth, HG and the maximum girth, MG positively correlated with the total length and the factor that determine the size was caught in gillnet (Kurkilahti et al., 2002; Stergiou & Erzini, 2002). Fish caught will have the size of Head girth, HG and the maximum girth, MG that is equal to or slightly larger than the circumference of mesh sizes (Carol & Garcia-Berthou, 2009). Head girth, HG and the maximum girth, MG estimation of Midas cichlid and comparison against the circumference of mesh size is presented in **Table 4**.

Table 4. Estimation and ratio head and maximum girth versus mesh perimeter for Midas cichlid

Mesh size (cm)	HG:MP	MG:MP
3,2	0,79-1,41 (1,02 ±0,12)	0,91-1,14 (1,14 ±0,14)
3,8	0,90-1,29 (1,05 ±0,10)	1,00-1,40 (1,1 ±0,11)
4,5	0,76-2,00 (1,1 ±0,13)	0,76-2,10 (1,2 ±0,14)
5,1	0,62-1,52 (1,01 ±0,1)	0,70-1,70 (1,1 ±0,11)
5,7	0,69-1,20 (1,0 ±0,69)	0,70-1,20 (1,1 ±0,12)
6,4	0,63-1,22 (0,98± 0,63)	0,70-1,10 (1,0± 0,11)

Midas cichlid was caught in mesh sizes from 3.2 to 5.1 are generally caught on the head. For Midas cichlid was caught in mesh sizes from 6.4 to 7.1 cm will be trapped in the body. Generally, fish will be caught in the mesh with a mesh ratio of the circumference to the head and maximum girth ranging from 1.0 to 1.1 (Reis, & Pawson, 1999). The ratio between head circumference and maximum girth to the circumference of mesh size can be used to estimate the position of the fish when caught in gill nets (Marais, 1985; Jawad et al., 2009). The size of Midas cichlid before first mature dominance caught at mesh size ≥ 3,8 cm. The size of first mature smaller when compared with the results of research Purnamaningtyas & Tjahjo (2010), which ranges from 12-21 cm. Therefore, control of Midas cichlid can be done using gillnets with a mesh size of 3.8 cm. In the mesh size, native fish caught was low (<3%) and most are alien fish that could potentially become invasive, ie Mexican mojarra and banded jewel cichlid. Mesh size that is most efficient for caught of fish have lower selectivity curve compare with another mesh size (Hamley, 1980). Mesh size with the lowest selectivity was 3.8 cm, so that gillnets with a mesh size of 3.8 cm is more efficient to catch fish compared to other mesh sizes (Purnomo & Kartamihardja, 1983). The location for setting gillnet which aims to control Midas cichlid population in Ir. H. Djuanda Reservoir is in the aquaculture zone. The catch with using gillnets indicates that the aquaculture location zone 5 (Baras Barat) is the location with the highest Midas cichlid catches. The fish with mature gonads is dominant caught at that location. The gillnet installation can be done by surrounding the floating cages net.

CONCLUSIONS

The control of Midas cichlid populations can be done using gillnets with a mesh size of 3.8 cm (1.5 inches). The use of mesh sizes can catch of Midas cichlid before reaching the first of maturity size that is 7.9 to 11.9 cm. With this mesh sizes are also lower catches another economically important fish. Location of gillnet installation for the control of Midas cichlid at aquaculture location likes Baras Barat (zone 5).

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PHYTOTECHNOLOGY APPLICATION TO CONTROL LAKE WATER QUALITY: A PRELIMINARY TRIAL TO USE FLOATING PLANTS FOR CONTROLLING WATER QUALITY IN A SMALL LAKE OF SITU CIBUNTU, CIBINONG, INDONESIA

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ABSTRACT

A preliminary trial to use aquatic plants for controlling small lake – Situ Cibuntu in Cibinong, West Java, Indonesia - water quality has been carried out. A phytotechnology pond system consisted of 2 tarpauline pond series, each contained 1 reservoir pond, 4 phytoremediation ponds, and 1 buffer pond. The phytoremediaal function was facilitated by some floating plants which were planted in the phytoremediation ponds. The experimental floating plants were minute duckweed (Lemna perpusilla), greater duckweed (Spirodella polyrizha), water lettuce (Pystia stratiotes) and water hyacinth (Eichornia crassipes). The phytoremediation capacity was evaluated according to some water quality parameters monitored at points of the reservoir pond, phytoremediation ponds, and buffer pond. They included pH, DO, conductivity and turbidity measured twice a week, as well as total suspended solid (TSS), total organic matter (TOM), total nitrogen (TN) and total phosphorous (TP) which sampled and analysed every week. There were variations in ability to absorp and eliminate water contaminats among the experimental plants which appeared to be associated with their growth and biomass productivity. A remarkable high phytoremediation capacity was shown by water hyacint and water lettuce, which under the experimental condition able to eliminate TSS, TOM, TN and TP up to 81.48 %, 51,21 %, 85.82 %, 24.07%, and 79.63 %, 26.18 %, 78.95%, 100 %, respectively. The results shows that floating aquatic plants can be potentially used for lake water phytoremediation agents. Meanwhile, the observed variation among the plants phytoremedial capacity emphasizes the important of plant selection in developing the phytotechnology for lake water quality control. This selection has to consider the lake water trophic status and in particular has also optimized by appropriate phytotechnology pond design.

Key words: phytotechnology, aquatic plants, lakes, water quality

INTRODUCTION

Water contamination has been a major problem in inland waters, which is mainly caused by input of waste water to the river stream that flows through dense populated and industrial area. As an example, Garno (2001) has reported that contamination load from domestic and industrial activities in the high Citarum River watershed was up to 338.92 tons BOD/day and 545.11 tons COD/day which enter to the Saguling reservoir water. At the same time, load of nutrients enter the Saguling Reservoir water was approximately 34.032 tons N/day and 5.5 tons P/day. There was still some more additional load from floating cage aquaculture activities which accounted up to 10.952 tons organic/year, 478 ton N/year, and 68 ton P/year (Garno, 2002). The high nutrient input has caused water eutrophication in the reservoir, as has been reported that the water contain 0.684-3.460 mg/L TN and 0.067-0.364 mg/L TP, while the chlorophyll content 5.364-71.126 mg/m^3 (Hart et al., 2002; IHP-UNESCO, 2011).

Even though it has been occurred since a long time ago, the problem of water contamination and eutrophication has not yet been able to overcome effectively, due largely to its complexity. This is particularly related to the dense population which give a consequency of high demand on land and water for housing, agriculture, aquaculture, and industrial purposes. It is considered, therefore, the need of a strong breakthrough measure that can be more effectively and efficienly overcome this problem in line with local community empowerment programmes, particularly in terms of economic development sectors. One of the effort is by application of phytotechnology, which is using aquatic plants to become water quality phytoremedial agents (UNEP, 2003). Aquatic plants give advantage in controlling water pollution due to the natural properties so as less side impacts imposed to the environment. . Indeed, aquatic vegetation can be potentially served as habitat for some aquatic organisms, so that can also be useful to increase the biodiversity over there. Some aquatic plants has also known to have high nutrition value and can be used for protein source and natural feed (Chrismadha et al., 2013).

Efforts to employ aquatic plants for water pollution control has been widely innitiated. For examples, some duckweeds has been employed for domestic and industrial waste water treatments (Cheng et al., 2002; El-Kheir et al., 2007; Ansal et al., 2010; Ferdoushi et al., 2008; Schroder et al., 2007). Cedergreen & Madsen (2002) reported the ability of *Lemna minor* to absorp NH_4 and NO_3 through the roots and leaves. Under in vitro condition, the absorption rate of nitrogen and phosphorous compounds was up to 3.36 g/m^2/day and 0.20 g/m^2/day, respectively, while in the field the absorption rate was up to 2.11 g/m^2/day and 0.59 g/m^2/day (Cheng et al., 2002). In the mean time, El-Kheir et al. (2007) reported the capacity of *Lemna gibba* to eliminate some water quality parameters, including total suspended solid, BOD, COD, NO_3, NH_4, o-PO_4, Cu, Pb, Zn, and Cd as much as 96.3 %, 90.6 %, 89.0 %, 100.0 %, 82.0 %, 64.4 %, 100.0 %, 93.6 %, and 66.7 %, respectively. Alaert et al. (1996) reported that duckweed could eliminate 74% TKN (Total Kyeldahl N) in a waste water treatment pond with retention time of 21 days, to produce output of relatively low nutrient content water, which was 2.7 mg/L TKN and 0.4 mg/L TP.

At the same time, water lettuce (*Pistia stratiotes*) has been reported to remove as much as 190-329 kg N/ha and 25-34 kg P/ha annualy, and potentially eliminate some heavy metals as well as some water contamination parameter, such as COD, BOD, suspended solid, and nutients (Khan et al., 2014; Fonkou et al., 2002; Lu et al., 2010; Chakraborty, 2015). Meanwhile, other floating aquatic plant of water hyacinth (*Eichornia crassipes*) has pointed out to be potential for river water improvement, water pollution controll in palm oil industry, and also heavy metals ellimination (Weiliao & Chang, 2004; Hammad, 2011; Swain et al., 2014; Chukwunonso et al., 2014; Maulion et al., 2015; Moyo et al., 2013; Omondi et al., 2015).

Beside as waste water treatment agent, some aquatic plants has also been known to have high potential for natural feed, such as those of belong to duckweeds (Hasan & Chakrabarti, 2009; Chrismadha et al. 2014). This duckweed species has high protein content, which is 10-43 % of the dry weight (Leng et al., 1995; Landesman, 2005), as well as supporting by high biomass productivity up to 13-38 ton dry weight/Ha/year (Ansal et al., 2010). Some experiments has been carried out to use these aquatic plants for feeding some animals, including duck, pig, and nile tilapia fish (Leng et al., 1995). A trial in Brazil has shown the potential of dried duckweed biomass for supplement feed to replace commercial pellet up to 50% without any detrimental effect on the growth (Tavares et al., 2008). Feed convertion ratio (FCR) of *Lemna gibba* biomass for feeding tilapia fish was 1.5, while the specific growth rate was up to 0.71 (El-Shafaia et al., 2004).

Situ Cibuntu is a small lake located in Cibinong Science Center and Botanical Garden of Indonesian Institute of Sciences (CSCBG-LIPI) Cibinong, West Jawa, Indonesia. It has a wide of 15.026 m^2, maximum depht of 1.6 m, total water volume 13.460 m^3, and water retention time of about 10 days (Nugroho, 2002). Some previous studies reported that the lake water was in classification of mesotrophic – eutrophic. For examples, Tarigan (2000) reported the lake water condition was eutrophic with TN and TP content 2.30 mg/L and 0.33 mg/L in average, respectively. Damayanti (2001) reported the water NO_3 and o-PO_4 content in the range of 0.22-1,62 mg/L and 0.0004-0.988 mg/L, respectively, followed by phytoplankton abundance of 58,746-11,543,786 individu/L and water tranparency of 22.7-85.0 cm. Nugroho (2002) reported that the NO_3 content was 0.54-1.13 mg/L, o-PO_4 was 0.02-0.03 mg/L, and chlorophyll content was 25.55-87.61 mg/L, and classified the water was suitable for fishery purposes. Accoding these facts, it is considered the need efforts to improve Situ Cibuntu water quality by controlling nutrient content in the water. In this study, a trial of phytotechnology application was carried out to reduce nutrient concentration in the lake water, by chanelling the water into a series of phytoremedial ponds where some floating aquatic plants was grown. The study aims to figure out the capacity of various floating aquatic plants in eliminating nutrients, which were TN and TP from the lake water.

METHODS

The phytotechnology pond system consisted of 2 tarpauline pond series, each contained 1 reservoir pond (RP), 4 phytoremediation ponds (FP-1 and FP-2), and 1 buffer pond (BP). The reservoir pond has a function to collect water from the lake, which then channelled into the phytoremediation ponds before it flows out to the buffer pond and discharged back to the lake. The average water debit was 35 m^3/day which set up the water residence time of 27,42 hours. A set of solar cell system was employed to enable the water circulation by means of a water pump (Shimizu® 128 bit). Under low irradiance the source of power was switched to publick electricity to maintain the continuous flow. The schematic of phytotechnological pond is presented in **Figure 1**.

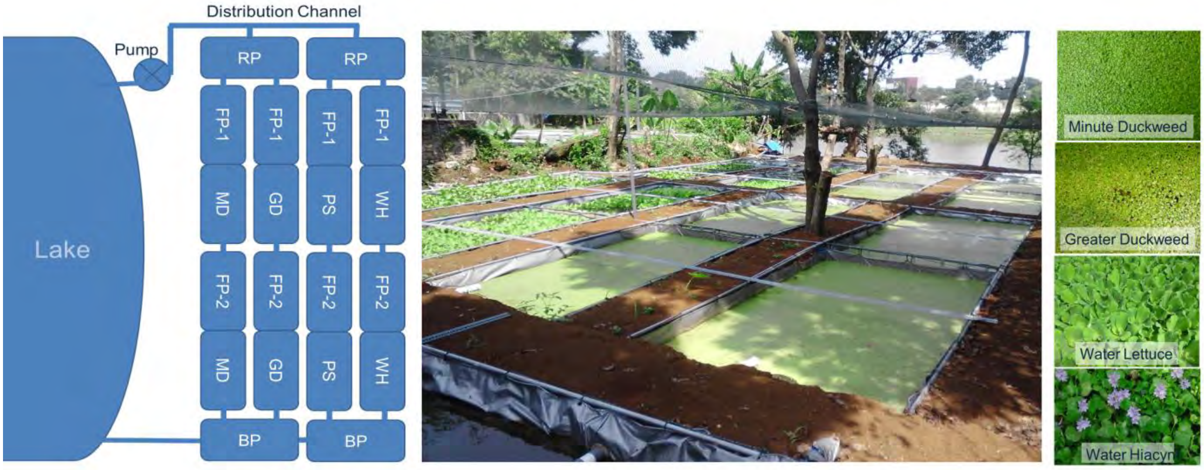

Figure 1. Schematic (left) and field lay out of the experimental phytotechnology pond (middle) with various floating aquatic plants (right)

The phytoremedial function was facilitated by some floating plants which were planted in the phytoremediation ponds, all obtained from aquatic plants collection of Research Center for Limnologi – Indonesian Institute of Sciences in Cibinong, Indonesia. The experimental floating plants were minute duckweed (MD; *Lemna perpusilla*), greater duckweed (GD; *Spirodella polyrizha*), water lettuce (WL; *Pystia stratiotes*) and water hyacinth (WH; *Eichornia crassipes*). Each plant was reared in one line consisted of 4 tarpauline ponds, and the growth and biomass productivity were observed fortnightly for minute duckweed and greater duckweed and every 2 weeks for water lettuce and water hyacinth. The plants specific growth rate (μ) was calculated according to a formula as follow:

$$\mu = \frac{\ln (X_t/X_o)}{t} \text{ X } 100\%$$

in which: μ= specific growth rate (%/day), Xo = innitial biomass, Xt = biomass at day t, and t = time (day). Meanwhile, the plant biomass productivity (P) was calculated following formula:

$$P = \frac{X_t - X_o}{t}$$

in which: P = biomass productivity (kg/day), Xo = innitial biomass, Xt = biomass at day t, and t = time (day). The phytoremediation capacity was evaluated according to some water quality parameters monitored at points of the reservoir pond (RP), phytoremediation ponds (FP-1 and FP-2), and buffer pond (BP). They included total suspended solid (TSS), total organic matter (TOM), total nitrogen (TN) and total phosphorous (TP) which sampled and analysed every week, be analysed according to APHA (1998). The plants capacity to eliminate contaminants (ER) was calculated according a formula below:

$$ER = \frac{X_t - X_o}{X_o} \times 100\%$$

in which: ER = ellimination rate (%), X_o = innitial contaminant concentration, X_t = contaminant concentration at day t.

RESULTS AND DISCUSSIONS

Observation on water inlet from the lake into experimental phytotechnology ponds shows average TN, TP and TSS content were 4.06-5.21 mg/L, 0.041-0.054 mg/L, and 28-36 mg/L, respectively. This observed TN and TP content was higher than that was reported by Tarigan (2000) and confirms that Situ Cibuntu water was under eutrophic condition. According to **Figure 2**, however, this trophic status was not enough to vapor growth of all the experimental plants. The minute duckweed grew only at specific growth rate of around 4.51 %/day, which is remarkably lower than those grown in Saguling Reservoir water that grrew at rate of 12-24 %/day (Chrismadha & Mardiyati, 2012), and in ponds received aquaculture waste containing water of more than 30 %/day (Chrismadha et al*.,* 2013; Chrismadha, 2014). At the same time, greater duckweed growth was recorded at around 4,94 %/day, while previous reports stated doubling time of the plant was 27.5-40.1 %/day

(Olah et al., 2014). Similarly, water lettuce grew at rate of 5.30 %/day, also remarkably lower than that was previously reported by Fonkou et al. (2002) whose observed doubling time of the plant at averege of 5 days (equivalent to SGR value of 34 %/day) base on sewage water. Water hyacinth grew at rate of 2,47 %/day, considerably low compared to those reported by Christanty et al. (2016) of 2.82-3.56 %/day in swamp water and Gupta et al. (2012) of around 3.10 %/day. These spesific growth values made up the plants biomas productivity which was observed to be the highest in water lettuce (3.71 kg/week), followed by water hyacinth (2.59 kg/week), greater duckweed (0.69 kg/week) and minute duckweed (0.32 kg/week), respectively. This can be attributed to the plants size, in which the biger size made up population density higher than the smaller ones, and then together with the spesific growth value it contributed to the plant biomass productivities. The highest biomass producivity observed in water lettuce was apparently due to its biger population density up to 12.2 kg/m^2 and higher growth rate of 5.3 %/day.

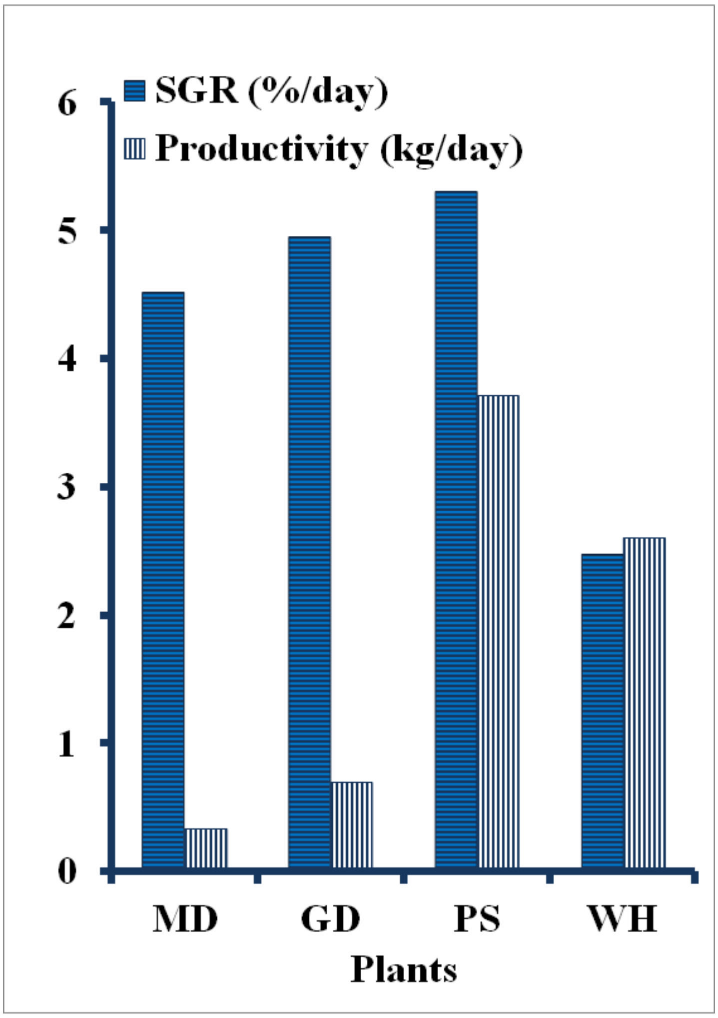

Figure 2. Growth and biomass productivity of various floating aquatic plants in the experimental

Growth rate and biomass productivity were appeared to determine the ability of aquatic plants to absorp and eliminate water pollutants. As it is shown by **Figure 3**, even though a consistent progresive reduction in most of observed water quality parameters from inlet to final outlet of the phytoremediation ponds were occurred, the rate of reduction was varied among the plants. Water hyacinth and water lettuce was observed to have remarkably higher capability to eliminate TSS, TOM, TN and TP, comparing to those of minute duckweed and greater duckweed. Under the experimental condition, water hyacinth and water lettuce were obeved to eliminate TSS up to 81.48 % and 79.63 %, respectively, while minute duckweed and greater duckweed only eliminated 39.29 % and 46.43 % TSS from the water, respectively. Whereas, in terms of TN, elimination rate of 85.82 % and 78.95 % were oberved in water hyacinth and water lettuce, respectively, while in minute duckweed and greater duckweed the elimination rates were as lower as 29.45 % and 12.45 %, respectively. At the same time, in the reared water hyacinth and water lettuce phytoremediation ponds, the trend of progresive decline in TOM and TP content were still consistently occurred, in which the elimination rate were accounted of 51.21% and 26.18 % for TOM, and 24.07 % and 100 %, for TP, respectively. However, in these cultivated minute duckweed and greater duckweed phytoremediation ponds there were even increases in TOM and TP content were observed, means that there were releases of both organics and phosphorous substances into the water. This particularly due to low capability of these two duckweed species in eliminating both TOM and TP from the water, as well as the interfere of leaves garbage from some trees standing suroundding the experimental ponds. Although there was a net spreaded out above the ponds to prevent leaf fall from standing trees around, there was stiil some wind driven leaves come into the ponds, particularly those in the side of minute duckweed and greater duckweed phytoremediation ponds. The accumulated leaves biomass in the ponds led to biodegradation proccesses which increase the TOM and TP content over the initial concentration in the inlet water. Apart from this, this experimental results shows the ability of aquatic plants, particularly water hyacinth and water lettuce to improve lake water quality, as well as to highlight the important of plant biomass productivity aspect in selection of aquatic plants for water quality phytoremediation.

Success of using floating aquatic plants for phytoremediation of water quality has been widely reported. For examples, Chrismadha & Mardiati (2012) reported the ability of minute duckweed (*Lemna perpusilla*) to eliminate nitrate and phosphate substances from eutrophic water of Saguling reservoir. In addition, El-Kheir et al. (2007) reported the capacity of *L. gibba* to eliminate TSS, NO_3, NH_4, and o-PO_4, as much as 96.3%, 100.0%, 82.0%, and 64.4%, respectively. At the same time, Fonkou et al. (2002) observed water quality improvement by employing water lettuce to control water pollution from domestic sewage, in which more than 70% reduction in nitrate and phosphate substances was obtained. It is in line with Hermawati et al. (2005) that reported the ability of water lettuce to eliminate phosphate up to 41.9 % from detergent comtaminated water, and Lu et al. (2010) that reported reduction in inorganic ammonium and nitrate by more than 50 % using the same plant species to treat eutrophic waterstorms. Similarly, Gamage & Yapa (2001) also reported reduction up to 83.5 % and 52.9 % of TN and TP content by aplication of water hyacinth to treat waste water from textile mill, while TSS was removed up to 59 %. These three floating aquatic plants have also been reported to have potential capacity for phytoremediation of heavy metals and some other water contaminations, such as BOD, COD, turbidity, PCB, etc. (El-Kheir et al., 2007; Cheng et al., 2002; Ansal et al., 2010; Ferdoushi et al., 2008; Schroder et al., 2007; Khan et al., 2014; Fonkou et al., 2002; Lu et al., 2010; Chakraborty, 2015; Hammad, 2011). Unfortunately, less information was obtained for greater duckweed capacity for phytoremediation purposes.

This experiment reveals the high potential of using floating aquatic plants, particularly water lettuce and water hyacinth for phytoremediation small lake water quality, although some improvements in terms of operational design still being required. For example, prolonging the water rediential time in the phytoremediation can be very useful to improve the phytoremedial capacity, as the water residential time in this experiment was remarkably shorter than that was apllied by Allaert et al. (1996) whose obtained 76 % TKN reduction duckweed phytoremediation at 21 days residential time. Fonkou et al. (2002) also pointed out the important of maintaining plant population by regular harvesting which has to be carried out according to the plant life span. This experiment has also high lighted the important of ambient water trophic status in selecting plants being employed for water phytoremediation purposes. Employing a combination of some plants with various characteristics might also be worth to anticipate dynamic of water and environmental conditions. In addition, improving value of phytoremediation can also be conducted by application of plants having additional usages, such as for alternative feed (Ilyas et al., 2014; Hasan & Chakrabarti, 2009; Leng et al., 1995; Landesman, 200; Tavares et al., 2008; El-Shafaia et al., 2004), organic fertilizer (Sebayang et al., 2010; Moi et al., 2015), and enegy (Yonathan et al., 2013).

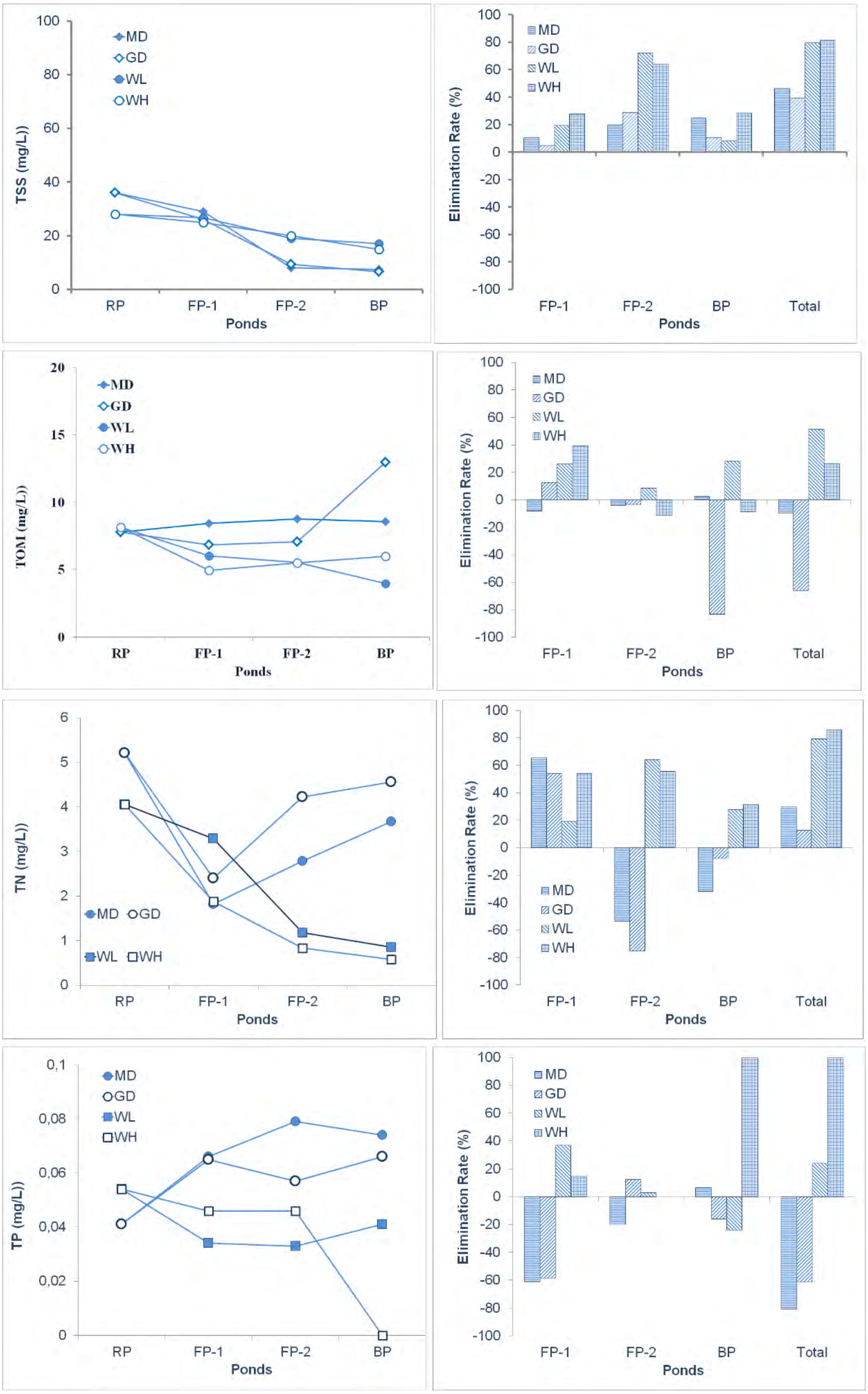

Figure 3. Growth performance and phytoremedial capacity of various floating aquatic plants: (MD minute duckweed; GD greater duckweed; WL water letuce; WH water hyacinth)

CONCLUSION

Phytotechnology can be applied to control lake water quality, which evidence in this experiment by application of floating plants to improve lake water quality. This phytoremediation capabilites, however was varied among species and largely detemined by the biomass productivity. Therefore, as far as for water quality improvement concern, it is suggested to use bigger size floating aquatic plants, such as water hyacinth and water lettuce for efective phytoremediation to improve lake water quality.

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Topic 9. Manmade lakes

EVALUATION OF FLOOD MITIGATION AND WATER PURIFICATION EFFECT IN URBAN LAKE, JABODETABEK

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ABSTRACT
Recently, severe flood occurred in Jakarta city in almost every year and water quality level in rivers flowing through Jakarta Metropolis became worse because only 3.0% of living households connected wastewater treatment system. In Jakarta, about 1000 urban lakes were existed before, however number of them decreased around 300 until now caused by urbanization. Reduction of urban lakes will accelerate the degradation of water environment in Jakarta, because urban lakes have multi-functionality for keeping water environment in suitable condition. Therefore, in this study, to conserve those lakes in adequate condition and in sustainable, multi-functionalities were evaluated in the view point of water purification and flood control in this region. Firstly, we selected 9 urban lakes and collected water samples from inlet and outlet of urban lakes. Average nitrogen purification rate was 21.2% in rainy season and 45.5% in dry season. *In rainy season, most of nitrogen runoff was Nitrate form originated from agriculture, however in dry season, most of nitrogen runoff was Ammonium form originated from housing. Secondly, flood mitigation effects were evaluated by using SCS-Curve Number method and hydraulic structure of the outlet also considered in calculation. Estimated flood peak cut ratio was 44.9% in average and most of urban lake had significant flood mitigation function.*
Keywords: lake water environment, land use change, GIS, JAVA, Jakarta

INTRODUCTION

As rapid population increase and economic growth, land use was drastically changed from agricultural land to urbanized built-up area especially in outer edge of Jakarta Metropolis. Jakarta lies in low-lying deltas served by the Ciliwung River and many other small rivers. Due to overpopulation in Jakarta, green open spaces are diminishing. Since infiltration capacities of land in Jakarta have decreased, surface runoff has become more extensive. As a result, Jakarta is often stricken by flood disasters which affect human life, property, and urban infrastructures (Hartono et Al., 2010). Before, sever flood occurred in every 5 years (1996, 2002, 2007). However, recently, severe flood occurred in Jakarta city in almost every year (2012, 2013, 2014). The effect of the land use change in the area of Jakarta on the local climate was investigated (Tokairin et al., 2010). In the past few decades, the surroundings of the initially urbanized area (the old city) of Jakarta, Indonesia, was rapidly urbanized and the daily mean air temperature increased by approximately 1 ℃. In addition, degradation of water environment in Jakarta became severe and water quality level in rivers flowing through Jakarta became worse because only 3.0% of living households connected wastewater treatment system (GWI, 2011). According to JICA feasibility reports, several flood controlling facilities or wastewater treatment plants were planned to construct, however settlement of living people relocation and land expropriation was very difficult in highly populated region. In surrounding of Jakarta metropolis, about 300 urban lakes exist. Effective use of urban lakes as a water storage or water purification facilities is one countermeasure to prevent becoming water environment more badly. Urban lakes constitute vital components of the regional hydrological cycle. They are highly productive, support exceptionally large biological diversity, and provide a wide range of ecosystem services such as food, fibre, waste assimilation, water purification, flood mitigation, erosion control, groundwater recharge, micro climate regulation, enhance the aesthetics of the landscape, and support many significant recreational, social and cultural activities, aside from being a part of our cultural heritage (Pradhan et al., 2008). However, it was acknowledged that most urban lakes or wetlands are seriously threatened by conversion to non-wetland purposes, encroachment of drainage through landfilling, pollution (discharge of domestic and industrial effluents, disposal of solid wastes), hydrological alterations (water withdrawal and inflow changes), and over-exploitation of their natural resources. This results in loss of biodiversity and disruption in goods and services provided by urban lakes (Naselli et al., 2008; Ramachandra et al., 2012). With urban development and economic growth, the conflicts between urban development and land shortage are becoming increasingly striking. An urban development featuring land shortage due to high population and urban expansion are leading to endangered urban water environment; human beings' asking for land from water bodies inevitably causes serious damage to urban lakes (Wu and Hao, 2011). In this study, we focused on multi-functionality of urban lakes (situ and waduk) which is naturally or artificially developed. In Jakarta, about 1000 urban lakes have been existed before, however number of them decreased around 300 until now. Reduction of urban lakes will accelerate the degradation of water environment in Jakarta, because urban lakes have multi-functionality for keeping water environment in suitable condition. Therefore, to conserve those lakes in adequate condition and in sustainable, quantitative evaluation of multi-functionalities were quite important in the view point of water purification and flood control in this region.

METHODS

Study Area

Jakarta is the economic, cultural, and political center of Indonesia. It is also capital of Indonesia and has the largest city population in Southeast Asia, estimated at 9.5 million. Jakarta's metropolitan area, called JABODETABEK (Jakarta, Bogor, Depok, Tangerang, Bekasi), is the sixth-largest in the world with over 24 million population. Jakarta covers 662 km^2 and is located on the northwest coast of Java island at the mouth of the Ciliwung River on Jakarta Bay. Jakarta also The topography of Jakarta varies, with the northern part just meters above current sea level and lying on a flood plain. Subsequently, this portion of the city frequently floods. The southern part of the city is hilly. In addition to the Ciliwung River, there are about 12 other rivers that drain the hilly southern part of the city into the sea. The Ciliwung River is the most significant river and divides the city West to East. Jakarta's economy depends heavily on financial services, which contribute almost a quarter of the national GDP. While there is significant wealth in Jakarta, the city has massive problems because of the extreme population growth, high levels of poverty, and inequitable distribution of wealth (WWF, 2010). Jakarta has struggled to provide basic needs such as water, shelter and waste management for some of its poorest residents. Jakarta has an equatorial tropical climate having rainy and dry season. Temperatures are very consistent, ranging from 23°C to 32°C. The city is humid throughout the year. Jakarta gets significant amounts of precipitation, totaling almost 2,200 mm annually. Jakarta's wet season peaks with an average 400 mm of precipitation during January and a dry season average rainfall of 70 mm during August. Heavy rainfall in rainy season is one of the reason of severe flood, however recently, floods occur even in drying season when there is high intensity rainfall. Land use change is also the significant reason of severe floods. Land use of JBODETABEK was drastically changed (shown in **Figure1**) and the number of urban lakes also decrease about 300. In this study, The urban lakes in megacity Jakarta can have mixed urban and other types of watershed, such as rural, industrial and even agricultural area. The impact of urban development in these distinct surrounding inhabited areas on urban lakes in megacity Jakarta have been so pervasive that makes the lakes very vulnerable to environmental disturbances. Land expansion is needed for housing as a result of urban development which has caused extensive lake shoreline development even reaching to the water bodies that causes serious damage to urban lakes and even disappearance of lakes due to land use change. Lakes are often used as a dumping place for garbage and collecting untreated sewer and storm water runoff. Moreover, lack of concern of the public and lack of management of the government have aggravated the damage of environmental conditions of urban lakes (Cynthia and Ami, 2014). In this study, 9 urban lakes were selected for the analysis of multi-functionality such as water purification and flood mitigation functions. **Figure 2** shows location of surveyed urban lakes and **Table1** shows general information about each urban lakes.

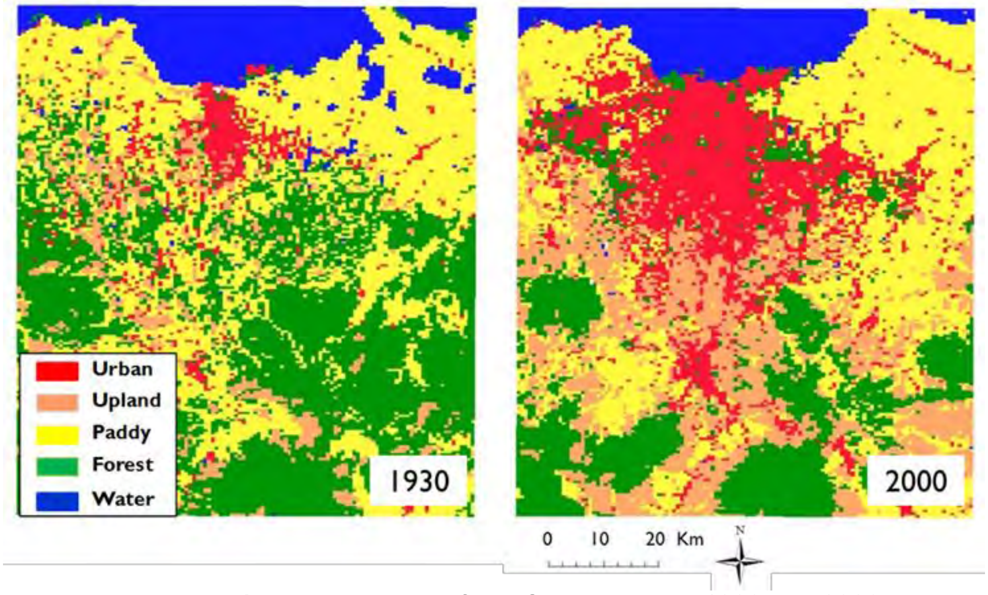

Figure 1. Land use map of JABODETABEK in 1930 and 2000

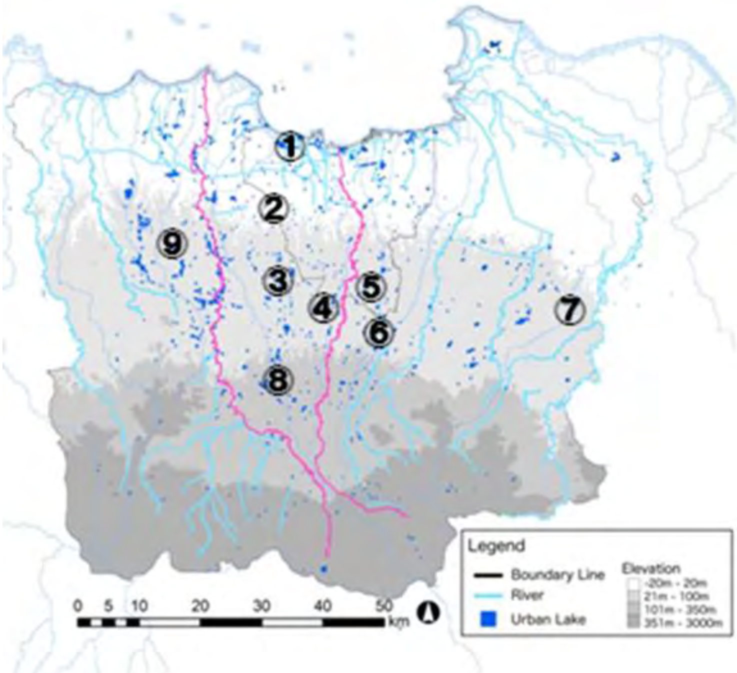

Figure 2. Location of surveyed urban lakes
①Pluit, ②Hutan Kota Surenseng, ③Gintung, ④Babakan, ⑤Kerapa Dua Wetan,
⑥Rawa Dongkal, ⑦Binong, ⑧Tonjong, ⑨Cihuni

Table 1. General information of surveyed urban lakes

	Name	shoreline (km)	area of lake (m^2)	depth (m)	storage volume (m^3)	catchment area (km^2)
①	Pluit	4.14	745,000	2.39	1,780,550	32.4
②	Hutan Kota Surenseng	0.53	14,000	1.71	23,940	–
③	Gintung	4.28	23,990	9.82	235,582	1.49
④	Babakan	3.69	32,000	2.11	67,520	5.56
⑤	Kerapa Dua Wetan	1.35	54,700	1.49	81,503	0.41
⑥	Rawa Dongkal	1.75	120,200	2.03	244,006	0.64
⑦	Binong	1.99	170,000	1.4	238,000	2.82
⑧	Tonjong	2.93	144,400	1.2	173,280	1.61
⑤	Cihuni	2.08	325,000	3.17	1,030,250	0.78

Evaluation of Water Purification Function

To evaluate water quality condition, lake waters were sammpled at the inlet and outlet of urban lakes (shown in **Figure 3**). Field observation was conducted in rainy season (March 2014) and dry season (August 2014) to grasp the influence of water discharge from upstream area. Measured water quality parameters are soil sediment (SS), total nitrogen (TN), nitrate nitrogen (NO_3-N), ammonium nitrogen (NH_4-N), chemical oxygen demand (COD), dissolved oxygen (DO), water temperature and PH. To calculate water purification rate, we assumed that discharges of inflow and outflow are balanced and water purification rate was calculated in eq (1).

$$\text{Water purification rate(\%)} = \text{TN concentration at outlet} / \text{TN concentration at inlet} \times 100 \qquad (1)$$

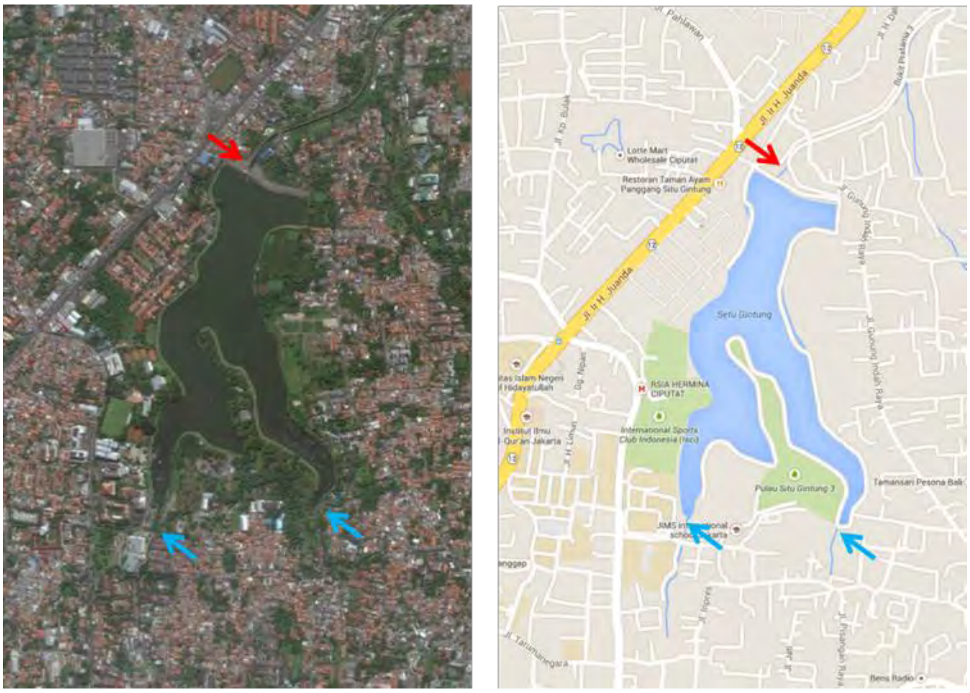

Figure 3. Inlet and outlet of situ Gintung (for example)

Evaluation of Flood Mitigation Function

In this study, rainfall data of February 2007 was used which had 440 mm during 1 Feb to 2 Feb 2014. Flood in Feb 2007 was most severe one historically. To evaluate the flood mitigation effect of each urban lakes, water balance in each lakes were calculated as following eq(2).

$$\frac{dS_{ul}}{dt} = Q_{in} - Q_{out} \qquad (2)$$

where Sul is water storage in urban lake, Qin is inflow from upstream catchment, Qout is outflow from outlet of urban lakes.

Rainfall-runoff model was used to calculate inflow discharge Qin from upstream catchment area. SCS Curve Number method (CN method) was employed for surface runoff analysis. This CN method is developed by the United States Department of Agriculture (USDA) Soil Conservation Service (SCS) and is a method of estimating rainfall excess from rainfall (USDA-SCS, 1985). The CN method is widely used, efficient method for determining the approximate amount of direct runoff from a rainfall event in a particular area and is accepted in numerous hydrologic studies. This method was developed for agricultural watersheds in the mid-western United States; however, it has been used throughout the world far beyond its original developers would have imagined. The runoff curve number is based on the area's hydrologic soil group, land use, treatment and hydrologic condition. References, such as from USDA indicate the runoff curve numbers for characteristic land cover descriptions and a hydrologic soil group.

The basic assumption of the SCS curve number method is that, for a single storm, the ratio of actual soil retention after runoff begins to potential maximum retention is equal to the ratio of direct runoff to available rainfall. This relationship, after algebraic manipulation and inclusion of simplifying assumptions, results in the following eq (3).

$$Q_{in} = \frac{(P-0.2S)^2}{P+0.8S} \qquad (3)$$

where Qin is runoff from catchment area, P is Rainfall, S is the potential maximum soil moisture retention after runoff begins. S is calculated by eq (4).

$$\mathrm{S} = \frac{1000}{CN} - 10 \qquad (4)$$

where CN is runoff curve number which having a range from 30 to 100; lower numbers indicate low runoff potential while larger numbers are for increasing runoff potential.

In this study, CN number were evaluated from land use and soil characteristic condition from GIS analysis. At first, catchment area of each urban lakes were evaluated from DEM (Digital Elevation Map) and then, land use and FAO soil data were extracted by catchment boundary (shown in **Figure 4**). Paddy water storage also considered in runoff calculation.

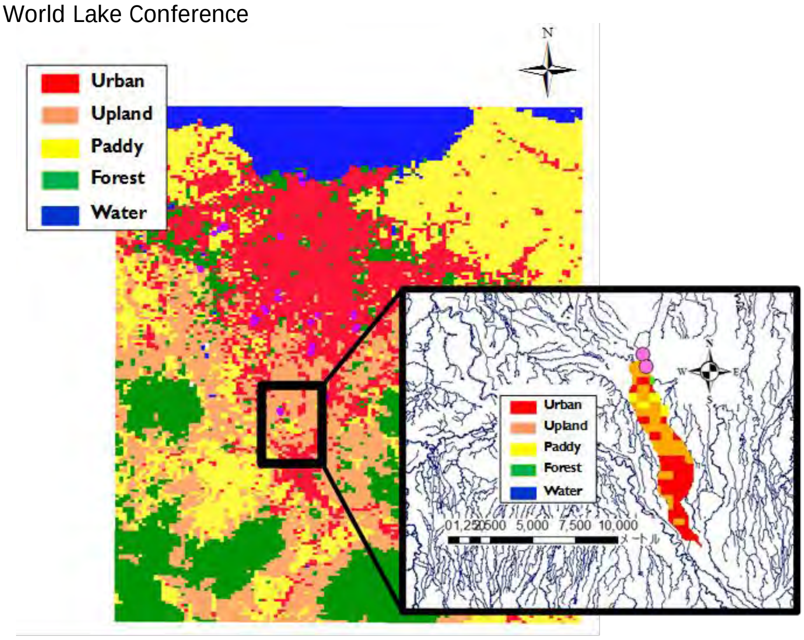

Figure 4. Land use extraction of Tonjong catchment area (for example)

Outflow Qout from outlet of urban lake was calculated based on the hydraulic structure of lake outlet. There were several types of outlet structure such as normal type weir, labyrinth type weir (**Photo 1**) or siphon type outlet (**Photo 2**).

Photo1. Outlet of situ Gintung

Photo2. Outlet of situ Cihuni

In this study, flood peak cut ratio were calculated as a index of flood mitigation function.

Rpc(%) = maximum inflow discharge / maximum outflow discharge ×100 (5)

where Rpc is flood peak cut ratio in % unit.

RESULTS AND DISCUSSIONS

Figure 5 shows observed Total Nitrogen (TN) concentration at inlet and outlet of each urban lake in rainy season (March) and dry season (August). The value superscripted upper of bar graph means nitrogen purification ratio in % unit calculated by eq (1).

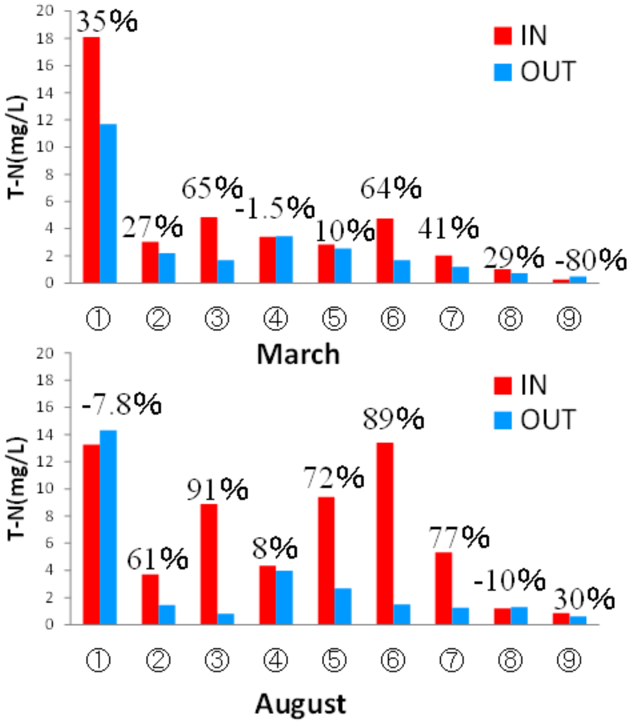

Figure 5. Observed TN concentration at inlet and outlet of each urban lake in rainy season (March) and dry season (August)

As a result, TN concentration reduced at outlet in most of lakes so that urban lakes have nitrogen purification function. Average purification rate was 21.2% in rainy season and 45.5% in dry season. TN concentration was higher in dry season, because wastewater from housing was not so diluted by runoff water from other land use. And retention time of inflow water in dry season was also relatively longer than rainy season. That is the reasons why average purification rate is greater in dry season.

Figure 6 shows observed NO_3-N and NH_4-N concentration at inlet and outlet of urban lakes in rainy season and dry season. In rainy season, NO3-N was dominant, on the other hand NH_4-N was dominant in dry season. In dry season, small amount of rain, which fall to the land surface, evaporate or transpire rapidly, therefore wastewater contained much NH_4-N from housing was not so diluted by runoff water from other land use. On the other hand, large amount of rain infiltrated to surface soil layer and runoff with soluble NO_3-N in rainy season. The main source of NO_3-N was fertilizer in agricultural land.

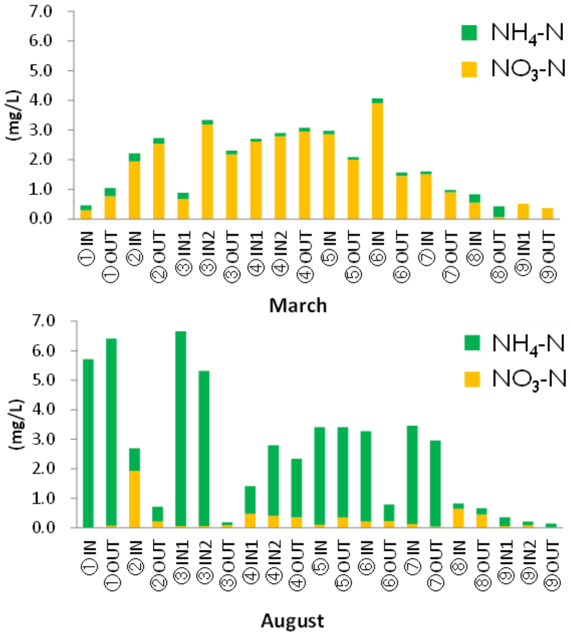

Figure 6. Observed NO3-N and NH4-N concentration at inlet and outlet of urban lakes in rainy season and dry season

Figure 7 shows inflow and outflow discharge change from 2/1 0:00 to 2/2 24:00 in each urban lake. Red line shows inflow and blue line shows outflow discharge. The values scripted in Figure6 shows flood peak cut ratio Rcp. Rcp was estimated the range of 0.6 – 91.0 % and average was 44.9%. Most of urban lake had significant flood mitigation function. However, in situ Gintung, Rcp is small 0.6% because width of outlet labyrinth type weir is relatively longer than other urban lakes. In 2009, dam brake accident r in situ Gintung. And current dam outlet was reconstructed after the accident. Therefore, hydraulic structure of outlet labyrinth type weir was designed in safety condition. In situ Cihuni, Rcp is 91.0% because lake surface area is relatively large compare to upstream catchment area. Therefore, lake water level did not increase so much even during heavy rainfall period, and most of inflow can be storage in situ Cihuni during heavy rainfall period.

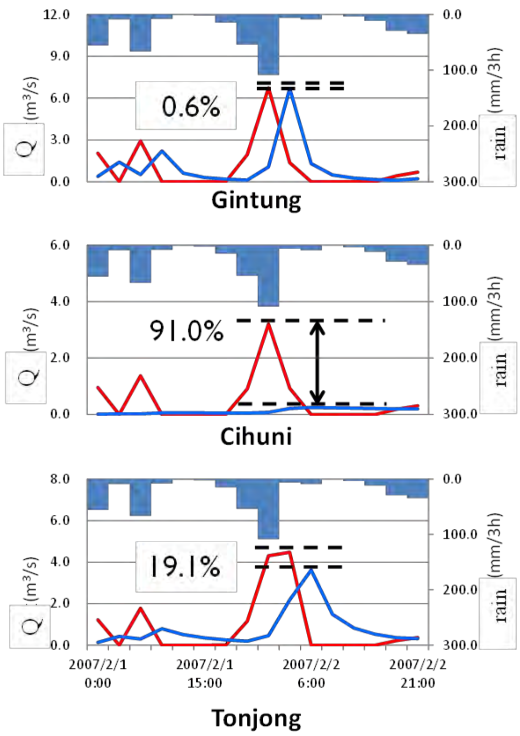

Figure 7. Inflow and outflow discharge from 2/1 0:00 to 2/2 24:00 in 2007

CONCLUSIONS

In this study, multi-functionality of urban lakes in JABODETABEK was evaluated focused on it's water purification and flood mitigation function. Firstly, we selected 9 urban lakes and collected water samples from inlet and outlet of urban lakes. Average nitrogen purification rate were 21.2% in rainy season and 45.5% in dry season. In rainy season, most of nitrogen runoff was Nitrate form originated from agriculture, however in dry season, most of nitrogen runoff was Ammonium form originated from housing. Secondly, flood mitigation effects were evaluated by using SCS-Curve Number method and hydraulic structure of the outlet also considered in calculation. Estimated flood peak cut ratio was 44.9% in average. As a results, most of lakes have effective function to purify the wastewater flowing from upstream area and to mitigate flood discharge outflowing to downstream region. The performance of multi-functionality can be improved under the adequate maintenance of urban lakes.In fact, Jakarta metropolis has been facing many problems of severe flash floods from the upstream region during rainy season. In addition, the exploitation of groundwater usage and polluted surface water has caused shortage of fresh water during the dry season. In current condition, the urban lakes in Jakarta have lost their capacity to support their function as flood control, water supply, and for water purification. The negative impacts of urbanized catchment area can be minimized by optimizing the function of urban lakes such as flood control, ground water recharge and water purification. The solution of the problems faced by urban lakes in Jakarta requires a comprehensive management plan that is not only effective in maintaining the stability of lake ecosystem but also effective in improving urban life, such as socio-culture-economic conditions of people around the lakes.

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EFFECTS OF CHECK DAM ON MACROINVERTEBRATE COMMUNITIES IN HUAI TON KOK WATERSHED, CHIANG MAI PROVINCE, THAILAND

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ABSTRACT

Check dam is a construction used for water and soil conservation. However, following the check dam construction, the river ecosystem changes. The aim of this research was to obtain the comparation of the physico-chemical parameters and macroinvertebrate communities before and after check dam construction. The study was carried out in three check dam sites including above and below check dams and one non-check dam site as reference site in Huai Ton Kok watershed, Chiang Mai Province, Thailand. Physico-chemical parameters including DO, BOD_5, pH, electric conductivity, water velocity, and inorganic nutrients were measured and the macroinvertebrates were collected between June 2015 and April 2016. It was found that check dam had no significant effect on physico-chemical factors, except velocity, BOD_5, and nutrients. The BOD_5 and inorganic nutrients of the below check dam sites were lower than above check dam sites. In addition, the BOD_5 and inorganic nutrients increased after check dam construction. Similarly, following the construction of check dam, the macroinvertebrate communities changed. The insects of order Trichoptera, Coleoptera, and Ephemeroptera were dominant before the check dam was constructed. However, after the construction, the Coleopterans, Hemipterans, and Dipterans were dominant in above check dam sites which were different from the below check dam sites where Trichoptera, Odonata, and Ephemeroptera were dominant orders. In addition, according to the Thailand Standard for Surface Water Quality, both before and after check dam construction, the water quality was classified as moderate clean level. However, the water velocity and habitat types changed following the check dam construction, which affect the macroinvertebrate communities.

Keywords: check dam, macroinvertebrate, water quality, Huai Ton Kok

INTRODUCTION

Population and economic growth lead to change natural forest areas into anthropogenic agricultural lands. Therefore, global deforestation has been increasing which affects the water supply. It is well known that forest catchments supply a high proportion of water for human and environments. In the present time, forest destruction in Thailand has affected the water resources. However, there are ways to restore the natural resources and impose the sustainable management, such as check dam construction in highland streams (Kositpon and Phalaraksh, 2012). Check dam is an important engineering measure to retain the floodwater, intercepting sediment, increasing farmland for agricultural production, and reducing sediment transport in the downstream (Li Erhu *et al*., 2016). Check dam slows down the flow of water in the stream. It can also change the sediment types and aquatic life forms. Following a check dam construction, the forms of sediments changed from gravel, stone, and sand to silt, clay, and mud that affected the macroinvertebrates and aquatic plant communities (Phanittawongsa, 2007). In addition, Harding (1992) found lower diversity and density of aquatic insect orders of Plecoptera, Ephemeroptera, and Diptera in the streams with post-impoundment sites. Ban Pong community is located in Chiang Mai Province, Thailand. The Ban Pong Royal Project for conservation of the forest and ecosystem was selected as a study area in the upstream of Huai Ton Kok watershed. The aim of this research was to obtain the comparison of physico-chemical parameters and macroinvertebrate communities before and after check dam construction in Huai Ton Kok watershed, Chiang Mai Province, Thailand.

METHODS

Study sites

The Huai Ton Kok watershed is located in Pa Phai Sub-district, Sansai District, Chiang Mai Province. Four study sites in Huai Ton Kok watershed (**Figure 1**) consisted of one site of no check dam area (Reference site, R) at approximately 18°56'56''N 99°3'58''E, altitude 426 meters above sea level and three check dam sites which were divided into above and below check dams. These check dam sites consisted of Site 1 (S1) at approximately 18°56'58''N 99°3'59'' E, altitude 420 meters above sea level, Site 2 (S2) at approximately 18°56'57''N 99°3'58'' E, altitude 380 meters above sea level, and Site 3 (S3) at approximately 18°56'56''N 99°3'58'' E, altitude 410 meters above sea level (**Figure 1**). The data were collected before check dam construction in June 2015 to compare with the ones after check dam construction in August, October, and December 2015.

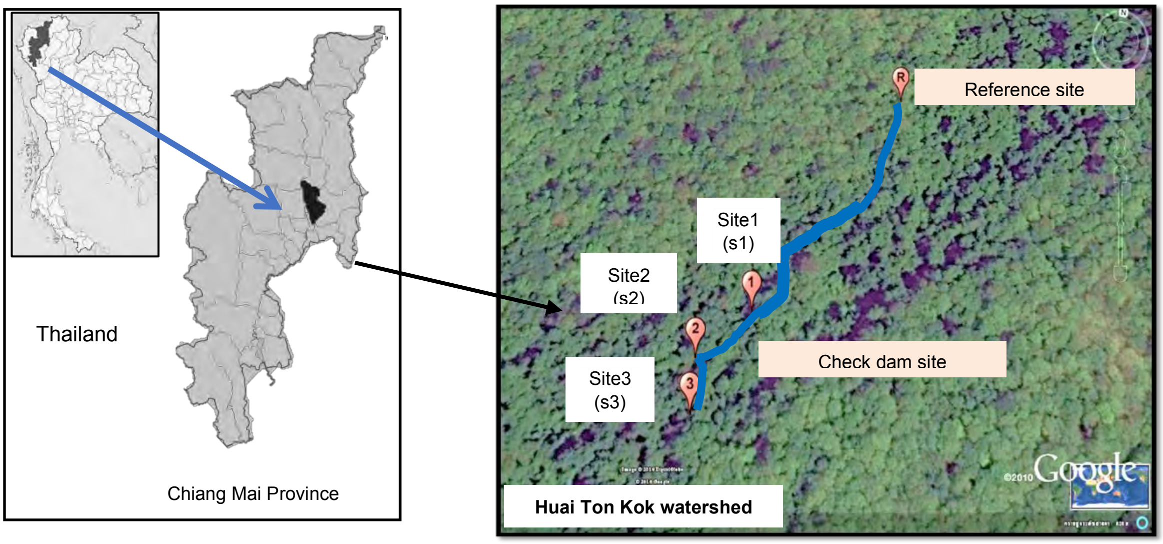


Figure 1 Study location at Huai Ton Kok watershed in Sansai District, Chiang Mai Province.

Physico-chemical properties
Dissolved Oxygen (DO) and Biochemical Oxygen Demand (BOD) were measured following the Azide Modification Method (APHA, AWHA, WPCF, 1998). Whereas, the pH, electric conductivity (EC), and Total Dissolved Solid (TDS) were measured at 10 cm depth using Multi-Parameter Analyser (Consort C533).
Inorganic nutrients such as nitrate-nitrogen was determined by employing the Cadmium Reduction Method, whereas ammonia-nitrogen was determined by the Nesslerization technique. In addition, the ortho-phosphate was determined by Ascorbic Acid Method (APHA, AWHA, WPCF, 1998). Water velocity was measured by manual flow stop watch.
Biological properties
Macroinvertebrate samples were collected using pond net and following the Kick and Pick method (McCafferty, 1981). All macroinvertebrate samples were preserved in 70% alcohol prior to sorting and identification to family level in the laboratory using the classification books of McCafferty (1981), Merritt and Cummins (1984), Dudgeon (1999), Mustow (2002), and Sangpradup and Boonsong (2006).
Data analysis
The one-way Analysis of Variance (ANOVA) was used to compare the physico-chemical parameters. In addition, Shannon-Weiner Diversity index was applied to study species diversity and evenness after morphological identification. The macroinvertebarte-based Biomonitoring Working Party (BMWP) Score and the Average Score Per Taxon (ASPT) were applied to determine the water quality of each study site. The cluster analysis was also applied to compare all data sets according to study site and collecting period based on biological data.

RESULTS AND DISCUSSIONS
Water quality analysis
The physico-chemical parameters of the water in Huai Ton Kok watershed before check dam construction are shown in Table 1 and after check dam construction are shown in **Table 2, 3, and 4** from measurements taken in August, October, and December respectively. The physico-chemical parameters changed after the check dam was constructed.
The results of physico-chemical parameter measurements were compared between above and below check dams, which found that DO, BOD_5, and nutrients were different at each study site. Most of DO values in below check dams were higher than the above check dams. The highest DO was detected in December in which the water temperature was lower than other collecting times. In addition, the BOD_5 and nutrients at below check dam sites were also lower than above check dam sites. Furthermore, the BOD_5 values were also significantly different between before and after the check dam was constructed. It was found that the check dams slowed down the water current and blocked the sediment and leaf litter from above the check dams. The trend of nutrients increased after check dam construction in December. The physico-chemical parameters did not exceed the Thailand Standard for Surface Water Quality (1995). This result also showed that by slowing down the water velocity the check dams affected the other parameters such as DO and electric conductivity. The

DO, turbidity, BOD_5, and nutrients in dry and wet seasons were different at each study site because the check dams blocked the water from point to point, making the stream to be divided into sections (Kositpon and Phalaraksh, 2012).

Table 1 The physico-chemical parameters **before** check dam construction at each study site.

Study site	DO (mg/L)	BOD (mg/L)	pH	TDS (mg/L)	Conductivity (µS/cm)	Nitrate (mg/L)	Phosphate (mg/L)	Ammonia (mg/L)	Velocity (m/s)
S1	5.8± 0.0	0.63±0.1	6.45±0.2	15.53±0.1	31.10±0.1	0.63±0.1	0.10±0.0	0.18±0.0	0.29±0.0
S2	6.2± 0.0	0.56±0.1	6.44±0.1	15.43±0.1	31.06±0.1	0.50±0.0	0.08±0.0	0.21±0.0	0.27±0.0
S3	6.0± 0.0	0.40±0.1	6.51±0.1	15.63±0.1	31.56±0.1	0.26±0.1	0.10±0.0	0.20±0.0	0.34±0.0

Table 2 The physico-chemical parameters **after** check dam construction (August)

Study site	DO (mg/L)	BOD (mg/L)	pH	TDS (mg/L)	Conductivity (µS/cm)	Nitrate (mg/L)	Phosphate (mg/L)	Ammonia (mg/L)	Velocity (m/s)
R	6.47±0.1	0.40±0.1	6.52±0.3	18.30±0.2	36.60±0.2	0.30±0.0	0.16±0.0	0.20±0.0	0.26±0.1
S1. A	6.20±0.1	0.27±0.0	5.88±0.1	19.07±0.0	38.23±0.0	0.20±0.1	0.19±0.0	0.10±0.0	0.00±0.0
S1. B	6.40±0.1	0.37±0.0	6.16±0.2	19.83±1.2	39.70±2.3	0.50±0.1	0.32±0.0	0.17±0.0	0.36±0.2
S2. A	6.20±0.1	0.27±0.1	6.32±0.3	19.33±0.2	38.57±0.1	0.40±0.0	0.20±0.0	0.11±0.0	0.00±0.0
S2. B	6.27±0.1	0.53±0.1	6.37±0.2	20.43±0.1	40.97±0.2	0.20±0.0	0.23±0.0	0.09±0.0	0.22±0.0
S3. A	6.40±0.1	0.60±0.0	6.24±0.1	20.57±0.1	41.13±0.1	0.40±0.0	0.21±0.0	0.16±0.0	0.00±0.0
S3. B	6.60±0.1	0.47±0.1	6.11±0.2	21.03±0.4	41.77±0.7	0.30±0.0	0.21±0.0	0.15±0.0	0.38±0.1

Table 3 The physico-chemical parameters **after** check dam construction (October)

Study site	DO (mg/L)	BOD (mg/L)	pH	TDS (mg/L)	Conductivity (µS/cm)	Nitrate (mg/L)	Phosphate (mg/L)	Ammonia (mg/L)	Velocity (m/s)
R	6.93±0.2	0.40±0.0	6.53±0.3	15.10±0.0	30.43±0.4	0.50±0.1	0.12±0.0	0.14±0.0	0.13±0.2
S1. A	5.87±0.5	0.40±0.0	6.27±0.3	16.10±0.2	32.20±0.4	1.30±0.0	0.12±0.0	0.09±0.0	0.00±0.0
S1. B	6.50±0.1	0.30±0.0	5.92±0.1	16.90±1.4	33.77±2.9	0.30±0.0	0.15±0.0	0.08±0.0	0.19±0.0
S2. A	6.37±0.1	0.23±0.1	6.46±0.3	16.17±0.5	32.57±1.2	0.60±0.0	0.14±0.0	0.09±0.0	0.00±0.0
S2. B	6.60±0.4	0.27±0.1	6.12±0.1	16.27±0.1	32.67±0.1	0.40±0.0	0.15±0.0	0.08±0.0	0.12±0.0
S3. A	6.13±0.1	1.20±0.1	6.42±0.2	16.73±0.2	33.47±0.2	0.30±0.0	0.13±0.0	0.12±0.0	0.00±0.0
S3. B	6.60±0.1	0.43±0.1	6.09±0.0	17.20±0.2	34.53±0.4	0.30±0.0	0.20±0.0	0.17±0.0	0.12±0.1

Table 4 The physico-chemical parameters **after** check dam construction (December)

Study site	DO (mg/L)	BOD (mg/L)	pH	TDS (mg/L)	Conductivity (µS/cm)	Nitrate (mg/L)	Phosphate (mg/L)	Ammonia (mg/L)	Velocity (m/s)
R	8.33±0.1	0.20±0.0	6.13±0.1	12.23±0.2	24.53±0.3	0.40±0.0	0.37±0.1	0.27±0.1	0.57±0.3
S1. A	7.80±0.1	0.60±0.2	6.29±0.2	12.93±0.2	25.57±0.3	0.60±0.0	0.33±0.1	0.25±0.1	0.00±0.0
S1. B	7.80±0.1	0.33±0.2	5.88±0.1	12.83±0.1	25.70±0.2	0.37±0.6	0.41±0.1	0.18±0.2	0.25±0.1
S2. A	7.80±0.1	1.80±0.1	6.68±0.4	13.23±0.6	26.40±1.4	0.50±0.0	0.37±0.1	0.21±0.1	0.00±0.0
S2. B	7.93±0.1	1.13±0.1	6.10±0.1	13.20±0.2	26.50±0.3	0.57±0.1	0.28±0.1	0.24±0.1	0.36±0.0
S3. A	7.80±0.1	0.33±0.1	6.44±0.3	14.53±1.6	28.33±2.1	0.57±0.1	0.37±0.1	0.19±0.0	0.00±0.0
S3. B	8.00±0.1	0.27±0.1	5.94±0.0	14.30±0.3	28.67±0.5	0.60±0.0	0.20±0.1	0.44±0.1	0.19±0.2

Macroinvertebrate analysis

The dominant macroinvertebrate orders before the check dam construction were Trichoptera, Coleoptaera, and Ephemeroptera (**Figure 2**). After the check dams were constructed, the composition of macroinvertebrate communities changed following the changes in habitat. The dominant orders changed to Diptera, Ephemeroptera, and Coleoptaera (**Figure 3A**) in above check dam sites, while in the below check dam sites, Trichoptera, Ephemeroptera, and Diptera were dominant (**Figure 3B**). The macroinvertebrate communities were not clearly different before and after check dam construction in the below sites. However, during before to after check dam construction, the trend of individual numbers of Dipterans increased which indicated that the composition of macroinvertebrate communities changed, especially in the above check dams. Check dams changed the substrate on the bottom of the stream that might change the habitat of macroinvertebrates. Organic matters and substrate types are important to macroinvertebrates which used them as shelter and food sources. Culp and Davis (1985) reported that the addition of organic materials into inorganic sediments of several particle sizes generally resulted in an increase of the number of individuals or total invertebrate biomass. The diversity index of the below check dam sites was higher than the above ones (**Figure 4**). In addition, the macroinvertebrate diversity did not clearly change from before the check dam construction. This is due to the fact that macoinvertebrates usually change in composition by seasonal variations. In Figure 5, the cluster analysis of dendrogram showed the four groups. Group 1 consisted of all below check dam areas. Group 2 consisted of most of above check dam areas, and Site 3 at below check dam in December. Group 3 consisted of Site 1 and Site 2 at above check dams in December and the Group 4 consisted of Site 1 above check dam and Site 3 below check dam in August.

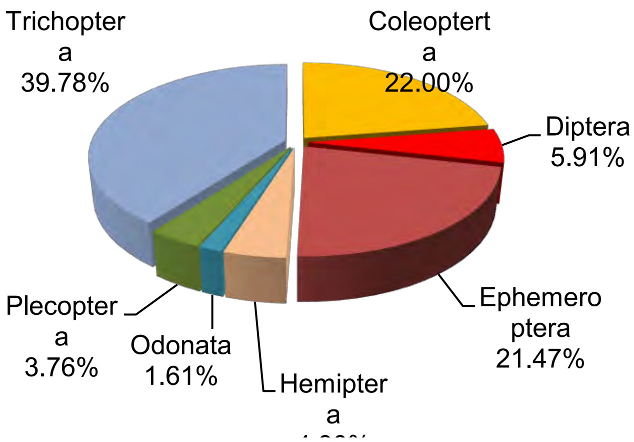
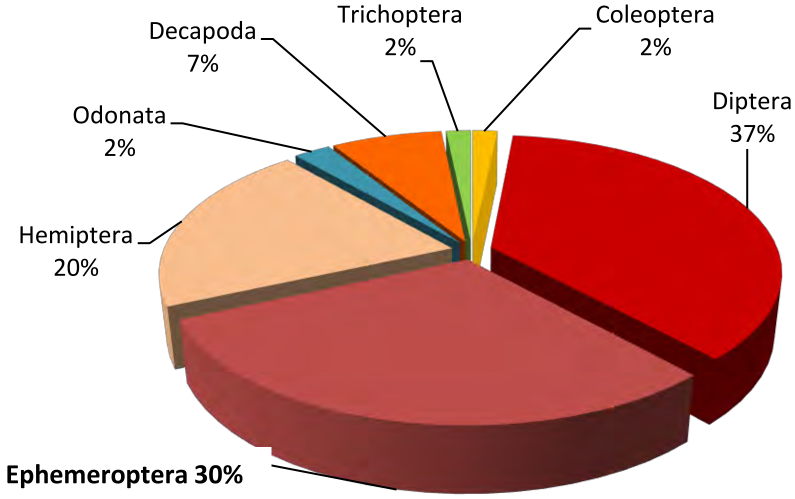
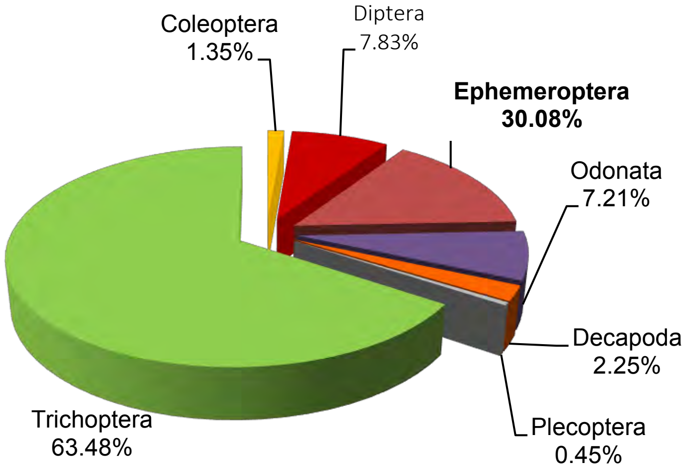


Figure 2. Percentages of macroinvertebrate orders before check dam construction



(A)



(B)

Figure 3. Percentage of macroinvertebrate orders after check dam construction: above (A) and below (B) check dam respectively.

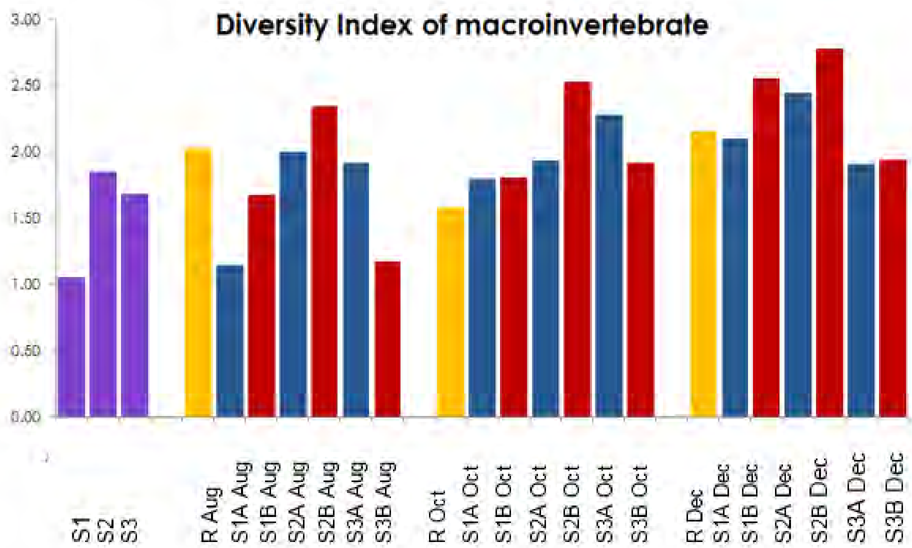


Figure 4 Diversity index of macroinvertebrates in Huai Ton Kok watershed

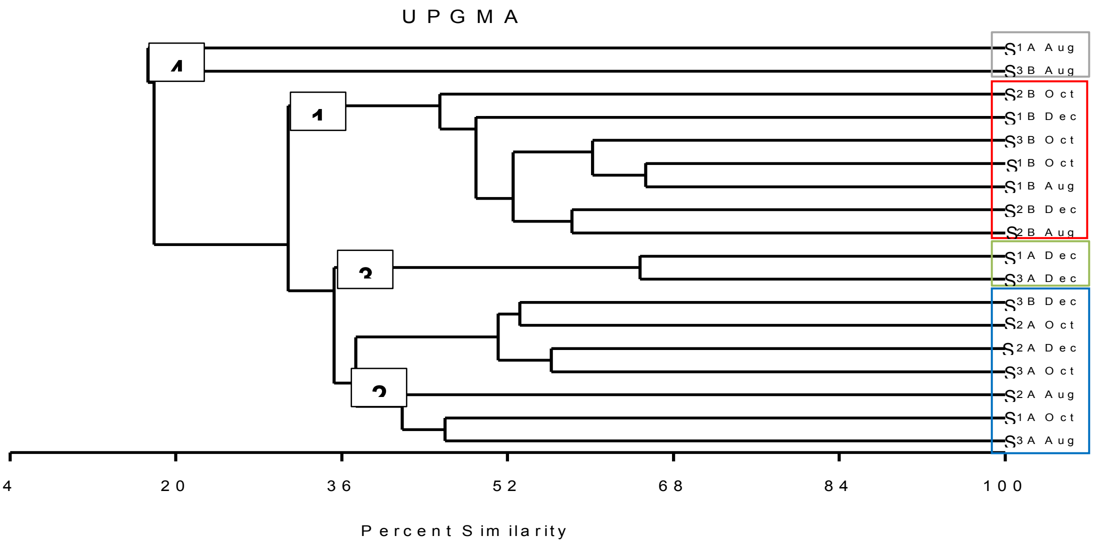


Figure 5 Cluster analysis of stations based on similarities of macroinvertebrate communities.

CONCLUSIONS

Check dam had affected some physico-chemical parameters in Huai Ton Kok watershed. Water velocity at each study site changed from running water to standing water in above check dam sites. The physico-chemical parameters did not exceed the Thailand standard for surface water quality. Check dam had affected the macroinvertebrate communities after its construction. This research showed that the check dams had unclear effects on diversity of macroinvertebrate communities in Huai Ton Kok watershed.

ACKNOWLEDGEMENT

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NITROGEN LOAD INFLOW TO LARGE SCALE RESERVOIRS IN THE CITARUM RIVER BASIN, INDONESIA

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ABSTRACT

Citarum River Basin, West Java, Indonesia is important watershed for Bandung city and also for Jakarta Metropolis, however severe water pollution occurred caused by waste water inflow from housing and agricultural land. To estimate the annual inflow of the eutrophic nutrients to reservoirs, quantitative evaluation is important and simulation model is useful to test the future scenarios. In this study, a nitrogen-load estimation model, which has three nitrogen pools, was developed and applied to the Citarum River Basin. Simulated river discharge and nitrogen load were in good agreement with observed data, and the proposed model successfully estimated nitrogen inputs into reservoirs. Estimated Nitrogen inflow to Saguling, Cirata, Jatiluhur reservoirs were 5973, 8064, 4123 t/year respectively. Next, we investigated the future variation of nitrogen load in this basin under population growth scenarios. Future population growth increased the nitrogen inflow to all reservoirs, but the magnitude of the increase varied between the different scenarios. Simulated results indicated that a spread-type population increase is desirable for the water environment of the Citarum River.

Keywords: Nitrogen balance, Population growth, Urban and rural areas, Reservoir, West Java

INTRODUCTION

Human population growth has led to increases in energy and food production, use of fertilizers, and wastewater flows. Enhanced availability of nitrogen is a cause of eutrophication of rivers, lakes, and estuaries worldwide; however, quantitative evaluation of the impact of population growth on nitrogen load has been insufficient in developing countries because data are often unavailable.

The Citarum River Basin is a most important basin in West Java, supplying water for Bandung and Jakarta City, with 80% of domestic water in Jakarta being withdrawn from this basin. The river has three large dams: the Saguling dam in the upstream reach, Cirata dam in the middle reach, and Jatiluhur dam in the downstream reach. As the population and economic growth in this basin, sediment accumulation and eutrophication have become serious issues in downstream reservoirs due to inflows of wastewater from urban areas and fertilizer components from hilly upland fields into the river (Hart, 2002).

In this study, a nitrogen-load estimation model, which has three nitrogen pools, was developed and applied to the Citarum River Basin, West Java, Indonesia. Simulated river discharge and nitrogen load were in good agreement with observed data, and the proposed model successfully estimated nitrogen inputs into reservoirs. Next, we investigated the future variation of nitrogen load in this basin under population growth scenarios.

METHODS

Study Area

Having a length of 350 km and catchment area of 6,600 km2 (**Figure1**), the Citarum River is the largest river in West Java. Annual mean precipitation varies from 1,600 to 2,800 mm/year, and 70% of the annual precipitation falls during the rainy season from November to March. Bandung city is located along the upstream reach of the Citarum River. The river has three large dams: the Saguling dam in the upstream reach, Cirata dam in the middle reach, and Jatiluhur dam in the downstream reach. Table 1 lists the characteristics of the Saguling, Cirata, and Jatiluhur reservoirs. The Citarum River is the most important river in West Java. It supplies water for the cities of Bandung and Jakarta, with 80% of the domestic water in Jakarta being withdrawn downstream of the Jatiluhur dam (Loebis and Syamman 1993; Fares 2003). The land uses in the Citarum River Basin are paddy (35%), upland crop (25%), forest (23%), urban (12%), water (2%), and others (3%).

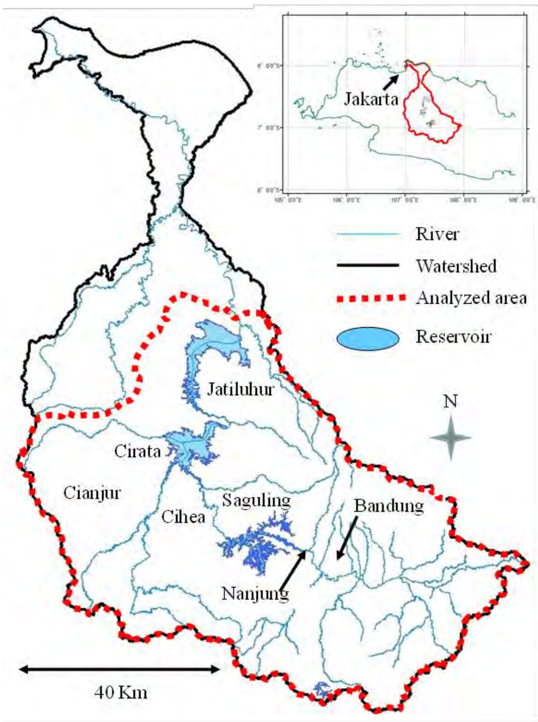

Figure 1. Citarum river basin

Table 1. Characteristics of the three reservoirs in the Citarum River basin

Characteristics	Saguling Reservoir	Cirata Reservoir	Jatiluhur Reservoir
Catchment area (km^2)	2283	4061	4500
Dam height (m)	99	125	96
Volume (million m^3)	603	1927	2448
Purpose	Electricity	Electricity	Multiple/irrigation
Surface area (ha)	4869	6200	8200
Effective volume (million m^3)	598.4	784.9	1869
Installed capacity (turbins × MW)	700 (4 × 175)	1000 (8 × 125)	180 (6 × 30)

TOPMODEL

To evaluate nitrogen transportation according to the river water flow, a distributed water-cycling model was developed and applied to analyse the water balance in the basin (Yoshida, 2011). TOPMODEL was employed for the rainfall-runoff analysis. This distributed model can include the spatial distributions of topography, land use, and soil characteristics. Therefore, TOPMODEL is used widely for hydrological characteristic analysis, water management, water quality analysis, and future forecasting. TOPMODEL was proposed by Beven and Kirkby (1979) based on the contributing area concept in hillslope hydrology. **Figure2** illustrates the conceptual structure of the water cycle as estimated by TOPMODEL. TOPMODEL includes three soil layers: the root zone, unsaturated zone, and saturated zone. The water contents of the root zone and unsaturated zone are calculated by distributed parameters, whereas the water content of the saturated zone is normally calculated by lumped parameters. Because TOPMODEL requires only three parameters (i.e., m, To, and Srzmax),

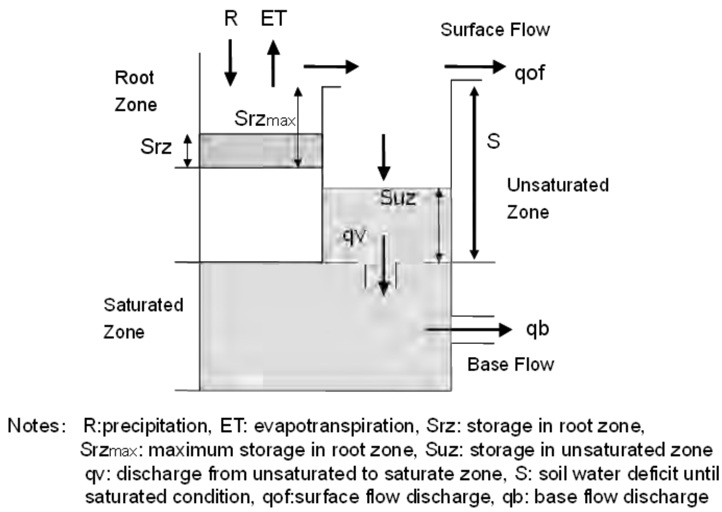

Figure 2. TOPMODEL structure

the model is easy to link with GIS data (for details, see Ao et al. 1999 and Nawarathna et al. 2001). In addition, a dam operation model was combined with TOPMODEL to calculate water storage in the reservoirs (Hanasaki et al. 2007, Juthithep, 2014).

Nitrogen balance model in soil of non-point sources (diffuse pollution)

For a nitrogen dynamics analysis in soil, Lin, et.al. (2000) or Suga (2005) mentioned that three type of nitrogen such as organic, ammonium, nitrate should be considered. In this study, a conceptual nitrogen balance model was developed by considering three pools in soil, organic N, ammonium N, and nitrate N, as shown in **Figure3**. In this study, organic N here is assumed as nitrogen contained in relatively firstly decomposed organic matter which can be obtained by autoclave-extractable nitrogen test. The soil N, present mainly in organic form, is almost unavailable for plants. The vegetation uses mostly inorganic forms of N, which are made available by decomposition of organic matter. Soil microorganisms convert the N contained in the organic matter through the process of mineralization. Although plants can use both forms of inorganic N, nitrate is used in preference to ammonium because of its greater solubility in water. In other words, nitrates dissolve quickly in pore solution, which is taken up by plants. On the other hand, this also means that nitrate is easily leached to groundwater.

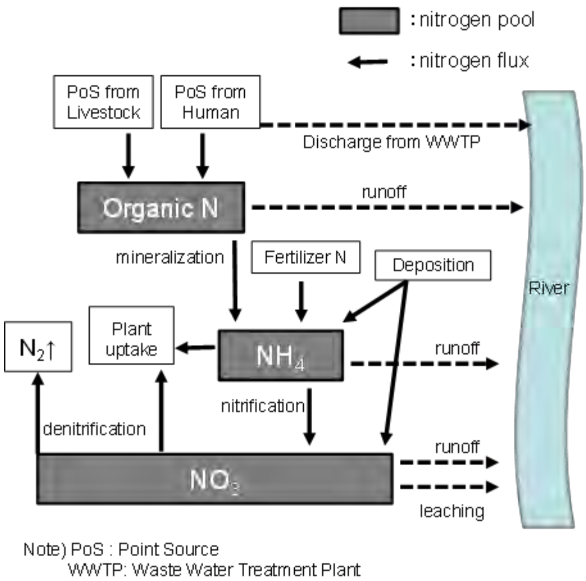

Figure 3. Structure of the nitrogen balance model in soil

Ammonium N is less mobile because it is strongly adsorbed on clay minerals because of its positive charge. Denitrification is the anaerobic microbial reduction of N, which is used as an electron acceptor, resulting in a transfer of soil nitrogen to the atmosphere.

Population change and future growth scenarios

In this study, population data and distribution of population density data were available only in 2010; therefore, population in the upper Citarum River Basin was estimated by using the population increase ratio of West Java Province and the distribution rate in 2010 was applied to the entire analysis period. Only the total population amount was changed each year. According to the future population prediction of the United Nations in 2010, the population of Indonesia will increase 1.3 times by 2050. In this study, the effect of the population increases on nitrogen loading in the upper Citarum River Basin was evaluated. In 2010, the total population of the upper Jatiluhur Basin was 9.82 million. Therefore, a population increase of 3 million people by 2050 was assumed and used for the impact analysis. In addition, two scenarios, one for the urban increase case and one for the rural increase case, were employed and evaluated. For population increase in the urban case, 3 million people were additionally distributed to the urban area (7,194 persons/km^2 were added to 417 urban cells at 1 km × 1 km resolution). For population increase in the rural case, 3 million people were additionally distributed to the rural area (702 persons/km^2 were added to 4,269 rural cells at 1 km × 1 km resolution). **Figure4** shows population density maps for both cases.

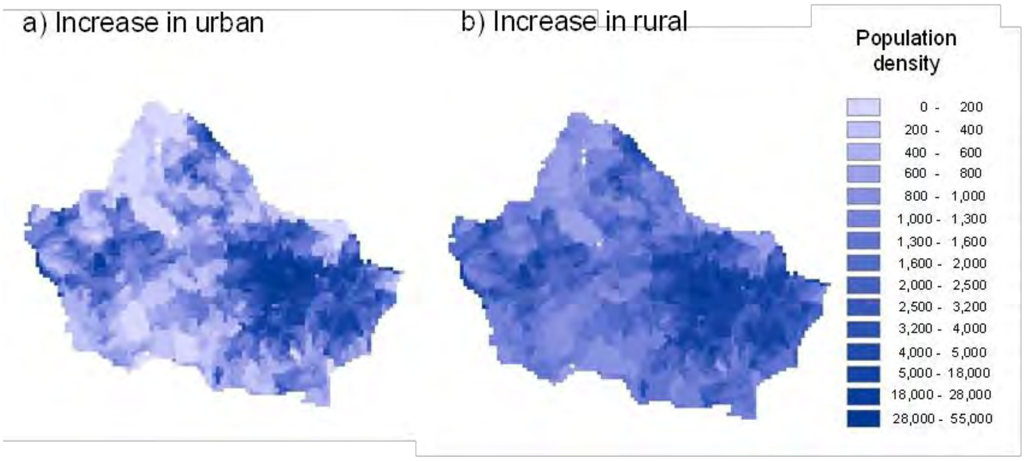

Figure 4. Population density maps of the population growth scenarios

RESULTS AND DISCUSSIONS

By using the proposed model, water and nitrogen balances in the Citarum Basin were calculated at a resolution of 1 km × 1 km. The calculated river discharge was in good agreement with the amounts observed at the Nanjung and the Cirata stations from 1996 to 2009 (**Figure5**). The first 5 years of data were used for parameter calibration, and the latter 9 years of data were used for validation. At the Nanjung station, Nash-Sutcliff efficiency (NSE) were 0.59 and 0.55 in the calibration and validation periods respectively. Model performance can be evaluated as "satisfactory", if NSE > 0.50 (Moriasi et. al., 2007). At the Cirata station, Nash-Sutcliff efficiency (NSE) were 0.62 and 0.57 in the calibration and validation periods respectively.

The observed and calculated daily nitrogen load change at the Nanjung station is shown in **Figure6**. Estimated Nash-Sutcliff efficiency in calibration and verification period were 0.55 and 0.51, respectively. The agreement between observed and simulated values is good, especially for the low-nitrogen-loading period. The data of total nitrogen concentration in the Citarum River Basin were measured only once in the wet season and once in the dry season; therefore, there is a possibility that peak nitrogen load might not be observed in such data. The current monitoring system of water quality data is manual, so if the frequency of monitoring were to be improved by using an automatic monitoring system, the model parameters also could be calibrated through better fitting.

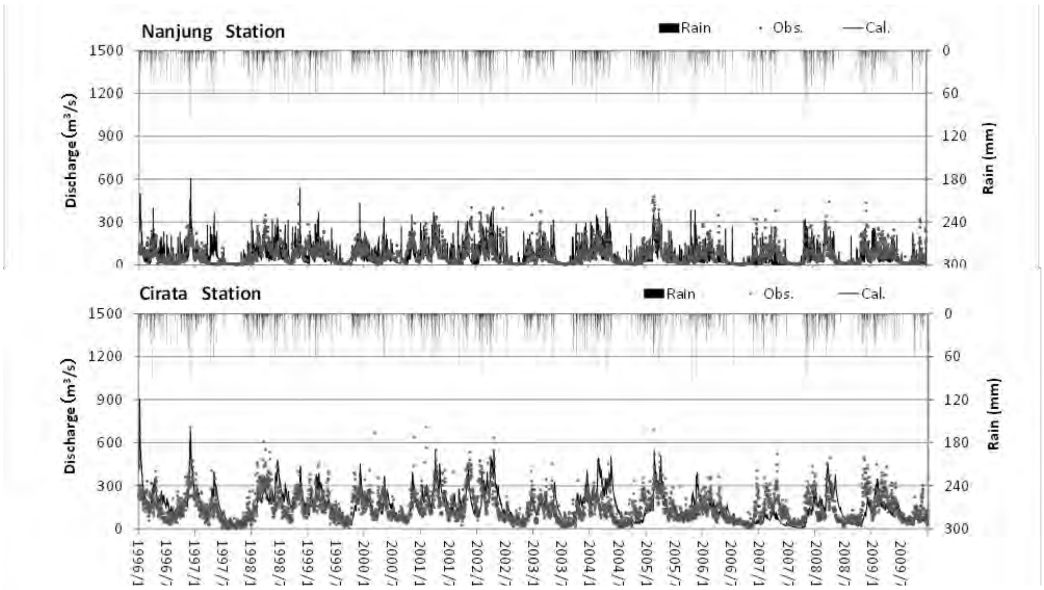

Figure 5. Comparison of observed and calculated river discharges (1996–2009)

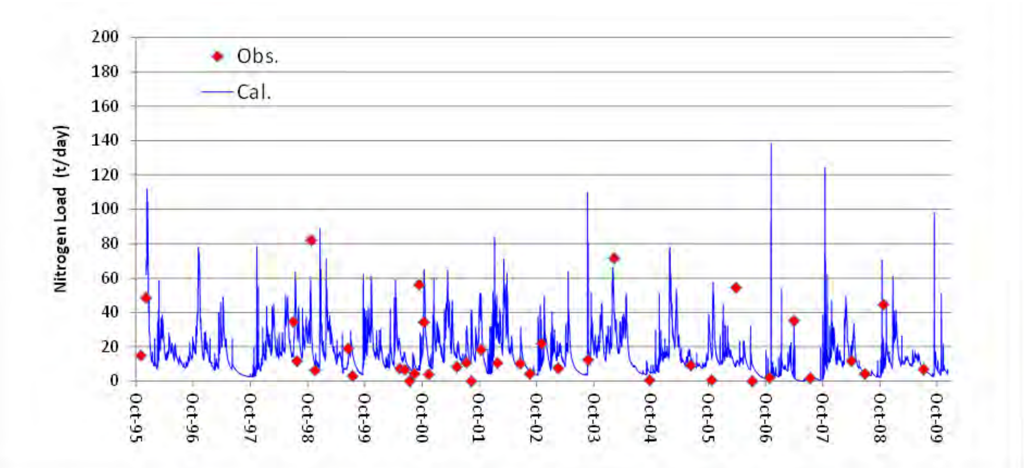

Figure 6. Comparison of observed and calculated nitrogen load change at the Nanjung (1996-2009)

Figure 7 shows observed and calculated nitrogen load inflow at Saguling, Cirata and Jatiluhur reservoirs from 2007 to 2009. Only 3 years water quality data was available, however sampling frequency were improved. In this study, three different nitrogen trap ratio at dam reservoir were tested, which were 45%, 55% (literature value) and 65%. As a result, 55% case shows a best coefficient of determination so that 55% trap ratio case was shown in **Figure 7**, and that value was used for impact analysis also. The coefficient of determination R^2 were 0.50, 0.35 and 0.23 respectively. Model accuracy became worse in downstream reservoir. **Figure 8** shows the result of the change in annual average nitrogen load from the current situation to the inputted population growth scenarios for each reservoir. Future population growth increased nitrogen inflow to all reservoirs, but the magnitudes of the change were different between the scenarios.

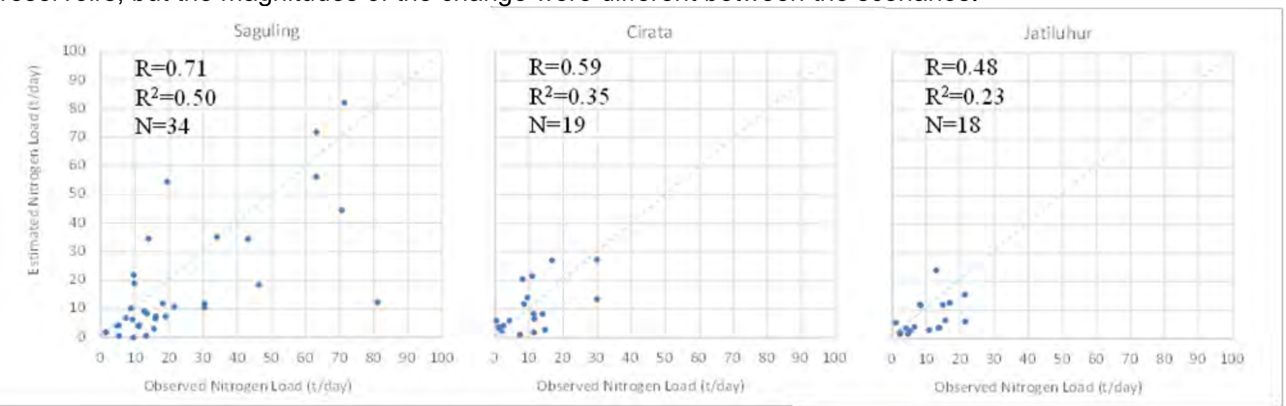

Figure 7. Comparison of observed and calculated nitrogen load inflow to the reservoirs

In both cases, the nitrogen increase at the Jatiluhur reservoir was relatively small compared to those at the other reservoirs because most of the nitrogen was trapped and stored in an upstream reservoir. In the case of population increase in the rural area, nitrogen load increase was not significant compare to the case of population increase in the urban area. In the rural area, nitrogen leaves septic tanks primarily as ammonium in leachate. Some of the ammonium is adsorbed to soil particles and is effectively immobilized from further transport; thus, this nitrogen stays relatively longer in the soil. On the other hand, population density in the urban area is quite high, so the nitrogen load from the point source exceeded the capacity of decomposition and absorption in soil. In addition, surface runoff occurs easily in the urban area because of concrete paving of the land surface. Surface runoff is a main factor transporting nitrogen to the stream, as is soil erosion. For the water environment in the Citarum River Basin, spread-type population increase is desirable; however, population increase normally occurs mainly in urban areas because living in the city is more convenient for housing, finding employment, accessibility of public services.

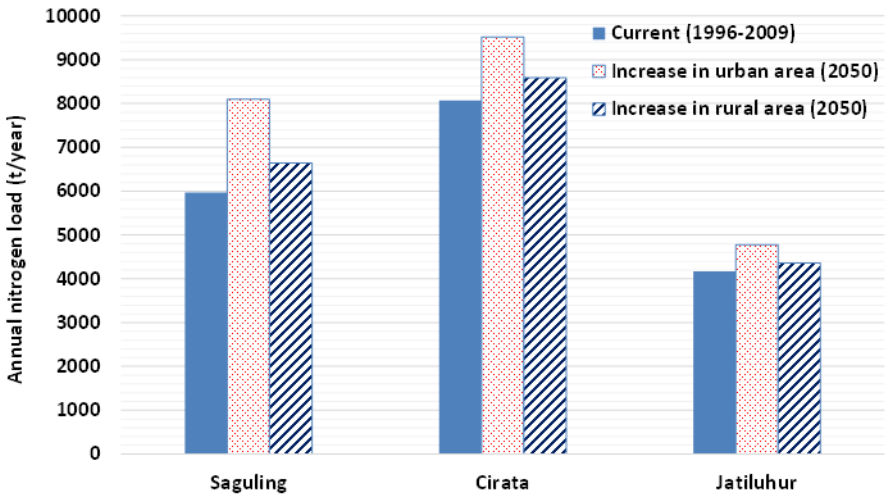

Figure 8. Annual nitrogen load inflow in current and population growth cases

CONCLUSIONS

In this study, a nitrogen-load estimation model was developed and applied to the Citarum River Basin, West Java, Indonesia. Simulated river discharge and nitrogen load were in good agreement with observed data, and the nitrogen-load estimation model successfully estimated nitrogen inputs into the reservoirs. By using the proposed model, two future population-increase scenarios were tested. One was a 30% of basin population (≒ 3 million people) increase in the rural area, and the other was a population increase in the urban area until 2050 based on the estimation of the United Nations. As a result, the nitrogen inflow to the Cirata reservoir was largest among the three reservoirs, and its annual variation was also large. On the other hand, most of the nitrogen flow into the Saguling and Cirata reservoirs was trapped and removed by fishes used for aquaculture or removed by denitrification, so the Jatiluhur reservoir, which is the source of the water supply for the Jakarta metropolis, was not strongly affected even under increased population in the future. In this study area, long-term water quality data were available only at the Najung monitoring station, but monitoring frequency was quite poor (twice per year). Therefore, this distributed-type nitrogen-load estimation model is useful for evaluating the nutrient inflow to the reservoirs and for assessing the distribution of nitrogen sources within the watershed. For future research, an impact analysis of global climate change on nitrogen load is required to evaluate the vulnerability of the mainstream and tributary water environments.

ACKNOWLEDGEMENT

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Topic 10. Limnology and limnological science fundamentals

TROPHIC STATE CHARACTERISATION FOR MALAYSIAN LAKES

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ABSTRACT
This study investigated the trophic conditions and water quality of three selected lakes of different trophy namely Dayang Bunting Lake (oligotrophy-mesotrophy), Subang Reservoir (mesotrophy-eutrophy) and Sembrong Reservoir (eutrophy-hyper eutrophy) with the objective to characterize a trophic classification for Malaysian lakes. The study assessed various environmental variables including chlorophyll-a, total phosphorus, total nitrogen, dissolved oxygen, pH, turbidity and water transparency. Our results showed a low transparency in all lakes which ranged from 0.2 to 3.7 m. Dayang Bunting Lake has the highest transparency, salinity and conductivity among the lakes. Mean concentration of chlorophyll-a was below 10 µg/L while mean Secchi depth transparency exceeded 3.0 m indicating oligotrophic-mesotrophic environment. TP concentrations were lowest in Dayang Bunting compared to other lakes. Sembrong Reservoir has the highest turbidity and chlorophyll-a, and lowest transparency among the lakes. Mean concentration of chlorophyll-a in this reservoir exceeded 25 µg/L, indicating eutrophic to hyper-eutrophic environment. The physical-chemical properties of Subang reservoir, such as turbidity, transparency, dissolved oxygen and nitrate, were in between the two lakes. TSI differences indicated both Subang and Sembrong reservoirs are non-phosphorus limited while Dayang Bunting Lake is phosphorus limited. Sembrong Reservoir was dominated by cyanobacteria, such as Planktothrix and Oscillatoria spp while Subang Lake was dominated by green algae. The most common algae in Dayang Bunting Lake were dinoflagellates and diatoms, indicating the influence of the adjacent marine waters.
Keywords: lakes, reservoirs, eutrophication, Malaysia, trophic state

INTRODUCTION
Eutrophication, is a global issue that impacted the quality of water in lakes and their ecosystem services. Lake eutrophication has been reported to be of concern in Malaysia with more 60% out of the 90 major lakes were categorised as eutrophic while the rest was mesotrophic (NAHRIM 2009). Characterising trophic state in lakes were mostly carried out using nutrient-chlorophyll-*a* relationship as measured by the Carlson trophic state index. The index which is based on chlorophyll-a, total phosphorus and Secchi depth transparency was developed on the assumption of linear relationship between the three variables (Carlson 1977). The growth of algal growth is assumed to be in proportion to the increased in nutrients specifically phosphorus (Carlson 1977). Carlson trophic state index was developed for temperate environment and the use of this index for tropical setting has been cautioned to be non-accurate due to the differences of temperature and solar irradiance in the threshold limits. Biological productivity specifically phytoplankton and zooplankton were dependent on nutrient availability and overall aquatic food web structure. In a tropical reservoir, water quality, phytoplankton biomass and zooplankton changed along the river-lacustrine continuum which in turn are related to nutrient availability (Yusoff et al. 2002). Phytoplankton species such cyanobacteria have been associated with eutrophication (Yusoff and McNabb, 1997) while some diatom species, such as *Cyclotella* are known to dominate in oligotrophic lakes (Ofem et al. 2011; Romo et al. 2013). Similarly, zooplankton species such as some species of *cladocerans* (i.e. *Bosmina longirostris)* and some species of rotifers (i.e. *Synchaeta longipes*) were identified as indicators of oligotrophic and mesotrophic conditions (Ofem et al. 2011). Changes in aquatic environment such as nutrients and water level may affect the plankton structure and dominance (Reynold 1987; Hoyer et al. 2005).
This study was undertaken to investigate the trophic conditions and water quality of three selected lakes of different trophy in Malaysia, and specifically to evaluate the chlorophyll-a-nutrient relationship, to identify the existing plankton community and their relationship with the trophic state. The focus of this study, however, is given to shallow lakes due to limited resources to monitor the deeper lake systems.

METHODS

Study area

Three lakes of varying trophy were selected for this study namely the Dayang Bunting Lake in Kedah, The Subang Lake in Selangor and the Sembrong Lake in Johor (**Figure 1**). The characteristics of the lakes are given in **Table 1**. Both Dayang Bunting and Subang lakes are smaller compared to Sembrong reservoir. Dayang Bunting Lake is a natural lake that is widely used for recreational purposes. The lake was thought to be of a doline origin of geological significance. Both Sembrong and Subang are man-made lakes; Sembrong Lake was created for flood mitigation in 1984 and later was used for water supply (JPS and UTHM 2012) while Subang Lake was completed in 1950 and used for water supply.

Table 1: Morphometric characteristics of the Malaysian three lakes with different trophy

Details	Dayang Bunting	Subang	Sembrong
Function	Recreation	Water supply	Water supply, flood mitigation
Origin	Doline	Impoundment	Impoundment
Surface are (ha)	28	76	850
Mean depth (m)	12.0	8.5	3.0
Shape	Oval	Dendritic	Dendritic
Perimeter (km)	2.2	19.1	42.3
Total storage (m^3)	3,300,000	3,500,000	18,000,000
Catchment area (km^2)	0.6	10.2	130

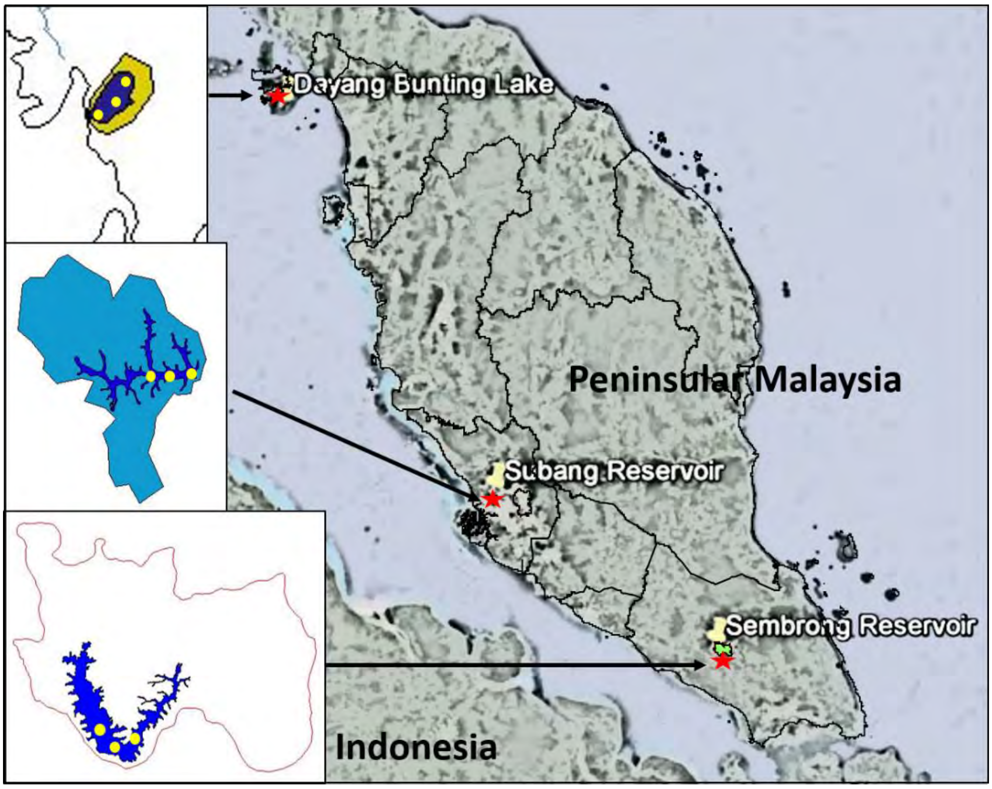

Figure 1: Location map of study areas

Data collection and analysis

In-situ measurements of temperature, pH, dissolved oxygen (DO), salinity, turbidity and conductivity were carried out using a multi-parameter probe (YSI 6600) whilst water samples for chemical analyses were collected using van dorn sampler. Measurements were performed at three locations (Figure 1) in each lake.

Additionally, water transparency (SD) was measured using a Secchi disk. Water samples were analysed for total phosphorus, nitrate-nitrogen and chlorophyll-a (Chl-a) in accordance to APHA (1995). Samplings in both Subang and Sembrong reservoirs were carried out bi-monthly between the period of December 2014 to August 2015 while samplings in Dayang Bunting Lake were performed between the period of April 2015 to February 2016.

Phytoplankton samples were collected in all three lakes at the sampling stations. In all lakes, phytoplankton samples were collected by taking water samples using a Van Dornsampler at two depths (surface, mid-depth). All phytoplankton samples were immediately preserved in the field with Lugol's solution. Zooplankton samples were collected by vertical tows from the bottom (30 cm from the sediment) to the surface using 60µm mesh conical net. All zooplankton samples were preserved with 5% buffered formalin. Both phytoplankton and zooplankton samples were processed, identified and enumerated in the laboratories. Pearson correlation was used to measure association between the trophic state index and environmental variables.

RESULTS AND DISCUSSION

Environmental variables

Our results showed low transparency readings in all lakes which ranged from 0.2 to 3.7 m (**Table 2**). Dayang Bunting Lake had the highest transparency, salinity and conductivity levels among all the lakes. Mean concentration of chlorophyll-a was below 10 µg/L while mean Secchi depth transparency exceeded 3.0 m indicating oligotrophic-mesotrophic environment. Total phosphorus concentrations were lowest compared to other lakes. High salinity, conductivity, transparency and pH levels in Dayang Bunting have been reported to be associated by its location in a limestone area bordering the sea. The south-western end of the lake is separated from the sea only by a narrow strip of land of about 3 m wide (Fig. 1) (FRI 1996). The transparency levels found in this study were much lower compared to previous study where the Secchi depth transparency were reported to exceed 6 m (FRI 1996). Salinity levels also has decreased indicating some changes in water quality of Dayang Bunting Lake since the last report in 1996, probably due to the increased anthropogenic activities associated with tourism in the lake basin.

Sembrong Reservoir had the highest turbidity and chlorophyll-a, and lowest transparency among all the lakes. Mean concentration of chlorophyll-a in this reservoir was 65.4 µg/L, indicating eutrophic to hyper-eutrophic environment (Table 2). Transparency levels were very low (below 0.5 m) while TP concentration was extremely high. The transparency and TP levels in this study were consistent with prior studies by other researchers (Singh et al. 2013; Sharip et al. 2014; Baharim et al. 2016). However, in this study, the transparency levels were consistently low throughout the year whereas findings by Singh et al (2013) showed an increase in transparency level during the wet season. The physical-chemical properties of Subang reservoir, such as turbidity, transparency, dissolved oxygen and nitrate, were in between the values found in Dayang Bunting and Sembrong lakes (**Table 2**).

Table 2. Mean ± standard deviation SD of environmental variables in Dayang Bunting, Subang and Sembrong lakes

Parameter	**Lake**		
	Dayang Bunting	Subang	Sembrong
Water transparency (m)	3.2±0.3	1.1±0.1	0.3 ±0.1
Temperature (°C)	30.7±0.9	30.3±0.7	30.3±0.5
DO (mg/L) – day time	6.7±1.8	7.8±1.3	8.2±1.4
pH	7.8±0.4	6.7±0.8	8.2±0.7
Salinity (ppt)	0.70±0.06	0.01±0.00	0.14±0.08
Conductivity (mS/cm)	1.58±0.0	0.01±0.0	0.12±0.04
Nitrate-N (mg/L)	0.02±0.01	0.01±0.02	nd
TP (mg/L)	0.002±0.00	0.040±0.06	0.125±0.18
Turbidity (NTU)	1.6±1.4	4.0±8.0	25.5±10.3
Chl-*a* (µg/L)	8.8±7.0	11.3±4.8	65.4±45.3

nd is non-detectable

Trophic state index

The calculation of trophic state based on Carlson Index is given in **Table 3**. The TSI for all the three parameters showed consistent values for Subang and Sembrong lakes suggesting linear relationship between the nutrient and biological productivity in both reservoirs. Yusoff et al (1997) reported that tropical lake trophy, similar to temperate lakes, was very closely related to the nutrient input. In fact, Osborne (2004) reported that tropical lakes are more sensitive to nutrient inputs compared to temperate lakes. TSI (Chl-a) showed divergent with TSI phosphorus in Dayang Bunting Lake and thus require further investigation. Estimation of TSI differences indicated Dayang Bunting Lake is phosphorus limited. Yusoff and McNabb (1989) reported that inorganic nitrogen to orthophosphate-P ratio of >36 indicated phosphorus limitation in a tropical pond. Positive deviation of TSI (Chl-*a*) from TSI (SD) in both Sembrong and Subang reservoir indicate light limitation by non-algal turbidity such as clay. Both Subang and Sembrong are man-made lakes, and reservoirs are known to be limited by turbidity (Rast and Lee 1978). Yusoff (1989) also reported that light became a limiting factor in a turbid fish pond. Positive divergent of TSI (Chl-a) from TSI (TP) in both reservoirs indicated that Subang and Sembrong lake maybe non-phosphorus limited, although nitrogen values are necessary to confirm the limiting factors.

Table 3. Trophic State Index*

Details	Dayang Bunting	Subang	Sembrong
TSI (SD transparency)	43.4	58.6	77.4
TSI (TP)	14.1	57.4	73.8
TSI (Chl-*a*)	51.9	54.4	71.6

Note: * based on Carlson TSI

In the eutrophic Sembrong reservoir, TSI (chl-*a*) was correlated to conductivity and DO (P<0.05) while in Subang, TSI (chl-*a*) was correlated to temperature (P<0.01) (**Table 4**). In Dayang bunting, TSI (TP) was correlated to turbidity while in Sembrong, TSI (TP) was correlated to turbidity, pH, conductivity and temperature.

Table 4. Correlation coefficient between trophic state index and environmental variables

Correlations									
	TSI(SD)			TSI(TP)			TSI(Chl-a)		
Parameter	Dayang Bunting	Subang	Sembrong	Dayang Bunting	Subang	Sembrong	Dayang Bunting	Subang	Sembrong
Temperature	-0.448	0.294	**-0.489***	-0.193	0.273	**0.536***	-0.040	**-0.691****	-0.019
pH	0.151	-0.139	-0.215	0.279	0.006	**0.605****	0.216	0.387	0.378
Turbidity	0.311	-0.013	0.123	**0.570***	0.091	**-0.578***	-0.248	0.067	-0.457
DO	-0.185	0.182	0.060	-0.033	-0.166	0.451	-0.074	-0.453	**0.518***
Conductivity	-0.227	-0.381	**-0.478***	-0.123	0.094	**0.530***	-0.090	0.100	0.013
Salinity	-0.115	0.409	**0.515***	-0.081	-0.130	**-0.557***	-0.071	-0.151	-0.323
TD	-0.185	0.051	0.362	-0.441	0.174	-0.285	0.144	0.035	0.078
SD	**-0.921****	0.218	-0.150	-0.054	0.113	0.074	0.083	0.041	0.272
TP	0.106	-0.409	-0.142	**0.862****	-0.378	-0.244	0.073	0.175	0.007
Chl-a	-0.259	**0.528***	-0.360	0.149	0.455	0.315	**0.974****	-0.147	-0.086
Nitrate-N	-0.179	-0.354	0.210	0.092	-0.308	-0.003	0.339	0.249	0.159

Note: Values in bold denote significant correlations: * correlation is significant at 0.05 level, ** correlation is significant at 0.01 level

Plankton analysis
In terms of phytoplankton analysis, blue-green algae (cyanobacteria) were the most dominant group in Sembrong reservoir with densities contributed more than 95.0% of the total phytoplankton during the study period. Excessive inflow of nutrients, especially nitrogen and phosphorus from the surrounding agriculture lands caused the increased phytoplankton abundance with cyanobacterial dominance (Yusoff and Patimah, 1994; Yusoff and McNabb, 1997). The most dominant species were *planktothrix* and *Oscillatoria* spp. The dominance of *Oscillatoria* spp. was also reported in the past such as written in Sembrong Lake Brief (JPS and UTHM 2012). In fact a work by Singh et al (2013) also showed that *Planktothrix* was the most dominant species in the reservoir during her study in 2013. The dominant species could be attributed to the mixing regime, season and organic and nutrient contents in the lakes (Elliott 2010; Yang et al. 2016).
In Subang Lake, Chlorophyta (green algae) formed the most dominant group contributing to more than 60% of the total phytoplankton in the Lake. The most dominant species were the desmids which are normally associated with oligo-mesotrophic waters such as *Cosmarium*, *Closterium* and *Staurastrum.* Yusoff et al (1998) also reported that the desmids (*Cosmarium* and *Staurastrum*) were dominant in Kenyir mesotrophic metalimnetic layer. The most common algae in Dayang Bunting Lake were dinoflagellates and diatoms, probably due to the influence of the adjacent marine environment. The dominant phytoplankton species was a dinoflagellate, *Peridinium* sp. The low nutrient level contributed to the low phytoplankton densities in Dayang Bunting Lake. The high salinity levels in this lake could also influence the type of plankton species. The phytoplankton results in this study indicate variation in the dominance of phytoplankton species with trophic levels.

CONCLUSIONS

This study showed that lakes of different trophy have different physical and biological characteristics. Oligotrophic-mesotrophic lakes such as Dayang Bunting has low nutrient level and the phytoplankton community structure was dominated by diatoms and dinoflagellates. The mesotrophic-eutrophic Subang lake was mostly dominated by green algae whilst the eutrophic-hyper-eutrophic Sembrong lake was dominated by blue-green algae. In addition to different trophic conditions, the limiting factor for the lake varied with other environmental variables such as pH and salinity.

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CURRENT STATUS OF LAKE ARAL – CHALLENGES AND FUTURE OPPORTUNITIES

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ABSTRACT

The Aral Sea was the fourth largest lake in the world before 1960. However, it is now four separate water bodies, fed mainly by collector-drainage waters because of excessive upstream irrigation water withdrawals from the two main influent rivers, the Syr Darya and Amu Darya, which is clearly shown on satellite images. The resulting rapid increase in salinity has caused a dramatic decrease in the lake biodiversity and loss of a once thriving fishery. Only a small part of the indigenous biota has survived. The regression of the Aral Sea also has had profound socioeconomic and human impacts on the lake riparian populations. Accordingly, it is encouraging to note the reversal of the degradation of the Northern (Small) Aral Sea after the erection of a dike at Berg's Strait in 1992. This first dike was washed out in 1999, but was replaced with the new structurally-sound Kok-Aral dam in 2004-2005. The water level in the Northern Aral has increased several meters and its salinity has returned to levels that can sustain the pre-1960 ecosystem. The biodiversity also has been somewhat rehabilitated, and the commercial fisheries have revived. The remnants of the hyperhaline Southern (Large) Aral continue their retreat and salinization. The Large Aral contains no fish species, and almost all the invertebrate species have been lost. To restore the Aral Sea to its former state would be very difficult, if not impossible, in the foreseeable future. However, a partial restoration of its separate parts is possible. Plans for further rehabilitation of the Small Sea and possible restoration of some parts of the Southern (Large) Aral Sea are discussed.

Keywords: Aral Sea, salinity, biodiversity.

INTRODUCTION

The Aral Sea is a terminal, or closed basin (endorheic) lake, lying amidst the vast deserts of Central Asia. Its drainage basin encompasses more than two million km^2 (**Fig. 1**). As a terminal lake, it has surface inflow but no outflow. Therefore, the balance between inflows from its influent rivers, the Amu Dar'ya and Syr Dar'ya and net evaporation (evaporation from the lake surface minus precipitation on it) fundamentally determine its level. In 1960 the Aral Sea was the 4th largest lake in the world by surface area. The main parameters of the Aral Sea in the middle of the 20th century: area: 67,499 km^2 (Large Aral 61,381 km^2 and Small Aral 6118 km^2), volume: 1089 km^3 (Large Aral 1007 km^3 and Small Aral 82 km^3), level: +53.4 m above sea level (actually above the Kronstadt gage near St. Petersburg, Russia, maximal depth: 69 m, salinity: about 10 g/l (Aladin, et al., 2008).

Figure 1. The Aral Sea basin

Prior to the modern desiccation, the Aral Sea was inhabited by about 20 species of fishes and about 200 species of free-living invertebrates (Plotnikov et al., 2014a). Between the middle of the 19th century and 1961, the shape and salinity of the Aral Sea practically did not change. We must note, however, that due to both the intended and the accidental introductions that started in the 1920s, the number of free-living animals grew substantially. In the Aral Sea appeared 10 species of new invertebrates and 17 species of new fishes (Plotnikov et al., 2014b).

METHODS

The results presented here are based on data gathered in annual expeditions to the shores of the Aral Sea, conducted since 1960. Zoological and botanical samples were taken and the hydrological parameters measured. Additionally, satellite images have been used to monitor the changing geographical features. The results of different projects conducted around and on the Aral Sea have been critically evaluated and incorporated into this paper. Also, available official information and data concerning the Aral Sea and its surrounding have been used.

RESULTS AND DISCUSSIONS

Since 1960 the Aral Sea has steadily shrunk and become shallower (**Fig. 2**) owing overwhelmingly to irrigation withdrawals (**Fig. 3**) from its influent rivers (Amu Dar'ya and Syr Dar'ya). At the end of the 1980s, when the water level had dropped by about 13 m and reached about +40 m, the Aral Sea divided into two lakes – the Large and the Small Aral. At that time, the total area of the Aral Sea (Large Aral and Small Aral) was 40,000 km^2 with a volume of 333 km^3 and a salinity of 30 g/l (Aladin et al., 2008). By September 2009, the total Aral area was only 8410 km^2, with a volume of 85 km^3. The Large Aral area had a surface of 4922 km^2 with a volume of 58 km^3 and a salinity >100 g/l. The Small Aral area at that date was 3487 km^2, volume 27 km^3 and salinity 10-14 g/l.

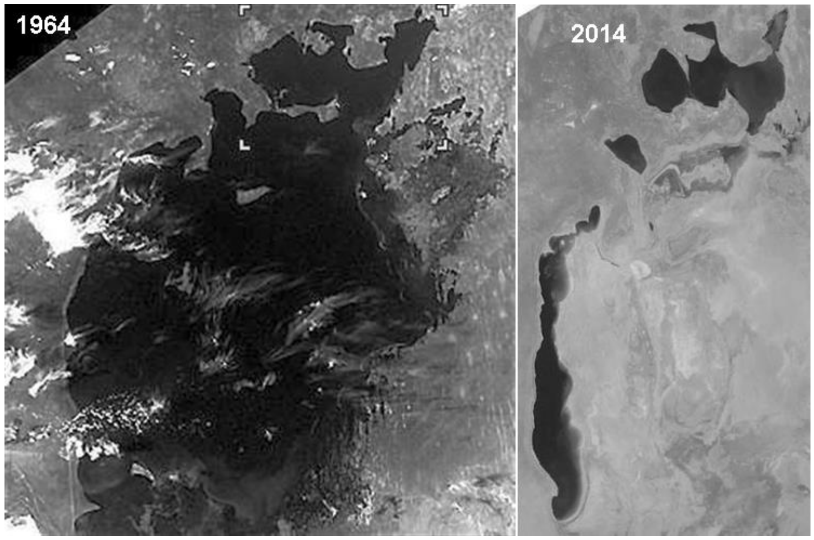

Figure 2. Since 1960 the Aral Sea has steadily shrunk and become shallower (left image from Corona spy satellite right from MODIS 250-meter sensor).

After the division of the Aral Sea, the Northern/Small Aral Sea started to have a positive water balance. Therefore, water from the Syr Dar'ya River, ground inflow, and precipitation on the sea's surface have contributed in total more water than evaporated from the surface of the Small Aral. In the case of the Large Aral Sea, the water balance continued to be negative. Thus, evaporation from its surface continued to be significantly higher than the total amount of water reaching it. Due to the positive water balance in the Northern/Small Aral Sea, there was a flow of excess water from it to the Large Aral Sea at that time. This discharge of water from the Small Aral occurred primarily in spring-early summer and corresponded to the high flow period on the Syr Dar'ya River. Consequently, it was decided to build a dam on the Berg Strait (**Fig. 4**) to keep the water in the Northern/Small Aral Sea. In August 1992, a basic dam was built. (Aladin et al., 1995). This dam helped preserve the Small (Northern) Aral and rehabilitate its biodiversity.

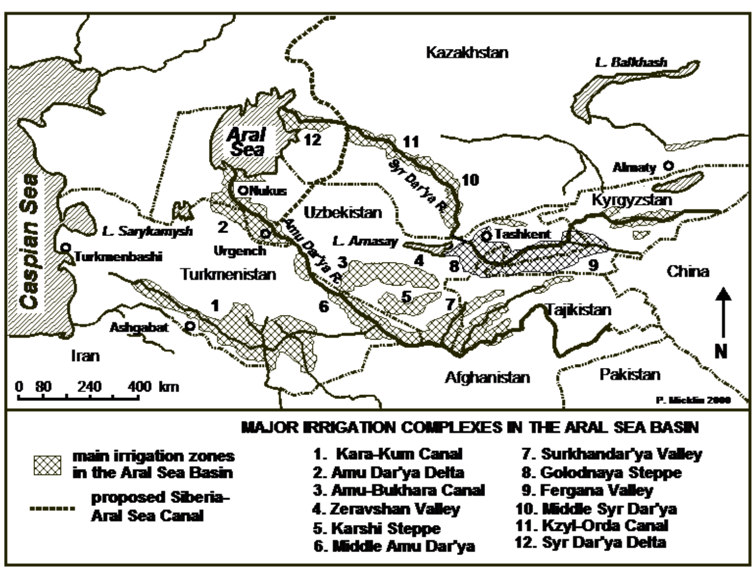

Figure 3. Irrigation development in the Aral Sea basin.

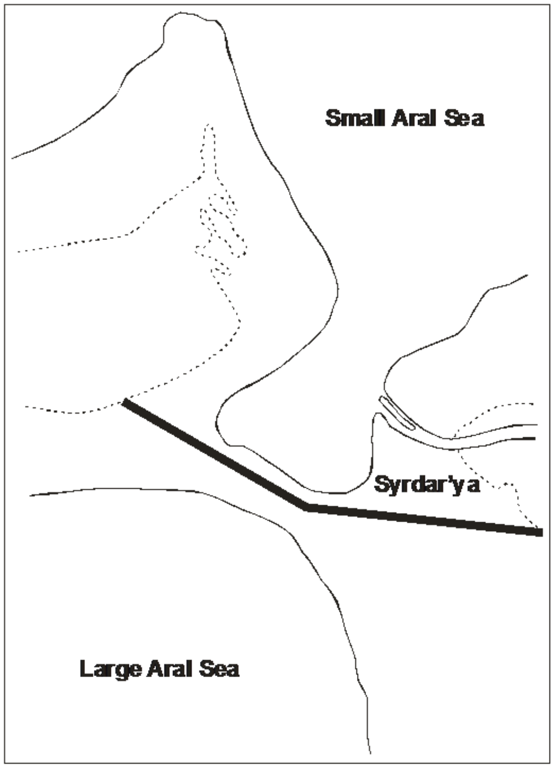

Figure 4. Dam in Berg strait.

The basic dam in the Berg Strait was partly destroyed a number of times by the high spring water levels but the broken parts of the dike were always restored by local people. Unfortunately, in April, 1999, when the Small Aral Sea water level rose by more than 3 m and reached +43.5 m (**Fig. 5**), the dam completely failed with the loss of two lives (Micklin, 2010).

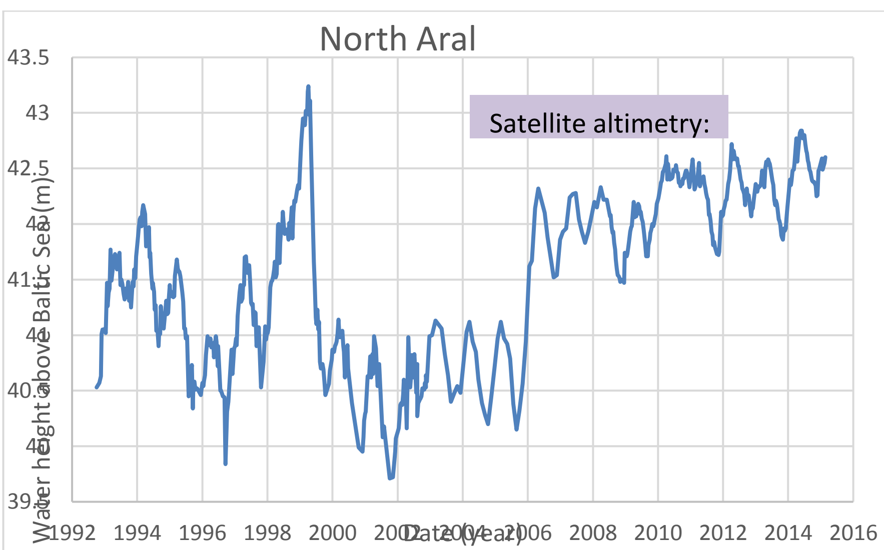

Figure 5. The Small Aral Sea level (data from satellite altimetry: Topex/Poseidon, Jason1, Jason2 and Jason3).

Figure 6. New Kok-Aral dam built by Russian company "Zarubezhvodstroy" in 2005

A new Kok-Aral dam (**Fig. 6**) was built by the Russian company "Zarubezhvodstroy". As a result, since August 2005, outflow has been controlled by a discharge structure (gates) in the dam. When the water gates are open at the Kok-Aral dam and there is heavy outflow, all the remaining southern water bodies of the Aral Sea are connected for a period of time (Micklin, 2014).

This dam on the Berg Strait was funded by the World Bank using funds from GEF (Global Environmental Facility) and the Kazakhstan government for the purpose of improving the brackish water environment of the Small (Northern) Aral Sea. Local people call this dam "Dam of life". The Kok-Aral dam has allowed an increase of the water level in the Small (Northern) Aral Sea in 6 months to +42 m a.s.l., and with "forcing" to 42.5 m (Cretaux et al., 2013). The present average salinity in the Small (Northern) Aral Sea is less than 10 g/l (Micklin, 2010). it will decrease even more in the near future.

It is possible to make the present dike higher and thus raise the water level to +45 m a.s.l. (recent research by P. Micklin, indicates it may even be possible to maintain the level at 48 m). This increase will allow the enlargement of the volume and area of the Small (Northern) Aral Sea. An alternative 2nd phase of the project would raise the level only of the Saryshaganak Gulf. For further increases in the inflow from the Syr Darya, significant improvements in irrigation efficiency are needed.

The second phase of the project would allow further improvement in the health of the local people, a decrease in poverty and unemployment, an increase in living standards as well as additional income for local families. The local economy also will be improved (fishery, aquaculture, shipping, etc.). The local microclimate around the Small (Northern) Aral Sea is expected to be much better than now.

When the basic first dam in the Berg Strait was built in 1992, fishing on the Small Aral recommenced. After construction of the Kok-Aral dam, conditions for fishing improved tremendously (**Fig. 7**) (Ermakhanov et al., 2012).

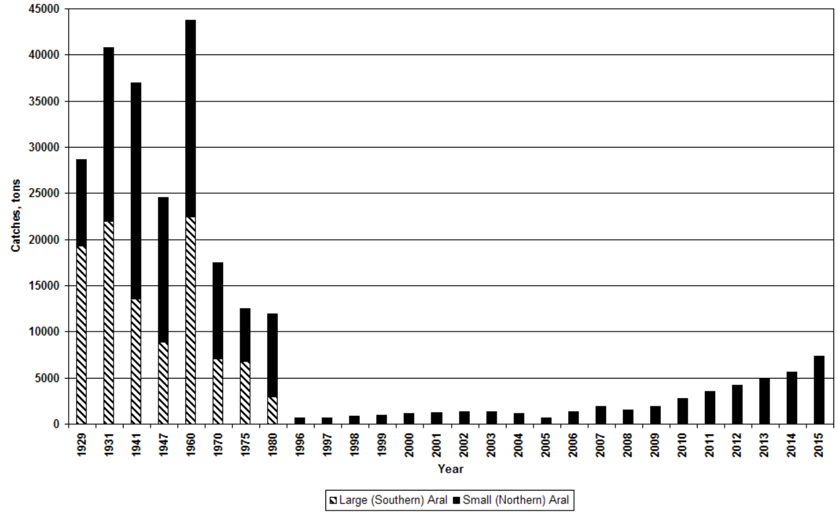

Figure 7. Commercial fish catches on the Small Aral Sea.

Since the Aral Sea divided into 2 lakes at the end of the 1980s, the level of the Large Aral Sea has declined intensively. In early 2003, when the level of the Large Aral Sea dropped by 22 m and fell to about +31 m, the Large Aral Sea divided into the Eastern Large and Western Large Aral (**Fig. 8**). In September 2009, the area was 4922 km^2 (8% from 1960), the volume 58 km^3 (6% from 1960), and the salinity in the Western part of the Large Aral Sea and Tschebas Bay >100 g/l, whereas salinity in the Eastern part was >200 g/l (Micklin, 2014). The level of the Eastern Large Aral Sea is always higher than the level of Western Large Aral Sea. In both lakes, salinity increased so much that all the fish disappeared (**Fig. 7**) and only a few free-living invertebrates survived. In the Eastern part of the Large Aral only one species of invertebrates – brine shrimp *Artemia* (represented here by parthenogenetic clones) – has survived. At the end of the 20th century, this species appeared in the Large Aral Sea (Plotnikov et al., 2014b). Today, industrial harvesting of brine shrimp cysts has started. *Artemia* cysts (or eggs) is a semi-product and is nourishing food for fingerlings and small fish or shrimp.

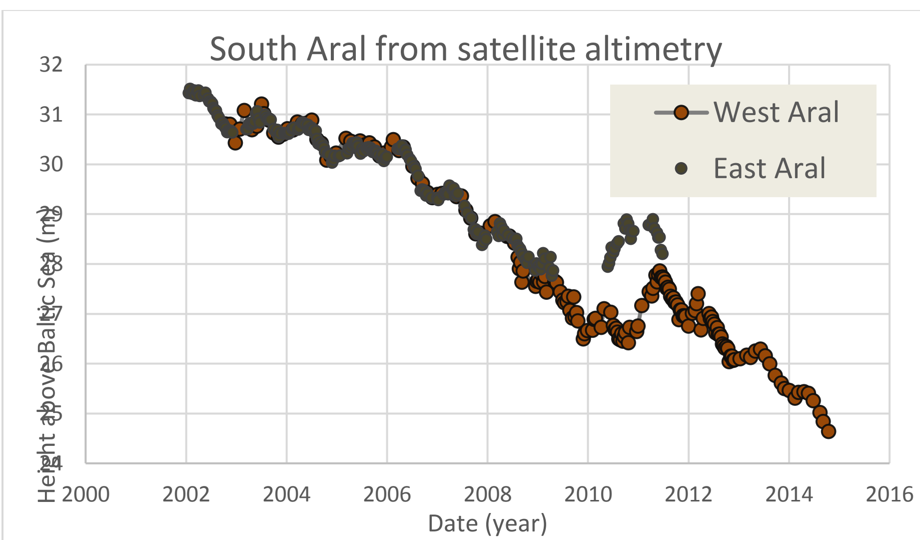

Figure 8. The Large Aral Sea level (data from satellite altimetry: Topex/Poseidon, Jason1, Jason2 and Jason3).

Since the completion of the Kok-Aral dam in 2005, excess water has been released southward creating a large lake that extends westward and southward and in some years extend sufficiently far south to aid in refilling the Eastern Basin of the Aral Sea. This lake also reaches what was formerly Tschebas Bay and supplements its water balance. It also provides some water through the connecting channel to the Western Basin of the Aral Sea. Fish from the Small Sea are carried into it by outflow from the Kok-Aral dam. This water body has been named the Central Aral by some experts (**Fig. 9, 10, 11**).

Figure 9. The Central Aral (Oct. 10, 2015).

However, the Central Aral is large, very shallow (the eastern part is now more a wetland than a true lake) and has extensive areas of reeds contributing to high rates of evapo-transpiration and thus significant water loss. Also, the western part has salinity levels too high (~70 g/l) for fish to survive. Finally, the area of the lake experiences great annual variation (**Fig. 9, 10**): enlarging greatly during the winter/spring period of heavier inflow from the Syr Darya and shrinking rapidly during the summer and autumn (and some years entirely disappearing).

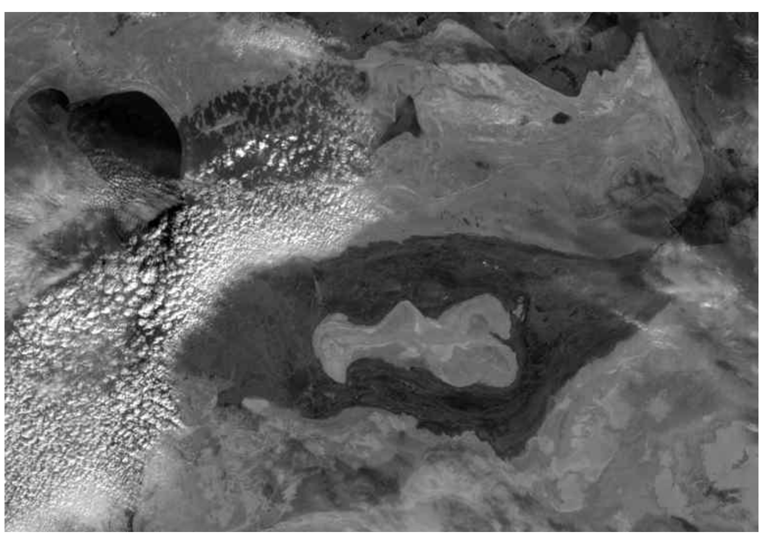

Figure 10. The Central Ara (Jan. 23, 2016)

In the Central Aral at the end of the dry season (July-November) (**Fig. 9**), when it receives little water from the Small Aral Sea, salinity is probably quite high. The Central Aral during the winter/spring season (from December to June) (**Fig. 10**) has a large surface area when large volumes of water discharge into it from the Small Aral Sea due to the large winter water releases into the Syr Darya through the Toktogul dam on the Naryn River in Kyrgyzstan for power generation and normal spring flooding (Cretaux et al., 2015). Mineralization of the lake at this time is low. The lake is covered with ice during winter as a result of the diminished salinity.

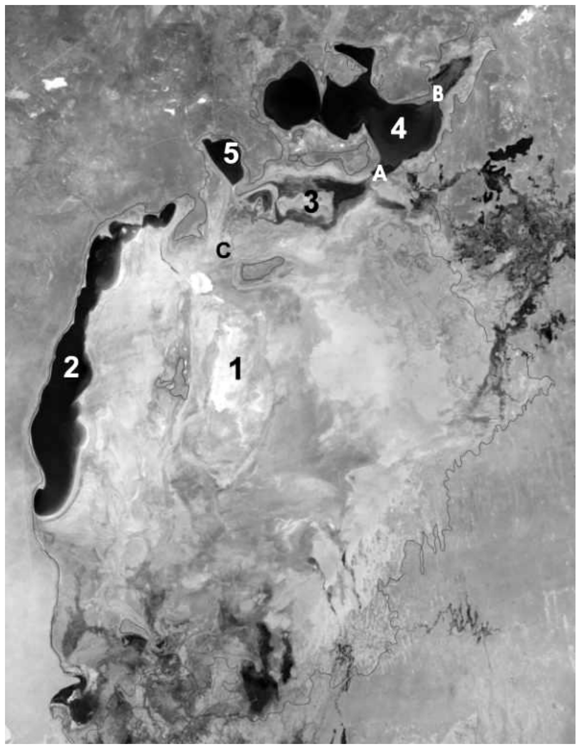

Figure 11. The Aral Sea on August 19, 2014. 1 - dried Eastern Basin of the Large Aral Sea; 2 - Western Basin of the Large Aral Sea; 3 - New Central Aral Sea; 4 - Small Aral Sea; 5 - Tsche-Bas Bay; A - Kokaral dam (Central dam) B – Proposed Northern dam; C – Proposed Southern dam.

The Small (Northern) Aral Sea (**Fig. 11**) acquired a common name – in its short form, the "Kazaral Sea" or "Kazakhstan Aral Sea". While the correct scientific name is – Northern Aral Sea derived from the brackish-water regulated reservoir. The Western Large (Southern) Aral Sea (**Fig. 11**) also acquired a common name – in short, the "Western Uzaral" or "Uzbekistan Aral Sea". The correct scientific name is Western Basin of the Southern Aral Sea derived from the southwest hyperhaline non-regulated lake. Likewise, the Large (Southern) Aral Sea (**Fig. 11**) acquired a common name, in short, "Eastern Uzaral" or "Eastern Uzbekistan Aral Sea". The correct scientific name is Eastern Basin of the Southern Aral Sea derived from the southeast hyperhaline non-regulated lake. The former Tschebas Bay (**Fig. 11**) also acquired a common name – "Tschebas-Kul". The correct scientific name is – Southern Aral Sea derived from Tschebas hyperhaline non-regulated lake. The strait between the Eastern and Western Large Aral (**Fig. 11**) has a common name – "Uzun-Aral". The correct scientific name is the natural channel between the Eastern and Western Large Arals.

The Eastern Large (Southern) Aral periodically receives inflow from the Amu Darya during high flow years on that river (e.g. 2010). Unfortunately, the newly reborn Eastern Large Aral is very shallow and dries up soon after water inflow from the Amu Darya ceases. It is unfortunate that this event is occasional and is not repeated annually.

The Large Aral Sea is the most ecologically devastated part of the lake. In the beginning of the 21st century, it divided into three parts: Western Large Aral Sea, Eastern Large Aral Sea and Tsche-Bas Bay (Plotnikov et al., 2014a, 2014b). The future of the Large Aral Sea is most connected with oil and gas extraction from the dry seabed and with brine shrimp cysts harvested in the Western Large Aral Sea. Currently only the Small (Northern) Aral Sea can be used for fishing.

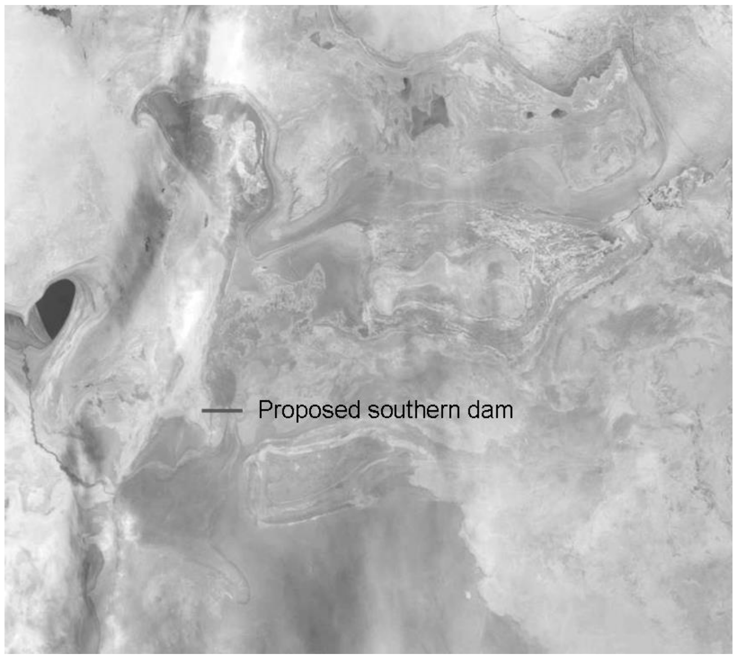

Figure 12. Discharge of Syr Darya water to the Eastern Large Aral (May 5, 2015)

The new Kok-Aral dam (**Fig. 11**) could be made higher. In this case, the volume of this reservoir would increase and more fish could be caught. To the north of the New Kok-Aral dam in the entrance to Saryshaganak Gulf one more dam could be built (**Fig. 11**), too (Micklin, 2014). Moreover, to the south of the New Kok-Aral dam a third dam could be constructed (**Fig. 11**). If in the future two more dams were built, it would be possible to have year-round fishing in all reservoirs controlled by these dams, as we have now year round fishing in the Small (Northern) Aral Sea. Three dam systems: Kok-Aral dam (Central dam), Saryshaganak Gulf dam (Northern dam) and the proposed third dam (Southern dam) would help not just the fishermen, but everyone live better. Construction of the Saryshaganak Gulf dam (Northern dam) would allow water to be brought back to the large city of Aralsk (town of Aralsk district). Local people would like to call it Dam of Happiness. Construction of the third dam (Southern dam) (**Fig. 11, 12**) would prevent the escape of residual water southward and improve fishing in the so-called Central Aral Sea. Local people would like to call it Dam of Despair. Currently, due to the lack of this dam, the Central Aral Sea dries up during periods of water shortage.

CONCLUSIONS

Considering the positive effect of the Kok Aral dam for the wildlife and for the population inhabiting this area what should be done for the additional conservation of biodiversity and biological resources of the Aral Sea? First, as soon as possible a raising rise of the dam by 2-3 m would increase the water level throughout the Small Aral. This will improve the fishery and the husbandry as well. It also will give the population easier access to the lake and the settlements will be closer to the sea.

A further suggestion is to build in the next few years a dam in the entrance to Saryshaganak Gulf. After that is finished, a simple dam to the south of Kulandy peninsula is needed to keep the water from the Central

Aral from overflowing to the vast area of the big Aral, where it only evaporates and increases the salinity of the former seafloor.
Regarding the Southern Aral Sea and Amudarya River delta region in accordance with ideas of some leading Aral researchers (Lvovich, Tsigelnaya, Micklin and some others), we should not refill shallow reservoirs in Amu Darya delta, but redirect the residual Amu Darya flow to the Western Large Aral Sea. However, most of Uzbek researchers have an opposite position, i.e. they consider using excess of river water for the watering of former sea bays (Jiltirbas, Sarbas, Muynak, Adjibay) and Lake Sudochye, as well as Mejdurechye reservoir on the delta of Amu Darya river. It must be noted that in the Republic of Karakalpakstan these water bodies are viewed as environmentally and economically vital. These measures will allow improving local microclimate and partly rehabilitating Southern Aral fishery and animal husbandry, create ecological conditions for the conservation of flora and fauna, and generate additional jobs and income sources for the local people.

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IDENTIFYING SOURCES OF NITRATE IN AN IRRIGATED RICE PADDY WATERSHED, TSUKUBA JAPAN

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ABSTRACT

The objective of this study is to identify sources of nitrate (NO_3^-) in river water using the stable isotope ratios of NO_3^- nitrogen ($\delta^{15}N_{NO3}$) and oxygen ($\delta^{18}O_{NO3}$) in an irrigated rice paddy watershed where irrigation water is supplied from outside of the watershed as well as the upstream mountain area. The study was conducted in a rice paddy watershed which covers 9.9 km² in the southern foot of Mt. Tsukuba, Ibaraki, Japan. We determined $\delta^{15}N_{NO3}$ and $\delta^{18}O_{NO3}$ of NO_3^- for river water, hillside stream water, foothill stream water, irrigation water, and drainage water every other month. Stable isotopes were analyzed by isotope-ratio mass spectrometer (IRMS) after converting NO_3^- to N_2O by the denitrifier method. Analysis of $\delta^{15}N_{NO3}$ and $\delta^{18}O_{NO3}$ from this watershed showed that the decrease in NO_3^- concentration in the mainstream river water occurred mainly because of the mixing of NO_3^- from different sources (foothill stream water and drainage water) during irrigation period. Our data suggested that denitrification is a lesser contributor to the decrease in NO_3^- concentrations in this watershed, because enrichment of isotopic transformation (positive relationship between $\delta^{15}N_{NO3}$ and $\delta^{18}O_{NO3}$) with decreasing NO_3^- concentration was not apparent. Different hydrological components suggest that NO_3^- in the mainstream river water in this watershed consisted mainly of mountain stream-derived NO_3^- during the non-irrigation period. The research highlights that the $\delta^{15}N_{NO3}$ and $\delta^{18}O_{NO3}$ can be used as a powerful tool, in order to evaluate nitrogen cycling in a watershed-level agricultural field where irrigation water is supplied from outside of the watershed.

Keywords: Agriculture, Irrigation, Nitrate, Stable Isotope, Watershed

INTRODUCTION

It is important to identify actual nitrogen (N) sources and understand the dynamics of N in surface waters and groundwater system if we are to develop effective watershed management practices for conserving water quality against nitrate (NO_3^-) pollution and plan to remediate sites where the waters are already polluted by N. The stable isotopes of NO_3^- nitrogen ($\delta^{15}N_{NO3}$) and oxygen ($\delta^{18}O_{NO3}$) are utilized in identifying different sources of N (e.g. atmospheric deposition, chemical fertilizers, and animal wastes) and evaluating the extent of isotopic fractionation during different N-transformation processes (i.e. nitrification and denitrification) have distinct $\delta^{15}N_{NO3}$ and $\delta^{18}O_{NO3}$ values (Kendall et al., 2007; Baily et al., 2011; Kaushal et al., 2011; Jin et al.,2012). However, this approach has not been applied to an irrigated rice paddy watershed because of its complex hydrology.

In rice paddy watersheds, N dynamics are influenced markedly by artificial alteration of the hydrological cycle by irrigation, ponding, and drainage practices. Generally, the drainage water from rice paddies has a low NO_3^- concentration because on denitrification in ponded rice paddies and assimilation by rice plants during the irrigation period (Tabuchi & Kuroda, 1991; Park et al., 1998; Takeuchi et al., 2005; Hitomi et al., 2005; Eguchi et al., 2009). Irrigation may also decrease NO_3^- in each rice paddy and in the drainage water. A major question regarding irrigated rice paddies is the relative importance of denitrification versus assimilation by rice plants as N nutrient uptake (Park et al., 1998; Hitomi et al., 2005). However, as yet there is no comprehensive collection of isotopic composition data from these water components in rice watershed because, isotope ratio mass spectrometry (IRMS) analysis of a series of surface water samples is costly. Previous study has fastened the fully automated IRMS system for quantifying $\delta^{15}N_{NO3}$ and $\delta^{18}O_{NO3}$ in water samples and reduced operational costs by saving on carrier helium gas (He) and liquid nitrogen (LN_2)(Yada et al., 2016). The objective of this study is to identify sources of NO_3^- in river water using improved IRMS determination of $\delta^{15}N_{NO3}$ and $\delta^{18}O_{NO3}$ in an irrigated rice paddy watershed where irrigation water is supplied from outside of the watershed as well as from the upstream mountain area.

METHODS

Study area

The study was conducted in an irrigated rice paddy watershed (the Sakasagawa River watershed) at the southern foot of Mt. Tsukuba, Ibaraki, Japan (**Fig. 1(a)**). The watershed has an area of 9.9 km^2 and is located in the eastern Kanto plain, about 70 km northeast of Tokyo. The elevation of the watershed extends from the lowlands (St.1; 23 meters above sea level, m.a.s.l.) to the peak of Mt. Tsukuba (877 m.a.s.l.) (**Fig. 1(b)**). The mean annual precipitation is about 1,283 mm and the temperature, 13.8°C (according to the Automated Meteorological Data Acquisition System of the Japan Meteorological Agency at Tsukuba). Basement rocks in the area consist of granitic and gabbro forming the Mt. Tsukuba and metamorphic rocks (**Fig. 1(c)**). The base of the Mt. Tsukuba is alluvial fan as debris of flow deposits. The watershed consists of two dominant land-use types: one is the quasi-national park (6.3 km^2), which is mostly forested by beech and conifer, and the other is agricultural area (3.0 km^2) consisting mainly of irrigated rice paddy fields (**Fig. 1(d)**).

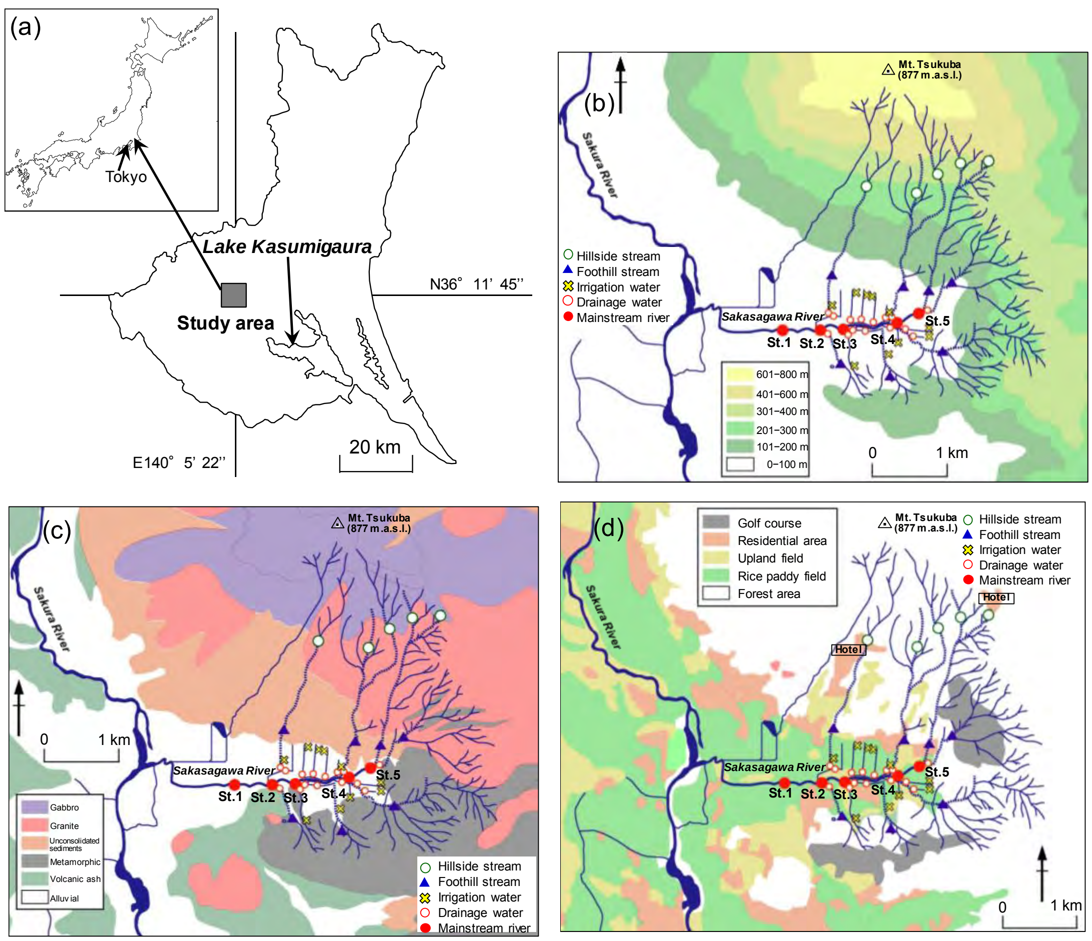

Figure 1. Watershed maps of the Sakasagawa River, showing (a) location, (b) river network, sampling points, and topography, (c) geology, and (d) land use.

The former area includes two large (0.8 km^2 and 1.4 km^2) grasslands (golf courses) created on the eastern and southern hillsides. The rest is occupied by residential areas and accommodation facilities (Hotels) for tourists (0.6 km^2). The Sakasagawa River, which is the main river, runs from the northeast to the west of the watershed and is formed from seven major tributaries or foothill streams. Five water sampling stations (St.1 to St.5) were selected to collect water from the main river. The most upstream station in the river, St.5

(43 m.a.s.l.) collected water mainly from the forest area. St.1 (23 m.a.s.l.) was at the outlet of the watershed. The downstream station, St.4 (32 m.a.s.l.), was surrounded mostly by rice paddies and located in a lowland area. Sample of water exporting NO_3^- into the main river were taken from each water component as follows: hillside stream water (n=5), foothill stream water (n=7), drainage water (n=15), and paddy irrigation water (n=9). About 50 mL of each water sample was filtered immediately on site with a pore size of 0.2 μm (25CS020AN, ADVANTEC, Tokyo), put in ice box to carry to the laboratory, and stored at −28°C until IRMS analysis for $\delta^{15}N_{NO3}$ and $\delta^{18}O_{NO3}$.

In the lowland area, drainage water ditches lay below the level of the paddy fields, and a portion of the drainage water was recycled for irrigation after being mixed with water from Lake Kasumigaura (the intake of which was outside this watershed) via National Kasumigaura Water Conveyance (WEPA Database 2015) and irrigated-water pumping stations (**Fig. 2(a)**). The irrigation-water pumping stations (n=5) (not shown in **Figs 1b, 1c and 1d**) convey 760 mm of irrigation water in total (calculated by monitoring the flow at each pumping station (m^3 day $^{-1}$), the total number of days of operation (days), and the size of the catchment area (km^2) during the irrigation period (from April t o August 2012)).

IRMS determination of $\delta^{15}N_{NO3}$ and $\delta^{18}O_{NO3}$ in water samples

We determined $\delta^{15}N_{NO3}$ and $\delta^{18}O_{NO3}$ for mainstream river water, hillside stream water, foothill stream water, drainage water, and irrigation water every second month during April 2012 to April 2013. At St.1, we determined $\delta^{15}N_{NO3}$ and $\delta^{18}O_{NO3}$ in mainstream river water weekly during irrigation period.

(a) Irrigation period

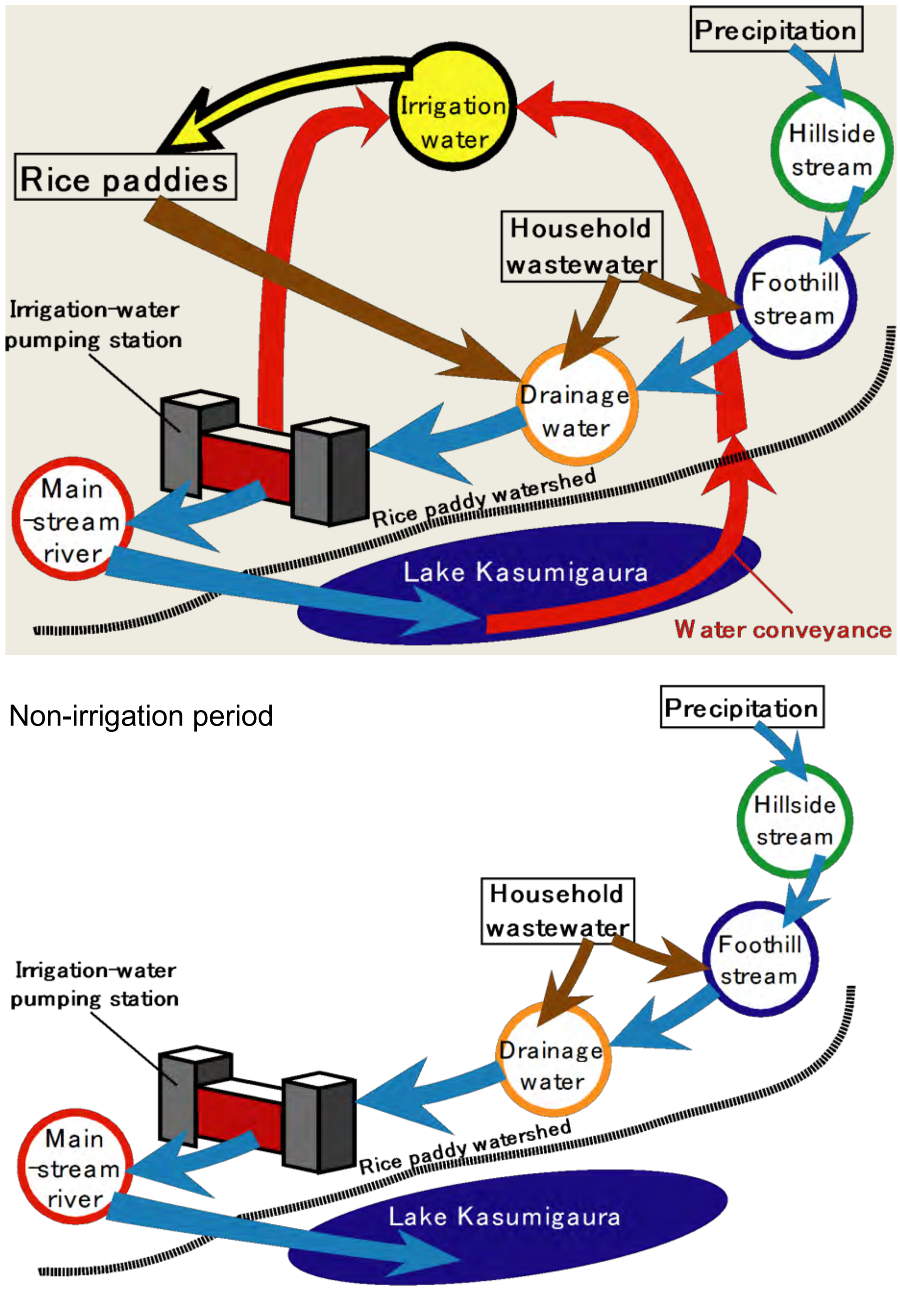

Figure 2. Schematic of the water circulation systems inside and outside of the rice paddy watershed during the (a) irrigation period and (b) non-irrigation periods. The black dotted line boundary shows the Sakasagawa watershed. Each arrow shows the water flow direction. The round frames show the key components affecting water and/or nitrogen cycles inside and outside of the watershed. The waters in the round frames were investigated in this study.

Samples were analyzed by using the rapid procedure for IRMS determination of $\delta^{15}N_{NO3}$ and $\delta^{18}O_{NO3}$ (Yada et al., 2016). A culture of denitrifying bacteria which lack N_2O reductive activity was used in the enzymatic conversion of the NO_3^- to N_2O in a vial. After 24 hours of incubation to complete the conversion, N_2O is purged from the vial, and introduced to a pre-GC (gas chromatograph) concentration device (PreCon; Thermo Scientific, Bremen, Germany) in LN_2 with the introduction system with CombiPAL autosampler (Thermo Scientific, Waltham, MA, USA). The cryofocused gas is warmed to 25°C and then trapped gases are released into the separation column (GS-Carbon PLOT, Agilent Technologies, Santa Clara, CA, USA) for chromatographic separation of trace CO_2 from the sample N_2O gas which are separately introduced into IRMS system (MAT252, Thermo Scientific).

Nitrate isotope standards (IAEA-N3, USGS32, USGS34, and USGS35) are typically made to a concentration of 30 µM in KNO_3 in pure water; the volume injected into each sample designed to result in the same amount of N_2O as the water samples. The slope and intercept of the reference materials (normalized to AIR and VSMOW by using an N_2O reference gas tank) and the known isotopic values of the reference materials (vs. AIR and VSMOW) were then used to calculate the absolute $\delta^{15}N_{NO3}$ and $\delta^{18}O_{NO3}$ values of the water samples (vs. AIR and VSMOW) from the measured values.

One-way analysis of variance (ANOVA) was performed for Cd content in crop seedlings among application of different alkaline materials by using R version 3.2.2 (The R Foundation for Statistical Computing, Vienna). Tukey's HSD test at a 95% family-wise confidence level was conducted on those treatments for which there were significant differences in the ANOVA.

RESULTS AND DISCUSSIONS

Spatial and temporal variability of nitrate during irrigation and non-irrigation periods

Nitrate concentration of the mainstream river water at St. 1 showed marked temporal variation as impacted by rice paddy irrigation. The NO_3^- concentration decreased significantly from 1.29 to 0.47 mg N L^{-1} during the irrigation period (late April to end of August); after that, the NO_3^- concentration returned to higher than 1.0 mg N L^{-1} and was relatively stable during the non-irrigation period (beginning of September to mid-April) (**Fig. 3(a)**). In contrast, NO_3^- concentration at St. 5 was almost stable throughout the year with 0.90 to 1.22 mg N L^{-1} (**Fig. 3(a)**). The upstream area of St. 5 does not have paddy fields; therefore, the river water NO_3^- concentration was not affected by rice paddy irrigation.

The mean NO_3^- concentration in the mainstream river water at St. 1 to St. 5 during the irrigation period (0.87 ± 0.26 mg N L^{-1}), was lower than that during non-irrigation period (1.11 ± 0.13 mg N L^{-1}) (**Table 1**). This is partly due to the input of irrigation water with lower NO_3^- concentration (0.81 ± 0.46 mg N L^{-1}, **Table 1**) from outside of the watershed; furthermore, the drainage water with the lowest NO_3^- concentration (0.56 ± 0.41 mg N L^{-1}, **Table 1**) in the watershed should have had much more of a significant effect on the decrease in NO_3^- concentration of mainstream river water. Some nitrate removal process by assimilation or denitrification in the irrigated paddy field should have played a significant role on decreasing NO_3^- concentration of the drainage water to almost half of that during the non-irrigation period (1.24 ± 0.77 mg N L^{-1}, **Table 1**). The foothill stream water had the highest NO_3^- concentration (1.31 to 1.40 mg N L^{-1}, **Table 1**) in the watershed throughout the year, suggesting that there is a major source of NO_3^- around the foot of mountain. The NO_3^- concentration of hillside stream water was almost stable (1.00 to 1.06 mg N L^{-1}, **Table 1**) during the observation period.

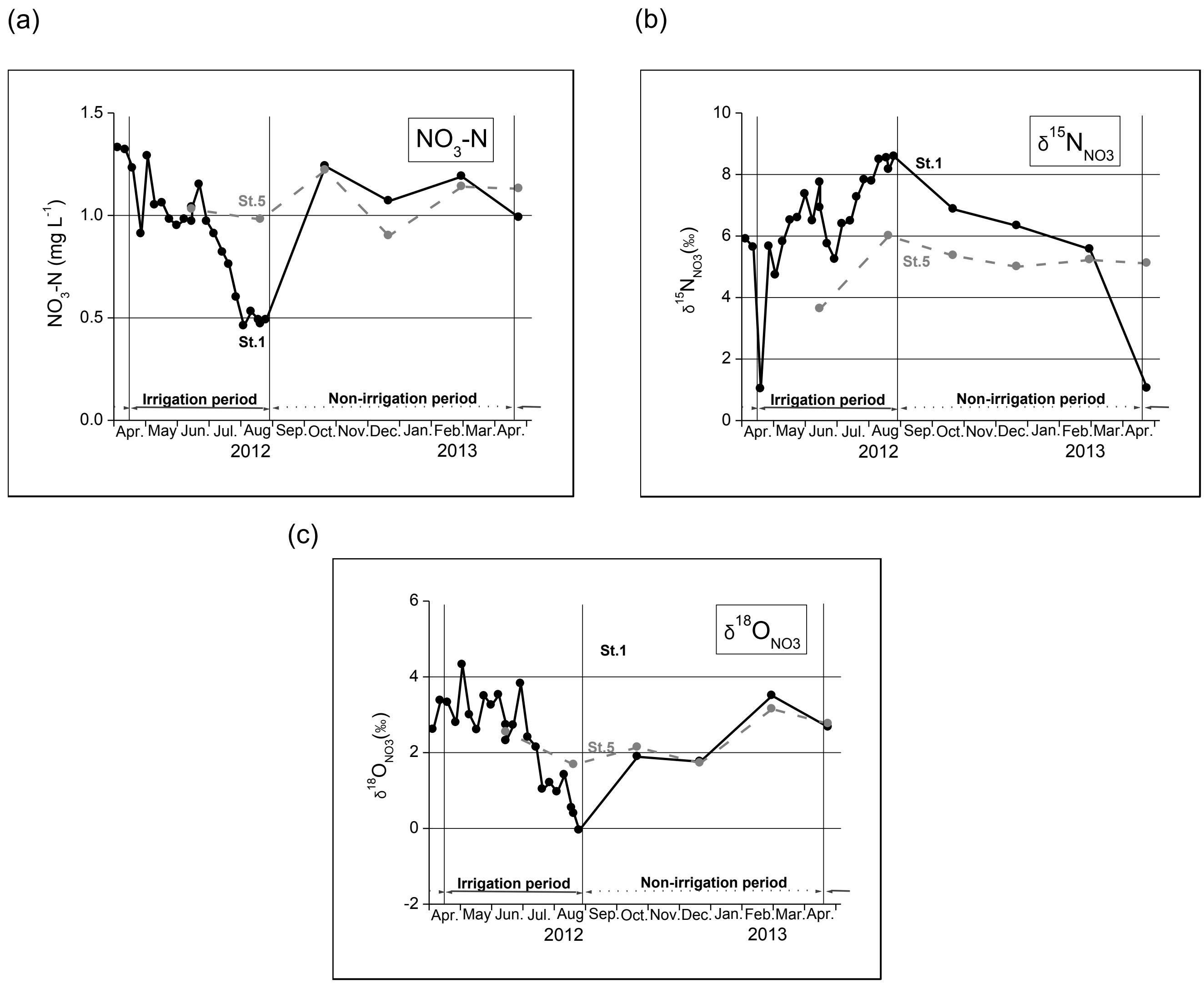

Figure 3. Changes in the (a) nitrate concentration, (b) $\delta^{15}N_{NO3}$ and (c) $\delta^{18}O_{NO3}$ values in the mainstream river water (St.1 and St.5) from April 2012 to April 2013.

Seasonal patterns of dual isotopic composition of nitrate

Seasonal patterns of $\delta^{15}N_{NO3}$ and $\delta^{18}O_{NO3}$ values of mainstream river water were different between St. 1 and St. 5 (**Figs. 3b and 3c**). $\delta^{15}N_{NO3}$ and $\delta^{18}O_{NO3}$ values were relatively stable at St. 5. That is, the $\delta^{15}N_{NO3}$ and $\delta^{18}O_{NO3}$ values, were 3.63 to 6.00 ‰ and 1.68 to 3.15 ‰, respectively, whereas those at St. 1 varied largely from 1.05 to 8.58 ‰ and −0.05 to 3.82 ‰, respectively. The NO_3^- concentration at St. 1 (**Fig. 3(a)**) significantly decreased with the increase of $\delta^{15}N_{NO3}$ (**Fig. 3(b)**) and with the decrease of $\delta^{18}O_{NO3}$ (**Fig. 3(c)**). This indicates that denitrification was not the major factor for decreasing the NO_3^- concentration at St. 1 and that the major factor was the dilution effect by mixing with some end-member of lower NO_3^- concentration, higher $\delta^{15}N_{NO3}$, and lower $\delta^{18}O_{NO3}$ values. The irrigation water showed lower NO_3^- concentration (0.81 ± 0.46 mg N L^{-1}), the highest $\delta^{15}N_{NO3}$ (8.19 ± 2.79 ‰), and the lowest $\delta^{18}O_{NO3}$ values (1.44 ± 2.51 ‰)(**Table 1 to 3**). This suggests that the decrease in NO_3^- concentration at St. 1 during the irrigation period is attributable to the dilution effect of the water from Lake Kasumigaura (the intake of which

was outside of the watershed) via the National Kasumigaura Water Conveyance, in association with the NO_3^- removal effect of the paddy fields. NO_3^- removal in these fields is probably mainly as a result of plant or algae NO_3^- uptake rather than denitrification.
The hillside stream water had the smallest $\delta^{15}N_{NO3}$ (3.15 to 3.21 ‰) and the highest $\delta^{18}O_{NO3}$ (5.00 to 5.42 ‰) values in the watershed (**Tables 2 and 3**) and there were no significant seasonal variations between irrigation and non-irrigation periods. This is partly affected by atmospheric NO_3^- input to the mountain, that had a $\delta^{15}N_{NO3}$ value of almost zero (**Table 2**) with the highest $\delta^{18}O_{NO3}$ (**Table 3**). The foothill stream water also showed relatively stable $\delta^{15}N_{NO3}$ (5.69 to 6.02 ‰) and $\delta^{18}O_{NO3}$ (2.16 to 2.37 ‰) values (**Table 2 and 3**).
These results suggest that the major sources of NO_3^- in hillside and foothill stream water did not change largely throughout the year.

The $\delta^{18}O_{NO3}$ versus $\delta^{15}N_{NO3}$ plots in the rice paddy watershed
The $\delta^{18}O_{NO3}$ versus $\delta^{15}N_{NO3}$ relationship (**Figs. 4a and 4b**) was used to identify sources of mainstream river water NO_3^- in this watershed. **Fig. 4(b)** shows all the $\delta^{18}O_{NO3}$–$\delta^{15}N_{NO3}$ plots in this watershed during non-irrigation period, including that of the mainstream river water $\delta^{15}N_{NO3}$ and $\delta^{18}O_{NO3}$ values that may be simply regarded as a mixture of two end-members: foothill stream water and drainage water.

Table 1. Arithmetic mean, range and standard deviation of NO_3–N (mg L^{-1}) in the rice paddy watershed (23 April 2012−28 April 2013) .

	NO_3-N (mg L^{-1})				
	Mean	Minimum	Maximum	Standard deviation	
Precipitation:					
(18 Jan. 2013 to 23 Apr. 2013)	0.46 bc	0.06	0.74	0.28	(*n*=5)
Mainstream river water:					
Irrigation period (23 Apr . 2012 to 31 Aug. 2012)	0.87 ab	0.47	1.20	0.26	(*n*=10)
Non-irrigation period	1.11 ab	0.90	1.24	0.13	(*n*=15)
Inputs					
Irrigation period					
1. Hillside stream	1.06 ab	0.41	1.67	0.46	(*n*=10)
2. Foothill stream	1.31 abc	0.59	2.48	0.58	(*n*=14)
3. Drainage water	0.56 b	0.13	1.53	0.41	(*n*=30)
4. Irrigation water	0.81 bc	0.07	1.71	0.46	(*n*=19)
Non-irrigation period					
1. Hillside stream	1.00 ab	0.50	1.70	0.43	(*n*=15)
2. Foothill stream	1.40 a	0.65	2.84	0.72	(*n*=21)
3. Drainage water	1.24 abc	0.03	3.50	0.77	(*n*=45)

Table 2. Arithmetic mean, range and standard deviation of $\delta^{15}N_{NO3}$ (‰) in the rice paddy watershed (23 April 2012−28 April 2013)

	$\delta^{15}N_{NO3}$ (‰)				
	Mean	Minimum	Maximum	Standard deviation	
Precipitation: (18 Jan. 2013 to 23 Apr. 2013)	0.90 d	-2.21	2.94	2.06	(*n*=5)
Mainstream river water:					
Irrigation period (23 Apr. 2012 to 31 Aug. 2012)	6.43 abc	3.63	8.16	1.39	(*n*=10)
Non-irrigation period	5.72 abc	5.00	6.84	0.51	(*n*=15)
Inputs					
Irrigation period					
1. Hillside stream	3.15 cd	1.43	6.71	1.66	(*n*=10)
2. Foothill stream	6.02 abc	2.90	14.16	3.10	(*n*=14)
3. Drainage water	7.25 ab	3.07	14.50	2.53	(*n*=30)
4. Irrigation water	8.19 ab	4.04	15.03	2.79	(*n*=19)
Non-irrigation period					
1. Hillside stream	3.21 cd	1.40	7.94	2.13	(*n*=15)
2. Foothill stream	5.69 ab	2.75	11.90	2.56	(*n*=21)
3. Drainage water	8.19 a	2.20	16.09	3.43	(*n*=45)

Table 3. Arithmetic mean, range and standard deviation of $\delta^{18}O_{NO3}$ (‰) in the rice paddy watershed (23 April 2012−28 April 2013).

	$\delta^{18}O_{NO3}$ (‰)				
	Mean	Minimum	Maximum	Standard deviation	
Precipitation: (18 Jan. 2013 to 23 Apr. 2013)	73.50 a	59.90	83.92	9.95	(*n*=5)
Mainstream river water:					
Irrigation period (23 Apr. 2012 to 31 Aug. 2012)	1.96 bcd	0.39	2.91	0.86	(*n*=10)
Non-irrigation period	2.54 bcd	1.72	3.50	0.59	(*n*=15)
Inputs					
Irrigation period					
1. Hillside stream	5.00 bc	2.43	8.08	1.62	(*n*=10)
2. Foothill stream	2.16 cd	-0.70	4.27	1.36	(*n*=14)
3. Drainage water	1.90 cd	-1.92	6.80	1.98	(*n*=30)
4. Irrigation water	1.44 d	-3.27	5.67	2.51	(*n*=19)
Non-irrigation period					
1. Hillside stream	5.42 b	2.75	7.70	1.51	(*n*=15)
2. Foothill stream	2.37 cd	-0.37	4.46	1.38	(*n*=21)
3. Drainage water	3.00 bcd	-2.98	20.94	3.52	(*n*=45)

The higher NO_3^- concentrations (up to 3.50 mg N L^{-1}) in these two end-members appears to be derived from household wastewater with $\delta^{15}N_{NO3}$ values of about 10 to 15 ‰ and $\delta^{18}O_{NO3}$ values of about 0 to 5 ‰, and also from chemical fertilizer with $\delta^{15}N_{NO3}$ and $\delta^{18}O_{NO3}$ values of less than 5 ‰ **(Fig. 4(b))**. The chemical fertilizer may have been used in the grasslands of the golf course.

During the irrigation period (**Fig. 4(a)**), the drainage water NO_3^- concentrations decreased and the NO_3^- concentrations of foothill stream waters remained higher (values up to 2.48 mg N L^{-1}) as impacted by household wastewater and the application of chemical fertilizers on the golf course. At St. 1, chemical fertilizer impacted $\delta^{15}N_{NO3}$ and $\delta^{18}O_{NO3}$ values that were observed in late April 2012 as well as 2013 (**Figs. 3b, 3c and 4a**); however, the NO_3^- concentration was low (0.99 to 1.23 mg N L^{-1}). Therefore, the effect of chemical fertilizer N used in paddy fields on the mainstream river water NO_3^- concentration was very limited. Moreover, **Fig. 4(a)** also shows that irrigation water gradually impacted isotopic composition of NO_3^- in mainstream river water as the paddy irrigation and drainage waters are quantitatively dominant in the hydrological cycle during the irrigation period.

These results indicate that the major sources of mainstream river water NO_3^- in this watershed were household wastewater drained from the foot of the mountain and chemical fertilizer in the hillside golf course. The chemical fertilizer applied in paddy fields appears to have a very limited effect on the effluent NO_3^- load. This study demonstrates that the dual-isotope approach is a powerful tool to identify sources of NO_3^- on a watershed scale, even in a hydrologically very complicated area such as irrigated rice paddy watersheds where irrigation water is supplied from outside of the watershed.

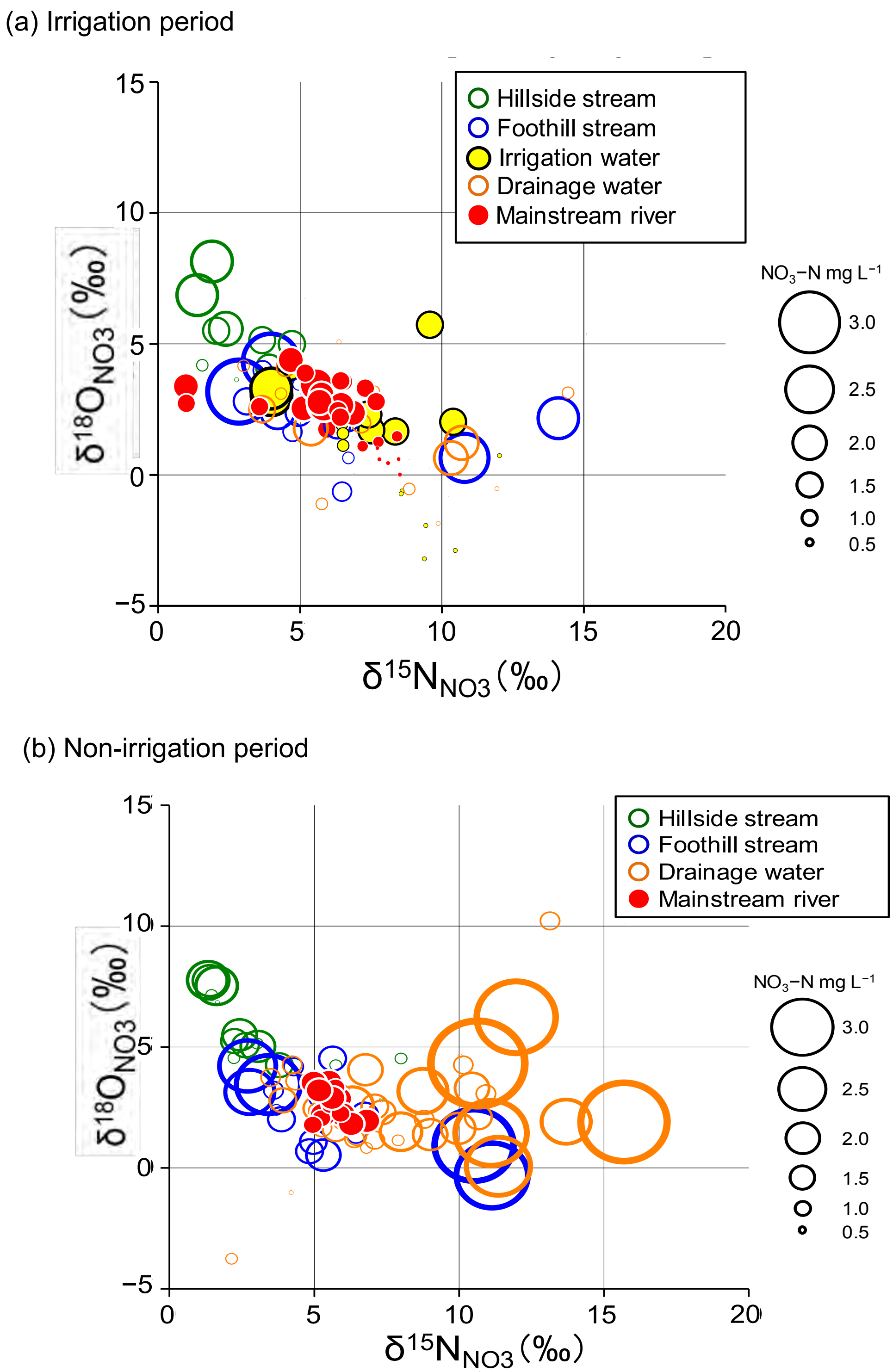

Figure 4. Dual isotopic composition ($\delta^{15}N_{NO3}$ and $\delta^{18}O_{NO3}$) of the key hydrologic components in the rice paddy watershed during the (a) irrigation and (b) non-irrigation periods.

CONCLUSIONS

The natural abundance of nitrogen ($\delta^{15}N_{NO3}$) and oxygen ($\delta^{18}O_{NO3}$) isotopes of nitrate (NO_3^-) was used to identify sources of mainstream river water NO_3^- in an irrigated rice paddy watershed where irrigation water is supplied from outside of the watershed. Different hydrological components suggest that NO_3^- in the mainstream river water in this watershed consisted mainly of mountain stream-derived NO_3^- during the non-irrigation period.

The research also highlights that the $\delta^{15}N_{NO3}$ and $\delta^{18}O_{NO3}$ can be used as a powerful tool, in order to evaluate nitrogen cycling in a watershed-level agricultural field where irrigation water is supplied from outside of the watershed.

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RELATIONSHIP BETWEEN TROPHIC STATES AND NUTRIENTS LOAD IN WATERS SURROUNDING SAMOSIR ISLAND, LAKE TOBA, NORTH SUMATERA

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ABSTRACT

*Lake Toba as the largest lake in Indonesia is fast developed in fish aquaculture, tourism, agriculture, and human settlement. These activities will produce organic and inorganic materials that will affect water quality and can cause eutrophication. Some indicators of eutrophication in Lake Toba are nutrients increasing and trophic states changing. The aim of this study was to analyze the effect of nutrients load to the trophic states in waters surrounding Samosir Island, Lake Toba, North Sumatera. This study was conducted at 23 stations around Samosir Island. Water samples were taken for water quality, nutrient (P and N), and phytoplankton analysis. Data analyses were conducted for nutrients load, trophic states, and spatial distribution mapping of those and dominant species of phytoplankton. Result showed that P and N load in waters surround Samosir Island mainly sourced from floating cage aquaculture and land activities. P and N load from floating cage aquaculture activity was higher than land activity. Those P and N load had increased P and N concentration in waters surround Samosir Island. The P and N concentration showed high trophic states (eutrophic). Biological trophic states index (Nygaard) also showed that waters surround Samosir Island have already in eutrophic states. This was strengthened by high abundance of Anabaena (*Cyanophyceae*) that indicates eutrophic condition.*

Keywords: Lake Toba, nutrients, phytoplankton, trophic states

INTRODUCTION

Lake Toba is the biggest natural lake in Indonesia. The lake was formed as caldera of eruption of Mount Toba at 75000 years ago. There was also formed relatively big 'pseudo-island' with an isthmus inside of lake that came from resurgent cauldron process, namely Samosir Island. The Samosir became a real island when Dutch government constructed channel along the isthmus that separated it from the main island. Lake Toba lay on 905 m msl, with total area of 1 124 km^2, volume of 256,2 x 10^9 m^3, average depth of 228 m, and residence time of 81 years. The north part of lake was separated from the south part by Samosir Island. The maximum depth of the north past is 508 m, and the south part is 420 m. From the relative depth (Zr = 1.34%), Lake Toba indicates as an unstable lake, especially for the the surface layer, while at the depth of more than 100 m, the waters are stable (Lukman&Ridwansyah 2010). There is about 3.700 km^2 catchment area of Lake Toba with 26 sub-catchment area. From 289 rivers surrounded the lake, 112 from Samosir Island and 117 from main-island. 222 of them are intermittent and 57 permanent; and 19 directly outfall to the lake (BLHPP 2014). There are also other sources of materials came into the lake, from some activities in lake especially floating cage activityand tourism. Meanwhile, other materials sourced from landuse runoff and sediment erosion (Boyd 1990).

The organic and inorganic materials thatenter into the lake could influence the water quality, or even to lead eutrophication. The eutrophication occurred in Lake Toba, that was indicated by nutrientsincrease in last few years and change the trophic statesbecome eutrophic or hypertrophic condition (Lukman 2011; Nomosatryo&Lukman 2011). In eutrophic condition, the enrichment of nitrogen and phosphorous will increase the growth of specific group of microalgae or phytoplankton, that related to the concentration and ratio of N:P. Eutrophication is a natural process in all kind of waters, that could be hasten by anthropogenic involved (Rohlich 1969).

The variation of the density and composition phytoplankton related to the water quality changing, especially nutrients, it indicatethe level of the trophic states inwaters. The dominance or high density of phytoplankton could indicate oligotrophic, mesotrophic, or eutrophic state. Lake Toba has been reported as eutrophic lake, it is presumably to be dominated by phytoplankton as eutrophic indicators (Rahman *et al*. 2016). Therefore, it is very important to estimate the trophic state of Lake Toba related to the community structure of phytoplankton. This study was conducted in the waters surrounding ofSamosir Island. The waters receive material inputs fromSamosir Island and the mainland (Sumatera Island), and also from cage culture activities. Based on these backgrounds, the aim of this research was to analyze the influence of nutrients loading to the trophic states and community structure of phytoplankton in the waters surroundingSamosir Island of Lake Toba, North Sumatera. The results are expected, it could provide the ecological reference as scientific base for the implementation of lake management in Lake Toba.

METHODS

The observation was conducted at October 2014 that consist of two collecting data activities, for field primary data and desk secondary data (from Haranggaol distric and the whole Lake Toba). Primary data collection consists of direct water collection for water quality and phytoplankton analysis from 23 sites surround Samosir Island (**Figure 1**). Secondary data collection consists of recording the result of last observations and water quality monitoring data of Lake Toba from the office of BLHPP Samosir. There was also observation of mainland activities and inside of the lake itself, which might add nutrient load to the lake. Phosphorous loads were come from floating cage activity, mainland domestic community waste, and other land use activities. The highest P loads were recorded in Haranggaol, the waters surroundingSamosir Island, and the lake itself.

The water quality analysis was based on APHA (2012). The load of P, especially from land activities, was estimated followed Jorgensen and Vollenweider (1988) and Rast& Lee (1983), with formulation as described below. Furthermore, the load from floating cage was based on observation result of Oakley (2015).

$$I_{Pt} = A \times E_P$$

with:

I_{Pt} : land use load of P (mg/y)

A : land use area (m^2)

E_P: P export coefficient

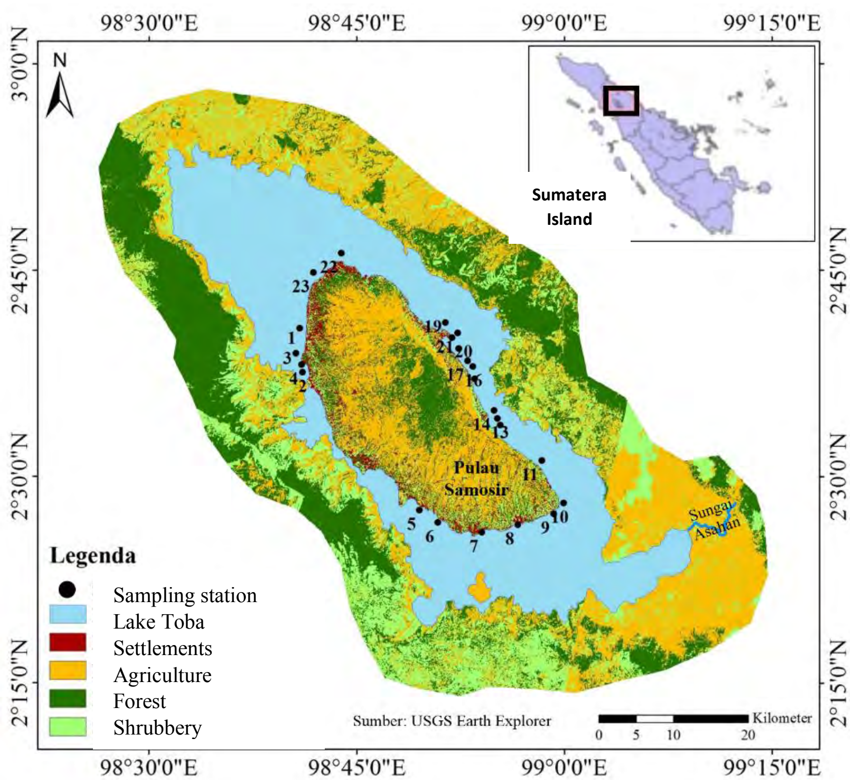

Figure 1. Sampling site surround Samosir Island, Lake Toba

The phytoplankton identification was referred Prescott (1970) and Mizuno (1979). The sampling site cluster analysis was followed Brower *et al.* (1990). Furthermore, the estimation of trophic state of waters wasbased on nutrients condition (Goldman and Horne 1983) and phytoplankton community structure (Nygaard 1949*in* Rawson 1956).

FINDING AND ARGUMENT

The anthropogenic activities at land and water area surround Lake Toba could affect its water quality. The domestic activities in land area and floating cage and transportation in water area, support organic materials into lake water, and increased nutrients. The total area of Lake Toba watershed is 3658 km^2, with around 28% people was concentrated in Samosir District, Samosir Island (Moedjodo*et al*. 2003; BPS 2013; Oakley 2015). The high P source loads to Lake Toba came from cage activities, residential wastes, and land use activities, such as agriculture. There were some spots of cage activities in the lake, and Haranggaol is the most active spot. Based on the loads estimation, in the whole lake, the highest P loads came from cage activities of Haranggaol. The load of P at waters surround Samosir Island was mainly came from cage culture, that highly similar to the load fromresidence wastes (**Table 1**). Generally, the load of the input will increase water body nutrients. Furthermore, the nutrients affected the community structure of phytoplankton. There was not only phosphorous that was measured as nutrient parameter in the waters surround Samosir Island, but also nitrogen (**Figure 2**). The concentration of orthophosphate and total phosphate were in range 0.06-0.73 mg/L and 0.12-1.53 mg/L, respectively. Besides, the concentration of DIN was in range 0.12-1.53 mg/L, the average is 0.74 mg/L. The nutrients concentration was relatively higher than that was reported by Baruset *al*. (2008). The nutrient values indicated eutrophic condition of lake water (Lukman 2011; Nomosatryoand Lukman (2011).

Table 1. The source and loads of P in Lake Toba

Source of P	Load of P (mg/m^3/year)		
	Lake Toba	Haranggaol waters	Waters surroundSamosir Island
Cage culture	1.14	4.76	1.70
Residence wastes	0.50	1.67	1.69
Agricultural	0.43	1.28	1.16
Total	2.08	7.70	4.55

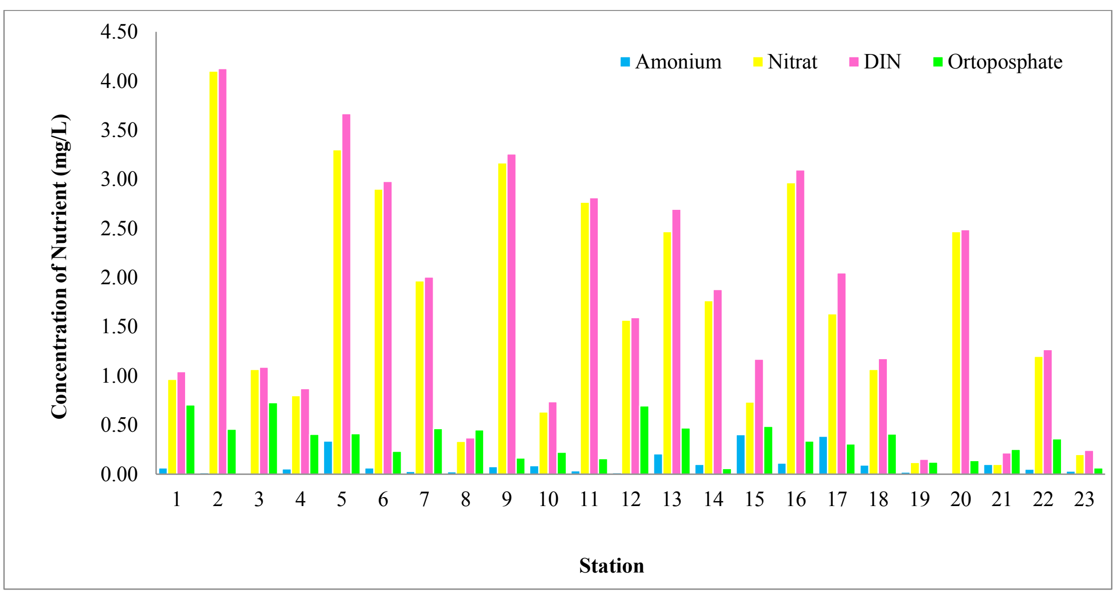

Figure 2. Nutrient in the waters surrounding Samosir Island

The water condition of waters can be estimated by density and composition of phytoplankton. The density of phytoplankton was in the range of 216-68 319 716 cell/m^3; that consist of 35 genera and included in four classes (**Figure 3**). The density and composition of phytoplankton was influenced by the environmental condition, such as organic materials (May *et al*. 2003), nutrients concentration, light intensity, temperature, pH, and predators (Lau & Lane 2002; Yu 2010 *in* Jiang *et al.* 2014). The community structure of phytoplankton shows that the diversity was moderate, evenness and the dominance relatively low to high. Those were quite lower that observed byYazwar (2008), butrelatively similar to the result of Astuti & Satria (2009). It seemed that only few species aretolerable withthis water condition (Soedibjo, 2006). Based on phytoplankton species density¸ there were constructed three groups of sampling site. Group I was characterized by the domination of *Anabaena* sp., Group II dominated by *Gloeotila*sp., and Group III by *Sphaerocystis* sp.

The high density of phytoplankton was shown by *Anabaena* (Cyanophyceae), *Gloeotila*, and *Sphaerocystis*(Chlorophyceae), with the total of 68.319.716 cell/m^3 (42,53%)34.534.869 cell/m^3(21,50%) dan 31.917.017 cell/m^3 (19,87%), respectively. There were some genera that found at all stations, i.e. *Botryococcus, Gloeocystis, Anabaenopsis* and *Melosira.*

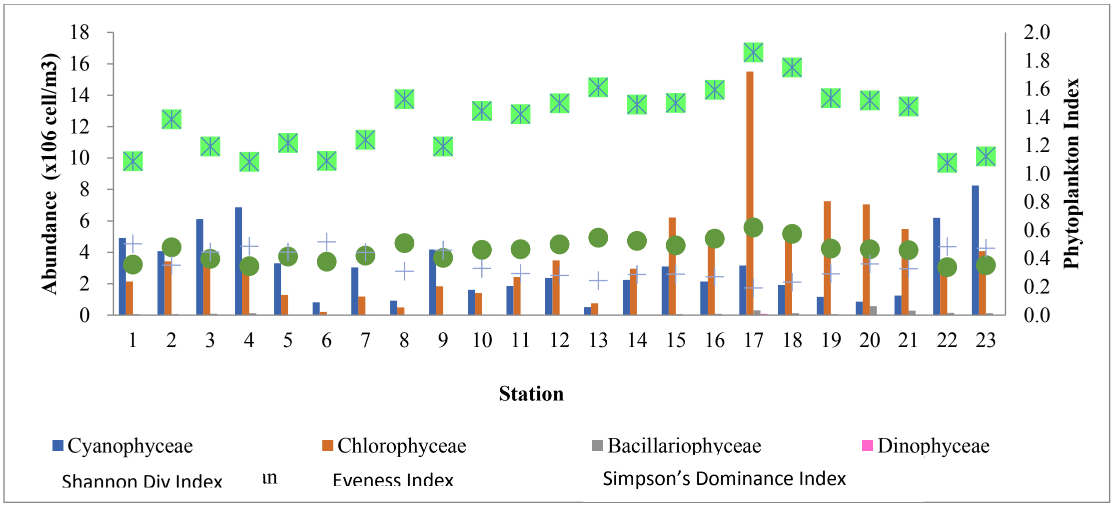

Figure 3. Phytoplankton density and the biological indices

The phytoplankton was composed by Chlorophyceae (14 genera), Cyanophyceae (4 genera), Bacillariophyceae (16 genera), and Dinophyceae (1 genus). Cyanophyceae was the most abundant in spite of less number of taxa. Furthermore, the Nygaard Index was 3.5-5.5 in ranged (**Figure 4**). It was indicated that waters surround Samosir Island, Lake Toba, was in eutrophic state.

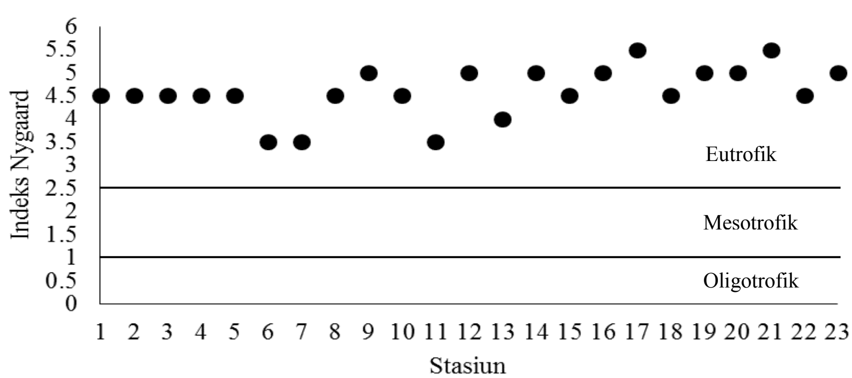

Figure 4. Nygaard Index of waters surround Samosir Island

Based on nutrients concentration and phytoplankton performance, Lake Toba was stated as eutrophic lake in some areas. Generally, the map of trophic states, the nutrients condition, and species dominance is shown in **Figure 5**. **Figure 5** shows that the eutrophication was spread similarly throughout all of observation sites. It was indicated that eutrophication in Lake Toba was categorized as cultural eutrophication.

Some previous research reported that the eutrophication of Lake Toba was led by high human activity, such as cage culture, and residential wastes (Lehmusluoto, 2000), and mismanagement of catchment area (Saragih & Sunito 2001). Eutrophic states of waters are an indication of the human activity impact to the waters (Kagalou *et al.* 2008). Total phosphate increases gradually by time as reported by some researchers (**Table.2**). Based on some research, the trophic state of Lake Toba was increasing from 1929 to 2014 as shown in **Table 3**.

Table 2. General description of total phosphate of Lake Toba (1951-2014)

Year	Total Phosphate	References
1991	0,240 mg/L	Schmittou 1991 in Wijopriono*et al*. 2010
2005	0,550 mg/L	Wijopriono*et al*. 2010
2014	0,740 mg/L	This research

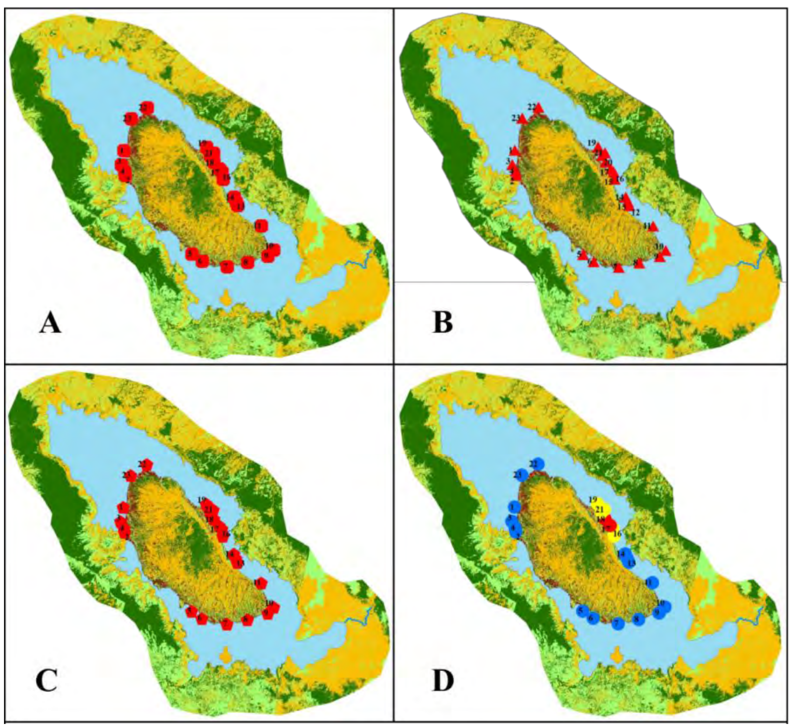

Figure 5. Site cluster of waters surround Samosir Island, Lake Toba, based on (A) trophic states: < 1 (oligotrophic), 1-2.5 (mesotrophic), >2.5 (eutrophic);(B) orthophosphate: 0.003-0,01 mg/L, 0.011-0.03 mg/L, 0.031-0.1 mg/L; (C) nitrate: < 0.1 mg/L; 0.1-0.2 mg/L; > 0.2 mg/Land (D) phytoplankton: Group I, Group II, Group III

Table 3. The change of Lake Toba trophic states

Year	Trophic State	References
1929	Oligotrophic	Ruttner 1930 *in*Lukman 2011
2005	Mesotrophic	Purnomo*et al*. 2005 *in*Lukman 2011
2009	Mesotrophic	Nomosatryo&Lukman 2011
2014*	Eutrophic	This research

*restricted to surround Samosir Island

There were found a specific condition of the relationship between nutrients and phytoplankton, especially the N:P ratio and community of phytoplankton. The N:P ratio was varied in range 0.82-31.91, with rates of 7.39. This study revealed that the different level of N:P ratio in eutrophic state condition was not followed by different community structure of phytoplankton. Usually, the high N:P ratio willfollowed by the dominance of diatoms (Pratiwi*et al*. 2013)

CONCLUSIONS

The highest nutrients loading in the waters surroundingSamosir Island was sourced from floating cage activities. This condition willlead increasing of trophic states to eutrophic level, with phytoplankton structure that dominated by *Anabaena*sp. The high ratio of N: P from nutrient load that entered this eutrophic level was not affect the phytoplankton community structure, which mainly dominated by Cyanophyceae.

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ZOOPLANKTON DIEL VERTICAL MIGRATION IN LAKE LAUT TAWAR, ACEH, INDONESIA

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ABSTRACT

Lake Laut Tawar is *located in the tropical sub-alpine area with high light intensity throughout the year and low air temperature. Watershed supplies high sediment input during the rainy season while floating cages culture and domestic wastes supply nutrients. The aim of this research was to study zooplankton diel vertical migration (DVM) pattern and physical factors that drive it in Lake Laut Tawar, Aceh. Sampling took place in the center of the lake using water sampler in March and June 2015. Sampling was conducted three times a day, before dawn at 03.00 WIB, before culmination at 11.00 WIB, and after the sun sets at 20.00 WIB. Samples were collected in 0, 1, 3, 5, 8, 15, 30 and 60 meters with 5 replications. Physicochemical factors measured were Secchi depth, air temperature, vertical water temperature, DO,* CO_2, *nitrate and phosphate. Zooplankton in Lake Laut Tawar showed temporal DVM. Zooplankton did not perform DVM in March, however strong DVM was observed in June. Zooplankton DVM in Lake Laut Tawar was driven by the presence of predators and light penetration. March is the end of spawning season for Depik (Rasbora tawarensis). Zooplankton density increased in June after spawning season ended. The increase of zooplankton density caused the decrease of phytoplankton density. Copepods had the widest diel vertical migration. It could reach up to 30 m to avoid predators. Diel Vertical Migration was also driven by competition over species and functional groups*

Keywords: cascade migration, trophic cascade, temporal diel vertical migration, tropical subalpine lake

INTRODUCTION

Plankton is free-living microorganism with limited locomotion. Plankton disperses in water column mostly by turbulence and other water movement. Plankton locomotion is a strategy to adapt to environmental conditions. These movements can cause changes in species composition in each depth creating plankton vertical distribution (Hylander et al., 2009). Zooplankton perform active vertical migration to avoid predators. They can move vertically and horizontally in finding the right niche. Zooplankton vertical migration affects phytoplankton abundance and density in the water column. They are also responsible for nutrient cycling in a lake (Hylander et al., 2009; Silva, 2006). Zooplankton diel vertical migration (DVM) is an adaptation to respond to environment condition. Diel vertical migration is a habitat selection mechanism and reaction to intra and inter-species interaction (Williamson et al., 2011). Zooplankton migrate to deeper water column at noon. They avoid sunlight to hide from predators' sight. After the sun sets, zooplankton swim to the water surface where phytoplankton is abundant. Small zooplankton tend to avoid bid zooplankton. They might show reverse migration (Easton & Gophen, 2003; Williamson et al., 2011).

Zooplankton DVM is also driven by several physicochemical factors. The main factor is light penetration. The oligotrophic lake has clear water that allows sunlight to penetrate deeper in the water column. Otherwise, eutrophic lake only allows sunlight to penetrate in the surface area. Deeper light penetration caused zooplankton swim deeper to avoid predators. In oligotrophic lakes, zooplankton swim deeper than in eutrophic lakes. Zooplankton DVM amplitude is narrow in a eutrophic lake. Sunlight penetration is shallow in the eutrophic lake (Aguilera et al., 2006). Zooplankton DVM is also affected by biological factors, which are food and predators (Legnani et al., 2005).

Zooplankton such as *Daphnia* performs strong DVM. *Daphnia pulex* shows DVM even in a fishless lake. This behavior showed that sunlight plays an important role in driving Cladocerans DVM. In a lake with fish, zooplankton DVM is driven by predators and sunlight. Pigmented zooplankton like *Boechella* never performs DVM. They always hide under Secchi depth. Transparent zooplankton can swim freely in the water column (Aguilera et al., 2006). Zooplankton predators are comprised of bigger zooplankton, fish larvae, and planktivorous fish. Planktivorous fish in Lake Laut Tawar are Depik (*Rasbora tawarensis*) which is an endemic fish that lives only in Lake Laut Tawar. Depik spawns in a rainy season thus it decreases zooplankton density (Muchlisin et al., 2010).

Factors which drive DVM are different at each lake. The subalpine lake has high sunlight radiation throughout the year. In this lake, sunlight is the main factor controlling zooplankton DVM. High sun radiation inhibits phytoplankton photosynthesis in the lake surface. This condition creates *Deep-water Chlorophyll Maximum* (DCM) which is a condition where phytoplankton dense is deeper due to ultraviolet radiation. Deep-water Chlorophyll Maximum can cause phytoplankton and zooplankton abundant in the same depth at noon. This event only happens in an oligotrophic lake or alpine lake due to high ultraviolet penetration (Beklioglu et al., 2008; Hylander & Hansson, 2009).

Lake Laut Tawar is a subalpine tropical lake located in the middle Aceh, surrounded by Bukit Barisan Mountains. It is hypothesized that zooplankton performs the diel vertical migration in Lake Laut Tawar. The DVM shows cascading migration over predatory and nutrient. The purpose of this research was to study zooplankton DVM pattern, predation, competition, physicochemical factors which affect DVM, and water quality condition of Lake Laut Tawar.

METHODS

Lake Laut Tawar is a subalpine lake located in the eastern part of Takengon city, Middle Aceh, Aceh Province, Indonesia. Lake Laut Tawar ends in Malacca Strait through Peusangan River. Lake surface area is 54.72 km^2, average depth of 51.13 m, and a maximum depth of ±70 m. Lake lies at an elevation of 900-1000 m above sea level. There are 25 inflows and only one outflow. Total water debit flowing into the lake are 10.043 L/second, and water debit going out through Peusangan River are 5664 L/second.

Two kinds of samples were taken, plankton and physico chemical samples, in the center of the lake on 13 March and 5 June 2015. Sampling was conducted three times a day, before sun rise at 03.00, before culmination at 11.00, and after the sun sets at 20.00. Samples were collected at depths 0, 1, 3, 5, 8, 15, 30, and 60 meters with 5 replications. Depths were chosen for the light regime. Plankton was sampled with *Varn Dorn* water sampler and plankton net size 20 mesh, fixated with 4% formaldehyde. Samples were identified based on Shirota (1966), and Edmonson (1959) and counted in the laboratory of Ecology and Conservation Gadjah Mada University by strip counting method using a light microscope with SRCC (Sedgwick Rafter Counting Chamber) (40x10 magnification). Physicochemical factors measured were Secchi depth, water temperature, ambient temperature, dissolved oxygen (DO), carbon dioxide (CO_2), Nitrate (NO_3), Phosphate (PO_4), and pH.

Water temperature was measured vertically at the same depth where plankton samples were collected using mercury thermometer. Secchi depth was measured with Secchi disc. Dissolved oxygen and carbon dioxide were measured vertically using *micro Winkler* method. Water nutrient was measured in the laboratory. Plankton density and abundance were analyzed using ordination to show temporal difference in March and June.

RESULTS AND DISCUSSION

There were four functional groups of zooplankton found in Lake Laut Tawar. They were Copepods, Cladocerans, Protozoa, and Rotifers. The number of zooplankton were 17 species. Zooplankton were less abundant in March 2015 and did not perform DVM. Zooplankton were mostly dense in 1m depth at 11.00 WIB, reaching up to 2.1 ind/L. The highest density of zooplankton at 20.00 WIB were in 8 m depth, they were 1.64 ind/L. While at 03.00 WIB, they were most dense in 1 m depth, 0.86 ind/L (**Fig. 1**).

Zooplankton density increased in June 2015. The highest density at 03.00 were in 1 m depth, they were 10.42 ind/L. While at 11.00, the highest abundance was in 5 m depth, they were 9.04 ind/L. And at 20.00, the highest density was in 3 m depth, they were 11.04 ind/L. Zooplankton showed DVM patterns in June 2015 which were quite different from March.

The reason that zooplankton did not perform DVM in March was probably because of the presence of planktivorous fish. There are several endemic fishes live in Lake Laut Tawar. The fishes are all planktivores. Previous research was only exploring Depik (*Rasbora tawarensis*), while other planktivorous fishes lived in this lake remain unknown. Depik are mostly found in epilimnion to metalimnion. Their spawning seasons are in January to March. Spawning decreases rapidly in April and starts to peak in July (Muchlisin et al., 2010).

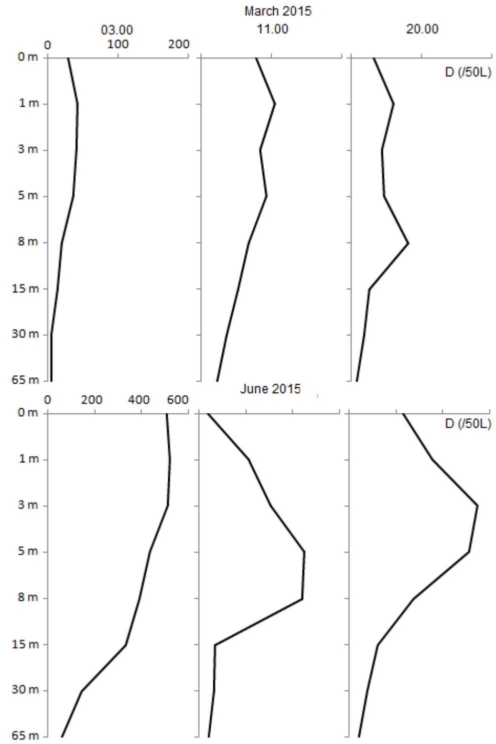

Figure 1. Zooplankton Diel Vertical Migrations in Lake Laut Tawar, the upper image is DVM in March 2015, the lower image is DVM in June 2015.

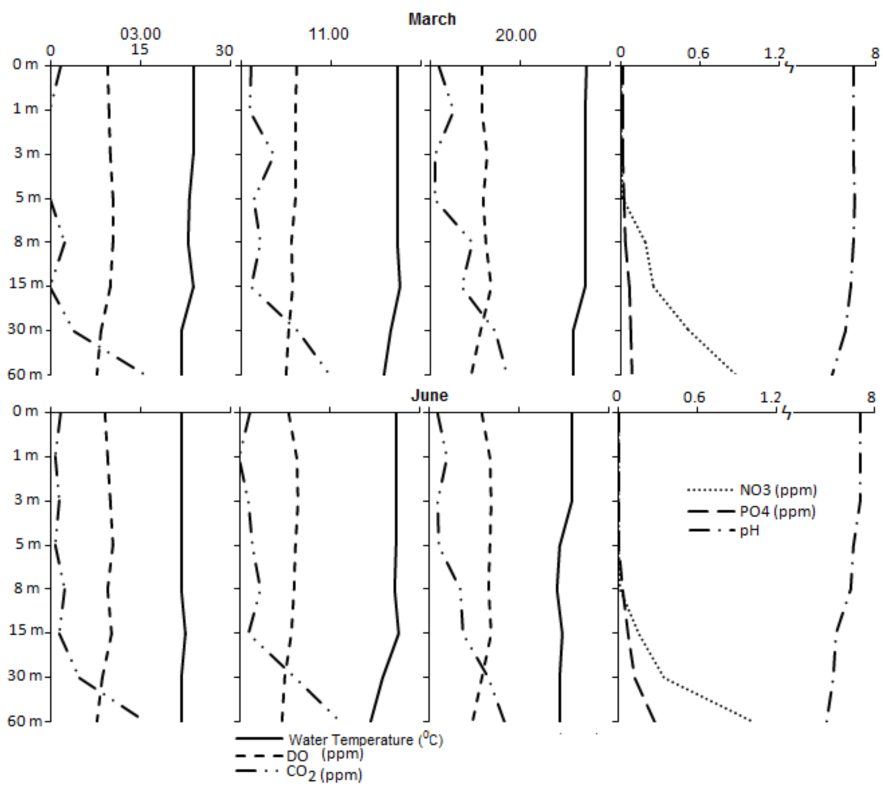

Figure 2. The physical and chemical characteristics of Lake Laut Tawar

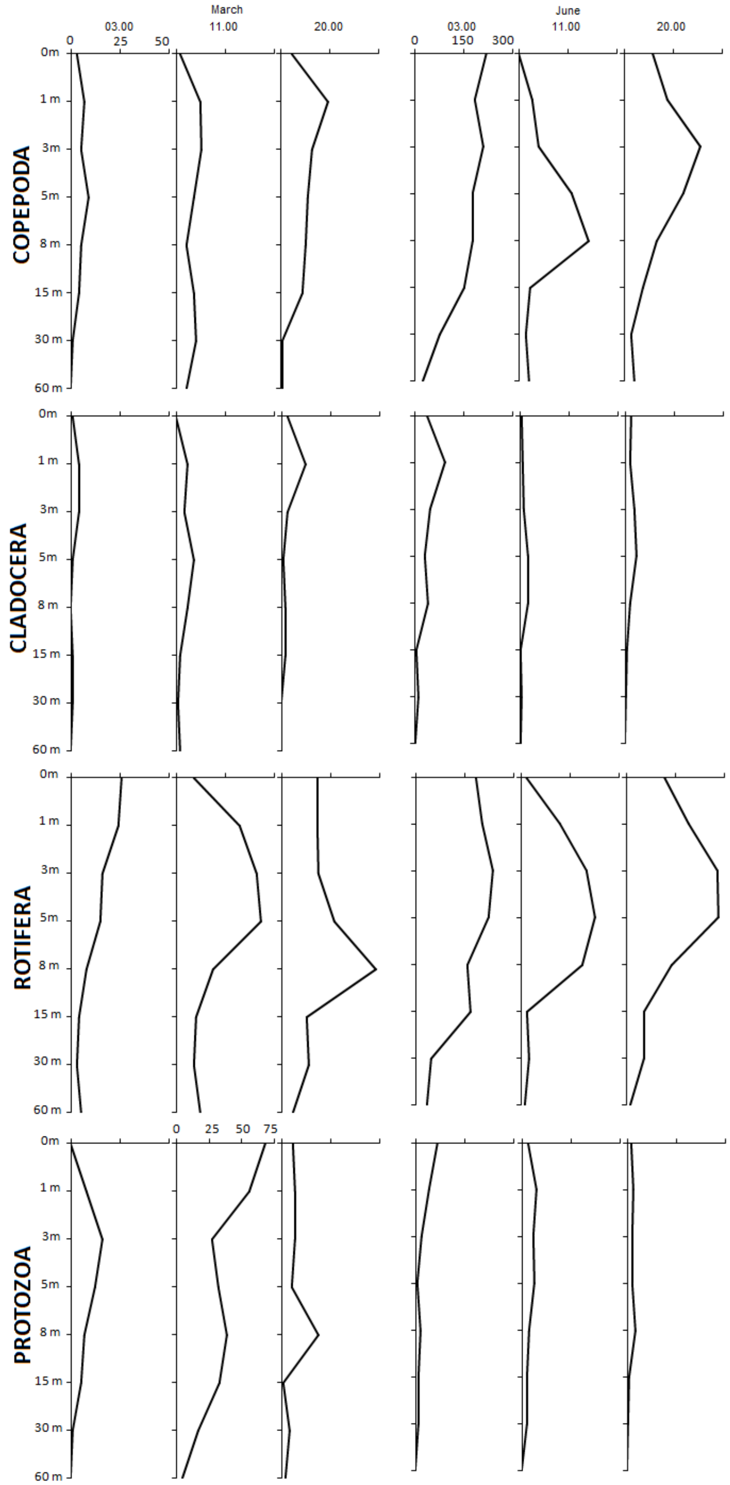

Figure 3. Zooplankton DVM per functional groups

Copepods showed different DVM behavior in the months where samples were taken (**Fig.3**). It was observed that Copepods avoided water surface in March, they did not swim to the surface at dawn. Copepods were abundant in 1 m and 3 m depth. After the sun sets, Copepods were dense in 1 m depth. Cladocerans showed DVM in June 2015. At 30.00, Cladocerans were mostly abundant in 1 to 8 m. At 11.00, they were dense in 5 to 8 m. At 20.00, they were up to the water surface where density was the highest in 3 to 5 m. Cladocerans were mostly more abundant in March than in June.

Lake Laut Tawar environment conditions are unique. It is characterized by high light intensity throughout the year, low air temperature, high rainfall, and strong winds. Lake is surrounded by almost barren pine forest. The rocks are granite, which are poor nutrient but contributing high sediments in the rainy season. Many floating cages culture are found at the lake side. These floating cages supplied nutrient to the lake thus decreasing water transparency. Lake Laut Tawar Secchi's depth were 5 m in March, and 5.5 m in June. Water temperature profile in Lake Laut Tawar showed stratification in both months. Epilimnion was between 0-5 m depths. Metalimnion was in 5-8 m where temperature shifted from 24°C to 23°C. The hypolimnion was less than 15 m **(Fig. 2**). Lake Laut Tawar is a huge lake that surrounded by mountains. Strong waves always occur after 13.00. Takengon area was in a wet month in March with 113.11 mm rainfall whereas in June the rainfall was 66.71 mm.

Predators give huge effect on DVM patterns in Lake Laut Tawar. Zooplankton were avoiding predators by hiding below Secchi depth. They did not swim to the surface at night or at dawn. This behavior is the vice versa of DVM real pattern where zooplankton are mostly abundant in the surface area. Diel vertical migration in March could probably be best explained by Game Theory. Game Theory mentioned that predator and prey can change their behavior to adjust one another. Predators have the ability to optimize their grazing by following prey behavior (Sainmont et al., 2014). Planktivorous fish also perform DVM by swimming to epilimnion after the sun sets. This would decrease zooplankton density, and zooplankton did not perform DVM in March.

Zooplankton showed strong DVM in June. They hide below Secchi depth at noon and go upward to epilimnion at night. Zooplankton were mostly abundant in 0-3 m and decrease rapidly after 5 m at 03.00. The absence of predators causes widening of DVM amplitude. Zooplankton Migrate vertically from 0-15 m in June which resulted in high zooplankton densities compared to March. This could also happen in the absence of predators.

Copepods densities were very low in March. This could be because Copepods are fish favorite prey. Copepods contain high protein that provides good nutrition for fish. While in June, when spawning season has ended for 3 months, Copepods were abundant in epilimnion at night. Copepods are a good swimmer (Sainmont et al., 2013), they can swim to hypolimnion at noon avoiding predators. After the sun sets, Copepods swim to the surface to prey for phytoplankton and small zooplankton.

Cladocerans did not perform DVM in March. They were highly abundant only in 1 m with a peak slightly at noon where they were abundant in 5 m. They are also favored by the fishes, their abundance decreased at dawn. Cladocerans showed DVM in June. They were abundant in 1-8 m at 03.00. At 11.00 they were abundant in 5-8 m. After the sun sets, they were abundant in 3-5 m. Cladocerans abundance were higher in June than in March. These were probably because of planktivorous fish grazing or the water quality was better in June. Cladocerans and Copepods behavior performed differently. Cladocerans abundance were higher than the Copepods. Cladocerans prefer water with low turbulence. Lake Laut Tawar has waves at noon, this could be the reason Cladocerans avoided surface area. Also, rainfall is higher in March, causing high turbulence which resulted in a low abundance of Cladocerans.

Rotifers have different DVM pattern compared to Copepods and Cladocerans. Rotifers are normally doing reverse DVM to avoid bigger zooplankton like Copepods and Cladocerans. While in March, Rotifers performed normal DVM. This was because Copepods and Cladocerans abundant were low. Bigger Copepods graze on Rotifers, this is why Rotifers abundance were lower in depth where Copepods were dense. Rotifers in June were highly abundant. They showed strong normal DVM. At 03.00, they were mostly dense in the surface area. Rotifers are competing with Cladocerans in grazing phytoplankton Cladocerans are very good filter feeders (Cooke et al., 2008).. Rotifers cannot compete with Cladocerans when they were abundant. Phytoplankton are mostly abundant above water transparency, this is why Rotifers were dense in the epilimnion. Rotifers were found at 60 m in Lake Laut Tawar. This might happen because the dissolved oxygen was sufficient for respiration.

Protozoan did not show DVM in Lake Laut Tawar. Protozoans are very bad swimmers. They are mostly moved by the mercy of the current. They are also very hard to identify under the light microscope (Ahmad & Sharma, 2009).

CONCLUSIONS

Zooplankton performs temporal DVM in Lake Laut Tawar in March and June. They did not show DVM in March, however a very strong DVM was observed in June. Zooplankton DVM was driven mostly by lights penetration and predator in Lake Laut Tawar. Diel Vertical Migration also driven by the competition over species and functional groups.

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WATER QUALITY CHARACTERISTICS IN THE PLANKTOTHRIX DOMINANT YEARS IN SHALLOW LAKE KASUMIGAURA

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ABSTRACT

Cyanobacterial blooms in lakes cause serious problems in the world. In Lake Kasumigaura, a eutrophic lake located in Japan, the bloom of Planktothrix (one of the filamentous cyanobacterium) occurred during winter and spring from 2007 to 2011. In this study, we analyzed characteristics of lake water quality during the Planktothrix dominant years (2007-2010) by comparing with that in the succeeding years without Planktothrix blooms (2012-2015) at the center of Lake Kasumigaura. Average phytoplankton biovolume in the dominant years was larger than that in the succeeding years. This would attribute to high chemical oxygen demand (COD_{Mn}; 9.7 mg/L in annual average) in the dominant years as compared to the succeeding years (7.6 mg/L). Total phosphorus (TP) concentration peaked in spring and summer in the dominant years but only in summer in the succeeding years, whereas the seasonal variation in total nitrogen (TN) concentration between two periods was relatively small. Annual average of Secchi disk depth increased before the dominant years by the decrease of fixed suspended solids (FSS) concentration which is mainly composed of inorganic materials. The change of irradiance condition seems to affect in occurrence of the Planktothrix blooms.

Keywords: filamentous cyanobacteria, Lake Kasumigaura, Planktothrix suspensa, shallow

INTRODUCTION

Occurrence of cyanobacterial blooms have been recognized in many lakes and reservoirs around the world and caused serious problems such as toxic production. The most common blooms in eutrophic lakes, mainly formed by Microcystis, Anabaena, and Aphanizomenon, occur in the epilimnion. Most of cyanobacteria have gas vesicles enabling cells to regulate their buoyancy to maintain vertical position in response to physical and chemical factors (Reynolds, 2006). On the other hand, the bloom of Planktothrix, one of a filamentous cyanobacterium, appears in the dysphotic zone and does not accumulate in the epilimnion. In the lake of European countries, Planktothrix bloom is typically encountered (e.g. Lake Steinsfjorden in Norway, Halstvedt et al., 2007). The bloom was also known in North American lakes (Konopka et al., 1993). Some Planktothrix species produce toxic and musty odor compounds, causing serious problems in lakes as a drinking water source. The Planktothrix bloom has occurred in many lakes in the world. In Lake Kasumigaura, located in the eastern part of Japan, the Planktothrix blooms have occurred during 1992 to 1999 and 2007 to 2010 after heavy bloom of Microcystis (Takamura & Nakagawa, 2012). After the latter bloom, Microcystis blooms occurred again. In this study, we focus on the lake water quality during the Planktothrix bloom period (2007-2010) to understand the reason and results of occurrence of Planktothrix bloom. We analyzed the characteristics of the lake water quality during the bloom period by comparing with that in the succeeding period without Planktothrix blooms (2012-2015).

METHODS

Study area

Lake Kasumigaura (**Fig. 1**), located in Ibaraki Prefecture in the eastern part of Japan, about 50 km northeast of Tokyo, is the second largest lake in Japan (219.9 km^2 as the total lake area). This lake is relatively shallow (4 m as the average depth), polymictic and eutrophic lake. The watershed area is 2,157 km^2. 975,000 people live in the watershed. The dominant landscapes in the lake watershed are paddy fields (~31,400 ha), ploughed fields (~31,400 ha), forests and others (~83,000 ha) in 2010. The lake water is used as drinking, industrial, and agricultural water. Drinking water is supplied to about one million people. And the irrigation area is about 35,000 ha.

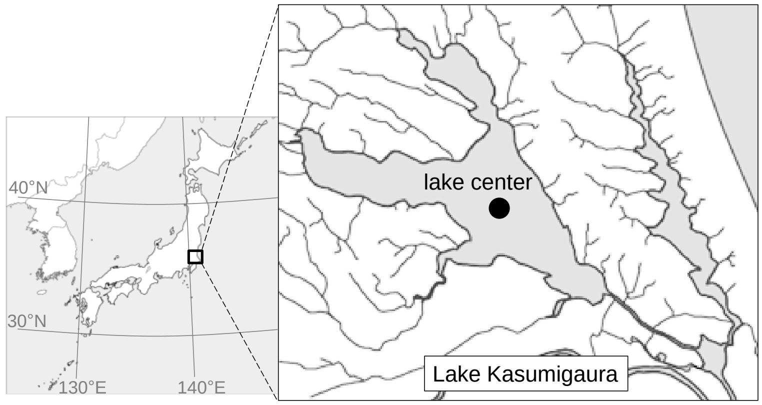

Figure 1. Location of Lake Kasumigaura and the sampling point.

Sampling and chemical analysis

The survey was carried out from January 2007 to December 2015. Lake water samples were collected from the surface layer (0.5 m below the water surface) at the lake center (shown in Fig. 1) by a peristaltic pump. Samples for phytoplankton biovolume measurement were fixed by glutaraldehyde fixative immediately after the collecting.

Chemical oxgen demand (COD_{Mn}) was analyzed according to the standard method (Japanese Industrial Standards Committee, 2016). Concentrations of total nitrogen (TN) and total phosphorus (TP) were measured by the continuous flow analysis (CFA) method using an autoanalyzer (BRAN+LUEBBE AutoAnalyzer3). The data of Secchi disk depth (SD) and suspended solids (SS) concentration taken by Freshwater Branch Office, Fishery Research Institute, Ibaraki Prefecture were used. The SS concentration was separated as volatile SS (VSS) which is mainly composed of organic materials and fixed SS (FSS) which is mainly composed of inorganic materials by heating to 450 °C for 2 hours.

RESULTS AND DISCUSSIONS

Temporal variation of phytoplankton biovolumes

Figure 2 shows temporal variation of phytoplankton biovolumes at the lake center since 2007. Planktothrix blooms have occurred during 2007 and 2010. We divided the study period into the two periods for analysis of water quality characteristics in Planktothrix dominant period. The Planktothrix dominant period, 2007 to 2010, is defined as “dominant years”. The period after dominant years, 2012 to 2015, is defined as “succeeding years”. In the dominant years, Planktothrix bloom occurred during winter and spring. In the succeeding years, bacillariophyceae had dominated in the lake center area, and heavy Microcystis blooms also occurred in bay areas. According to Takamura and Nakagawa (2012), bacillariophyceae (e.g. Aulacoseira, Nitzschia) had dominated for about 5 years before 2007.

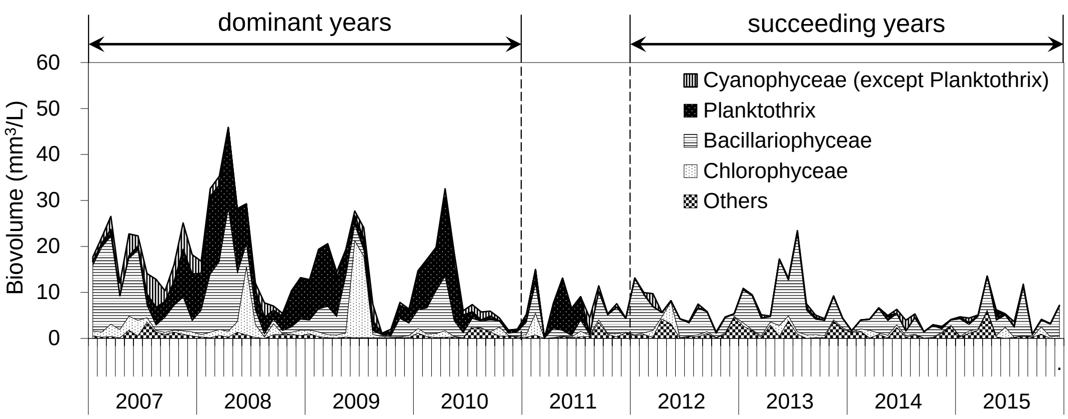

Figure 2. Temporal variation of phytoplankton biovolumes at the lake center.

Changes in COD_{Mn}, TN and TP concentrations

Figure 3 shows monthly mean values of COD_{Mn} and phytoplankton biovolumes in each period. COD_{Mn} was high in the dominant years (annual average of 9.7 mg/L, whereas annual average of 7.6 mg/L in the succeeding years at lake center). Especially, high COD_{Mn} was observed during winter and spring in the dominant years. The phytoplankton biovolumes during winter and spring in the dominant years were also larger than that in the succeeding years due to the occurrence of Planktothrix bloom. Thus, high COD_{Mn} in the dominant years would be largely explained by large biovolumes of phytoplankton, especially Planktothrix.

The seasonal variation in TN concentration between the two periods was relatively small (**Fig. 4(a)**). Average TN concentrations of each period were 0.94 mg/L. On the other hand, the seasonal variation in TP concentration was different between two periods (**Fig. 4(b)**). Average TP concentrations in the dominant and succeeding years were 0.091 and 0.074 mg/L, respectively. Two peaks of TP concentration were observed in dominant years, but only one peak in summer was observed in the succeeding years.

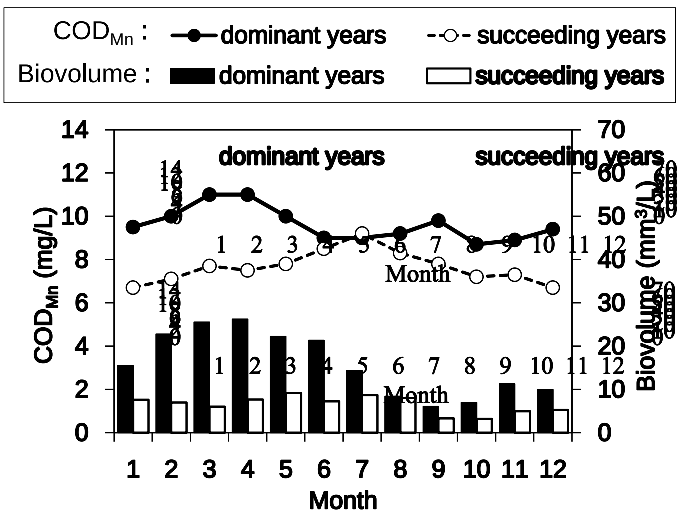

Figure 3. Monthly mean values of COD_{Mn} and phytoplankton biovolumes in the Planktothrix domonant years (2007-2010) and succeeding years (2012-2015).

The peak in summer of both periods would be due to the phosphate release from the bottom sediment (Ishii et al., 2009). However, TP concentration during winter and spring was higher in the dominant years than the succeeding years. Occurrence of Planktothrix bloom would have a relationship with the high TP concentration, although the mechanism of this interaction has not been clearly resolved.

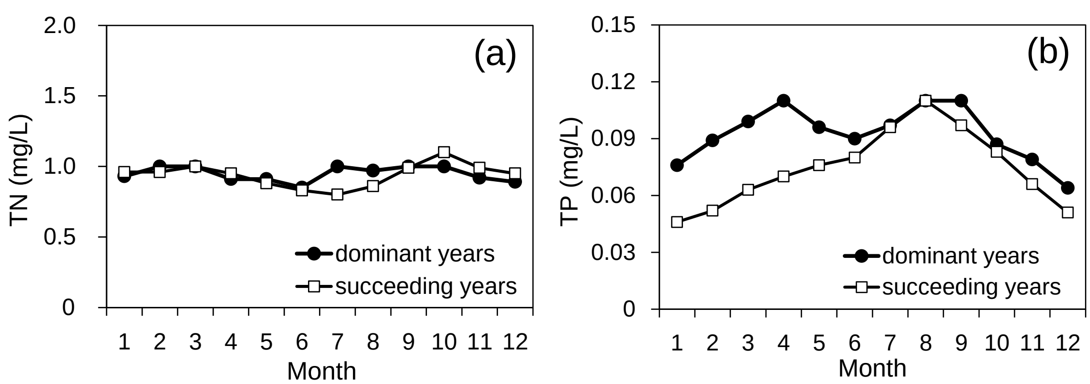

Figure 4. Monthly mean concentrations of (a) TN and (b) TP during the Planktothrix dominant years (2007-2010) and succeeding years (2012-2015).

Changes in SD and SS concentration

Figure 5(a) shows the change in annual average of SD from 2004 to 2013. Since the difference of SD would be related to the reasons and results of the occurrence of Planktothrix bloom, we indicated as annual average before and after the dominant years in Fig. 5(a). The SD increased before and after the dominant years, and the SD was maintained about 0.8 m in the dominant years. **Figure 5(b)** shows the change in annual average concentration of SS. The SS concentration indicated roughly inverse correlation with SD. SS concentration was about 20 mg/L throughout in the dominant years.

Figure 6 shows the concentrations of VSS and FSS. They also changed before and after dominant years. FSS which is mainly composed of inorganic materials decreased before the dominant years. The decrease of inorganic materials seems to relate to occurrence of Planktothrix blooms. From 1998 to about 2005, the lake water had white turbidity in Lake Kasumigaura, called “whiting period” (Naya & Kitamura, 2006,

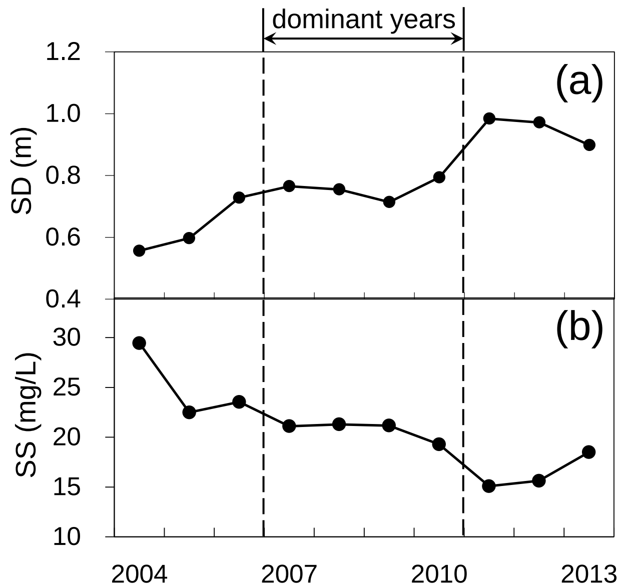

Figure 5. Changes in annual average of (a) SD, (b) SS.

Utagawa & Takamura, 2007). According to Takamura and Nakagawa (2012), bacillariophyceae had dominated in this period. Nakamura et al. (2012) demonstrated Planktothrix can be dominant at low light intensity condition, or dysphotic zone, in Lake Kasumigaura. The increase of SD caused by the decrease of FSS concentration before dominant years would expand dysphotic zone, and it would result in Planktothrix bloom. On the other hand, the VSS concentration decreased after the dominant years. This result indicated the decrease of organic materials such as Planktothrix. At this time, Daphnia, one of zooplankton, increased significantly, and Planktothrix may be taken by Daphnia.

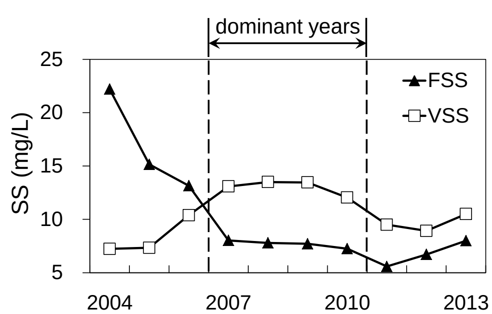

Figure 6. Changes in annual average concentrations of FSS and VSS.

CONCLUSIONS

We analyzed characteristics of water quality in Lake Kasumigaura during the Planktothrix dominant years (2007-2010) by comparing with that in the succeeding years (2012-2015). Average phytoplankton biovolume in the dominant years was larger than that in the succeeding years. This would attribute to high COD_{Mn} in the dominant years as compared to the succeeding years. TP concentration peaked in spring and summer in the dominant years but only in summer in the succeeding years, whereas the seasonal variation in TN concentration between two periods was relatively small. Annual average of SD increased before the dominant years by the decrease of FSS which is mainly composed of inorganic materials. The increase of SD caused by the decrease of FSS concentration would expand dysphotic zone, and it would bring the Planktothrix bloom.

ACKNOWLEDGEMENT

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STUDY ON THE NITROGEN LEACHING MECHANISM FROM AGRICULTURAL LANDS

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ABSTRACT

In Lake Kasumigaura basin, agricultural production value is the top class in Japan. As a result, agricultural non-point source loads measures have become a big problem. It is an object to clarify the mechanism of the nitrogen pollution. In the Hokota river basin, there are many cultivation, such as melons and tomatoes and strawberries that use a large amount of nitrogen fertilizer. In addition, livestock is also very large. Therefore, livestock compost is produced in large quantities, large amounts of compost is thought to be fertilizer to agricultural lands. As a result, the total nitrogen concentration of the HOKOTA river has been increased to about 10mgL-1 was observed. This case was similar to the results of measurement of the nitrogen pollution spring water by compost put in the past. Therefore, although nitrogen fertilizer reduction was intended for chemical fertilizers, it was found to cause nitrogen contamination over an extended period of time even organic fertilizers. Moreover, we were core boring the agricultural lands subsoil until 10m, and analysed the nitrogen component. Therefore, it was found that it is necessary to solve the three mechanisms shown below as nitrogen pollution mechanism of agricultural simultaneously. 1) Reduction of "the total input nitrogen" (the total amount of chemical fertilizers and organic fertilizers), 2) Reduction of "the necessity nitrogen leaching" (minimum required soil residual nitrogen content for the crop harvest), 3) Countermeasure of "the accumulated nitrogen" (inorganic nitrogen content which is present in less than or equal to about 1m subsoil).

Keywords: accumulated nitrogen, necessity nitrogen leaching, nitrogen pollution, non-point source load, total input nitrogen

INTRODUCTION

Lake Kasumigaura is located 70 km northeast of Tokyo and the second largest lake in Japan (**Figure 1. and Figure 2.**). The lake has a surface area of 219.9 km^2, a basin area of 2,157 km^2. Water from the lake is used for urban consumption, industry, agriculture and recreation, and is an important water resource for the Tokyo area. However, since the 1970's, eutrophication of Lake Kasumigaura (ILEC 2017) has become a serious problem.

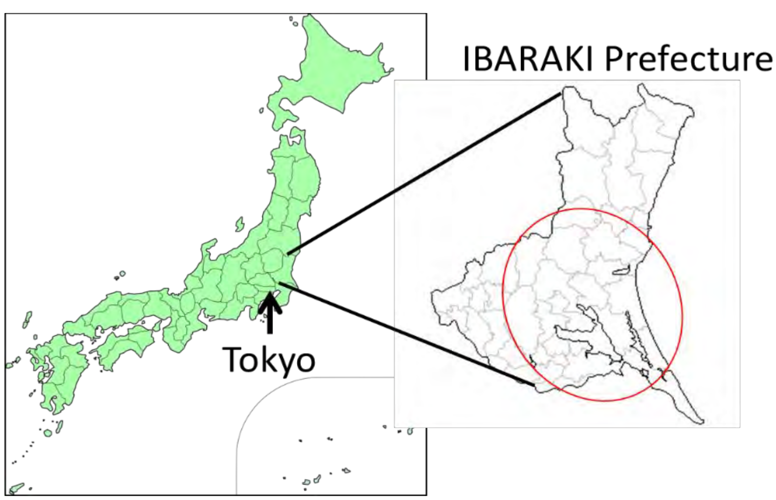

Figure 1. The map of Ibaraki prefecture location.

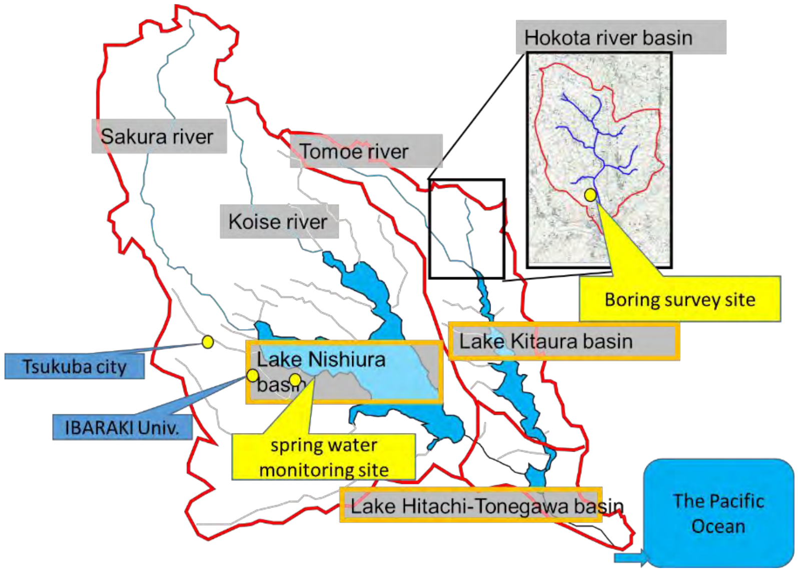

Figure 2. The map of Lake Kasumigaura and Hokota river basin

Recently, water quality of the lake is improving. Of the three basins that feed the lake, the water quality from the Kitaura basin has not improved, with high nitrogen loads continuing. **Figure 3.** shows change of Total Nitrogen (TN) concentration at 4 main rivers (Sakura, Koise, Tomoe and Hokota River) in Lake Kasumigaura basin from 1972 to 2015 (Ibaraki Pref. 2016). Change of TN concentration in the Hokota river is increasing extremely. In this river basin of agricultural production value is the top class in Japan. And, pig farming is thriving and a large amount of compost (organic nitrogen fertilizer: compost) is generated. And it seems that over using organic nitrogen fertilizer put into agricultural land. From 1994 to 1997 we have observed similar phenomena. Our investigated area is illustrated in **Figure 4.** We had observed a similar phenomenon of nitrogen concentration variation. From **Figure 5.** (Kuroda 2013) a peak of nitrogen concentration appeared 3 years after organic nitrogen fertilizer input. "Livestock manure Control Act" came into force on November 1, 2004 three years before the nitrogen concentration peak of the Hokota River. It is an object to clarify the mechanism of the nitrogen pollution.

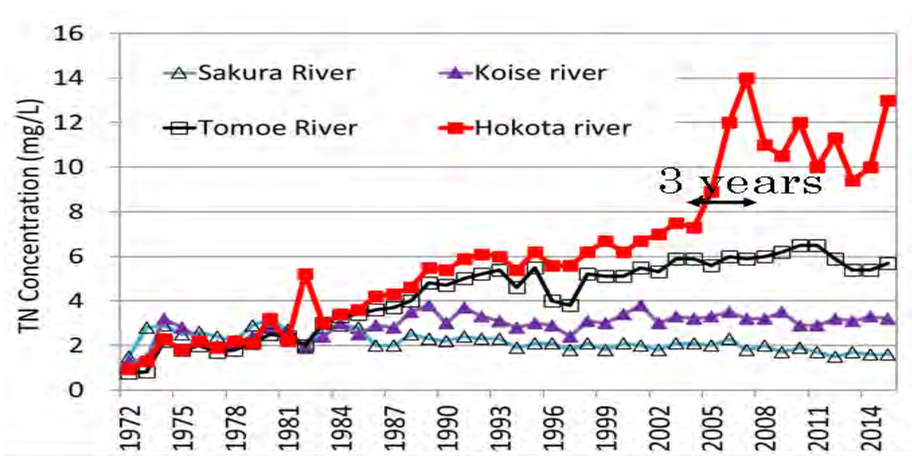

Figure 3. Temporal change in TN concentration of four major rivers (Sakura, Koise, Tomoe and Hokota River) in Lake Kasumigaura basin.

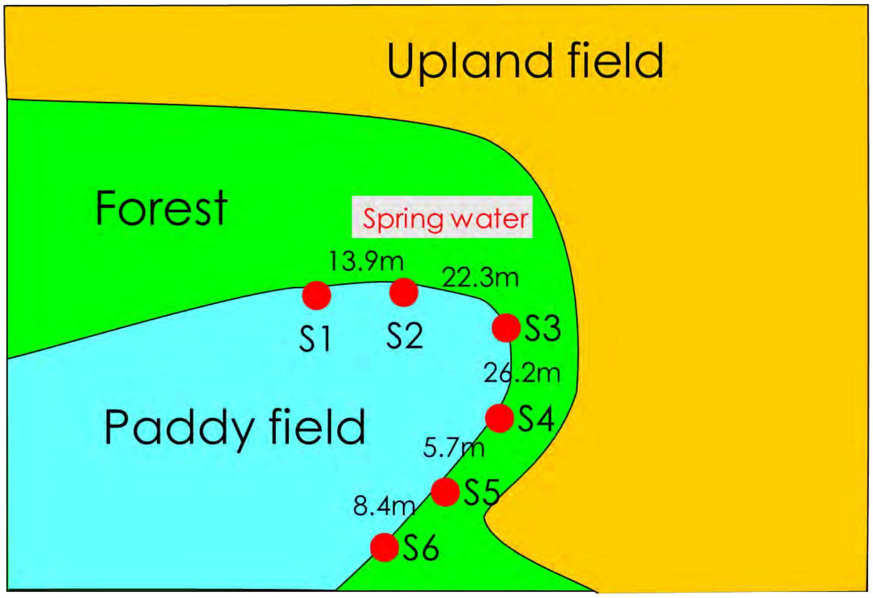

Figure 4. Location of spring waters for NO_3-N conc. monitoring

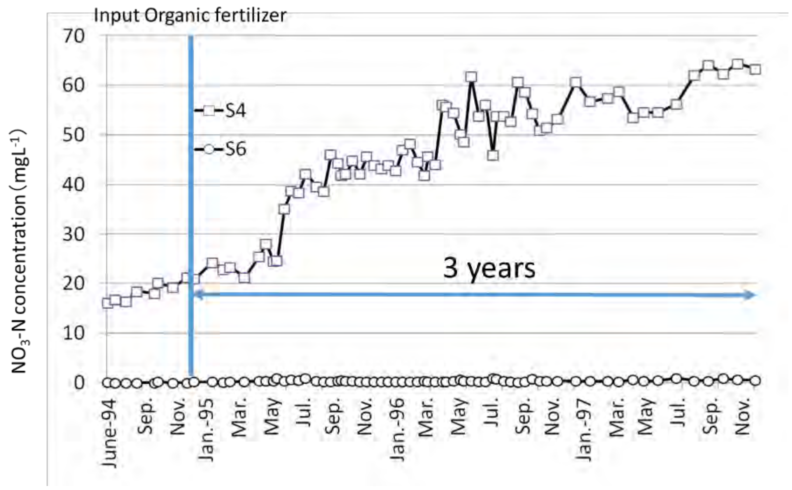

Figure 5. Change of NO_3-N concentration in spring waters

METHODS

We were core boring different types subsoils (undisturbed soil) until 10m, and analyzed the nitrogen component. On top of this upland fields to about 30 years ago, a swimming pool was built. This pool has been dismantled in 2011. Therefore, this period, rain, did not infiltrated downward. Three years later in 2014, undisturbed soil core samples were collected by a boring to a depth of 10m. And we brought the sample to the laboratory. The sample was divided into the following 8 parts based on soil texture: 0 - 115 cm, 115 - 290 cm, 290 - 325 cm, 325 - 536 cm, 536 - 640 cm, 640 - 737 cm, 737 - 830 cm, 830 - 1,000 cm.

RESULTS AND DISCUSSIONS

Figure 5. is a result of a lot of horses' compost (organic nitrogen fertilizer) put into agricultural land in December 1995, the nitrate nitrogen concentration increased after six months, the nitrogen concentration shows a state in which peaked after 3 years. **Figure 3.** shows that a peak TN concentration in 2007. Livestock manure Control Act has been enacted in 2004. In Japan. In order to escape the penalties of this law we think that livestock farmer processed a large amount of organic nitrogen fertilizer excretion to

agricultural land before enforcement. Results of the core sample analysis (**Figure 6.**), the nitrogen was found to be lowered by 1 m year^{-1}. This was the same as the rain of the penetration rate. From these results, nitrogen removal has been found can not be expected in the upland subsoil. From the results of **Figure 3.** and **Figure 5**, the use of excessive organic fertilizer has been found to cause serious nitrogen pollution of groundwater. Organic farming, but are considered as environmentally friendly, nitrogen pollution from excess manure is also the same as nitrogen pollution of chemical fertilizer.

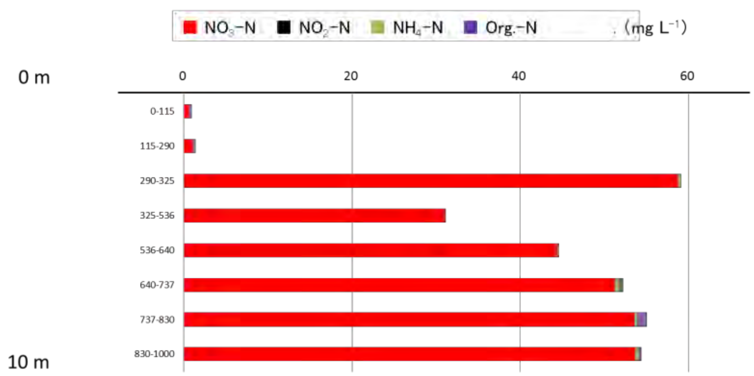

Figure 6. Vertical distribution of each nitrogen conc. in soil pore

In order to reduce the nitrogen pollution that agriculture cause is considered in three ways. 1) We need to recognize that nitrogen pollution mechanism of organic fertilizer and chemical fertilizer is the same. Reduction of chemical fertilizer in Japan are believed to environment conservation agriculture. Therefore, the reduction of “the total input nitrogen” is the most effective. In particular, in the livestock there are many areas it is important balance of organic fertilizer and chemical fertilizer. 2) Vegetables and fruit trees, it is necessary that the remaining nitrogen in the soil at the time of harvest. It is necessary amount of fertilizer to minimize excess nitrogen in the soil. As a result, “necessity nitrogen leaching” remain in the soil it is important to tolerate. 3) The cause of the high nitrogen concentration region as the HOKOTA area, due to excessive total input amount of nitrogen. Measures of “accumulated nitrogen” from previous to take two measures of the above is required. Accumulated nitrogen measures in order to improve the HOKOTA river water quality is considered as an important problem.

CONCLUSIONS

It is important to reduce the nitrogen inflow from agricultural watershed in order to prevent the eutrophication of the lake. In particular, agriculture and livestock is one of the causes of nitrogen pollution. The agricultural nitrogen pollution three mechanisms shown below are considered to be important.
1) Reduction of “the total input nitrogen” (the total amount of chemical fertilizers and organic fertilizers),
2) Reduction of “the necessity nitrogen leaching” (minimum required soil residual nitrogen content for the crop harvest),
3) Countermeasure of “the accumulated nitrogen” (inorganic nitrogen content which is present in less than or equal to about 1 m subsoil).

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THE ORIGINAL METHOD OF CLASSIFICATION OF WORLD LAKES BASED ON FORMULAS AND RESULTS OF ITS APPLICATION

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ABSTRACT

In world practice, there are many classifications of lakes, based on the use of 1-2 parameters. The aim of the present study was to develop a new method of classification of lakes and identifying opportunities for its application. During large-scale studies of lakes in different regions of the world original way to classify of lakes the authors was developed. The method allows to classify each lake on the feature set using special formulas. The structure formulas contain geographical, hydrological, hydro-chemical and hydro-biological indicators. Each indicator is denoted by a specific letter. Each feature is indicated by the numeral index. The set of indicators and signs gives a certain formula. With the help of this method and formulas was carriers the typing and classification of lakes for several regions of the world. For Russia, the inventory of lakes in Kazan Republic of Tatarstan was held. The study of 180 lakes showed that the main type of city lakes are small floodplain lakes, with increased salinity, eutrophic trophic status. In the Republic of Mari El (Russia) has an inventory of more than 100 lakes. Here, among the lakes of karst origin meets a wide variety of types. With the use of this method are classified as lowland lakes Abkhazia (Caucasus), some lakes in Italy (Trazimeno) and Turkey (Iznik, Yuzla). During the testing of the method it is proved that it can be used both to refer to the individual lakes (identification of the formula), and for large-scale typing in the regions, with the identification of belonging to one or another type.

Keywords: Lake classification, method of classification, lake, formula of lake.

INTRODUCTION

One of the most complex theoretical problems of limnology should be named a problem of lake classification. Nowadays there is a plenty of limnological classifications in which separate parameters of lakes are put. Among limnological classifications it is possible to allocate genetic (formation, genesis of lakes), physical, chemical, hydrological, biological, etc. as which it is possible to consider classification which has only one parameter. There are plenty enough of lake classification with one parameter. But lake classifications with more than one parameter are extremely rare and are as a matter of fact universal.

The aim of the present study was to develop a new method of classification of lakes (the universal limno-ecological classification (ULEC), allowing to typify lakes on a global scale, using of formula. and identifying opportunities for its application (Mingazova and Galeeva, 2011).

METHODS

Research in the given area have been begun in 1990th by results of ecological studying 600 lakes of the Middle Volga region and other regions by the Laboratory of water ecosystems in Kazan University. During large-scale studies of lakes in different regions of the world original way to classify of lakes the authors was developed (the universal limno-ecological classification - ULEC).

The structure formulas of lakes by ULEC contain 15 geographical, hydrological, hydro-chemical and hydro-biological indicators. Each parameter includes from 4 up to 18 attributes. Each parameter has substantiation, being in the appendix of classification with reference. The type of lake could be generalized by graphical way or is designated by the formula. Having designated parameters in letters and attributes in figures, it is possible to receive the formula describing type of lake. Offering universal classification of lakes considers all basic components of lakes, describes type of lake in the form of the uniform formula and suits for the use on a global scale.

Parameters (**Table 1**): Geographical zone - Z (1-4); Height above sea level - SL (1-5); Genesis of lake holes – G (1-16); Area – A (1-5); Depth – D (1-5); Water balance - W (1-4); Temperature – T (1-5); Mixing type – Mix (1-5); Transparence – Tr (1-5); Hydrogen parameter – Ph (1-3); Mineralization – M (1-6); Ion composition - I (1- 3); Trophic status - TS (1-6); Flora – Fl (1-4); Fauna – Fa (1-4).

Table 1. Structure of Universal limno-ecological classification (ULEC)

Geographical zone -Z (1-4)	Height above sea level - SL (1-5)	Genesis of lake holes - G (1-18)
Z1 Tropical	SL1 Very low	G1 Tectonic
Z2 Subtropical	SL2 Low	G2 Volcanic
Z3 Temperate	SL3 Moderate	G3 Glacial
Z4 Arctic	SL4 High	G4 Flood-plain
	SL5 Very high	G5 Oxbow ....
		G6 Karst
		G7 Thermokarst
		G8 Formed between sand dunes
		G9 Suffozic
		G10 Relictical
		G11 Gravitational
		G12 Formed due to wind processes
		G13 Fluviatic
		G14 Moraine
		G15 Hydrogenic
		G16 Liman
		G17 Meteoritic
		G18 Artificial
Area – A (1-5)	**Depth – D (1-5)**	**Water balance - W (1-4)**
A1 Very large	D1 Very deep	W1 Flowing
A2 Large	D2 Deep	W2 Inflowing
A3 Moderate	D3 Moderate	W3 Drain
A4 Small	D4 Small	W4 Enclosed lake
A5 Very small	D5 Very small	
Temperature – T (1-5)	**Mixing types of water - Mix(1-5)**	**Transparence – Tr (1-5)**
T1 Cold	Mix1 Dimictic	Tr1 Very high
T2 Moderate	Mix2 Meromictic	Tr2 High
T3 Warm	Mix3 Monomictic	Tr3 Moderate
T4 Very warm	Mix4 Amictic	Tr4 Low
T5 Hot (thermal) lakes	Mix5 Polymictic	Tr5 Very low
Mineralization – M (1-6)	**Ion composition - I (1- 3)**	**Hydrogen parameter – Ph (1-5)**
M1 Very low	I1 Hydrocarbonate – HCO_3	Ph1 Neutral
M2 Low	I1(1) Ca	Ph2 Above acidic
M3 Moderate	I1(2) Mg	Ph3 Under alkaline
M4 High	I1(3) Na K	Ph4 Acidic
M5 Very high	I2 Sulfate – SO_4	Ph5 Alkaline
M6 Division on salinity	I2(1) Ca	
	I2(2) Mg	
	I2(3) Na K	
	I3 Chloride - Cl	
	I3(1) Ca	
	I3(2) Mg	
	I3(3) Na K	

Trophic status TS (1-6)	Flora Fl (1-4)	Fauna Fa (1-4)
TS1 Ultraoligotrophic	Fl1 Low number aquatic plant vegetation	Fa1 Fish with rare species
TS2 Oligotrophic	Fl2 Macrophyte lakes with high biodiversity	Fa2 Fish with rich biodiversity
TS3 Mesotrophic	Fl3 Macrophyte lakes with low biodiversity	Fa3 Fish with widespread species
TS4 Eutrophic	Fl4 Planktic lakes	Fa4 Fishless lakes
TS5 Hypertrophic		
TS6 Dystrophic		

Designations and a substantiation of ULEC classification (Mingazova and Galeeva, 2011):
1. GEOGRAPHICAL ZONE – Z (1-4). The Zafar's classification is used for division lakes on geographical zone and height above sea level [6]. Depending on a geographical zone of lake are subdivided on Z1-tropic, Z2 - subtropic, Z3 - temperate and Z4-arctic.
2. HEIGHT ABOVE SEA LEVEL– SL (1-5). Lake classification on height above sea level has been taken from the physical atlas of the world and subdivided on SL1-very low (0-200 m); SL2-low (200-500 m); SL3-moderate (500-1000 m); SL4-high (1000-2000 m); Sl5-very high (above 2000 m)/
3. GENESIS OF LAKE HOLES - G (1-18). The classification of Hutchinson and Muraveiskiy has been used for gradation of lakes on genesis of lake holes [6]. Genesis of lake holes are subdivided on: tectonic - G1, volcanic - G2, glacial - G3, flood-plain -G4, oxbow-G5, karst - G6, thermokarst-G7, formed between sand dunes-G8, suffozic -G9, relictical-G10, gravitational-G11, formed due to wind processes -G12, fluviatic - G13, moraine -G14, hydrogenic-G15, liman -G16, meteoritic-G17, artificial-G18.
4. AREA – A (1-5). Division of lakes on the areas are divided on [5]: A1 - very large- above 1000 km^2; A2 – large - from 101 up to 1000 km^2; A3 – moderate - from 10 up to 100 km^2; A4 – small - from 1 hectare up to 10 km^2. The category - very small A5 (up to 1 hectare) - has been brought in addition from regional classifications.
5. DEPTH (DEPTH)-D (1-5). Division of lakes on depths are divided on (GOST, 1977): D1 - very deep – over 100 m; D2 - deep - from 51 up to 100 m; D3 - moderate - from 11 up to 50 m; D4 - small - from 5 up to 10 m; D5 - very small - up to 5 m. The category D1 - very deep (over 100) - has been brought in addition.
6. WATER BALANCE – W (1-4). Division of lakes on water balance are divided on (GOST, 1977): W1 - flowing-the lake having both a constant drain and inflow within all year; W2 - inflowing-the lake having constant inflow within all year; W3 - drain- the lake having a constant drain within all year, W4 - enclosed lake - the lake having no constant drain or inflow within all year.
7. TEMPERATURE – T (1-5). The temperature mode has been taken from Kitaev's classification [6] where the average integrated temperature of water during the years period (tmod) is used: T1 - cold: tcp <10 °C; T2 - moderate: tmod = 10-15 °C; T3 - warm: tmod = 15-20 °C; T4 - very warm: tmod = 20-30°C. The additional category – T5 - hot (thermal) lakes has been added with: tmod> 30 °C.
8. MIXING TYPES OF WATER- Mix (1-5). The classification of Hutchinson and Kevern's classification [6] have been used for gradation of lakes on mixing water types: Mix4 - amictic - never mixing, usually ice covered year around, in the polar regions; Mix2 - meromictic - lakes that may mix once or more annually, but do not mix completely; Mix5 - polymictic - these lakes have many periods of mixing annually, even approaching continuous mixing and are influenced more by daily temperature changes than seasonal; Mix 3 -monomictic - one period of mixing annually, the cold monomictic lakes are ice covered most of the year and mix during a brief summer, while the warm monomictic lakes are the opposite with a brief ice-free winter period of mixing. Mix1 - dimictic - lakes that usually mix twice annually in the spring and in the fall. This category covers the lakes in the temperate zones of our globe and includes the majority of our lakes.
9. TRANSPARENCE – Tr (1-5). The classification of Kimstach on a transparence (Konstantinov, 1986) has been used: Tr1 - very high – more than 12 m; Tr2 - high-from 6-12м; Tr3 - moderate-from 3-6 m; Tr4 - low – from 1.5 – 3 m; Tr5 - very low – less than 1.5 m/
10. MINERALIZATION–M (1-6). Classification of Alekin and the Venetian system of water salinity classification [3] are put in a basis of division on a mineralization of waters: M1-very low – up to 100 mg/l;

M2-low – 100-200 mg/l; M3-Moderate – 200-500 mg/l; M4-high – 0.5-5 g/l; M5-very high –above 5 g/l; M6-division on salinity.
11. ION COMPOSITION – I (1-3). The gradation of lakes on ionic composition has been taken from classification of Schukarev and Kurlov (1986). Waters of lakes concern to three chemical formations – I1-HCO_3, I2- SO_4 and I3- Cl, each of which is in turn subdivided on 1- Ca, 2- Mg and 3- Na-K – these designations are specified in brackets.
12. HYDROGEN PARAMETER – Ph (1-5). On a hydrogen parameter of lake are subdivided on: Ph1 - neutral (6.5-8.5); Ph2- above acidic (6.4-5); Ph3 - under alkaline (8.6-9.5), Ph4 - acidic (below 5); Ph5 - alkaline (above 9.5).
13. TROPHIC STATUS - TS (1-6). Tinemann and Nauman's classification has been put in a basis [6]: TS2 - oligotrophic, TS4 - eutrophic, TS6 - dystrophic. Nowadays additional categories are in use: TS3 - mesotrophic and TS5 - hypereutrophic lakes. Category TS1 - ultraoligotrophic (from Jadin and Gerd's classification (1961)).
14. FLORA – FL (1-4). Division on flora has been used from ecology-limnological classification (Mingazova, 2001): Fl1 - low number aquatic plant vegetation; Fl2 - macrophyte lake with rich biodiversity; Fl3 - macrophyte lake with low biodiversity; Fl4 - planktic lakes.
15. FAUNA – Fa (1-4). Division on fauna has been used from ecology-limnological classification (Mingazova, 2001): Fa1 - fish lakes with rare species; Fa2 - fish lakes with rich biodiversity; Fa3 - fish lakes with widespread species; Fa4 - fishless lakes (Mingazova and Galeeva, 2011).

RESULTS AND DISCUSSIONS

With the help of this method and formulas was carriers the typing and classification of lakes for several regions of the world. Opportunities of use universal limno–ecological classification (ULEC) are shown to on an example of Middle Volga region lakes, the Russian Federation lakes and lakes of the world from different continents. For Russia, the inventory of lakes in Kazan Republic of Tatarstan was held. The study of 180 lakes showed that the main type of city lakes are small floodplain lakes, with increased salinity, eutrophic trophic status.
For the Middle Volga region, it has shown formulas of widely known lakes of Kazan: Lower Kaban (**Fig. 1**), Big Lebyajie (**Fig. 2)**, Big Glubokoe (**Table 2**).

Table 2. Formulas of Kazan lakes (Russia) by ULEC

Name of lake	Formula	Description of lake
Lower Kaban	Z3 SL2 G5-6 A4 D3 W4 T3 Mix1 Tr5 M4 I2(1) Ph3 TS5 Fl3 Fa3	Geographically temperate with low height above sea level, oxbow-karst, small (56 he), with moderate deep depth (up to 16 m), enclosed, with warm water, dimictic, with very low transparence, with high mineralization, SO^4-Ca, alkaline water, hypertrophic, macrophyte with low biodiversity (20 plant species), fish lake with widespread species.
Big Lebyajie	Z3 SL2 G8 A4 D5 W4 T2 Mix3 Tr5 M2 I1(1) Ph1 TS4 Fl3 Fa3	Geographically temperate with low height above sea level, formed in sand hole, small (13 he), with very low deep depth (2 m), enclosed, moderate on water temperature scale, monomictic, with very low transparence, with low mineralization, HCO_3-Ca, with neutral water, eutrophic, macrophyte with low biodiversity, fish lake with widespread species.
Big Glubokoe	Z3 SL2 G6 A4 D3 W4 T2 Mix1 Tr4 M1 I1(1) Ph1 TS3 Fl3 Fa3	Geographically temperate with low height above sea level, karst, small (11 he), with moderate deep depth (12 m), enclosed, moderate on water temperature scale, dimictic, with low transparence, with very low mineralization, HCO_3-Ca, neutral water, mesotrophic, macrophyte with low biodiversity, fish lake with widespread species (5 fish species).

Figure 1. Lake Lower Kaban (Kazan city, Russia)

Figure 2. Lake Lebyajie (Kazan city, Russia)

In the Republic of Mari El (Russia) has an inventory of more than 100 lakes. Here, among the lakes of karst origin meets a wide variety of types. In the Mari El Republic of the Russian Federation dominated by the type of the lakes with the formula G6 A4 D3 W1 T1 Mix1 S4 M2 – karst lakes, small, with an average depth, flow, cold, dimiktic, low transparency, low mineralization (Mingazova, 2001). To this type belongs karst Lake Gluhoe in the national park "Mari Chodra" in Mari El Republic (**Fig. 3**).

Figure 3. Karst Lake Gluhoe (Mari El Republic, Russia)

With the use of this method are classified as lowland lakes Abkhazia (Caucasus), some lakes in Italy (Trazimeno) and Turkey (Iznik, Yuzla).
During the testing of the method it is proved that it can be used both to refer to the individual lakes (identification of the formula), and for large-scale typing in the regions, with the identification of belonging to one or another type.
As an example of ULEC use for Russia its shown formulas of lakes Baikal and Ladoga (**Fig.4, 5, Table 3**).

Figure 4. One of the biggest freshwater lakes in the world - Lake Baikal (Russia)

Table 3. Formulas of Russian lakes (Russia) by ULEC

Name of lake	Formula	Description of lake
Lake Baikal	Z3 SL3 G1 A1 D1 W1 T2 Mix1 Tr1 M2 I1(1) Ph1 TS1 Fl2 Fa1	Geographically temperate with moderate height above sea level, tectonic, very large (31500 km^2), with very deep depth (1637 m), flowing, moderate on temperature scale, dimictic, with very high transparence, low mineralization, HCO_3-Ca, with neutral water, ultraoligotrophic, macrophyte with rich biodiversity (133 plant species), fish lake with rare species (52 fish species) .
Lake Ladoga	Z3 SL3 G1 A1 D1 W1 T1 Mix1 Tr3 M2 I1(1) Ph1 TS3 Fl2 Fa1	Geographically temperate with moderate height above sea level, tectonic, very large (9720 km^2), with very deep depth (230 m), flowing, cold water, dimictic, with moderate transparence, low mineralization, HCO_3-Ca, with neutral water, mesotrophic, macrophyte with rich biodiversity (107 plant species), fish lake with rare species (60 fish species).

Figure 5. Lake Ladoga (Russia)

To show an opportunity of ULEC use for lakes of the world, its shown formulas of lakes from different continents (**Table 4**): for Europe – Lake Geneva (Switzerland); for Asia – Lake Issyk Kul (Kirghizia); for Northern America – Lake Michigan (USA - Canada); for South America – Lake Titicaca (Peru).

Table 4. Formulas of lakes in different areas of the world by ULEC

Name of lake	Formula	Description of lake
Europe		
Lake Geneva (Switzerland)	Z3 SL3 G1 A2 D1 W1 T3 Mix1 Tr2 M2 I1(1) Ph1 TS2 Fl2 Fa1	Geographically temperate with moderate height above sea level, tectonic, large (582 km^2), with very deep depth (310 m), flowing, warm water, dimictic, with high transparence, low mineralization, HCO_3-Ca, with neutral water, oligotrophic, macrophyte with rich biodiversity, fish lake with rare species.
Asia		
Lake Biwa (Japan)	Z2 SL1 G1 A2 D1 W3 T2 Mix1 Tr2 M2 I1(1) Ph1 TS3 Fl2 Fa1.	Geographically temperate with a very low altitude, tectonic, large (670 km^2), with very deep depth (103 m), flowing, moderate on temperature scale, dimictic, with very high transparence, low mineralization, HCO_3-Ca, with neutral water, ultraoligotrophic, macrophyte with rich biodiversity, fish lake with rare species.
Lake Issyk Kul (Kirghizia)	Z3 SL4 G1 A1 D1 W2 T4 Mix1 Tr1 M5 I 2(2) Ph1 TS2 Fl2 Fa1	Geographically temperate with high height above sea level, tectonic, very large (6236 km^2), with very deep depth (688 m), inflowing, very warm, dimictic, with very high transparence, very high mineralization, SO_4-Mg, with neutral water, oligotrophic, macrophyte with rich biodiversity, fish lake with rare species (20 fish species).
North America		
Lake Micigan (USA-Canada)	Z3 SL3 G1 A1 D1 W1 T2 Mix1 Tr3 M2 I1(1) Ph1 TS3 Fl? Fa?	Geographically temperate with moderate height above sea level, tectonic, large (57750 km^2), with very deep depth (281 m), flowing, moderate on temperature scale, dimictic, with moderate transparence, low mineralization, HCO3-Ca, with neutral water, mesotrophic.
South America		
Lake Titicaca (Peru)	Z2 SL5 G1 A1 D1 W1 T1 Mix5 Tr2 M4 I? Ph? TS? Fl2 Fa1	Geographically subtropic with very high height above sea level, tectonic, very large (8290 km^2), with very deep depth (304 m), flowing, cold water, amictic, with high transparence, very high mineralization, macrophyte with rich biodiversity, fish lake with rare species.

Thus, its shown the possibility of application universal limno-ecological classification (ULEC) on a global scale. This approach is used for the first time and can be applied to large-scale typification of lakes in different areas of the world.

CONCLUSIONS

The method allows to classify each lake on the feature set using special formulas. The structure formulas contain geographical, hydrological, hydro-chemical and hydro-biological indicators. Each feature is indicated by the numeral index. The set of indicators and signs gives a certain formula. With the help of this method and formulas was carriers the typing and classification of lakes for several regions of the world.
ULEC could be used for scale zoning, for the comparative analysis of measurements occurring to lakes, for monitoring, for statistical and mathematical data processing of monitoring, etc.

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THE RELATIONSHIP OF RIPARIAN VEGETATION COMPOSITION WITH RAINBOWFISH ABUNDANCE IN LAKE SENTANI, PAPUA, INDONESIA

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ABSTRACT
The relationship between riparian vegetation and rainbowfish in Lake Sentani was studied. This research was conducted from September until October 2014 using survey method in 3 stations. The survey recorded a total of 27 species within 17 families. Imperata cylindrica (L.) Beauv*. (Cogongrass) was found as the most abundant species during the survey. Jaifuri was the station with the most species (20 species) and the most abundant of riparian vegetations (304 individuals). The rainbow fish found in the stations were barred rainbow fish (*Chilaterinna fasciata*) (45 individuals) and red rainbow fish (*Glossolepsis incisus*) (837 individuals). Dondai was the station with the most abundant of rainbow fish (595 individuals). Both of barred rainbow fish and red rainbow fish found in Dondai station. The result of this study proved that riparian vegetation has strong relationship with the presence of rainbowfish in Lake Sentani.*
Keywords: riparian vegetation, rainbowfish, Lake Sentani

INTRODUCTION

Lake Sentani is one of the priority lake in Indonesia (Kementrian Lingkungan Hidup, 2011). Lake Sentani is the largest lowland lake of Papua and located in northern Papua, Papua Province, Indonesia. The lake is a part of Cycloops Mountain Nature Reserve. It is located in four districts covering Sentani, Ebungfau, Waibu, and East Sentani. Geography around the lake is hillside in the south and the Cycloops Mountain in the north, which separate the lake from Pacific Ocean (Andersen, 2006). Riparian zone of Lake Sentani generally has a diverse topography. Some of them have steep topography, due to the Lake Sentani is surrounded by Cycloops Mountains. The lake is situated 70–90 meters above sea level covered area 9,360 Ha and the depth about 51.8 m (Ohee, 2013). This lake is also used as one of the water source for Jayapura regency. Water source of Lake Sentani comes from 14 large and small rivers with total catchment area of approximately 600 km^2. The inlets of Lake Sentani include Belo River, Flafouw River and Harapan River, while the outlet is only Djaifuri River (Ohee, 2003 and Kementrian Lingkungan Hidup, 2011). There are 61,477 people live in Lake Sentani, 45% of them live in the water area and 55% live in the land area surround it (Kabey, 2014). They live from the fisheries and agriculture activities which conducted around the lake (Kementrian Lingkungan Hidup, 2011). The local communities, who live in small islands within the lake, live in traditional stilt houses, they use Lake Sentani for daily needs such as fishing, washing, bathing, and cooking. The communities still use traditional means to fulfill their daily needs. Other activities, such as tourism and aquaculture, are mostly conducted by non-locals from other parts of Indonesia. They live further out from the lake (Ohee, 2013). The lake plays a great role for supporting the humans and organisms living in and around it. It has also been identified as an important ecosystem for species conservation.

Lake Sentani has endemic and indigenous fish species. The endemic fish are Sentani Rainbowfish (*Chilaterinna sentaniensis*) and Red Rainbowfish (*Glossolepsis incisus*) (Ohee, 2013 and Polhemus et al., 2004). The distribution of *Ch. sentaniensis* and *G. incisus* are known to be limited to Lake Sentani and its tributaries, meanwhile the *Chilatherina fasciata* is an indigenous species.

The Rainbowfish is a lake-dwelling species reside in the edge of lake, shoaling amongst the submerged grass, water plants, dead wood, and leaves. Some species prefer creeks, streams, or rivers with fast-flowing and clear water, living on a boulder or gravel substrate, while some occupy a sand and silt substrate. Other species prefer estuaries, especially in the mouth of a river that flows into the sea. Along the water body, the riparian vegetation varies, with many kinds of trees, shrubs, and grasses, shading the habitats of the fish, and serving as a food source for the fish (Ohee, 2013). In Lake Sentani, rainbowfish is found along the edge of the lake, around riparian and aquatic plant.

Riparian forests are situated in the transition zones from terrestrial to aquatic ecosystems, including mountain torrents, rivers, lakes, or swamps (Sakio, 2008). Riparian vegetation has a very important role in the landscape as a connecting zone between terrestrial and aquatic ecosystems (Naiman and Decamps,

1997). It is also as a source of organic matter inputs, known as allochthonous (Nasution et al., 2011). It brings plant and animal debris such as insects to the water body and provide food for several endemic fish species and benthic organisms in the lake. In addition, riparian forests provide aesthetic and recreational values (Burton, et al., 2005).
Riparian zones are semi-terrestrial transition area which is regularly affected by fresh waters which generally extends from the edge of a body of water towards the edges of the plateau (Naiman *et al*., 2005). Riparian vegetation is generally composed of forest trees, but also includes other types of vegetation such as shrubs, herbs, and grasses. Vegetation is one of the crucial components in the zone riparian ecosystems have a significant role as a provider of food and habitat for animals, maintain biodiversity and maintaining ecological balance (Gong et al., 2015). In addition, riparian vegetation serves as a drag force flows into the river and absorbing particles brought in it from the mainland. The loss of riparian vegetation can cause increased input of sediment into streams and rivers change microhabitat (Heartsill-Scalley & Aide 2003).
The aim of this research was to survey the composition of riparian vegetation and to determine its relation with the abundance of rainbowfish in Lake Sentani. The result of this study is expected to provide latest riparian vegetation data in Lake Sentani and it is used for aquatic resources management plan.

METHOD

A study of the relationship of riparian vegetation composition with rainbowfish abundance was conducted in Lake Sentani (140°23'-140°38'E and 02° 35'-02°41'S) on September until October 2014. The location of Lake Sentani can be seen in the **Fig. 1**. The study used simple stratified random sampling, the study sites were categorized (stratified) into three zones: Deyau (2°37'17,5"S, 140°30'43"E) as inlet from Center Sentani zone, Dondai (2°35'43,8"S, 140°24'81,1"E) for West Sentani zone and Jaifuri (2°40'42,7"S, 140°35'02,1"E) as outlet from East Sentani zone. Three locations in each zone were then selected based on their position and location.

Figure 1. Lake Sentani, study location map. (Source: Google with modification)

Riparian vegetation data was collected from a line transect set up in 3 stations (Dondai, Deyau, and Jaifuri) using purposive random sampling technique. In each station, line transects installed along 100 meters from the shoreline. The vegetation that located on either side of the transect line being recorded and photographed. In each station installed one line transects. Thus, there were 3 line transects observed in 3

stations. Vegetations were sampled using 10 x 10 m transects which were placed parallel to the coast for each of the three replications. The samples were preserved in 70% alcohol and dried in an oven at 70°C. A gillnet with the dimension of 200 m in length, 2 m in height, and 4 types of mesh size (0.75, 1, 1.5 and 2 inch) were used to collect fish along the shoreline at very shallow depths of each station. The gillnet was equipped with floats on its top and weights at the bottom. It operated in a manner laid perpendicular to the shoreline. The gillnet was tied in a surround a tree trunk on one end and a person holding the other end then it positioned under water surface, until there are some fish in the net. Fish samples were preserved in 4% formalin and then soaked in 70% alcohol. This method was used in 3 stations.
After gillnet placed in the water, observation plot for riparian vegetation sampling was installed. In each line transect, the vegetation found were recorded and identified based on Womersley (1978). If there are any vegetation that can not be identified in the field, then the whole plant or some part of the plant was taken and made into herbarium to be identified in Research Center for Limnology or Research Center for Biology. Fish samples were preserved in 4% formalin and then soaked in 70% alcohol. To determine the type of fish, sample were identified to the level of species using Weber and Beaufort (1913; 1916; 1922). Bivariate correlation was used to determine the relationship between riparian vegetation and Rainbowfish in Lake Sentani. Interpretation of the correlation coefficient was done based on Prayitno (2013) if the coefficient close to 1 or -1, thus it has stronger relationship, but if it close to 0 then the relationship is weak. To determine the direction of the relationship, it can be seen from the coefficient sign, if positive sign means it has positive relationship, and vice versa.

The formula of Pearson Correlation Coeficient:

$$r_{xy}=\frac{n\sum xy-(\sum x)(\sum y)}{\sqrt{[n\sum_x 2-(\sum x)^2][n\sum_y 2-(\sum y)^2]}}$$

x = first variable
y = second variable
n = data amount

RESULTS AND DISCUSSIONS

Composition of Riparian Vegetation

The results found the total number of riparian vegetation in Lake Sentani is 27 species within 17 family. There were 5 species recorded at Dondai station, 13 species at Deyau station, and 20 species at Jaifuri station (**Table 1**). *Pandanus tectorius* Parkinson and *Cyperus* sp. recorded in all stations. Both of them are wild vegetation and can spread rapidly. There were four species recorded from two Deyau and Jaifuri. While two species were recorded in Dondai and Jaifuri, and only *Panicum repens* L. was found in Dondai and Deyau station (**Table 2**).

Table 1. Family, Species and Amount of Riparian Vegetation In Lake Sentani

No.	Family	No.	Species	Amount
1	Anacardiaceae	1	*Anacardium occidentale* L.	1
		2	*Mangifera indica* L.	4
2	Araceae	3	*Colocasia esculenta* (L.) Schott.	3
3	Arecaceae	4	*Arenga pinnata* (Wurmb) Merr.	16
		5	*Cocos nucifera* L.	7
		6	*Metroxylon sagu* Rottb.	61
4	Caricaceae	7	*Carica papaya* L.	3
5	Cyperaceae	8	*Cyperus sp*.	70
6	Euphorbiaceae	9	*Manihot utilissima* Pohl.	25
7	Fabaceae	10	*Clitorea ternatea* L.	12
		11	*Erithrina sp*.	1
		12	*Mimosa pudica* L.	40
8	Lamiaceae	13	*Hyptis rhomboidea* Mart & Gal.	10
		14	*Tectona grandis* Linn. f.	1
9	Malvaceae	15	*Hibiscus tiliaceus* L.	3
10	Moraceae	16	*Artocarpus heterophyllus* Lamk.	1
11	Musaceae	17	*Musa sp.*	20
12	Myrtaceae	18	*Syzygium sp.*	2
		19	*Syzygium malaccense* (L.) Merr. & Perry.	2
		20	*Psidium guajava* L.	3
13	Oxalidaceae	21	*Averrhoa carambola* L	1
14	Pandanaceae	22	*Pandanus tectorius* Parkinson	7
15	Poaceae	23	*Panicum repens* L.	80
		24	*Imperata cylindrica* (L.) Beauv.	140
		25	*Bambusa* sp.	20
16	Sapindaceae	26	*Pometia pinnata* J.R.Forst. & G.Forst.	2
17	Zingiberaceae	27	*Alpinia galanga* (L.) Willd.	40
			TOTAL	575

Table 2. Species and the stations

No	Species	Station		
		Dondai	Deyau	Jaifuri
1	*Pandanus tectorius* Parkinson	√	√	√
2	*Cyperus sp*.	√	√	√
3	*Imperata cylindrica* (L.) Beauv.		√	√
4	*Alpinia galanga* (L.) Willd.		√	√
5	*Clitorea ternatea* L.		√	√
6	*Mangifera indica* L.		√	√
7	*Hibiscus tiliaceus* L.	√		√
8	*Metroxylon sagu* Rottb.	√		√
9	*Panicum repens* L.	√	√	

Pandanus tectorius or screwpine are native in Southeast Asia including Philipines and Indonesia (Thomson, *et al*., 2006), it found grows in forest habitat, along seashores, river banks, ponds, canals and other water bodies (Gurmeet and Amrita, 2015). *Pandanus tectorius* can grow at elevation 66 ft and up to 1970 ft (20 - 600 m) (Thomson, *et al*., 2006; Gurmeet and Amrita, 2015), it is suitable to live in seashore of Lake Sentani, because the location of Lake Sentani is on 70–90 meters asl. It grows quickly in tropical climate, where it can withstand strong winds and droughty salty sprays (Gurmeet and Amrita, 2015). Rainfall varies considerably across its range, both in amount and seasonal distribution (Thomson, *et al*., 2006). Thus, *P. tectorius* has an excellent adaptability to live in the riparian zone of Lake Sentani.

Imperata cylindrica or cogongrass is one type of grass that comes from Southeast Asia and usually grows in coastal areas, disturbed areas, natural forest, planted forests, grasslands, riparian zones, bushes, urban areas, and wetlands (Miller, 2003). Cogongrass performs well on droughty, thrives on fine sand to heavy clay and does well on soils of low fertility (MacDonald *et al*., 2006; Holzmueller and Jose, 2012). This caused by the specialized anatomy of the rhizome allows for water conservation. The rhizome can also penetrate to a depth of 4 feet in the soil. In addition, the rhizome can also produce allelopathic substances which inhibit growth of other plants. (MacDonald *et al*., 2006). The persistent and aggressive rhizomes of cogongrass are reported to be the main mechanism for survival and spread. Rhizomes can give rise to 350 shoots in six weeks and can cover 4 m^2 in 11 weeks (Shilling, et al., 1997). It make cogongrass difficult to control.

The species was initially intended as a forage crop, but high silica content when the plant matures makes it unpalatable to livestock. It was also used for soil stabilization along road banks and mined lands, but unintended spread into adjacent areas. This is led to placement of the species considered one of the worst weeds in the world. The grass can decrease native species plant biodiversity and change nutrient availability (Holzmueller and Jose, 2012). *Imperata cylindrica* prone to fires. It is very clearly visible in several places near the shore of the Lake Sentani that had been burned. Land fires will only increase the number of cogongrass population (Holzmueller and Jose, 2012). Some riparian zones and the islands around Lake Sentani are sand mining area. This proves that the land around Lake Sentani is sandy soil suitable for the growth of cogongrass.

Sand mining is one of the activities that can accelerate the erosion surround Lake Sentani, because the structure of the sediment and soil layers in Sentani more dominated by mud and sand (Bungkang & Soemarno, 2013). Erosion can cause mudslides because most of the area surround Lake Sentani is quite steep hilly areas. Sand mining also leads changes in the ecosystem. Such changes can occur because of forest land in the coastal lake that used to be the location of riparian vegetation that serves as vital spawning grounds for aquatic organisms opened for sand mining, thus made the aquatic organisms losing their place for spawning.

Hibiscus tiliaceus or sea hibiscus is one of the most widespread species in the genus, with a pantropical, mainly coastal, distribution. Whether this widespread distribution occurred primarily through natural dispersal or through human intervention is unknown. It tolerates wide variety of soils, ranging from coralline, skeletal soils to waterlogged swampy soils of medium to heavy texture. It also tolerates aerosol salt spray, brackish water and shallow flooding very well. Well-established tree can also withstand drought (Selvam, 2007). It means *H. tiliaceus* is a wild vegetation that have wide environment tolerance.

Alpinia galanga, *M. indica*, and *M. sagu* are used as crop plant in Sentani. Those plants was found on riparian zone of Lake Sentani which used as farmland by local people together with some other crops. *A. galanga* found in Indonesia, India, China, Arabic gulf areas, Malaysia, Egypt, Thailand and Sri Lanka. (Chudiwal, *et al*., 2010; Shetty and Monisha, 2015). It grows in open sunny places, forests and brushwood (Shetty and Monisha, 2015). Its plant and plant products are being used as a source of medicine since long time ago. Its used in medication, cullinary, and cosmetics for centuries (Chudiwal, *et al*. 2010). Because of that *A. galanga* widely cultivated in Indonesia. While the genus Mangifera originates in tropical Asia, with the greatest number of species found in Indonesia (Borneo, Java, Sumatra) and the Malay Peninsula. The most-cultivated Mangifera species, *M. indica* has its origins in India and Myanmar (Dept.of Agriculture Republic South Africa, 2008). *M. sagu* or sago is native vegetation in Indonesia, and Indonesia has very spacious natural forest of sago, which is about 1.2 million ha with the largest area is located in Papua. This area is the location of 51.2% of the sago population in the world (Rostiwati, et al., 2014). Sago is the main carbohydrate stable for Sentani people (Andersen, 2006). Thus make sago often cultivated by the local people in Sentani. The sago is often cut down by the chainsaw, although some still do it with a steel-axe. When the sago is securely on the ground, the bole will be worked on by the men to obtain the sago grain.

In Lake Sentani, *C. ternatea* or butterfly pea found in Deyau and Jaifuri station as wild vines in trees. The persistence of *C. ternatea* is very high against the of changing seasons, the soil, and very suitable in association with other crops (Suarna, 2014). These species is originated from the central part of South America which spread to the tropic area since 19th century, mainly to the Southeast Asia including Indonesia. *C. ternatea* is one of shrubs commonly grown in the open area along the road and slopes. These plants are naturally found in grasslands, forests, shrubs, riverbanks, and other open places, and vines in tree or fence yard. This plant grows on various types of soil, especially in sandy soils and the red clay soil (Sutedi, 2013). *C. ternatea* is potencial as a forage crop because besides having high nutritional value, its also very palatable for livestock (Suarna, 2014).

Poaceae is the most abundance family of riparian vegetation. There are three species found that include into Poaceae family in three sampling sites. The species are *I. cylindrica*, *P. repens* L., and *Bambusa* sp. Poaceae is one type of grass kind family, thus make them easily to grow and live in open area. It clearly sees the islands surround Lake Sentani is dominated by the Poaceae family. Poaceae is one of the pioneer plant that can reproduction both in vegetative and generative on an open site, so it has wide tolerance range and has characteristic as cosmopolitan plants (Pasaribu, *et al*., 2013). Two kind of Poaceae that have most recorded number is cogongrass (*I. cylindrica*) with 140 individuals and torpedo grass (*P. repens*) with 80 individual. In addition Cyperaceae is also grass types whose population is quite high (70 individuals) in the riparian area of Lake Sentani. This is caused by the islands around Lake Sentani is dominated by open areas (**Fig. 2**). An open area can accelerate the growth of the grass population.

	
One of the settlements in the Lake Sentani.	One of cogongrass site that is burned on Lake Sentani.
	
One side of Lake Sentani that opened for sand mining and road expansion.	Bridges in Jaifuri stations that have fairly strong current.

Figure 2. Several conditions of Lake Sentani

The most number of individuals is *I. cylindrica* with a total of 140 individuals while the least number are *A. occidentale*, *Erithrina sp*., *T. grandis*, *A. heterophyllus*, and *A. carambola*, each species with only one individu (Table 1). *I. cylindrica* is one kind of grass, that suitable and adaptable to live in the open and steep topography like the riparian area surrounding Lake Sentani. In addition the area surround Lake Sentani that had been burned, thus it can increase the number of cogongrass population. Some riparian zones and the islands around Lake Sentani are also sand mining area which proves that the land around Lake Sentani is sandy soil and its suitable for the growth of cogongrass. *A. occidentale, Erithrina sp., T. grandis, A. heterophyllus*, and *A. carambola* that found in Lake Sentani's riparian areas largely are cultivated plants and found as shrubs. Tree-shaped plant reproduction capabilities are not as fast as the grass. Thus make its population is not as much as the cogongrass. Some of the riparian vegetations that found in Lake Sentani can be seen in the **Fig. 3**.

	
M. sagu Rottb.	*P. tectorius* Parkinson
	
H. tiliaceus L.	*P. pinnata* J.R.Forst. & G.Forst.
	
C. nucifera L.	*Bambusa sp.*
	
S. malaccense (L.) Merr. & Perry.	*Musa sp.*, *C. papaya* L., *M. utilissima* Pohl., *I. cylindrica* (L.) Beauv.

Figure 3. Riparian vegetation of Lake Sentani (Source: Personal documentation).

The number of individuals riparian vegetation was recorded in Deyau station was 185 individuals, Dondai station was 86, and Jaifuri station was 304. So the total individuals found were 575 individuals (**Table 3**). The highest number of individuals riparian vegetation was recorded in Jaifuri station. The Jaifuri station is the only outlet of Lake Sentani. The station has a fairly strong current with a depth is only ankle. The soil in sampling locations is dominated by gravel and sand substrate, making it easier for plant seeds or shoot to attach and grow among the soils and sands. The most dominating plant in Jaifuri station were family

Poaceae and Cyperaceae. The grass may appear as dominant vegetation in the area if the area is getting high sunlight penetration due to the small canopy cover. Jaifuri station is the most widely covered by plantation species such as coconut (*C. nucifera*), sago (*M. sago*), malay apple (S*. malaccense*), Starfruit (*A. carambola*), Matoa (*P. pinnata*), areca (*A. pinnata*), mango (*M. indica*) guava (*P. guajava*), and galangal (*A. galanga*), although the population of those plants has not been too many. The most dominating plantation is sago (*M. sago*) (51 individuals), galangal (*A. galanga*) (20 individuals), and areca (*A. pinnata*) (16 individuals). Those plants are the annual plants that can provide benefits to the community, so the local people around Sentani were cultivated those plant species. In the sampling sites has also begun to settlements with few houses on the edge of the lake, although not too crowded, but in this area is already there a road and bridge are passable by motor vehicles, which allows the people to access another places.

Table 3. Stations and Species Abundance

No.	Station	No.	Species	Amount	Amount each station
1	Deyau	1	*Artocarpus heterophyllus* Lamk.	1	185
		2	*Pandanus tectorius* Parkinson	1	
		3	*Panicum repens* L.	30	
		4	*Musa sp.*	20	
		5	*Manihot utilissima* Pohl.	25	
		6	*Imperata cylindrica* (L.) Beauv.	50	
		7	*Mangifera indica* L.	2	
		8	*Syzygium sp*.	2	
		9	*Clitorea ternatea* L.	10	
		10	*Alpinia galanga* (L.) Willd.	20	
		11	*Anacardium occidentale* L.	1	
		12	*Carica papaya* L.	3	
		13	*Cyperus sp*.	20	
2	Dondai	1	*Hibiscus tiliaceus* L.	1	86
		2	*Pandanus tectorius* Parkinson	5	
		3	*Panicum repens* L.	50	
		4	*Cyperus sp*.	20	
		5	*Metroxylon sagu* Rottb.	10	
3	Jaifuri	1	*Metroxylon sagu* Rottb.	51	304
		2	*Syzygium malaccense* (L.) Merr. & Perry.	2	
		3	*Bambusa sp*.	20	
		4	*Cocos nucifera* L.	7	
		5	*Pometia pinnata* J.R.Forst. & G.Forst.	2	
		6	*Pandanus tectorius* Parkinson	1	
		7	*Imperata cylindrica* (L.) Beauv.	90	
		8	*Averrhoa carambola* L.	1	
		9	*Hibiscus tiliaceus* L.	2	
		10	*Cyperus sp*.	30	
		11	*Mangifera indica* L.	2	
		12	*Arenga pinnata* (Wurmb) Merr.	16	
		13	*Tectona grandis* Linn. f.	1	
		14	*Colocasia esculenta* (L.) Schott.	3	
		15	*Clitorea ternatea* L.	2	
		16	*Mimosa pudica* L.	40	
		17	*Alpinia galanga* (L.) Willd.	20	
		18	*Psidium guajava* L.	3	
		19	*Hyptis rhomboidea* Mart & Gal.	10	
		20	*Erithrina sp*.	1	
				TOTAL	**575**

Dondai has the lowest number of individuals and number of species among all stations. Dondai has five riparian vegetation species. The species that found in Dondai is sea hibiscus (*H. tiliaceus*), pandanus (*P. tectorius*), Torpedo grass (*P. repens*), *Cyperus sp*. and sago (*M. sago*). The torpedo grass (*P. repens*) (50 individuals) has the most individual number of the vegetation. Dondai has canopy plants around the shoreline of the lake, but at the top of the island there are open areas that allow sunlight directly touch the ground so that the species which originally dormant in the soil, including the type of grasses (Poaceae) can grow well (Pena (2003) in Sutomo and Darma (2011)). This is make Dondai dominated by grasses.

Relation between Riparian Vegetation and Rainbowfish

The results from three sampling locations showed that Jaifuri station has the highest number of riparian vegetation species. There were 20 species vegetation and one species of rainbow fish (**Fig.4**). Rainbow fish species found in Jaifuri Station was *Glossolepsis incicus* (Red Rainbowfish). Dondai was the station with the fewest vegetation species. There were five species of vegetation and two species of rainbowfish *G. incicus* and *Chilatherina fasciata* (Barred Rainbowfish). *G. incicus* is endemic species while *Ch. fasciata* is indigenous species (Ohee, 2013). Deyau station has 13 vegetation species with only *G. incicus* that found on that site. According to Ohee (2013) actually there are three species of rainbowfish in Lake Sentani, they are *G. incicus* (endemic species), *Ch. fasciata* (indigenous species) (**Fig.5**), and *Ch. sentaniensis* (endemic species), but *C. sentaniensis* assumed extinct in the wild. All of them are Melanotaeniidae family.

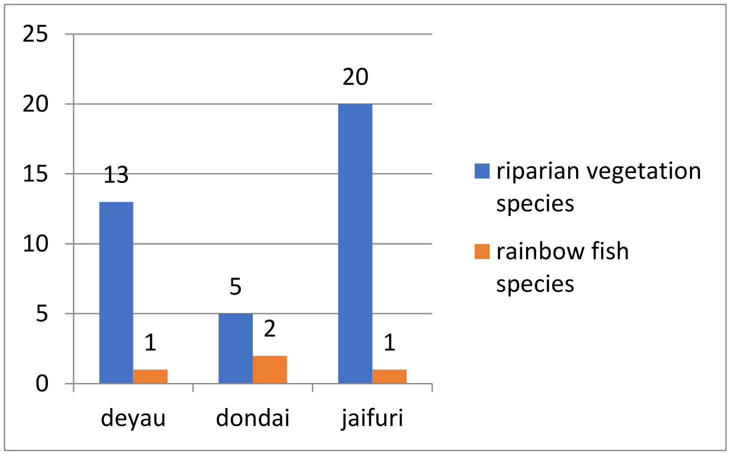

Figure 4. The number of riparian vegetation and Rainbowfish in Lake Sentani

	
Glossolepsis incicus (Red Rainbowfish) an endemic species.	*Chilatherina fasciata* (Barred Rainbowfish) an indigenous species.

Figure 5. Rainbowfish in Lake Sentani

Based on the Pearson Correlation values that obtained for -0.885, shows that the relationship between the vegetation with rainbowfish species is very strong. This showed that the species of rainbowfish in Lake Sentani whether endemic or indigenous were dependent on the riparian vegetation species. This shows that the relationship between riparian plant species with rainbowfish species in Lake Sentani is negative because the coefficient is negative. it is means the fewer of plant species, the more types of rainbow fish can be found, and vice versa.

The results of three stations showed that Jaifuri station has the highest number of riparian vegetation, but has the lowest number of rainbowfish population. The vegetation were 304 individuals and the fish were 14. Dondai was recorded as station with the lowest number of riparian vegetation, but has the highest number of rainbowfish population. There were 86 individuals of vegetation with 595 fish (**Fig.6**).

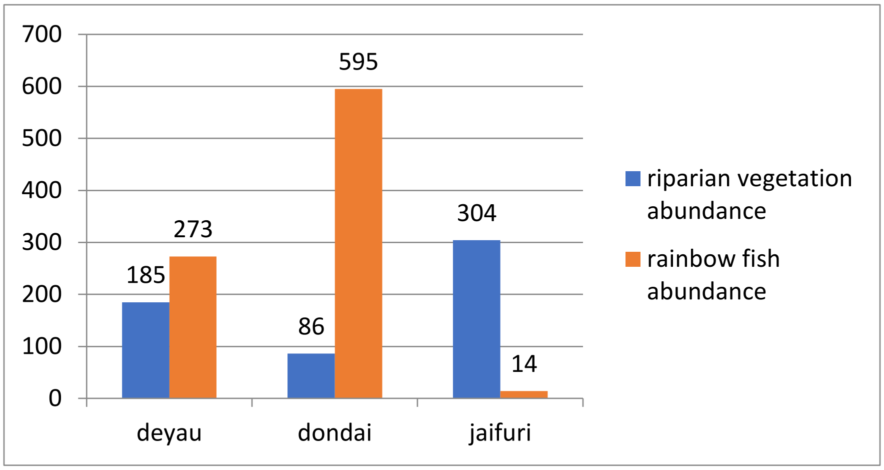

Figure 6. Abundance of riparian vegetation species and rainbow fish at each station

Based on the Pearson Correlation values obtained for -0.993 shows that the relationship between the abundance of riparian vegetation with the abundance of rainbowfish is very strong. This shows that the relationship between the population of riparian vegetation with rainbow fish populations in Lake Sentani is negative because the coefficient is negative. The fewer plants, the more rainbow fish populations that will be found, and vice versa.

According to the results of Syahroma et al. (2011) research in Lake Towuti found that riparian plants have an important role in the distribution of fish in the lake such as *Telmatherina celebensis*, *Paratherina striata*, and *Glossogobius flavipinnnis*. While Wang et al. (2003) found that watersheds and riparian variables had indirect connections with fishes through their direct influence on reach variables. Research by Lee, et al. (2001) found that streams with wooded-local riparian zones had greater fish species richness than streams with open-local riparian zones. This study suggests that maintenance of wooded riparian cover along streams could be effective in maintaining or improving fish community composition in streams draining heavily agricultural areas. As same as this study in Lake Sentani, riparian vegetation play an important role in distribution, maintaining and improving fish community composition.

Jaifuri is a station with a strong current so that small fish such as rainbow fish reluctant to settle there. In addition Jaifuri station is a station that has been touched by humans, it can be seen from the circumstances of Jaifuri that already has several buildings. In contrast to the Dondai situation is still quite natural and seem more rarely touchable by man, beside that the circumstances surrounding the sampling site in Dondai is quite steep, so only a few types of vegetation that can be recorded because of our limited ability.

According to Ohee (2013) red rainbowfish (*G. incicus*) is a lake-dwelling species, and found along the edge of Lake Sentani, around riparian, dead wood, leaves and aquatic vegetation. It occupies the same habitat as some other species, such as barred rainbowfish (*C. fasciata*). They both can live along the water body, the riparian vegetation varies, many kinds of trees, shrubs, and grasses. So the presence of ornamental fish species including rainbow fish in Lake Sentani did not need any specific vegetation species, because they also can live on all of the macrophyte and riparian vegetation species (Paramitha *et. al*., 2014).

CONCLUSIONS

Lake Sentani have 27 riparian vegetation species within 17 families. Poaceae is the family which have the most species found. One of Poaceae species is *I. cylindrica* that have the most abundant (140 individuals). Jaifuri was the station with the highest vegetation species number (20 species) and the highest vegetation population (304 individuals), while Dondai was station with the most abundant of rainbowfish (595 individuals) within two species (*G. incicus* and *C. fasciata*). Based on Pearson Correlation value, the abundance of riparian vegetation have a strong relationship with the presence of the rainbow fish in Lake Sentani.

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DISTINCTIVE FLUCTUATION IN WATER QUALITY AND PLANKTON COMPOSITION IN THE CENTER OF LAKE KASUMIGAURA, JAPAN SINCE 2001

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ABSTRACT

Lake Kasumigaura is a wide and shallow maritime lagoon lake in which the water is artificially desalinated to be utilized effectively for tap water, irrigation water and industrial water. The water is highly eutrophicated and its improvement has been an urgent matter for some time. We have scientifically monitored the water quality and plankton periodically at six monitoring points since 2001 in citizen activities. We experienced outbreaks of Bosmina, high transparency in early summer and a massive microcystis bloom in midsummer, 2011 after the Great East Japan Earthquake and the subsequent radioactive cesium pollution from the accident in the Fukushima nuclear power plant in March. We propose that the outbreak of Bosmina grazing diatoms and green algae in early summer caused the increment of transparency, resulting in a massive proliferation of microcystis in midsummer. However, the causalities from this abrupt outbreak of Bosmina are uncertain. It was observed that water fleas including Daphnia and Cyclops became scarce during the white turbidity period, 2002~2006. White turbidity in the lake water inhibits the photosynthesis by phytoplankton, resulting in a decrement in primary production, including the population of zooplankton and the fishery catch. While COD values also decreased, the inorganic nitrogen and phosphorus values were relatively high during the white turbidity period. Since 2012, a restoration of transparency has brought about relatively high COD values probably because of the proliferation of phytoplankton. Through these experiences we have learned the importance of transparency for the productivity and health of our lake ecosystem.

Keywords: water quality, plankton, transparency, productivity, fishery catch

INTRODUCTION

Lake Kasumigaura is a maritime lagoon lake located in Ibaraki Prefecture near to Tokyo in the Kanto plain, Japan. It is a typical wide and shallow lake (max. depth: 7m, mean depth: 4m, surface area: 220km^2, volume: 0.85 billion m^3, mean chloride ion: 40mg/l, electro-conductivity: 260μS/cm, mean transparency: 70~80cm). It has 2157 km^2 of catchment area and 56 inflowing rivers. The water quality has deteriorated due to rapid eutrophication and desalination. Desalinated water due to the construction of a sea water barrier (Hitachigawa Water Gate, 1963), now provides a vital water resource utilized as agricultural irrigation water, industrial water and drinking water for the Ibaraki Prefecture and the Tokyo metropolitan area. At the same time, the littoral zone is mostly reclaimed and a concrete dyke is constructed along most of the shore line. The lake has been completely enclosed by a dyke. Lake water has been managed over the last four decades by the national and prefectural government. The water quality has remained at the eutrophicated level. Recent values in water quality are approximately 7~8mg/l in Chemical Oxygen Demand i.e.COD ($KMnO_4$), 0.1mg/l in total phosphorus, 1.0mg/l in total nitrogen. Water quality improvement is one of the important matters to be addressed not only by local residents using the lake water as tap water, irrigation water and industrial water but also by the local or national government and the people who live in the Tokyo Metropolitan area.

The problem is that once the water quality deteriorates in a big lake, improvement becomes a very difficult issue. Many countermeasures and a large budget have been utilized on this based on statutes against eutrophication or pollution of the lake. We, in citizen activities, have been continuing the water quality monitoring by ship since 2001. During this monitoring, we have experienced several interesting phenomena and events concerning the water quality of the lake and learned some lessons for the appropriate management of such a wide and shallow lake located in a plain. Through this research, we could watch the situation of the water quality and plankton composition of Lake Kasumigaura by a non-governmental organization. Eventually, we could detect the severe influences of low transparency due to white turbid water against the ecosystem of the Lake Kasumigaura, resulting in the impact to the local government and society.

METHODS

During 2001-2015, the monitoring was carried out monthly (2001-2009) or bimonthly (2010-2015) from an investigation ship scheduled from 10:00 a.m. to 4:00 p.m. at six monitoring points positioned by Global Positioning System as follows: Okijyuku-offshore (36°03′00″N,140°15′23″E), Ushiwata-offshore (36°02′34″N、 140°19′30 ″E), Edosaki inlet (35°59′13″N,140°22′07″E), Tennouzaki-offshore (35°58′37″N、 140°27′57″E), Mitsumata-Lake Center (36°00′48″N、 140°25′12″E), Takahama Inlet (36°07′22″N、 140°22′28″E). At each monitoring point, we measured the water temperature, dissolved oxygen, pH, transparency and electric conductivity of the surface water (30 cm depth). At the same time, we recorded the color of the water. A plankton net (NXX13, made by RIGO CO., LTD Cat. No. 5513) was pulled up 5 meters vertically at each point to collect zooplankton. Zooplankton specimens were fixed with 5% formalin or 10% ethanol immediately after collecting. The plankton net was used to collect and count zooplankton individually under the microscopic examination. For the phytoplankton count, the surface water was sampled and examined under the microscope. The number of cell or colonies per ml were counted microscopically as cited in the Y axis caption of figure 2~4 in the results.

The water samples were brought in a cooling carrier box to the laboratory and the suspended solids (until 2009), chloride ions and chemical oxygen demand (COD) were measured along with the inorganic nitrogen (ammonium nitrogen, nitrite nitrogen, nitrate nitrogen) and phosphate phosphorus, on a HACK colorimeter DR/890.

RESULTS AND DISCUSSIONS

During the white turbid water period (2002-2006) when the water color of Lake Kasumigaura showed vague white, the transparency of the lake water was significantly low, showing about 80 cm even in the lake center. The mean transparency of 6 monitoring points was seen to be 50-60 cm in the worst period (**Fig.1**). During the same period, the numbers of Diatoms and Green algae were all low (**Fig. 2, 3**). Just after the end of the white turbid water, Planktothrix or fibrous Blue-green algae proliferated temporarily for several years (2007-2010) as shown in **Fig.4**. The levels of phosphate phosphorus and inorganic nitrogen were significantly high during the white turbid water period (**Fig.5,6**). Additionally, the COD values were relatively high for the same period (**Fig. 7**).

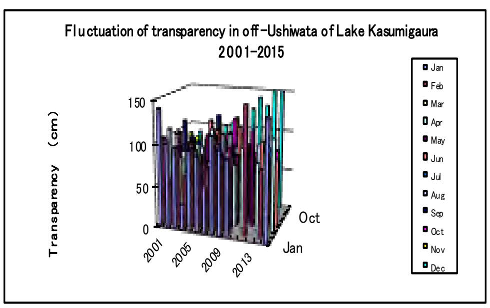


Fig.1

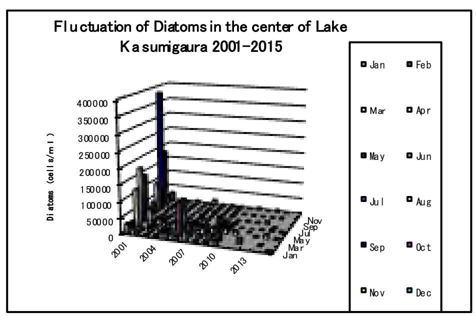
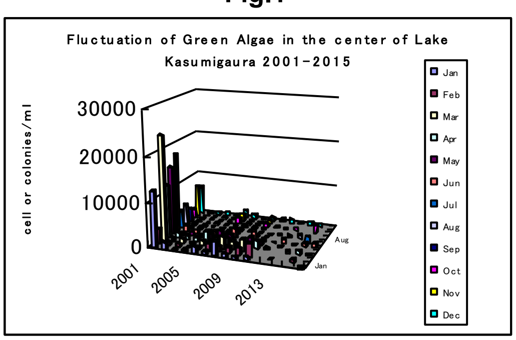


Fig.2



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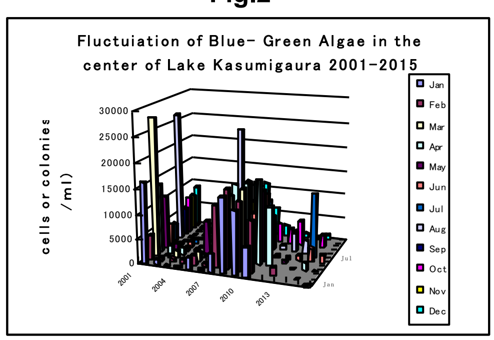

Fig.4

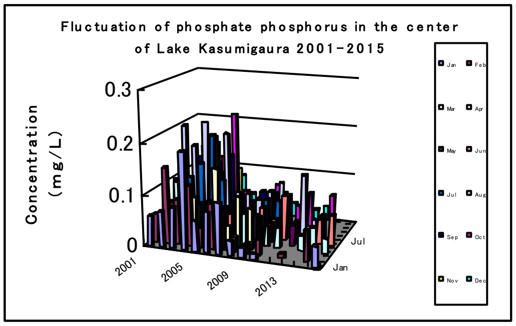

Fig.5

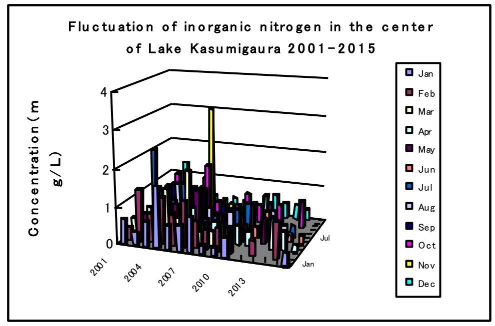

Fig.6

Zooplankton fauna in the lake center fluctuated distinctively during 2001-2015. An outbreak of *Bosmina* occurred in June 2011 (**Fig.8**) just after radioactive cesium pollution, suggesting activation of dormant eggs in the mud of the lake bottom. The supposed cause of this abrupt increment of *Bosmina* is discussed later. The *Daphnia* number increased in 2008 and 2012 (**Fig. 9**). The number of *Diaphanosoma* increased mainly in the summer of every year (**Fig. 10**). Copepodas were observed from spring to autumn through the monitoring period including the white turbid water period (**Fig. 11**). Rotifers proliferated after the end of the white turbid water (**Fig. 12**).

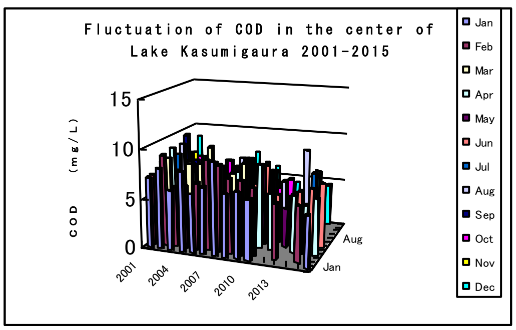

Fig.7

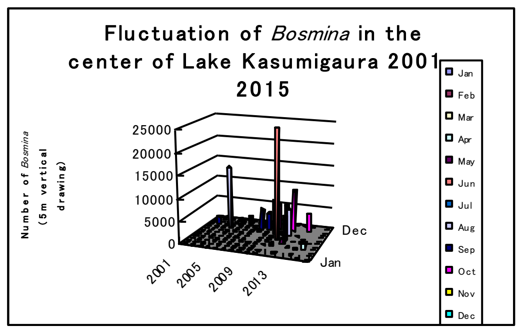

Fig.8

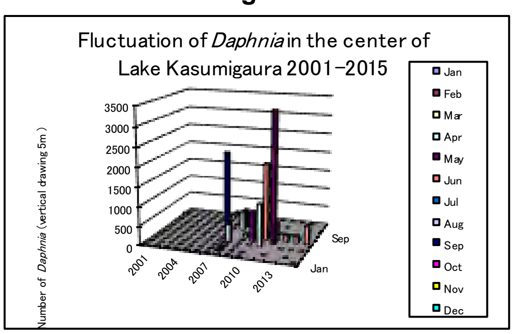

Fig.9

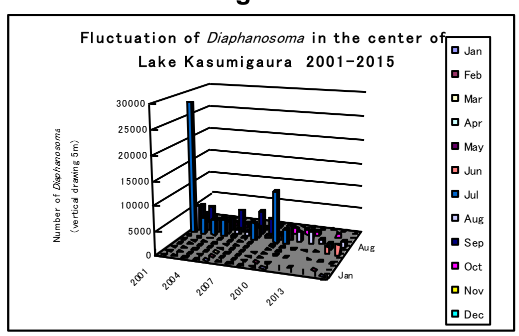

Fig.10

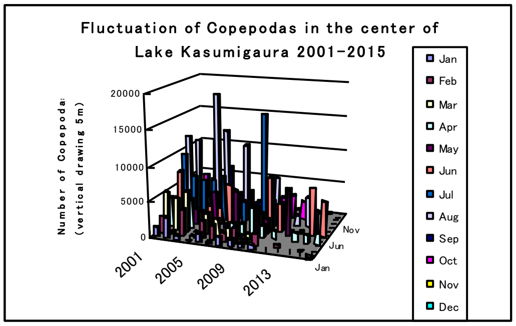

Fig.11

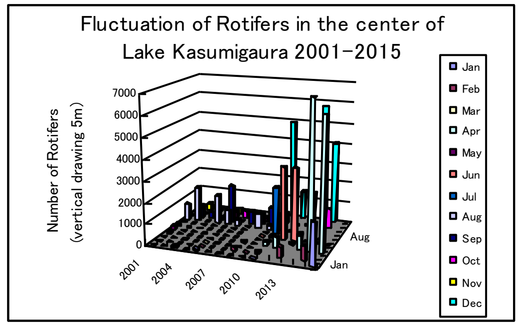

Fig.12

Lake Kasumigaura is the wide but shallow. Therefore, the transparency is always relatively low in comparison with a deep-water lake due to three factors at least, i.e. the re-suspension of bottom sludge during high waves induced by strong winds, inflow of turbid water from the rivers during torrential rain in the catchment area and high proliferation of phytoplankton induced by lake water eutrophication. Five decades ago, the mean transparency of Lake Kasumigaura was still about 150 cm. In those days, there were many bathing beaches on the sandy shores. Afterwards, the transparencies were reduced to about 60~80 cm due to the progress of eutrophication of the lake water. During the white turbid water period (2002-2006), the worst transparency was 40~50 cm at the Ushiwata-offshore monitoring point and some other points. The primary productivity of the lake water was seen to be also worst in such periods due to the inhibition of phytoplankton proliferation accompanying the low light intensity.

Moreover, the COD values in the lake water from the 6 monitoring points were relatively low during same period. Infection of Koi (Carp) Herpes Virus and the resulting massive death of cultured carp occurred in the worst period (2003), suggesting some relationship with the white turbid water. In addition, some researchers pointed out the influence of the floating micro-suspended solids from large scale dredging by the Ministry of Construction aiming at a decrement in the release of nitrogen and phosphorus from the lake bottom for improvement of the lake water quality. We did not determine that this project was the only cause of this turbid water occurrence or not. The exact reason why the terrible white turbid water occurred is uncertain in spite of some earnest following research projects (Nakamura and Aizaki, 2016; Numazawa, 2015; Udagawa and Takamura, 2007). Fortunately, transparency has gradually improved with the replacement of lake water due to high precipitation in the catchment area in the rainy or typhoon seasons (2004, 2010). Consequently, the large-scale dredging project finished after the completion of the planned area. Nowadays the mean transparency is improved to 80-100 cm in the lake center. The proliferation of phytoplankton and zooplankton has been altering seasonally in recent years. Additionally, the fishery catch of Pond Smelt and Icefish which are the main fishery products in Lake Kasumigaura is recovering to the former level before the white turbid water period suggesting rehabilitation of the food web, material circulation and the lake ecosystem.

Outbreaks of *Bosmina* in June and water bloom in August 2011 proved difficult problems. It is probable that the dormant eggs of *Bosmina* were activated and hatched by some stimuli, possibly radioactive cesium pollution in the lake bottom, the fall of water level (about 10~20cm below from the average level) due to dyke damage, accompanying ultraviolet rays radiation, and the strong tremors from the Great East Japan Earthquake in March 2011. In addition, the transparency of the lake water transitory rose to about 200-250 cm probably due to the decreasing phytoplankton grazed by *Bosmina.* Radioactive cesium pollution after the accident of Fukushima Nuclear Power Plant caused by Great Earthquake or Tsunami, prevailed in the catchment area of Lake Kasumigaura. Radioactive air containing cesium released from the Nuclear Power Plant fall out, polluted the Lake Kasumigaura and its watershed. Fortunately, the lake is located about 150km far from the Fukushima and the radioactive levels of polluted soil in the catchment area, bottom sludge, lake water and aquatic organisms, were relatively low. The radioactive level of the bottom sludge temporarily rose just after the accident. Afterwards, the level gradually decreased (**Fig.13**). At present, the levels of radioactivity in the lake water, bottom sludge, fishery catch and the soil in the catchment area are all well below the standard for safety levels designated by the Environment Ministry. We are able to drink the tap water originating from the lake water and to eat the fishery products safely. The mystery of the abrupt outbreak of *Bosmina however* has remained elusive.

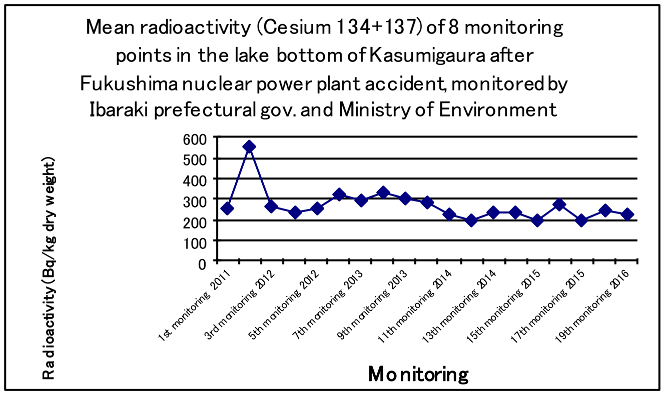

Fig. 13

Likewise, the partial outbreak of water bloom in the summer of the year 2011 when the Great East Japan Earthquake occurred in March remains another mystery. We guess that with temporal high transparency induced by the outbreak of herbivorous zooplankton, *Bosmina* brought about sufficient light intensity for the proliferation of *Microcystis* of blue-green algae. This accumulated on the surface of the water in the port of Tsuchiura, the lakeside city, released a hazardous rotten smell, and forced the residents to react by calling for the countermeasures from the administration.

Other important events have occurred since 2001. They are as follows; tide gate and dykes suffered damage from the Great East Japan Earthquake and their repairs took time to complete (2013); wave breaker installment as an urgent measure for vegetation conservation were performed (2001-2004); dredging gravel as aggregate was ended by several private companies (2013); Smelt resource management by the fishery department of Ibaraki Prefectural Office began (since 2006); the fishery catch of Smelt recovered (since 2009); decrease in COD, attained its target value in the Prefectural plan for conservation of the lake water quality (2013); partial sandy shore development by the Ministry of Construction and the Water Resources Development Public Corporation (since about 2010).

These events were performed mostly independent of each other to pursue beneficial good effects for the lake water or the lake ecosystem through various business agencies or administrations. Of these, the restoration of the fishery catch of Smelt and partial improvements in water quality like the slight decrement of COD values and a certain recovery of transparency were somewhat auspicious, but the effects of the other measures are still uncertain and will need some time to evaluate.

During the white turbid water period, the proliferation of blue- green algae, diatoms and green algae were inhibited. After the end of the white turbid water period, diatoms were dominant in spring and fibrous blue–green algae were dominant from spring to autumn respectively. Sadly, afterwards, phytoplankton became relatively scarce. The number of phytoplankton at present seems to be inhibited by the outbreak of herbivorous zooplankton, *Bosmina, Daphnia*, *Diaphanosoma* and Rotifers, resulting in a slight decrement of COD values in the lake water.

Rotifers also proliferate and have been dominant especially from early spring to early summer since 2012. The outbreak of Rotifers is another interesting factor in evaluating the recent ecosystem of Lake Kasumigaura. There seems to be some relationship between the outbreak of Rotifers and the decrement of phytoplankton caused by grazing, resulting in a decrement of organic substance including phytoplanktons. Promising ideas to solve the reason for the tendency of decrease in the COD values of the lake water in recent years are as follows. Herbivorous zooplanktons proliferate satisfactorily and graze on phytoplankton, resulting in low COD values. Herbivorous zooplanktons are a good food source for Smelt. In particular, Rotifers are initial food for the fry or juvenile Smelt after hatching. Smelt become to predate medium sized zooplanktons like *Bosmina* and large-sized zooplanktons *Daphnia* or *Diaphanosoma* during their growth in the lake water. Smelt are the main fish catch for the fishermen of Lake Kasumigaura. Caught Smelt are the base for Tsukudani, a popular local side-dish specialty made by simmering the small fish with sweetened dense soy sauce. A good fish-catch means the removal of the nitrogen and phosphorus through the fish from the lake water to ensure smooth material circulation and improvement of the water quality. In recent years, the Smelt catch in Lake Kasumigaura is over 400 tons per year, while this was only about 50 tons in the peak year of the white-turbid water. The fishing industry in the lake proves to be a good criterion for evaluating the ecosystem.

Other phenomena concerning the water quality were as follows: The levels of PO_4-P have tended to decrease along with the levels of inorganic nitrogen while levels of NH_3-N have tended to increase, all since around 2009. According to the monthly research performed by Ibaraki Prefectural Government, the annual mean levels of total nitrogen in the lake water of Kasumigaura has remained roughly the same in recent years. The total phosphorus level in the lake water however has increased annually. The reason why the total phosphorus level increased in the Lake water remains uncertain despite eager research by scientists. Analyses of inorganic nitrogen and phosphate phosphorus levels are very important but do not explain the fluctuation of the current water quality, fauna and flora of plankton including the fish-catch.

Probable macro-views about the load influencing the water quality, ecosystem including plankton and fish are as follows; Increase in precipitation in the catchment area results in shortening the retention time in the lake water. Water qualities of the inflowing river have improved in recent years. Successful measures against household wastewater including the gradual installation rate of sewage system rise and combined septic tank and so on, have been more effective, resulting in a tendency of decrement of the load from the catchment area.

CONCLUSIONS

During white turbid water period, 2002-2006, in Lake Kasumigaura, the photosynthesis and the proliferation of phytoplankton were inhibited. After the white turbid water period, diatoms were dominant in spring and fibrous blue-green algae including the *microsystis* bloom were dominant from spring to autumn, suggesting the importance of transparency for the productivity and healthy of lake ecosystem. But afterwards, the number of phytoplankton was relatively few until now. The number of phytoplankton at present seems to be regulated by the herbivorous zooplankton, Rotifer or Daphnia. Herbivorous zooplanktons proliferate satisfactorily and graze on the phytoplankton, resulting in low COD and offering the initial food for the Smelt fry. This has brought about a relative good transparency and a proliferation of Smelt and smooth material circulation with removing the nitrogen and phosphorus through the fish catch. The exact causality of the abrupt outbreak of *Bosmina* and *Daphnia* in summer 2011 was uncertain because to reproduce the experiment is not practical.

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THEORETICAL PELAGIC TO BENTHIC PRIMARY PRODUCTION RATIOS IN TWO LAKES WITH CONTRASTING LIGHT CONDITIONS

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ABSTRACT

Theoretical pelagic primary production of phytoplankton and benthic primary production of periphyton were modelled in two small lakes of Estonia (north-east Europe). Although located only 500 m apart from each other, the water colour and light attenuation of these two lakes differed markedly. Secchi depth in the clear-water lake was 4.5 m and only 0.47 m in the dark-water lake, total phosphorus was, respectively, 15 µg L^{-1} and 28 µg L^{-1}. We employed an empirical model whose inputs were morphometric, light conditions, and dissolved organic carbon parameters obtained from in situ measurements. The model calculated primary production with a time step of 10 minutes, and a spatial resolution of 10 cm, from sunrise to sunset and from surface to lake bottom. While in the clear lake, the primary production of periphyton and phytoplankton were almost equal, in the dark lake only phytoplankton contributed to whole-lake primary production because of the stronger light attenuation in the water column. Results showed that the depth-distribution profiles differed dramatically between the two lakes. The clear lake had deep, U-shaped curve with the productive layer reaching considerable depth soon after sunrise and maintaining a similar profile throughout the light hours; the dark lake production, on the other hand, declined rapidly with increasing depth whereas the profile changed over the day reaching highest depth at noon.

Keywords: DOC, K_d, nutrients, periphyton, production

INTRODUCTION

The partitioning of primary production of lakes between pelagic and benthic producers constitutes what is called the “autotrophic structure” of lakes (Higgins et al. 2014). Theoretically, primary production of a lake can thus be dominated by phytoplankton, by benthic producers (periphyton) or having equal production values for both. Autotrophic structure carries a critical ecological importance as it defines the magnitude of energy fluxes in food webs (Vadeboncoeur et al. 2002), enables to trace steady state changes from clear- to turbid conditions (Jeppesen et al. 2014) and is also a useful tool for monitoring alterations of lake trophic status (Higgins et al. 2014). However, the autotrophic structure of even some of the most intensively studied lakes remains largely unknown because of the paucity of estimates regarding benthic primary production (Vadeboncoeur et al. 2002). Indeed, although the planktonic and macrophyte components of a lake primary production are often well documented, there are comparatively very few studies addressing the specific primary production rates of periphyton[2]. Consequently, modelling is often the best and only way to measure the autotrophic structure of lakes (Cremona et al. 2016). Vadeboncoeur et al. (2008) have developed an empirical series of equations called Lake Autotrophic Structure (LAS) model which relies on four main sets of input parameters: morphometry, bathymetry, light and nutrients. Although LAS is more designed as a conceptual tool for numerically exploring theoretical production partitioning between phytoplankton and periphyton than for measuring actual rates, it is nevertheless suitable for guessing production ranges (Cremona et al. 2016). Furthermore, it requires only a few input variables, of which most are easily measurable. Lakes from the Baltic Sea region (North-east Europe) constitute ideal case studies for the application of LAS as they are located at the boundaries between light- and nutrient-limited zones (Nõges et al., 2011) and thus provide suitable research material for testing drivers of lake productivity and hence autotrophic structure. Our objective was to assess the autotrophic structure of two small hemiboreal lakes located in Estonia, differing markedly by their nutrient content and light regimes in order to test LAS model sensitivity.

[2] In Google Scholar (https://scholar.google.com) research engine typing “lakes + *production + periphyton*” will give only 129 entries compared to 999 entries if “phytoplankton” replaces “periphyton” in the research query.

METHODS

Study sites

We selected two lakes situated in Estonia (north-east Europe): Nohipalo Valgõjärv and Nohipalo Mustjärv (hereafter lakes LL and DL for “light lake” and “dark lake” respectively). Despite the two lakes are located only 500 m from each other and exhibit relatively similar bathymetry and morphometry their nutrient and light-related parameters are remarkably different (**Table 1**). Lake LL is clear and oligo-mesotrophic (Secchi depth, SD = 4.5 m, total phosphorus, TP = 15 μg L^{-1}) whereas Lake DL is dark-colored and dystrophic (SD = 0.47 m, TP = 28 μg L^{-1}). As the catchments of both lakes fully remain within the sparsely populated Meenikunno landscape protection area, the dominant land cover is essentially consisting in natural mixed and conifer forests and bogs devoid of any notable point-source pollution (Ott and Kõiv, 1999).

Sampling

TP, TN, chlorophyll *a* (Chl *a*) and SD were measured as a part of a routine national lake monitoring program in Estonia. Chl *a*, TP and TN were analyzed using standard methods. For the determination of dissolved organic carbon concentrations (DOC), water samples were filtered through Whatman GF/F glass microfibre filters previously washed with 500 ml of ultrapure water (Milli-Q) and DOC was then measured using a TOC-V_{CPH} analyzer (Shimadzu, Japan). This method conforms to the European standard method (EN 1484:1997).

Model

We employed a modified version of LAS model (Cremona et al. (2016) for assessing LL and DL lakes primary production and autotrophic structure. An exhaustive description of the original model is available in Vadeboncoeur et al. (2008). To summarize, LAS is an empirical model based on four input parameters: light attenuation, nutrient availability, bathymetry and morphometry. The model empirical equations are employed for calculating whole-lake primary production and its partitioning between planktonic and benthic producers. The LAS model is semi-distributed as it is able to cope with depth-specific calculations, and it is dynamic because diel variability in production is taken into account. The water column of LL and DL lakes was divided into 0.1 m thick successive layers for which plankton and benthic production were calculated down to lake bottom. The 1995-2015 summer averages of Chl *a*, and SD in the epi- and metalimnion were used as input data for LAS. For DOC, measurements were available only for the year 2015. Both lakes are dimictic and experience notable stratification during summer periods. Consequently, only epi- and metalimnion values of Chl *a* were employed in this analysis which was not supposed to represent episodes of water-column mixing. Model calculations were done with a 10-min increment for a 15-hour period as it is typical of summer light conditions at northern, hemiboreal latitudes. Lake-specific surface available for macrophyte and periphyton colonization (A_z) was obtained by actual bathymetric measurements for Lake DL but were missing for Lake LL. In that case A_z was calculated with equation (1) from Vadeboncoeur et al. (2008):

$$A_z = A_0\left[1-\left(z / z_{\max}\right)\right]^{\gamma} \tag{1}$$

where A_0 is lake surface area, γ is a shape factor (γ = DR / (1-DR)), and DR is the depth ratio of mean and maximum depth (z/z_{max}). We considered that phytoplankton colonized lake water column (i.e. lake volume) and periphyton was present on lake bottom (i.e. lake area). Lake volume (V_z) was calculated as a succession of truncated cones (Carpenter 1983):

$$V_z = \frac{z}{3}(A_{z-\Delta z} + A_z + \sqrt{A_{z-\Delta z} A_z}) \tag{2}$$

Where $A_{z-\Delta z}$ is the area of the upper surface and A_z is the area of the lower surface of the stratum whose volume is to be calculated.

Diurnal variability in surface irradiance (I_{0t}, μmol m^{-2} s^{-1}) was fitted to a sinusoid function (McBride 1992, Kirk 1994):

$$I_{0t} = I_{0\max} \sin(\pi \tfrac{t}{daylen}) \qquad (3)$$

where I_{0max} is the surface light at solar noon (1500 µmol m^{-2} s^{-1}), *t* is the number of hours after sunrise, and *daylen* are hours of daylight (15 h).

Light conditions at depth below surface was calculated with the following equation:

$$I_{zt} = I_{0t} e^{-K_d z} \qquad (4)$$

with K_d being the lake-specific diffuse light attenuation coefficient. In this study K_d was calculated using the modified empirical relationship from Armengol et al. (2003) where K_d = 1.448 / SD with SD being measured average Secchi depth (m).

For determining pelagic maximum primary productivity PPP_{max} (mg C m^{-3} h^{-1}) Chl *a* concentration was used as a proxy of phytoplankton carbon fixation (Guildford et al. 1994):

$$PPP_{\max} = 2.2Chl \qquad (5)$$

Depth-specific phytoplanktonic production was then calculated on the basis of PPP_{max}, solar irradiance and morphometry:

$$PPP_z = \Delta t \sum_{dawn}^{dusk} PPP_{\max} \tanh\left(I_{zt} / I_k\right)\left(V_z - V_{z-\Delta z}\right) \qquad (6)$$

with Δ*t* being the time increment (10 min in the current study), I_k is the light intensity at onset of saturation (180 µmol m^{-2} s^{-1} for phytoplankton) and Δ_z the depth increment (0.1 m). To assess whole-lake total PPP, we summed from surface to lake bottom primary production profile time series obtained from equation (6) at different depth intervals.

For calculating benthic maximum primary productivity BPP_{max} (mg C m^{-2} h^{-1}) we used the modified relationship from Godwin et al. (2014) where the maximum rate of benthic primary production is light-limited and depending on DOC concentration, as it is mostly the case for northern temperate lakes that exhibit phosphorus and algal content within the ranges of TP 6-70 µg L^{-1} and Chl *a* 2-21 µg L^{-1}. Our study lakes were fitting within these DOC, TP and Chl *a* ranges (**Table 1**):

$$BPP_{\max} = \frac{e^{8.121-0.166\times[\mathrm{DOC}]}}{24} \qquad (7)$$

Benthic primary production (BPP) was calculated as a function of incident light and availability of substrate:

$$BPP_z = \Delta t \sum_{dawn}^{dusk} BPP_{\max} \tanh\left(I_{zt} / I_k\right)\left(A_{z-\Delta z} - A_z\right) \qquad (8)$$

with the slope coefficient being 0.046 and the standard deviation of intercept in the exponent being 0.574. Light intensity at onset of saturation (I_k) for benthic producers was fixed at 100 µmol. m^{-2} s^{-1} (Liboriussen and Jeppesen 2006). Uncertainty analysis was carried out on input parameter variability rather than mechanistic errors because LAS model is based on empirical relationships which are supported by literature and are constrained within data from in situ measurements (Cremona et al. 2016). As lake volume and surface, surface light and time increment are all constants, only errors on PPP_{max} and BPP_{max} were accounted for. Maximum and minimum values for PPP_{max} were selected according to the range of measurements obtained for Chl *a* during monitoring studies (**Table 1**). Conversely, for BPP_{max}, we calculated the error value by varying DOC values within the standard deviation of equation (7) and DOC concentration corresponding of each lake.

RESULTS AND DISCUSSIONS

Autotrophic structure differed strongly between the two lakes. In LL primary production was distributed nearly equally between pelagic (557 mg C m^{-2} day^{-1}) and benthic primary producers (479 mg C m^{-2} day^{-1}), while in DL, pelagic primary production was totally dominating the autotrophic structure of the lake (311 mg C m^{-2} day^{-1} for PPP and only 0.05 mg C m^{-2} day^{-1} for BPP). Diurnal isopleths of pelagic PP revealed that if production was still important in LL at 8-meter depth, it dropped to zero already at 1 meter in DL (**Fig. 1**). The clear lake (LL) had a deep, U-shaped curve with the productive layer reaching considerable depth soon after sunrise and maintaining a similar profile throughout the light hours; conversely, in the dark lake (DL) production declined rapidly with depth and the profile changed over the day reaching highest depth at noon. For benthic primary production, the difference was even greater between the two lakes (**Fig. 2**). Benthic primary production was consistently high at all depths in LL but attenuated rapidly in DL, as it did for pelagic PP. When error calculation was entered into the PPP and BPP equations, the range of possible values stayed generally within the same order of magnitude (**Fig. 3**). Planktonic primary production ranges were nearly identical between Lake LL (222-714 mg C m^{-2} day^{-1}) and Lake DL (163-705 mg C m^{-2} day^{-1}), meaning that the two lakes may display the same rates of primary production despite possessing very contrasting light and nutrient conditions. Conversely, BPP ranges differed strikingly between the two waterbodies, being close to zero in Lake DL and reaching up to 1966 mg C m^{-2} day^{-1} in Lake LL. If a comparison of total primary production rates (PPP + BPP) of these two lakes were to be made, Lake LL should be theoretically considered the most productive, except during episodes of adverse light conditions which impacts more heavily BPP than PPP.

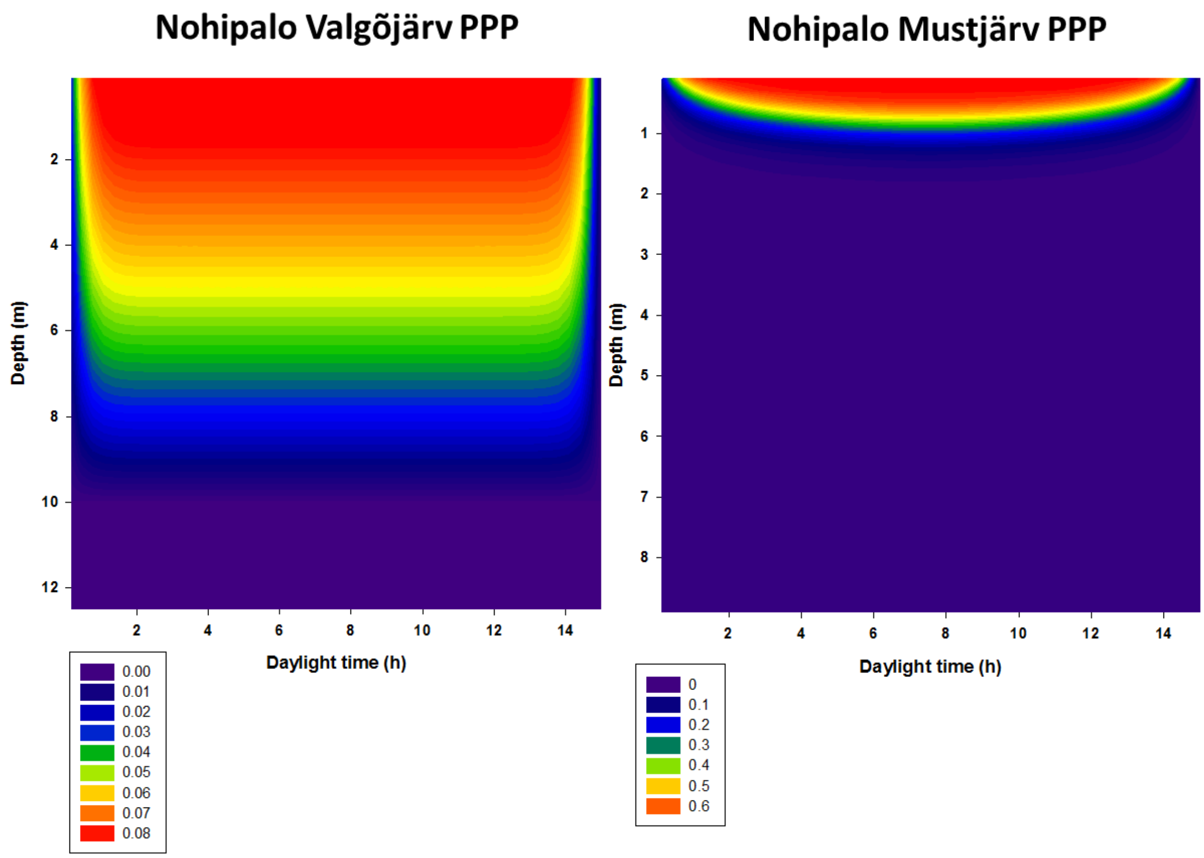

Figure 1. Dynamic profiles of instant planktonic primary production (PPP, mg C) as modelled for lakes LL (left) and DL (right), from sunrise to sunset. Note that the two primary production legends are not on the same scale.

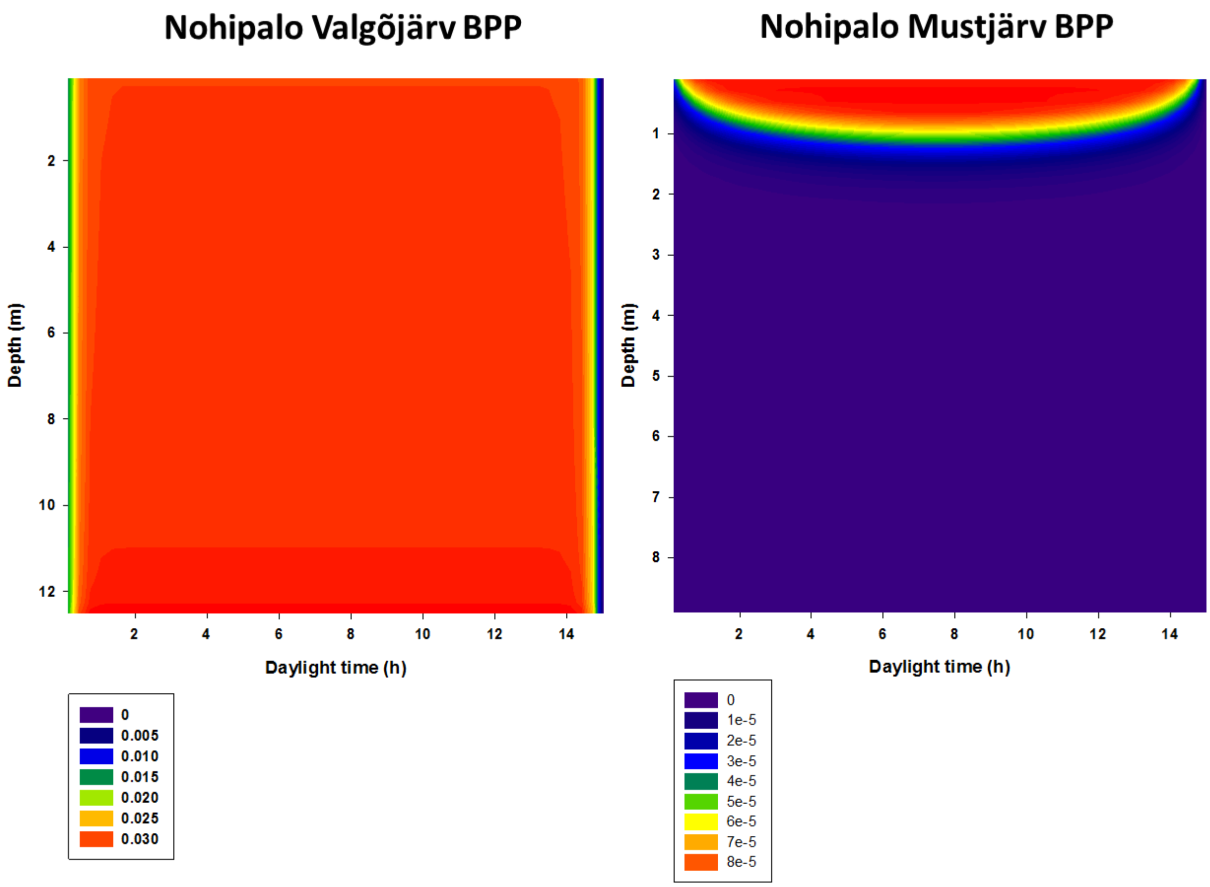

Figure 2. Dynamic profiles of instant benthic primary production (BPP, mg C) as modelled for lakes LL (left) and DL (right), from sunrise to sunset. Note that the two primary production legends are not on the same scale

Nohipalo Valgõjärv autotrophic structure, which shows a dominance of benthic producers over planktonic producers is similar to that of clear, shallow Estonian lakes like Äntu Sinijärv and Mullutu Suurlaht (Cremona et al. 2016). On the other hand, in Nohipalo Mustjärv the complete dominance of phytoplanktonic producers corresponds to the autotrophic structure observed in turbid, nutrient rich Estonian lakes like Võrtsjärv or Ülemiste (Cremona et al. 2016). It appeared that at least nutrient availability could still support a thriving phytoplankton biomass in poor light conditions whereas light extinction drew a more critical limit to benthic growth. Previous studies have revealed a stronger effect of nutrients on planktonic than benthic producers (Hecky et al. 1993, Vadeboncoeur et al. 2001). More generally, the resource competition theory predicts that nutrient-rich lakes should be dominated by phytoplankton irrespective of their natural light extinction coefficient (Jäger and Diehl, 2014). Indeed, shading of water column by phytoplankton cells in eutrophic systems is often responsible for a plummeting of light availability for benthic primary producers. In Nohipalo Mustjärv the (essentially planktonic) primary production is concentrated into the uppermost surface layers of the water column whereas in Valgõjärv the same amount of production is dissipated in a layer that goes eight times deeper. The vastly different autotrophic structures of the two lakes will have strong implications on their respective food web structures (Jeppesen et al. 2014). We can expect that food linkages in Lake DL will rely more heavily on the consumption of detrital material as most of the phytoplankton biomass will escape grazing pressure and will thus settle on lake bottom (Liboriussen and Jeppesen, 2003). Conversely, benthic and pelagic grazing will be proportionally more intense in LL because the primary production is distributed on a larger surface or volume unit basis.

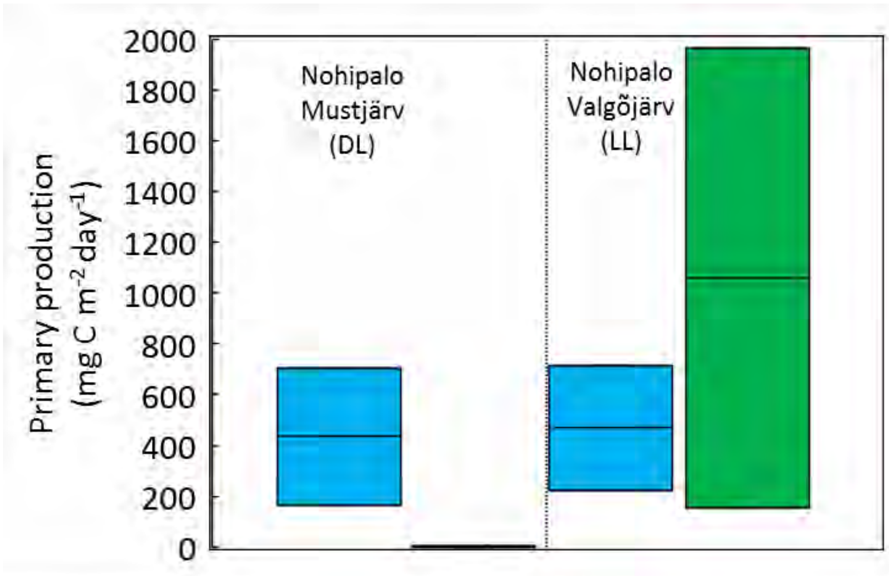

Figure 3. Primary production quantiles of Nohipalo Mustjärv (left) and Valgõjärv (right). Blue and green boxes represent planktonic and benthic component of total primary production respectively. Please note the very low range of values of benthic primary production for Mustjärv.

CONCLUSIONS

Our results demonstrated that light-related variables were more important than nutrient-related ones to explain primary production partition in two hemiboreal lakes. Greater water transparency promoted a relatively balanced primary production between benthic producers and phytoplankton while high light extinction favoured phytoplanktonic production only. This conclusion can be extended to other systems were dissolved organic matter is the main factor responsible for light extinction, which is often the case in high-latitude waterbodies. However, in subtropical or tropical lakes where phytoplankton and particles contribute most to light extinction, the applicability of the model is less straightforward and would need updates of the equations that constitute the main corpus of the model. We have modified several empirical relationships (e.g. I_k and BPP_{max}) that are related to light and maximum photosynthetic activity in accordance to the conditions that are prevailing in the Baltic region, and we thus encourage researchers to improve the applicability of LAS in their region by doing the same.

Table 1. Limnological characteristics of the two studied lakes. Nutrient parameters represent the average for epi- and metalimnion. For Chl *a* minimum and maximum values are given in brackets.

Variables	Nohipalo Mustjärv (DL)	Nohipalo Valgõjärv (LL)
A (km^2)	0.22	0.07
Z (m)	3.9	6.2
z_{max} (m)	8.9	12.5
Trophic state	Dystrophic	Oligo-mesotrophic
Chl *a* (µg L^{-1})	14 (7-32)	6 (2-7)
TP (µg L^{-1})	28	15
TN (µg L^{-1})	726	317
DOC (mg L^{-1})	48	5.7
SD (m)	0.47	4.5
K_d (m^{-1})	3.08	0.32

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STUDY OF FISHERY LOAD CAPACITY IN SUTAMI AND LAHOR RESERVOIRS, EAST JAVA, INDONESIA

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ABSTRACT

Sutami and Lahor reservoirs are man made reservoirs in East Java Province, Indonesia with multiple functions: flood control, irrigation, power plant, tourism and aquaculture. Based on measurement in 2014, the storage volume of Sutami and Lahor reservoirs were approximately 158,600,000 m^3 and 29,060,000 m^3 respectively. Fishery activities with floating net, trawl, and fishnet separator in Sutami and Lahor reservoirs held by society living nearby the reservoirs. Those activities produce wastes that create higher pollutant load in the reservoirs. Study of fishery load capacity in Sutami and Lahor reservoirs was conducted using chlorophyll-a method and intended to preserve the sustainable benefits of reservoir water resources. Measurement and steps to determine the fishery potential in Sutami reservoir started with the calculation of chlorophyll-a concentration in unit area (mg/m^2), calculation of primary productivity through Beveridge Equation, unit value adjustment of result primary productivity with unit value of primary productivity in Beveridge Table, calculation of conversion result from productivity primary value to fish weight, and calculation of fish production based on width of Sutami reservoir. The right system to manage fisheries is sowing fishing with zoning system, which means dividing the territorial waters of the reservoir surface based on their physical and biological to organize the reservoir fisheries pattern based on reservoir priority function. The results showed the average potential of fishery in Sutami reservoir in range of 73.18 - 166.85 tons/year and 10.70 - 16.64 ton/year in Lahor reservoir.

Keywords: Chlorophyll-a, Fishery, Sutami-Lahor Reservoirs, Zoning.

INTRODUCTION

The study was conducted in Sutami and Lahor reservoirs located in Malang Regency, East Java, Indonesia (**Figure 1**). As the biggest reservoir in East Java province, Sutami and Lahor have multiple functions based on its priority as flood control, irrigation, hydro-electric power plant, tourism and fisheries. In these reservoirs, we can find fishery activities with floating net, trawl, and fishnet which owned by the people living around the reservoirs. Fishery activities in Sutami and Lahor reservoirs produce pollutant and allochthonous pollutant carried by the river will increase the capacity load of Sutami and Lahor reservoirs. Therefore, in the development of aquaculture in the reservoirs, there should be considered the load capacity of the reservoir so that the sustainability of water resources can be achieved.

Chlorophyll is a natural pigment that can be found in plants (except for parasite and saprophyte plant), bacteria, or algae. This pigment can transform light energy into chemical energy that is needed for photosynthesis. There are many kinds of chlorophyll, the most common one is chlorophyll-a with dark green colour (SNI, 1990). Chlorophyll-a content indicates the amount of photosynthetic pigment in phytoplankton. It is also directly proportional with phytoplankton population in the water (Subarijanti, 1990).

Figure 1. Location of the study

METHODS

Station Determination

Sample collection was conducted in the last week of wet season that was predicted as eutrophication time. Samples were taken in four parts of reservoirs, starting from upstream, middle, downstream, and bay of those reservoirs (**Figure 2 and 3**). Samples were also taken from the different depth using Secchi Disk.

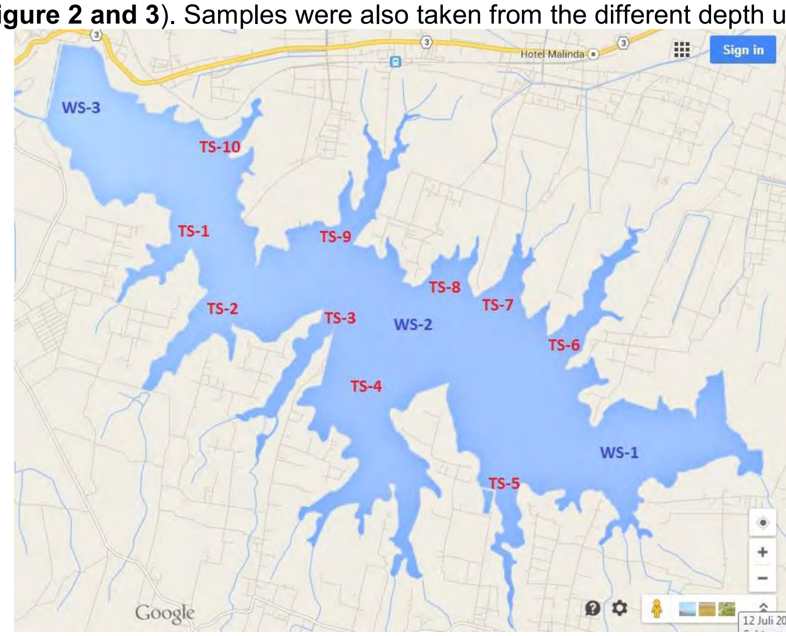

Figure 2. Sampling stations in Sutami reservoir

Figure 3. Sampling stations in Lahor reservoir

Fishery Load Capacity in Reservoir

Study on fishery load capacity was conducted using a model of reservoir capacity pollutant load. Calculation of reservoir fishery potential production implemented through primary productivity approach (Beveridge, 1984) calculated using chlorophyll-a approach with the following equation:

$$\text{Primary Productivity (PP)} = 56.5*(\text{Chl-a})^{0.6}$$

In this calculation, fish production was estimated around 1-3% from its primary productivity. Theoretically, total carbon released from the fish is around 10% from its body weight (wet density). Calculation of fish potential production was based on **Table 1**.

Table 1. Conversion of primary productivity (gr C/m^2/day) to wet density of fish (gr fish/m^2/h) (Beveridge, 1984).

PP (gr C/m^2/day)	% Conversion (gr C - fish/m^2/day)
< 2,74	1 – 1,2
2,74 – 4,11	1,2 – 1,5
4,11 – 5,48	1,5 – 2,1
5,48 – 6,85	2,1 – 3,3
6,85 – 8,26	3,2 – 2,1
8,26 – 9,59	2,1 – 1,5
9,59 – 10,96	1,5 – 1,2
> 12,33	1

RESULTS AND DISCUSSIONS

Chlorophyll-a Measurement Result

Chlorophyll-a measurement contents in both Sutami and Lahor reservoir are shown in **Table 2** and **Table 3** below. Chlorophyll-a value of Sutami reservoir is ca. 0.95 – 32.11 µg/L, while chlorophyll-a value of Lahor reservoir is approximately 4.5 – 25.95 µg/L. It is classified into hyper-eutrophic water for Sutami reservoir and eutrophic water for Lahor reservoir (Seller and Markland, 1987).

Table 2. The chlorophyll-a measurement in Sutami reservoir.

Number	Location [a]	Chlorophyll-a μg/L
1	WS 1-1[b]	26.88
2	WS 1-2	32.11
3	WS 1-3	25.12
4	WS 2-1	0.95
5	WS 2-2	4.97
6	WS 2-3	8.29
7	WS 3-1	7.40
8	WS 3-2	7.63
9	WS 3-3	5.02
10	TS 1-1[c]	6.50
11	TS 1-2	6.52
12	TS 1-3	6.06
13	TS 2-1	7.93
14	TS 2-2	3.90
15	TS 2-3	6.33
16	TS 3-1	5.86
17	TS 3-2	5.99
18	TS 3-3	8.83
19	TS 4-1	4.66
20	TS 4-2	5.19
21	TS 4-3	8.39
22	TS 5-1	7.75
23	TS 5-2	23.21
24	TS 5-3	21.91
25	TS 6-1	15.91
26	TS 6-2	21.89
27	TS 6-3	18.80
28	TS 7-1	19.54
29	TS 7-2	24.22
30	TS 7-3	27.46
31	TS 8-1	18.28
32	TS 8-2	16.79
33	TS 8-3	19.49
34	TS 9-1	19.00
35	TS 9-2	11.82
36	TS 9-3	18.30
37	TS 10-1	13.84
38	TS 10-2	17.34
39	TS 10-3	15.08

[a] WS = Waduk Sutami (Sutami reservoir); TS = Teluk Sutami (Sutami bay)
[b] WS 1-1 to WS 3-3 = Sutami reservoir station 1 depth 1 to Sutami reservoir station 3 depth 3
[c] TS 1-1 to TS 10-3 = Sutami bay station 1 depth 1 to Sutami bay station 10 depth 3

Table 3. The chlorophyll-a measurement in Lahor reservoir.

Number	Location [a]	Chlorophyll-a μg/L
1	WL 1-1[b]	5.49
2	WL 1-2	6.38
3	WL 1-3	11.80
4	WL 2-2	6.60
5	WL 2-2	5.66
6	WL 2-3	5.67
7	WL 3-3	6.63
8	WL 3-3	5.55
9	WL 3-3	4.83
10	TL 1-1[c]	10.96
11	TL 1-2	7.19
12	TL 1-3	7.36
13	TL 2-1	5.92
14	TL 2-2	4.50
15	TL 2-3	6.46
16	TL 3-1	25.95
17	TL 3-2	6.53
18	TL 3-3	5.99

[a] WS = Waduk Lahor (Lahor reservoir); TS = Teluk Lahor (Lahor bay)
[b] WS 1-1 to WS 3-3 = Lahor reservoir station 1 depth 1 to Lahor reservoir station 3 depth 3
[c] TS 1-1 to TS 10-3 = Lahor bay station 1 depth 1 to Lahor bay station 10 depth 3

Fishery Load Capacity

The potential of Sutami and Lahor reservoir measured with chlorophyll-a approach was taken spatially in several sampling stations with three different depth in representing photic area. Measurement and step to determine the fishery potential in both reservoirs is as follows:

1. Measurement result of chlorophyll-a concentration
2. Determination of photic depth
3. Calculation of chlorophyll-a in unit area (mg/m^2)
4. Calculation of primary productivity through Beveridge Equation
5. Unit value adjustment of result primary productivity with unit value of primary productivity in Beveridge Table
6. Calculation of conversion result from productivity primary value into fish weight
7. Calculation of fish production based on width of reservoirs
8. Fishery potential determination in reservoirs

A. Fishery Load Capacity in Sutami Reservoir

Table 4. Chlorophyll-a concentration in Sutami reservoir.

Depth of station	Chlorophyll-a (mg/m^3)												
	WS 1	WS 2	WS 3	TS 1	TS 2	TS 3	TS 4	TS 5	TS 6	TS 7	TS 8	TS 9	TS 10
Surface of Photic	26.88	0.95	7.40	6.50	7.93	5.86	4.66	7.75	15.91	19.54	18.28	19.00	13.84
Middle of Photic	32.11	4.97	7.63	6.52	3.90	5.99	5.19	23.21	21.89	24.22	16.79	11.82	17.34
Bottom of Photic	25.12	8.29	5.02	6.06	6.33	8.83	8.39	21.91	18.80	27.46	19.49	18.30	15.08

Table 5. Photic depth observed in Sutami reservoir.

Depth of station	Station depth (m)												
	WS 1	WS 2	WS 3	TS 1	TS 2	TS 3	TS 4	TS 5	TS 6	TS 7	TS 8	TS 9	TS 10
Surface of Photic	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Middle of Photic	0.44	0.70	0.55	0.60	0.60	0.60	0.55	0.51	0.56	0.5	0,74	0.55	0.54
Bottom of Photic	0.88	1.40	1.10	1.20	1.20	1.20	1.10	1.03	1.13	1.00	1.48	1.10	1.08

Table 6. Chlorophyll-a concentration for each location in photic depth.

Depth of station	Chlorophyll-a (mg/m^2)												
	WS 1	WS 2	WS 3	TS 1	TS 2	TS 3	TS 4	TS 5	TS 6	TS 7	TS 8	TS 9	TS 10
Surface of Photic	9.41	0.33	2.59	2.27	2.77	2.05	1.63	2.71	5.56	6.83	6.39	6.65	4.84
Middle of Photic	14.04	3.47	4.19	3.91	2.34	3.59	2.85	11.89	12.31	12.11	12.38	6.50	9.32
Bottom of Photic	21.98	11.60	5.52	7.27	7.59	10.59	9.22	22.45	21.15	27.46	28.74	20.13	16.21
Average	15.14	5.13	4.10	4.48	4.24	5.41	4.57	12.35	13.01	15.46	15.84	11.09	10.12

Table 7. Primary productivity of Sutami reservoir for each location and photic depth.

Depth of station	Primary productivity (mg C/m^2/day)												
	WS 1	WS 2	WS 3	TS 1	TS 2	TS 3	TS 4	TS 5	TS 6	TS 7	TS 8	TS 9	TS 10
Surface of Photic	222	29	101	93	105	88	76	104	161	183	175	179	148
Middle of Photic	283	121	136	130	95	123	107	256	261	259	262	177	220
Bottom of Photic	372	252	160	190	195	238	219	377	363	426	438	353	309
Average	296	153	134	141	136	158	143	262	270	300	305	245	232

Table 8. Adjustment result of primary productivity in Sutami reservoir for each location.

Depth of station	Primary productivity (mg C/m²/day)												
	WS 1	WS 2	WS 3	TS 1	TS 2	TS 3	TS 4	TS 5	TS 6	TS 7	TS 8	TS 9	TS 10
Surface of Photic	0.22	0.03	0.10	0.09	0.11	0.09	0.08	0.10	0.16	0.18	0.18	0.18	0,15
Middle of Photic	0.28	0.12	0.14	0.13	0.09	0.12	0.11	0.26	0.26	0.26	0.26	0.18	0.22
Bottom of Photic	0.37	0.25	0.16	0.19	0.19	0.24	0.22	0.38	0.36	0.43	0.44	0.35	0.31
Average	0.30	0.15	0.13	0.14	0.14	0.16	0.14	0.26	0.27	0.30	0.30	0.25	0.23

Table 9. Conversion of primer productivity into fish weight (gr/m²/day) for each location.

Depth of station	Fish weight (gr/m²/day)												
	WS 1	WS 2	WS 3	TS 1	TS 2	TS 3	TS 4	TS 5	TS 6	TS 7	TS 8	TS 9	TS 10
Surface of Photic	0.02	0.002	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.01
Middle of Photic	0.028	0.01	0.01	0.01	0.01	0.01	0.01	0.03	0.03	0.03	0.03	0.02	0.02
Bottom of Photic	0.04	0.03	0.02	0.02	0.02	0.02	0.02	0.04	0.04	0.04	0.04	0.04	0.03
Average	0.03	0.02	0.01	0.01	0.01	0.02	0.01	0.03	0.03	0.03	0.03	0.02	0.02

Table 10. Fish production in Sutami reservoir (ton/15,000,000 m²/year.

Depth of station	Fish weight (ton/15,000,000/year)												
	WS 1	WS 2	WS 3	TS 1	TS 2	TS 3	TS 4	TS 5	TS 6	TS 7	TS 8	TS 9	TS 10
Surface of Photic	121	15	55	51	58	48	42	57	88	100	96	98	81
Middle of Photic	155	66	74	71	52	68	59	140	143	142	144	96	121
Bottom of Photic	204	138	88	104	107	131	120	206	199	233	240	193	169
Average	162	84	73	77	75	87	78	143	148	164	167	134	127

Table 11. Maximum and minimum values, average, deviation, variation coefficient of Sutami reservoir.

Depth of station	N	min	max	average	STDEV	CV
Surface of Photic	13	15.8025	121.4132	70.0803	29.70551	42.3878
Middle of Photic	13	51.9582	155.0529	102.3554	38.95489	38.0585
Bottom of Photic	13	87.7226	239.9832	163.9554	52.07442	31.7613
Average	13	73.1836	166.8514	116.9307	38.35493	32.8014

B. Fishery Load Capacity in Lahor Reservoir

Table 12. Chlorophyll-a concentration in Lahor reservoir.

Depth of station	Chlorophyll-a (mg/m^3)					
	WL 1	WL 2	WL 3	TL 1	TL 2	TL 3
Surface of Photic	5.49	6,60	6.63	10.96	5.92	25.95
Middle of Photic	6.38	5,66	5.55	7.19	4.50	6.63
Bottom of Photic	11.80	5.67	4.83	7.36	6.46	5.99

Table 13. Photic depth observed in Lahor reservoir.

Depth of station	Station depth (m)					
	WL 1	WL 2	WL 3	TL 1	TL 2	TL 3
Surface of Photic	0.35	0.35	0.35	0.35	0.35	0.35
Middle of Photic	0.50	0.60	0.46	0.50	0.55	0.55
Bottom of Photic	1.07	1.18	0.92	1.03	1.11	1.08

Table 14. Chlorophyll-a concentration for each location in photic depth.

Depth of station	Chlorophyll-a (mg/m^2)					
	WL 1	WL 2	WL 3	TL 1	TL 2	TL 3
Surface of Photic	1.9215	2.3100	2.3205	3.8360	2.0720	9.0825
Middle of Photic	3.1900	3.3960	2.5530	3.5950	2.4750	3.6465
Bottom of Photic	12.6260	6.6906	4.4436	7.5808	7.1706	6.4692
Average	5.9125	4.1322	3.1057	5.0039	3.9059	6.3994

Table 15. Primary productivity of Lahor reservoir for each location and photic depth.

Depth of station	Primary productivity (mg C/m^2/day)					
	WL 1	WL 2	WL 3	TL 1	TL 2	TL 3
Surface of Photic	84.1529	94.1568	94.4177	128.2964	88.1143	217.0470
Middle of Photic	114.6465	119.1074	100.0805	123.3175	98.2040	124.3921
Bottom of Photic	167.0432	134.2515	112.7887	150.8789	129.7168	175.3046
Average	121.9475	115.8386	102.4290	134.1643	105.3450	172.2479

Table 16. Adjustment result of primary productivity in Lahor reservoir for each location.

Depth of station	Primary productivity (mg C/m^2/day)					
	WL 1	WL 2	WL 3	TL 1	TL 2	TL 3
Surface of Photic	0.0842	0.0942	0.0944	0.1283	0.0881	0.2170
Middle of Photic	0.1146	0.1191	0.1001	0.1233	0.0982	0.1244
Bottom of Photic	0.2654	0.1801	0.1403	0.1944	0.1879	0.1765
Average	0.1670	0.1343	0.1128	0.1509	0.1297	0.1753

Table 17. Conversion of primer productivity into fish weight (gr/m^2/day) for each location.

Depth of station	Fish weight (gr/m^2/day)					
	WL 1	WL 2	WL 3	TL 1	TL 2	TL 3
Surface of Photic	0.0084	0.0094	0.0094	0.0128	0.0088	0.0217
Middle of Photic	0.0115	0.0119	0.0100	0.0123	0.0098	0.0124
Bottom of Photic	0.0265	0.0180	0.0140	0.0194	0.0188	0.0176
Average	0.0167	0.0134	0.0113	0.0151	0.0130	0.0175

Table 18. Fish production in Sutami reservoir (ton/2,600,000 m^2/year).

Depth of station	Fish weight (ton/2,600,000/year)					
	WL 1	WL 2	WL 3	TL 1	TL 2	TL 3
Surface of Photic	7.9861	8.9355	8.9602	12.1753	8.3620	20.5978
Middle of Photic	10.8800	11.3033	9.4976	11.7028	9.3196	11.8048
Bottom of Photic	25.1818	17.0942	13.3178	18.4476	17.8321	16.7469
Average	15.8524	12.7405	10.7037	14.3184	12.3101	16.6364

Table 19. Maximum and minimum values, average, deviation, variation coefficient of Lahor reservoir.

Depth of station	N	min	max	average	STDEV	CV
Surface of Photic	6	7.9861	20.5978	9.2838	4.8536834	52.28099329
Middle of Photic	6	9.3196	11.8048	10.5407	1.0916126	10.35621138
Bottom of Photic	6	13.3178	25.1818	18.3747	3.9001634	21.22570666
Average	6	10.7037	16.6364	13.7602	2.2559506	16.39470105

CONCLUSIONS

The average potential of Sutami Reservoir ranges between 73.1836 - 166.8514 tons/year, meanwhile in Lahor Reservoir, this ranges between 10.704 - 16.636 tons/year. The management of reservoir was held by managing planning of integrated fishery reservoir with reservoir zonation approach. Based on the result, it is recomended for competent stakeholders to create Integrated Management Fishery Planning for Sutami and Lahor reservoirs.

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ENVIRONMENTAL FACTORS REGULATING THE DOMINANCE SPECIES OF PHYTOPLANKTON IN LAKE MANINJAU, WEST SUMATERA, INDONESIA

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ABSTRACT

Together with the occurrence of algal bloom, high concentration of nutrient is always associated with eutrophication in lakes. However, direct links between nutrient composition and the dominant phytoplankton taxa in eutrophic lakes are often limited. Using canonical correspondence analysis (CCA), we elucidated phytoplankton assemblage and the associated nutrient and other environmental variables in a highly eutrophic Lake Maninjau, West Sumatera, Indonesia. Subsurface water samples were collected at 8 study sites in April and July 2009, April 2014, August 2015 and March 2016 to determine species composition and distribution of phytoplankton and physico-chemical parameters including Secchi depth, temperature, conductivity, dissolved oxygen (DO), pH, ammonium (NH_4^+-N), Total nitrogen (TN), Phosphate (PO_4^--P) and Total phosphorus (TP). Succession in the assemblage was observed in August 2015 where the dominance of cyanobacteria was replaced by diatoms and dinoflagellates. Cyanobacteria taxa of Anabaena sp., Cylindrospermopsis raciborskii *were associated with TP, TN and phosphate while Microcystis and Oscillatoria were associated with ammonia.* Planktolyngbya sp. *and* Ceratium hirudinella *was related to nitrate while* Chroococcus sp*. was linked to temperature, pH and phosphate concentration. Our results confirm that changes in nutrient compositions may have implications for the dominance of taxa in phytoplankton assemblage*

Keywords: canonical correspondence analysis, cyanobacteria, eutrophication, nutrients,

INTRODUCTION

Water eutrophication has become a worldwide environmental problem in recent years. Lake eutrophication is affected by a wide range of anthropogenic and natural factors. The potential effect of artificial or cultural eutrophication includes the increase of phytoplankton biomass and shift to bloom-forming alga species that might be toxic, a decrease of water transparency, increased of fish kill incidence and oxygen decline (Liu *et al*., 2010; Dokulil & Teubner, 2011). In Indonesia, most of major lakes are also facing environmental problems including eutrophication, sedimentation, and decline in surface area. Lake Maninjau is one of the 15 Indonesian lakes and identified as a National Priority Lakes for conservation (State Minister for the Environment, 2011). Eutrophication in Lake Maninjau is as much a threat to the lake ecosystem such as the occurrence of *Microcystis aeruginosa* blooming was found in 2000 and 2011, the incidence of fish kill and oxygen decline were often occurred in this lake (Syandri, 2000; Tanjung, 2013; Ministry of Environment, 2011, Sulastri *et al*, 2015). *Microcystis aeruginosa* blooming in Lake Maninjau was indicated by the high of chlorophyll-a concentration (62.97 $\mu g.L^{-1}$ and 168.7 $\mu g.L^{-1}$) respectively (Sulastri *et al*., 2001; Tanjung, 2013). Lake Maninjau has been utilized to generate electric power since 1983 and consequently the lake water rarely flows through its natural outlet into Batang Antokan River and flushing the lake water out through the intake. Lake Maninjau has also been utilized to culture the fish in floating cages since 1990. The number of cages has increased continuously to the point where it exceeds the carrying capacity limit. The development of fish culture in cages is suspected of increasing the organic material level and stimulating Cyanobacteria blooming, change the water quality and increased incidence of fish kill in Lake Maninjau (Sulastri 2009; Lukman, 2013; KLH, 2011)

Monitoring phytoplankton composition in this lake showed that the composition changed from Chlorophyta to Chrysophyta in 2001 and 2005 respectively, then in 2009 and 2014, phytoplankton was dominated by Cyanophyta (Cyanobacteria). There was also a shift in the dominant of phytoplankton species in Lake Maninjau from time to time observation. *Synedra ulna* was dominant in October 2001 and *Cylindrospermopsis raciborskii, Anabaea affinis*, *Aphanizomeon* was dominant in April and June 2009, while Plangtolyngbia was dominant in April 2014 *Microcystis aeruginosa* which has been blooming in 2000 and October in 2011 was not dominant during observation (Sulastri *et al*., 2015). The abundance of phytoplankton species is depended on a variety of ecological factors, particularly nutrient status, illumination, turbulence, and temperature. Together with the occurrence of algal bloom in high concentration of nutrient are always associated with eutrophication in lakes. However, direct links between nutrient composition and the dominant phytoplankton taxa in eutrophic lakes are often limited. This study was to elucidate phytoplankton assemblage and the associated nutrient and other environmental variables in a highly eutrophic Lake Maninjau, West Sumatera, Indonesia.

METHODS

Research location

Lake Maninjau is located in West Sumatera, between 100° 08'5384" E to 100° 14'02.39" E and 0° 14' 52.50" S to 0° 24' 12.17"S (**Figure 1**) at 462 m above sea level, with a surface area of 9,737.50 ha, an average depth of 105.5 m and a maximum depth of 168 m (Fachrudin *et al*., 2002). The volume of water stored in the lake (V), shore line (L) and shore line development (DL) is 10.33 billion m^3, 52.7 km and 1.51 km/km^2 respectively (Fachrudin *et al*., 2010). There are two peak rainy seasons on April to May and October to November. The rainfall is relatively high all the years and dry season is not so dominant (Apip, 2004).

Data collection

Subsurface water samples were collected at 8 study sites (**Figure 1**) on September and October in 2001, April 2009, June 2009, April 2014, August 2015, and March 2016 to determine species composition and distribution of phytoplankton and physico-chemical parameters including Secchi depth, temperature, conductivity, dissolved oxygen (DO), pH, ammonium (NH_4^+-N), Total nitrogen (TN), Phosphate (PO_4^--P) and Total phosphorus (TP). Physical description of research station was presented in **Table 1**.

Physical and Chemical measurement

Water temperature, pH, DO, and conductivity data was collected using a water quality checker (Horiba U-10), while water transparency was examined by the measurement of the Secchi depth. The vertical distribution of Temperature, Dissolved Oxygen (DO) and pH was conducted by discrete measurement using Water Quality Checker (WQC, Horiba U-10) at the deepest part of the lake (DM7).

The annual and daily of temperature data was obtained from online monitoring measurement installed in Lake Maninjau by Research Center for Limnology, Indonesian institute of Sciences.

Nutrients (Total Nitrogen (TN), Total Phosphorus (TP), ammonia, and nitrate) were analyzed at the Hydrochemistry Laboratory, Research Centre for Limnology, Indonesian Institute of Sciences (LIPI). Samples of nutrients were preserved according to APHA (1999). Total Nitrogen (TN) was measured using the persulphate digestion method (APHA, 1999), then followed by nitrate-N analysis using the Brucine method (APHA, 1975). Total Phosphorus (TP) was determined using the persulphate digestion method and followed by phosphate-P analysis using the Ascorbic Acid method (APHA, 1999).

Table 1. Physical description of research stations.

Name of Station	Physical description
Bayur	Crowded area for fish culture
Koto Gadang	A few areas for fish culture, surrounding area is agricultural
Muko-Muko	Near outlet (Batang Antokan), area for aquaculture
Sigiran	Crowded area for aquaculture, surrounding area is human settlement
Pandan	Area for aquaculture
Sungai Batang	Area for aquaculture, surrounding area is agricultural
DM 4	Central part of lake (145 m depth), no aquaculture
DM 7.	Deepest part of lake (165 m depth), no aquaculture

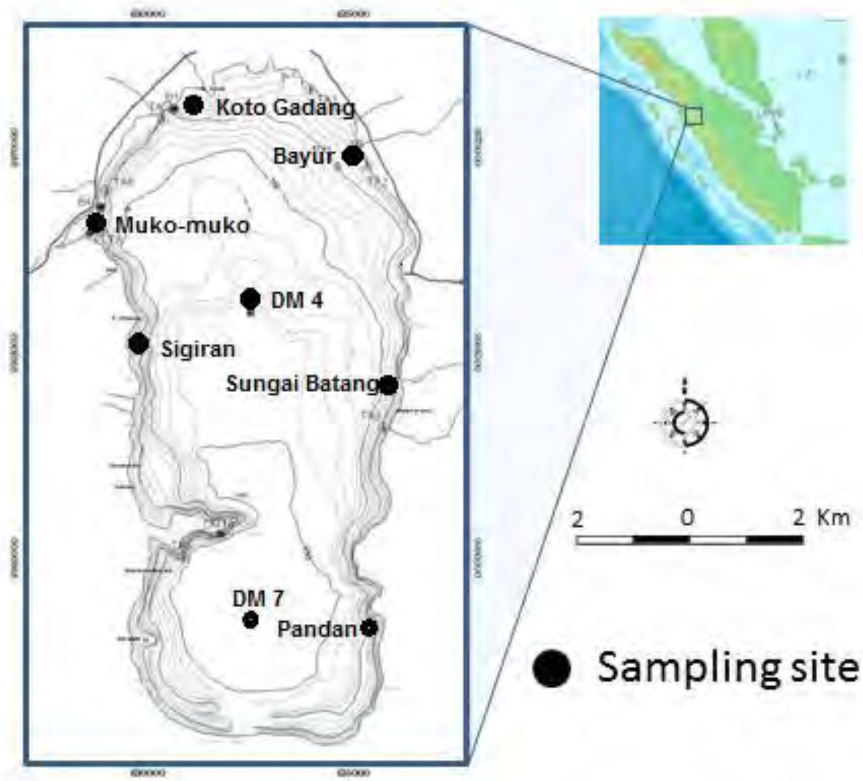


Figure 1. Research location

Phytoplankton Analysis

Phytoplankton sample was collected at the euphotic zone (surface water and Secchi depth) by filtering 2 L of water through plankton net with a 40 µm mesh size. The samples were preserved with 1% lugol solution for taxonomic study in the laboratory. Phytoplankton species was identified according to Prescott (1951), Scott and Prescott (1961), Baker and Fabro (1999), Gell *et al.* (1999) using an inverted microscope with a magnification of 400 x. Quantitative analysis of phytoplankton used the Lackey Drop Micro Transect method as presented in APHA (1992). Direct links between nutrient composition and the dominant phytoplankton taxa was analyzed using canonical correspondence analysis (CCA),

RESULTS AND DISCUSSIONS

Water quality

Distribution of temperature in Lake Maninjau showed that water column was stratified thermally during observation. The warmer water was found in upper layer of water column (**Figure 2**). However daily and annual monitoring showed that the stratification of water temperature in this lake was not permanent over the year (**Figure 3**). The annual of temperature distribution in 2014 showed that there was not a gradient temperature vertically in the water column for some certain periods (**Figure 3**). It indicated that mixing of water column was occurred many times during of the year. Daily temperature distribution also indicated that mixing of water column was of occurred in certain days. This pattern of water mixing in Lake Maninjau may influence the dynamic of phytoplankton growth.

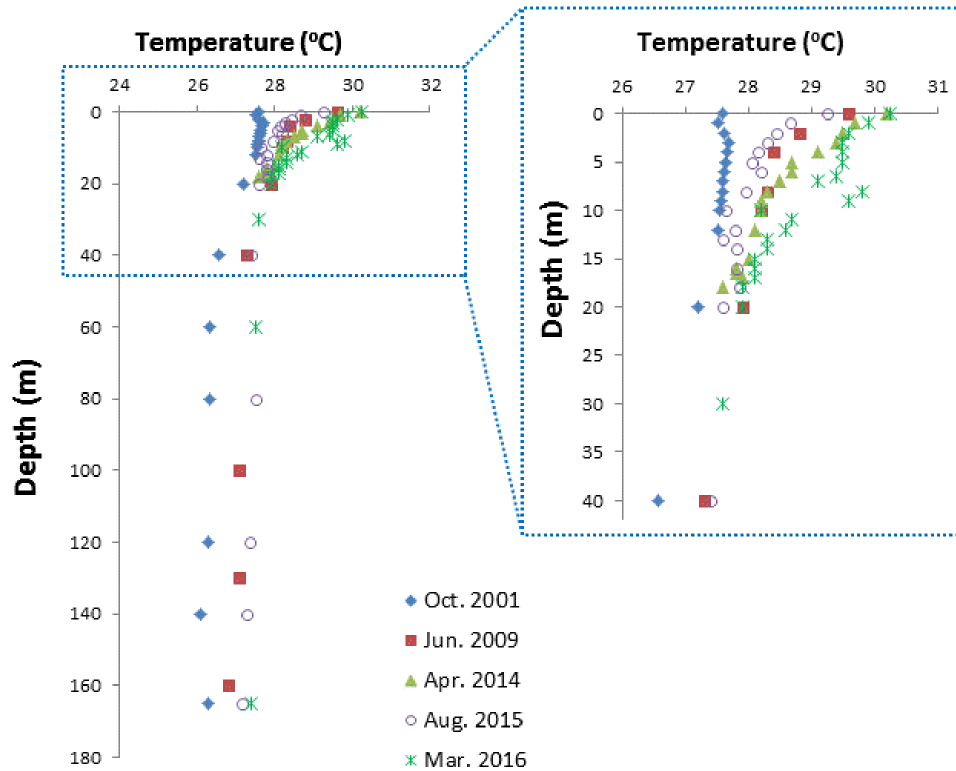
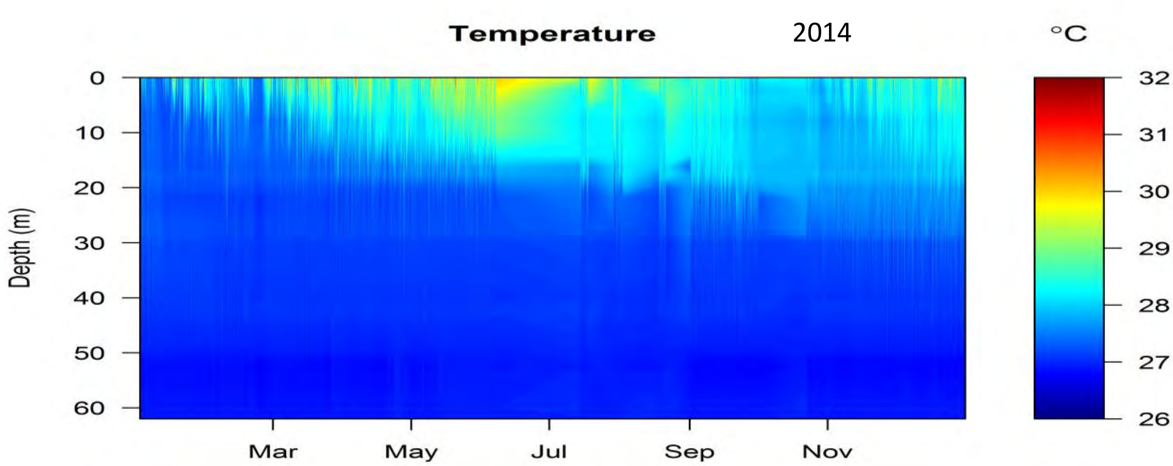


Figure 2. The profile of temperature distribution in Lake Maninjau



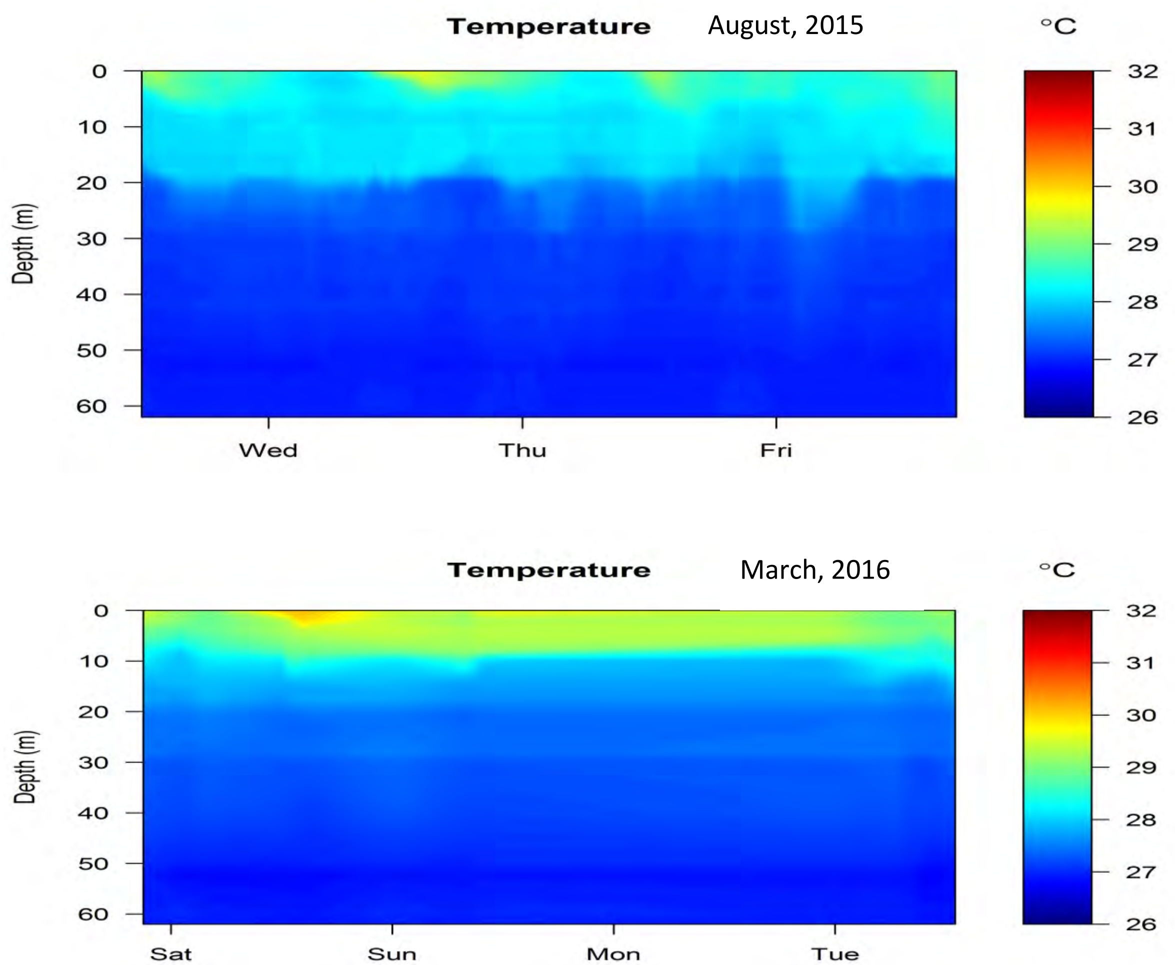


Figure 3. The annual and daily of temperature distribution in Lake Maninjau (Budisantoso *et al*, unpublished)

Stratification and mixing of water in lake may be influenced by the local weather condition. According to Wetzel (2001) in a stable water column and hot weather, the thermocline can occur near the surface layer and when the epilimnion zone is exposed by strong wind, the thermocline layer extends to the deeper layer. According to Apip *et al* (2003), the regional climate can be used for indicator of water mixing in Lake Maninjau. Transition of dry season to rainy season is in March to April and September to October indicated by the weather disturbance such as a strong wind with the rate of 111.6 to 161.5 km/day.

The dissolved oxygen (DO) profile in the middle part of lake showed that the anoxic zone increased and rose to the upper water column during observation (**Figure 4**), In October 2001 and June 2009 the anoxic zone was found in 40 m depth then in April 2014, August 2015 and March 2016 anoxic zone was found above of 20 m depth. Eutrophication cause increasing of biological production such as phytoplankton. Therefore, the consequence of high biological production is increasing the organic materials and the bacterial oxygen demand which itself may deplete oxygen demand to decompose the organic materials (Happer,1992). In Lake Maninjau, the increasing of organic materials may not only from biological production but also input from waste of aquaculture activities.

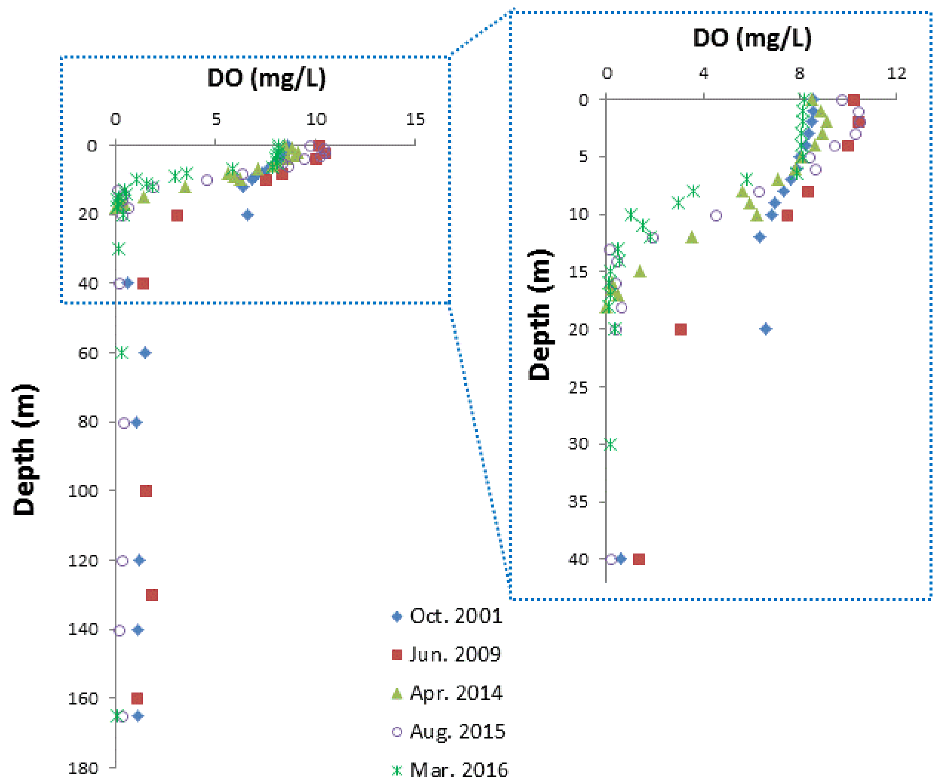


Figure 4. The distribution of dissolved oxygen (DO) in the center part of Lake Maninjau.

The value of pH showed that the surface water was more alkaline than that in the bottom (**Figure 5**). The pH in the sub surface layer is more than 8 (9 to 10) especially in April 2014 and August 2015. According to Goldman and Horne (1983), most lakes have a pH ranging from 6 to 9, and pH increases when vigorous photosynthesis occurs in productive lakes. In eutrophic lake, day time photosynthesis may elevate pH value (Happer, 1992).

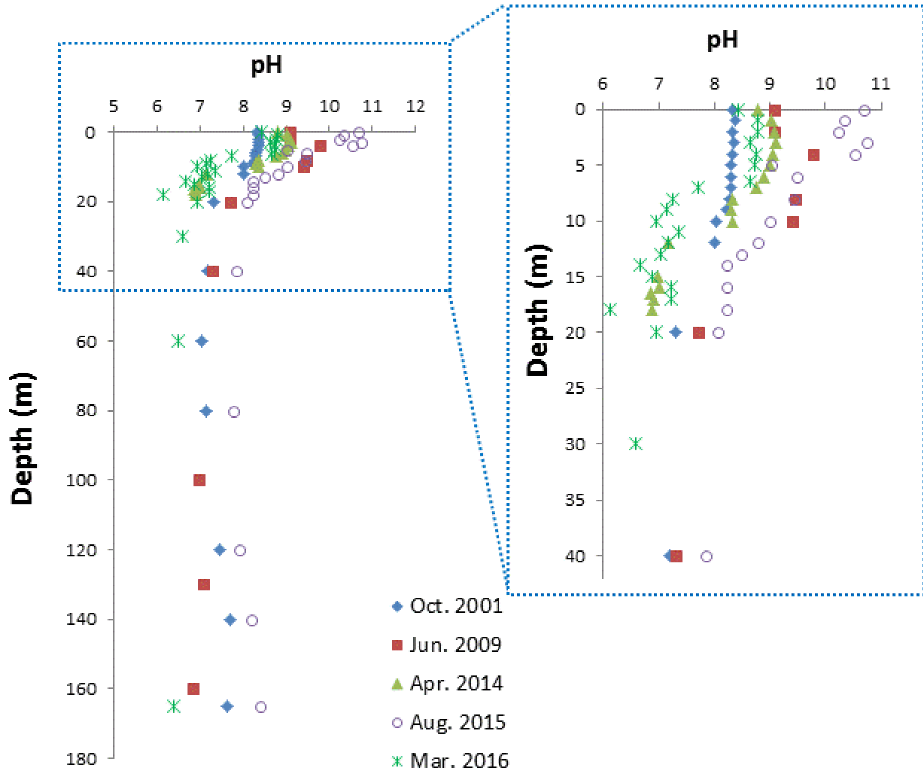


Figure 5. The profile of pH distribution in Lake Maninjau

The average value of some water quality parameter was presented in **Table 2**. The value of Secchi depth range from 1.7- 3.8 m and the low value was found in Jun 2009 and August 2015. The low value of Secchi depth is common found in eutrophic lake. The Secchi depth of Lake Rawa Pening a shallow eutrophic lake in Central Java range from 0.63-0.95 m and in Lake Ranau a mesotrophic lake in South Sumatera, the value of Secchi depth range from 5.0-7.5 (Sulastri *et al,* 2016; Sulastri *et al*, 2000). Secchi depth is also influenced by time of day, cloud cover, and wind action (Hutchinson, 1957). It was also reported that there are some important factors influence the Secchi depth such as autochthonous production (the amount of plankton, detritus, etc.) (Hakanson & Boulon, 2003). The detritus such as the waste from fish aquaculture and phytoplankton may influence the Secchi depth in Lake Maninjau.

The temperature value was commonly found in tropical lakes. The lower value was found in September and October 2001 or in rainy season and the highest value was found in March 2016. Lake Maninjau has a normal conductivity condition with the value ranging from 100 – 140 $\mu S \cdot cm^{-1}$. Many equatorial lakes in the forest regions have a conductivity of less than 600 $\mu S \cdot cm^{-1}$ (Payne, 1986). The value of pH ranged from 8.28 – 8.69 which showed an alkaline condition. As previous reported that in eutrophic lake such as Lake Maninjau, day time photosynthesis may elevate pH value (Happer, 1992). The highest value of pH was found in March 2001, it was also compliment with the highest of temperature in this month.

The DO concentration was fluctuated during observation (**Table 2**). The lower values was 2.88 $mg.L^{-l}$ and 4.35 $mg.L^{-l}$ found in April 2009 and August 2015. The fluctuated of DO concentration may be related to the water mixing phenomenon. It was indicated by thermal stratification in Lake Maninjau was not stable. Therefore, when the water mixing phenomenon occurred, the anoxic water zone found at 20 m depth could easily move to the upper layer of water.

Total phosphorus concentration range from 0.022 to 0.071 $mg.L^{-1.}$ In general, the concentration of total phosphorous demonstrated the condition of eutrophic lake (Table 2). The average concentration total phosphorous in epilimnetic zone for eutrophic lake range from 30 to 100 $\mu g.L^{-1}$ (Vollenweider, 1968 *in*

Wetzel, 2001). The highest value of TP was found in October 2001 and the lower value was found in March 2016.

Tabel 2. The average value of some water quality parameters and nutrient concentration in euphotic zone

	Time observation						
Parameters	Sp.01	Oc.01	Ap.09	J.09	Ap.014	Ag.015	Mr.016
Secchi depth (m)	3.8	3.3	2.25	1.7	2.1	1.9	2.98
Temperature (^oC)	27.96	27.83	28.65	29.29	29.61	29.34	30.63
Conductivity ($\mu S.^{-cm}$)	128	140	113	100	132	129	110
pH	8.39	8.40	8.44	8.60	8.55	8.24	8.69
DO ($mg.L^{-l}$)	6.82	8.52	2.88	6.00	8.21	4.35	7.76
TP ($mg.L^{-l}$)	0.048	0.071	0.039	0.048	0.065	0.032	0.022
$P\text{-}PO_4$ ($mg.L^{-l}$)	0.017	0.015	0.007	0.015	0.017	0.010	0.005
TN ($mg.L^{-l}$)	0.814	0.361	1.486	0.582	1.058	0.974	0.415
$N\text{-}NO_3$ ($mg.L^{-l}$)	0.035	0.053	0.275	0.069	0.667	0.217	0.028
$N\text{-}NH_4$ ($mg.L^{-l}$)	0.150	0.055	0.100	0.160	0.026	0.130	0.060
TN/TP ($mg.L^{-l}$)	17	5.1	39.7	13.3	21.5	48.2	20.2

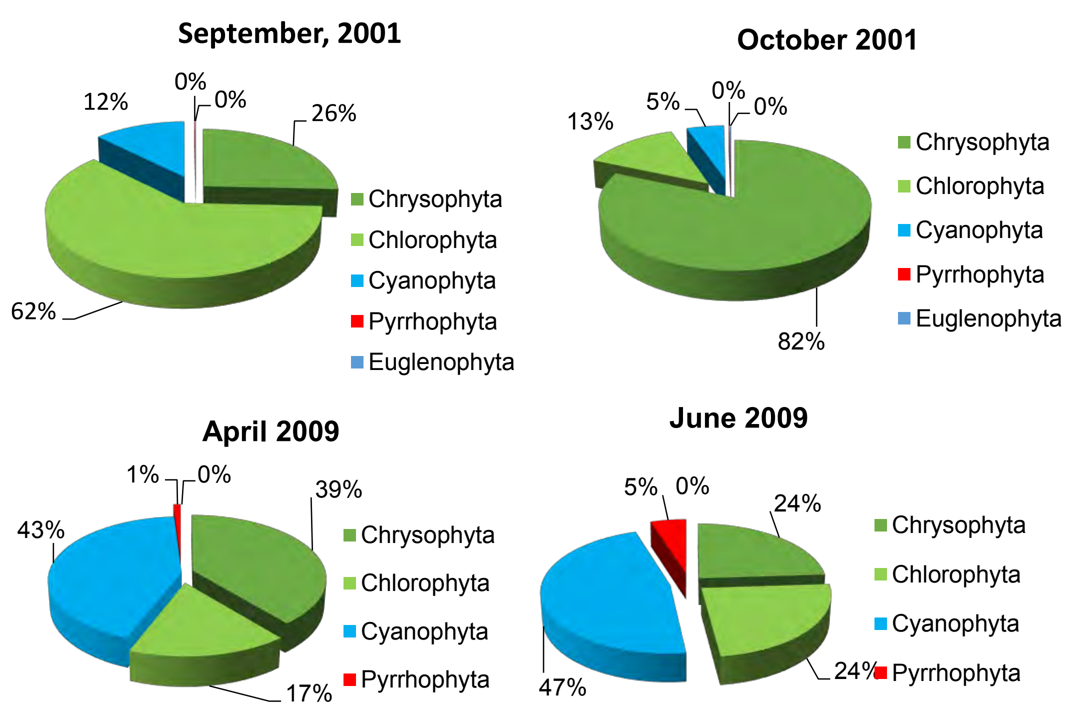
*Remark: Sp: September, Oct: October, Ap: April, J: June, Ag: August, Mr: March

The high concentration of TP in October 2001 may be related to the input of TP from the run off. As reported that October is the second of peak rainy season in this area (Apip, 2004). The lowest TP in March 2016 may be related to nutrient uptake by phytoplankton growth. The highest temperature in March supported the photosynthesis of phytoplankton. This is also compliment with the lowest of phosphate concentration and the high value of pH in March 20016 (**Table 2**). Total nitrogen range from 0.361 to 1.486 $mg.L^{-l}$ In general, total nitrogen concentration demonstrated the condition of eutrophic lake (**Table 2**).
The average of total nitrogen concentration for eutrophic lake reported range from 0.393 to 6.100 $mg.L^{-1}$ (Wetzel, 2001). The higher total Nitrogen concentration was found in April 2009 and 2014. This is similar phenomenon with the nitrate concentration that the higher value was found in April 2009 and April 2014. April is the first peak of rainy season (Apip, 2004), therefore the high concentration of TN and nitrate in April may input from runoff. Ammonia concentration showed a variability range from 0.055 to 0.160 $mg.L^{-l}$. during observation. The distribution of ammonia is highly seasonal and spatially variable depending upon the level of productivity and the extent of pollution of organic matter (Wetzel, 2001). The value of TN: TP showed a variability, range from 5.1 – 48.2. The variability of TN:TP ratio may be related to TP concentration that the value seems related to run off input

Phytoplankton

The dominant of phytoplankton composition changed from Chlorophyta to Chrysophya and then to Cyanophyta except in August 2015 phytoplankton was dominated by Chrysophyta (**Figure 6**). In March 2016, 87 % of phytoplankton was dominated by Cyanophyta again (**Figure 6**). The changes of phytoplankton in Lake Maninjau may related to the water quality changes (Sulastri, 2015). The variability in blue green-bloom formation has been linked to physical and chemical features include, water column stability buoyancy control, high water temperature, nutrient concentration and low TN:TP ratio. As reported that cyanobacteria (blue green algae) tend to dominate in more stable water column (Reynold, 1984). The dominant of cyanobacteria (blue green algae) during summer period are the water temperature above 25^{o}C and low TN:TP and light intensity in water (Mankiewicz *et al*.2003). Ni *et al*. (2012) in Laugaste *et al*. (2013) hypothesized that a combination of high water temperature (> 24 °C) and a high TP value (> 0.06 mg $L.^{-1}$) together with TN:TP ratios less than 40 enhance the growth of Cyanobacteria and particularly *Microcystis*. In this study, canonical correspondence analysis (CCA) showed that the dominance of Cyanophyta related to high temperature, pH and low phosphate concentration (**Figure 8**) and low TN:TP ratio was not main factor for determining blue green algae dominance. It indicates that low TN:TP ratio may not universal diagnostic tool to assess blue green algae dominance. As reported by An & Jones (2000) that the main

factors influencing blue green algae dominance in Korean Reservoir was weak monsoon which direct linked to strong water stability, high water temperature, reduced silica input, while the low TN:TP ratio was not determining factor in this system.
Furthermore, it was reported that light and pH seem as the second factors influence blue green algae dominance. In this study area, the rainfall is relatively high all the years, dry season is not so dominant and stratification of water is not permanent, but high-water temperature may increase a stable water column and photosynthesis of blue green algae. As reported that pH increased when vigorous of photosynthesis was occurred in eutrophic lake (Goldman & Horne, 1983). Vigorous of photosynthesis, then, increases the phosphate assimilation.
Species dominance of phytoplankton changed in each period observation (**Figure 7**). *Staurastrum* sp was dominance species in September 2001 then October 2001 that *Synedra ulna* was a dominance. From April 2009 to March 2016, dominance species was species belong to blue green algae group (*Aphanizomenon* sp*, Anabaena* sp, *Cylindorspermopsis raciborskii*, *Planktolyngbia* sp. and *Chroococcus* sp). From April 2014 to March 2016 *Monallantus* sp. were found high percentage of dominance species (**Figure 7**). It was reported that *Mollanantus* sp was commonly found in organic pollution waters (Prescott, 1951). In August 2015, Pirrophyta (Dinophyta) also showed a high percentage of composition compared to previous observation.
The high percentage of Pirrophyta was dominated by *Ceratium hirudinela*. As reported that The Dinophyta was commonly found in the water with abundance of phosphate and nitrate. *C. hirudinela* will move to the upper of water and avoid an anoxic zone in the stratified water column (Wehr and Sheate, 2003). The dominance species from Cyanophyta change every period of observation (**Figure 7***). Aphanizomenon* was dominant in April 2009, *Anabaena* and *Cylindrosperpsis raciborskii* was dominant in June 2009, *Planktolyngbia* was dominant in April, 2014 and *Chroococcus* sp.was dominant in March 2016. Canonical correspondence analysis (CCA) showed that the environmental factors separated each dominance of species of phytoplankton (**Figure 9**).



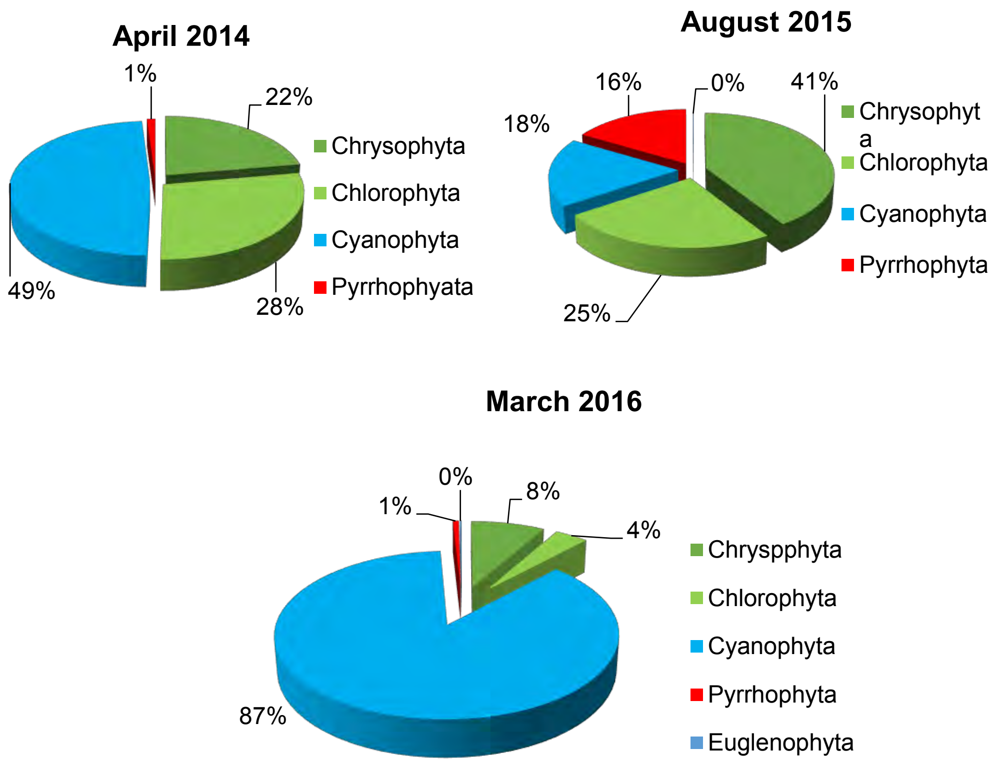


Figure 6. Phytoplankton composition in Lake Maninjau

The high percentage of Synedra sp related to high concentration of phosphate, TP and TN. The high presented of *Staurastrum* sp *Aphanizomenon sp, Anabaena.sp*. related to, high ammonia (N-NH_4) concentration, *Cylindorspermopsis raciborskii* related to high TP and TN concentration. *Planktolingbya* was related to high nitrate and conductivity nitrate value while *Chroococcus* was related to high temperature and pH. Reynolds (2006) in Laugaste *et al,* (2013) pointed out that an experiments of mineral N forms, particularly NH_4-N, are important for N_2 fixers and also for *Microcystis* growth. It seems the change of species dominance of phytoplankton in Lake Maninjau often occurred in Lake Maninjau. As reported that Reynolds' possibility matrix showing the most likely phytoplankton assemblages as a function of nutrient and water mixing (Harris, 1986). Therefore, unstable stratification of water temperature may also be influenced the variability of species dominance in Lake Maninjau.

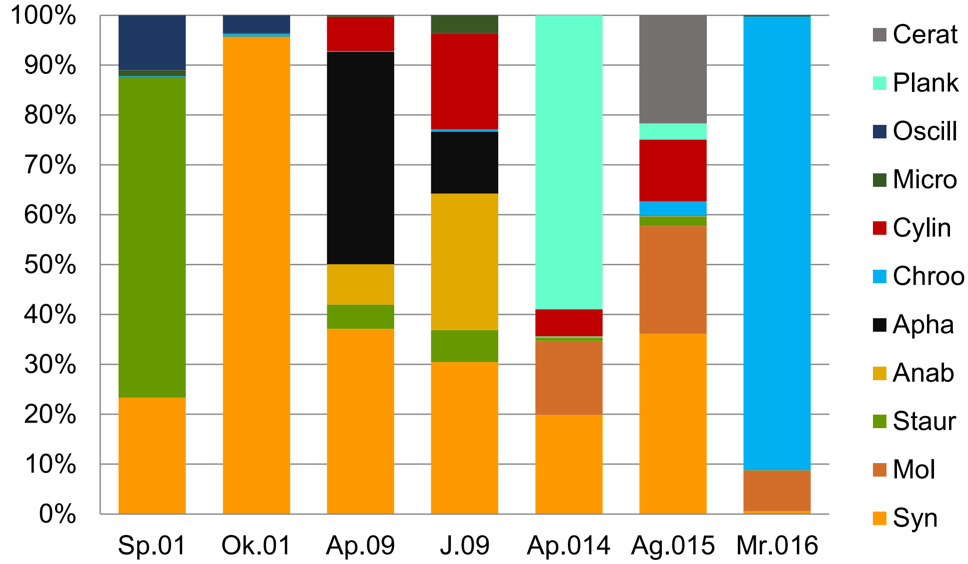


Figure 7. The percentage of phytoplankton dominant in Lake Maninjau

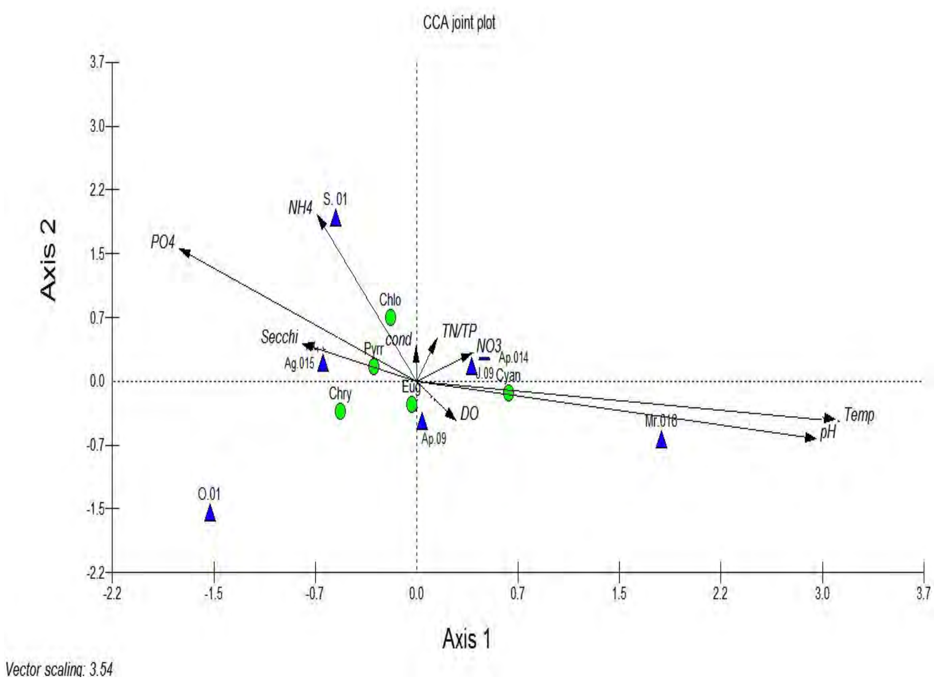


Figure 8. Canonical correspondence analysis (CCA) biplot of phytoplankton composition for seven observations and seven water quality parameters

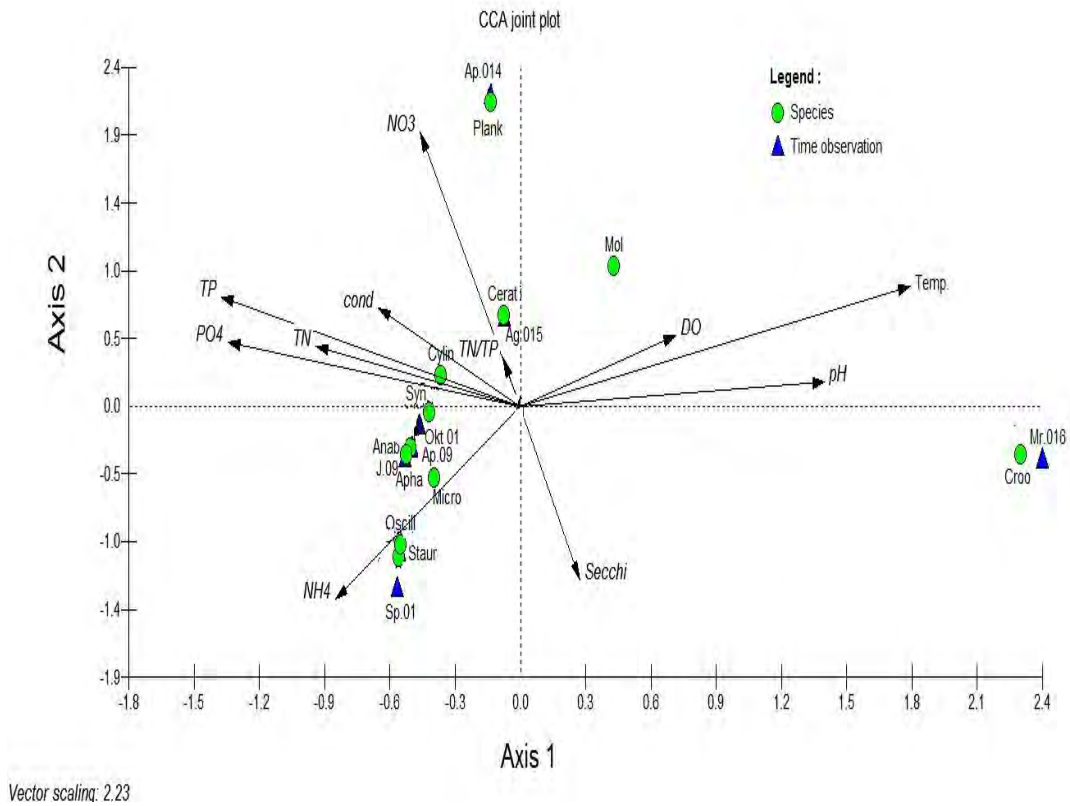


Figure 9. Canonical correspondence analysis (CCA) biplot of phytoplankton species for seven observations and 7 seven water quality parameters

CONCLUSIONS

Stratification water column in Lake Maninjau was not permanent or weak. Secchi Depth value, TN and TP concentration indicated Lake Maninjau was a eutrophic Lake, Phytoplankton composition change from Chlorophyta to Chrysophyta then to Cyanophyta (blue green algae). The dominance of Cyanophyta related to temperature, pH dan phosphate. The dominance sp*ecies of phytoplankton change from Staurastrum sp to Synedra ulna then to species from blue green (Ananbaena sp, such as Aphanizomenon sp, Cylindrospermopsis raciborskii*, *Planktolyngbia* sp and *Chroococcus sp*). Each dominance species was related to different environmental factors, the dominance *Synedra ulna, Cylindrospermopsi raciborskii*, *Anabaena*, *Aphanomizon* were related to the high of TP, TN and phosphate concentration, while the dominance of *Staurastrum*, *Microcystis and Oscillatoria* related to high concentration of ammonia. The dominance of *Planktolyngbia* sp *Ceratium hirudinela* were related to the high of nitrate concentration while the dominance of *Chroococcus* sp was linked with low phosphate concentration, high temperature and pH value. Our results confirm that changes in nutrient compositions and unstable of water column stratification may have implications for the dominance of taxa in phytoplankton assemblage in Lake Maninjau.

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DIATOMS, WATER QUALITY OF TOBA LAKE AND ITS MANAGEMENT

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ABSTRACT

Toba Lake is one of the largest lakes in the world: 1,124 km^2 wide, 508 meter-depth; total volume of water 256.2 x 10^9 m3, and 2,486 km^2 of total catchment area. There is Samosir Island in the centre of Toba Lake. Toba Lake has 19 inlets (rivers) but only has 1 outlet i.e. Asahan River. The main functions of Toba Lake are for hydroelectricity power, resource for drinking water, transportation, tourism, irrigation, and fish culture. The town development in Toba Lake side and Samosir Island had induced water quality deterioration. This research was conducted in order to study the diatoms and water quality of Toba Lake, particularly in Parapat and Tomok Harbours and its management. Water samples were taken on August 2014 from 3 sites for diatom and water quality analysis. Identification of diatoms was done using microscope with 1,000X magnification. Based on this research, the main problem of water quality in Toba Lake was heavy metals of copper (Cu) that exceeded Indonesian water quality criteria for all class, a high concentration of total nitrogen (1.085-2.03 mg/L) that was in the state of mesotrophic – hypereutrophic; and a high concentration of total phosphorous (0.37-0.42mg/L), that was in the state of hypertrophic. Based on chlorophyll-a Toba Lake, particularly in the harbor of Parapat and Tomok, as well well near fish culture cage is in the state of hypereutrophic. pH in Toba Lake were in the range of 7-8. There are 31 diatom species found in Toba Lake, the domination of Ctenophora pulchella Kutzing, Gomphonema brasiliense Grunow, Denticula vanheurcki Brun, Navicula aurora Sovereign, Synedra famelica (Kutzing), Fallacia pygmaea (Kützing) Stickle et Mann, *and* Gomphonema brasiliense Grunow *are more indicated pH rather than trophic state.*

Keywords: Toba Lake, diatom, water quality, hyper-eutrophic, *Denticula, Fallacia*

INTRODUCTION

Toba is the largest lake in Indonesia, with the large unique peninsula called Samosir Island in the midle of the lake. Geographycally, Toba Lake located in Bukit Barisan highlands in North Sumatra Province, situated 175 km Southern of Medan City, and parts of 7 regencies. Toba Lake is located in coordinates of 980 31' 2"E – 980 09' 14"E and 20 19' 15"N – 20 54'02"N, and 903 meters above sea level. Geologically, Toba Lake is resulted of volcanic eruption 74,000 years ago and became the largest caldera in the world (Chesner, 2011). Administratively, Toba Lake included 7 regency areas, namely regency of Karo, Simalugun, Dairi, Toba Samosir, Samosir, Humbang Hasundutan, and North Tapanuli.

The Toba Lake has a surface area of 1,124 km^2, and maximum depth 508 meters, with the total volume of water around 256.2 x 10^9 m^3, and catchment area 2,486 km^2 (Lukman and Ridwansyah, 2010). Toba Lake have 19 inlet (rivers) enter to Toba Lake, but only has 1 outlet: Asahan River which flows east to the Strait of Malacca. The main function of Toba Lake are sources for drinking water, hydroelectricity power, tourism, transportation, agriculture, and culture (Ministry of Environment of Republic Indonesia, 2011). The development of hydroelectricity dam at the mouth of Asahan River has increased retention time that limit the flushing of nutrients from Toba Lake (Lehmusluoto, 2000). The water retention time of Toba Lake upwards of 81 years with oligomictic water stratiphication (Lukman & Ridwansyah, 2010).

Ecologically, the terrestrial of water catchment area, riparian zone, and eutrophic lake are the main problem on the Toba Lake. The problems of Toba Lake in the water catchment area are illegal logging, illegal mining, and agriculture. The problems in the riparian zone are mining, land occupation become residential, tourism, fascilities and infrastructure, source of domestic and agricultural waste. Meanwhile, eutrophication, floating fish cage, domestic, agricultural, husbandary and business wastes in the waterbody had induced water hyacinth bloom (Ministry of Environment & Forestry of Republic Indonesia, 2016). The significant concerns throughout the watershed is the lack of wastewater management (Lehmusluoto, 2000).

Toba Lake was habitat for some various aquatic organisms, particularly for endemic fish of *Lissochilus sumatranus* and *Labeobarbussoro*, locally known as ikan batak, and *Corbiculatobae* or remis Toba[3]. There were also found other fish, macrobenthic, phytoplankton, zooplankton, and emerge, floating and submerged macrophytes. *Eichornia crassipes, Potamogeton, Myriophyllum, Ceratophyllum, Hydrylla,* and *Chara* had reported found since 1939. It was reported that there were some kind of specific diatoms found in Toba Lake. *Denticula vanheurckii* is one species that found epiphytic in *Potamogeton* sp in 1929 (Hustedt, 1935).

Diatoms are microalgae that dominated almost in all aquatic ecosystem. Their silicious unique of cell wall persist in sediment and able to tell the environmental condition across the time. Diatoms glass walls are usually well preserved in sediments and they are very good bioindicators of water quality changes. Many studies have demonstrated the value of diatoms as a bioindicator of water. Their value in monitoring relates to a range of their characteristics. Being primary producers diatoms play significant roles in the food web. They are distributed worldwide in saline or freshwater, have short life cycles and quick response to environmental change. Some species are sensitive across ecological gradients and they are easily sampled and analysed at low cost (Soeprobowati et al., 2016).

The composition and abundance of planktonic algae have not changed in Toba Lake at least during the last 70-year period, are most responsible for influencing water clarity. There was strong correlation between free floating algae and algal growth rate at the most greatest shoreline development as well as attached algae. In the central portion of the lake, the algal density was low, while the areas nearest to the Parapat tourist area and south shore developments showed an increase of algal production. Community wastes and waste waters had stimulate algal growth. The highest nutrient deposition onto the lake may be found near the areas of greatest development. The nutrient sources from the numerous Toba watersheds is mostly related to the extend of disturbance of soils, particularly pronounced in Samosir (Lehmusluoto, 2000).

The town development in Toba Lake side and Samosir Island had induced water quality deterioration. Long term environmental monitoring and research offers opportunity for providing data as a base for the best future planning and regulatory decisions. Based on those background, this research was conducted in order to study the diatoms and water quality of Toba Lake, particularly in Parapat tourist area and Samosir (Tomok) Harbours in comparison with site around traditional net fish culture.

METHODS

Water samples were taken from 3 sites with 3 replications: Parapat Harbour (T1), Tomok Harbour (T2), and nearby fish culture cage (T3, **Figure 1**) for diatom identification and water quality analysis for heavy metals of Pb, Cd, Cu, Cr, Total Nitrogen, Total Phosphorous, SiO_2, and chlorophyll-a. Heavy metals were analyzed using AAS, Total Nitrogen with micro Kjeldahl, Total Phosphorus and silicate using Spectrophotometry method, and chlorophyll-a content using extraction and spectrophotometry method. In T1, epiphytic diatoms were collected from *Potamogeton sp*, epilitic diatoms were collected by brush the stone. In T2, epilitic diatoms were collected from the stone. In T3, only collect water sample to identify planktonic diatoms. Diatoms were collected from *Potamogeton* sp and stone by brush 4 cm^2 the thallus and solute in 50 mL aquadest. Diatoms were identified under microscope with magnification of 1,000. The Shannon Wiener diversity and Evennes indices were calculated.

Shannon Wiener Index (H’) (Magguran, 2004).

$$H' = -\sum_{i=1}^{s} (ni/N) \log (ni/N)$$

Note:
H’= Shannon-Wiener Diversity Index
ni = number individual of species -i
N = total indivdual of all species

The H’ value indicates the distribution of abundance species among all the species in the community. High values of H’ would be representative of more diverse communities.

Eveness Index (J)

J = H’/H’max

Note:
J = Eveness index
H' = Diversity index
H_{max} = In S
S = number of species encountered

Dominance Index:

C = □□[n_i/N]

Note:
C = Simpsom dominance index
n_i = number individual of species -i
N = total indivdual of all species

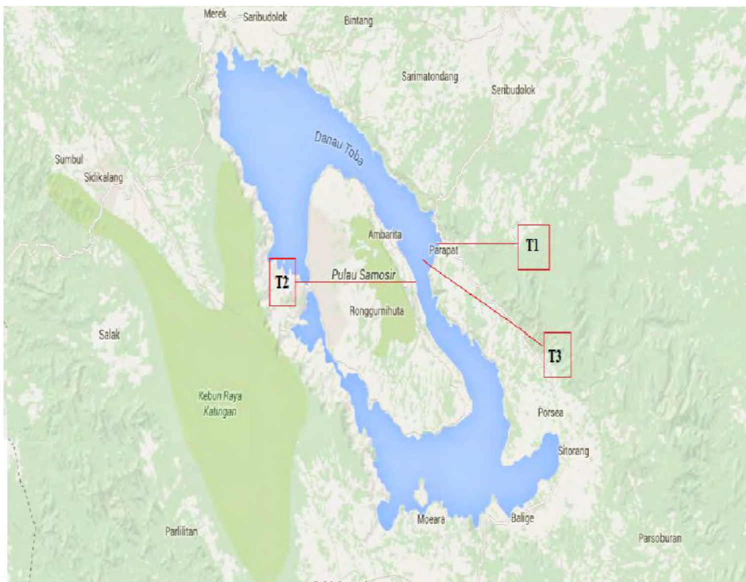

Figure 1. Sites sampling: Parapat Harbour (Ajibata) (T1), Tomok Harbour (Samosir Island) (T2) and nearby floating fish cage (T3)

RESULTS AND DISCUSSIONS

There were at least 31 diatom species identified from Toba Lake that were collected from water (as planktonic sample), epilitic on the rock, and epiphytic on *Potamogeton* sp. The composition of diatom's community consist of 33% symmetric biraphid (*Adlavia, Anomoeoneis*, *Brachysira, Eolimna, Fallacia, Mastogloia, Navicula, Pinnularia,* and *Sellaphora*), 26% asimatric biraphid (*Amphora, Brebissonia,* and *Cymbella*), 16% araphid (*Ctenophora, Fragilaria*, *Synedra,* and *Tetracyclus*), 13% nitzschioid (*Denticula, Nitzschia)*, 3% epithemoid (*Epithemia*), 3% eunotioid (*Eunotia*), 3% surirelloid (*Surirella*), and 3% of monoraphid (*Achnanthidium,* **Figure 2**). Centric species was not found during this research. Usually, in the eutrophic lake, such as in Rawapening Lake, some species of *Aulacoseira* and *Melosira* were found dominantly (Soeprobowati et al., 2012). This might be related to the pH that tent to neutral around 7 whereas in Rawapening Lake tend to alkali (7-9).

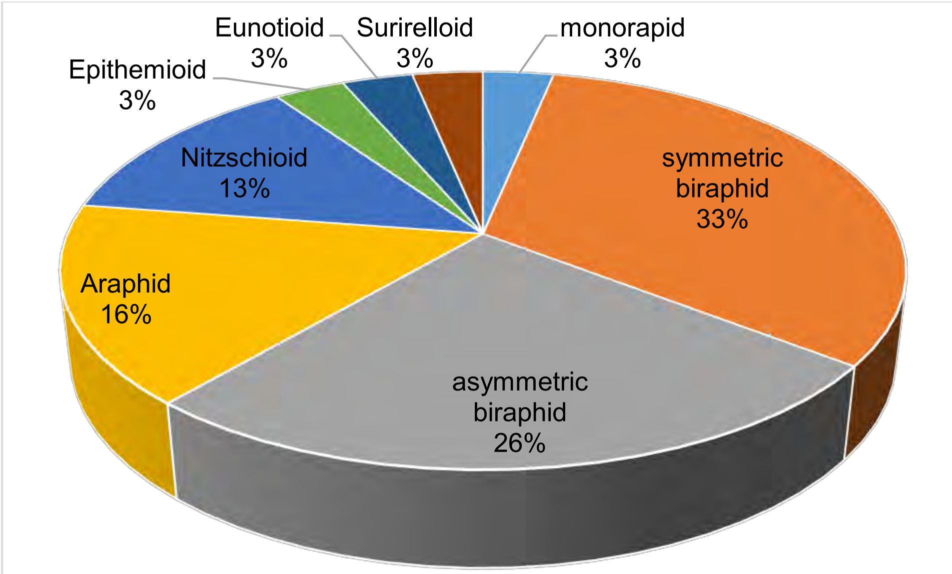

Figure 2. The composition of diatom's community based on morphological categories

The criteria of those grouping are based on morphological categories that is used to provide a visual aid in identification and do not strictly evolutionary. Symmetric biraphid is a diatom that has bilateral symmetry to both apical and transapical axis, and raphe system well developed. This group has the greatest diversity among the freshwater diatoms. Asymmetric biraphid is a diatom with valves asymmetrical to apical or transapcial axis or both, well developed raphe system. Araphid is a diatom that lack of a raphe system therefore lack significantly motility, valve with bilateral simmetry, rimoportulae (labiate process) may be present. Nitzschioid is diatom with bilateral symmetry, valve usually simmetrical to both apical and transapical axes, raphid system well developed, positioned near the valve margin, raphe is enclosed within a canal and may be raised onto a keel. Epithemioid is a diatom with bilateral symmetry, valves asymmetrical to apical axis, raphe system enclosed within a canal and positioned near the valve margin. Eunotioid is characterised by bilateral symmetry, valves often asymmetrial to the apical axis, raphe system is short therefore provides weak motility, raphe loacetd on valve mantle and face, cell may possess 2 or more rimoportulae. Surirelloid is a diatom with bilateral symmetry, raphe system extremely well developed and enclosed within a canal, raphe positioned around the entire valve margin and raised onto a kell. Monoraphid is a diatom with bilateral symmetry, raphe system present on one valve (raphe valve), raphe system absent on one walve (rapheless valve), heterovalvar ornamentation (Spaulding et al., 2010).

The dominant species which has more than 5% relative abundance at T1 are and *Ctenophora pulchella* Kutzing, *Gomphonema brasiliense* Grunow, *Denticula vanheurcki* Brun, Navicula aurora Sovereign, and *Synedra famelica* (Kutzing). At T2 the dominant species are *Ctenophora pulchella* Kutzing, *Fallacia pygmaea* (Kützing) Stickle et Mann, *Gomphonema brasiliense* Grunow, and *Synedra famelica* (Kutzing). At T3 the most dominant species is *Ctenophora pulchella* Kutzing, and *Synedra famelica* (**Table 1**). *Ctenophora pulchella* Kutzing formerly known as *Synedra pulchella*, has a wide range distribution, high conductivity and alkalinity in upland peat and forest rivers at Mayo, Ireland[11]], usually in freshwater of high mineral content (Guiry and Guiry, 2017).

Gomphonema has mucilaginous peduncles for attachment to the substrate making *Gomphonema* more resistant to disturbances (Burliga et al., 2013). The highest values for density and richness of diatoms in the lentic system is partly related to their specialized structures that confer a competitive advantage over other species of different classes in stressfull environmental conditions, but usually also found in lotic environments (Tremarin et al., 2009).

Denticula vanheurckii Brun is one species that found epiphytic in *Potamogeton* sp in 1929 (Hustedt, 1935) and recently is still found in Toba Lake. *D. vanheurckii*, appears more similar morphologically to the Rhopalodiales, especially the genus *Epithemia*. The current accepted name for *Denticula vanheurckii* Brun is *Tetralunata vanheurckii* (Brun) Hamsher, Graeff, Stepanek & Kociolek with type locality Java and Bali

(Hamsher et al., 2014). *Denticula* species are often found in the littoral margins of lakes, ponds and streams with high conductivity, particular species inhabiting either cold mountain streams or hot springs (Krammer, 1988). *Denticula vanheurckii* fossil was also dominant in Buyan Lake Bali in core of 360-289 cm, deposited about 7.7-6.5 cal ky BP indicated pyrite (Fukumoto, 2015). This benthic diatom indicated low organic pollution and alkaline water (Taylor et al., 2007), *Fallacia pygmaea* (Kützing) Stickle et Mann is freshwater diatom of high mineral content; sometimes in polluted water (Guiry and Guiry, 2017).

The highest diversity index are at the station 1 (H '= 3.03) and 2 (H' = 2.91) and the lowest diversity index are at the station 3 (H'=2.14), that indicating the ecosystem stability. Site 3 that located in next to the floating fish cage has the lowest diversity index, lowest number of diatom species due to a high covering water hyacinth in this area.

Based on water quality, the problem in Toba Lake is heavy metal Pb and Cu. The content of Total Nitrogen about 1.085 to 2.03 mg/L and Total Phosporous ranged between 0.37 to 0.42 mg / L (Table 2), indicated hypereutrophic condition. Based on the chlorophyll-a content (Table 2), Toba Lake is eutrophic - hypereutrophic category. Hypertrophic lake has a Total Nitrogen >1.9 mg/L, Total Phosporous > 0.1 mg/L, and chlorohyll-a content >2mg/L (Ministry of Environment Republic of Indonesia, 2008).

This condition had been reported in 2012 that based on average chlorophyll-a data, Toba Lake is classified as eutrophic to hypereutrophic (Lehmusluoto, 2000). The water quality of Toba Lake was moderate to ligh polluted (EPANS, 2014).

Table 1. The composition and relatif abundance of diatoms in Toba Lake

No	Species	T1	T2	T3
1	*Adlafia muscora* Moser, Lange-Bertalot and Metzeltin	1,67	2,94	7,14
2	*Achnantes minutisimum* (Kutzing)	1,67	-	-
3	*Amphora ovalis* (Ehrenberg) Kützing	1,67	-	-
4	*Anomoeoneis sp*	1,67	2,94	-
5	*Brachysira brebissonii* (R. Ross)	1,67	2,94	7,14
6	*Ctenophora pulchella* (Kutzing)	15,00	11,76	28,57
7	*Cymbela amplificata* (Krammer)	6,67	-	-
8	*Cymbella cistula (Ehrenberg) Cleve*	1,67	-	-
9	*Cymbella tropica* Krammer	-	2,94	-
10	*Denticula subtilis Grunow*	1,67	2,94	-
11	*Denticula tenuis* Kutzing	1,67	2,94	-
12	*Denticula vanheurcki Brun*	6,67	2,94	7,14
13	*Encyonema yellowstonianum* Krammer	3,33	2,94	-
14	*Eolimna martinii* (Schiller and Lange-Bertalot)	0,00	5,88	7,14
15	*Ephitemia turgida* (Ehrenberg)	1,67	2,94	7,14
16	*Eunotia exigua* (Brébisson in Kutzing)	1,67	-	-
17	*Fallacia pygmaea* (Kützing) Stickle et Mann	3,33	11,76	-
18	*Fragillaria capucina* (Desmazieres)	6,67	2,94	-
19	*Gomphonema brasiliense* Grunow	10,00	11,76	-
20	*Gomphonema johnsonii* Bahls	3,33	2,94	-
21	*Gomphonema olivaceum* (Hornemann) Brébisson	1,67	5,88	7,14
22	*Mastogloia grevillei* (W. Smith)	1,67	0,00	-
23	*Navicula aurora* (Sovereign)	6,67	0,00	-
24	*Navicula subbacillum Hust*	1,67	2,94	-
25	*Nitzschia linearis (Agardh) W Smith*	1,67	2,94	-
26	*Pinnularia acoricola Hust*	3,33	2,94	7,14
27	*Sellaphora meriodionalis* (Grunow)	1,67	-	-
28	*Surirella angusta Kutzing*	-	2,94	-
29	*Synedra bacillaris* (Grunow)	1,67	2,94	7,14
30	*Synedra famelica* (Kutzing)	6,67	5,88	14,29
31	*Tetracyclus rupestris (Braun ex Rabenhorst) Grunow*	1,67	-	-
	Number of species	28	23	11
	Shannon Wiener Index	3,03	2,91	2,14
	Eveness Index	0,91	0,93	0,89

The composition of diatom's community in Toba Lake do not indicate eutrophic condition. The relatively high content of chlorophyll-a in Toba Lake related to the abundance of phytoplankton population of *Spyrogyra, Zygnema, Pediastrum*, and *Chladophora*, and aquatic plant of *Potamogeton*. Cyanophyceae is a dominant phytoplankton in Toba Lake that was controlled by orthophosphate and nitrate, whereas Dinophyceae was controlled by ammonium (Rahman et al., 2016).

Table 2. Water quality of Toba Lake

Parameter	Unit	Toba Lake			Indonesian Water Quality Standard PP No. 82/2001			
		T1	T2	T3	Class I	Class II	Class III	Class IV
pH	-	7.85	8.14	7.83	6-9	6-9	6-9	6-9
Lead (Pb)	mg/L	0.006	0.004	0.005	0.03	0.03	0.03	1
Cadmium (Cd)	mg/L	0.003	0.005	0.003	0.01	0.01	0.01	0.01
Cromium (Cr)	mg/L	0.002	0.003	0.004	0.05	0.05	0.05	1
Copper (Cu)	mg/L	0.185	0.229	0.218	0.02	0.02	0.02	0.2
Silika (SiO_2)	mg/L	0.045	0.018	0.03	-	-	-	-
Total P	mg/L	0.42	0.395	0.37	-	-	-	-
Total N	mg/L	1.085	2.03	1.452	-	-	-	-
Chlorophyll a	mg/L	4.025	5.113	4.37	-	-	-	-

Notes
Class I : used for drink
Class II : used for recreation, live stock and fish farming
Class III : used to live stok, fish farming and agriculture
Class IV: used for agriculture

Water pollution load capacity and floating fish cage capacity exceeded the carrying capacity of Toba Lake, particularly for total phosphorous. Recently this condition still remain degrade, suppose to reduce 43% of phosphoous from catchment area and 44% from floating fish cage (EPANS, 2014). Lake Toba Ecosystem Management Plant (LTEMP) had been started on 2004 to monitor water quality of Toba Lake, then strengthened by Governour Regulation No 1 Year 2009 regrading Water Quality Standard for Toba Lake. Furthermore on 2014 Save Lake Action (in Indonesia called Gerakan Penyelamatan Danau (Germadan) Toba had been launched as a guideline for conservation action.

CONCLUSIONS

In Parapat and Tomok Harbours and around traditional fish culture cage of Toba Lake, there are 31 diatom's species. The high population of *Ctenophora pulchella* Kutzing indicates a high conductivity and alkalinity and high mineral content. *Denticula vanheurckii* Brun is specific diatom from Toba Lake that was reported since 1929 until now, which indicates high conductivity low organic pollution and alkaline water. *Fallacia pygmaea* (Kützing) Stickle et Mann is freshwater diatom of high mineral content; sometimes in polluted water. The diatom's composition do not reflect eutrophic-hypereutrophic condition of Toba Lake.

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CARBON DIOXIDE AND METHANE ACCUMULATION IN A HIGHLY EUTROPHIC TROPICAL LAKE, INDONESIA

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ABSTRACT

Accumulation of carbon dioxide (CO_2) and methane (CH_4) has been estimated in a highly eutrophic Lake Maninjau (West Sumatera, Indonesia). The lake receives high inputs of not only nutrients (Nitrogen (N) and Phosphorus (P)) but also organic carbon (C) from intensive cage aquaculture activity. The lake contains fair amount of sulphides in the permanent anoxic hypolimnion. More than 95% of lake volume is hypolimnion anoxic water. Deep profile water samples were collected at two sites of lake (one is the master deep station and another one is on the shallower area of the cage aquaculture). CH_4 was determined from the headspace of the crimp-sealed vials by using gas chromatography (Agilent Technologies) and CO_2 concentration were calculated from alkalinity data, temperature and pH. The lake indicated considerably high CO_2 and CH_4 accumulation in the anoxic hypolimnion. Biogenic CH_4 accumulates to high concentrations (up to 1.5 mmol L^{-1}) in deep anoxic hypolimnion waters, which contain a total of 158.5 tons CH_4. There is no sign of inhibition of methane production in the presence of sulfides. The lake acts as a CO_2 sink with flux of around – 3 mmol $m^2 d^{-1}$ however the lake emits around 4.9 mmol m^2 d^{-1} of CH_4. Although the lake acts as CO_2 sink, the accumulation of CO_2 and CH_4 in the bottom water is substantially high. The lake is weakly stratified with permanent anoxic hypolimnion and with weather driven lake mixing, the lake could release elevated CO_2 and CH_4 to the atmosphere. Considering the amount of gasses in the lake bottom and frequent lake mixing, limnic eruption would be unlikely. Elevated CO_2 and CH_4 emission from the lake can make significant contribution to global climate change.

Keywords: Carbon dioxide, methane, emission, eutrophic, tropical lake

INTRODUCTION

Lakes have been known to have important role in the processing and transport fixed carbon to the atmosphere (Downing *et al*, 2006). High organic carbon input as allochtonous carbon source in the lake will be decomposed via heterotrophic metabolism producing CO_2 and CH_4 in the water column and sediments. CO_2 mainly is produced as results of aerobic decomposition of organic carbon while CH_4 is mainly produced as end product of anaerobic decomposition (Kortelainen *et al*, 2006). Both CO_2 and CH_4 in the lake can be released to the atmosphere. CO_2 and CH_4 have been concerned green house gas (GHG) to have contribution to the earth global warming (IPCC, 2014; Chilingar *et al*, 2014). Most of the world's lakes are supersaturated with CO_2 and CH_4 and most lakes in temperate, subtropical and tropical area can be atmospheric CO_2 sources or sinks depending on seasonal dynamics and lake trophic status (Repo *et al*, 2007; Xing Ye *et al*, 2005; Santoso *et al*, 2017; Kortelainen *et al*, 2006).

Highly productive, with large volume of anoxic water volume and most likely high organic carbon (OC) accumulation in the sediment due to waste input from cage aquaculture, Lake Maninjau could have potential high production of CO_2 and CH_4 in its anoxic bottom water. Lake Mainjau, Indonesia, a tectonic-volcanic origin type of lake, has been overexploited by floating cage aquaculture over two decades (Syandri *et al*, 2014; Lukman *et al*, 2015). Increasing the cage aquaculture activity (cage unit number) unquestionably increases the waste inputs and thereby accumulates organic material into the lake. It is estimated 111,890 tons organic waste input to the lake in 13 years (Junaidi *et al*, 2014). Total and volatile solids in the sediment of L. Maninjau from 2006 to 2009 increased more than 70 % where 40 - 60 % of volatile solids consisted of organic carbon (OC) (Henny, 2009). Not only carbon, nutrients as nitrogen and phosphorus have been increasing steadily resulting in phosphorus accumulation in the sediment (Henny and Nomosatryo, 2012a, 2012 b, 2016). Nutrient enrichment in the water and organic carbon accumulation in lake sediment have deteriorated lake water quality and resulting in prolonged lake eutrophication (Syandri *et al*, 2014, Lukman *et al* 2015, Henny and Nomosatryo, 2016, 2012 b). The lake also generates fair amount sulphides in the anoxic hypolimnion. Sulfide oxidation and high oxygen consumption derives from microbial activity have pushed oxycline upward and increased the thickness of anoxic hypolimnion (Henny, 2009; Henny and

Nomostryo, 2016).
Many studies have reported on CO_2 and CH_4 emission from freshwater ecosystem especially temperate (Repo *et al*, 2007) or subtropical lakes (Xing *et al*, 2005), however only limited studies reported in tropical lake especially looking at the effect of eutrophic condition on these GHG accumulation or emission in a tropical lake as impact of high organic carbon accumulation due to cage aquaculture activity in the lake. In this study, we estimate the accumulation and the flux of CO_2 and CH_4 in a highly eutrophic tropical lake, to determine the influence of sulphide production on the methane generation and to evaluate potential contribution on the earth global warming or even the potential risk of both gasses driven limnic eruption in the lake.

METHODS

Study and sampling and analyses

Lake Maninjau (surface area = 9737.5 Ha, maximum depth of 165m) is located at 461.50 m above sea level in the Western area of Sumatra (**Fig. 1**). Hydrologically, major water sources is from groundwater and major outflow of Lake Maninjau is controlled by an existing hydropower dam at depth of 6 – 8 m. Lake is surrounded by mountains. Although agriculture activity dominates in its catchment, nutrient and majorly organic loadings to the lake mostly is originated from waste input of floating cage aquaculture. It was estimated more than 10000 units of floating cage aquaculture in Lake Maninjau (Lukman *et al*, 2015; Junaidi *et al*, 2014). Lake is in eutrophic condition since 2008 (Syandri *et al*, 2014; Henny and Nomostaryo, 2016). Sampling was conducted at deep water location (DM7 station) (S: 0°22’33.0” E: 100°11’35.1”) with water depth of > 160 m and area in the major cage aquaculture (Bayur Station) (S: 0°19’45.0” E: 100°11’6.0”) with water depth of 30 – 50 m in September 2009, in July 2011, in May 2015 and in August 2016 for CO_2 and for CH_4 July 2012 and August 2016 only . Water samples were collected with a 5 L Go-Flow (Niskin; General Oceanics Miami, FL, USA) bottle attached to a rope marked each at 1 m long and a hand-operated winch. Water samples for CH_4 and sulfide determination were drawn directly using a 60 mL syringe from the spigot of the Niskin bottle. Water samples for CH_4 from the syringe were transferred to a 60 mL crimp seal serum bottle that had been vacuumed contain 200 μL $HgCL_2$ solution. Water samples for sulphide directly transferred through syringe filter with pore size of 0.45 μm to a 5 mL vial and added with HACH reagent and analized directly in situ . Total alkalinity was determined from water sample, which was transferred to a 125 mL glass bottle sample.
Temperature, conductivity, turbidity and pH were measured by using WQC U-10 (Horiba) and DO were measured by using YSI 6000 Data Logger. Total sulfide was determined by using HACH DR 2010 spectrophotometer.

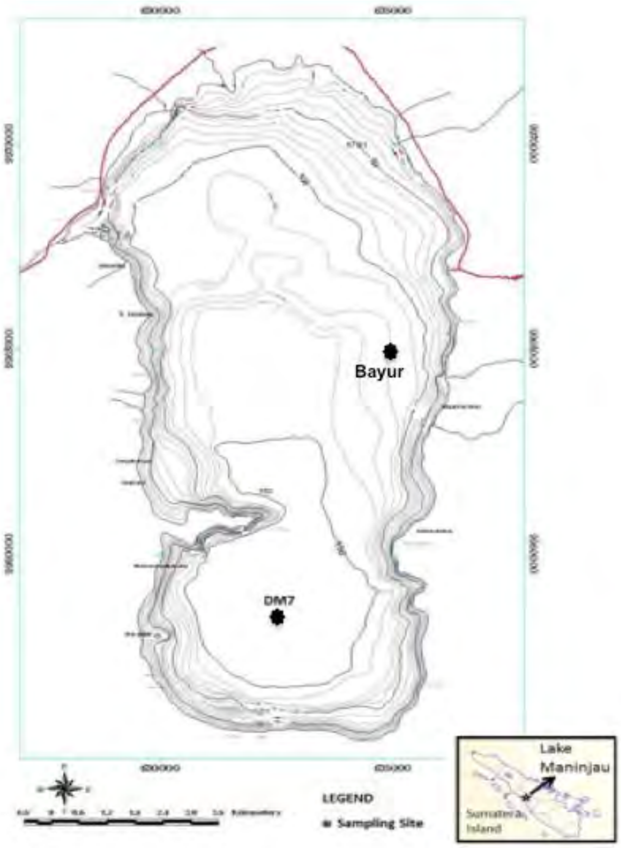

Figure 1. Lake Maninjau and sampling location (the map by Ridwansyah, 2015); Sumatera Island, Indonesia (Google Earth map 2017)

CH_4 and CO_2 measurements and calculations

A gas chromatograph equipped with a flame ionization detector (GC-FID Agilent Technology) was used to determine CH_4 concentrations in the headspace. The concentrations of dissolved CH_4 in the water samples were then calculated based on the solubility function for CH_4 following Wiesenburg and Guinasso (1979). Concentrations of CO_2 (μmol CO_2 L^{-1}) in the water column were calculated from the dissociation of dissolved inorganic carbon in freshwater according to pH and alkalinity values at a given temperature (Stumm and Morgan 1996).

Air-water exchange of CH_4 and CO_2 was computed using Fick's law of gas diffusion:

$$Fgas = k_{gas} (C_{aq} – C_{sat}) \quad (1)$$

where Fgas is the gas flux across the air-water interface (mmol m^{-2} d^{-1}), C_{aq} is the concentration of dissolved gas in the surface water (μmol L^{-1}), k_{gas} is the gas exchange coefficient (cm d^{-1}; Cole and Caraco, 1998) and C_{sat} is the saturation concentration of gas (μmol L^{-1}) for a given temperature and its atmospheric mole fraction in dry air (Weiss and Price, 1980).

RESULTS AND DISCUSSIONS

Physical and chemical properties of Lake Maninjau

Representative temperature profiles showed slightly increase in temperature from 2009 to 2016 (**Figure 2**). A very thin layer of thermocline between at depth of 10 m to less than 20 m was observed. Above 10 m depth and below depth of 20 m there is no gradient temperature observed. The results indicate the lake is very susceptible to lake mixing. In fact, the online monitoring data in 2015 specified several times of lake mixing occurrence based on temperature profile data (Santoso and Fachrudin, 2016). Based on climate pattern Months January to April and September to Desember are rainy season in which usually accompanied by strong wind (BMKG, 2015 (data is not shown)). During these months Lake Maninjau is often experienced lake mixing. Frequent fish kill accidents each year took places mostly in February to April. Based on temperature profile results, Lake Maninjau is considered polymictic and weakly stratified. The density profiles in October 2016 recorded by data logger demonstrate non-persistent pycnocline (seasonal) between 0 – 50 m and persistent pycnocline at 50 – 60 m (**Figure 3**). Above 50 m lake is inclined to mixing if there is trigger such as extreme climate (heavy wind) or water temperature decrease with increasing depth.   support this statement that the lake also has non-persistent pycnocline (**Figure 4**). Differ from Lake Maninjau, a very deep tectonic lake of Matano (South Sulawesi), an utra-oligotrophic lake, remained stratified with persistent thermocline and pycnocline between 100 and 120 m depth (Crowe *et al*, 2010; Katsev *et al* 2010).

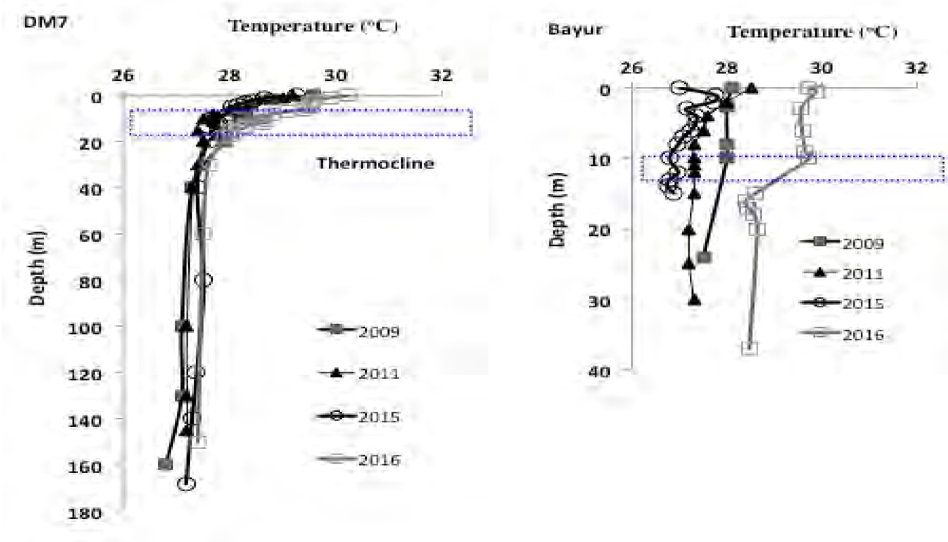

Figure 2. Temperature profiles in September 2009, July 2011, May 2015 and in August 2016 showing fluctuation thermocline between 10 m and 20 m at station DM7.

Depth profiles of dissolved oxygen and redox potential indicates that at depth of less than 10 m, the lake water has been in hypoxic (< 2 mg/L) to anoxic condition (**Figure 4**). The oxic-anoxic line in Lake Maninjau keep moving upward pushing the epilimnion layer where in the past it stared 40 m in 2006, and fluctuates between 15 - < 10 m recently from 2011, in which implies that the lake before 1990's when no cage aquaculture activity, its oxic-anoxic line is > 40 m. In 2011 the lake water turned to anoxic condition at depth of less than 10 m. The hypolimnion thicknes of Lake Maninjau has been increasing resulting in very large volume of anoxic water. Only 10 % of lake water volume is oxic. Lake Matano, an ultra oligotrophic lake has its oxic-anoxic line at 100 m depth although having large volume of anoxic water in hypolimnion (Crowe *et al*, 2010).

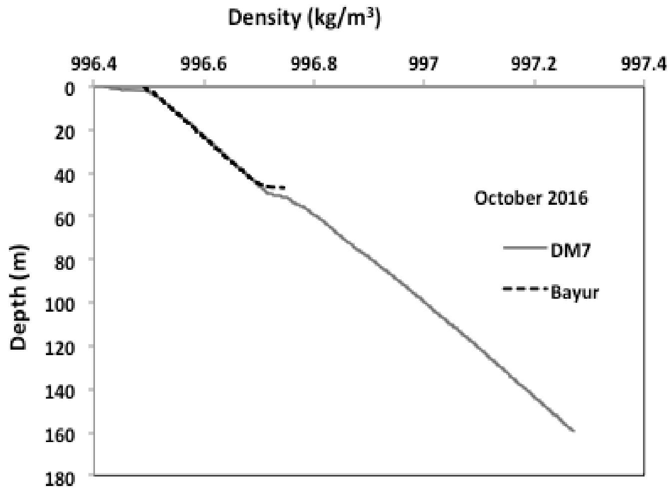

Figure 3. Density depth profiles in October 2016. The measurement was conducted using Data Logger (RYNCO) a few days after lake experiencing mixing.

Similar pattern with thermocline and oxycline, chemocline also was observed at between less than 20 m to 10 m (**Figure 5**). Large gradient pH was observed ranging from 11 to near neutral. Increase

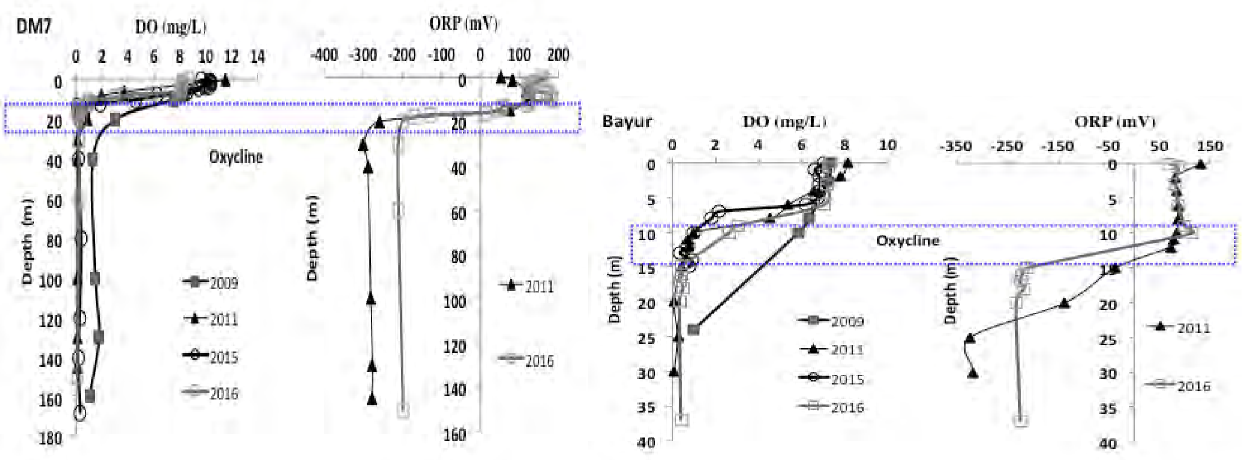

Figure 4. Dissolved Oxygen (DO) in September 2009, July 2011, May 2015 and in August 2016 and ORP profiles in July 2011 and August 2016 at DM7 station (left) and Bayur station (right)

in 2 units of pH was observed from 2009 to 2016. Lower pH in the bottom water is probably due to high organic acids as intermediate compounds produced by anaerobic degradation of organic carbon by microbial activity (). High conductivity observed in 2011 where the lake is in hypereutrophic condition (Henny and Nomostaryo, 2016). High conductivity indicates high salts concentration in the water (Stumm and Morgan, 1996).

Distribution of CO_2 and CH_4

Concentration of CO_2 in Lake Maninjau ranged from 0.0002 – 0.003 mmol L-1 in 2009 to 0.002 - 0.007 mmol L-1 in 2015 and 2016 in the surface water of epilimnion layer and ranged from 0.1 mmol L^{-1} in 2009 to about 0.63 mmol L^{-1} in 2015 in the anoxic bottom waters giving the total amount of (**Figure 6**). The concentrations of CO_2 in the area where most cage aquaculture were slightly higher than those in the deepest area (DM7 station) at the same depth, although in deep anoxic hypolimnion CO_2 concentrations were pretty close. The amount of CO_2 in lake Maninjau is much lower than the amount of CO_2 in Lake Matano accounted about 4 mmol L^{-1} (Crowe *et al*, 2010) and much smaller than those in Lake Manoun and Nyos (Africa) of about 10^8 and 10^{10} mol in hypolimnion water (Evans *et al*, 2010).

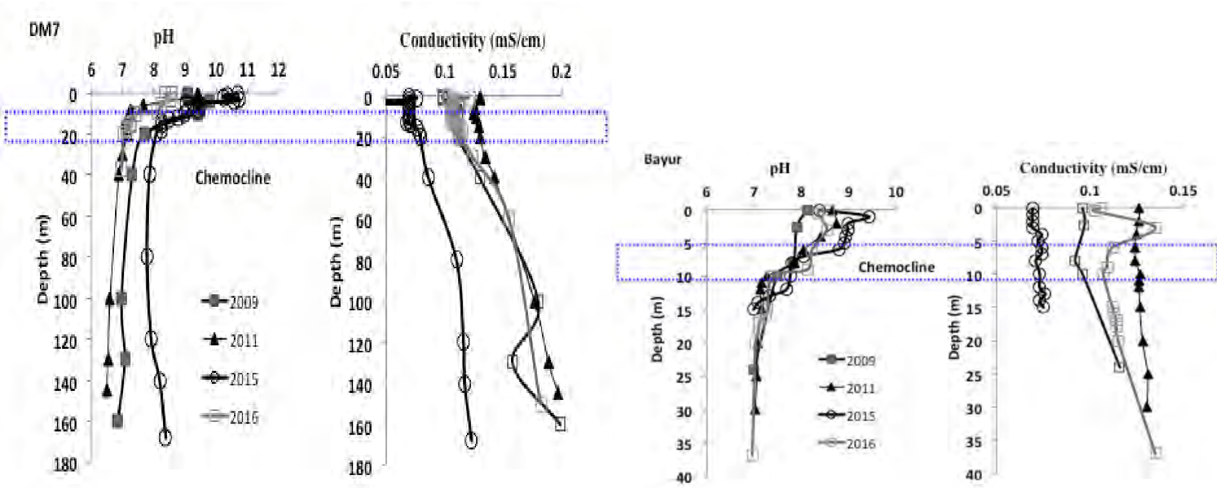

Figure 5. Depth profiles of pH and conductivity of Lake Maninjau at DM7 station (left) and Bayur station (right)

The flux of CO_2 from Lake Maninjau ranged from (- 2.4) – (- 3.17) mmol m^2d^{-1} (**Table 1**) indicating that the lake acts as a CO_2 sink. No substantial different is observed between two sampling stations suggesting that the organic carbon accumulation also occurs in the deeper station with no cage aquaculture.
Biogenic CH_4 accumulates to high concentrations (up to 1.5 mmol L^{-1}) in deep anoxic hypolimnion waters, which contain a total of 158.5 tons CH_4. No substantial increase has been observed on the concentrations of CH_4 from 2012 to 2015 except at depth of 20 m. The lake emits around 4.9 mmol m^2 d^{-1} of CH_4. In comparison, the deepest and the largest volume of anoxic bottom water, the tectonic ultra oligotrophic lake of Matano (35 km^3), contains 7.4 x 10^5 metric ton of CH_4 with about the same concentration (Crowe *et al*, 2010)
In comparison with both subtropical and temperate lakes, Lake Maninjau emits much higher CH_4 (1788 mmol m^{-2} annually) with range of 0.5 – 1 mmol m^{-2} d^{-1} (30 – 365 mmol m^{-2} annually) but much less CO_2. Both subtropical and temperate lakes emit as high as > 25 - 31 mmol m^{-2} d^{-1} (Xing *et al*, 2005; Demarty *et al*, 2009).

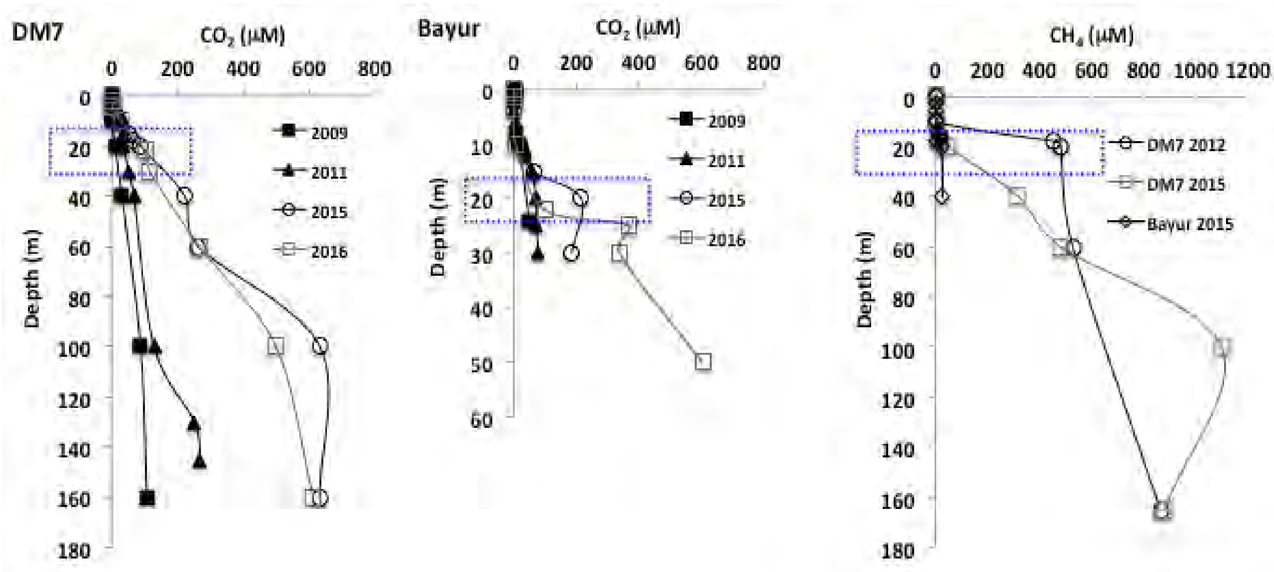

Figure 6. Depth profiles of CO_2 in September 2009, July 2011, May 2015 and in August 2016 and CH_4 in July 2012 and May 2015

Table 1. Flux of CO_2 in Lake Maninjau

Year	DM7	Bayur
2009	-3.02	-2.40
2011	-3.17	-3.09
2015	-2.74	-
2016	-2.67	-2.78

CH_4 and CO_2 were positively correlated with high Pearson coefficient correlation (0.9841; $p< 0.01$). The results indicate that high CO_2 production is readily transformed in to CH_4 by methanogens in hypolimnion. Lake Maninjau generates amount of sulphides as high as 400 µg/L in hypolimnion anoxic water. Sulfides total detected were high in the water at depth of 20 − 30 m (Henny and Nomsatryo, 2012, 2016). To see whether there is influence of sulphate reduction on CH_4 and CO_2 generation, the correlation between CH_4 and CO_2 and sulphides total were performed. Both CH_4 and CO_2 and sulphides total were positively correlated (r= 0. 8436 and 0.8176; $p<0.01$). The results indicate that sulphate reduction bacteria activity does not outcompete methanogens due to abundant carbon sources from the input waste. Lake Maninjau has been in highly eutrophic condition since 2009 (Henny and Nomosatryo, 2016). Range of TN, TP and Chlorophyll-a concentrations at time of measurements were 0.65 – 0.85 mg/L; 0.02 – 0.08 mg/L and 10 – 25 mg/L respectively. Total Organic Matter (TOM), Volatile Suspended Solids (VSS) were about 13 – 23 mg/L and 20 – 30 mg/L respectively in 2016. Where in 2009 the concentrations were < 10 mg/L. Estimation of average of organic waste input based on the number of units of cage aquaculture was around 6650 ton per year and around 15000 ton/yer in 2006 – 2008. That gave the estimation of organic waste accumulation in the lake from cage aquaculture from 2000 to 2014 reached at about 111885 ton (Junaidi et al, 2014). Deep profile volatile solids considered as organic constituents in the sediments showed accumulation of organic waste at 10 – 20 cm depth in DM7 station in 2009 (Henny and Nomosatryo, 2009). Estimation of 40 – 60 % C organics out of VSS concentration was observed in the surface sediments (Henny, 2008). High accumulation of organic carbon in Lake Maninjau sediment, which is indeed as allochthonous carbon, would result in high organic carbon burial efficiency. Allochthonous carbon influences lake metabolism and subsequently CO_2 and CH_4 generation (Sobek *et al*, 2009; Hanson et al, 2003).

Lake Maninjau has been highly eutrophic since 2009. Sulfide oxidation and high oxygen consumption derives from microbial activity have pushed oxycline upward and increased the thickness of anoxic hypolimnion (Henny, 2009; Henny and Nomostryo, 2016). Eutrophication also increases the input of autochthonous OC to the sediment, which is further mineralized than buried in the sediments. Oxygen consumption during OC mineralization leads to anoxic bottom waters, which is typically observed in eutrophic stratified lakes as in Lake Maninjau (Sobek *et al*, 2009). Based on TP, TN and Chlorophyll-a concentrations at the time of measurements, CO_2 flux and TP, TN and Chlorphyll-a were positively correlated with Pearson coefficient correlation (r) of 0.7491 and 0.5145 and 0.8430 respectively ($p<0.01$). CO2 concentrations were positively associated with lake trophic state and one important factor contributing to high CO_2 supersaturation and emission was sediment respiration due to carbon burials. Depth distribution indicated strong CO_2 accumulation in hypolimnetic waters during the stratification periods (Santoso et al 2017; Kortelainen et al, 2006).

Although the lake acts as CO_2 sink, the accumulation of CO_2 and CH_4 in the bottom water is substantially high. The lake is weakly stratified with permanent anoxic hypolimnion and with weather driven lake mixing, the lake could release elevated CO_2 and CH_4 to the atmosphere. Surface and bottom temperatures at tropical caldera lakes near times of seasonal lake overturn differ only slightly. Unusually high winds, cool surface temperatures, or heating through the caldera floor can destabilize them and cause overturn (Newhall et al, 1987). During overturn, oxygen-poor, H_2S-rich bottom water rises to the surface, displacing oxygenated surface water and often resulted in mass kill-fish. Overturn can also release dangerous amounts of CO_2 and CH_4 gas, as at Lake Nyos (Evans *et al*, 2012). Considering the amount of gasses in the lake bottom, limnic eruption would be improbable. Elevated CO_2 and CH_4 emission from the lake can make significant contribution to global climate change

CONCLUSIONS

The lake indicates substantially high CO_2 and CH_4 accumulation in the anoxic hypolimnion during the stratification periods. The lake acts as CO_2 sink and emit considerable amount of CH4. The fact that the lake is weakly stratified and frequent lake mixing causing lake overturn, not only anoxic H_2S-rich bottom water rises to the surface displacing oxygenated surface, high amount of CO_2 and CH_4 in the bottom water could escape as well. Elevated CO_2 and CH_4 emission from the lake can make significant contribution to global climate change. The study also suggests that although high enough, the concentration of CO_2 and CH_4 is not likely to cause limnic eruption.

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EVALUATION OF LAKE WATER QUALITY IN KLANG VALLEY USING MULTIVARIATE STATISTICAL TECHNIQUES

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ABSTRACT

Lakes are major sources of water for human consumption, domestic uses, and recreational purposes in Malaysia, but suffered deterioration in water quality due to anthropogenic activities. This study investigates the Physico chemical parameters and heavy metals distribution of five selected lakes at Klang Valley in Malaysia to evaluate its quality status and possible sources of the identified pollutants. The physico-chemical parameters analyzed were Dissolved Oxygen, pH, Biological Oxygen Demand, Ammoniacal Nitrogen and metals include Cd, Mn, Pb, As, and Fe. The levels of these parameters were compared to Malaysia's interim national water quality standard. The multivariate statistical analysis methods applied were Hierarchical cluster analysis (HCA) and Principal component analysis (PCA). The PCA shows PC1 is strongly loaded with AN and Mn, and negative loading with DO and pH, while PC2 was strongly loaded with As, Cd, Pb and Fe. HCA classified the sample sites into three clusters, and the results showed variations in degree of pollution due to oxygen consuming organic pollutants possibly from domestic sewage, waste water, and other anthropogenic sources. The lakes were classified as the most polluted, polluted and less polluted. There is a need to monitor the lakes to prevent further deterioration. Proper lake management and environmental law enforcements will assist in maintaining a healthy lake ecosystem.

Keywords: Klang Valley, Lake, Multivariate statistical analysis, Pollution, Water quality.

INTRODUCTION

Water is an invaluable resource requirement for the economic development of a nation as well as healthy growth of plants and animals. Lakes are good source of water for beneficial purposes in many countries but are threatened by continuous increase in human and industrial activities resulting in the deterioration of the water quality and destroy the aquatic ecosystem. About 73 lakes were created in Malaysia for irrigation, flood control and water supply. Most of the lakes are popular tourism and recreational centers, thus having economic potentials. The greatest number of lakes in Malaysia lack sufficient mechanism for proper management (Sharip & Zakaria, 2007). The pollution encountered in most of the lakes includes eutrophication due to high concentrations of nitrogen, phosphorous and ammonia, and elevated heavy metals concentrations due to sporting and racing activities. High coliform and faecal coliform rendered lakes unsuitable for recreational purposes (Idris, 2007). The frequent racing and navigating on the lakes resulted in the discharge of toxic heavy metals specifically lead and cadmium into the water and sediment (Sharip & Zakaria, 2007). Agricultural activities also contributed to the pollution of the lakes by increasing the suspended solid and releasing pollutants such as Nitrate and Phosphate into the lakes (Shuhaimi-Othman et al., 2007). Several studies of Malaysia's lakes had documented pollution at various levels due to discharge of domestic effluent, industrial discharges or rain water runoff from urban areas (Kah Hin et al., 2016). The surface water quality of lakes is mainly influenced by human activities such as the use of agricultural chemicals and effluent discharges (Niemi et al., 1990). It is therefore pertinent to control the water pollution in the lakes and to establish monitoring programs so as to protect humans and aquatic organisms. Hence the need for periodic monitoring of the lake water and carefully analyzing and interpreting the water quality data matrix of physico-chemical and heavy metal parameters (Chapman, 1992).

Application of multivariate statistical technique such as principal component analysis (PCA) is important in identifying the pollutants and their possible sources (Zhao et al., 2012). Many researchers applied these techniques for analysis of environmental data and arrive at useful information (Alkarkhi et al., 2009; Reghunath et al., 2002; Vandendriessche et al., 2006). PCA is a statistical technique used to study the variation and generate patterns in the data set. It explains maximum amount of variance by converting a set of observations of likely correlated parameters into a set of values of linearly uncorrelated parameters called principal components (PCs). It provide an idea on the most important variable that describe the entire set of data and gives the statistical correlation among parameters without altering the primary information (Alberto et al., 2001). PCA identified the parameter(s) responsible for the variation in water quality of the lakes. Hierarchical cluster analysis (HCA) is an unsupervised classification technique measuring the similarity between parameters or objects to be clustered. The objects are grouped into clusters based on similarities (Baharuddin et al., 2014). Objects that are most similar are first grouped and joined according to their similarity. Finally, decreased similarity joined the groups into a separate cluster (Alkarkhi et al., 2009).

In this study, a set of data obtained from 5 selected lakes in Klang Valley were subjected to two way HCA and PCA to obtain information on (a) the latent natural and anthropogenic pollutants, levels of the pollution, and probable sources of pollution to the lakes. (b) Similarities and/or dissimilarities between the lakes with respect to the studied parameters. This was aimed at preserving the lake ecosystem and to project future sources of pollutants for better management.

METHODS

Study Area

The study area is located in Selangor which comprises of Kuala Lumpur and neighboring cities. Klang Valley is one of the most important regions of Malaysia in terms of human and economic development. It can also be regarded as a greater Kuala Lumpur. In this study, assessment of the lakes water quality was considered so as to arrive at a conclusion on their general water quality status considering the increased recreational activities in Malaysia.

Table 1: Description of sampling locations

Sample Code	TJYA	TPJY	TPDN	TSHA	TSH7
Coordinate	N 03° 06' 17.8" E 101° 38' 53.0"	N 02° 55' 12.5" E 101° 40' 52.6"	N 03° 08' 31.9" E 101° 41' 06.5"	N 03° 04' 27.0" E 101° 30' 47.3"	N 03° 04' 42.4" E 101° 29' 28.7"
District	Petaling Jaya	Putrajaya	Kuala Lumpur	Shah Alam	Shah Alam

Sample preparation and analysis

Field sampling was conducted in the five lakes described above, surface water samples were collected using the Wildco vertical water sampler. About three replications for the water samples were collected at a sampling point. Different parameters like ammoniacal nitrogen (AN), pH, and dissolved oxygen (DO) were accurately measured insitu using YSI Pro Multi parameter Water Quality Meter. BOD was measured at the time of sampling using a modern water portable meter. Few drops of conc. HNO_3 (Suprapur) was applied to the water samples in polyethylene bottles (Previously soaked in acid solution) for preservation, and transported to the laboratory in ice boxes (Muhammad et al., 2011). The samples were coded as follows; Perdana (TPDN), Taman Jaya (TJYA), Shah Alam (TSHA and TSH7) and Putrajaya Lake (TPJY) (**Table 1**).

Heavy metal analysis

Water samples were filtered with a 0.45 μm pore size filter paper and analyzed for Cd, Pb, As, Mn, and Fe with inductively coupled plasma mass spectrophotometer (Model 7500ce). All the working conditions of the ICP-MS and the standards to obtain optimum metal concentrations were monitored and maintained. The calibration standard and blank preparation was done with ultrapure water produced from water deionizer. The calibration stock solution of 1000 mg/L and 10 mg/L (Agilent, New castle) was prepared for Fe, and for Cd, As, Pb, and Mn respectively. A detailed quality control and validation was done using standard reference material (Merck, Germany) so as to ensure the reliability of the results. All the plastic wares used in the analysis were soaked in 15% HNO_3 (v/v), and subsequently rinsed twice with ultrapure water. A good metal recovery of the reference material was obtained; the reagent blanks and standard reference materials were synchronized accordingly with the samples and analyzed. All analyses were carried out in triplicate (Haydar et al., 2014).

Data Analysis

The calculations of means and range of the experimental values were carried out using MS Excel 2013, and the results applied to identify the differences among the sample locations. The statements described in this study were reported at $p<0.05$ levels. JMP Pro 12 statistical software was used for the multivariate statistical analysis. HCA and PCA were used to analyze the data of the selected water quality parameters.

RESULTS AND DISCUSSIONS

The basic statistics for the 9 water quality parameters in the lakes were calculated. The selection was based on the importance of the parameter in the past lake water researches. There were significant variations in the concentrations of the parameters analyzed. The differences are significant at $p<0.05$ and found to be in the following ranges; Cd, 0.02 - 12.18 µg/L; As, 1.03 - 14.91 µg/L; Pb, 0.04 – 4.60 µg/L; Fe, 144.2 - 1575 µg/L and Mn, 35.25 – 411.34 µg/L. For the physico chemical parameters are DO, 1.27 - 4.51 mg/L; pH, 7.44 - 8.71; AN, 0.02 - 0.55 mg/L and BOD, 1.98 - 8.96 mg/L.

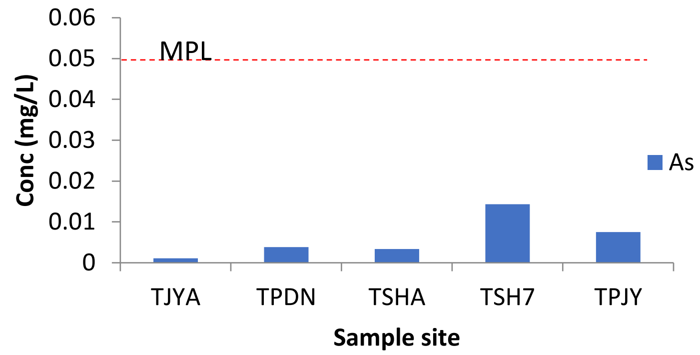
The measured dissolved metal concentrations were generally low. The heavy metals (Cd, As, Pb) were found to be below class IIB (Table 2) Malaysia's interim national water quality standard (INWQS) of 0.003, 0.05 and 0.01 mg/L for cadmium, lead and arsenic respectively (DOE, 2012), except for cadmium concentrations of 12.17 µg/L in Putrajaya lakes (TPJY) (**Fig.1**). The TPJY also record the highest concentration of Pb among the lakes studied. This could be due to successive movements of the motorized power boats and other sports activities (Abdullah, 2013; Ebrahimpour & Mushrifah, 2008). The lowest Pb concentration of 0.05 µg/L was obtained in Shah alam lake (TSHA). Analysis of water samples from Chini lake reveals highest Pb and Cd concentrations of 18.7 µg/L and 0.36 µg/L respectively (Ebrahimpour & Mushrifah, 2008). However, the highest As and Pb concentrations in Timah Tasoh lake were 12.60 µg/L and 2.37 µg/L respectively, these values were below Malaysian INWQS (Permulaan, 2014). Findings on Chini lake confirmed the lake to be free from heavy metal pollutants based on the sediment and fish samples analysis (Ahmad & Shuhaimi-Othman, 2010). Therefore, domestic effluents and human activities around the lakes were mostly the major sources of pollution.

For the physico-chemical characteristics of the lakes water, the pH values of the water samples studied was found to be within Malaysia's INWQS of 6 to 9 (DOE, 2012). pH is an essential parameter that determines the fitness of water for diverse utilization (Ahipathy & Puttaiah, 2006). Similar results were obtained in Chini lake with a mean pH of 6.49 (Shuhaimi-Othman et al., 2007). It was observed that the Ammoniacal nitrogen (AN) of 0.33 µg/L and 0.49 µg/L respectively for TJYA and TSH7 was higher than Malaysia's class IIB INWQS. This could be as a result of domestic sewage and agricultural runoff. This result is similar to findings on lake water studies (Solanki et al., 2010; Zhao et al., 2012). Conversely, low AN was obtained in surface water of Bukit Merah lake which is attributed to a very low or absence of sewage discharge into the lake, the major pollution sources to the lake were found to be from infrastructural developments (Akinbile et al., 2013). Oxygen depletion is a major sign of pollution in water bodies due to its importance for the survival of aquatic organisms. Sufficient DO in water is considered satisfactory for human consumption and aquatic organisms (Sánchez et al., 2007). Dissolve oxygen values in all the lakes studied were found to be below Malaysia's INWQS of 5 mg/L, this corresponds to the high BOD in all the lakes above the class IIB INWQS of 3 mg/L except for Putrajaya (TPJY) lake with BOD of 2.1 mg/L. Similar results on pollution of the lakes by oxygen depletion were obtained (Kazi et al., 2009; Solanki et al., 2010). Previous findings on water quality status of the three major lakes in Malaysia (Bera, Loagan Bunut and Chini) reveals water quality deterioration due to high nutrient and organic matter contents as a result of surface run off, sewage discharges, logging activities and oil spill from motorist boats (Chong, 2007; Idris, 2007; Nik & Sayok, 2007; Shuhaimi-Othman et al., 2007).

Table 2. Malaysia's Interim national water quality standard values (DOE, INWQS)

Class	Use	As	Cd	Pb	Mn	Fe	pH	DO	BOD	AN
IIB	Recreational activities	0.05	0.01	0.05	0.1	1.00	6-9	5-7	3	0.3

Metals are given in mg/L, physico chemical parameters in mg/L, pH (no unit)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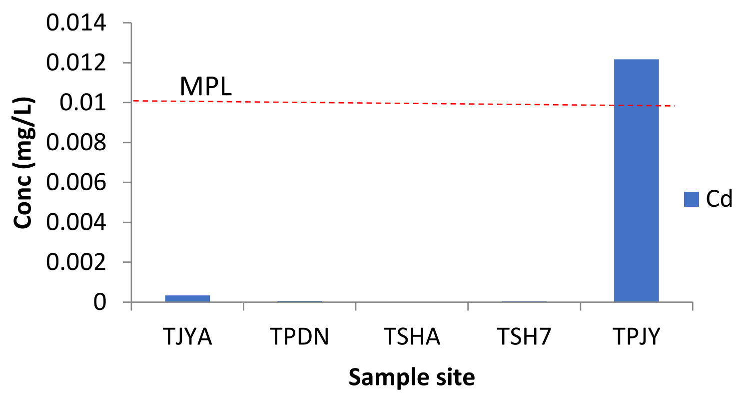
0.05
0.04
0.03
0.02
0.01
0
MPL
Conc (mg/L)
As
TJYA
TPDN
TSHA
TSH7
TPJY
Sample site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0.012
0.01
0.008
0.006
0.004
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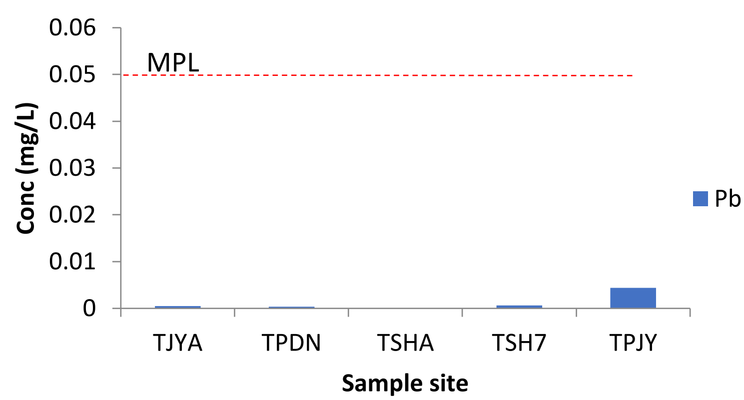
MPL
Conc (mg/L)
Cd
TJYA
TPDN
TSHA
TSH7
TPJY
Sample site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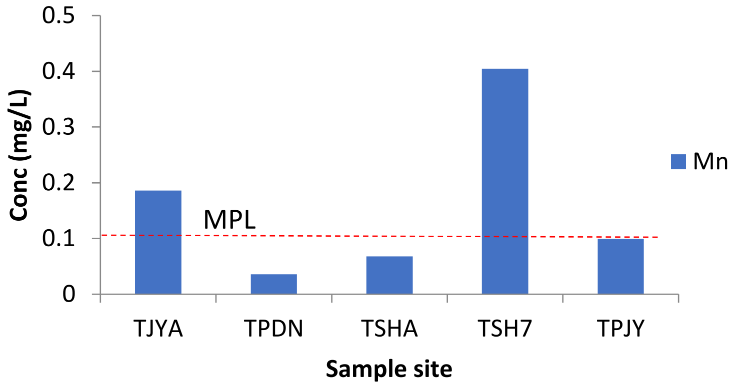
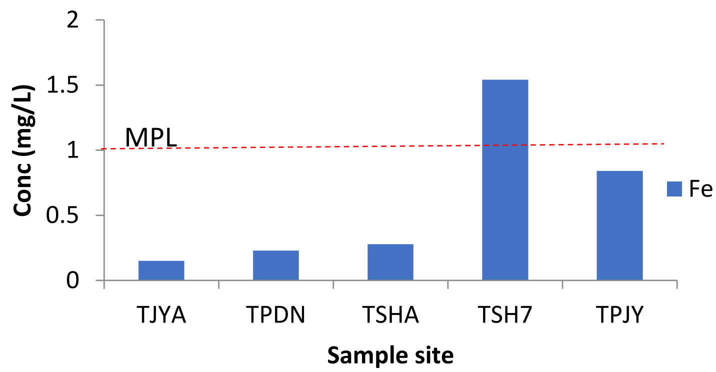
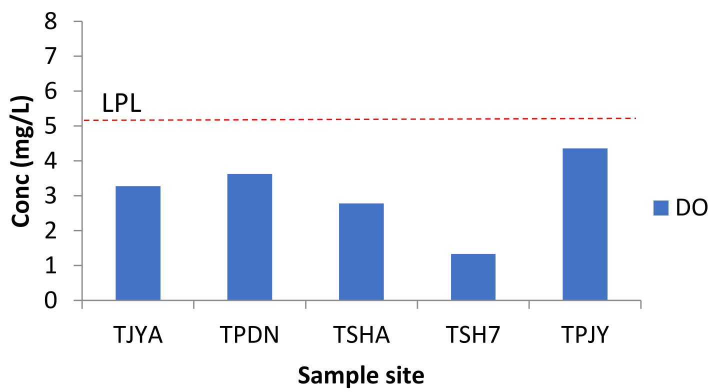
Sample site


0.5
0.4
0.3
0.2
0.1
0
Conc (mg/L)
MPL
Mn
TJYA
TPDN
TSHA
TSH7
TPJY
Sample site


2
1.5
1
0.5
0
Conc (mg/L)
MPL
Fe
TJYA
TPDN
TSHA
TSH7
TPJY
Sample site


8
7
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3
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Conc (mg/L)
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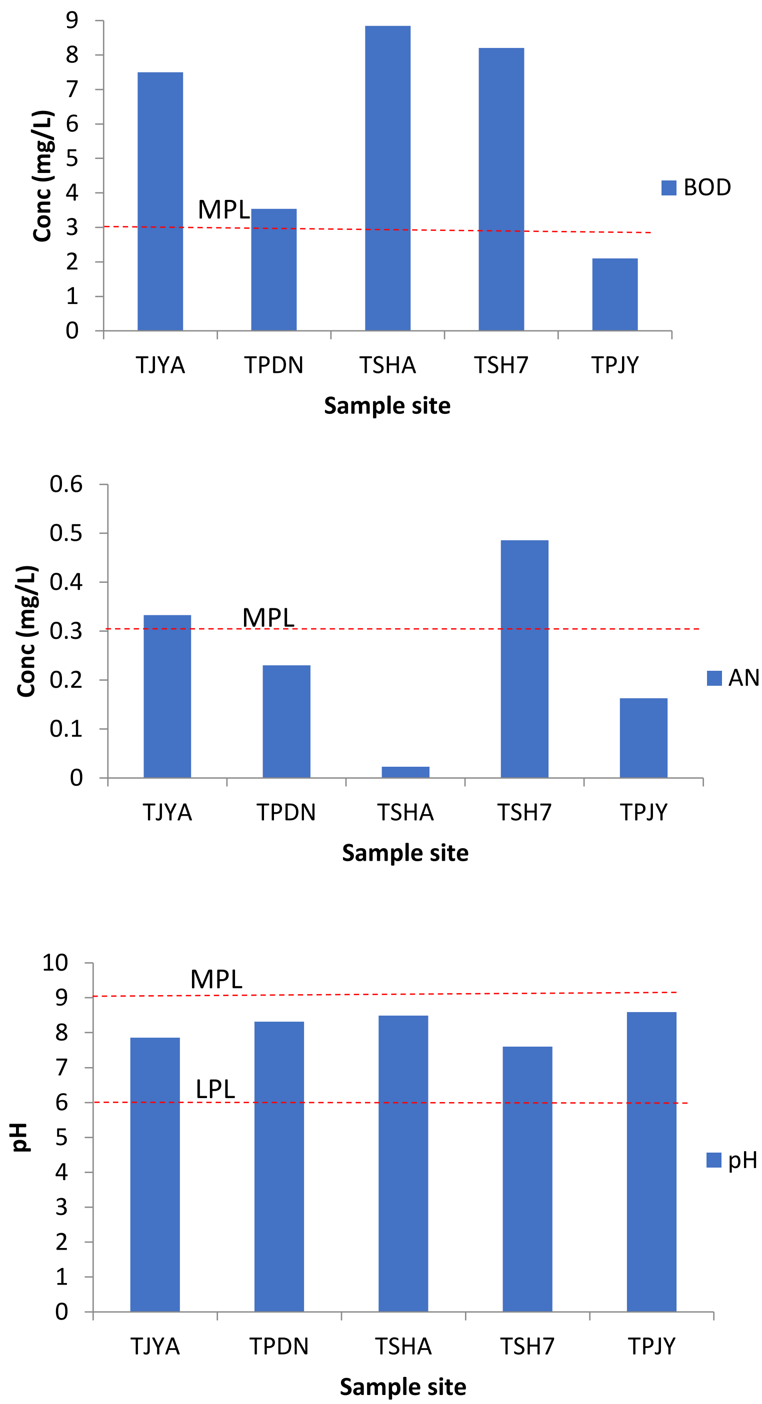
DO
TJYA
TPDN
TSHA
TSH7
TPJY
Sample site



MPL = Maximum permissible limit
LPL = Lower permissible limit

Figure 1. Levels of heavy metals and physicochemical parameters in water samples from selected lakes in Klang Valley, Selangor with respective Malaysia's (Class IIB) interim national water quality standard limits (dotted line).

Principal Component Analysis
The PCA bi-plot of PC1 against PC2 shows principal component loadings with respect to each parameter studied (**Fig. 2**). Based on the correlation matrix, the PCA (**Table 3**) gives three extracted principal components with 95 % of the total variance in the data set, in which the eigenvectors grouped the 9 metal and physico-chemical parameters into three sets. Selection of the three most significant principal components was based on eigenvalue >1 (Zhang et al., 2009). The first principal component (PC1) accounted for 55 % of the total variations and shows strong positive loadings on AN and Mn, and strong negative loadings on DO and pH. The loadings in PC1 indicate parameters responsible for anthropogenic pollution as a result of discharge of domestic sewage (Gazzaz et al., 2012; Shuhaimi-Othman et al., 2007), this shows the level of organic pollution of the lakes. The parameters with negative sign suggest an inverse relation with other parameters (Atanacković et al., 2013). It was reported that decomposition of organic matter results in low pH with corresponding decrease in DO (Kurosawa et al., 2006; Wetzel, 1983). The Mn in this category is naturally found abundantly on earth crust and easily gets to the environment by soil leaching (Simeonov et al., 2003). The second principal component (PC2) accounted for 32 % of the total variance and indicates strong positive loadings for As, Cd, Pb and Fe which is likely associated with soil leaching process, vehicle traffic, and industrial discharge (Sekabira et al., 2010; Simeonov et al., 2003; Willis & McDowell, 1982). Lastly the third principal component (PC3) with variance of 8.4 % was loaded with As, BOD and pH, and strong negative loadings on DO and AN signifying dominance of organic matter which could be due to domestic waste discharge and natural background concentration (Alkarkhi et al., 2009; Moore & Ramamoorthy, 2012).

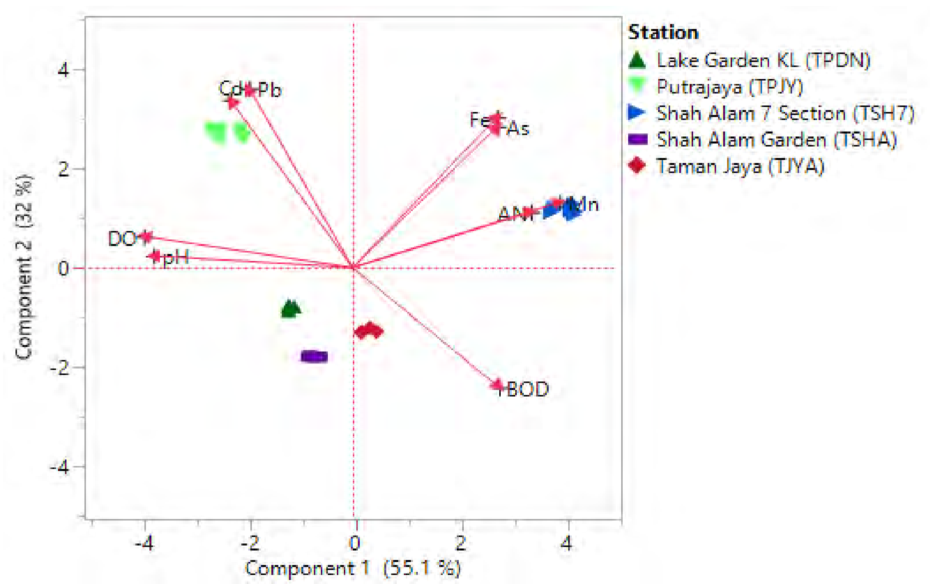


Figure 2. Bi-plot shows coordinates of principal component based on the monitored parameters

Table 3. Principal component loadings and Eigen values on the correlation matrixes of the variations explained by the extracted four principal components after varimax rotation

Variable	PC1	PC2	PC3
As	0.29147	**0.39788**	**0.30856**
Cd	-0.24641	**0.47321**	0.04285
Pb	-0.20828	**0.50614**	-0.02547
Mn	**0.41653**	0.18471	-0.05343
Fe	0.29041	**0.42375**	0.27450
DO	**-0.42033**	0.08841	**-0.34165**
BOD	0.29482	-**0.33809**	**0.37732**
AN	**0.35890**	0.15702	**-0.59913**
pH	**-0.40087**	0.03359	**0.45392**
Eigen Value	6.35	4.85	1.02
Variability %	55	32	8.4
Cumulative %	55	87	95.4

Bold Parameters indicate contribution to the variation in the component

Hierarchical Cluster Analysis

Application of two-way cluster analysis to water quality data by wards method gives a dendrogram that revealed three groups (**Fig. 3**). Cluster 1 contained TJYA, TPDN, and TSHA, cluster 2 contained TPJY while cluster 3 contained TSH7. The groupings show differences in physico-chemical properties and heavy metal concentrations with respect to the lakes. Therefore the lakes water quality measured was shown to be influenced by different pollution sources (Zhao et al., 2012). Two of the lakes in cluster 1 are polluted with high organic matter content; the lakes received domestic sewages and waste water resulting in low DO and high BOD. TJYA was once declared the most polluted urban lake in Malaysia with the highest number of pollution sources (Zubaidah Kasim & Rahman, 2013). The pollution in cluster 2 was due to high metal concentrations and influence of organic matter due to many sports and recreational activities. The pollution in cluster 3 is due to low DO, high BOD, AN, Mn, and as due to industrial run off, domestic waste and effluent discharges. This cluster received pollution from point and non-point sources with highest average concentrations As, Fe, Mn, AN and BOD. A suggestion was made on the association of As and low DO, emphasizing that As concentration in low DO water samples was higher than well oxygenated water samples (Hinkle, 1997). High concentration of AN is related to microbial decomposition of organic matter which consumed high amount of DO (**Fig. 2**), there by resulting in low oxidation-reduction potential which consequently accelerate the release of As from sediment to the surrounding water (Kurosawa et al., 2006).

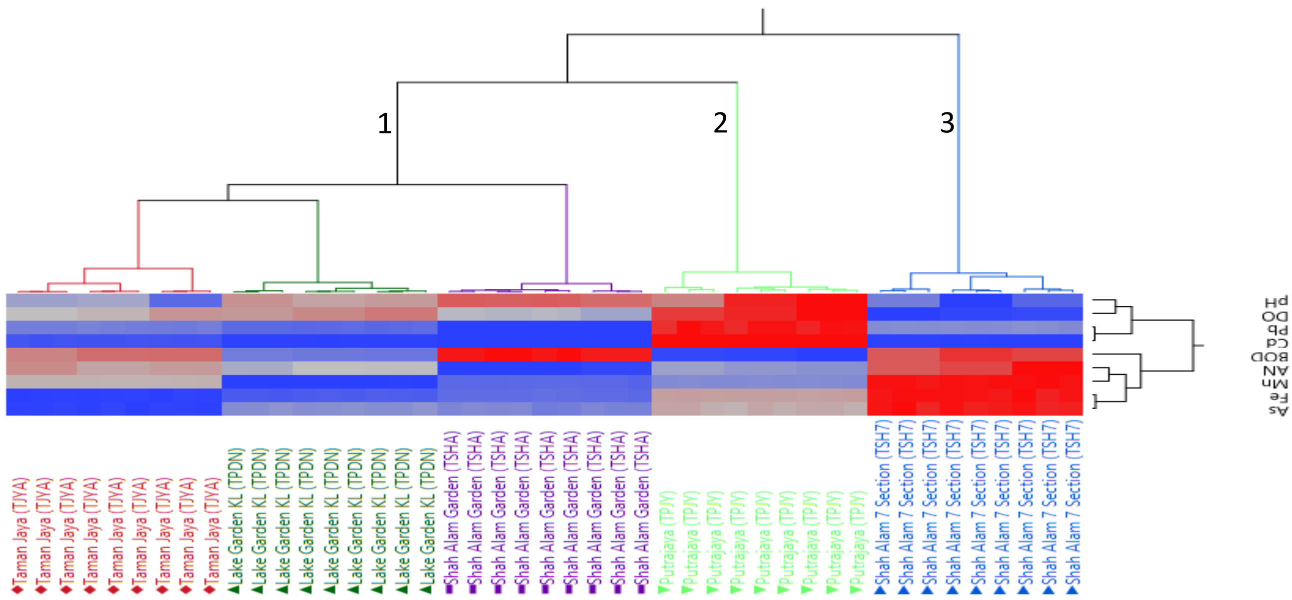


Figure 3. Dendrogram shows two-way clustering of lakes in Klang Valley bases on heavy metals and physicochemical parameters

CONCLUSIONS

Application of multivariate statistical techniques to study the water quality of selected lakes in Klang valley was successfully carried out. PCA identified the parameters responsible for the variations in water quality, and the probable sources of pollution. PCA also showed three principal components responsible for explaining about 95 % of the total variance in the data. And establish a single latent pollution source which dominantly causes the deterioration of the lakes water quality as oxygen consuming organic pollutant possibly related to discharge of domestic sewage and effluents. HCA grouped 15 sample locations from 5 lakes into 3 groups based on similarity in water quality characteristics. It therefore provides a practical classification of surface water for the prospective monitoring of pollution in the lakes studied. The results of the study also demonstrate the applicability of multivariate statistical techniques in the evaluation of water quality information, identifying the pollution sources for functional and successful lake water management. An action should be taken to monitor and reduce sewage and other domestic effluents discharged into the lakes.

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WATER QUALITY IMPACT ON FISH CULTURED IN LAKE TUTUD, NORTH SULAWESI, INDONESIA

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ABSTRACT

Lake Tutud is a lake located in North Sulawesi, Indonesia. The estimate terrain elevation above seal level is 390 meters. Latitude: 1°2'40.56", Longitude: 124°41'49.55". We determined the current condition of the water quality of Lake Tutud in terms of physical and chemical parameters in a fish farming location, Tombatu village. The determination of sampling points at each station was placed vertically at three predetermined points from the guard house toward the front of the net, the distance between one point to the next point was ± 15 m; whereas the analysis of water quality parameters was done using a HORIBA water quality checker type U-536. Determination points were done by purposive sampling which refers to the physiographic location wherever possible in order to represent or describe the water condition. The research was carried out for 6 months and done in 3 stages - morning, afternoon and evening. Direct measurement (in situ) was performed once a week at the three points which included parameters pH, temperature, conductivity, DO, Oxidation reduction potential, turbidity, TDS, depth and GPS. In conclusion, the water quality condition at the aquaculture site still complies to water quality standard according to PP No.82 of 2001.

Keywords: Aquaculture, Lake Tutud, Water Quality

INTRODUCTION

Lake is one of the natural resources that can be utilized to increase demand and meet human nutrition, such as the development of fish farming business (Zonneveld et al, 1991). Lake Tutud, one of natural lakes in North Sulawesi, is located in Southeast Minahasa Regency and has been used as hatchery for fish by village communities Tombatu 3. In recent years, based on the results of interviews with fish farmers in the village Tombatu 3, it was revealed that their cultured fish are often stricken with the disease in certain seasons. In fact, in 2015 the cases of mass death of fish farming in Lake Tutud emerged, and caused 3,000 fish loss. The case shows that Lake Tutud has problems of water quality degradation affecting the health of fish leading to a high fish mortality rate.

To determine whether good or not the water quality, the measurement is based on various parameters of water quality either biological, physical or chemical. Physical parameters such as temperature and chemical parameters are dissolved oxygen and pH of the environment is a limiting factor, if it does not qualify the needs of farmed fish will have an impact on the health of the fish. So that the water quality standard size of the health condition of the fish.

Recognizing the importance of aquaculture activities on Lake Tutud, observation of water quality monitoring of physcisc and chemistry in the area needs to be done, to get the current data for fish cultured in Lake Tutud with reference to regulation government No. 82 of 2001 on water quality management and control water pollution. Accordingly, it can be seen the impact of water quality on the health of fish in aquaculture development area in Lake Tutud (**Figure 1**).

METHODS

The determination of sampling points at each station was placed vertically at three predetermined points from the guard house toward the front of the net, the distance between one point to the next point was ± 15 m; whereas the analysis of water quality parameters was done using a HORIBA water quality checker type U-536. Determination points were done by purposive sampling which refers to the physiographic location wherever possible in order to represent or describe water condition. The research was carried out for 6 months and done in 3 stages - morning, afternoon and evening. The direct measurement (in situ) was performed once a week at the three points which included parameters pH, temperature, conductivity, DO (Dissolved Oxygen), ORP (Oxidation Reduction Potential), turbidity, TDS (Total Dissolved Solids), depth and GPS (Global Positioning System).

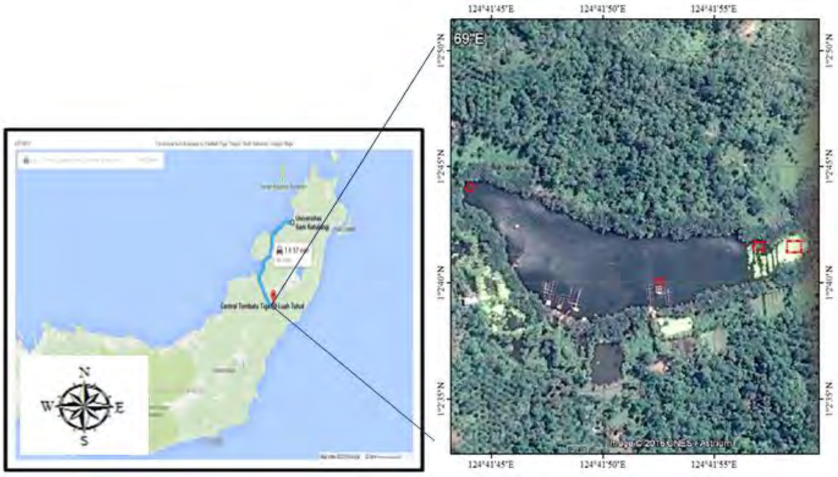

Figure 1. Lake Tutud

RESULTS AND DISCUSSIONS

Temperature

Based on the results of temperature measurements, Lake Tutud had a variation on temperature between 26.82ºC - 32.04ºC (**Figure 2**). Temperature has a significant effect on the exchange process or metabolism of living beings. In addition to affecting the process of exchange of substances, temperature also affects the amount of oxygen dissolved in the water, it also gives impacts on growth and appetite of fish (Pujiastuti et al, 2013). In addition, temperature affects the solubility of oxygen in the water, where the higher the temperature the lower the level of dissolved oxygen (Buttner et al, 1993), which in turn have an impact on the concentration of dissolved oxygen in the water.

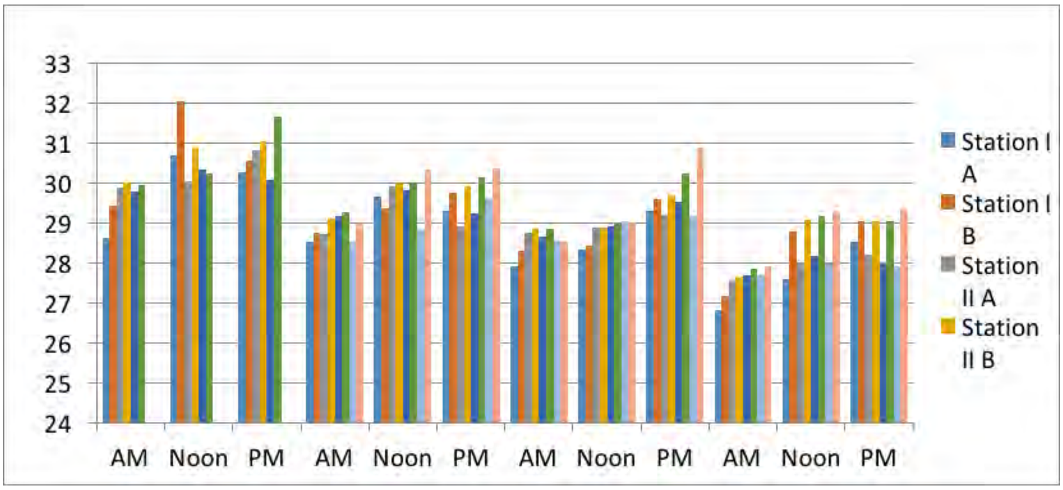

Figure 2. Temperature (ºC) at different stations

pH of water (**Figure 3.**) affects fertility because it affects the life aquatic microorganisms. Acidic waters will be less productive, even kills fish farming. At low pH (high acidity), dissolved oxygen content will be reduced, as a result of decreased oxygen consumption, respiratory activity rose and appetite will be reduced. The opposite occurs in alkaline conditions (Koordi and Tancung, 2007).

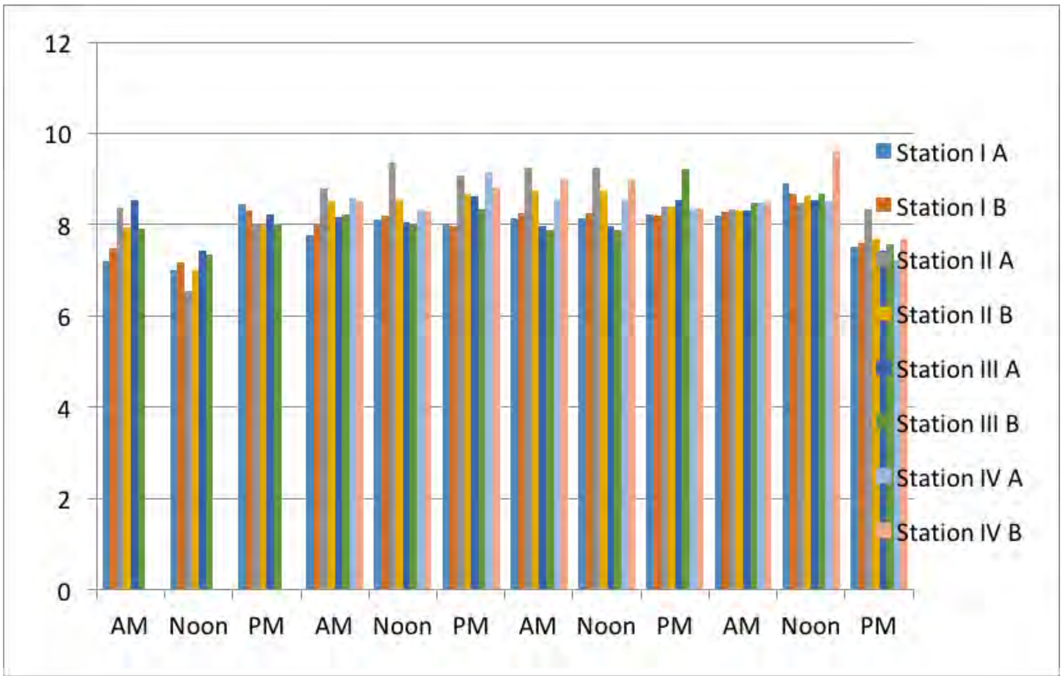

Figure 3. pH at Different Stations

Dissolved oxygen (DO)

The results of the measurement of dissolved oxygen (DO) at all sampling points in the area of cultivation nets at Lake Tutud ranged from 1 to 5.5 mg/L as measured by HORIBA (**Figure 4**). DO measurement results (5.5 mg/L) in the lake of Tutud were not that distinct to that as measured by de Breving and Rompas (2012). As well as results of research Tatangindatu et al (2013) the value DO in the village of Lake Tondano Paleloan ranged from 7.41 to 7.77 mg / L, where the position of village Paleloan are right across the village of Lake Tondano Toulimembet.

However, based on research results Kamsuri et al (2013), which was run in March-April 2013, the DO values ranged from 3.88 to 6.39 mg / L. While the distribution of DO value on the results of this study between 6.31 to 10.2 mg / L. Values DO experiencing an upward trend and were higher as compared to the results of previous studies. This shows that in the waters of Lake Tondano Village Toulimembet fitness level of the water in 2014 is better when compared to the year 2013.

The values of DO in the waters of the lake in the village of Toulimembet already exceeded the Standards of Quality of Water Quality set in Government Regulation PP No. 82 in 2001 on Water Quality Management and Pollution Control class I as a source for drinking water, which requires the value of DO is > 6 mg / L and Class III minimum DO value is 3 mg / L (Tabel 1). Kordi and Tancung (2007), the DO level appropriate for fish cultivation is between 5- 7 mg / L. This shows the general level of DO in the cultivation area is not polluted by biodegradable organic materials from the waste cultivation itself so that the impact of the DO value is still appropriate for the health of fish cultivation.

Tabel 1. Government Regulation (PP. No. 82 in 2001)

Parameters	Class I	Class III
Temperature (°C)	Deviation 3 (from natural)	Deviation 3 (from natural)
pH	6 - 9	6 - 9
DO (mg/L)	6	3

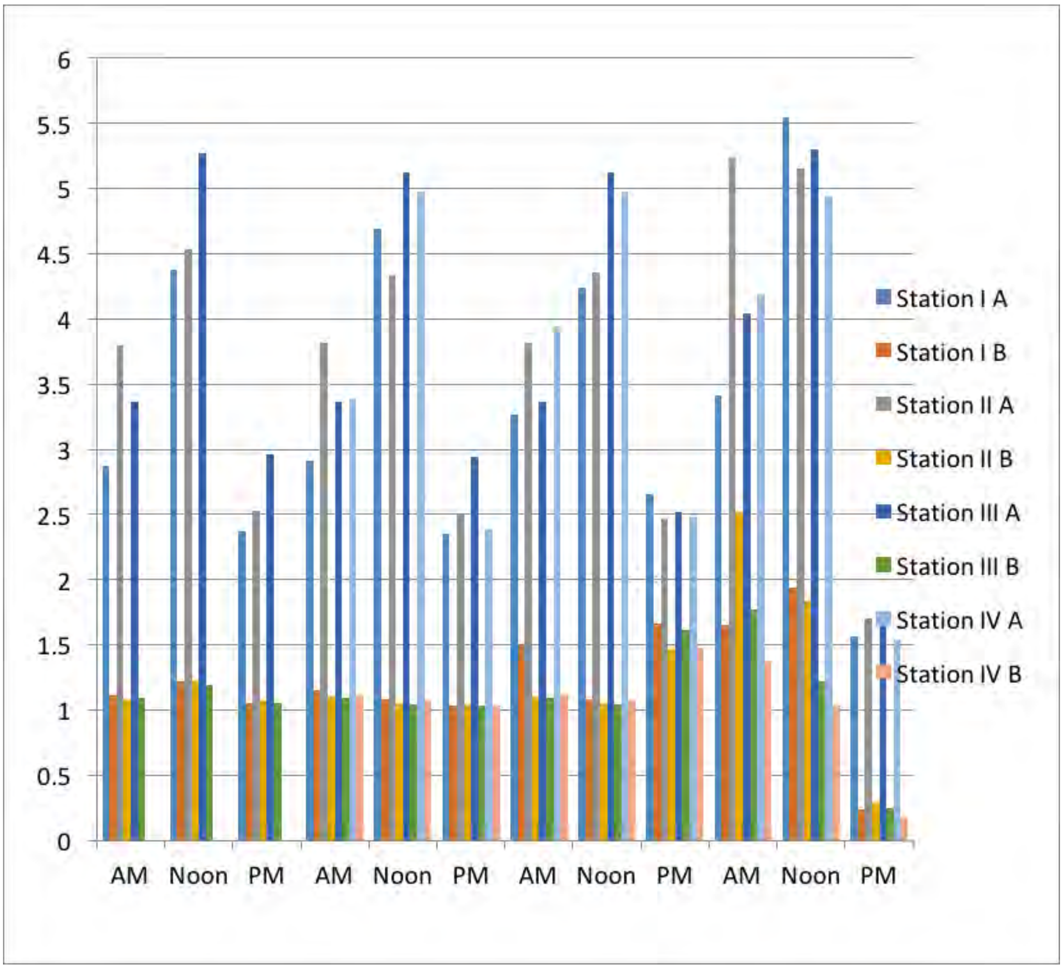

Figure 4. DO at Differents Stations

CONCLUSIONS

The water quality condition at the aquaculture site still complies to water quality standards according to PP No.82 of 2001.

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WATER QUALITY AND DIVERSITY OF AQUATIC INSECTS IN HIGHLAND AGRICULTURAL AREA, CHIANG MAI, THAILAND

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ABSTRACT
The highland agricultural products are widely popular in Thailand. One of the most important rose production area is located in Northern Thailand. In high production season, high volumes of chemicals have been used for enhancing their products, which have also contaminated highland soil that eroded by rain and runoff to stream. The stream organisms have been affected by the chemical erosion. This study was aimed to investigate physico-chemical parameters and diversity of aquatic insects from upstream to downstream of Mae-Sa tributary streams in Buak Tuei Village, Pong Yang Sub-district, Mae Rim District, Chiang Mai Province, Thailand. The water samples and aquatic insects were collected from 5 study sites of Mae-Sa tributary stream. The upstream sites located nearby agricultural area. The results showed pH, water velocity, electric conductivity (EC), TDS, BOD_5 and ortho-phosphate were significant difference ($p<0.05$) between sampling sites. According to aquatic insect diversity, the highest abundant in upstream were represented by Chironomidae, Simuliidae, and Gerridae family respectively, whereas, the downstream sites were presented by Chironomidae, Simuliidae, Hydrosychidae and Baetidae respectively. The downstream sites showed higher diversity as they presented 27 of insect families, while upstream sites presented only 17 families. As the results, upstream sites showed the higher concentration of BOD_5 and ortho-phosphate than downstream sites. Therefore, these parameters might be affected to diversity of aquatic insects nearby agricultural area.
Keywords: water quality, highland agriculture, aquatic insects

INTRODUCTION

The increasing demand for agricultural products and the urbanization in lowland areas has led to the expansion of permanent cultivation to the vulnerable slopes of the mountainous areas in northern Thailand. The climate is characterized by the sequence of distinct rainy and dry seasons (Panuwet *et al*., 2008). To protect crops from diseases and to increase crop yields, the application of pesticides has been intensified during the last decades. Rainfall-induced surface runoff is considered an important transport pathway of pesticide loss from agricultural fields. Thus, pesticide contamination in water resources is a relevant environmental issue in this region (Ng and Clegg, 1997). Biological monitoring is an alternative approach in cases of sporadic and non-point sources of pollution. Different human activities can alter physical, chemical or biological processes associated with water resources and thus modify the resident biological assemblages (EC – European Commission, 2000). Changes in species richness and abundance can be a signal of impairment and together with other traditional measurement. This may be used to register environmental degradation (Rosenberg and Resh, 1993). The advantages of using biological indicators include long term assessments and higher sensitivity to detect subtle changes in water quality and low concentrations of chemicals. Also, biological responses tend to integrate the independent and interactive effects of many stressors, resulting in more robust indicators than analysis of individual chemicals (Cairns *et al.*,1993). Therefore, this study was aimed to investigate effects of agrochemical (pesticide and fertilizer information from farmer interviews) on physico-chemical parameters and diversity of aquatic insects from upstream to downstream of Mae-Jha stream is a main water resource of this area. This stream is tributary of Mae-Sa river. Mae-Jha stream located in Buak Tuei Village, Pong Yang Sub-district, Mae Rim District, Chiang Mai Province, Thailand.

METHODS

Study sites:

The 5 studied sites (**Figure 1**) were located along Mae-Jha stream Mae-Sa tributary streams in Buak Tuei village, Pong Yang Sub-district, Mae Rim District, Chiang Mai Province. Site 1 and 2 were upstream sites and located along the rose production area, whereas, the site 3 to 5 were located in downstream sites respectively. The width of each sampling sites are less than 1 meter, which have also composition of streambed substrates are diverse and characterized by rock, sand and muddy. Moreover in site 5 is mainly consisted by cobble. Data was collected between June and October 2015.

Water quality parameters:

Physical and chemical parameters were on site measured and recorded in each time which consisted of pH, DO, electric conductivity, TDS, water and air temperature, and water velocity. In addition, water samples were also taken and preserved for further laboratory analysis for BOD_5, nitrate-nitrogen, ammonia-nitrogen and ortho-phosphate according to APHA, AWWA, and WEF procedures.

Aquatic insect sample:

Kick method (Mustow, 2002) was used to collect aquatic insect samples. The Kick net was sampled randomly by stepping and kicking at the left, centre and right stream banks within about 5 minutes over the sampling area until an adequate number of aquatic insects was collected. After that, aquatic insect samples were preserved in 95% ethanol and packed for further examination in the laboratory. Aquatic insect samples were sorted, counted and identified mostly at genus level under stereoscopic microscope.

Figure 1 Upstream to downstream of Mae-Jha stream, Mae-Sa tributary streams in Buak Tuei village

Analysis data:

The physico-chemical parameters were compared according to the Surface Water Quality Standard of Thailand. Shannon-Wiener Index (H) which, accounts for both abundance and evenness (based on the Shannon-Wiener index) was used to characterize species diversity. The higher biodiversity index might reflect the more stable water quality which lower diversity may indicate an unstable community (Chiangthong and Phalaraksh, 2007). In addition, the Pearson correlation was used to analyze the relationship between aquatic insects and physico-chemical parameters.

RESULTS AND DISCUSSIONS

The results showed that pH, velocity, conductivity, TDS, BOD_5 and ortho-phosphate were significant difference ($p<0.05$) between sampling sites. The highest pH was shown at site 5, whereas, water velocity was between 0.27-0.47 m/s where the highest value at site 5. The conductivity was detected between 62.0-114.9 µS/cm where the highest value was at site 1, whereas, TDS was detected between 31.4-57.3 mg/l where the highest value was shown at site 1 and site 5. The BOD_5 were detected between 0.38-1.04 mg/l where the highest value was found at site 2. For inorganic nutrients, the ortho-phosphate values were detected between 0.18-0.36 mg/l where the highest value was at site 1. Physico-chemical characteristics in all sampling sites (**Table1**) can be classified from the Surface Water Quality Standard of Thailand in class 2 (Very clean fresh surface water resources). Due to water volume in site 1 and 2 are really low and there are located near rose production area. For this reason, agrochemical that reaching from rose production area cannot flow into downstream, leading to the high level of conductivity, TDS and ortho-phosphate. The study of Tambo J. et al. (2010) in agriculture intensified lands located in upper zone has been associated to increase soil concentrations in soil organic matter, nitrate, potassium and contamination with phosphorus as well as pesticide residues (organophosphate and carbamates) and increased in the frequency of erosion, flooding and siltation in the watershed. Pesticide and fertilizers from intensive agriculture can be the main problem for water pollution in that area, especially in dry season, which is low runoff chemical.

Table 1 Mean values (±SD) of physico-chemical characteristics in the sampling sites.*$P<0.05$; NS = not significant*

site	Temp (ºC)		Lux	pH	EC (µS/cm)	TDS (mg/l)	Velo. (m/s)	DO (mg/l)	BOD_5 (mg/l)	NO_3-N (mg/l)	NH_3-N (mg/l)	Ortho-P(mg/l)
	Air	Water										
1	24.25 ± 4.88	21.04 ± 1.39	655 ± 165	6.5 ± 0.3	114.9 ± 9.2	57.3 ± 7.5	0.27 ± 0.20	6.6 ± 0.6	0.83 ± 0.21	0.56 ± 0.09	0.14 ± 0.04	0.41 ± 0.16
2	22.63 ± 2.69	21.30 ± 1.15	1208 ± 743	6.2 ± 0.2	62.0 ± 3.2	31.4 ± 3.2	0.27 ± 0.15	6.3 ± 0.7	1.04 ± 0.41	0.60 ± 0.30	0.20 ± 0.07	0.28 ± 0.14
3	23.88 ± 3.69	21.49 ± 1.70	710 ± 400	6.5 ± 0.2	84.1 ± 6.1	42.1 ± 2.9	0.37 ± 0.04	6.9 ± 0.6	0.87 ± 0.30	0.53 ± 0.08	0.17 ± 0.06	0.18 ± 0.03
4	23.69 ± 3.13	21.63 ± 1.73	4318 ± 1342	6.7 ± 0.2	101.6 ± 9.3	50.3 ± 9.3	0.39 ± 0.12	6.4 ± 0.7	0.38 ± 0.04	0.59 ± 0.16	0.16 ± 0.03	0.24 ± 0.10
5	26.13 ± 4.37	23.88 ± 1.59	9775 ± 4899	6.8 ± 0.2	114.6 ± 3.1	57.3 ± 3.1	0.47 ± 0.21	6.8 ± 0.3	0.88 ± 0.38	0.52 ± 0.17	0.15 ± 0.04	0.36 ± 0.17
P value	-	*	*	*	*	*	*	NS	*	NS	NS	*

According to aquatic insect diversity, the downstream sites showed higher diversity as they presented 27 of insect families, while upstream sites presented only 17 families, the highest abundant in upstream were represented by Chironomidae, Simuliidae, and Gerridae family respectively. Whereas, the downstream sites were presented by Chironomidae, Simuliidae, Hydrosychidae and Baetidae. However, the correlation between number of aquatic insect taxa and physico-chemical parameters (**Table 2**), which showed positive correlations with DO (dissolved oxygen) and ortho-phosphate. The negative correlation was found in ammonia-nitrogen. Human activities along Mae-Jha stream are the source of pollution, especially in agricultural areas. Moreover, seasonal can be effected to water volume in Mae-Jha stream and also relate to physico-chemical and biological parameter respectively.

Table 2 The correlation between number of aquatic insect taxa and physico-chemical parameters

		AT	WT	Light	pH	EC.	TDS	Velo.	DO	BOD	NO_3-N	NH_3-N	Ortho-P	No.individual	No.Taxa
Air Temp.	Pearson Correlation	1	$.824^{**}$	.289	.431	.341	.322	$.697^{**}$	-.022	-.195	.204	$.615^{**}$	$-.510^{*}$	-.217	-.302
Water Temp.	Pearson Correlation		1	$.606^{**}$	$.589^{**}$	.327	.316	$.507^{*}$	-.288	-.218	-.146	$.472^{*}$	$-.509^{*}$	-.166	-.406
Light	Pearson Correlation			1	$.630^{**}$	.415	.383	.277	-.097	-.291	-.265	.079	-.175	-.107	-.032
pH	Pearson Correlation				1	$.602^{**}$	$.589^{**}$	.207	-.319	-.338	-.055	.317	$-.448^{*}$	$-.584^{**}$	-.231
EC	Pearson Correlation					1	$.993^{**}$	.290	.115	-.169	-.042	-.160	.111	-.200	.231
TDS	Pearson Correlation						1	.242	.072	-.136	-.064	-.149	.095	-.223	.184
Velo	Pearson Correlation							1	.236	-.180	.335	.291	-.296	.026	.231
DO	Pearson Correlation								1	.003	.347	-.247	$.450^{*}$	.342	$.590^{**}$
BOD	Pearson Correlation									1	-.036	.034	.122	-.100	.207
NO_3-N	Pearson Correlation										1	.404	-.087	.082	.219
NH_3-N	Pearson Correlation											1	$-.724^{**}$	-.431	$-.596^{**}$
Ortho-P	Pearson Correlation												1	$.562^{**}$	$.625^{**}$

CONCLUSIONS

The effect of the agrochemicals was not clear according to the related parameters such as concentrations of nitrate-nitrogen and ammonium-nitrogen from fertilizers were not significantly different along the study sites. Therefore, the concentrations of pesticides and related nutrients in both water and soil samples are recommended to measure in the future study.

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PHYSICAL AND CHEMICAL CHARACTERISTICS OF SEDIMENT IN LAKE TEMPE USING MULTIVARIATE ANALYSIS APPROACH

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ABSTRACT

Lake Tempe located in South Sulawesi province is a lake having great potentials. One of them is its function as the most important center for freshwater fish production in Indonesia. Problems that is quite of them are sedimentation. One of the major problems facing this lake sedimentations. The sediment was dominated by silt containing materials deposited through chemical and biological processes. Multivariate statistical techniques, such as cluster analysis (CA) and principal component analysis (PCA), were applied in this study for analyzing physical and chemical characteristic of sediment associated with spatial and temporal variations in Lake Tempe. This study aimed to reveal characteristics of sediment substrates in Lake Tempe. Sampling was conducted by using Ekman Grab in March 2016 at six stations. The sediment samples were analyzed in the laboratory with parameters of total N, total P, total organic carbon, total organic matter (TOM), and particle size with three fractions (sand, silt, and clay) based on technical analysis methods of sediment. There are two components of the PCA analysis result with varimax rotation. Sediment texture of River Bila, St. 1, and St. 3 were characterized by silt and clay with high Total N content and acidic pH. Whether that from Station 2, St. 4, and St. 5, were characterized by high Total P, C-organic and organic matter content. Results of the hierarchical cluster analysis, showed that three groups of sampling locations had specific characters. St. 1 in Group I, St. 2 & St. 4 in Group II and St. 3, St. 5 and the mouth of River Bila in Group III.

Keywords: physical and chemical, characteristic, sediment, Lake Tempe, statistical

INTRODUCTION

At Present time, the environmental conditions of inland waters in Indonesia have been many degraded, both in quality and quantity. Various anthropogenic activities have been known to affect to the lake ecosystem, which include deforestation and land use change in the catchment area that can lead to erosion, sedimentation and changes in the hydrological cycle. Furthermore, the degree of exploitation and the rate of pollution tend to increase the utilization of water resources.

Lake Tempe is one of the large lakes in Indonesia located in the province of South Sulawesi, precisely being shared by three districts namely Wajo, Sidrap and Soppeng. Geographically Lake Tempe is located at 4°00'00"- 4°15'00" LS and 119°52'30 "- 120°07'30" BT. Lake Tempe was formed by a depression of Asian-Australian tectonic plates, located in the River Basin Walannae Cenranae.

The various issues have led to environmental degradation in Lake Tempe, sedimentation is of the major issues. Siltation in Lake Tempe is due to the high rate of erosion and sedimentation (Dina et al., 2014). Erosion is the process of the transfer or carryover of land or part of land from one place to another (Sinukaban, 1989). Increasing the amount of erosion and sedimentation will have a great impact on the lake. Silt derived from crushed rocks, or biological materials were transported through liquid and solids (sludge) were hovering inside, or deposited in the water (Selley, 1988). Erosion and sedimentation cannot be separated from high deforestation rates in each watershed. Lake Tempe is influenced and affected by three biggest watersheds. They are Walanae - Cenranae in the southern part, Bila in the north, and Tempe Depression / Stones in the West.

Morphology of Lake Tempe at present is thought to have reached the level of sedimentation equilibrium, where the morphology at the moment is very suitable for breeding of aquatic life, especially fish. Soil particles were carried through the process of erosion resulting in improvement of nutrients in the water body. These nutrients have accelerated the process of eutrophication in the waters of Lake Tempe. Explosion of plant growth might be one indicator that nutrient enrichment or eutrophication might have been occurred in Lake Tempe.

Multivariate statistical techniques have been applied to characterize and evaluate the condition of water quality, because the technique is useful for verifying the variation of temporal and spatial caused by natural and anthropogenic factors associated with the season. Several studies applied multivariate statistics in the different ecosystems such as lake (Kazi et al., 2009), watersheds (Shrestha & Kazama, 2007), and coastal waters (Vijay Kamble, 2011; Erlania & Radiarta, 2011). Multivariate statistic widely used is the cluster analysis, principal component analysis, and factor analysis. The analysis is used to

assist in the interpretation of complex data matrix to better understand of water quality and ecological status of the system being studied. Results of analysis sometimes create a new variable to reduce the number of original variables in the comparison and interpretation of data (Ragno et al., 2007)
Principal Component Analysis is a group of multivariate analysis whose main purpose is to classify the object based on the characteristics they have. Component Analysis (CA) performed on the data that has been standardized through scale transformation-Z (Z-scale). This transformation is to avoid incorrect classification due to the variation of each unit water quality parameters; in addition, standardizing can increase the influence of parameters a variant of small and otherwise far the influence of parameters with large variance (Varol & Sen, 2009). PCA classifies objects so that similar objects are grouped in the same cluster, in accordance with the criteria used (Varol & Sen, 2009; and Vijay Kamble, 2011). PCA results from a group of objects should show a high similarity in the cluster and between clusters of high inequality. In this research, agglomerative hierarchical clustering method from Ward (Ward's method) and squared Euclidean distances CA were the methods used to measure the degree of similarity of objects. CA results can be described in the form of dendogram (tree diagram).

METHODS

The study was conducted in Lake Tempe, Wajo, South Sulawesi Province. Sampling was conducted in March 2016 within five stations spread over the observation location (**Fig 1**). Sampling was conducted using Ekman Grab. Sediment samples were added to sealed container and then taken to the laboratory for analysis. physical – chemical parameters. The parameters measured were Total N, Total P, TOM, organic carbon and sediment textures (i.e. are silt, clay, and sand.
Sampels analysis was conducted by using method based on technical Guide of Soil analysis (Eviati & Sulaeman, 2009). Data analysis was using Microsoft Excel 10 and XLstat software.

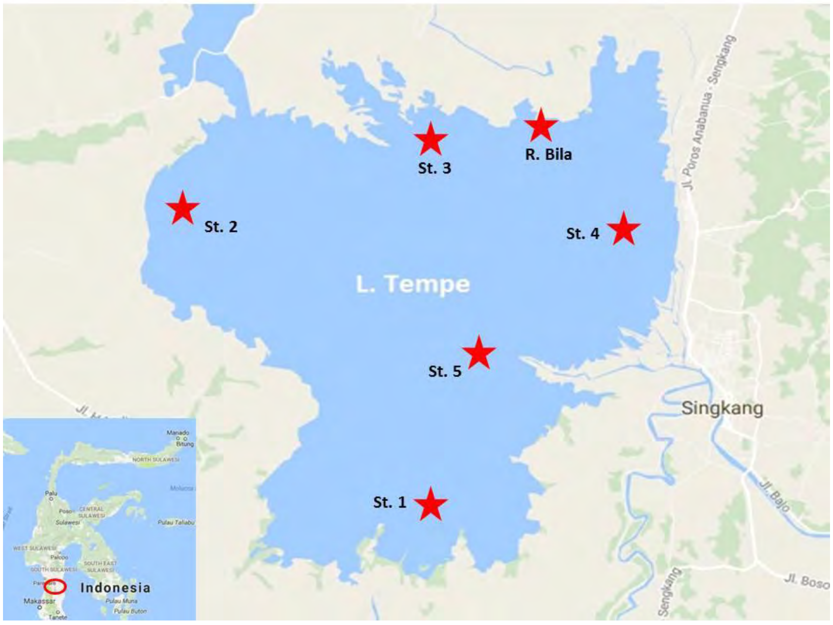

Figure 1. Sampling Location in Lake Tempe

RESULTS AND DISCUSSIONS

Physical Characteristic

Analysis result of sediment sample in Lake Tempe during the study showed that there are three sediment fractions, sand, silt and clay. Distribution of the average percentage of each fraction at each stationcan be seen in **Fig 2**. It showed that the concentration of clay had the highest percentage as compared to sand and silt across study sites. The highest percentage of clay was found in the Station River Bila. Clay has the particle size of less than 2μ, the smallest of all the soil texture (Hardjowigeno, 2007). The sediments containing a lot of clay fraction have a slow water exchange rate, it is caused by the small size of the clay particles. Consequently O_2 exchange brought by the water comes into the sediments to be obstructed (Emiyarti, 2004).

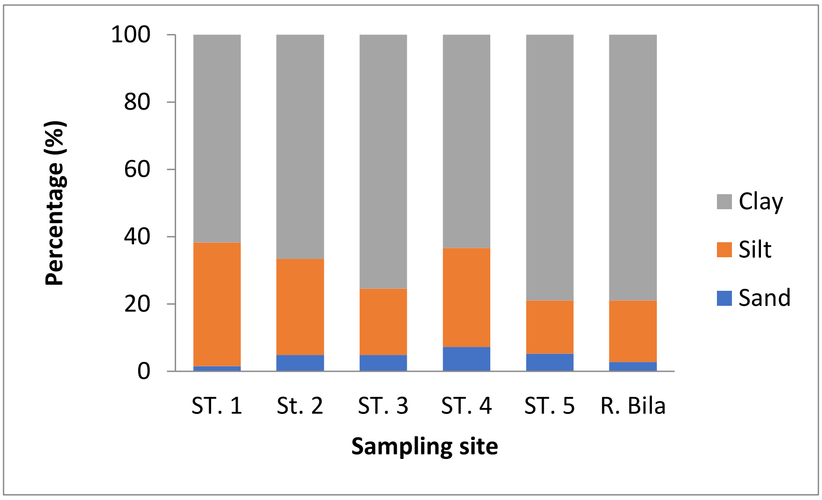

Figure 2. Proportion of Sediment Texture

The second highest concentration of sediment texture from Lake Tempe is silt. Silt is one of the ingredients of land which has a particle size that is smaller than 50µ to 2µ (Hardjowigeno, 2007). Washing of the silt entering the area in the form of fine particles are carried by the flow of the river to the lake. The main source of silt load is the result of weathering rinse the top layer of rock or soil in a watershed (Sudradjat et al, 1996 in Tamod, 1998).

Type of particles in Tempe Lake is relatively smooth. Sediment with the largest percentage in the form of fine particles showed that the sediment in Lake Tempe was derived from organic compounds and deposition of the dissolved particles originating from the input streams that enter Lake Tempe.

Chemical characteristic

Organic Carbon & Total Organic Matter

The results of analysis of organic carbon in the sediments of Lake Tempe shown in **Fig 3**. The image showed that the levels of C-organic sediments of Lake Tempe ranged between 3.44% - 16.86%. The high concentration of organic carbon is suspected due to agricultural activities of communities around Lake Tempe where the land management was carried out intensively ignoring the principles of conservation land, there for it is more susceptible to erosion.

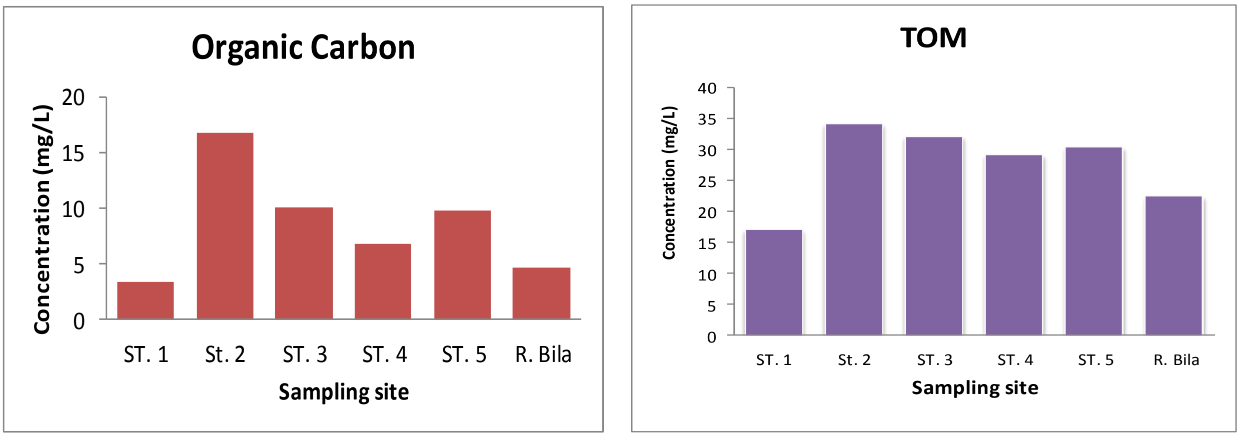

Figure 3. Distribution of Organic Carbon and TOM Concentration in Lake Tempe Sediment

Arsyad (2000) suggested the nutrient content of organic matter in the sediment and erosion results in higher concentration than that in the soil left remained. This is partly due to the selectivity of erosion events. Besides the top layer of soil contains nutrients higher than that from lower layers of the soil.

Sediment is a deposit for a wide variety of the compound, one example is a deposit for the compound of carbon and nitrogen. This is needed by aquatic plants and can potentially be the compound easily available for the growth of aquatic organisms. Degradation of C and N will produce compound that is easily absorbed by the aquatic organisms.

Total Nitrogen
Fig 4 showed that concentration of total nitrogen in Lake Tempe sediments ranged between 0:35 % - 0.77%. High concentration of total nitrogen is likely related to organic-C concentration found in sediments of Lake Tempe. Nitrogen source in soil was mainly derived from organic matter after atmospheric-N. Organic-N compounds in soil are generally present in the form of amino acids, proteins, amino sugars and complex compounds are difficult to determine. Complex compounds, among others, are the reaction $NH4^+$ - lignin polymerization of Quinon and nitrogen compounds and condensation of sugar + amino (Leiwakabessy et al, 2003).

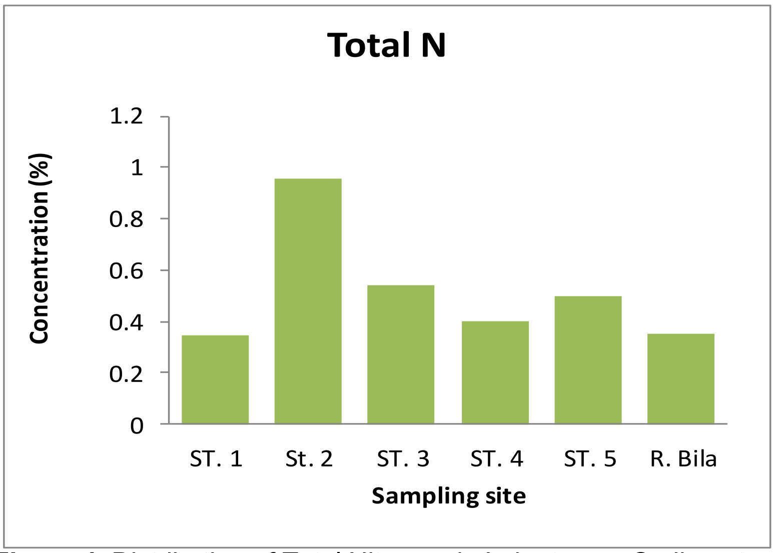

Figure 4. Distribution of Total Nitrogen in Lake tempe Sediment

Total Phophorus
From the analysis of total phosphorus, it was shown that, the concentration of Total P in Lake Tempe sediments ranged between 0.05% - 0.091% (**Fig 5**). Phosphorus concentration in Lake Tempe sediment was not significantly different at α 0.05 (Kruskal-Walls) between sampling stations.
Leiwakabessy et al (2003) reported that, the levels of P-total in the soil are generally low and vary depending on the type of soil and phosphates in the soil are usually in the form of a relatively poorly soluble. Arsyad (2000) also noted that, the number of lost nutrients is contingent upon the amount of the nutrient content and the amount of sediment was carried away by erosion.

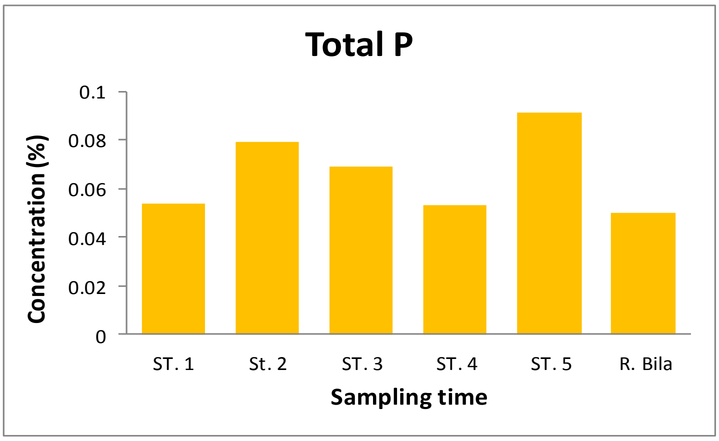

Figure 5. Distribution of Total Phosphor in Lake Tempe Sediment

pH

Fig 6 showed that the pH value of Lake Tempe sediments ranged from 6:27 to 6:43. Slightly acidic pH value is due to the contribution of H^+ ions derived from humus functional groups such as carboxyl (-COOH) and phenol ($-C_6H_4OH$) and also enol and amide groups that can contribute to H^+ ion. As the case of Total P. pH value of Lake Tempe sediments was also not significantly different between sampling stations. This is probably due to the morphology that resembles a flat plate (type entropies) to enable distribution of chemical and physical material evenly on the surface layer of sediment.

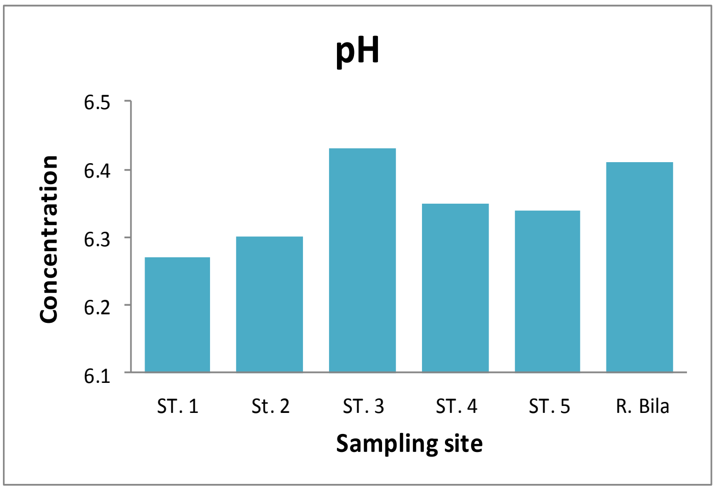

Figure 6. pH Value in Lake Tempe Sediment

Multivariate analysis

There are two components of the PCA analysis result with varimax rotation (**Fig 7**). Sediment texture of River Bila, St. 1, and St. 3 was characterized by silt and clay with high Total N content and pH with slightly acidic values. Station 2, St. 4, and St. 5 were characterized by high Total P, C-organic and organic matter content.

Mouth of R. Bila, St. 1 and St. 3 are the locations strongly influenced by the river activities. Silt and clay are texture considered to be optimal for agriculture (Foth, 1994). The content of clay comes from the river, the material that is carried by the flow of water (run-off) from the surrounding areas, including agriculture. This is supported by the high content of Total N in these locations. The high concentration of Total N is supposed to be derived from anthropogenic pollutants from the surrounding area and agricultural activities. While the high content of organic matters and total P in St. 2, St. 4 and St. 5 is probably caused by soil coarser particles (sand) that accumulate along with other organic materials.

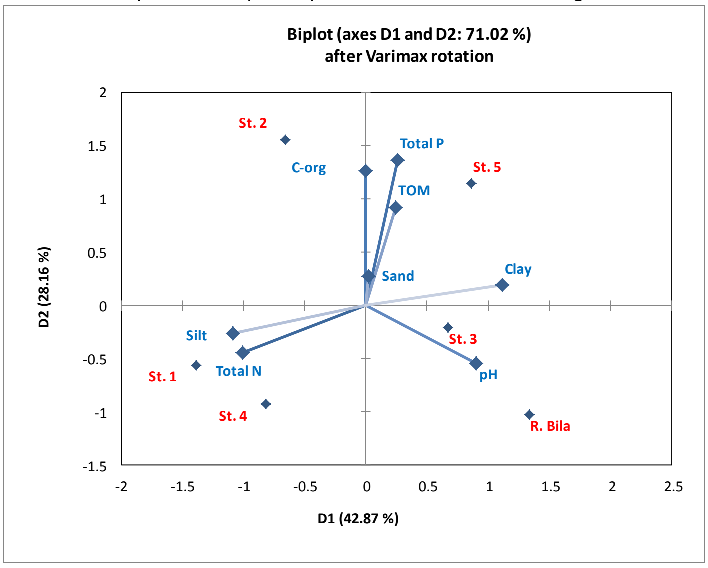

Figure 7. Principle Analysis Component with Varimax Rotation

Result of the hierarchical cluster analysis (**Figure 8**) explained three groups of sampling locations with specific physicochemical characteristic. St. 1 in Group **I**, St. 2 & St. 4 in Group **II**, and St. 3, St. 5 and the mouth of River Bila in Group **III**

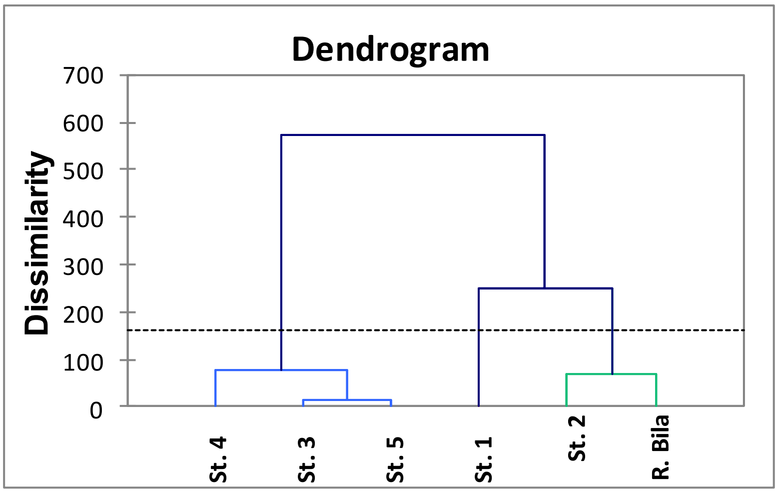

Figure 6. Analysis of Hierarchical Cluster

CONCLUSIONS

There are two components of the PCA analysis result with varimax rotation. River Bila, St. 1, and St. 3, sediment texture was characterized by silt and clay with the high Total N content and pH with slightly acidic values. Station 2, St. 4, and St. 5, were characterized by high Total P, C-organic and organic matter content. Result of the hierarchical cluster analysis, found three groups of sampling locations with specific physicochemical characteristic. St. 1 in Group **I**, St. 2 & St. 4 in Group **II**, and St. 3, St. 5 and the mouth of River Bila in Group **III**

Multivariate statistical techniques could be applied to characterize and evaluate the condition of the quality of the environment. Further research is needed to obtain more representative data series.

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THE SEASONAL OF THERMAL STRATIFICATION AND WATER COLUMN STABILITY OF LAKE MANINJAU, WEST SUMATERA

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ABSTRACT

Lake Maninjau is a deep and eutrophic lake, located in west Sumatera, Indonesia. Geographically, lake Maninjau experiences a hot and humid climate throughout the year. Atmosphere temperature variations was greatly influenced the physical phenomena in lake, especially thermal stratification and water column stability of lake. This paper describes the fluctuation of thermal stratification and water column stability in lake Maninjau. There are four mathematical calculations related to water column stability of lake as a function temperature: thermocline depth (t.d), bouyancy frequency (N^2), Relative Thermal Resistance to Mixing (RTRM), stabilty index (SI) and stratification index. The water column temperature is measured in May 2007, April 2009, May 2015 and March 2016 located in DM7 station. The water column and air temperature in May 2007 and March 2016 are hotter than in April 2009 and May 2015. The deepest thermocline depth is 10.9 m in 2009 and the shallowest is 1.5 m in May 2015. While the thermocline depth in May 2007 and March 2016 are 8.9 and 9.3 m respectively. Thermal stratification and stability index of water column is varying which are shown by the highest thermal stratification index and stbilty index in May 2007 and the lowest in May 2015. The same with SI and t.d, buoyancy frequency and RTRM are varying in every observation. The fluctuation of thermal stratification and the water column stability parameter in every observation are equivalent to fluctuation of air temperature. It is indcates that lake Maninjau is very susceptibe to a driving forces from atmosphere.

Keywords: Lake Maninjau, thermal stratification, water column stability.

INTRODUCTION

Thermal stratification is the important physical event in the lakes which contributes so much to ecosystem structure of lake and it is strong influenced by heat of the sun (Goldman & Horn, 1983). Thermal stratification is formed in vertical direction which is usually expressed by means of temperature gradients (Heitmann. 1973). Many lakes have a vertical thermal stratification in their water bodies~~,~~ for some time periods and is contributes to density differences in water (Boehrer and Schultze, 2008). The stratified lakes are characterized by the formation of the thermocline layer. The thermocline is a layer of water in which temperature changes more rapidly with depth than it does in the layers above (surface or mixed layer) or below (deep water) (Fiedler, 2010).

Thermal stratification is one of the indicators to determine the water column stability status of lake. The stability of a lake is the work that would be required to transform the density distribution into one of new uniformity without further addition or subtraction of heat (Schmidt, 1928 in Madsen, et al., 1978). When the density distribution is uniform, mixing process will easy to occur and even can reach to the depth. But, for the lake with the thermal stratification, a difference of only a few degrees in temperature is then sufficient to prevent complete circulation (Wetzel, 2001). Lake whose temperature is stratifying, can be suppresses mixing between the nutrient enriched hypolimnion and the nutrient poor epilimnion.

Physical characteristics of lake surface are greatly influenced by the atmosphere. The atmosphere temperature can change a surface temperature of lake. As a result, when in dry season, thermal stratification or thermocline can be established in deep lake. On the contrary, during the cold period, surface cooling forces the water masses to deep and remove of gradients of water temperature and thermocline disappeared (Boehrer and Schultze, 2008). The depth and shape of the thermocline vary with season (Fiedler, 2010). As a result, thermal stratification and water column stability of lake will be vary with season. Actually, there are often two thermoclines, the upper one is the diurnal thermocline and the lower one is the seasonal thermocline (Virta and Elo, 2011).

In Indonesia, special studies of thermal stratification and water column stability of lake, is rarely done. Analyzing Trough the thermal stratification and stability analysis, we can determine the dynamic of water mixing, that have many consequences for living organisms in lakes. For example, in ~~l~~ Lake Maninjau, there are often occurs the mass fish killed, when the wheatear is cool and clouds covering the sun for a long time. This wheatear changes, affect decreasing of water surface temperature and disappearing of thermal stratification. It is lead to circulation of the water mass between epilimnion and hypolimnion layer, and cause sulfide diffusion to the upper layer, which is danger for fish. Therefore, the objective of this study is to know the fluctuation of thermal stratification and water column stability of lake with case studies in Lake Maninjau.

Study Area

Lake Maninjau is a deep and a tecto-vulcanic lake, located in west Sumatera, Indonesia E: 00012'26.63" - S: 0025'02.80" and E:100007'43.74 " - E: 100016'22.48 ", 0°19’N, 100°12’E. (Syandri, et al., 2014). Length and wide of lake Maninjau is 17 km and 8 km, respectively. The maximum and average depths of the lake are 169 m and 106 m. Maximum surface area and total volume of the lake are 99,5 km^2 and 10.4 km^3, the average retention time is 47 yr. Lake Maninjau only has one outlet named Batang Antokan. This river flow to the Indian Ocean (Nontji, 2016). Geographically, lake Maninjau experiences a hot and humid climate throughout the year.

METHODS

The collection of temperature profile data was conducted by two methods. First, is direct measurement in 2015 and 2016 and the second is by downloaded the data from SIDI (Sistem Informasi Danau Indonesia) website for temperature data in 2007 and 2009. Each of temperature measurement was conducted in DM7 station (**Figure**. **1**). The air temperature data was collected from e-most (environmental monitoring and warning system) was installed in Koto Malintang (0° 16.373', 100° 9.849') and Sicincin climate station, Padang Pariaman. The linier interpolation was conducted to fill the temperature data gap in several layer of depth. The data is then used to calculate the stability indices. There are several stability indices or numbers have been proposed, thermocline depth, thermocline strength index (Yu, et al, 2010), stratification index (Adams, et al., 2007), stability index (Sahoo, et al., 2015), Brunt-Vaisala frequency (Sahoo, et al., 2015), relative thermal resistance to mixing, etc.

Figure 1. Bathymetry map of Lake Maninjau, West Sumatera Province.
DM7 is an observation site.

Thermocline Depth

The precision method to estimate the thermocline depth is to find the maximum gradient temperature with depth (dT/dz) (Fiedler, 2010). In recent studies, Virta and Elo (2011) reported, thermocline depth can easily be defined numerically, e.g., using spline interpolation, or visually from the depth-temperature graph. Kim and Miller (2007) in Fiedler (2010) used piecewise cubic spline interpolations of observed profiles to estimate the thermocline depth. In this study, thermocline depth is calculated by numerical method used rLakeAnalyzer package in RStudio software, version 0.99.896.

Stratification Index

Stratification index is a part of density stratification. Just like the other stability parameters, stratification index show the strength to resistance the mixing. Stratification index is calculated by the following equation :

$$Stratification\ index = \sum_{i=0}^{n}(\rho_i - \bar{\rho})gh_i\Delta h$$

Where ρ_i is the density of i- layer, $\bar{\rho}$ is the average density, g is gravitation, h_i is the depth of i-layer and Δh layer difference.

Stability Index

Stability index is the simple term use to ~~in~~ measure~~s~~ the energy required to mix the lake water when it is stratified. This formula is appropriate used to measure~~s~~ the stability of upper layer of lake. Because this formula assumes that the surface area of the whole upper layer at this depth is uniform. Stability index is calculated by

$$SI = \sum_{z0}^{z}(z - \bar{z})\rho_z$$

Where ρ_z is water density at depth, $\bar{z}$ is the centroid of the water column, $z0$ and z are the depths of the surface water and the lower end, respectively. Energy required to mix the lake water when it is stratified can be calculated by multiplying this formula and by the gravitational acceleration each layer volume.

Buoyancy Frequency (N)

Buoyancy frequency is the index used to measure the stratification and it is defined as the resistance to the turbulent. Physically, this formula is to interpret the frequency of vertical fluid displacement (fluid oscillation). The frequency estimated using the following equation:

$$N = \sqrt{\frac{g}{\rho_z}\frac{\partial\rho_z}{\partial z}}$$

Where $\partial\rho_z/\partial z$ is the vertical density gradient, g is the acceleration due to gravity, and ρ_z is the density at depth z.

Relative Thermal Resistance to Mixing (RTRM)

RTRM is a simple method for the quantitative evaluation of thermal stratification due to temperature differences. This parameter is non-dimensional quantity and RTRM indicates total stratification intensity (Birge, 1916).

$$RTRM = \frac{\text{Density of upper layer } - \text{Density of upper layer}}{\text{Density of water at 5 }^{\circ}\text{C } - \text{Density of water at 4 }^{\circ}\text{C}}$$

RESULTS AND DISCUSSIONS

Temperature Structure of Lake Maninjau

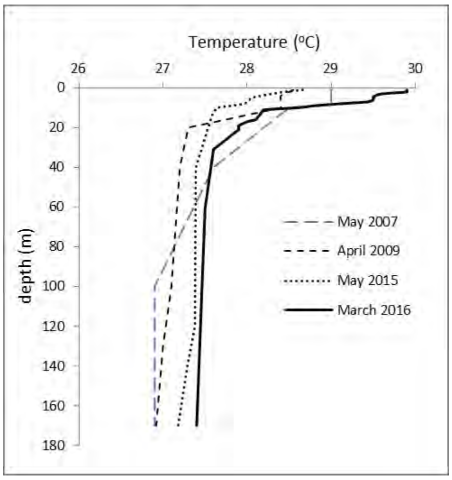


Figure 2. Temperature profiles of Lake Maninjau.

Temperature profiles of Lake Maninjau in May 2007, April 2009, May 2015 and March 2016 are shown by **Figure 2**. Water column remain stratified in every observation with the difference of temperature from surface to bottom up is not more than 3 °C. There is the difference of subsurface water temperature in every observation times, such as the subsurface water temperature in April 2009 and May 2015 were lower than in May 2007 and in March 2016. It is convenient to the air temperature in April 2009 and May 2015 which are lower than in May 2007 and March 2016 (**Figure 3**). The lower air temperature indicates that the radiated sunlight intensity is low. The difference of radiated sun light intensity in every observation affects the difference of the heat vertical distribution of water layer and varies according to the amount of radiation absorbed.

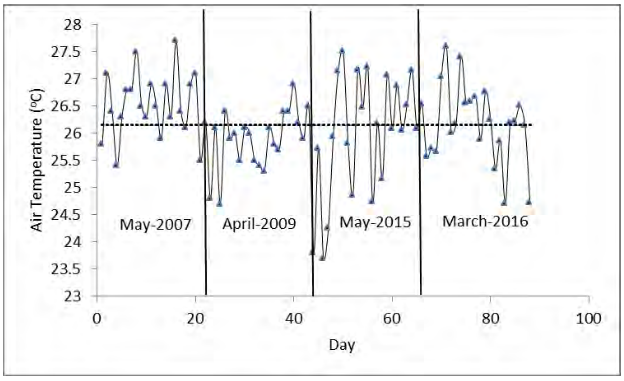


Figure 3. Daily air temperature (▲) and average of air temperature (-).

Referring to **Figure 2**, the water column was divided into three primary layers: the epilimnion is the warmer and less dense water located in upper layer. This layer is bordered by thermocline layer, which is the thermocline depth (t.d) is differ in every observation times. The deepest of t.d is about 10.9 m in 2009 and the shallowest of t.d is about 1.5 m in 2015, whereas the t.d in 2007 and 2016 were about 9.3 m and 8.9 m, respectively. The differences in t.d reflected both the seasonal and annual variation affecting the absorption of heat intensity. Hypolimnion zone is the lowest layer and cooler showed a different depth in every observation times. The water column in May 2007, showed that the hypolimnion depth was started at the depth of > 10 m, and is the deepest of layer border than others. Whereas the shallowest border of hypolimnion layer at upper-layer in 2015 is started at 10 m depth.

The position of t.d closely related to thermal stability of water column. The water columns stability in May 2007, 2009 and 2016 was high enough, that is characterized by the position of t.d deeper than 2015. In contrary, the shallow position of t.d in May 2015 indicated that the thermal stability of water column was weaker than others. The weak of thermal stability in May 2015 was also characterized by the changes temperature that is lower than in any years. It could be explained that the mixing of water column was easier than in May 2007, April 2009 and March 2016.

The depth of the thermocline varies with season (Fiedler, 2010). We can see that there are slightly differences of t.d in May 2007, April 2009 and March 2016, these are no more than 2 m. But there is significant descent of t.d in May 2015. It is induced by decreasing of air temperature, and lead to heat transfer from water surface to air and affecting the decreasing of surface water temperature (Wetzel, 2001). The decreasing of the water surface temperature will rise up the t.d closer to the surface.

Stratification Index and Stability Index

Stratification Index and Stability Index estimate the idealized amount of energy required to mix the entire lake to a uniform temperature over the entire depth of the water column (Sahoo, et al., 2015). **Figure 4** shows the stratification index (SI) and Stability index of Lake Maninjau found in May 2007, April 2009, May 2015 and March 2016. There is greatest stratification index in May 2007 and the lowest is in May 2015. SI for water column in 2007 (14422.4 Jm^{-2}) comparable to the t.d and temperature profile curve in **Figure 2**. The result of that indicates the water column in 2007 more stable than others. In contrary, the stratification index for water column in 2015 is about 3270.6 Jm^{-2} and it is the lowest value than others. Its value is suitable to the t.d that has the lowest value than other observation times.

The same result was also shown by the stability index of water column in May 2007 that still had the highest stability, while the lowest water column stability was found in May 2015. This result is caused by the cooling of air temperature (**Figure 3**). As a result, there is a negative heat income to the water surface, and heat lost exceeds inputs from solar radiation. The declining of surface water temperature yield of thermocline in May 2015 is weak and the stratification to be lowest. The high of stratification and stability index in May 2007, April 2009 and March 2016 showed that the energy needed to mix the entire lake was also large, implying that the water column at that time was stable.

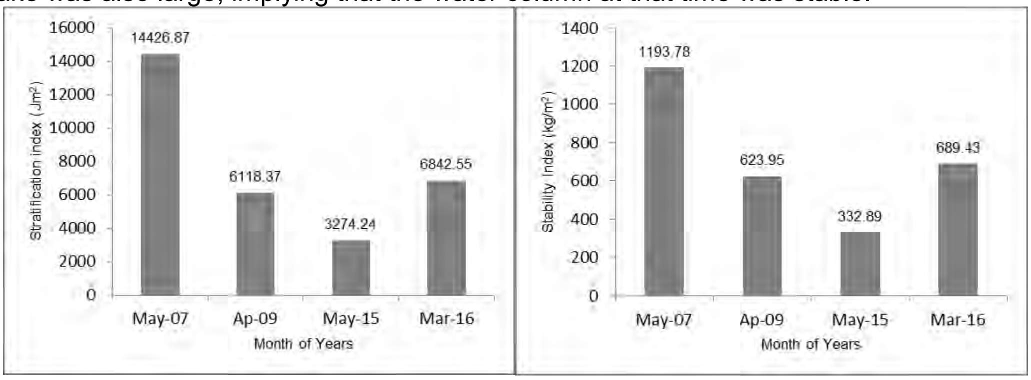


Figure 4. Stratification index (left) and stability index (right) of water column in 2007, 2009, 2015 and 2016.

There are no significant differences both of Stratification Index and Stability index between water column in April 2009 and March 2016. But, from water temperature profiles (**Figure 2**), the hypolimnion depth position in April 2016 is deeper than March 2009. Therefore, stratification index and stability index of water column in March 2016 greater than in April 2009. It is convenient with air temperature (**Figure 3)** that highly influences the water column stability.

Buoyancy Frequency (N) and Relative Thermal Resistance to Mixing (RTRM)

The other factor to characterize the thermal stability is by the buoyancy frequency analysis. The calculation of buoyancy frequency based on the gradient temperature to the depth. Refers to **Figure 5**, the buoyancy frequency for all time observations showed increaseing to maximum stability at the thermocline layer and then a decrease almost the zero at the hyplolimnion layer. The curve of buoyancy frequency in 2015 is not as sharp as of buoyancy frequency in May 2007, April 2009 and March 2016, It is because of the thermocline begins to destabilize as an effect of heat lost in the water surface. As a result to this, the temperature gradient in 2015 is not as strong as they are in others.

In general, the difference of temperature at the surface water and at the bottom layer of tropical lakes are not as significant as with the temperature in the temperate lakes at summer. For example in Lake Tahoe California, the difference of temperature difference on July and August 2010 was not less than 8 ^oC (Sahoo, et al., 2015). But, in Lake Maninjau, the highest values happen in various periods reach 0.11 to 0.4 $^oCm^{-1}$ (**Figure 5**). Therefore, the gradient temperature in metalimnion layer is low. Contrary to another temperate lakes (Polish Lakes), they have the gradient temperature in the metalimnion layer reach to 4.5-5.5 $^oCm^{-1}$, even in extreme case the gradient temperature can be higher than 7.5-8 $^oCm^{-1}$ (Skowron, 2014).

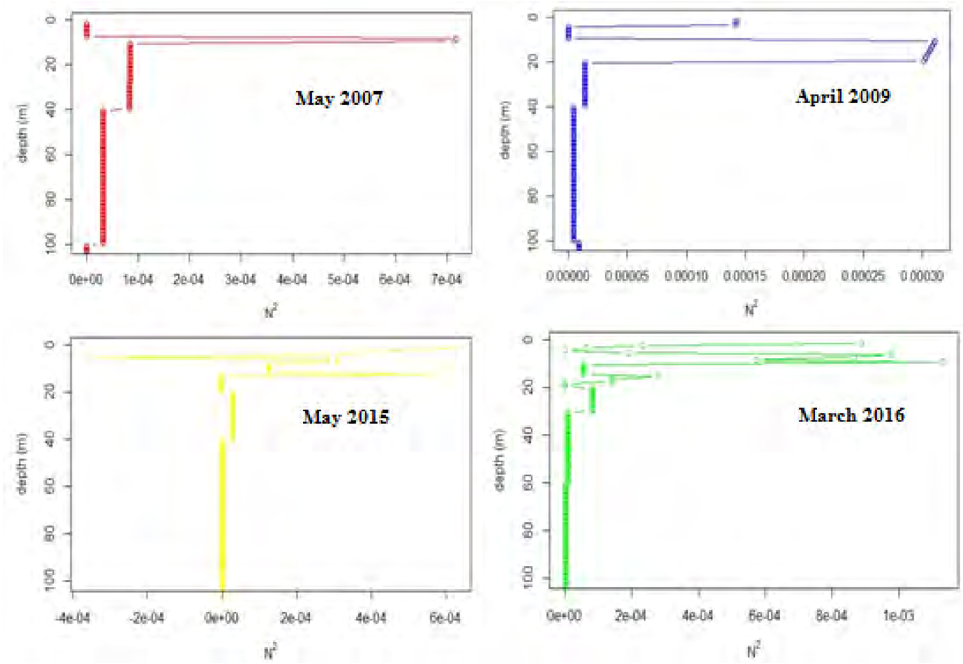
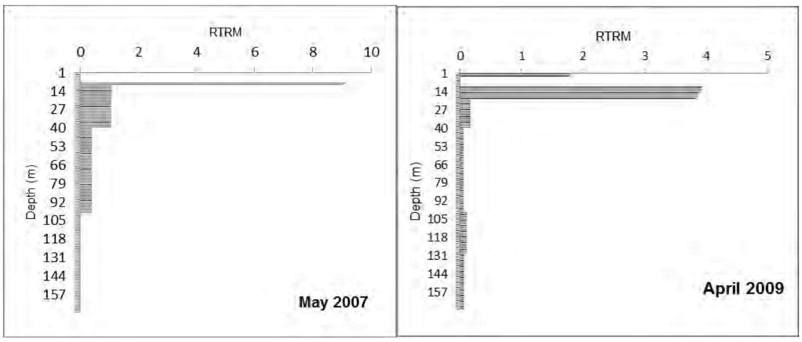


Figure 5. Buoyancy frequency of lake Maninjau.

In addition to determine the strength of thermal stratification, RTRM is also used to view the depth of thermocline, the position and width of the metalimnion layer and the temperature difference amplitude of metalimnion layer. **Figure 6** show that the shallowest and the deepest of the upper boundary conditions of the metalimnion position is in May 2015 and April 2009, respectively. In accordance with the N in **Figure 6**, the metalimnion layer was clearly visible in April 2009, and it is the widest of metalimnion layer than others. But the water column in April 2009 still had a smaller stability than water column in May 2007 and March 2016. This is caused by the amplitude of temperature difference at metalimnion layer in April 2009 was smaller than May 2007 and March 2016 (**Figure 6**).
Based on the depth of the upper boundary condition of the metalimnion layer, water column in 2015 more unstable than others and it is in accordance with the stratification and stability index in **Figure 4**. This is due to the metalimnion layer 2015 is close to the water surface, so it can easily to be mixed by the wind.



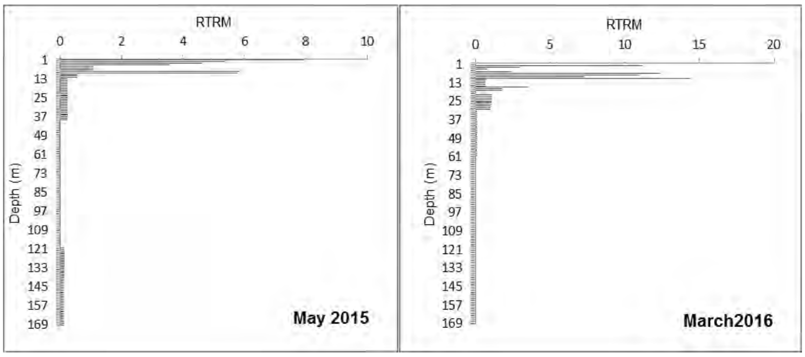


Figure 6. Relative thermal resistance to mixing lake Maninjau in 2007, 2009, 2015 and 2016.

CONCLUSIONS

Analysis of water and air temperature data in May 2007, April 2009, May 2015 and March 2016 shows that the water column remain stratified with different strength stratification. Water column in May 2007 more stratified and stable than others, while the water column stratification and stability in May 2015 is the lowest. The stratification and stability of~~l~~ Lake Maninjau is greatly influenced by daily weather condition. The water column will be more stratified and stable when the weather is warm than cold.

ACKNOWLEDGEMENT

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WATER QUALITY ANALYSIS AT SAGULING RESERVOIR

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ABSTRACT

Indonesia is one of the countries with the highest precipitation in the world. It implies that the actual availability of water is plentiful but water availability is not balanced in terms of place (location) and season (time). The purposes of the construction of reservoirs in Indonesia are varied such as irrigation, water supply and hydropower plant. The amount of the rainfall in Indonesia as tropical country is relatively high. In a year, approximately 80% of water is available during the rainy season (5 months) otherwise, only 20% of water available in the dry season which is relatively longer than rainy season (7 months). The objective of this study is to analyze the water quality records represented by Saguling reservoir. Surveys at Saguling reservoir was conducted in September 2015. Meanwhile, the results on the survey in Saguling reservoir showed that the average depth is 17.9 m. Saguling reservoir covers approximately 4,869 ha of area with maximum depth of 90 m. The other fact, the potential impact from fish cages as the source of pollutant at Saguling reservoir. Based on water quality data from Saguling authority (1994 – 2014), anthropogenic and fish cage activities led to water quality degradation. It reflected by decreasing value of Secchi disk from 1.28 m (1986) to 0.30 m (2014). Similarly, DO values showed 2.76 mg/L and 1.91 mg/L for 2007 and 2014, respectively. In order to maintain the sustainability of the lake, basic ecological information is necessary for the next study.

Keywords*:* Saguling reservoir - Water quality – Fish cages – Population – Precipitation

INTRODUCTION

Water is our most valuable natural resource. The availability and quality of inland waters not only impact human health and well-beings, but also the functioning of essential ecosystems, including rivers, wetlands, lakes and coastal ecosystems. Without sound water resources management, human activities can upset the delicate balance between water resources and environmental sustainability. The purposes of the construction of reservoirs in Indonesia are varied such as irrigation, water supply and hydropower plant. Being located in a tropical region, Indonesia is exposed to the sun throughout two seasons; dry season and rainy season. The rainy season in Indonesia occurs from October to April. In big cities and areas with few forests, rainy season often produces floods. On the other hand, dry season occurs from March to November. The long dry season is often detrimental to the population, especially for the farmers whose crops get lack of water

Indonesia is one of the countries with the highest precipitation in the world. It implies that the actual availability of water is plentiful but water availability is not balanced in terms of place (location) and season (time). It was found that the condition where excessive is in the western part of Indonesia and lacking in eastern part of Indonesia. Another fact shows that since the 20th century, there has been a conflict of interests among the various water uses due to imbalance of seasonal stream flow. These imbalances in Java become worse by the reduction of catchment areas because of land conversion into residential, agricultural, industrial and others. In addition, illegal logging occured in the upstream and reduced forests function as a water reserves.

In general, 85% of the reservoirs are to serve irrigation, and the rest is for power generator. In the period after the construction of Jatiluhur reservoir, reservoirs were constructed with the development of science and technology. Reservoirs after 1960s have multi purposes. After the second world-war, Indonesia experienced the rapid population growth which caused the increasing of necessity for food and energy for electricity. The Indonesian government decided to carry out the construction of large reservoirs to fulfill the food supply and electricity.

The strategic functions of Citarum River basin and Jatiluhur, Cirata and Saguling reservoirs at the national scale (*Presidential Decision* of the *Republic of Indonesia No.12/2012)* and its socio-environmental problems are two important reasons why the locations have been selected here. Citarum River basin is one of main river basins in Indonesia which experiences flood problem. Furthermore, the topographic condition and geographical location also contribute to the occurrence of flood disaster in Citarum River basin. The upper Citarum River basin is also recognized as an area with some of the most persistently active landslides in Indonesia. The floods that trigger the landslides occur almost every year and cause extensive damage. The Citarum River is of vital importance for West Java

Province and Jakarta City, Indonesia, in terms of economic development and the prosperity of the people.
On the other hand, Saguling reservoir is used for power generation that Installed capacity of 700 MW (Sembiring 1985; Garno 2002). In addition, the condition of the upper river basin is an important factor in controlling its hydrological response, including floods, soil erosion, landsliding, and sediment input to the Saguling Reservoir.
Eutrophication and toxic algal blooms have restricted the function of those reservoirs. Pollution originates mainly from the upper catchment and mostly from improperly treated urban and industrial sewage, agriculture and land-use transformation due to urbanization and deforestation. A significant nutrient source for eutrophication is the internal load from the sediments that intensively accumulate at the bottom of the reservoir from the ever-expanding traditional fish cage culture. The objective of this study is to analyze the water quality at Saguling reservoir.

METHODS

We conducted survey at Saguling reservoir to understand water quality conditions (**Figure 1**) not only to do survey at field, but also to collect the secondary data from the authority for supporting the analysis.

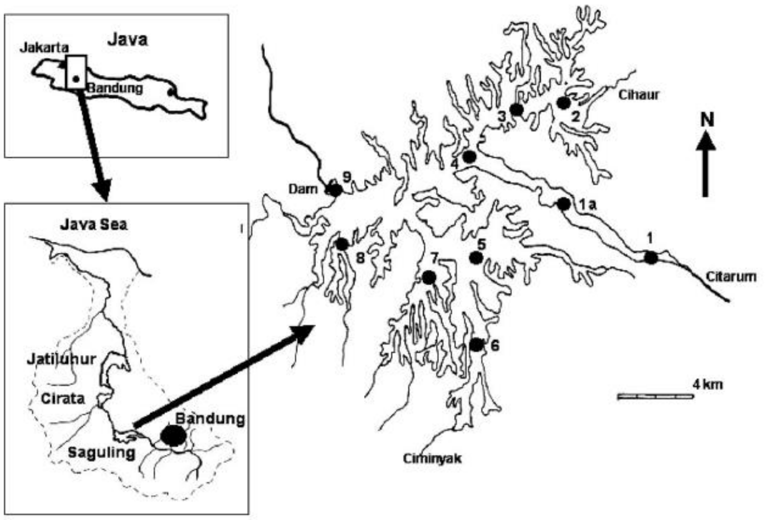

Figure. 1 Locations of study area: Saguling reservoir, part of cascade reservoirs (source: Hart et al., 2001)

Water samples at Saguling reservoir were taken in September 2015. We used ringko profiler, supported by University of Tsukuba, Japan. The logger version CTD profiler with optical fast DO sensor RINKO-Profiler was used for survey. Depth (semiconductor pressure sensor with measurement range from 0 to 600 m and resolution 0.01m), temperature (thermistor with measurement range from -3 to 45°C and resolution 0.001°C) and dissolved oxygen/DO (phosphorescence with detectable range from 0 to 20 mg/L and resolution 0.001mg/L) were obtained at each station. Measurements were carried out until 47.8 m depth with an interval of 10 cm.

RESULTS AND DISCUSSIONS

The degradation of environment, including in water quality of reservoir, the anthropogenic activities contributed to the decrease of water quality. The growth of population influenced the activities of people surrounding the reservoir. The location of Saguling reservoir is located in West Bandung Regency. It covers the region of Padalarang, Cililin, Sindangkerta and Batujajar. The growth of pupulation since 1983 is shown in **Figure 2**. It could be explained that during 30 years, the population has increased significantly.

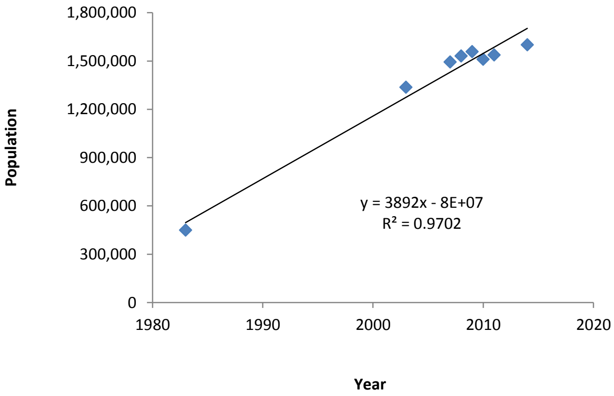

Figure 2. The growth of population near Saguling watershed

Another data was obtained from Saguling authority explaining the average monthly rainfall from 1986 to 2013 as shown in **Figure 3**. The lowest rainfall was 40.5 mm in August and the highest was 225.6 mm in March. On the other hand, the average yearly rainfall seemed to increase, the maximum rainfall was 281. 5 mm in 2010.

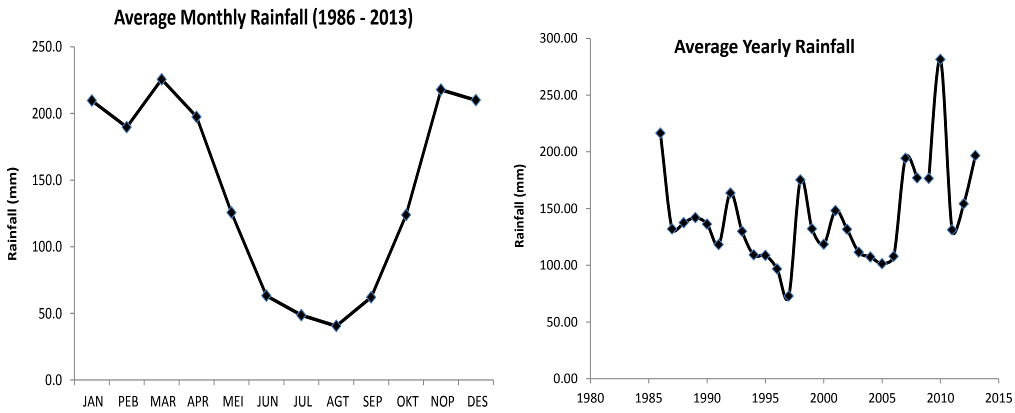

Figure 3. The average monthly rainfall and average yearly rainfall at Saguling watershed

The amount rainfall which comes into to the reservoir influenced the water quality condition. Based on measurement by CTD profiler, we obtained the water quality parameters such as: DO, temperature, chl-a and conductivity as desribed in **Figure 4**.

Figure 4 refers to the water column at Saguling reservoir and it was divided into two primary layers: epilimnion was characterized as a column of hot water and less dense layer at the surface to a depth of 10 m and hipolimnion, a cooler denser deeper layer, divided between the average depths of 20 m to 47.8 m. Between the two layers, there is a layer that resembles metalimnion layer indicated by a sudden drop in temperature between the average 27^{0}C to 26^{0}C from an average depth of 10 m to 20 m. The top of this layer bordering the epilimnion constantly changing depth, while the bottom layer adjacent to hipolimnion remained stable at an average depth of 47.8 m. It suggested the density at Saguling reservoir was stratified in September 2015. In addition, the characteristics of conductivity were related to temperature profile (Subehi et al. 2014; Subehi et al 2015).

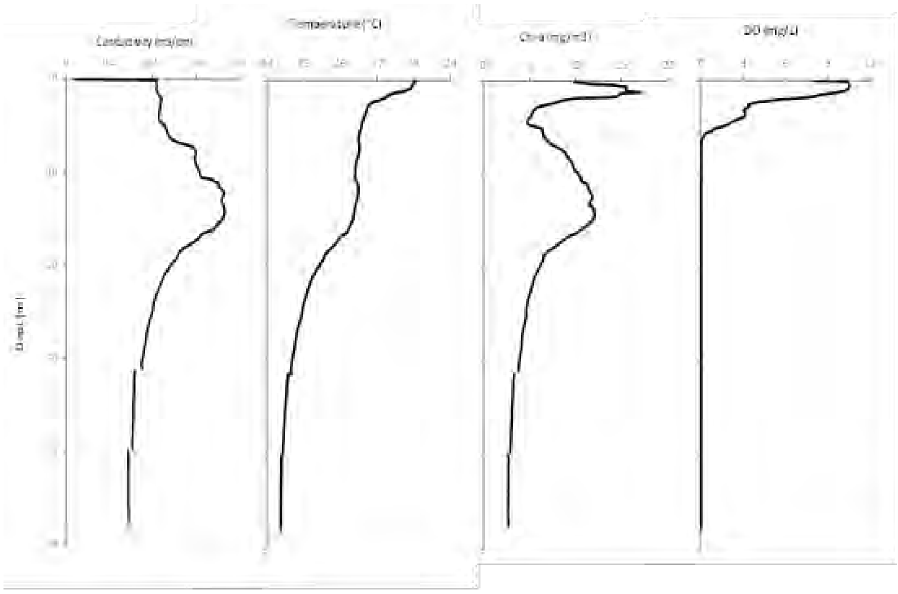

Figure 4. Water quality profiles (conductivity, temperature, chl-a and DO in September 2015 at Saguling reservoir.

In case of conductivity, the values seemed larger, because the rainfall in September was lower, so the addition of fresh water (rain) lowers conductivity because rainwater has low conductivity and the increase in water levels dilutes mineral concentrations. Conversely, during low flow conditions (summer and fall) the dissolved solids are more concentrated and therefore conductivity levels are higher. Moreover, conductivity is also affected by temperature, the warmer the water, the higher the conductivity (USGS, 1994).

The value of conductivity can be an indicator that a discharge or some other sources of pollution have entered the water. It could be also explained by the larger chl-a obtained. Particularly, the DO was zero at the depth 5 m, so it influenced the fish survival in the water. Perhaps, the impact from increasing of fish cages was also an influence towards the decreasing DO. The composition of the water can be critical for aquatic organisms as well, as many criteria have very specific ranges that they can tolerate. Meanwhile, secchi disk (SD) was decreasing also from 1.28 m (1986) to 0.30 m (2014). It suggested the degradation of water quality at Saguling reservoir. Similarly, DO values changed from 2.76 mg/L to 1.91 mg/L for 2007 and 2014, respectively (**Figure 5**)

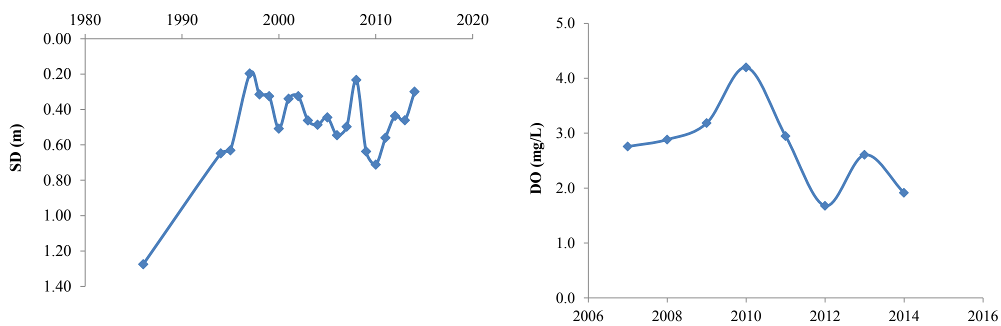

Figure 5. Secchi disk and DO parameters at Saguling reservoir

CONCLUSIONS

Analyzing the water quality data from 1986 to 2014 at Saguling reservoir has been done. It confirmed that some degradation of water quality was observed. The growth of population also influenced the condition of reservoir. Many activities such as: fish cages, settlement, industries, city influenced this phenomenon. In addition, the meterological condition supported the processes in the water. Consequently, in order to maintain the sustainability of Saguling reservoir, basic ecological information and society supports are necessary for the next study.

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WATER QUALITY ASSESSMENT OF VASTRAPUR & SOLA LAKE OF AHMEDABAD CITY, GUJARAT, INDIA

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ABSTRACT

The water bodies are facing a severe threat of pollution all over the world. To ensure fresh water availability from the local water sources has become a big challenge. The main objectives of this paper are to assess water quality of these lakes situated in the city. This paper discusses the water quality of two small artificial lakes situated in Western part of Ahmedabad. Both lakes are considered artificial as recreational resource. The purpose of the survey was to collect information concerning use and value of water quality improvements. During January-2012 to December-2012, water samples were collected from aforesaid lakes and analyzed in monthly interval. The analysis was carried out for the parameters such as temperature, pH, color, odor, Dissolved Oxygen (D.O), Biochemical Oxygen Demand (B.O.D), Chemical Oxygen Demand (C.O.D), Chloride, Calcium, and Magnesium. The study report discusses the analysis of the lake water quality and suggests the means to improve the lake water. It was observed that due to presence of impurities in the lake, there are many different parameters (DO, COD, Chloride, Total Hardness, ph, and Alkalinity) found to increase during summer season and have been diluted during rainy season. Thus, these changes affected the aquatic environment. The increase in nitrogen content would result in eutrophication naturally which leads to the decrease in oxygen level.

Key words: water pollution, water quality, Sola lake, Vastrapur lake, Eutrophication

INTRODUCTION

Lakes are important source of fresh water; generally, represent additional storage capacity of hydrologic systems. Natural or artificial changes in storage either in quality or quantity of water may alter not only the stream flow regime but also the water balance of the region, affecting ecological balance of the region. The hydrologic status of water of a lake in terms of quantity, quality and regimen is the results of complex processes of physical, chemical and biological inputs. The physical features include wind, terrain relief, water current, temperature, light level etc. The chemical environment consists of water, gases like oxygen, minerals, trace metals and other complex chemicals. Water is the most vital resource for all kinds of life on the earth and essential for the sustainability of the earth's ecosystem (UNESCO, no year). The relationship between healthy humans and clean drinking water goes back more than 200,000 years when modern man first emerged. Later, when we developed agriculture and industry, the increasingrate of human exploitation and modification of theenvironment adverselyaffected the health ofwetlands, some of which are now no longer able to provide clean drinking water. Sources of drinking (and irrigation) water often contain toxic pollutants that poison plants, fish, people and microbial pathogens that kill almost two million children annually worldwide. So much agricultural runoff, inflow from domestic and industrial waste and human is adding much more toxic chemicals, antibiotics from animalhusbandry, untreated human sewage, pesticides etc that acts as 'endocrine disrupters' and more. Nowadays, the water quality problems and concerns for eutrophication are not only restricted to the urban lakes, but these threats have expanded to the rural lakes as well. Therefore, the present study was undertaken to study for water quality assessment.

Figure 1. Map of Ahmedabad

Study Area

Ahmedabad (**Figure 1**) is unique in the whole of India in matter of environmental neatness and flourishing conditions and it is superior to other cities in the excellence of its monuments. Ahmedabad Urban Development Authority (AUDA) carried out a survey of 645 lakes and identified 22 lakes which have been severely degraded. AUDA proposes to undertake works for revival, development of catchments area and beautification of lakes under the present project. Of these, two lakes studied are located at Sola and Vastrapur village. Peripheral development works including landscaping: recreation facilities are such as Amphi theatre, children park and Boating facilities and percolation wells to recharge ground water table. AUDA has commenced work on this lake also through own resources.

Ahmadabad city is located at 23^0.03’ N 72^0.58’ E in western India at an elevation of 53 meters (174 ft). The city sits on the banks of the river Sabarmati, in north-central Gujarat. Sola lake is located at Sola village near national highway no.8, Ahmedabad. Its total storage capacity is 24.6 crore liters and lake circumference is 1364 m. and desalting area is 82080 m^3.

Vastrapur Lake is situated in western part of Ahmedabad. It is officially named after Narsinh Mehta. The lake was beautified by the AMC after 2002 and has since become a popular spot in the city. Every weekend, a large number of people visit this lake. It currently boasts an open-air theater and children's park. There is a pathway all around the lake which serves many walkers and joggers in the early mornings and in the evenings. The lush green lawns surrounding this lake also serve as a central hub of Ahmedabad, wherein various cultural events take place regularly. At times, the water from Narmada River is allowed to flow into this lake. The lake is surrounded by pretty gardens with much stonework (Prashant Dayal, 2009).

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Figure 2. Vastrapur lake (Narsinhmehta lake) and Sola Lake

METHODS

For the present study, water samples were collected from six different sampling sites in airtight and transparent polythene containers at regular interval of 30 days from both lakes. All samples were analyzed for important physio-chemical parameters such as, dissolved oxygen, COD, TDS, Salinity, Nitrogen content. DO and pH were measured pH, Conductivity in the field with necessary precautions. The water samples were analyzed as per the procedures given in the standard methods (R.K. Trivedy (1986); APHA (1998)) and were compared to the Stream Standards. The samples were analyzed every month from January 2012 to December 2012.

RESULTS AND DISCUSSIONS

Table 1. Observation of odor at different localities of lake Water reducing January 2012 to December 2012

Locality	Summer--12	Monsoon-12	Winter-12
Sola	objectionable	Unobjectionable	Unobjectionable
Vastrapur	Unobjectionable	Unobjectionable	Unobjectionable

Table 2. Temperature (^{0}C) at different localities of lake water during January 2012 to December 2012

Lake	Jan -12	Feb -12	Mar -12	Apr -12	May -12	Jun -12	Jul -12	Aug -12	Sep -12	Oct -12	Nov -12	Dec -12
Sola	29	29	36	41	43	41	42	37	32	35	34	30
vastrapur	28	29	37	41	43	42	37	32	35	35	34	30

Table 3. Colour (Hazen) at different localities of lakes Water during January 2012 to December 2012

Lake	Jan -12	Feb -12	Mar -12	Apr -12	May -12	Jun -12	Jul- 12	Aug -12	Sep -12	Oct -12	Nov -12	Dec -12
Sola	55	78	25	74	110	110	100	100	78	70	75	72
Vastrapur	78	88	20	88	110	122	90	90	70	62	70	70

Table 4. pH at different localities of lakes Water during January 2012 to December 2012

Lake	Jan -12	Feb -12	Mar -12	Apr -12	May -12	Jun -12	Jul -12	Aug -12	Sep -12	Oct -12	Nov -12	Dec -12
Sola	7.1	7.1	6.8	8.3	7.0	8.4	7.6	6.7	8.1	8.1	8.3	7.5
vastrapur	8.5	8.2	7.3	7.7	7.6	7.5	7.8	7.1	7.2	7.6	7.1	6.8

Table 5. Chloride (mg/l) at different localities of lakes Water during January 2012 to December 2012

Lake	Jan -12	Feb -12	Mar -12	Apr -12	May -12	Jun -12	Jul -12	Aug -12	Sep -12	Oct -12	Nov -12	Dec -12
Sola	224.9	229.9	314.9	269.9	324.9	249.9	249.9	244.9	254.9	247.9	249.9	274.9

Vastrapur	210	364.9	489.9	210.0	529.9	244.8	289.9	239.9	359.9	359.9	344.9	384.9

Table 6. Turbidity (NTU) at different localities of lakes Water during January 2012 to December 2012

Lake	Jan-12	Feb -12	Mar -12	Apr -12	May -12	Jun -12	Jul -12	Aug -12	Sep -12	Oct -12	Nov -12	Dec -12
Sola	14	10	5	25	80	150	75	70	75	70	66	35
Vastrapur	10	17	20	15	89	140	70	50	50	41	45	40

Table 7. Dissolved Oxygen (mg/l) at different localities of lakes Water during January 2012 to December 2012

Lake	Jan -12	Feb -12	Mar -12	Apr -12	May -12	Jun -12	Jul -12	Aug -12	Sep -12	Oct -12	Nov -12	Dec -12
Sola	1.5	1.0	2.9	1.1	1.9	2.9	2.9	2.5	6.2	3.1	0.9	4.4
vastrapur	2.2	2.8	1.7	2.7	1.5	3.6	3.6	4.3	3.1	2.4	1.0	1.7

Table 8. Biological Oxygen Demand (mg/l) at different localities of lakes Water during January 2012 to December 2012

Lake	Jan -12	Feb -12	Mar -12	Apr -12	May -12	Jun -12	Jul -12	Aug -12	Sep -12	Oct -12	Nov -12	Dec -12
Sola	2.5	8.5	15.0	2.0	26.3	31.0	5.1	9.0	8.2	6.2	12.5	19.8
Vastrapur	2.2	3.4	11.2	15.3	35.7	10.0	5.0	9.6	5.6	5.2	16.0	11.1

Table 9. Chemical Oxygen Demand (mg/l) at different localities of lakes Water during January 2012 to December 2012

Lake	Jan -12	Feb -12	Mar -12	Apr -12	May -12	Jun -12	Jul -12	Aug -12	Sep -12	Oct -12	Nov -12	Dec -12
Sola	40	88	45	23	156	158	171	75	80	62	150	85
Vastrapur	18	56	12	51	110	64	49	201	120	55	24	5

Table 10. Total Hardness (mg/l) at different localities of lakes Water during January 2012 to December 2012

Lake	Jan -12	Feb -12	Mar -12	Apr -12	May -12	Jun -12	Jul -12	Aug -12	Sep -12	Oct -12	Nov -12	Dec -12
Sola	250	270	300	230	190	200	190	250	170	150	290	370
Vastrapur	210	190	200	250	190	220	220	250	160	312	360	320

Table 11. TDS (ppm) at different localities of lakes Water during January 2012 to December 2012

Lake	Jan -12	Feb -12	Mar -12	Apr -12	May -12	Jun -12	Jul -12	Aug -12	Sep -12	Oct -12	Nov -12	Dec -12
Sola	576	683	888	612	692	577	576	625	582	600	608	754
Vastrapur	483	792	843	984	1000	547	607	595	776	750	703	824

Month wise variations in physico-chemcial characteristics of both lakes have been studied. The status of the following parameters was observed.

Odor

Many organisms impart taste and odor to the aquatic environment due to their defiance mechanism by releasing repellents and other organic compounds (WHO). In monsoon odor may be maintained due to flow of rain water. In present study, objectionable odor was recorded at Sola lake in summer. Vastrapurlake maintained its odor during whole year.

Temperature

Temperature is one of most important factor in the aquatic environment that regulates the various physical chemical activities (Usha et al., 2007). There is a close similarity between the temperature of atmosphere and water. Due to the depth of reservoir, high summer temperature and bright sunshine accelerate the Process of decay of organic matter resulting into the liberation of large quantities of CO_2

and nutrients. (Agarwal et al., 2010). It was observed maximum during summer, 43ºC, in May and minimum during winter, 27ºC, in January.

Color

Colour of water is one of the most important and conveniently observed indicators of its quality. Higher value of Color was recorded in late summer and early monsoon in both lakes during study period. Suspended and dissolved particles in water influence color. Suspended material in water bodies may be a result of natural causes and/or human activity. Transparent water with a low accumulation of dissolved materials appears blue and indicates low productivity.

pH

As per pH value is concerned, it was found that throughout the month slightly lower values duringmonsoon season and slightly higher values during winter, but throughout the month it remained slightly alkaline. Vastrapur lake water showed more fluctuation then sola, may be due to a picnic spot.

Chloride

The chloride concentrations were found almost in permissible limit during this study. Chlorides are present in water as sodium chloride, Magnesium chloride and Calcium chloride. Although they are not harmful as such, their concentration over 250 ppm imparts a particular taste to the water rendering the water unacceptable fordrinking purposes. Existence of unusually highconcentration of chloride in lake indicates pollutants from domestic sewage and industrial effluents which leads to eutrophication. In addition to that salinity was also calculated which shows increase during summer season and decrease in monsoonseason. It was originally conceived as a measure of the mass dissolved salts in the water samples. The salinity content ranged from 210 to 529. It was observed higher in Vatrapur lake then Sola lake. High chloride content in water sample may be because of pollution from Cl rich effluent of sewage and municipal waste (Preeti et al., 2009).

Turbidity

Highest Turbidity was recorded at Sola in Jun-2011(150 NTU) and the lowest concentration was recorded at in Jan-Feb-2011(0.0 NTU) During 2011. Water clarity, presence of cloudiness etc generally used routinely as an indicator of the condition and productivity of an aqueous system. Agarwal et al. (2010) observed increased turbidity during rainy months in Tehri Dam Reservoir, Garhwal, India. It was attributed to soil erosion in the nearby catchment and massive contribution of suspended solids.

Dissolved Oxygen

Dissolved Oxygen content in was found to be very low throughout the year. DO content ranged from 0.9 to 4.4 mg/l indicating the anaerobic conditions in both lake water. Both lake shows great variation in different months. This indicates low rate of primary production in aquatic ecosystem of lake. Minimum amount required for optimum fishpopulation may be as high as 5 to 8 mg/L. The oxygen depleting substances reduce the availableDO. According to Trivedy and Goel (1986) low oxygen concentrations are associatedwithheavy contamination by organic matter.

Biological Oxygen Demand

BOD is the amount of oxygen required by the living organisms engaged in the utilization and ultimate destruction or stabilization of organic water (Hawkes, 1963). It is very important indicator of pollution status of water body. The Value of BOD greatly varies month wise and clearly showed higher concentration in summer and rainy months and comparatively low during winter. Many workers like John (1952), Robert (1969) and Richard (1966) have noticed higher values of BOD during hot period. Similar observations are found in Amli and Makarba lake of same city by Desai (2009). This may be attributed to the photosynthetic activity and abundance of phytoplankton during hot period, especially spring (Abodo, *et al.,* 2004).

Chemical Oxygen Demand

Chemical Oxygen Demand test determines theoxygen required for chemical oxidation of most organic matter and oxidizable inorganic substances with the help of strong chemical oxidant. Throughout the month from April to September variations were found. The COD value ranged from 23 to 171 mg/l.at sola and 12 to 201mg/l at Vastrapur lake. The variations indicate presence of some toxic pollutants which are released to the lake water having definitely bad impact on the aquaticlife of lakes.

Total Hardness

During present investigation, the maximum total hardness (370) was recorded in December at Sola lake 360 in November at Vastrapur lake i.e starting of winter and minimum (170) in September i.e. Monsoon. Productive watershould have hardness value above 20mg/l. Fishhave been found to be susceptible to diseases in water with hardness below 20 mg/l. If there isincrease in hardness content it becomes unpleasant for fish production because of higher pH. Optimum hardness for fish culture has been observed to bearound 75 to 150 mg/l. (Das, 2000).

Total Dissolved Solid

It indicates the general nature of salinity of water. It signifies the inorganic pollution load of water system (Adarsh et al., 2006). Total Dissolved Solids ranged from 483 to 1000 ppm. In present study, the total dissolved solidswere comparatively high in summer which decreasedduring rainy season due to dilution of lake water and was also observed higher in Vastrapur lake then Sola lake.

R. M. Khan, M. J. Jadhav, I. R. Ustad (2012) studied and analyzed physicochemical parameters such as temperature, pH, conductivity, free CO_2, total solid, dissolved oxygen, Total alkalinity, total hardness etc., of Triveni Lake for the period of one year i.e. December 2010 to November 2011. They revealed significant seasonal variation in some physicochemical parameters and most of the parameters were in normal range and indicated better quality of lake water. It has been found that the water is best for drinking purpose in winter and summer seasons.

CONCLUSIONS

1. The seasonal values indicate that during summer season, lake water is more affected than during winter. This could be due to the fact that the microbial activity is reduced due to low temperature, thereby keeping DO level at a very satisfactory range during entire winter season.
2. The suggested measures to improve the lake water quality includes total ban on the activities that causes pollution.
3. Result of water quality assessment clearly showed that most of the water quality parameters slightly higher in the wet season than in the dry season.
4. Water quality is dependent on the type of the pollutant added and the nature of self purification of water.
5. Threats to the Lake Environments, *Anthropogenic activities*
   Lakes are deteriorated due to anthropogenic activities by Domestic sewage and Industrial Effluents and drainage. Domestic wastes including plastics, religious floral wastes as well as immersions of idols are done in the lake which leads to damage the lake environment. Due to increase in nitrogen content level eutrophication was observed in the form of weedy and other plant growth on surface of water.

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DISTRIBUTION AND DIVERSITY OF DIATOM IN SURFACE SEDIMENTS OF URBAN PONDS IN CIBINONG BOTANICAL GARDEN

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ABSTRACT

Diatoms are classified as algae within the Division of Bacillariophyta. They are unicellularly eukaryotic organisms characterized by siliceous cell walls that can be long preserved in sediments. Therefore, diatom analysis in sediment records is potential indicator used for environmental reconstruction. The current knowledge on the distribution and diversity of diatoms in the sediments in many Ponds in Cibinong-Bogor is poorly known. This study aimed to identify the distribution and diversity of diatoms from the sediments of the Pond. We expect to obtain primary data base of a variety of diatoms. The sediment samples were taken from Cibuntu and Cilalay Ponds in Cibinong Botanical Garden. Sediments were digested using HCl and H_2O_2*. The resulting diatom solution was dried and transferred onto glass coverslip, which subsequently mounted onto microscope slides using Naphrax (Refraction index 1.7). Diatom Identification was examined using light microscopy at 1,000x maginification. Diatom communities in Cibuntu Pond were dominated by species* Aulacoseria ambigua*,* Eunotia bilunaris*,* Cymbopleura *sp,* Discostella stelligera*, and* Rossithidium *sp with diversity index (H') 2.4 and species eveness (J') 0.8. Whereas, species* Fragilaria sp*,* Eunotia monodon*,* Navicymbula pusilla*,* Eunotia bilunaris*, and* Pinnularia viridis *were predominant in Cilalay Pond with number of diversity index in Cilalay Pond is 1.6 and species eveness 0.7. This exploratory survey provides the first inventory of diatom assemblage in Cibinong region for roughly inferring the environmental changes in shallow lake ecosystem.*

Keywords: *Diatoms, palaeolimnology, urban ponds, Cibinong Botanical Garden*

INTRODUCTION

Cibinong is one of the metropolitan city in Indonesia that has many ponds. There are 17 ponds in central Cibinong and 95 ponds around central Cibinong area. Ponds in cities are often classified as "green-space areas", because they are usually located within parks or other urban green zones and constitute important components of these areas (Harisson et al., 1995). Cibuntu Pond and Cilalay Pond are located in Central Cibinong within Cibinong Botanical Garden. Those ponds serve as a source of agricultural irrigation water and sights. Cilalay Pond is a closed pond, water source came only from spring around of pond. Whereas, Cibuntu Pond has one inlet from Kalibaru River. The river flows along industry, housing, and plantation area before coming in to the pond (Nugroho, 2002). Urban Ponds are often polluted by industrial waste and household waste, impact of development city that ignore environmental aspect. Previous research by Nugroho (2002) examined the vertical water quality of Cibuntu Pond showed good quality to support life aquatic organisms. Further research by Sadi (2013) showed significant changes of the nutrients; nitrogen and organic matter in Cibuntu Pond that were relatively high. This was also indicated by the high value of clorofil-a 25.55 to 87.61 mg/L, it has come from anthropogenic activities around ponds and industrial waste that were carried from Kalibaru River. Cilalay Pond has nutrients; nitrogen and organic matter lower than those in Cibuntu Pond (Sadi, 2013). To determine environmental changes in ponds, one proxy that can be used is diatom. Diatoms are classified as algae within the Division of Bacillariophyta. They are eukaryotic organisms unicellularly characterized by siliceous cell walls that can be long preserved in sediments (Battarbee, 2001). Currently, thousand species of diatoms have been identified. Taxonomy is based on the size, shape, and sculpturing of the silica cell walls, called frustule (Smol, 2008). Different taxa reveal different diatoms environment and tolerance. Analysis of the fossil species abundances can be used to reconstruct environmental variables such as pH and nutrient levels. Diatoms are very sensitive to many environmental variables including pH, oxygen, salinity, current velocity, temperature, moisture condition, light, inorganic nutriens (carbon, phosporus, nitrogen, silica), organic carbon and organic nitrogen. Consequently, they are considered to be powerful indicator for environmental changes, including eutrophication, climate changes, and acidification, bot in present and paleolimnological studies (Van Dam, 1993). The data base of diatom species in many Ponds in Cibinong are currently not available. The purpose of this study was to identify diatom fossils distribution and diversity in Cibuntu and Cilalay

Ponds. Further, diatoms database will be used for early water quality monitoring as a biological indicator in many ponds in Cibinong.

METHODS

Study Site

Cibuntu and Cilalay Ponds are located in Cibinong Botanical Garden, Cibinong City, West Java, Indonesia (**Fig. 1**). Cibuntu and Cilalay are closer within 366 m distance. Surface volume of Cibuntu Pond is 15.834 m² (Zulti et al., 2012), and Cilalay Pond has surface volume 12.910 m² (Sadi, 2013). Depth of Cibuntu Pond around 1.8 m, whereas Cilalay Pond has 0.5-1m water depth (Sadi, 2013). Regionally, base rock compotitions of Cilalay and Cibuntu Ponds are tuff, sandy tuff, and conglomerats tuff (Turkandi et al, 1992). Sediments inside ponds are dominated by soils and rocks debris around Ponds, and sediments are supplied from inlets river, where the materials look grayish black clays.

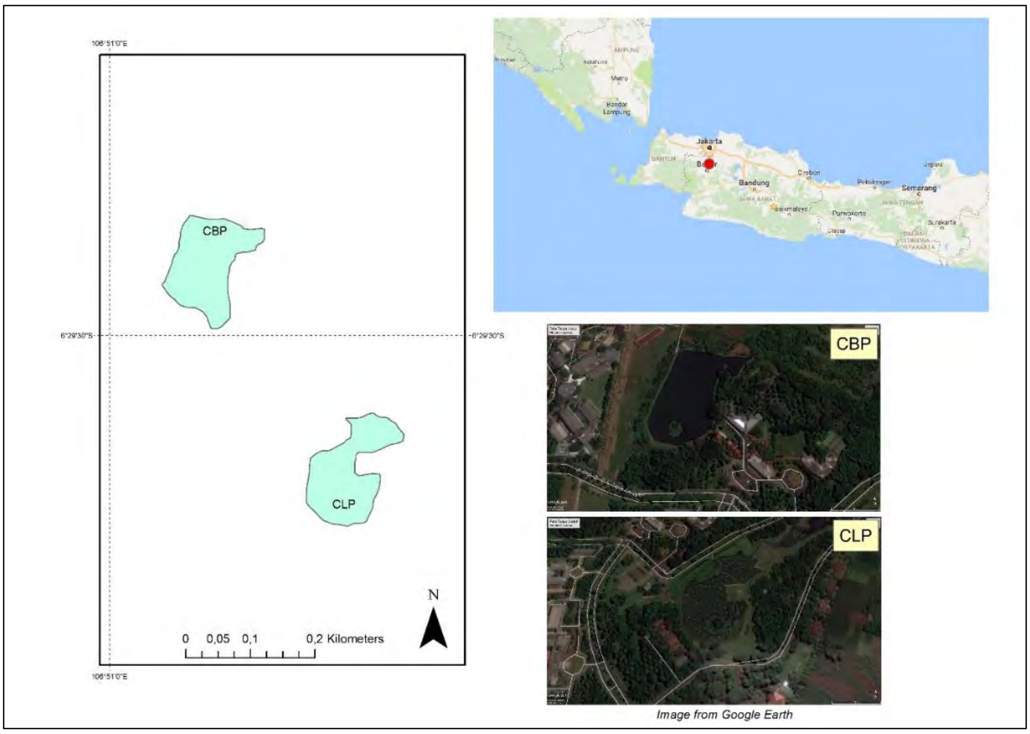

Figure 1. Study area showing the location of Cibuntu and Cilalay Ponds located in Cibinong Botanical Garden, Bogor, West Java.

Surface Sediment Sampling

Surface sediment samples (1-10 cm) were taken from Cibuntu Pond (CBP) and Cilalay Pond (CLP) in September 2016 using a coring tube (5 cm internal diameter). Samples were taken one point of each Ponds. Afterwards, sediments samples were removed from coring tube and stored in the laboratory for the preparation process. Water quality measurements were conducted during sediment sampling. Water quality measurements involved Temperature, DO, pH, Conductivity, TDS, Turbidity, and ORP.

Preparation, identification, and enumeration of diatom valves

Sediment preparation was conducted in chemistry laboratory of research center for limnology. Sediments samples were taken 5 grams then put into beaker glass and add 50 ml of 10% HCL to remove carbonates. Afterwards add 50 ml 10% H2O2 to remove organic matters. Around 30 ml diatoms residues are resulting. Further, we prepared for permanent slide, put 200 microliters onto coverslip glass then put onto microscope slide with Naphrax mountant, a syntethic resin with 1.7 reflaction index. Identification was done using light microscope with 1000X maginifications, individual calculation of diatom species encountered made up at least 300 valves (Soeprobowati, 2009). Taxonomy identification was done following Lange-Bertalot 2001 volume 2; Kramer & Lange-Bertalot 2003 volume 4; Gell *et al.*,(1999), database of the university of colorado (http://westerndiatoms.colorado.edu), and AlgaeBase (http://www.algaebase.org).

Data Analysis

The species distribution is expressed in precent of relative abudance in the whole assemblage. The number of relative abudance, shannon diversity and shannon’s equitability by Pielou’s Eveness index are calculated using PRIMER-E. Taxonomic richness using C2 software version 1.7.6 (Juggins, 2014). Shannon Diversity index (H’) and Pielou's Evenness index (J’) were calculated for all ponds to evaluate diatom biodiversity in surficial sediments, as follows:

$$H' = -\sum(p_i \ ln \, p_i)$$

Where p_i is the number of individuals of a given diatom taxon (i) divided by total number of individuals.

$$J' = \frac{H'}{Log\ (S)}$$

S is the number of total species counted in each lake. Shannon’s equatibillity have a range value between 0 and 1. For each diatom community H’ and J’ have been calculated to know individuals are distributed evenly among the different species.

RESULTS AND DISCUSSIONS

Cibuntu Pond

Total 19 species were identified in surface sediment samples of Cibuntu and Cilalay Ponds. The relative abudance of taxa was shown in **Figure 2**. Diatoms assemblages among ponds revealed significant differences especially for several dominant diatoms. Cibuntu Pond was dominated by *Aulacoseria ambigua, Eunotia bilunaris, cymbopleura* sp*, Discostella stelligera, and Rossithidium* sp, within 17 species were identified, *Cyclotella* sp*, Eunotia bidens, Eunotia monodon, Eunotia pectinalis var. undulata, Eunotia subherkiniensis, Fragilaria* sp*, Gyrosigma acuminatum, Navicula elsoniana, Navicula* sp. 1*, Pinnularia brebisonii, Pinnularia viridis,* and *Tabellaria* sp.

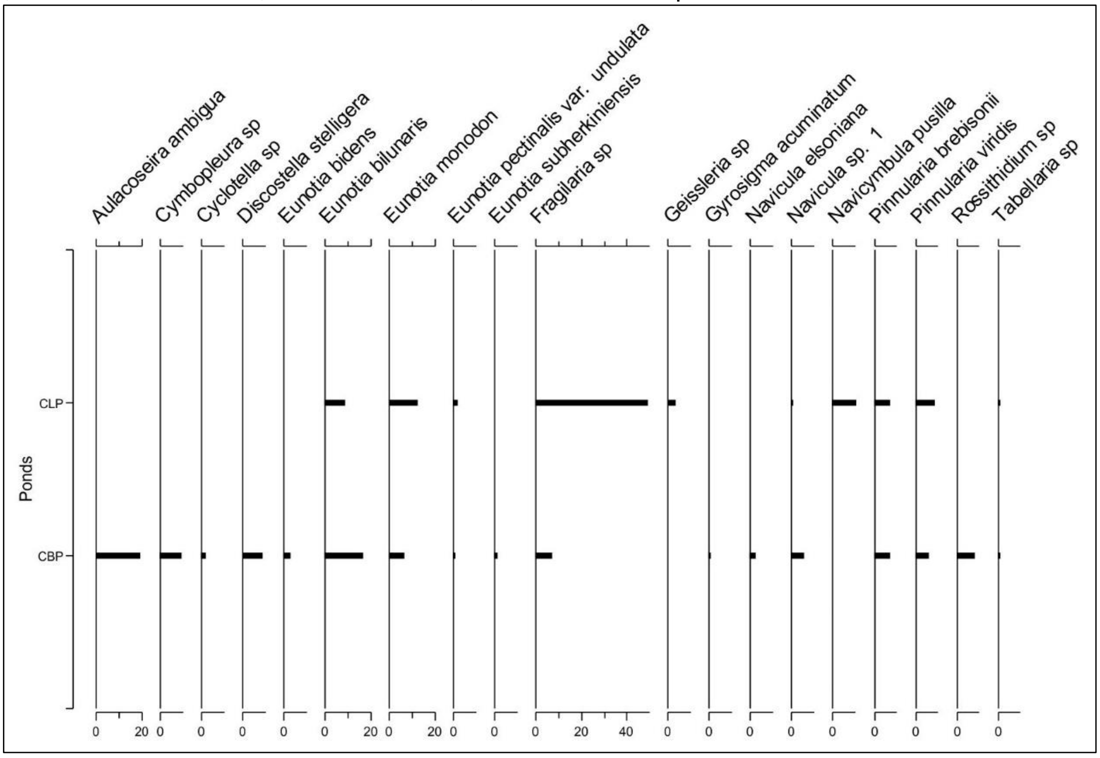

Figure 2. Relative abundance of diatom taxa in surficial sediments from Cibuntu and Cilalay Ponds.

Aulacoseria ambigua is relatively easy to identify because only these species has a hollow ringleist (**Fig. 3**) (Buczkó et al., 2010). In addition, *Aulacoseria ambigua* has frustules cylindrical and form colonies. *Aulacoseria* is one of the diatom genus that very widely distribution, the species most commonly found in mesotrophic and eutrophic waters (Gell et al., 1999). It has been known that Cibuntu nutrient contents are quite high due to anthropogenic activity around there, as reported by Sadi (2003) there Cibuntu TN content ranged from 2.74 mg/L, and can be categorized as mesotrophic waters (Volenweider, 1969 in Wetzel, 1975 in Effendi, 2003). Moderate nutirens concentrations in that pond also potensial to abundance of *Discostella stelligera* (Saros et al. 2012). Another dominant diatom in Cibuntu Pond that indicated oligotrophic to mesotrophic water condition are *Rossithidium* sp (Gell et al.,1999) and *Cymbopleura* (Taylor et al., 2007).

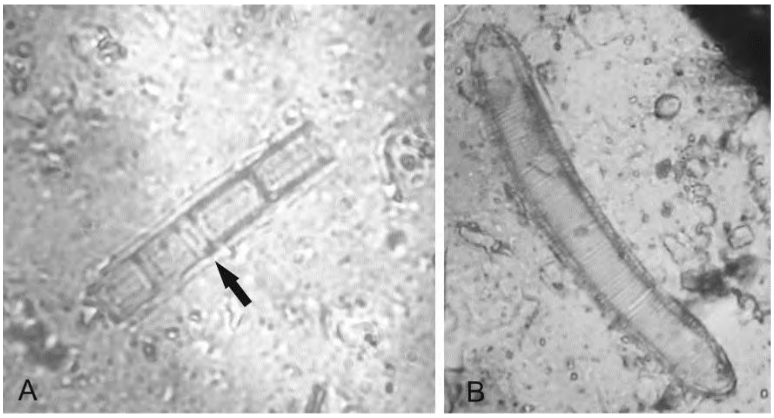

Figure 3. Microscope photograph of diatom species *Aulacoseria ambigua* (A) with hollow ringleist and *Eunotia bilunaris* (B).

Furthermore, *Enunotia bilunaris* also most diatoms in situ Cibuntu. *Eunotia bilunaris* valves are arcuate, with convex dorsal and ventral margins concave, rounded to acutely rounded apices (**Fig. 3**). This species is Widely distributed in waters with a low mineral content, commonly found in acid waters conditions (Kulikovskiy et al., 2010). The number of pH value at the time of direct measurement is 6.82 (**Table 1**), while monitoring which has been carried out in 2016 by Research Center for Limnology along Cibuntu Pond showed that pH value ranging between 5.7-6.8. The genus has a world-wide distribution, although numerous species are restricted to tropical areas, due to environmental water reviews their preference, land low pH and conductivity being the most abundant and diverse genus in these areas (Sala et al., 2002).

Table 1. Water quality of Cibuntu and Cilalay Ponds

Pond	DO	pH	Conductivity	TDS	ORP	Turbidity
Cibuntu	10.3	6.82	0.076	0.05	156	28.6
Cilalay	10.83	6.07	0.069	0.095	229	31.8

Cilalay Pond

Cilalay Pond has not been much affected by anthropogenic activities, in contrast to Cibuntu Pond which are already affected by anthropogenic activities and fisheries activities. Cilalay Pond surface water quality measurements during core sample collection was shown in **Table 1**. There are 10 diatoms species identified, *Eunotia bilunaris, Eunotia monodon, Eunotia pectinalis var. undulata, Fragilaria* sp*, Gissleira sp, Navicula* sp *1, Navicymbula pusilla, Pinnularia brebisonii, Pinnularia viridis,* and *Tabellaria* sp. The most dominant species were *Fragilaria sp, Eunotia monodon, Navicymbula pusilla, Eunotia bilunaris, and Pinnularia viridis*.

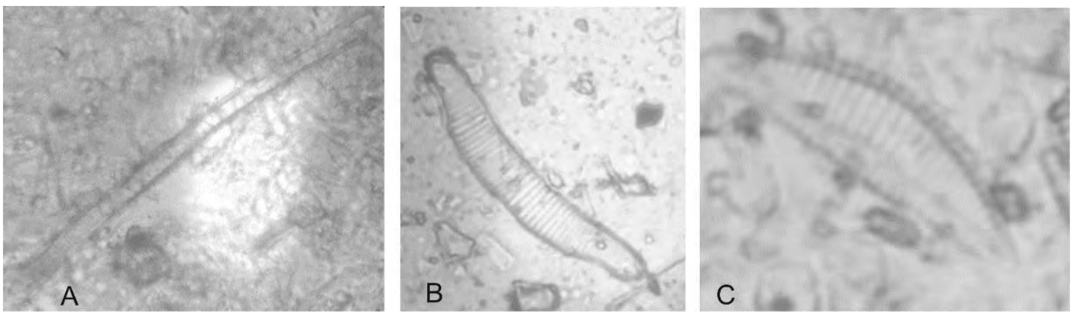

Figure 4. Microscope photograph of diatom species *Fragilaria* sp (A), *Eunotia monodon* (B), and *Navicymbula viridis* (C)

Fragilaria is a diverse genus including species that can live in lakes and flowing waters. Valves of this genus are lanceolate with capitate ends (**Fig. 4**). *Fragilaria* is species that tend to associate with circumneutral to slightly alkaline (Gell et al., 1999). The species is also commonly found in temperate waters mesotrophic lakes. Moreover, *Eunotia monodon* is the second large abundant in Cilalay Pond. This genus is a large genus of predominantly freshwater diatoms that are especially successful in acidic habitats, as well genus *Pinnularia* common found in acidic waters (Gell et al., 1999). *Eunotia monodon* valves are arcuate and the ventral margin of the valve is concave. *Eunotia* is diatom genus that has limited ecological tolerance. Their occurrence is limited to oligotrophic and oligosaprobic waters. In consequence, eunotia taxa are considered important ecological indicators (Kwandrans, 2007).
Furthermore, *Navicymbula pusilla* is also dominant in Cilalay Pond. This species has valve moderately dorsiventral, ends variable rounded (**Fig. 4**). This species is very cosmopolitan species from temperate to tropical zones and often found in the oligotrophic until eutrophic waters with middle to upper-middle electrolite contents, *Navicymbula* also found in inland waters krenophilitic and in the waters, that have high contents of Ca and Cl salinity (Krammer et al., 2003).

Diversity index (H') and Evenness Index (J') of Cibuntu and Cilalay Ponds

There are several results we can define from the study sites that represented in **Table 2**. Cibuntu Pond has a higher diatom diversity and eveness index than Cilalay Pond. Cibuntu lake not only has a greater number of species present, but individuals in the community are distributed more equitably among these species with eveness number 0.86829. Cibuntu Pond has 17 number of diatom species and 19% belongs to *Aulacoseria ambigua*. Furthermore, *Fragillaria sp* filled 49% at Cilalay Pond. Different levels of disturbance of limnological properties each lake have a different effect of diatom diversity.

Table 2. Ecological indices of recent diatom

Ponds	Individuals (N)	Species (S)	Shannon Index (H')	Pileou's eveness (J')
Cibuntu	300	17	2.4	0.8
Cilalay	300	10	1.6	0.7

The research objective is to preserve a biodiversity in a given area, we need to be able to study how diversity is impacted by different management area. Diatom community analysis showed that Cilalay and Cibuntu Ponds at least have a different limnological condition.

CONCLUSIONS

Our study provides a first inventory of recent diatom diversity and distribution in Cibuntu and Cilalay Ponds of Cibinong Botanical Garden, Cibinong. We identified significant difference between the diatom community composition of Cibuntu and Cilalay Ponds. The differences in diatom community composition are consistent with the prevailing limnological conditions among the ponds. In order to get a higher resolution environmental interpretation, these data should be a preliminary data to conduct a further research of Cibuntu and Cilalaly Ponds that will be supported by other abiotic parameters.

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TEMPERATURE EFFECTS ON LEAD TROPHIC TRANSFER WITHIN THE PHYTOPLANKTON –ZOOPLANKTON – NILE TILAPIA/COMMON CARP FOOD WEB: A CASE STUDY FROM THE CIRATA RESERVOIR, INDONESIA

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ABSTRACT

The transfer of lead (Pb) in the food web of pelagic fish (from phytoplankton and zooplankton to Nile tilapia, Oreochromis niloticus and common carp, Cyprinus carpio) will be investigated in the Cirata Reservoir. The purpose of this research is to (i) investigate seasonal and spatial variability of Pb in water, (ii) determine Pb bioaccumulation from phytoplankton, zooplankton to fish trophic levels and (iii) investigate the effect of temperature on Pb bioaccumulation in trophic levels. Data to be collected are Pb, Total Pb, ^{210}Pb activity concentration, C and N stable isotope ratios, measure from (i) different size classes of phytoplankton and zooplankton during dry and wet season as well as the transition period in Cirata Reservoir, and (ii) in two fish species. Two small plankton size fractions with the size of [20 – 200 □m] and [> 200 □m] will be retained. Common carp and Nile tilapia will be collected and dissected to extract muscle, gill, liver and body remain (skin, head and skeleton). Pb and ^{210}Pb analyzes will be performed on plankton, fish organ and water sample that filtered through 0.45 □m filter. Three replicates will be performed on each plankton fraction for each site and season for both □^{13}C and □^{15}N. Prior to stable isotope analyzing, the taxonomic composition of plankton fraction will be estimated under a binocular microscope with magnification of 400x. The dominant groups of organisms will be determined in each size fraction. Pb, Total Pb, ^{210}Pb activity concentration, □^{13}C and □^{15}N values will be tested using two-way crossed ANOVAs to assess the effects of the zone and size parameters for plankton fraction for each sampling season. To test for bioaccumulation process across plankton fraction and within the two fish species, linear regressions will be run between the log_{10} of ^{210}Pb activity concentrations and □^{15}N values of plankton fractions and fish.

Keywords: Common carp, Cirata Reservoir, Nile tilapia, ^{210}Pb, Pb, phytoplankton, zooplankton.

INTRODUCTION

Citarum river is the largest and the most important river in West Java, Indonesia, due its function for irrigation, the raw material for drinking water, and industry as well as covering the big three reservoirs namely Saguling, Cirata and Jatiluhur. The main function of these reservoirs is as hydroelectric power, to supply energy from Java and Bali. Besides, the other functions are for fishery, tourism and drinking water material as well as irrigation. However, this river received antrophogenic pressure for such as high sedimentation and heavy metal pollution from both industrial and domestic waste. Lead (Pb) is a very toxic heavy metal after mercury (Hg) that is sourced from indsuties such as textile, battery, electroplating and coloring material, etc. There are 60 textile factories existed along the upper part of Citarum River, which dump their waste with and without any treatment (Dhahiyat *et al*., 2016).

Figure 1. Cirata Reservoir polluted by Pb at concentrations above the standard quality

Cirata reservoir experienced of lead pollution from antrophogenic activities around reservoir and Citarum river flow. Lead is a non-essential metal and is poisonous at very low concentration. The contamination of Pb in water and sediment, when occurring in higher concentrations, is a serious threat because of their toxicity, long persistence, and bioaccumulation and bio-magnification in the food chain. Aquatic organisms take up and accumulate lead from water, sediment and food. Bio-magnification occurs along the food chain, enhancing the toxic effects.

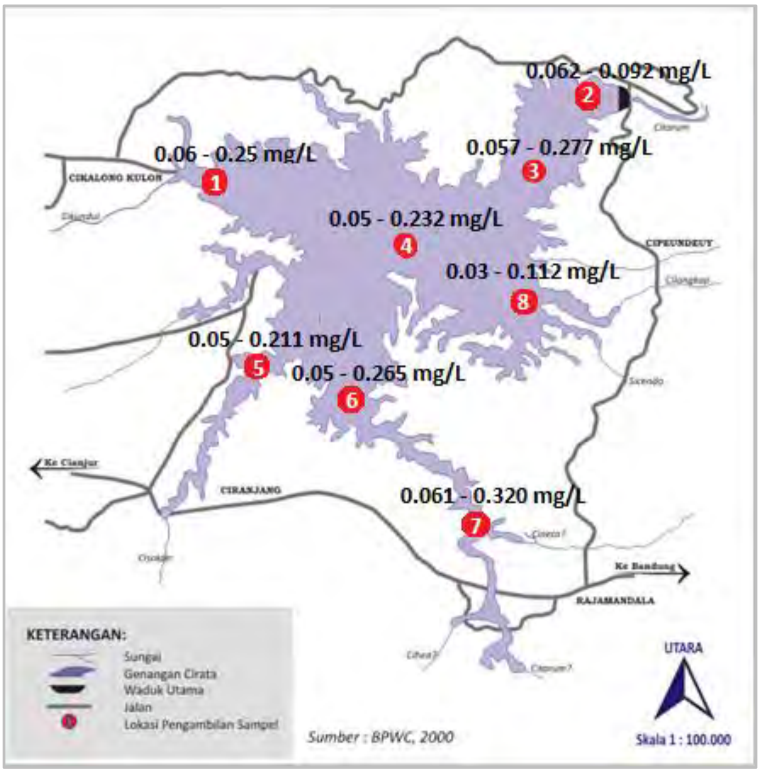

Figure 2. Maximum and minimum concentration of Pb in surface water in 8 sampling station in Cirata Reservoir (PPSDAL, 1995 – 2016)

According to the Pb concentration data that monitored in periods 1995 – 2016 in 8 sampling stations, it shown that Pb contamination were detected in Cirata reservoir in 2000. Pb spread evenly in each sampling station with concentration between 0.03 – 0.320 $mg.L^{-1}$ (PPSDAL, 1995 – 2016). The concentration of Pb in Cirata reservoir in certain location was ten times higher compare to National Water Quality Standard (0.03 $mg.L^{-1}$). The concentration of Pb was higher in sampling stations that located near the area of floating cages and lower in the restricted area (Station 2) (Figure 2). This is due to the Pb content in fish pellets.

Pb may affect the organisms that lived in aquatic; they are able to accumulate heavy metal in the environment than later can be transferred to higher trophic levels through the food chain. Bioaccumulation of Pb in *Liposarcus pandalis* in Cirata was considerably large (20 $mg.g^{-1}$), larger than the National Standard (0.3 $mg.g^{-1}$) and Standard of Ministry of Health Republic of Indonesia (2 $mg.g^{-1}$) (Dhahiyat *et al*., 2016). The cultured fish in floating cage in Cirata *(Cyprinus carpio* and *Oreochromis niliticus)* were high contaminated by Pb, Hg and Cd above the standard (Riani, 2010).

The uptake of Pb from water is influenced by various environmental factors such as temperature. The role of temperature on Pb uptake and accumulation on food chain has not been well studied and less extensively studied. A dietary uptake of metals may represent an important exposure route for aquatic organisms, and temperature dependent changes in food intake and absorption may play a key role in metal accumulation, toxicity and food web transfer and thus require further investigation.

Some recent studies have reported the uptake and increase of Pb which is dependent on the temperature (Wang *et al.*, 2005). Baines *et al*. (2005) also found a positive relationship between assimilation efficiency of dietary metals with temperature. A few reviews describe the effect of temperature on endpoints such as toxicity, uptake and accumulation of metals (Chairns *et al*., 1975,

McLusky *et al*., 1986, Huegens *et al*., 2002, Gordon, 2005, Rainbow, 2007 *in* Sokolova & Lannig, 2008). Metals can accumulate in aquatic organisms and are easily transferred through the food chain to the top consumers, including human. The elevated toxicity of metals at higher temperature may be partially explained by the higher uptake rate and accumulation increase with increasing temperature. Temperature can affect the bioavailability of metals due to the higher solubility of metal compounds and thus higher concentrations of free metal ions at elevated temperatures.
Tropical inland water has a relatively warm temperature so that bioaccumulation process occurs throughout the year. Tropical freshwater fish may be exceptionally sensitive to even small changes in temperature anticipated from global climate change. Increasing temperatures on aquatic ecosystems provide significant consequences on Pb bioaccumulation in the aquatic organisms. Temperature variations cause changes toxicokinetic, bioavalability, biotransformation, absorption rate and elimination rate of Pb. Temperature also affects to feeding rate (Heugens *et al*., 2001).

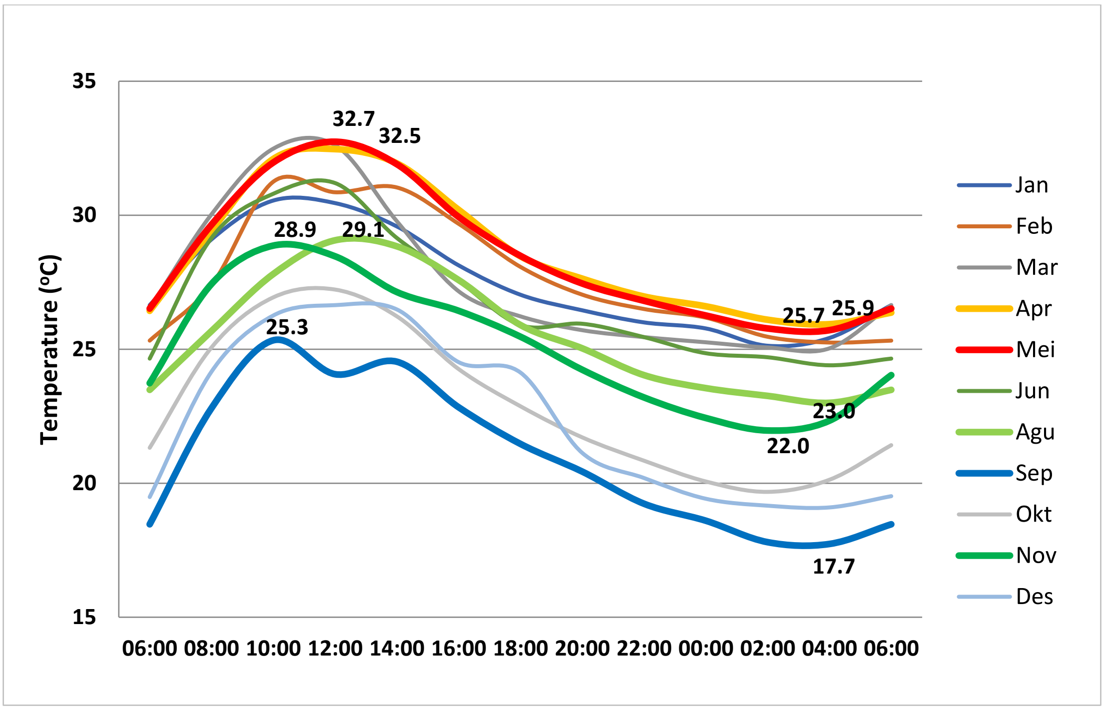

Figure 3. Monthly temperature variation in Cir ata (PJB, Unit Pembangkit Cirata, 2011)

Temperature variation in Cirata reservoir may reach to ± 8°C. In the dry seasons, daily temperature ranged from 25.9 – 32.7°C with average of 28.5°C (April and May). In the wet seasons, daily temperature ranged from 17.7 – 25.3°C with average of 20.9°C in September, and daily temperature ranged from 22 – 29°C with average of 25°C in transition periode (August and November). The rate of most reactions is very sensitive to temperature, mostly will increase rapidly with the increase of temperature. The temperature difference between the dry season and wet season reached ± 8°C in Cirata reservoir, which is predicted to give an effect on Pb bioaccumulation in aquatic organisms and the transfer of Pb in the food chain.
The ongoing study is (i) investigate seasonal and spatial variability of Pb in water, (ii) determine Pb bioaccumulation from phytoplankton, zooplankton to fish trophic levels and (iii) investigate the effect of temperature on lead bioaccumulation in trophic levels.

METHODS

Samples will be collected discretely in dry season (May 2017), wet season (Sept 2017) and transition period (March/November, 2017) to determine the effect of temperature on lead bioaccumulation in aquatic organisms. Sampling location will be carried out in the area surrounding the floating cage (station 3 and station 4) and in the area that restricted to the floating cage (station 2). Plankton size fraction will be divided into small plankton (20 – 200 □m) and larger plankton (> 201 □m). Plankton will be sampled by hauling plankton net horizontally through the water columns. Nile tilapia (*Oreochromis niloticus*) and common carp (*Cyprinus carpio*) with a weight of 300 – 400 grams will be collected and dissected to extract muscle, gill, liver, gut content and body remain (skin, head and skeleton). Total Pb and ^{210}Pb analyzes will be performed on water sample, plankton and fish organ. Three replicated will be performed on each plankton fraction for each site and season for both δ^{13}C and δ^{15}N. Prior to stable isotope analyzing, the taxonomic composition of plankton fraction will be estimated under a binocular microscope with magnification of 400x. The dominant groups of organisms will be determined each size fraction.

^{210}Pb activity concentration, δ^{13}C and δ^{15}N values will be tested using two-way crossed ANOVAs to assess the effects of the zone and size parameters for plankton fraction for each sampling season. To test for bioaccumulation process across plankton fraction and within the two analyzes fish species, linier regressions will be run between the $\log_{10}$ of ^{210}Pb activity concentrations and δ^{15}N values of plankton fractions and fish.

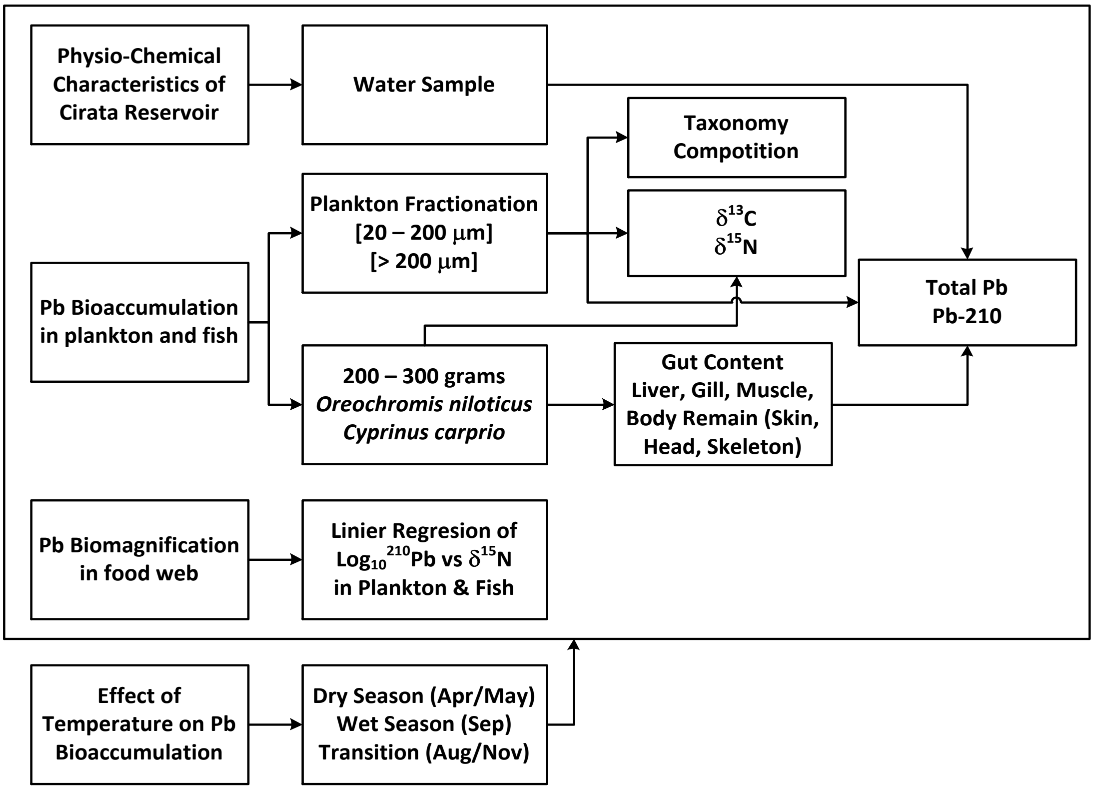

Figure 4. Diagram flow of the research

Nitrogen and carbon stable isotopes will be used to identify trophic position and food web structure. Stable isotope ratios of carbon (^{13}C:^{12}C; δ^{13}C) and nitrogen (^{15}N:^{14}N; δ^{15}N) are now recognized as powerful tools to provide time-integrated evaluation for energy flow and food web structures in ecological communities (Croteau *et al*., 2005). As a result of differential fractionation during food assimilation, δ^{13}C can be used to identify food sources, whereas δ^{15}N can be used for inferring the relative trophic position of an individual within a food web. Comparing data on pollutant concentrations with trophic levels inferred from stable isotope methodologies can enhance our understanding of trophic and contaminant interrelationship in aquatic biota (Croteau *et al*., 2005). Freeze-dried samples collected for stable isotope analysis were ground to a fine powder approximately 1 – 2 mg dry weight, analyzed for ^{13}C, ^{12}C, ^{15}N and ^{14}N by continuous-flow isotope-ratio mass spectrophotometer. All samples were standardized against atmospheric nitrogen or CO_2 as follows:

$$\delta^{13}C \text{ or } \delta^{15}N\ (^{o}/_{oo}) = [(R_{sample}/R_{standard}) - 1] \times 1000$$

Where R is ^{15}N:^{14}N or ^{13}C:^{12}C.

Metal concentrations in water and organisms will be analyzed by graphite furnace atomic-absoption spectrophotometry or by inductively coupled plasma-mass spectroscopy (ICP-MS). Two or three replicates will be measured for each sample.

RESULTS AND DISCUSSIONS

The sampling period have been conducted in March 2017 (transition period), including water quality measurements, retrieval the sample of water, phytoplankton, zooplankton, fish of tilapia and carp. Water samples and biota are being analyzed in the laboratory for measurement of Pb metal content.

Table 1 shows that the water temperature at the surface ranges from 27 – 29^{o}C. Water temperature that measured is a normal value for tropical waters. The conductivity in the three stations range from 145 – 147 mS/cm, which is tolerable for fish. pH in surface water ranges from 7.46 – 7.88, this range is ideal to support the life of aquatic organisms, especially fish, that live well in pH range 6 – 9 (Goldman & Home, 1983). Turbidity ranges from 3.92 - 19.88 NTU and dissolved oxygen concentration between 55.65 - 8.88 mg/L.

Table 1. Physical and chemical parameters in Cirata Reservoir

Sta.	pH	Temp. (^{o}C)	DO (mg/L)	ORP (mV)	Turbidity (NTU)	TDS (g/L)	Cond. (mS/cm)	Secchi depth (cm)
2	7.700	27.810	5.652	242.600	19.880	0.098	0.147	80
3	7.456	28.724	8.168	238.600	3.920	0.095	0.146	120
4	7.876	28.956	8.884	230.600	5.880	0.094	0.145	70

The secchi depth in the three stations ranges from 70 – 120 cm. This value indicates that the waters contain particles at high concentration and the light penetration hindered by the particles. The obstruction of light penetration in waters can be caused by a high abundance of phytoplankton, which occurs in eutrophic or hyper-eutrophic waters. The transparency below 300 cm classifies as eutrophic, while OECD classified waters with the transparency below 70 cm as hyper-eutrophic waters (Henderson *et al.,* 1987*)*.

Phytoplankton is an important primary produces and constitutes the basis of nutrient cycle of an ecosystem. Chemical, physical and hydrological of the waters are several factors that influence the abundance of phytoplankton (Reynold, 1993). The result of sample analysis revealed that the abundance of phytoplankton on the water surface is 17.820 ind.L^{-1} (station 2), 52,476 ind.L^{-1} (station 3) and 97,944 ind.L^{-1} (station 4) (**Table 2**).

Table 2. Phytoplankton Abundance in Cirata Reservoir

Phytoplankton	(%) Sta 2	(%) Sta 3	(%) Sta 4
Chlorophyceae (***Eudorina*, *Pediastrum***, *Pleodorina, Scenedesmus, Cosmarium, Actinastrum*)	**61.11**	**36.10**	0.71
Cyanophyceae (*Chamaesiphon*, ***Peridinium*, *Microcystis,*** *Merismopedia*)	**18.89**	1.52	0.84
Zygnematophyceae (*Spirogyra, Spondylosium, Straurastrum, Zygogonium*)	1.11	0.69	0.64
Xantophyceae (*Tribonema*)	2.78	**60.81**	**95.08**
Dinophyceae (*Ceratium*)	6.11	0.13	0.07
Bacillariophyceae (*Synedra, Navicula*)	10.00	0.76	**2.66**

Based on relative abundance (KR), the structure of the phytoplankton community in station 2 was composed by Chlorophyceae (61.11%) and Cyanophyceae (18.89%); Chlorophyceae (36.10%) and Xantophyceae (60.81%) at station 3; Xantophyceae (95.08%) at station 4. The Cyanophyceae community is abundant in eutrophic waters due to its ability to adapt to high dissolved oxygen fluctuations and at pH> 7 (Moss, 1988).

There are a number of reports that one, or more algae assemblage could be used as organism indicative of water quality. *Microcystis, Synedra, Strautrastrum, Pediastrum, Scenedesmus* are the genera/species that lived in Eutrophic water and pollution tolerant (Singh *et al*., 2013). *Peridinium* in station 2 and *Microcystis* in station 3 and station 4 becomes an indicator that the waters are contaminated with organic compounds. *Peridinium* and *Microcystis* are the family of Cyanophyta that thrive in nutrient-rich waters and extreme environmental conditions (Wehr & Sheath, 2003).

CONCLUSIONS

Temperature rise in aquatic ecosystem as the phenomenon of global climate change, effect on biological processes in water and organisms including metal bioaccumulation process. Pb contamination in Cirata Reservoir at concentrations above the national quality standard, has the potential for accumulation of Pb in aquatic organisms and transfer along the food chain. The effect of temperature on Pb bioaccumulation and its transfer in aquatic food web have been not studied.

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WATER QUALITY STATUS OF SINGARVA LAKE AT AHMADABAD, GUJARAT, INDIA

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ABSTRACT

The present study was carried out to determine the Water quality of Singarva Lake at Ahmadabad, Gujarat, for period of two year during 2010. The minimum and maximum values of pH varied from 6.8 to 8.5 respectively variation in TDS 305 to 1210 mg/l, Total hardness 100to 200 mg/l, Calcium Hardness varied from 50 to120mg/l were in good amounts in water and magnesium hardness is minimum and maximum 40 to 130 mg/l. Concentrations of Chloride is 141.91 to 629.85 mg/l. DO concentration 0.6 to 3.6 mg/l, COD varies from 1.0 to 117 mg/l and BOD 8.1 to 37 mg/l respectively in Singarva Lake.

Keywords: Lake, Singarva Lake, water quality

INTRODUCTION

Almost 70 % of the water in India has become polluted due to the discharge of domestic sewage and industrial effluents into natural water source, such as rivers, streams as well as lakes (Sangu and Sharma, 1987). About 95% of rural population living in India depends on ground water for domestics use (Moharir *et al.,*2002). The lakes are quiet large bodies of fresh water, usually deep enough that their beds lie much beyond the photosynthetic zone (Agrawal, 1999). Fluctuations of water level related to climate conditions and human requirements of water. The rate of water replacement of a lake also depends upon the season. A lake may be occasionally created by digging a basin that intercepts the water table. Such a lake is in a sense nothing but a wide shallow well. Most manmade lakes are created by damming a stream at a strategic point so that the water backed up the dam can be contained in a natural valley or basin. Many lakes are artificial and constructed for hydro-electric power supply, recreational purposes, industrial, agricultural use and domestic water supply. Ahmadabad is unique in the whole of India in matter of environmental neatness and flourishing conditions and it is superior to other cities in the excellence of its monuments. Ahmadabad Urban Development Authority (AUDA) carried out a survey of 645 lakes and identified 22 lakes which have been severely degraded. AUDA proposes to undertake works for revival, development of catchments area and beautification of lakes under the present project. Of these, 2 lakes were studied which are Singarva lake that located at Singarva village near Godhara, Ahmedabad road GIDC Kathwada, Ahmedabad. Its total capacity is 13.6 Carore liters. Lake Desilting area is 5675.0 m3 and peripheral development Works including landscaping: recreation facilities are such as Am phi theatre, children park and boating facilities and percolation wells to recharge ground water table. The aim of the present study is to determine the spatial and temporal distribution of physical variables (pH, TDS, Hardness, Chloride, COD, BOD and DO) in addition to Water of Singarva and lake during January to December 2010 of drought period to assess the environmental status of the Lake.

METHODS

The samples for physicochemical analysis were collected in pre-washed 1.5 L plastic bottles. The samples were taken from the surface at a depth of 6-9 inches from five different points, integrated and a representative sample was drawn. The sampling was carried out from January to December 2010.
Physicochemical Analysis of water was carried out referring to the 'standards methods' (APHA –1999). The pH, TDS, Hardness, Chloride, Dissolved Oxygen, Biological oxygen Demand and Chemical oxygen demand were measured in the field. The collected samples were brought to laboratory and analyzed within 24 hours, except the Biological Oxygen Demand, which require a period of five days for incubation at a temperature of 20^0C using standard methods (APHA –1999).

RESULTS AND DISCUSSIONS

Analysis of physicochemical parameters were conducted from January to December 2010, the data were shown in **Table1**. The Physico-chemical parameters are considered as the most important principles in the identification of the nature, quality and type of the water (fresh, brackish or saline) for any aquatic ecosystem (Abdo, 2005).
pH regulates most of the biological processes and bio-chemical reactions (Sculthorpe-1967). pH, free CO_2 and ammonia are more critical factors in the survival of aquatic plants and fishes than the oxygen supply, as reported. Fluctuations ~~in~~ of pH values mostly depend upon ingredient input in the water

bodies. The singarva lake water was found to be alkaline where pH varied from 6.8 sep-2010 and 8.5 Apr-2010. According to (Spence-1967) the pH of a typical eutrophic lake ranges from 7.7 to 9.6. The present findings are in support with of observation made by) that the Singarva lake is eutrophic on the basic of its pH range High pH value during Apr-2010. No significant change was observed in the water pH during different seasons and it was found within the permissible limits of 6.5-8.5 of WHO (Fresenius-1988). Total Dissolved Solids are simply the sum of cations and anions concentration expressed in mg/l. A high content of dissolved Solids elevates the density of water, influence osmo regulation of fresh water organisms, residue solubility of gases (like O2), residues utility of water for drinking purpose and result into eutrophication of the aquatic ecosystem. TDS in this lake fluctuated between 305 ppm to 1210 ppm. The highest value was recorded 1210 ppm in March to May 2010 (Vediya and Patel, 2010). The concentration of Total hardness in Lake Singarva During varied from lowest level 100 mg/l (in January 2010) and the highest 200 mg/l in Feb, 2010). Classified water on the basis of hardness values in the following manner. (i)0-60mg/l: Soft (ii) 61-120mg/l: moderately hard, (iii) 121-160 mg/l: Hard and (iv)>160mg/l: very Hard (Kannan, 1991). Calcium hardness varied from 50 mg/l (Dec, 2010) to 120 mg/l as the highest value (March, 2010) as the highest concentration. Comparatively magnesium hardness is higher from 130 mg/l in Dec-2010. Chloride is distributed widely in nature in the form of salts of sodium, potassium and calcium. The chloride status in lake water is indicative of pollution, especially of animal origin. In the present study chloride concentration in Singarva lake was found raining between minimum range of 141.91 mg/l in Sep-2010 and maximum range of 629.85 mg/l during to Jan-2010.the highest value of chloride was observed at the day of Jan to Jun -2009. Resulted due to large amount organic matter, mass bathing activities, urination and waste of animals. These results are in conformity with the study of (Zutshi-1988). The presence of dissolved oxygen is required to prevent odor and is used by aquatic plants and other life forms. The dissolved oxygen in Singarva Lake was found within 0.6 mg/l. Biochemical Oxygen Demand (BOD) showed the lowest range of 8.1 mg/l in August 2010 and the highest was 37 mg/l May 2010, respectively (**Table 1**). The minimum value of BOD was recorded at the surface layer during the functioning period of the aeration units. BOD indicates the presence of microbial activities and dead organic matter on which microbes can feed. BOD is directly linked with decomposition of dead organic matter present in the lake and hence the higher values of BOD can be directly related with pollution status of the lake (WQM-1999). An inverse relationship was found between the dissolved oxygen concentration and biological oxygen demand values (Coscun, 1987).

Chemical oxygen demand (COD) indicates the pollution level of a water body that is related to the present of organic matter in the lake (WQM-1999). COD concentrations in the lowest range of 1 mg/l oct-2010 and the higher range of 117 mg/l were obtained in the surface layer of stations May-2010. Respectively (**Table. 1**). The increase in COD concentration was found in the bottom water where organic matter is more (Prasad-1976). BOD and COD are important parameters that indicate contamination level, especially for wastewater. The values of BOD and COD were found in the range 8.1-37 mg/L, and 1.0-117 mg/L respectively. Slightly higher values of COD warn about the pollution in lake caused by anthropogenic activities.

Table 1. Physicochemical data of Singarva Lake, Ahmadabad, and Gujarat.

Parameters	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
pH	7.4	7.9	8.1	8.5	8.2	8	8	6.9	6.8	7.6	7.1	7.5
TDS (ppm)	832	820	954	908	1210	820	305	374	394	455	490	594
Total hardness (mg/l)	100	200	200	200	170	200	180	110	110	140	160	180
Calcium Hardness (mg/l)	60	90	120	110	70	90	90	60	50	70	90	50
Magnesium hardness (mg/l)	40	110	80	90	100	110	90	50	60	70	70	130
Chloride (mg/l)	629.85	525.93	429.91	528.97	494.84	498.2	321.23	154.95	141.91	174.96	189.9	244.94
DO (mg/l)	3.6	3	2.9	2.5	0.6	1.4	1.6	2	1.9	1.3	1.3	2.7
COD (mg/l)	20	28	61	46	117	48	24	11	23	1	10	69
BOD (mg/l)	20	15	28	8.3	37	21	10	8.1	12	20	17	19

CONCLUSIONS

The study shows that Singarva lake water exhibits low DO, High BOD, COD, TDS. pH value indicates slightly alkaline nature of water. The remarkable point is that the pollution load is significantly high during 2010. The analysis shows that hardness and chloride are above the permissible limits. It's observed that siltation is one of the key causes responsible for the degradation of the lake. Comparison of physicochemical parameters of Singarva Lake with those of WHO recommended values shows that water is not suitable for drinking purposes. The study of water and flora shows that the Lake contains adequate food potential and micro nutrients for development. Therefore, it is suggested to farmers should be encouraged to use organic fertilizers instead off chemical fertilizers and public awareness regarding benefits of not using plastic bags should be undertaken on priority basis.

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