Lake Baringo: A transient environment, diversity and livelihoods

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Abstract

Lake Baringo is located on the floor of the eastern arm of East African Rift System in Kenya. It lies between latitudes 0˚30′ N and 0˚45′ N and longitudes 36˚00′ E and 36˚ 10′ E approximately 60 km north of the equator at an altitude of 975 m.

The major resources of the lake and its basin include among others: water, fish, diverse wildlife and a diversity of people. The lake supports a small-scale fishery exploited by local population for both subsistence and commercial use. The fishery generates income to the community and revenue for the local government. The lake water is used for domestic purposes for both humans as well livestock. Water from rivers afferent to lake is used for irrigation. Baringo-Silali geothermal electricity development project is using water from the lake to enable the geothermal well drilling. Macrophytes in the lake are a source of food, herbal medicine, building material and mats. The 'Sebei' tree is harvested and the stem is used to make rafts which are used for navigation. Cattle and donkeys graze in the macrophyte zone of the lake and rivers. There is transport of people as well as goods to and from various markets and human settlements across the lake. The lake is platform for pleasure activities: water sports (speed boating, jetski, yachting, and skiing, kayaking and sport fishing) and the annual raft ('Ng'adich') competition, a cultural event for fostering peace and harmony among indigenous communities. Tourism is major source of income to the community and revenue to the government. Attractions to the lake include: high population of diverse birds and large vertebrates, indigenous conservative communities, their cultural items and aesthetic lake environment. The lake is an education resource for primary, secondary and tertiary institutions who tour the lake on education tours. The educational tours are source of income to both local tour guides and the local communities in general. Scientific professionals are attracted to the lake to undertake research.

In earlier years of the 2000 millennium, the water of Lake Baringo had very low aesthetic value as its water was deep tea brown in color. At that point in time it was unimaginable especially, for first time visitors to the lake to fathom that the lake will ever improve and regain past the near pristine status. However, since 2012, the lake improved regaining near pristine water quality status of the 1960s with the transparency increasing 100 times. In early years of the millennium, sedimentation was assumed to be the cause of deteriorating water quality, however, the long term view shows that the lake water quality is variable and corresponds to climatic pattern of the catchment and more so of climate change. Recent fossil diatoms evidence of the past 200 years showed water level fluctuations in lake are as consequence of climatic variations which follows 50 year climatic cyclic pattern. Thus, the lake is climate sensitive. Similarly, fluctuations in the fish production were always attributed to fishing effort, however, it has been demonstrated that a variable lake environment is responsible.

Solutions to sedimentation and poverty alleviation have been disseminated to the community and also applied, albeit at low scale in the catchment, but there is need to upscale the efforts. Parts of the forests of Ol Arabel and Marmanent forests were excised between 1982 and 1999 to give room to human settlement and agriculture affecting water flow to the lake. There are efforts by the government, corporate world and environmentalists to recover the deforested areas.

To solve the problem of sectoral management of the lake, Integrated Lentic Lotic Basin Management (ILLBM) is the appropriate strategy which was recently incorporated in management of lakes by the government.

Key words
Lake Baringo, water quality, sedimentation, diversity, fish production, conflicts,
Climate change, ILLBM

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1. Introduction

Odada *et al* (2006) did a review on Lake Baringo whose focus was on the ecological, socio-economic as well governance issues, efforts undertaken to solve various problems and possible future solutions. Since then, it is now thirteen years and there have been changes in the: the lake's biodiversity, scientific understanding of the lake ecology and governance structure. Projects which were being taken to solve or to alleviate various ecological and socio-economic problems came to completion. What are results after twenty years? The aforementioned changes necessitate a review to update the ramification of various interventions affected through local and international projects.

This review seeks to provide not only insight into new scientific understanding of the lake ecosystem based on new knowledge scientific which was produced after the last review but also considers knowledge which was available before the last review but was not considered.

2. Origin and Location

Lake Baringo, unlike other lakes in East and Central Africa such as Lakes Victoria, Malawi and Turkana, has throughout history been known by only one name. According Odada *et al.* (2006), the name is derived from the local word 'Mparingo' which means lake. Precisely, it is a word adapted from the Ilchamus, a nilotic community who live around the central to southern parts of the lake. Their language and culture is closely related to that of Maasai and Samburu communities. The lake, one of the seven lakes on the floor of the eastern arm of East African (Gregorian) Rift System, lies between latitudes 0°30′ N and 0°45′ N and longitudes 36°00′ E and 36° 10′ E (Ssentongo 1974). And it is situated approximately 60 km north of the equator at an altitude of 975 m a.s.l. (Kallqvist 1987, Tarits *et al.* 2006). The Rift valley lakes in Kenya extend from Lake Turkana in the north to Lake Natron in the south (Fig. 1). The other lakes are Naivasha, which is a freshwater lake, as well Lakes Magadi, Elmenteita, Nakuru and Bogoria which are saline (Fig 1).

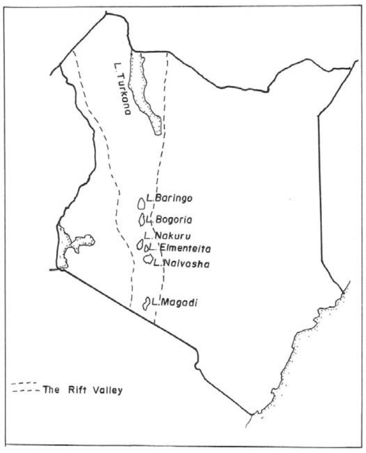

Fig. 1. Location of Rift Valley and lakes in Kenya.

Although Lake Baringo is entirely in Baringo County, its basin covers three administrative counties, namely; Baringo, Laikipia and Nakuru (Fig. 2). The counties are the former administrative districts which were created in 1992 and still cover exactly the same area. The difference is that counties are more autonomous units compared to former districts which were centrally controlled by the national government. County governments perform some functions which were devolved from the central government following the promulgation of new constitution of Kenya in 2010 (COK 2010). Districts still exist and occupy smaller administrative areas within the counties and are still controlled by the national governments albeit with different functions.

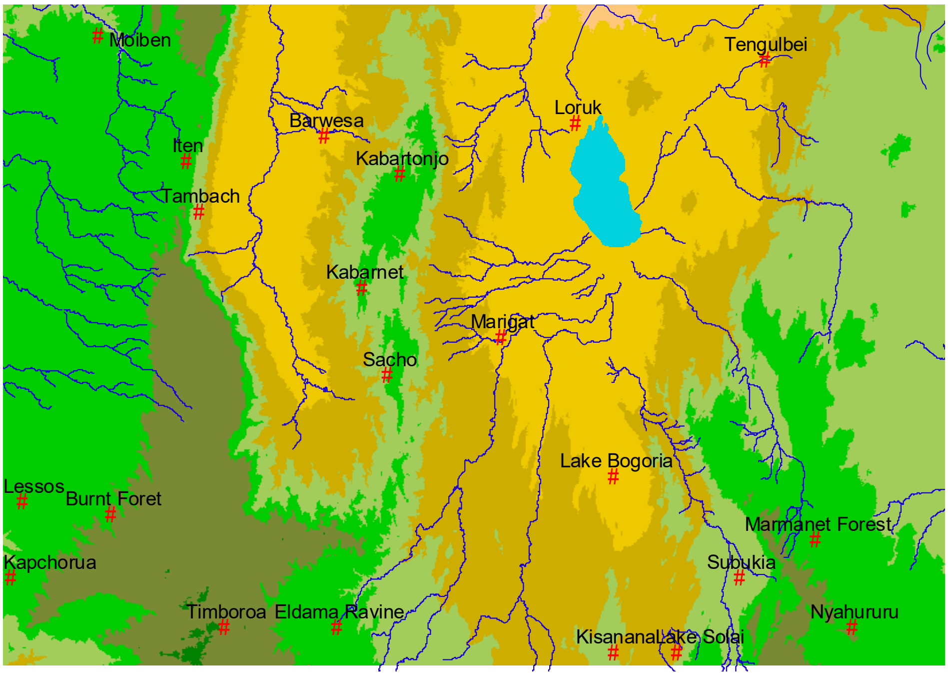

Fig. 2. A map of Lake Baringo basin showing the major rivers.

The Lake Baringo basin is bounded by Tugen hills in the west, Mau uplands in the southwest and the Laikipia plateau to the east (Fig. 3). The highlands form a large part of the catchment and rise as high as 2800 m a.s.l. Generally, in the highlands, the landscape is steep, especially in the Tugen hills and Laikipia escarpment. From the highlands are piedmonts which finally lead to the floodplains of Marigat and Lake Baringo (Odada *et al.* 2006, Tarits *et al.* 2006).

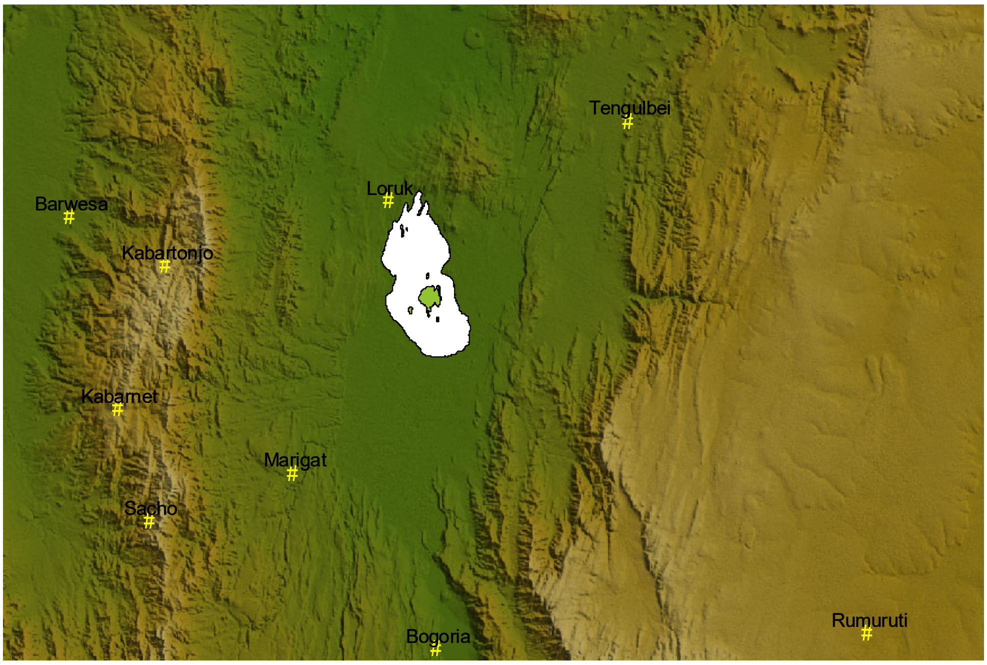

Fig. 3. Physiographic setting of Lake Baringo

Lake Baringo is tectonic in origin and it also known as fault lakes, where water is tapped in the down faulted valleys. The Baringo rift basin was formed during the Palaeogene period, between 43 to 23 million years ago (Mugisha *et al*. 1997; Hautot *et al.* 2000; Tiercelin and Lézzar 2002; Bunnet 2003). Since its formation, the basin has evolved over time, hosting a series of lakes that have emerged and declined over geological time (Woldegabriel *et al*. 2016). Renaut *et al.* (1999, 2000) notes that the current Lake Baringo is the remnant of a larger lake known as Lake Kapthurin which developed in the Lower Middle Pleistocene period (700-200 Ka). Studies on vertebra fauna and sediment mineralogy disclosed that Lake Kapthurin alternated from freshwater to saline lake (Tarits *et al.* 2006, Woldegabriel *et al*. 2016). According to Woldegabriel *et al*. 2016, Lake Kapthurin started to recede around 200 Ka and finally remaining in the northern end of the current lake while south become an alluvial plain. Paleolimnological studies (Kiage and Liu 2009a; Renaut *et al.* 2000) have been used to generate paleogeographic information and records of the past climatic conditions and variability in Lake Baringo. The stratigraphic record from Lake Baringo reveals two abrupt dry episodes at ca. AD 1650 and AD 1720 in East Africa that led to drying up of the lake. In the lake there are seven islands (Fig. 8), the biggest being the volcanic Kokwa (Plate 4). Others are Lekoros, Rongena, Longicharo, Samatiany, Parmalok and Lesukut ('Devil Island'). Kokwa Island is a small relic volcano that belongs to the Korosi volcanic chain which erupted during the Early Pleistocene, approximately 2.6 million years ago (Clément *et* *al.* 2003). On the northeastern part of Kokwa Island are a number of alkaline hot springs that discharge into the lake. These springs form part of what is referred as the Soro hydrothermal system and are indicators of former volcanic activity (Renaut *et al*. 2002).

3. State of the Lake

3.1. General Characteristics

A summary of morphometric and hydrological characteristics of Lake Baringo is listed in Table 1. The lake has a variable surface area, water depth and physical chemical characteristics which are a reflection of the high dry and wet seasonal influences in the semi-arid climatic zone (Tarit *et al*. 2006). The lake has a catchment area of 6,820 km^2 and measures 22 km long by 13 km wide (Tarit *et al*. 2006, Olilo *et al.* 2014). A recent estimate of the catchment area using ArcGIS resulted in an area of 7,090 km^2 demonstrating differences due different methods used in calculation of the lake's morphometric. Lake water volume is $726x10^6$ m^3 while water residence time is 12.7 years. The reported mean lake depth over the years is variable because of the time period considered when deriving the mean value. It is reported to have been 5.6m in the 1960s (Ssentongo 1995), over 8m in the late 1970s (Meyerhoff 1999), decreasing to just below 3 m in 1994, but rising again to 4.5 m in 1998 following the 1997/98 *El Niño* rains. At the time of the 2003 bathymetric survey, the mean depth was 2.65 m (Hickley *et al*. 2004). Between April 2008 and March 2013, Omondi *et al*. (2014) reported a mean depth of 3 m with the deepest point being 7 m. The mean (±SE) lake water depth ranged from 5.31±0.13 m to 6.35±0.12 m (Omondi *et al.* 2014), which is close to the maximum depth of 8 m reported by Schulter (1993) and Oduor *et al.* (2003). The lake has no surface outflow, though it is thought to lose water by seepage at the northern end, which enables it to maintain its freshwater status (Gregory 1894, Tarits *et al* 2006). The lake experiences very high annual evaporation rates of 1650 to 2300 mm (Odada *et al.* 2006) and its survival depends on the inflows from rivers originating from the hilly basin where rainfall varies from 1100 to 2700 mm.

A monthly monitoring exercise carried by KMFRI between April 2008 and May 2014 showed the lake water temperature ranges from 22.7-30.5 °C with a wide range of 7.8 °C. The high water temperatures recorded in the study were mainly attributed to the high intensity of solar radiation in the area (Ngaira 2006). Lake Baringo experiences a 24 h temperature cycle, which correlates well with the diel radiation cycle. Since the lake is near the equator, the diel cycle is characterized by equal hours of light and dark associated with high solar radiation during the day and cooling at night, respectively. Thermal stratification is observed during daytime while isothermal conditions occur throughout the night. In the presence of strong wind action in the late afternoon and evening, the thermal stratification is reduced or broken completely (Oduor *et al.* 2003).

Table 1. Morphometric and hydrological characteristics of Lake Baringo.

Feature	**Level**
Surface area	125-199 km^2
Mean depth	3.4-10.6 m
Lake length (L)	22 km
Lake width (W)	13 km
Catchment area	6,820 km^2
Maximum elevation catchment	2500 m
Lake Water volume	726 x 10^6 m^3
Annual mean temperature	26º C
Rainfall	400-1000 mm
Evaporation	1500-2000 mm
Annual inflow from the rivers	River Molo 126 x 10^6 m^3, River Perkerra 39 x1 0^6 m^3
Ground seepage	50-150 m^3 s^1
Residence time years	12.7 years

3.2. The Lake Shoreline

The shore has three main habitat types; the open water, the shore line (thin strip) of riparian land, and the arid or dry land. Edaphic factors as well as the altitude influence the species composition and distribution of vegetation types. The raised dry areas around the lake have savanna vegetation characterized by *Acacia tortilis* trees. Ficus plants in this area grow on the cliff faces. Communities dominated by *Acacia mellifora* and *A. reficiens* occur to the north and east of the lake. Other important communities include species of *Boscia*, *Commiphora*, *Terminalia* and *Balanites.* The alkaline tolerant grasslands of *Sporobolus spicatus*, *Cyperus papyrus* and strands of *Typha domingensis* and sedges dominate the low-lying wet/moist ground, or the shore line. Several species of macrophytes are confined to the delta region, Loruk and other sandy shore. These include *Typha, Pistia stratioes, Nymphea papyrus, Diplakin fuscus* or floating grass. The shores of the lake are fringed by macrophytes, except for the northern and midwestern shoreline which are rocky and basically devoid of macrophytes (Renaut *et al*. 2000). The wetland is endangered by poor land use practices in catchment. Algae dominate the open water. Lake Baringo has the plant species Moringa tree which has both medicinal and cultural values. *Aechynomene indica* is tree (locally referred as 'Sebei') which grows in wetland and is used for making rafts which are used for fishing in lake (Plate 1). *Prosopis juliflora* commonly known as *'Mathenge'* was introduced in Lake Baringo basin lowlands in 1984 following concerns about desertification and fuel wood shortages in the late 1970s and early 1980s. Since then, the plant naturally spread rapidly around the lake, though, now, it is largely confined to Marigat division, which covers an area of 1,276 km^2. The plant is a concern to the local pastoral community who has been lobbying the government to eradicate it as it has out-competed the local natural vegetation including grass and threatens indigenous biodiversity.

Plate 1. Fishermen on rafts made from *Aechynomene indica* ('Sibei') tree. Rafts are the only crafts used for fishing.

3.3. Water Balance and Lake Level Fluctuations

There are hydrological stations at various locations on the rivers flowing into Lake Baringo. The Water Resources Authority (WRA) is responsible for water level, water quality and sediment level measurement in the rivers flowing into Lake Baringo. Most inflows to the lake come from the Rivers Molo and Perkerra. Ojany and Ogendo (1973) estimated the annual inflow from the Rivers Molo and Perkerra in 1973 as being 126 x 10^6 m^3 and 39 x 10^6 m^3, respectively. The contributions of inflow from the other rivers and rainfall (mostly between March and August) into the lake have not been estimated. Similarly, the little contribution from the hot springs on Ol Kokwa Island has not been estimated, however, Dunkley *et al.* (1993) and Renaut *et al.* (2002) postulates that, they contribute very little to the annual flow. Some lake water is lost by underground seepage through the fractured lake floor (Tarits *et al.* 2006), and this discharge at the northern end has been estimated to be over 10^8 m^3 $year^{-1}$ (Dunkley *et al.* 1993), or about 50-150 m^3 s^1 (Olilo *et al.* 2014). Thus, there is insufficient information on the hydrology of Lake Baringo basin.

Monthly water levels in Lake Baringo fluctuate with time, responding to alternating wet and dry seasons. Rains normally lead to increased water inflows and lake surface area, sometimes accompanied by lakeshore flooding (Ouma and Mwamburi 2014, Omondi *et al.* 2014, Oduor *et al.* 2003, Schagerl and Oduor 2003). The most recent rise in water levels was reported in 2010: the area under water rose from 143.6 km^2 in January 2010 to a high of 231.6 km^2 in September 2013, an increase of 88 km^2 (61.3% increase by area). In December 2010, the lake area had increased by another 28.8 km^2 (Onywere *et al.* 2013). The lake level monitoring station RGS 2EH01 is located within the lake and has long term data from 1956 to 2015. Annual average lake level variations are illustrated in figure 4. Generally, long term trend in the lake level follows a similar pattern as the rainfall pattern in catchment. Peak rainfall periods of 1963-1964, 1978-79, 1998, 2003, 2007-2008, 2013-2015 had corresponding peaks in lake depth. Similarly, lowest depth periods were associated with lowest rainfall and drought periods in catchment of 1983-1985, 1986-1987 and 2002 (Ngaira 2006, Koskei *et al*. 2018). The increment in lake depth of 2013-15 was approximately double of the highest depth recorded since monitoring started in 1956. The assertion of Odada *et al.* (2006) that the lake's surface area will decrease by 50% by 2025 is simplistic. First it is based on short term data which indicated that the lake surface area was experiencing declining trend, however, long-term data shows the surface area fluctuates in the long term. The cause and driving forces of lake's surface area is complex and need more studies to ascertain the cause. According to Ngaira (2006) climate change is responsible for the recent changes in lake's surface area. It has been postulated that the increment was due to probably water inflows from underground (D. Olago pers. comm.).

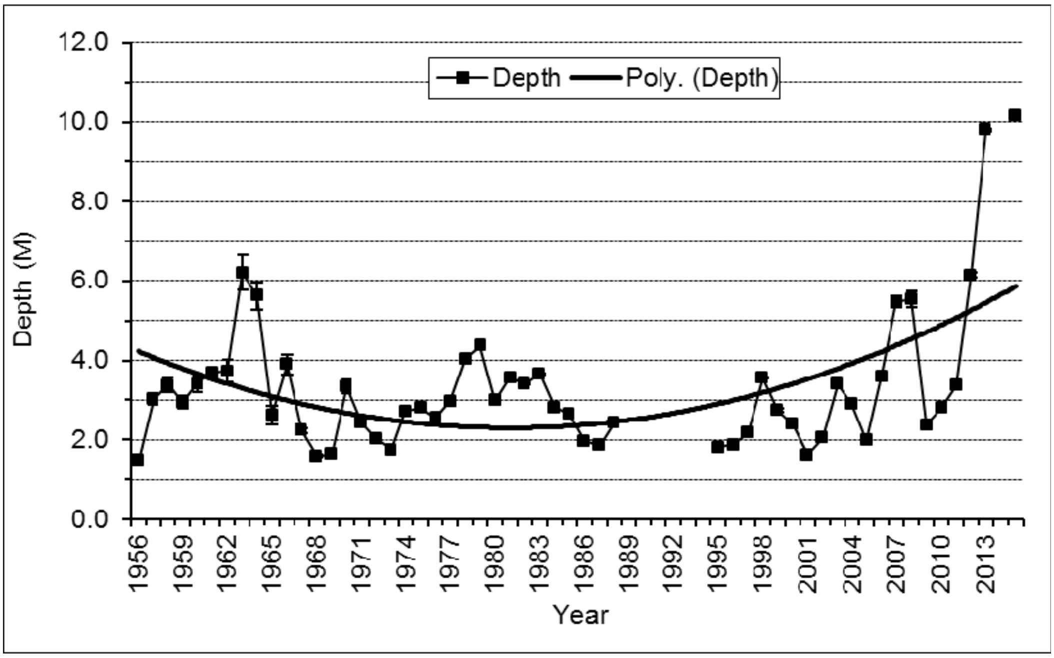

Fig. 4. Lake Baringo annual average depth as measured at water gauge station 2EH01. Error bars represent standard error of mean. Data for years 1989 to 1994 and 2014 are missing.

4. The Catchment

4.1. Geology

In their upper reaches, the Molo and Perkerra rivers drain areas that are composed of thick series of basalts, phonolites and trachytes of Mio-Pliocene age, while downstream they flow across Pleistocene trachyphonolites, pyroclastic deposits, and siliciclastic fluvial sediments. The eastern part of the Baringo watershed, drained by the rivers Mukutan and Ol Arabel, is characterized by a several hundreds of metres thick succession of basalts and phonolites of Miocene age, which are exposed on the Laikipia escarpment. Late Holocene to modern sedimentation in Lake Baringo is dominated by fine grained siliciclastics (Renaut *et al.* 2000). Most of the lake floor is covered by detrital muds and feldspathic silts that reflect the very high soil erosion rates in the catchment (Snelder and Bryan 1995; Oostwoud *et al*., 2001; Aloo 2002). The Rift Valley geological formations have been associated with high fluoride contents in underground water sources (Olaka *et al*. 2016), which compromises the desired natural water quality for human consumption.

Lake Baringo catchment soils are clay and clay loams and the risk of soil erosion is high because of the soil properties, since clay fills pores or seals the surface giving low infiltration capacity.

4.2. Climate

The area around Lake Baringo region is semi-arid; however, the catchment has a range of climate regimens ranging from semi-arid to humid in the highlands. It is characterized by two rainfall seasons which are controlled by the movement of Intertropical Convergence Zone (ITCZ). Long rainfall season occurs from April to August and short rainfall season from October to November (Odada *et al.* 2006). Most of the precipitation falls during long rainfall season (Tarits *et al*., 2006). Dry season is from September to October and December to March. Annual rainfall ranges from 600 to 900 mm on the Rift Valley floor and rises to 1500 mm in the adjacent highlands. There is inter-annual variation in amount of rainfall which is more pronounced due to cyclic influence of *El nino* and *La Nina* every 5-7 years (Kiage and Liu 2009b).

Potential evaporation exceeds 2600 mm per year. The mean annual temperature on the Rift Valley floor is about 23–33 °C. A regular diel pattern of wind occurs over the lake with regular north-easterly winds blowing in the late afternoon and early evening. The humidity is generally low in this area. Maximal PAR was around 1500 μmol photons m^{-2} s^{-1}, with 12 h daily of solar radiation and with only little variation due to the rare cloud cover (Oduor *et al.* 2003).

Koskei (2018) demonstrated using analysis of rainfall data of 27-29 years (1981-2010) that there has been climate change in Lake Baringo basin. The climate change is characterized by large annual rainfall variability which was related to *El Niño Southern Oscillation* (*ENSO*) phenomenon. The highland zone revealed an increasing trend in inter-annual rainfall amounts and low variability as opposed to the Arid and Semi-Arid Lands (ASALs) low lying zones which showed decreasing amounts and high variability within and between the years. Observed impacts of the climate change included among others: i) shifts in rainfall seasons, ii) extreme recurrent droughts iii) rivers becoming more seasonal or disappearing altogether iv) drying of wells, v) flooding of water bodies (rivers, lakes and swamps), vi) forest fires vi) scarcity of water and pasture, vii) destruction of infrastructure such as roads and bridges and irrigation systems, and vii) resurgences of some diseases. These physical impacts consequently resulted in: i) crop failure and massive livestock deaths which ultimately resulted in famine (Hickley *et al.* 2004), ii) an unhealthy community iii) pastoralists (with livestock) migration in search of pasture and water into other communities land, iv) conflicts over scarce resources (e.g. water and pasture), v) forced displacement of communities from their ancestral homes and land who become Internally Displaced Peoples (IDPs) vi) increase in poverty vii) loss of income, revenue and taxes and viii) governments and NGOs incurred huge financial expenses in responding to aforementioned Climate Change impacts which would have used for other development. The impact of climate change is more pronounced in ASALs than the humid highlands. Impact is pronounced because the economy of ASALs is depended on Climate Change sensitive sectors such as agriculture, apiary, pastoralism, fisheries and tourism. And also have weak capacity in climate change adaptation and mitigation.

4.3. Rivers

Rivers Molo and Perkerra are the main perennial rivers which originate from the Mau highlands in the south and discharge into the lake's southern end via the Molo delta. These rivers are characterized by high variation in annual discharge (Fig. 2 and 3). In very dry years discharge is significantly reduced (Tarits *et al.* 2006) by irrigation withdrawals south of the lake, and sometimes, water flow completely ceases in these rivers in the lowlands. Furthermore, long-term declines in discharge of particularly, River Perkerra, has been observed since about 1970 (Fig. 5 and 6). The decline assumed a polynomial trend with calculated trendline equation being $y = -0.0003x^2 + 0.0051x + 0.8108$, $R^2 = 0.6042$. Conversely, the discharge of River Molo has assumed a linear increasing trend albeit slightly. The calculated trendline equation being $y = 0.0007x + 0.3336$, $R^2 = 0.0181$. Other formerly perennial but now quasi-seasonal rivers are Ol Arabel and Mukutan which originate from the Laikipia plateau and flow into the lake on the east. Several large seasonal streams drain into the lake from the Tugen Hills to the west, with the Rivers Endao, Kapthurin and Chemeron being the main ones. There is little inflow along the steep northern shoreline, and no surface outflow. Thus, the lake is a topographically closed basin. Climate change is perhaps a significant long-term cause of decline in discharge of rivers afferent to lake. However, it has not been established scientifically and therefore there is need for a detailed study to establish the role of climate change in influencing not only seasonal variations as well as annual discharge trends.

Dams have been proposed to regulate the fluctuation of the Molo and Perkerra rivers. So far, Chemasusu dam has been built on River Perkerra to provide potable water and the process of constructing a dam on River Molo at Radad is on-going. Changwony (2009) and Tarits *et al.* (2006) have argued for, but not substantiated, the proposition that water abstraction from rivers leads to significant drops in the water level in the rivers and the lake. According to (Changwony 2009), about 40% of the natural discharge from rivers to the lake is intercepted and used for irrigation. However, this estimate cannot be substantiated because the water abstraction is not metered. In addition, the farmers who abstract water from the rivers are not licensed and do so illegally.

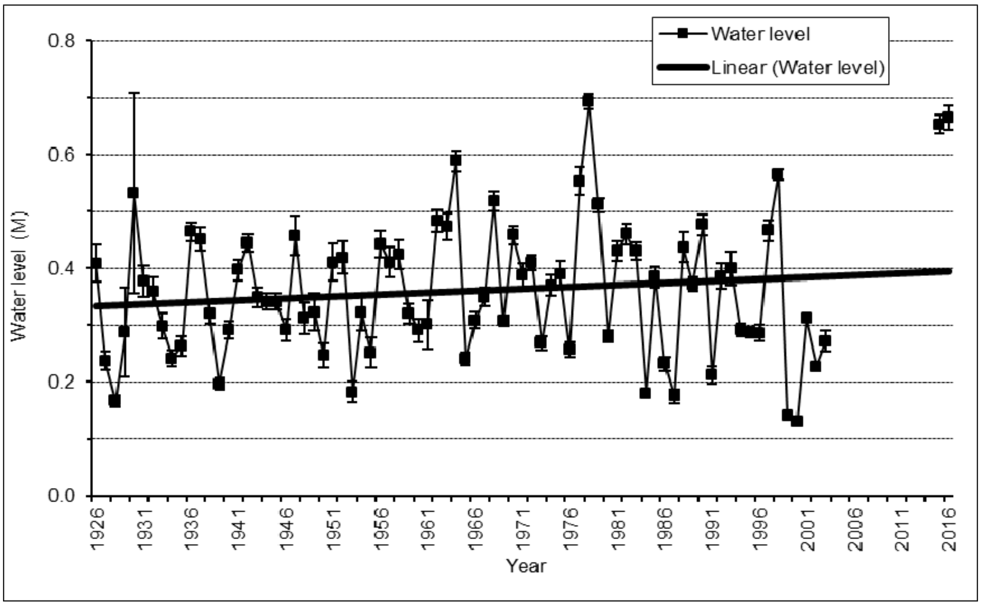

Fig. 5. River Molo annual mean water level as measured at river gauge station 2EGO1. Error bars represent standard error of mean. Data for years 2004 to 2014 are missing.

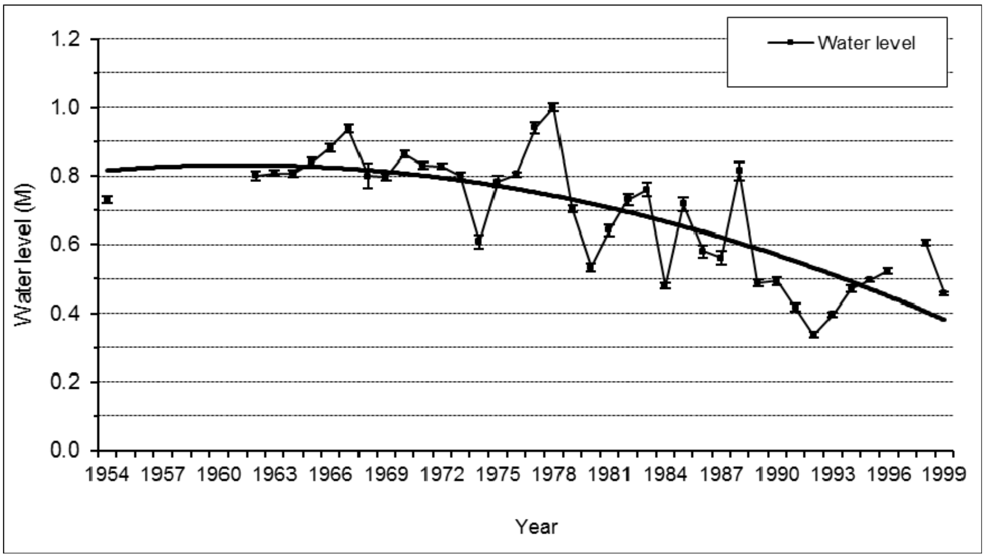

Fig. 6. River Perkerra annual mean water level as measured at river gauge station 2EE7. Error bars represent standard error of mean. Data for years 1955 to 1961 and 1997 are missing.

Figures 5 and 6 indicate that is monitoring of river discharge is not consistent and efficient as there are large gaps in the data sets. There is a gauge station on River Molo where monitoring was done for 90 years then data collection ceased. Another station on River Rongai which is a tributary of River Molo data was collected for 67 years since 1932, however, after 1998 no data is available for about 19 years. Data gaps are the norm in discharge data for the basin. This is caused by non-replacement of gauge meters when they get vandalized by humans or natural forces. At times data collectors miss taking measurements. The end result is difficult in using the data to infer trends and management of water resources in the catchment. For example, the lake water balance has not been determined yet and it might be difficult to establish a water balance based on empirical evidence. This is so due to lack of enough and quality hydrological data for the basin. Observational network and poor spatial coverage of weather stations in not only Lake Baringo basin but also in the country and the larger Eastern African region is partly responsible for the inadequate and poor quality hydrological data (Shilenje & Ogwang 2015). For instance, in 2006, catchment rain gauge station density was estimated as 97 km^2 $gauge^{-1}$ which was less than the World Meteorological Organization's recommendation of 17 km^2 $gauge^{-1}$ (Odada et al. 2006). In addition, there is no public (government) weather monitoring station by the shores of lake. Weather stations' network and poor spatial coverage has not improved since then. The nearest weather station is 20 km away at Marigat town. Some areas in semi-arid or arid northern frontier region which includes part of north and eastern part of basin have hardly had any weather stations. Incidentally these are the same areas that are subject to vagaries of high climate change and weather information is crucial for adaptation and mitigation (Shilenje and Ogwang 2015).

Meteorological methods require dense observational network of weather stations and good spatial coverage to be able predict weather and climate accurately for particular area (Shilenje and Ogwang 2015). One way to improve weather stations coverage in the catchment is to involve the general public and institutions. For example, many primary and secondary schools in Kenya had weather stations in the 1970s and students would be involved in weather monitoring even as a hobby. Schools can acquire basic weather station and provide basic data to national meteorological agency. Involvement of students would assist in building student capacity and character in environmental management.

There exist many indigenous climate forecast methods used in the catchment, however, the most preferred and widespread method is the reading of clouds, stars and intestines of slaughtered livestock (e.g. goat, sheep). Indigenous climate forecast is well disseminated to the larger public within a community with over 90% of people have heard about rainfall forecast before a forth coming season. Majority of the population (over 80%) have confidence with weather forecast on dates of rainfall onset, cessation and amount of rainfall (Luseno *et al.* 2003). Pastoralists in the catchment are already used to indigenous weather forecasting which has high geographical local focus. Thus, it is prudent for conventional meteorologist to go along with indigenous weather forecasting. Concomitant monitoring of weather using both indigenous and scientific climate knowledge in the Kericho, Nandi and Uasin Gishu Counties and Karachuonyo (Homa Bay County) showed that both methods of forecasting are comparable. And therefore they can be used as compliment methods to assist in planning for farming and pastoralism activities in the catchment (Kipkorir *et al.* 2011).

4.4. Land Use Pattern

Land use pattern is influenced by the prevailing climate regime (Table 2). Mixed agriculture takes place in the humid and sub-humid areas while pastoralism dominates in semi-arid zones. The Ilchamus, who live along the south and eastern shorelines of the lake and form about 50% of the riparian population, and the Tugens live to the east of the lake, mainly practice pastoralism and to a lesser extent agro-pastoralism. The Pokots are primarily pastoralists. Forty-six percent of the land in the Baringo County is too steep or too dry for agriculture and pastoralism (Plate 2) which are the main source of family income (Hickley *et al.* 2004). Considering the Lake Baringo catchment as whole, land use and land cover analysis based on a 2009 satellite image shows that most of the land (46%) in the basin is used for farming (Fig. 7). The forest cover is 12% while open to closed shrubs contribute 22% (Plates 2 and 3). The remaining area is covered by water bodies, grasslands and settlements. The land use pattern has changed significantly since the early 1970s. The forested areas of the catchment had decreased by ca. 50% since 1976 following deforestation to create land for farming (Odada *et al.* 2006).

Political expediency to satisfy supporters and nepotism on part of those holding highest political offices has been the major force driving deforestation in the catchment and more so of Ol Arabel and Marmanent forests (Fig. 2). Parts of Ol Arabel forest was excised in 1982 and Marmanent forest in 1993, 1995, 1998, 1999 (UNEP 2009, GOK 2018) and allocated to the members of the clans of Lembus and Arror of the Tugen tribe. The Endorois clan despite being one of the Tugen clans was not considered despite living closer to the forests compared to the Lembus and Arror. Thus, they have always agitated for the allocation to be cancelled so that they can be included. No reason has been advanced why they were not considered and those who allocated were not landless nor compensated for land compulsorily acquired by the government (Daily Nation 2014, GOK 2018, GOK 2019). The legal procedure of converting forest land to human settlement was not followed. First the degazzetting of the forest was not done and also an environmental impact assessment was also not done. The general public in the country was not involved as the proposal of change of user was not announced in at least two daily newspapers, one in Kiswahili and one in English, with wide national circulation and also of displayed at the offices of Chiefs as is the requirement of the Physical Planning Act, miscellaneous section, article 52 (PPA, 1996). Thus, the conversion of the forest land was illegal and now government wants the land to revert back to forest and has been making plans in this line. But the government has not gone ahead to evict squatters as it has had in the Mau forest. The Lembus and Arror clans have continued to resist this plan and are pushing for legalization of the allocated land (Chebet 2018, GOK 2018, GOK 2019). This is in despite of the factor that it is the aspiration of Kenyan people as community to achieve and maintain a forest cover to 10% land area of the Kenya as per Kenyan constitution and which is enshrined in article 69, (1) b COK 2010).

Table 2. Climatic regimes of Lake Baringo basin (modified from Odada *et al*. 2006).

Climate Regimen	**Mean Rainfall (mm)**	**Potential Evaporation (mm)**	**Risk of Crop Failure (%)**	**Potential for plant growth**
Semi-arid	450-900	1650-2300	25-75	Medium to low
Semi-humid	800-1400	1450-2200	5-10	High to medium
Sub-humid	1000-1600	1300-2100	1-5	High
Humid	1100-2700	1200-2000	<1	Very high

A **B**

Plate 4. Typical vegetation of ASALs zone dominated by Acacia species with little or no underground vegetation A) lowland plain B) steep areas.

A B

Plate 3. Typical Land use/Land cover in humid highland zone: A) conserved forest B) human settlement and agriculture.

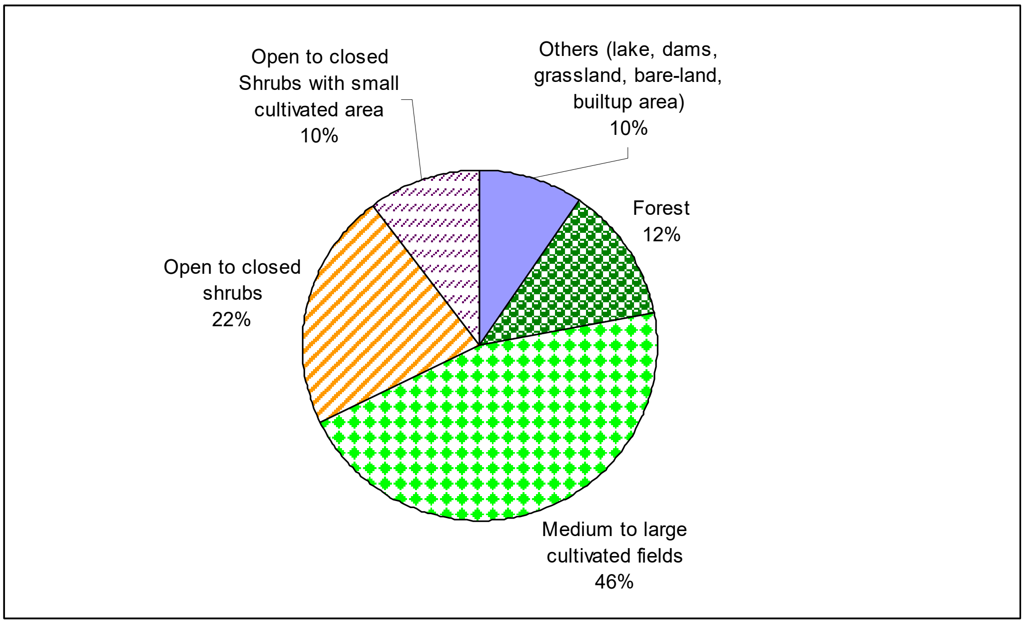

Fig. 7. Land use pattern in Lake Baringo basin (Based on 2009 analysis).

4.5. The Socio-economic Condition

4.5.1. Demography

The population density distribution pattern follows the climatic regime (Table 3). Semi-arid regions are sparsely populated, with the lowest density of approximately 337.2 (people/km^2). The highest density of 415 (people /km^2) is in the humid regions. Sub-humid areas have densities ranging from 118.3 to 199 people /km^2. The humid areas have the highest number of towns and the highest population - these towns include Eldama Ravine (1859 people/km^2) Molo (1422.6 people/km^2) and Bahati (655 people/km^2). Towns in semi-arid areas have low population densities, generally less than 100 people /km^2. Marigat is the only town in semi-arid region with a high population density (529 people/km^2), which is partly attributable to the nearby irrigation scheme.

Table 3. Population density and distribution (Adopted from Kenya Population Census 2009).

Climate Regimen	**Mean Density (people km^2) in rural regions**	**Density (people km^2) in Town**
Semi-arid	37.2 (7.7-102)	25-529
Semi-humid	118.3 (64-219)	80-562
Sub-humid	199 (168-562)	157-225
Humid	415 (160-870)	441-1858

4.5.2. Social Condition

The main town near the lake is Marigat, while smaller settlements include Kampi ya Samaki and Loruk. Major towns in the catchment are Eldama Ravine and Kabarnet. There are three indigenous communities living in the basin: Ilchamus, Pokots and Tugens. Around the lake, which is arid to semi-arid, the Pokots mainly practice pastoralism while the Ilchamus and Tugens practice agro-pastoralism. In the upper humid highlands: Tugens, Kipsigis and Kikuyus practice agriculture. In the highlands exotic cows and sheep are reared in small numbers while in the semiarid lowlands indigenous cows, sheep and goats are kept in large herds. The land in the semi-arid lower catchment is communally owned; thus, there is no individual motivation to conserve the land against soil erosion. Livestock rustling is the second major problem which occurs within the vicinity of the lake with Pokots being the main aggressors against the Tugens and Ilchamus. In the highlands of Laikipia there is also raiding of Kikuyu homesteads for livestock. The problem over the years exacerbated to extent that it is now apparent that the aim is more than livestock rustling but rather to gain political power and also to displace the Ilchamus from their ancestral land so that they acquire the grazing land for their livestock. The Ilchamus occupied the area around lake from Longicharo Islands on eastern shore downwards to the south and up to Kampi ya Samaki township on the western shore. They bordered with the Pokot around Longicharo Islands. Around 2003, the Pokots started destroying Ilchamus homesteads without harming human life along the Longicharo Islands border. Initially they would shoot mud walls of their houses using guns and bullets informing them that they are supposed to migrate from that area as it does not belong to them. These attacks increased and later focused on destroying public social infrastructure including among others: dispensaries, schools and intermittent stealing of livestock. The culmination of the attacks was murdering of people including women and children in their homesteads and not even stealing anything including the livestock which they really value and adore. The displacement involved large population and over large areas almost covering the whole of the administrative Mukutan location. Consequently, this led to closure of schools, dispensaries, churches and breakup of public administration and government services. There was also breakdown in socio-economic activities: farming, pastoralism apiary and ultimately increasing poverty and decrease in resilience. This has had an impact on the lake resources as it reduces the geographical as well occupational migration of people from the lake to the resources land (JR Muli pers. Observ.).

Since time in memorial, livestock rustling has always been respectable cultural practice among the Pokot. It is undertaken by young warriors who have graduated from childhood into adulthood after undergoing the circumcision ritual of passage. Thus most Pokot raids follow immediately the annual graduation of newly circumcised warriors. Livestock is not only a measure of wealth but valuable symbol of social status and the more you own the more respect you are accorded. And if you own wealth in terms of money and no livestock you are considered poor and worthless. Livestock are used in numerous cultural events such that if do not own any it would become very hard to live harmoniously with the community. For example, no girl can accept the hand of marriage, until a warrior pays dowry in form many cows, approximately 50 to 200. And the more he pays the more respect he gets from the community (Kamau 2017). Livestock wealth in the community is not bequeathed from parents; warriors must acquire it on their own. Since livestock is very precious commodity which defines the social value of person, they are under undue peer pressure to rustle from other communities. The community is conservative in terms of culture on livestock, thus livestock rustling has continued from generation to generation and has only increased in voracity and sophistication (B. Arwaita 2010 pers. comm.). There are instances in the recent past when livestock rustling is disguised as the usual cultural practice but in reality is an illegal commercial venture whereby cartels hire raiders to steal livestock for sale in the local markets. Politicians organize livestock rustling to acquire money to fund their elections and also to escalate tensions in order to chase “foreigners” from their locality so that they do not support rival candidates. In the 1970s the weapons of operation during livestock rustling and grazing were bows, arrows and spears, however, since the 1980s, guns and bullets are the basic weapons. Raiding is organized akin to a military manoeuvre. There is initial team which provides intelligence to establish location of valuable stocks, timing of the planned raid and routes to use before and after for a raid to succeed. Besides those herding the livestock stolen towards their home territory, there is team behind following the herd at distance to counter an opposing force following to recover their stolen livestock. At the front of the herd at a distance, there is another team in case there are waylaid head. Finally, to complete the all-round protection there teams on the left and right side of the herd. There is an element of surprise in the timing of a raid. For instance, a raid can be contacted early in morning when most people have not woken up or lunch hour when it is very hot and it rare to find many people on foot on the road. Seniors who are conversant on use of guns train young warriors on gun maintenance, precision target shooting and infantry military tactics. At times the training is done by their tribesmen who serve in national forces during their leave days. This ensures that they are able to confront without fear the national police or military when they pursue them to recover stolen livestock.

Moreover it builds the confidence they are as strong as police or military force and ensure continuity in the cyclic raids. It is important to note that the other neighbouring communities (Tugen, Ilchamus, and Kikuyu) do not possess guns and are therefore very vulnerable to the attacks of the Pokots. In terms of voracity during a raid in the former times (1970s) women and children would not be harmed but these days no one is spared. There is case where weak harmless recovering from giving birth was shot dead together with her one day old child while lying alone in her hut (B. Arwaita 2017 pers. comm.).

Use of gun force has also been occasionally played in the lake with Ilchamus fishermen killed in cold-blood to force them to move out of the lake area around Komolion beach which the Pokots claimed was their own territory. This finally resulted in partitioning of fishing grounds into three territories for each indigenous tribe. The fishing grounds of the Pokot are in the northern eastern area of lake, Tugen in the central and northern western side of the lake, while, the Ilchamus fish in southern section of the lake (Fig. 8). In earlier 2003, there were cases of theft of fishing nets at gun point although this occurrence is rare (B. Arwaita 2017).

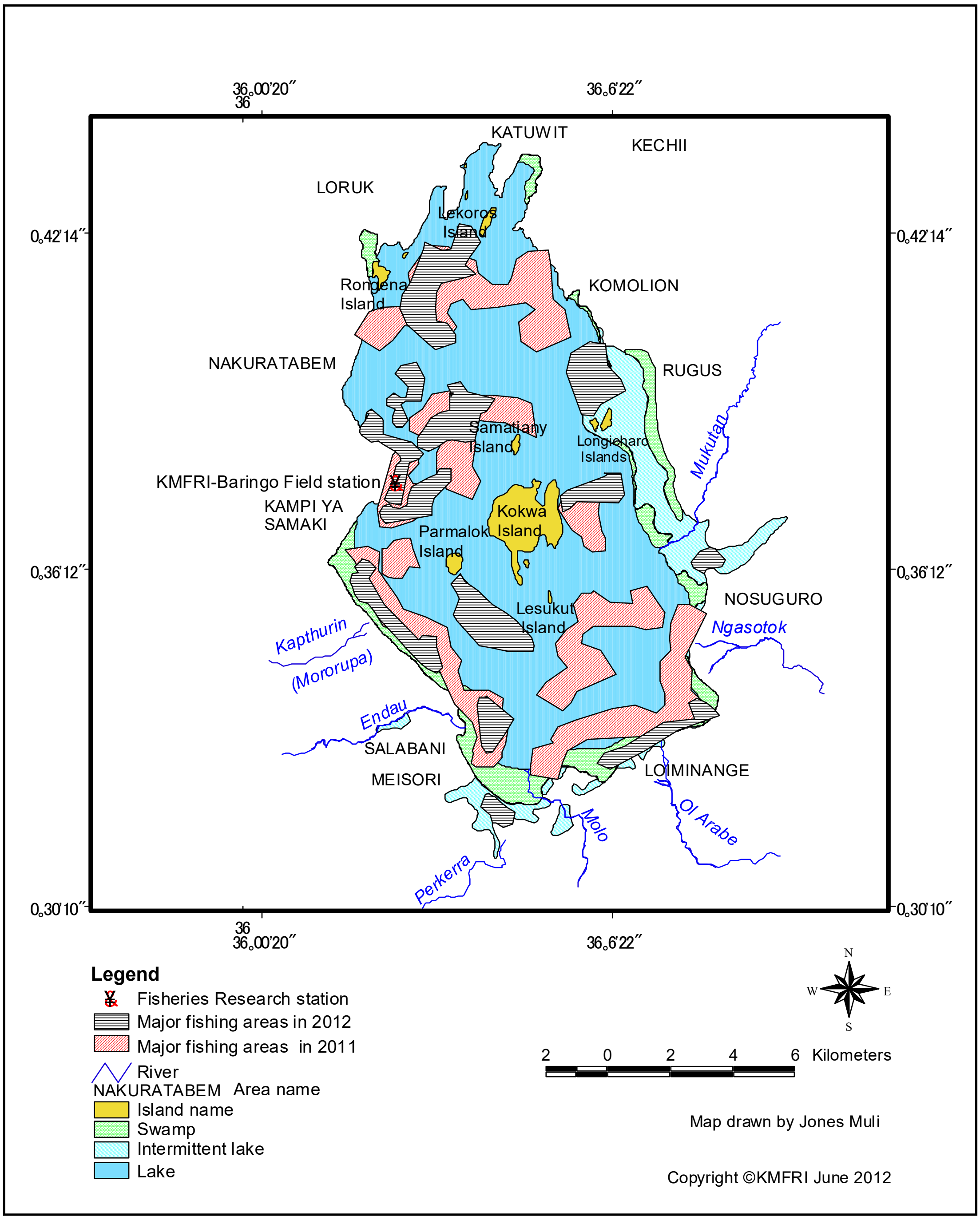

Fig. 8. Map of Lake Baringo showing setting geographical location of various fishing gears.

Livestock rustling is complex problem that successive governments have been unable to stop since 1930s. To elucidate the calamity, it's prudent to critically present the long term perspective so that current militarisation of Pokots is not lost in the simplistic explanation of cultural cattle raids. The 1883 Berlin conference which resulted in subsequent colonization and partitioning of Africa is a logical period and place to start. Eritrea was colonized by Italy from 1890 and from there Italy had always wanted to expand its colonies in Africa. Thus, Ethiopia was occupied by Italian troops in 1930s under Benito Mussolini of the National Fascist Party and Italian troops introduced Austrian Steyr rifles in the region. The Turkana in Kenya smuggled Steyr rifles from Ethiopia and which they bartered for camels. The Steyr rifles were used for decades to raid Pokots and Karamojong in Uganda who were armed only with bows and arrows. During 1960s and 70s the entire pastoralists' belt in Uganda, Southern Sudan, Ethiopia and Kenya was caught up by spillovers of the Cold War in Africa. In the 1970s, the Soviets became one of the biggest suppliers of arms to Uganda, Somalia and Ethiopia. The communist Soviet government signed a treaty of friendship with Somalia government in 1974, which resulted in pouring of arms and tanks into the country. Since the independence of Kenya in 1961, Somalia had always had territorial claims on lands occupied by Somali speaking people in Kenya and Ethiopia. Thus, in 1977 Somalia started war against Ethiopia to recover the Ogaden region and unite all Somalis under one country. During the Ogaden war, the Somali army discovered huge abandoned warehouses in Ethiopia stocked with American arms and ammunition which they looted. The conflict resulted in first barter trade between Somali cattle traders and Pokot for some good guns. This was an improvement as in 1970s, Pokots, were largely using spears and arrows in their cattle raids and had managed to buy rusty World War II guns and automatic weapons from Somali cattle traders at low scale as a result of insecurity in north eastern province of Kenya when Somalia and Kenya were still at war. Earlier in 1974, American leaning Ethiopia Emperor Haile Selassie was ousted through a coup d'état by Marxist regime led by Mengistu Haile Mariam. The Marxist regime later become a conduit for small arms into South Sudan as the Soviets backed John Garang's new outfit, Sudan Peoples' Liberation Army (SPLA), which had started a rebellion against the Khartoum based government. The Soviet was backing SPLA as part of an old Soviet strategy to bring the entire north-east of Africa under communist-style regimes. Meanwhile various rebel factions emerged in South Sudan which at times fought amongst one another and consequently resulting in lawlessness. With time the area become another arena for arms smuggling into Kenya and still continues to date as South Sudan has never stabilized, despite seceding from Sudan. On the western side of Kenya, the Uganda regime, under Idi Amin Dada, forged a military alliance with Soviet Union shortly after the 1976 Entebbe raid by Israeli soldiers that had destroyed most of his air force. The Uganda's Moroto barracks become a strategic armoury in the heart of Africa of Soviet arms under the watch of Ugandan soldiers. Moroto is close to the Kenyan border and to Mt. Moroto whose grasslands and water springs are the last mainstay of pastoralists from both Kenya and Uganda who migrate into this Karamoja territory in search of pasture during the dry seasons. After the regime of Idi Amin was overturned by Tanzania army in 1979, Ugandan soldiers abandoned the Moroto barracks and some flee to Kenya where they sold the guns at throw way price, transforming Pokot cattle raids into deadly force. Once the Moroto barracks was deserted, the Matheniko-based Karamojong pastoralists looted the abandoned unprotected Moroto barracks armoury and took off with Soviet-era guns. It is estimated that the barracks stored 15,000 guns and two million rounds of ammunition for the Soviets. In addition to Soviet AK47 assault rifles they also found the World War II Heckler & Koch-made G-3 army rifles and millions of ammunition. Acquisition of firearms by the Karamojong transformed their ability preserve their pastoralist identity against their Turkana rivals in Kenya who were already armed with Austrian Steyr rifles and always raided them for years since 1930s. This is one event which had major ramification on the whole northern and central rift Kenya security situation as some of the armaments were subsequently smuggled into Kenya and the Pokot acquired arms in massive quantities. Currently, almost every homestead has a gun and when boys are herding livestock they are loaded with guns to protect themselves. The fall of the Siad Barre regime in Somalia in 1992 and ensuing civil war has continued to be a source of armaments for smuggling into the Lake Baringo basin (Kamau 2019). Geopolitical instability in the larger horn of East Africa has continued since the 1970s to date to play a crucial role in the livestock rustling phenomenon as source of armaments used in basin over the years. Gun profile of the Pokots, Turkana and the Karamojong still reflects this cold war reality to date.

The national government over the years has tried to solve the problem of livestock rustling in Lake Baringo basin. One way has been to disarm of Pokots which was done in 1984, 1986 and again in 1989. However, this has never been successful as they always replenished. Karamojong war which resulted in the 1989 Pokot massacre is stark reminder which has contributed to Pokots refusal to part with their guns. A researcher found 1908 Budapest-made Austro-Hungarian rifle among the Pokots which proofs that illegal arms trade has been going in the community for a very long term (Kamau 2019). National government public administrators at local level i.e. the chiefs, District Officers (DO) and District Commissioner (DC) organized in past peace meeting of local village elders from the two conflicting communities after a livestock raid. Normality would return and peace would prevail for some period (months) after the peace meeting, however, the raids would resume and have continued perennially. Sometimes, the Police would be sent to recover stolen livestock and in some occasions would be recovered them but in most instances none would be recovered. The public administration formed local armed police reserves from among the local residents to provide security against livestock rustlers but they have not been effective in curbing the menace. There has never been any compensation for stolen livestock from the government.

Establishment of a community wildlife conservancy is another initiative which has been applied to end the bloody perennial conflicts. Ruko conservancy was established during a peace brainstorming meeting in 2010 of Pokots and Ilchamus elders from Rugus and Komolion regions respectively (Fig. 8). The name Ruko is coined from the first two letters of the name Rugus and Komolion. The Rothschild's giraffe (also known as Baringo giraffe) was introduced in 2012 after a decade of absence from their original habitat. Eight giraffes were introduced from Soysambu conservancy and Nakuru National Park in Nakuru County and Tsavo National park in Taita-Taveta County among other conservancies in the country. Other animals include: Impalas (*Aepyceros melampus*), Wild pigs (*Sus scrofa*), Warthog (*Phacochoerus* spp), Zebras (*Equus* spp), Ostrich (*Struthio camelus*) among numerous bird species. The conservancy covers an area of 19,000 hectares which includes Longicharo Islands in the lake and also the land adjacent to the lake. The creation of the conservancy had the support and guidance of Northern Rangelands Trust (NRT) which funded the establishment of park by contributing ksh 21 million. Kenya Wildlife Service (KWS) contributed in kind by helping relocate 33 impalas whose population has increased to the current 300 (Koech 2020). The current Rothschild's giraffe worldwide population is estimated as 2500 with 60% found in Uganda, Thus, the population is considered among one of the most endangered subspecies of giraffes in world. Introduction of the giraffes is an important contribution in conservation in world. According to Komen (Lake Warden, pers comm.), the conservancy is now birdwatchers paradise with 470 observed bird species attracting bird researchers as well photographers. Founding of the conservancy created new stream of income to the local community. 60 percent of the revenue from the park is shared by the two communities equally and other 40% caters for recurrent budget which includes among others employees' salary and operations for running the conservancy. Revenue is generated from numerous visitors to the conservancy who includes among others 500 school children who come from other counties including Nairobi. There is also indirect income of conservancy to the boating community who ferry visitors to and fro the conservancy. In nutshell establishment of the conservancy has increased the value of the lake as resource to the local community and the larger international community as well. Furthermore, warring communities have united in the common cause of conservation with mutual benefit to all and the bloody border conflict at Komolion is past history (Koech 2020).

Regardless of the creation of the conservancy and the benefits accruing therefrom, the bloody conflicts so far have continued over the years in Mukutan division. Thus, giving credit that conflict is more than border issue as aforementioned. With the continued escalation of the conflicts, national Government had to bring in the army in 2016 to pacify the area. All the same, schools have since been reopened but police provide security all day round. Even funeral processes and ceremony have to be accompanied by armed police (B. Arwaita pers. comm.).

5. BIOPHYSICAL ENVIRONMENT

5.1. Water quality conditions

In earlier years of the 2000 millennium, the water of Lake Baringo had very low aesthetic value as its water was deep tea brown in color with a crust of the same color covering the stony banks around the lake (Plate 4, Hickley *et al.* 2004). Similarly the rivers had same color (Muli 2011). At that point in time it was unimaginable especially, for first time visitors to the lake to fathom that the lake will ever improve and regain past the near pristine status.

Plate 4. Left pane: Paleo-turbidity and decreasing depth is visible on the rocks. Right pane: Kokwa Island in Lake Baringo. In the background is the Laikipia mountain range. The picture was taken from the western shore of the lake. Note the high turbidity.

Table 4 shows a summary of water quality values that are grouped into three periods to show trends over the years. The first period is when lake level was very low between 2000 and 2004 and Odada *et al.* (2006) authored the first lake brief. The second period was in 2013 which represents maximum lake level reminiscent of the mid 1960s as a result of very high rainfall. The last period was when lake level had slightly declined from the maximum.

Table 4. Physical-chemical parameters of Lake Baringo. Values are means and range values are in parenthesis.

Parameter	2000 (Data source: Oduor *et al.* 2003)	2001 and 2002 (Data source: Ballot *et al.* 2003)	2004 (Data source: KMFRI surveys)	2013 (Data source: KMFRI surveys)	2015 (Data source: KMFRI surveys)
Lake depth (m)	2.7	2	3.4 (2.1-4.5)	10.6 (9.3-11.4)	8.7 (7.66-9.96)
Temperature (°C)	24 (21.2-32.2)	25.3 (23.7-26.3)	27.4 (23.3-35.1)	25.01 (22.8-28.1)	
Oxygen (mgL^{-1})	6.8 (6-9.7)		5.7 (0.1-8.8)	6 (4-8.4)	
Transparency (cm)	7 (5-8)	< 1	6 (5-7)	100 (80-120)	80 (30-117)
Turbidity (NTU)	562 (420-763)	350-900	560 (382-936)	10 (3.9-17.3)	32.1 (35-29.3)
Conductivity (μScm^{-1})	1222 (1148-1274)	1390-1670	658.4 (389-762)	366 (351-388.1)	437.4 (400-499.6)
Total Alkalinity (mgL^{-1} as $CaCO_3$)			287 (266-312)	158.1 (122-190)	213.7 (160-257)
Total Hardness (mgL^{-1} as $CaCO_3$)			73.3 (65-85)	52 (34-70)	65.3 (40-100)
pH	8.6 (8-10.5)	9 (8.8-9.1)	8.2 (7.2-9.0)	8 (7.8-8.2)	8.5 (8.05-9.27)
Chlorophyll *a* ($mg L^{-1}$)			0.01 (0.006-0.11)	11 (2.1-46.2)	4.3 (1.3-14)

According to Odada *et al* (2006), the water quality had deteriorated over time and they did not envisage natural improvement through cyclic process of nature. Furthermore, they did not mention the reference point of good water quality before the deterioration. Nevertheless, it is apparent the reference point of near pristine water quality status was that of the 1960s and 1970s and perhaps the 1930s when the first documented scientific study was done. High rate of soil erosion in catchment was attributed as the proximate cause of sedimentation in the lake and ultimately resulting in very high turbidity and low transparency of the lake water (Oduor *et al.* 2003, Odada *et al* 2006). Thus, sedimentation was the main problem to tackle in order to resolve all the problems of lake. However, to attribute high turbidity and concomitant low transparency to sedimentation alone is rather simplistic. It more of a complex situation which needs detailed studies to conceptualizes. It crucial to look at the big picture of the interplay of climate, climate change, hydrology, human influence in determining the land use and land cover among other factors. A review of long term data indicates that sedimentation plays a role when the lake level is low (circa ≤ 5 m). Daily scouring by winds induced water currents becomes effective during periods of low lake level suspending sediments from the lake bottom to the water column on a daily basis (Oduor *et al.* 2003). As the depth lake increased gradually after year 2004 peaking in 2013 at 10.6 m, the transparency increased peaking at 100 cm and turbidity decreased to 10 NTU correspondingly despite the rivers continuously pouring sediment into lake (Table 3). Indeed sedimentation into the lake has increased over the years with increasing deforestation and concomitant land cover changes over the years in the catchment (Odada *et al.* 2006). Once the lake depth declined after 2013 to 8.7 m, the transparency decreased to 80 cm while turbidity increased to 32.1 NTU correspondingly. Similarly, other variable such ions are affected by changes in lake depth (Table 4). Climate change has an impact on the lake depth (Ngaira 2006). Generally, long term trend in the lake level follows a similar pattern as the rainfall pattern in catchment. Peak rainfall periods of 1963-1964, 1978-79, 1998, 2003, 2007-2008, 2013-2015 had corresponding peaks in lake depth. Similarly, lowest depth periods were associated with lowest rainfall and drought periods in catchment of 1983-1985, 1986-1987 and 2002 (Ngaira 2006, Koskei *et al*. 2018). The increment in lake depth of 2013-15 was approximately double of the highest depth recorded since monitoring started in 1956. Koskei *et al*. (2018) demonstrated through long term rainfall data analysis that the catchment has undergone climate change (see section on climate). According to Guya *et al.* (2011), there are also seasonal and annual variations in water quality variables which correspond to seasonal and annual variations climatic changes. In 2008 the lake levels had increased by 3 m comparing to the previous year. While transparency of the lake water by a factor of 2.6 and turbidity decreased by 4.6 times.

Odada *et al.* (2006) characterized Lake Baringo as a lake of high temperature and low transparency. Firstly, we are of the view that the lake's temperature of the range between 24°C and 27.4 °C is not high but rather moderate (Table 3). If the temperature ranged between 30°C to 40 °C, we would term it as high. Secondly, on the characterization of the lake as of low transparency, it apparent it is valid only in the short term. The long term view shows that the water quality of the lake is variable and corresponds to climatic pattern of the catchment. Recent evidence based on fossil diatoms study of over the past 200 years showed water level fluctuations in lake are as consequence of climatic variations which follows 50 year climatic cyclic pattern (Okech *et al.* 2019). The lake is thus climate sensitive (Okech *et al.* 2018).

It has been postulated that the recent increment in Lake Baringo water level and surface area was due to probably water inflows from underground (D. Olago pers. comm.). This is a line which needs investigation as all the lakes in the eastern arm of the Rift Valley including those in Ethiopia had similar increase in lake depth and surface area. It is implicit the complex nature of the problem of variation of lake water level, sedimentation and water quality variables.

Some of the short term trends variations in some water quality parameters which cover the period immediately after the first lake review of 2006 (Odada *et al.* 2006) are described below.

5.1.1. Transparency

Water transparency increases from south to north region. The mean transparency based on monthly measurements from April 2008 to March 2012 in the southern zone of the lake was calculated as 35 cm, in the central region it was 38 cm and in the northern region it was 45 cm. The difference in spatial transparency is attributed to the influence of rivers draining into the lake in southern zone only (Olilo *et al*. 2014). Monthly transparency (Secchi depth) values ranged from 7 cm in March 2010 to 146 cm in December 2012. The monthly transparency values were significantly different. The lowest transparency coincided with the rainy season whereas the highest coincided with the dry season (Omondi *et al.* 2014). Although detrital sediment is washed into the lake throughout the year, the maximum influx occurs in August following the heavy rains. Winds then mix the loose sediments on the shallow lake floor generating very high turbidity (Oduor *et al.* 2003).

5.1.2. Turbidity

High water turbidity is cited as a major contributor to reduced water quality. The turbidity of the lake for the period April 2008 to March 2012 ranged from 68.51 to 80.24 NTU and it decreased from south to north. The mean turbidity from April 2008 to March 2012 in the southern zone of the lake was 80.26 ± 4.26 NTU, in the central region it was 73.88 ± 3.89 NTU, and in the northern region it was 68.58 ± 3.48 NTU. The turbidity values were significantly different between various regions of the lake. Similarly, to transparency, the difference in spatial turbidity in the different regions of lake can be attributed to influence of rivers draining to the lake in southern zone only (Olilo *et al*. 2014). The monthly turbidity ranged from 4.67 NTU in December 2012 to 258 NTU in May 2010 with values being significantly different. The lowest turbidity coincided with the rainy season whereas the highest occurred in dry season (Omondi *et al.* 2014). It is important to note that highest turbidity (mean of 562 NTU) and lowest transparency (mean of 7 cm) occurred when the lake level was low with mean depth of about 4m.

Total suspended solids (TSS) concentrations for the period April 2008 to March 2012 ranged from 28 to 52 mg L^{-1}, respectively, with mean of 40 mg L^{-1}. The zonal comparison indicates a south to north a reducing trend. However, the differences in values between the southern, central and northern parts of the lake are not significant. Although there are variations in the level of Total Suspended Solids (TSS) along the vertical profile, the differences are not significant. According to Oduor *et al.* (2003), over 90% of the suspended solids were inorganic.

5.1.3. Oxygen

Lake Baringo is well supplied with oxygen. The measured concentrations range from 2.9 to 9 mg L^{-1}. Oxygen profiles reveal that there is stratification during the day with a slight gradient near the surface. The stratification is normally reduced or eliminated completely in the late afternoon or evening by the presence of strong wind action which mixes the water completely. At night oxygen concentration is uniform along the depth profile. Compared to the deeper waters, the near-surface concentration levels are significantly higher during daytime due to active photosynthesis (Ouma and Mwamburi 2014, Oduor *et al*. 2003). No seasonal variations in oxygen concentration are observed. Ouma and Mwamburi (2014) reported relatively lower levels in the northern end of the lake compared to the southern and central parts, based on one two-month sampling expedition. Data collected over a longer period, from 2008 to 2014, reveal that the spatial variations in oxygen concentration are random. Dissolved Oxygen depletion of up to 3 mg/L was recorded in August 2011 in some stations in the northern and southern sections of the lake. These occurred during periods when the lake levels were at or below 5 m and were also associated with low secchi-disk transparency (24-28 cm). According to Oduor *et al.* (2003), oxygen depletion could be attributed to very high turbidity in the lake as result of daily suspension of the sediments by the winds coupled with its shallowness.

5.1.4. pH, conductivity and alkalinity

Despite lack of an outflowing river and high net evaporation rate, the lake is not saline. Recent hydrogeological evidence confirms the original assumption suggested by Gregory (1894) that some lake water is lost by underground seepage through the fractured lake floor in the northern end of the lake (Tarits *et al.* 2006). The discharge of lake water through seepage at the northern end is what enables the lake to maintain its water fresh.

Conductivity of the lake for the period December 2009 to April 2010 ranged from 486 μScm^{-1} to 867 μScm^{-1}. Generally, conductivity increases from south to north in the lake. The mean conductivity from April 2008 to March 2012 in the southern zone of the lake was 573.36 ± 10.02 μScm^{-1}, in the central region it was 577.76 ± 9.47 μScm^{-1} and in the northern region it was 581.97 ± 9.37 μScm^{-1}. pH ranged from 7.18 to 9.93 in September 2009 and March 2010 (Omondi *et al.* 2014). Over the same period, the mean alkalinity values ranged from 196.95 ± 3.10 to 199.93 ± 2.66 (mgL^{-1} as $CaCO_3$) while hardness ranged from 68.86 ± 1.24 to 70.90 ± 3.51 (mgL^{-1} as $CaCO_3$). Over the period 2004 to 2015 which was characterized by significant lake level changes, conductivity decreased 2-fold, from a mean value of 566.9 in 2004 through 366 in 2013 to 437 in 2015. Concomitantly, alkalinity and hardness decreased 2-fold with increasing lake level. pH did not change substantially implying that the buffering capacity of the alkalinity is high.

5.1.5. Ionic composition

Table 5 summaries the ionic composition of Lake Baringo. According to Oduor *et al.* (2003), Na^+, $HCO_3{}^-$, $CO_3{}^{2-}$ and Cl^- ions are the dominant ions in Lake Baringo (Table 6). Ionic composition of the lake shows a trend of increase in salinity as lake level decreases. High ionic concentrations of Na^+ and Cl^- ions were observed with a three-fold increase in concentration between 1961 and 2000 while $SO_4{}^{2-}$ shows a four-fold increase in concentration. Both Mg^{2+} and Ca^{2+} ions did not to change substantially in concentration during that period of time.

Table 5. Ionic composition of Lake Baringo.

Parameter	**1930-31** (Beadle 1932)	**1961** (Talling and Talling 1965)	**2000** (Oduor *et al.* 2003)
Mean depth (m)		**5.6**	**2.7**
pH	8.8		8.6
Conductivity (μScm^{-1})		416	1222
K^+ (mval l^{-1})	0.4	0.3	0.6
Na^+ (mval l^{-1})	**5.5**	**4.1**	**15.5**
Mg^{++} (mval l^{-1})	0.2	0.3	0.2
Ca^+ (mval l^{-1})	0.1	0.6	0.6
Cl^- (mval l^{-1})	**1.0**	**0.7**	**3.2**
Total Alkalinity (mval l^{-1})	**5.6**	**4.4**	**13.2**
$SO_4{}^-$ (mval l^{-1})	**0.8**	**0.4**	**2.3**

5.1.6. Nutrients

The Total Phosphorus (**TP**) concentration range is 20–585 $\mu g\ L^{-1}$, with a mean of 103 $\mu g\ L^{-1}$. The Soluble Reactive Phosphorus (**SRP**) concentration range is 15.2–30.5 $\mu g\ L^{-1}$, with a mean of 23.5 $\mu g\ L^{-1}$. Recent studies conducted from January to May 2014 estimated the TP concentration as ranging from 9.7–576 $\mu g\ L^{-1}$ C while the SRP concentration range was 1.4–20.5 $\mu g\ L^{-1}$. Omondi *et al.* (2014) attributed the frequent peaks of nutrients to by flushing of ions into the lake after rains in the catchment. Recent studies conducted from April 2008 to May 2014 estimated the nitrates between 2.4 and 30 $\mu g\ L^{-1}$ while ammonium concentrations fluctuated between 6.4 $\mu g\ L^{-1}$ and 205 $\mu g\ L^{-1}$. Generally, the highest concentrations of all the nutrients were realized in the southern zone, and there was a decreasing trend from south to north. This has been attributed to flushing of nutrient from the influent rivers.

5.1.7. Trophic state

According to the levels of nutrients and chlorophyll *a* the lake can be categorized as eutrophic (Table 6). This aspect is reinforced by the fact that the lake is mostly dominated by the blue-green algae (Schagerl and Oduor 2003). Okech *et al.* (2018) recent (sampling done 2014-2015) study used Carlson trophic state indices and nutrient ratios confirmed the eutrophic nature of the lake. The study was done during period of high lake water level and there was no difference in trophic status between wet and dry seasons. Further his study shows that there is no difference in trophic level between low water level and high levels. Earlier Odada *et al.* (2006) had categorized the lake as hypereutrophic probably on the basis of low transparency. The use of transparency as measure of trophic status is not appropriate for Lake Baringo due to high suspended abiotic particles rather than algal matter. Light attenuation is high and euphotic zone is small estimated as 18 cm during period of low lake water and high turbidity (Oduor *et al* 2003, Okech *et al.* 2018).

Table 6. Trophic status of Lake Baringo (Data source: KMFRI samples).

Trophic category	TP (µg/L)	Lake Baringo 2008-13	Mean Chlo a (µg/L)	Lake Baringo 2008-13
Utraoligotrophic	<4.0		<1	
Oligotrophic	<10		<2.5	
Mesotrophic	10-25		2.5-8	
Eutrophic	35-100	**76.5-104.3**	8-25	**10.9-13.8**
Hypertrophic	>100		<25	

5.1.8. Heavy metals

Campbell *et al.* (2003) and Mwamburi (2015) studied heavy metals in Lake Baringo in 2000 and 2007 respectively. Campbell *et al.* (2003) analyzed the concentration of mercury in fish while Mwamburi (2015) analyzed trace metals in sediments. The overall mean (± s.d) contents of Zn, Pb and Cd in sediments were 127±20, 49.9±22.9, 3.5±1.6 µgg-1 respectively. Mwamburi (2015) used MOE (1993) and Persuad *et al.* (1993) guidelines for protection of aquatic biota to conclude that the values of Zn, Pb and Cd were above all the numerical guidelines and detrimental to the majority of sediment-dwelling organisms. Thus, it was necessary other assessments, such as sediment toxicity tests and biomagnification potential be conducted. Since the different guidelines have short coming, Mwamburi (2015) also used the guideline provided by MacDonald and Ingersoll (2000) to conclude that the estimate concentration is not likely to affect the health of organisms as they were below "probable effect concentration" (PEC). With such varying conclusions there is need for more and comprehensive studies as aforementioned study was based on single sampling and the lake is characterized by changes in water level and the concentrations of trace metals are likely to change. Campbell *et al.* (2003) demonstrated that concentration of mercury in fish was within the acceptable limits as they were below World Health Organization's recommended limit of 200 ng g^{-1}. Therefore, mercury in fish from Lake Baringo does not cause any harm to human consumer. The mean concentration ranged from 11- 75 THg (ng g^{-1} ww). It now over 17 years since the study on mercury level was conducted so they is need for new study to be done to establish the current concentration.

5.1.9. Biomass production

Phytoplankton production in lake is highly variable over time. Oduor *et al.* (2003) and Ballot *et al.* (2003) estimated phytoplankton production during period of low lake water level. The estimates of Chlorophyll *a* concentration were a mean of 55.2 μgL^{-1} (32.2-79.9) in year 1999 when the lake depth was 2.7 m and as range between 1.5 and 8.2 mg L^{-1} when the lake depth was approximately 2 m in 2001 and 2002. In April-May 2007 and March 2008 Chlorophyll *a* was estimated as 20 μgL^{-1} and 13.05 ±19.15 μgL^{-1} respectively (Guya *et al.* 2011). The lake exhibits a daily temporal trend in Chl-*a* biomass with higher concentration near the surface during the day than in the water column and while at the night it is generally uniform throughout the water column. In term of season, Okech *et al.* (2018) study conducted during high lake water level (11.6 m) in 2014-15, established that Chlorophyll *a* concentration is significantly higher during wet season than in the dry season. In long term, generally phytoplankton production trend mirrors the lake water level trend.

Ballot *et al.* (2003) estimated the phytoplankton individual families' contribution to primary production. The blue a green algae dominated the production by approximately 63% followed by green algae with contribution of 22%. The others were Euclenophyceace, Bacillariophyceace and Cryptophyceace in order of decreasing magnitude (Fig. 9).

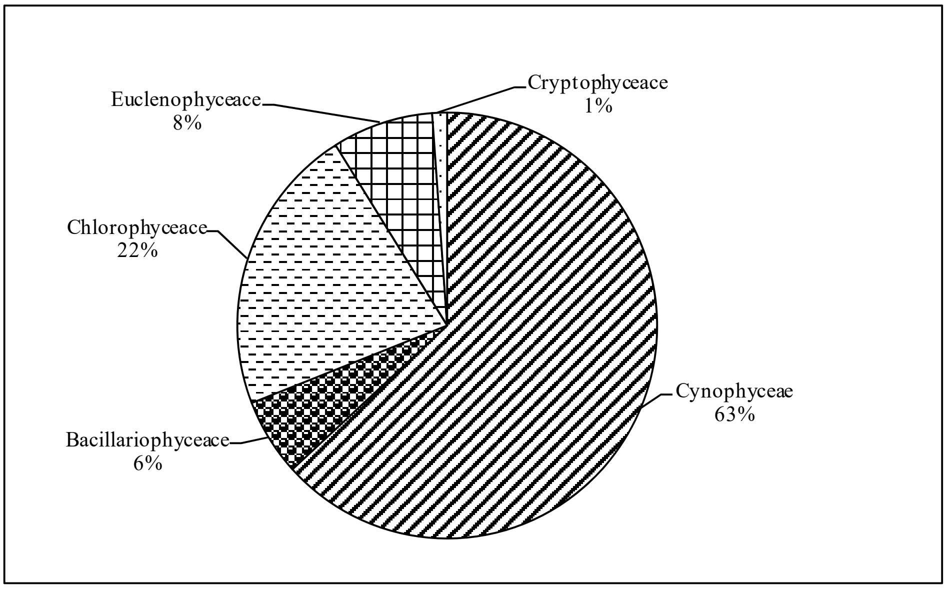

Fig. 9. Contribution of various phytoplankton families' primary production (adapted from Ballot *et al.* 2003).

According to Schagerl & Oduor (2003), high turbidity and low transparency is the cause of low phytoplankton production in the lake. High turbidity limits light penetration resulting in a high aphotic: photic zone ratio of 19. Firstly, a high aphotic: photic zone ratio results in decrease in productivity due to metabolism or increased respiration in the aphotic zone. Secondly, when the ratio exceeds 5, it is theoretically expected the lake would experience negative productivity (Talling 1971). Regardless of high ratio of 19, the lake experiences positive productivity, albeit small, because it is holomictic (Oduor *et al.* 2003). Thirdly, the lake is dominated by blue a green algae (cyanobacterium) which are adapted to produce in low light conditions. Phosphorus concentration is another factor which limits phytoplankton production. But as described in the water quality section above high turbidity and low transparency are highly variable and therefore biomass is equally variable.

Available gross primary productivity (GPP) values of the lake represent a period when the lake water level was low (< 3 m) and the transparency very low (Tables 4 and 7). The values for the different years are basically the same except that of Patterson & Kiplagat (1995) which is the highest. The difference could be due to the incubation period of Winkler bottles in lake. Patterson & Kiplagat (1995) incubated for 1 hour while the rest took 4 hours which can cause underestimation (Schagerl & Oduor 2003, Vollenweider 1969). According to Melack (1976), Lake Baringo's 1972 fish yield of 33 kg ha^{-1} yr^{-1} would need a primary productivity of 5.4 g O_2 m^{-2} d^{-1} whereas 1998 fish yield of 29 kg ha^{-1} yr^{-1}would need primary productivity 4.9 g O_2 m^{-2} d^{-1}. Thus, estimated daily gross primary productivity (GPP) values of the lake were are low and underestimate the relative high fish yield. On the other hand, the high fish yield may imply presence of allochthonous source of food for fish (Schagerl & Oduor 2003). In addition the contribution of microbial food chain needs to be assessed to establish its contribution to lakes food chain.

Table 7. Gross daily primary productivity (GPP) of Lake Baringo.

Year of measurement and source of information	**1987** (Kallqvist 1987)	**1989** (Kiplagat 1989)	**1995** (Patterson & Kiplagat 1995)	**1999** (Schagerl & Oduor 2003)
GPP g O_2 m^{-2}	0.2-1.0	0.8	3.8	0.5 ± 0.1
Lake depth (M)	1.9	2.4	1.8	2.7

5.2.Biodiversity

5.2.1. Phytoplankton

Lake Baringo is characterized by low phytoplankton species richness. Schagerl & Oduor (2003) recorded 49 species belong to four families (Fig. 10**).** Chlorophyceae was recorded as the most speciose family followed by Cynophyceae, Bacillariophyceace and Xanthophyceace in order of decreasing magnitude. In terms of abundance, Cynophyceae dominate with 2 of its species *Microcystis aeruginosa* and *Microcystis flox-*

aquae being the only ones which were the most copious. Although Chlorophyceae was the most speciose family, 71 % of its species were sporadic in occurrence, the rest in were rare or frequent. Conversely, only 40 % Cynophyceae species were sporadic while the other 40 % rare while the remaining frequent to copious. Only 33 % Bacillariophyceace species were very frequent in occurrence, the rest in equal measure were rare or sporadic. Xanthophyceace recorded only one species which was rare in occurrence. Full list of phytoplankton species can be found in Oduor (2003). Since only two species in the lake are the most abundant it may concluded that most of primary production is contributed by very few species. This +view is supported by results of Ballot *et al.* (2003) who showed that Cynophyceae contribute 63% of the production.

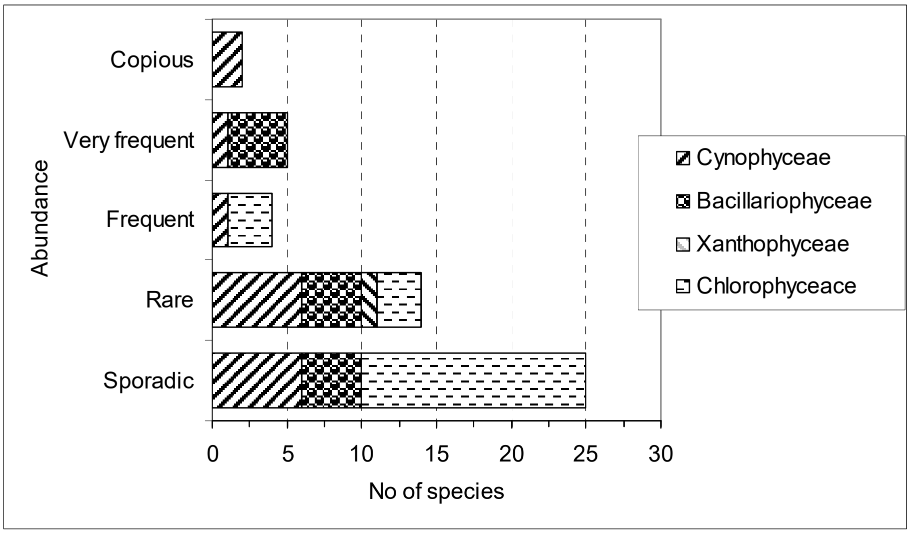

Fig. 10. Abundance of various phytoplankton families of Lake Baringo (modified from Oduor *et al.* 2003).

5.2.2. Zooplankton

Lake Baringo is characterized by low Zooplankton diversity. Schagerl and Oduor (2003) survey conducted in 1999 during low lake water level period, resulted in only 6 species. The most copious species were *Thermocyclops* sp. and *Brachionus patulus.* While *Keratella quadrata* and *Paradiaptomus* sp. were frequent but *Moina micrura* and *Pseudochydorus globosus* were sporadic in occurrence. This was the first study on zooplankton and it could have been milestone given the unique period of sampling when the lake water level was among the lowest and concomitant water quality variables of low lake depth. These include among others: very turbid waters and corresponding very low transparency, high conductivity (salinity) and low primary productivity (Table 3). Nevertheless, there are some shortcomings which make the study difficult to replicate in future. It is specified that samples were collected from littoral and pelagic zones of the lake and from other biotopes (stony shores, bark of aquatic plants) but the specific located is not given. So sites cannot be revisited in future as they are not known and this is crucial given that the lake has different ecological zones (Ssentongo 1974). Samples obtained were not quantified and therefore it is hard to compare with later studies in order to infer trends. Identification key used specifically for Zooplankton are not mentioned (Schagerl & Oduor 2003).

A long-term quantitative study on zooplankton was done from April 2008 to November 2009. The study represented the period when water level had slightly risen from mean of 2.7 m to 4.2±0.9 m with the minimum and maximum depth being 2.5 m and 6.1 m respectively. While the transparency had risen from mean of 7 cm to 27.1±7.4 cm. And the turbidity had decreased to range between 68.51 to 80.24 NTU. Monthly samples were obtained for 18 months from stations representing all major ecological zones of the lake. The focus of study was on composition, distribution and abundance (Omondi *et al.* 2011). Results of the study confirmed earlier assertion that the lake's zooplankton community is characterized by low species diversity and low abundance (Schagerl & Oduor 2003, Omondi *et al.* 2011). Rotifers dominated the species composition by contributing 68 % of the 31 species recorded during the study. Cladocerans followed with contribution of 26 % while copepods contributed 6 %. Although rotifers and cladocerans were both composed of 5 families each, rotifers had very high dominance. Only two families, Lecanidae and Brachionidae contributed 86% of the rotifer species. 63 % of the Cladocera species belonged to the families Chydoridae and Daphnidae. Copepoda had the lowest species richness and dominance with two families each contributing one species, Diaptomidae *(Thermodiaptomus galebi*) and Cyclopidae *(Thermocyclops consimilis*) (Fig. 11). A full list zooplankton list can found in Omondi *et al.* (2011). Among all the sites sampled, the site within a sheltered bay in the central zone of the lake on the western shores of the lake had highest estimated species diversity. The high diversity was attributed to calm and stable waters within the sheltered bay (Tiwari & Vijayyalakshimi 1993). Calm waters in the bay are as result of probably the bay being far from river mouths and path of wind induced water currents.

There are some similarities and differences in terms of species recorded between the studies of Schagerl & Oduor 2003 and Omondi *et al.* (2011). At species level both studies recorded the species *Cladocera Moina micrura and Rotifera Brachionus patulus.* At the genus level, both studies recorded the Copepod *Thermocyclops* as genus but Schagerl & Oduor 2003 identified only one species at genus level. While Omondi *et al*. (2011) went further and identified two species belong to two different families. Use of different identification keys could be the cause of the difference in copepods species recorded in two studies. Schagerl & Oduor (2003) recorded the rotifer *Keratella quadrata* which was included in species list of Omondi *et al*. (2011). Conversely, Omondi *et al*. (2011) collected the rotifer *Keratella tropica* which was included in species list of Schagerl & Oduor (2003). Other species which Schagerl & Oduor (2003) recorded and Omondi *et al*. (2011) did not list were *Paradiaptomus* sp. and *Pseudochydorus globosus.* Sampling methodology used in two different studies may partly account for the differences in species composition. Schagerl & Oduor (2003) used plankton net of smaller mesh size 37 μm than 60 μm which Omondi *et al*. (2011) used. The former net is able to catch smaller bodied rotifers. Furthermore, Schagerl & Oduor (2003) sampled for only 4 months while

Omondi *et al*. (2011) sampled for 18 months. A longer sampling period and more samples increases the probability of catching more species. Probably this explains why Omondi *et al*. (2011) recorded more species than Schagerl & Oduor (2003) despite using larger mesh sized plankton net.

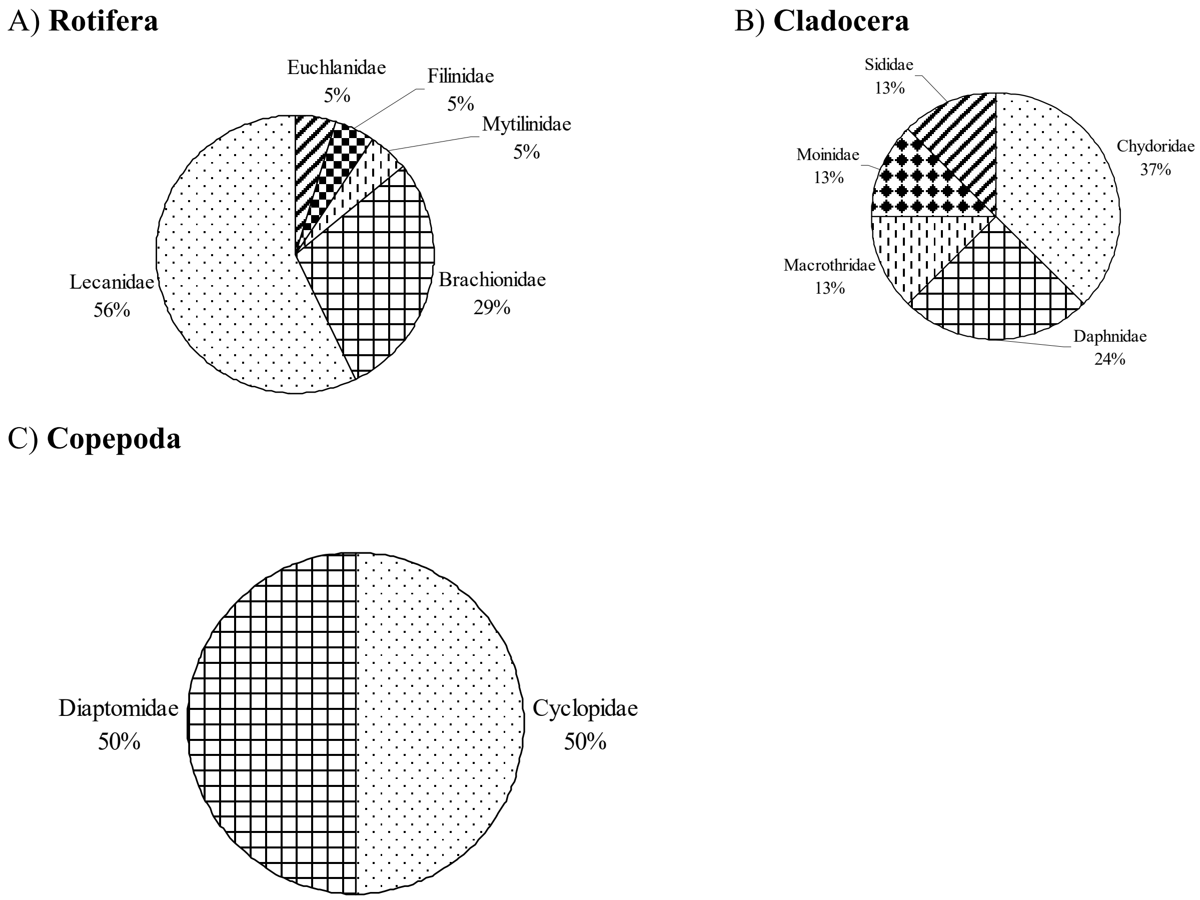

Fig. 11. Species richness various zooplankton taxa of Lake Baringo (modified from Omondi *et al.* 2011).

Zooplankton abundance in Lake Baringo is low and significantly variable in space and time. Estimates show the density ranges from 17 individuals L^{-1} to 163 individuals L^{-1} while mean density at different sites in lake range between from 56.37±6.58 individuals L^{-1} to 79.09±7.95 individuals L^{-1}. Sites near river mouths have the highest zooplankton density. This is attributed to higher nutrient input to the lake through river mouths which cascade in increased abundance of phytoplankton which is food for zooplankton. A positive correlation between chlorophyll *a* and density of zooplankton supports this inference. Low abundance is attributed to turbid nature of lake and presence of planktivorous fish species in the lake. Considering individual taxonomic group, Copepoda dominates zooplankton abundance in space and time forming 60-72% of the total zooplankton abundance. Copepod population is further dominated by their juvenile stages (nauplii) composing of 37.3 and 90.4% (Omondi *et al.* 2011). This study furthers confirmed the high abundance of *Thermocyclops* spp as Schagerl & Oduor (2003) had earlier inferred. The dominance of cyclopoids in the Lake Baringo is in conformity to other lakes in Africa such as a Lake Victoria (Mavuti & Litterick 1991, Ndawula 1994).

Omondi *et al.* (2011) *Diaphanosoma excisum* is the most abundant Cladoceran in lake. Other frequent cladocerans species are *Moina micrura (*Moinidae), *Ceriodaphnia cornuta*, *Daphnia barbata* and *Macrothrix spinosa (*Macrothricidae). Schagerl & Oduor (2003) found that *Moina micrura* were few as opposed to the finding of Omondi *et al.* (2011). On the other hand, *Filinia opoliensis* (Filinidae) and *Keratela tropica* (Brachionidae) are most abundant rotifer. Other rotifers though few, are Brachionidae species *Brachionus angularis, Brachionus calyciflorus, Brachionus falcatus* and *Brachionus patulus (*Omondi *et al.* 2011). Schagerl & Oduor (2003) noted that lake had few *Keratella quadrata.*

Physical chemical variables influence the species composition, distribution and abundance of zooplankton in lake. High zooplankton abundance correlates positively with high nutrients concentration and Chl *a* biomass (Omondi *et al.* 2011).

5.2.3. Macroinvertebrates

Aloo (2002) and Hickley *et al.* (2004) posited that Lake Baringo is devoid of benthos. However, a survey, on benthic macroinvertebrates conducted in 2004 demonstrates that the lake harbours some benthos albeit in low abundance and diversity. In addition, there are macroinvertebrates associated with macrophytes which also occur in lake (JR Muli pers. observ). In the 2004 survey, overall six benthic macroinvertebrates species were recorded from the lake. Mollusc species dominated the species composition and abundance in all sites of the lake survey. Of special interest in species composition are two snails, *Bulinus trigonus transversalis* and *Bulinus truncatus trigonus,* that are potential vectors of various diseases. The species richness per station ranged from 1 to 3. At Loruk bay no benthos were recorded. The density per station was low. It ranged from 4 to 64 individuals m^{-2}.

Seven taxa of macrofauna associated with macrophytes were recorded. *Cleopatra bulimoides* was the only species found on *Ceratophyllum dersum* at Loruk bay. The other species were associated with the water cabbage (*Pistia stratiotes*) that collected off Komolion beach. The species composition included *Bulinus scalaris* and *Bulinus trigonus transversalis* that are potential vectors flukes of which cause various diseases in Man and livestock. The other species were insects: *Anax* spp (Odonata), the dipterans *Bezzia* spp, *Stratiomys* spp and Coleoptera family Amphizoideae. Macrofauna associated with macrophytes are crucial as they could be playing significant role as food items of fishes in the lake given that the benthos are scarce. Perhaps more benthic species occur in lake and if a detailed study covering more sites sampling is done more species can be listed as occurring in lake.

5.2.4. Macrophytes

Similarly to the aforementioned fauna, macrophytes of Lake Baringo are characterised by low species diversity (Owili *et al.* 2008). On the basis of a survey conducted in 2008, a total of 8 species of macrophytes belonging to 9 families were listed as occurring in the lake. The species belong to 4 groups namely: submerged, free floating, floating leaved and emergents. *Ceratophyllum demersum* (Ceratophyllaceae) was the only submerged species while *Pistia stratiotes* L (Araceae) was the only free floating macrophyte species. Floating leaved was represented by *Nympheae lotus* L. (Nymphaceae). Emergents were the most speciose group with 5 families. These were the families Papilionaceae represented by species *Sesbania sesban* and *Aeschynomene indica,* Convulaceae with *Ipomoea aquatica* Forsk., Azollaceae represented by *Azzola pinnata* Forsk., Typhaceae represented by *Typha domingesis* pers. Poaceae had three species while Sedges had 4 species which were not identified. In terms of abundance the dominant macrophytes were mainly the emergents such as Poaceae family.

The macrophyte groups form a continuum of clear zones from land towards the lake to point below water down to the depth at which no plant growth is possible. This formation is more pronounced mainly in the southern zone of lake which has the only rivers draining into the lake. From the land towards deeper waters the emergent plant zone is successively replaced by floating plant-leaved and submerged plants zones. Free floating plants drift on and between these zones and further freely in the open lake (Table 8). The edge of the water on the landwards side, the emergent plant zone is occupied by dense stands of phragmites. While *Ipomea aquatica* grow over the wave washed zone between *Typha domingesis, Aeschynomene indica* and other grasses. In some sites in lake the clear zonation is interrupted with mixing of plants characteristic of different zones. For example, in the submerged zone *Ceratophyllum demersum* occurs mixed with *Nymphae lotus.* The submerged plants are not limited to only the vicinity of lake shore. In the open waters of the lake occurs *Ceratophyllum demersum* in some sites.

Table 8. Macrophyte inventory of Lake Baringo.

Land ←——————————————→ **Lake**

	Free-floating *Pistia stratiotes* ↓	**Free-floating** *Pistia stratiotes* ↓	**Free-floating** *Pistia stratiotes* ↓
Emergents	**Floating-leaved**	**Submerged**	**Open waters**
Aeschynomene indica *Ipomoea aquatica* Forsk *Typha domingesis* pers *Ludwigia* sp Grasses and sedges	*Nymphae lotus* L.	*Ceratophyllum demersum*	

5.2.5. Fishes and Fisheries

5.2.5.1.Fishes

The fishes of Lake Baringo and its catchment need a critical reexamination to establish the exact fish species composition of the lake. Since the Cambridge expedition to the East African lakes in 1930-31 when the first survey on the fishes was conducted (Worthington & Ricardo (1936), various authors over years have continued documenting differing species composition. Worthington and Ricardo (1936) listed only three families represented by four species: *Tilapia nilotica* Linnaeus 1757 (Pisces: Cichlidae), common catfish *Clarias mossambicus* Peters 1852 (Pisces: Clariidae), Redeye labeo *Labeo cylindricus* Peters 1852 (Pisces: Cyprinidae) and the barbs *Barbus gregorii* Boulenger 1902 (Pisces: Cyprinidae), as occurring in the lake in 1930-31. Ssentongo (1974) added the barbs species *Barbus lineomaculatus* Boulenger 1903 (Pisces: Cyprinidae) and the Topminnows/Lampeyes *Aplocheilichthys* sp (Pisces: Aplocheilichthyidae) to the list resulting in six species belonging to four families following a survey in lake and its affluents in 1969.

Similarly, Aloo (2002) and later adapted by Odada *et al.* (2006), reported five families occurring in the lake which was less than the six Ssentongo (1974) reported and more than the four Worthington and Ricardo (1936) reported. Furthermore, some of the families and species reported were different except for *Labeo cylindricus*. Aloo (2002) reported the marbled African lungfish, *Protopterus aethiopicus* Heckel 1851 (Pisces: Protopteridae) and Barb *Barbus intermedius* (Ruppell, 1836) which were hitherto not reported. Conversely, Aloo (2002) did not include *Aplocheilichthys* sp and the barbs species *Barbus gregorii* and *Barbus lineomaculatus* as occurring in the lake. The marbled African lungfish was introduced into Lake Baringo from Lake Victoria in 1975 and started to appear in the fish catches in 1984 (Ssentongo 1995, De Vos et *al.* 1998, Mlewa & Green 2006). Thus, marbled African lungfish did not exist in the lake when Worthington and Ricardo (1936) and Ssentongo (1974) sampled the lake. The other species which Aloo (2002) reported were the Baringo tilapia *Oreochromis niloticus baringoensis* Trewavas, 1983 (Pisces: Cichlidae) and *Clarias gariepinus* Burchell, 1852, (Pisces: Clariidae). Worthington and Ricardo (1936) and Ssentongo (1974) had reported these species as *Tilapia nilotica* and *Clarias mossambicus* respectively. These are the same species despite differences in names as *Tilapia nilotica* was revised to *Oreochromis niloticus baringoensis* (Trewavas, 1983) whereas *Clarias mossambicus* is synonym of *Clarias gariepinus* (Okeyo 2004).

Okeyo (2004) revised the scientific names, recommended English common names, distribution and taxonomic notes of fishes of Kenya eastern arm of Rift Valley. The revision resulted in seven species and included three barbs which were not reported by aforementioned authors namely: Baringo Barb *Barbus intermedius australis* Banister 1973, Zanzibar barb *Barbus zanzibaricus* Peter 1868 and Loveridge's barb *Barbus loveridgii* Boulenger 1916. Missing in the list was marbled African lungfish and

Topminnows *Aplocheilichthys* sp. The other species were Baringo tilapia, catfish and redeye labeo as reported by the other authors aforementioned.

Finally, Nyamweya *et al.* (2012) reported the fish composition as consisting of seven species. These were Baringo tilapia, common catfish, Redeye labeo and marbled African lungfish as reported by the other authors aforementioned. It also included the Line spotted barb *Barbus lineomaculatus* Boulenger 1903 which Ssentongo (1974) and Okeyo (2004) listed but Worthington and Ricardo (1936), Aloo (2002) and Odada *et al.* (2006) did not record as occurring in the lake. Nyamweya *et al.* (2012) also listed the species *Labeobarbus intermedius* (Rüpell, 1835) and the Guppy *Poecilia reticulata* Peters, 1859 (Pisces: Poeciliidae) which had never been reported before. Ssentongo (1974) recorded species *Aplocheilichthys* in samples collected in 1969 but Nyamweya *et al.* (2012) did not report it in samples collected in 2007.

Several reasons can be advanced to account for the aforementioned differences in fish species composition. First, past studies were not comprehensive enough as their samples were not representative of most areas of the lake. Evidence for this inference is based on a study by KMFRI in 2007 which divided the lake into geographical grids and had sample taken from each grid. The study yielded Guppy which had not been reported in the past studies (Muli 2012, Nyamweya *et al.* 2012). Second, the past studies were short-term in nature and sampling was not spatially widespread thus missing on rare fishes (Muli 2012). Lake fish samples of *Barbus lineomaculatus* and *Barbus loveridgii* are likely to be missed as they are largely riverine and likely to found in river mouths than in open lake. Further, fishes are very small in size and their abundance in lake is equally small so they are likely to be missed by gillnet samples .So they give the impression that they are rarer than other species simply because they do not appear in commercial catches (Hickley 2004, Okeyo 2004). Most differences in species composition over the years are mainly on genus Barbus. Most investigators tend to believe they can easily identify barbs species and therefore feel they do not need identification keys. Thus keen attention is not paid and the assumption results in misidentification of the various Barbus species (JR Muli pers observ). Ssentongo (1974) reported that no critical taxonomic examination was made on specimen of *Clarias mossambicus* collected during the 1969 survey. An assumption was made on the basis of the authority of Worthington and Ricardo (1936) who had decided so. According to Greenwood (1962) *Barbus loveridgii* is known from only types. Thus its type locality in River Amala is doubtful (Mann 1971, Ssentongo 1974). This confirms the need for more taxonomic studies in the Lake Baringo basin.

On rule of the thumb the Lake Baringo species composition based on what one can observe on commercial fishing landings consists of: Baringo tilapia *Oreochromis niloticus baringoensis*, marbled African lungfish *Protopterus aethiopicus*, common catfish, *Clarias gariepinus*, Redeye labeo *Labeo cylindricus* and Barbs spp. The other species are very rare in commercial catches (JR Muli pers observ). Aloo (2002) and Odada *et al*. (2004) contention that Barbs rarely appears in fishermen catches, while Redeye labeo had disappeared from the lake due to damming of afferent rivers which interfered its breeding habits might have appeared apparently true when the lake level was at its lowest at beginning of 2000 millennium. However, with increasing lake level, Redeye labeo and barbs always appear in commercial catches and are therefore did not disappear from the lake (JR Muli pers observ).

In terms of spatial distribution, *Barbus lineomaculatus* and *Clarias gariepinus* are strictly found in lake. *Poecilia reticulata* was collected during a one time sampling in lake. Thus it is not possible to conclusively decide that it is only found exclusively in lake (JR Muli pers observ). On the other hand, *Oreochromis niloticus baringoensis, Clarias gariepinus, Labeo cylindricus, Barbus intermedius australis* and *Barbus zanzibaricus* are found both in lake and affluents. *Barbus loveridgii* was reported from only River Amala (Greenwood 1962, Okeyo 2004).

Baringo tilapia is endemic in the lake while common catfish, Redeye labeo and barbs are indigenous. The marbled African lungfish was introduced from Lake Victoria (Ssentongo 1995, De Vos *et al.* 1998, Mlewa & Green 2006, Nyamweya *et al.* 2012). The endemism of Baringo tilapia calls for conservation of species. Perhaps the species has suitable characteristics which humanity has not established yet. For instance it might be a suitable candidate for aquaculture despite stunted growth in lake. There is also the threat of fish introductions from other lakes to restock the lake in order to improve the lake production. In the recent past Nile tilapia *Oreochromis niloticus* juveniles were introduced from the Lake Victoria catchment to boost dwindling production (Ogwai pers. comm. 2016). Introduction of tilapia could result in interbreeding with local Baringo tilapia and eliminate the endemism in the lake. In addition the local tilapia could be outcompeted by aggressive species like Nile tilapia as happened in Lake Victoria.

5.2.5.2. Fisheries

Commercial gillnet fishing started in Lake Baringo in 1946, before then fishing was done using rod and line only. Records on the fishery number of licensed fishermen, fishing effort, catch rate, and fish landings dates back from 1946. There is total fish landings data which dates back to 1963 (FLDLB 2016). But, according to Ssentongo (1974), comprehensive data collection started in 1966. Long-term Lake Baringo fish landing data shows catches are characterized by substantial fluctuations over the years. In the 1960’s the catch averaged 568 t and peaked to maximum of 717 t in 1970. It then plummeted drastically to low of 58 t in 1972 only to rise reaching a maximum of 467 t in 1980. The fluctuations in fish catches continued over years and the maximum peak so far was 867 t in 2013 (Fig. 12).

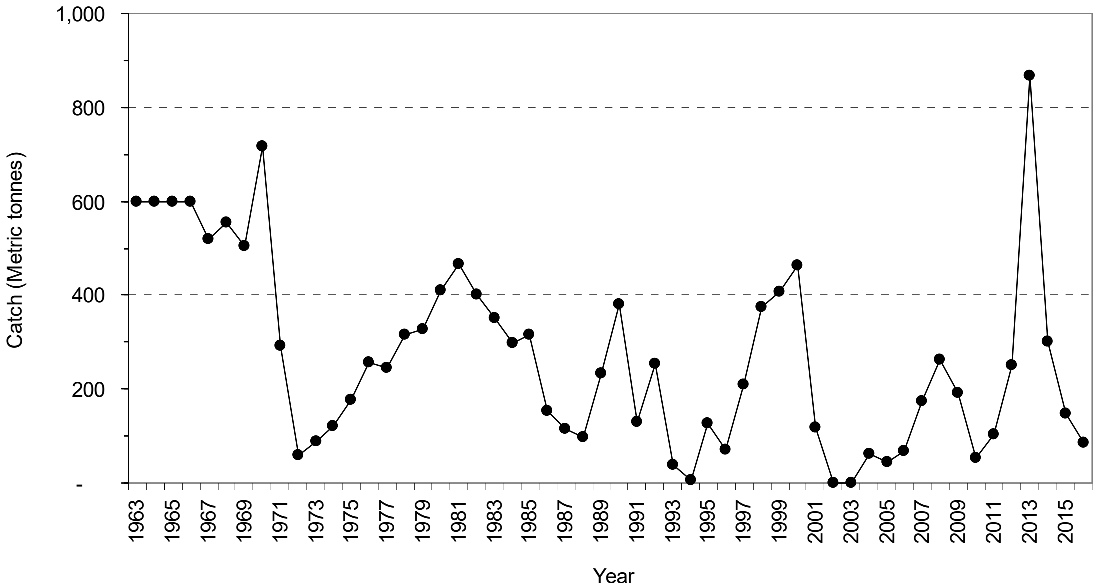

Fig. 12. Total annual catch in the Lake Baringo fishery, 1963 to 2016. From 2002 to 2003 there was fishing moratorium thus no data is available (Source of Data: FLDLB 2016).

According to Britton *et al.* (2008) the fluctuation in fish landings affected all species and was more pronounced on the Baringo tilapia. Available data suggest that fluctuations are not only more pronounced on tilapia but also conspicuous on the lungfish. Disaggregated catch data to species level is available from 1992 to 2016 and is displayed in figure 13, however, it is not easily available for the period 1963 to 1991.

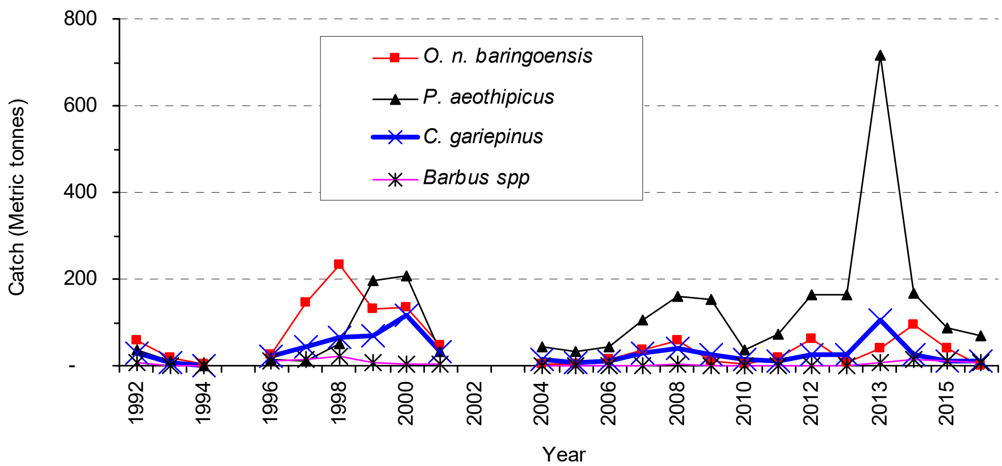

Fig. 13. Total annual catch of various fish species in the Lake Baringo fishery, 1992 to 2016. From 2002 to 2003 there was fishing moratorium thus no data is available (Source of Data: FLDLB 2016).

Since the 1940s to early years of the 2000 millennium, the fluctuations in the fish catch were always attributed to changes in fishing effort i.e. the exploitation effort exerted on the fishery (Ssentongo 1974, Odada *et al* 2006). Thus, to sustainably exploit the fishery, mainly two regulatory measures were applied before: closed fishing season and use of fishing gear of certain minimum mesh size (gillnet) and hook size. Fishing effort is controlled by limiting the number of fishermen entering fishery and adherence to fishing gear of certain minimum mesh size (gillnet) since 1940s to date. The regulations to follow to ensure sustainable exploitation and which are enforced by Department of Fisheries are legalized in Fisheries Act chapter 378 (FA, 2012) of Kenya laws. The high numbers of immature and smaller sized Tilapia observed at the landing beaches suggest that illegal fishing gears are still in use. Thus, the fisheries regulations on legal fishing gear to use are not adhered to and to what extent it not known (JR Muli pers. observ.). Closed fishing season were applied in May 1993 to April 1994 (Hickley *et al.* 2004) and again in February 2002 to 2003 to improve the fish stock (Hickley *et al.* 2004, Odada *et al.* 2006). However, the cyclical fluctuations in fish landings have continued since. Therefore, the fishing moratorium did not yield improvement in fish catch in long term as demonstrated by fish landings over the years (Figs. 12 and 13). This conclusion is not in conformity with claim of Odada *et al.* (2006) that fishing moratorium resulted in improved quality and quantity of fish catch at least in the long term. The period of the year when the two fishing moratorium were set were not based on any results of a scientific research. Despite the good fisheries laws, the management of fisheries is not based on scientific knowledge over the years. Therefore there is need for scientific information to guide management decision. Britton *et al.* (2008) demonstrated that fluctuations in the fishery catch are caused by corresponding changes in lake level. And not by intense unsustainable fishing effort as had been advocated before. Thus, it was advocated that the principle of Ecohydrology needs to be applied aiming that maintaining the maximum possible lake water levels at all the times with effort on water flow focused on upper levels of the catchment. Continuation of enforcement of fishing regulation on fishing gear and closed fishing season was also recommended.

6. Management of the Lake and its Basin

6.1. Lake Baringo Resource Values

The major resources of the lake and its basin include among others: water, fish, diverse wildlife and a diversity of people. The lake supports a small-scale fishery but a significant one in relation to the equally small size of resident fishing population (Aloo 2002). Fish from the lake is exploited by local population for both subsistence and commercial use. Thus, fish is a resource which generates income to community and revenue for the local government. There is sport fishing which takes place due to presence of fish in lake.

The lake harbours high population of diverse birds and large population of large vertebrates such as Nile crocodiles (*Crocodylus niloticus*) and hippopotamus (*Hippopotamus amphibius*). Gichuki (2000) estimated the birds' species richness to be about 400-500. Some bird species recorded include species which migrate from Europe seasonally. It is that there are over 40-60 hippos and about 2000 crocodiles in the lake (C. Olilo pers. comm.). The high diversity of animals attracts many tourists who tour the lake to view them in their natural environment. Tourism is major source of income to the local community who has invested in tour guide services. The local community has invested boats for ferrying tourist around the lake. Investment in hotels and camps around the lake to cater for tourists is another income and revenue stream which the local community and also other communities from parts of the country have has taken advantage of. Tourism is a valued industry and when tourists stop coming due to security concerns in the country (not necessary local, usually other parts of country or even adverse travel advisory by tourist country governments), the local economy generally suffers. In the recent past the creation of Ruko conservancy increased diversity and abundance of more large vertebrates. The biodiversity of the conservancy and benefits accruing are discussed in section on social condition.

A diversity of communities who still live their traditional lives is an attraction especially to foreign tourists. Indigenous communities include the Pokot, IIchamus and the migrant Turkana. The tourists visit to see the indigenous conservative communities and their cultural items such beautification items such as necklaces, armlets, clothing, and traditional villages and to understand their way of life.

Water is resource which the lake and its rivers provide for human use and livestock. In the highlands, Kirandich and Chemususu dams were built and are providing portable water to residents of Kabarnet and Eldama Ravine townships respectively. Water from rivers afferent to lake is used for irrigation. The lake is platform for pleasure activities by both local and foreign tourists. These include water sports such: speed boating, jetski, yachting, skiing and kayaking. There are annual boat and raft ('Ng'adich') competitions. The annual raft competition is more of a cultural event as it includes indigenous communities show casing their culture and includes traditional dances. It is an event sponsored by County Government of Baringo and is used to bring various communities together and to foster peace and harmony among them. The lake is used for transport of people as well as goods to and from various markets and human settlement across the lake.

Currently, there is an on-going Baringo-Silali geothermal electricity development project which plans to use water from the Lake Baringo to enable the geothermal well drilling (Ogola *et al.* 2012). Three prospective sites for steam power have been identified at Silale, Korossi and Paka within the vicinity of lake. The spotted sites have the potential to produce over 100 MW each. Already a pipe has been laid for pumping water from the lake to Paka and well drilling was set to begin by August 2018 (Mbogo 2018). Water is used during the geothermal drilling process to remove drilled sediments, lubricate and cool drill bit, maintain downhole hydrostatic pressure, and to convey drill cuttings from bottom of the hole to the surface. Once a well is in place, water is used to stimulate reservoir by pumping water down the well hole to open existing spaces within the formation to enable or enhance the circulation of geofluid (water extracted from geothermal reservoir). During operation of geothermal plants, water is used to condense geofluid for reinjection into the reservoir, In case a geo-reservoir is poor in water, makeup water may be abstracted from external sources and injected into the reservoir. In normal operations water is needed to manage dissolved solids and minimize scaling (Clark *et al* 2011). The use of water from the lake may potentially have an impact on the lake if the planned withdrawals are high. For example, Britton *et al*. (2008) demonstrated that Lake Baringo water level is significantly positively correlated with fish production.

Various macrophytes species are valuable resources for the indigenous communities around the lake who use them to meet various needs. Some species are harvested and used as human food. The grass *Ipomea aquatica* at Loruk Bay in northern zone of the lake is harvested by the Tugen community who use it as a vegetable. While the Ilchamus community who live around the south zone of the lake, harvest water lily seeds from the lake, which they dry in sun and grind to make flour. The flour is used to make porridge and local cake ('ugali') which is special delicacy for the community. Cattle and donkeys are driven to the macrophyte zone of the lake and rivers to graze upon the various grasses and sedges. They form a safety net during the dry season when grass is scarce. The 'Sebei' tree is harvested and the stem is used to make rafts which are used for navigation in lake by fishermen. Macrophytes are important building material for the communities. *Cyperus papyrus* which is abundant at Lorwai swamp is harvest for thatching houses. Typha (*Typha domingesis)* is used to make mats which are used as a carpet and as material for lying upon while resting or sleeping on ground or even for laying a mattress over. The mats are also used as ceiling materials.

The lake is an education resource. Many students of primary, secondary as well tertiary institutions tour the lake on education tours. These educational tours are source of income to both local tour guides from the local communities and tour companies from other parts of the country. According to Komen (Lake Warden, pers comm.), the lake attracts bird researchers as well photographers due to the high diversity.

6.2. Major Socio-economic and Political Implication of Use of the Lake Basin Resources

Damming of rivers to provide potable water to highland communities has had socio-economic and political implication. Provision of potable water from dams is a positive step forward in development. It has improved standard of life by reduction and preventing future the occurrence of water-borne diseases. It has empowered people to undertake other economic activities by relieving them from the hard and time consuming activity of fetching water from the rivers or brooks. This is more so for women who are socially charged with the responsibility of fetching water for their household. It can be considered as tool for gender parity as girls are released from chores of sourcing water and concentrate on education. Damming has had negative socio-economic and political implication to downstream communities as has resulted in significant decrease in discharge in some rivers. For example, River Endao had an irrigation scheme which depended on its waters, but with construction of Kirandich dam upstream, the irrigation no longer takes place due to lack of adequate water discharge in river. The farmers are now depended on erratic rainfall for food production and their income has considerably fallen. Communities of downstream especially in the lowland low section of the river felt marginalized politically by those from upper section of river where damming was done. And they feel the upstream communities are powerful and do not care about them.

There have been several geographical migrations of communities (tribes) into and out of the fishery over years since 1946 when commercial gillnetting started (Ssentongo 1974). European settlers started commercial fishing in Lake Baringo. They brought experienced fishermen of the Luo tribe from around Lake Victoria basin to fish for them in 1965. The ultimate goal of bringing the Luo fishermen was to ensure adequate supply of fish to run a fish processing factory with which they had established at Kampi ya Samaki Township in 1960. The local indigenous communities (Tugen, Pokot and IIchamus) then were involved in pastoralism and agriculture and lacked fishing skills. Moreover, they were not fish eaters and did not find the need to exploit the fishery. However, in the early 1970s, they entered the fishery and have remained there up to date. They practise both subsistence and commercial fishing. In addition, they process fish to preserve and ensure long shelf life. Others are involved in fish trading. Fishing is an occupation which they do in addition to pastoralism and agriculture. In late the 1980s, the native fishermen forced Luo fishermen out of the fishery. The natives were of the opinion that the Luos had undue advantage and were marginalizing them as they were benefiting from two water bodies: Lakes Victoria and Baringo, while indigenous had only one. The third geographical migration into the fishery was that of the fishermen of the Luyhia tribe from western Kenya around 2015. Luyhia fishermen were brought by the natives to fish for them and work as employees as they opined they had better skills in fishing and would provide a better return to their investment compared to the natives fishermen. The latest geographical migration has had ramification on the sustainable exploitation of the fishery. They introduced the technique of fishing using pieces of bar soap as bait for fish and which ends up large catch of undersize immature tilapia besides the use of soap is unhealthy. This fishing method is unacceptable to the local population and they having asking the government to eradicate. The ultimate cause of both the Luo fishermen geographical migration out of the fishery and entry of the Luyhia was due continued dwindling of fish stocks.

The communities exploiting fishery have partitioned lake among themselves with clear boundaries. The Pokot fish in north eastern part of the lake, Tugen in the central and North western part of the lake, whereas the IIchamus fish grounds are in south area of lake.

As the fishery has continued to be is exploited over the years and the fishery stock dwindling, locals have continued to employ several unsustainable practices: i) illegal fishing gears which catch undersize immature fish, ii) fishing in rivers mouths, iii) fishing during closed fishing season, and iv) fishing with bar soap as fish bait. The fisherfolk are aware that their actions contribute to in the dwindling of stocks; however, they shift the blame to government officials for not taking appropriate action to stop unsustainable fishing practices.

Exploitation of the lake for tourism has had positive social-economic implication to local community. In the early 2000s, the boats which were used by tour guides in lake were owned by youths as a group. This situation has since changed. Plight of tour guides has improved as by year 2016, virtually every tour guide individually owned his own boat. Similarly there has been growth in hotels and camping sites around the tourists. In early 2000s there were only two tourist hotels which were owned by Europeans, but now there are several hotels owned by the indigenous communities.

The parcels of land were Ol Arabel and part of Marmanet forests falls were allocated to the Lembus and Arror clans of Tugen tribe from 1982 to 2001. Consequently, deforestation took place to give room for human settlement and farming. This allocation has had political ramification. The Endorois clan of the Tugen feel marginalized as they were not considered when land was allocated despite living closer to the forests compared to the Lembus and Arror. The excised part of the forest was exploited for timber, wood fuel, charcoal and settlement which have led the forest to lose ability to sequestrate carbon (Locatteli 2011). It also resulted in decrease in ground water recharge, streams drying up during dry season and flash floods during rainy seasons. Decrease in water flow and quality has had major socio-economic and political implication on people who are downstream the forest especially those in the lowlands as they depend on river water for their domestic use, livestock and irrigation agriculture.

6.3. Resource conflicts and how they are management

There is conflict over the excision of parts of Ol Arabel in 1983 and Marmanent forest in 1993, 1995, 1998, 1999 and 2001 (UNEP 2009) which effected change of land use from public land (COK 2010, article 61, (1)g) to private land (freehold tenure) (COK 2010, article 64, (a)). This resulted in conversion parts of the forest and to human settlement and farming and consequently deforestation. Conflict is partly due to lack of inclusivity as the Endorois clan of the Tugen tribe was not considered when land was allocated despite living closer to the forests compared to the Lembus and Arror. Thus they have always agitated for the allocation to be cancelled so that they can be included. The legal procedure of converting forest land to human settlement was not followed. First, the degazzetting of the forest was not done and so was an environmental impact assessment of converting the forest to farmland. The general public was not informed and involved as the proposal of land change of user was not announced in at least two daily newspapers, one in Swahili and the other in English, with wide national circulation and also the announcement displayed at the office of Chiefs as is the requirement of the Physical Planning Act, miscellaneous section, article 52 (PPA, 1996). Thus, the conversion of the forest land was illegal and now government wants the land to revert back to forest and has been making plans in this line. The exception is for areas: Kwa Maina and Kwa Wanjiku in South Marmanet forest which were degazetted for settlement (Daily Nation 2010, GOK 2018, GOK 2019). The Lembus and Arror communities have continued to resist this plan and are pushing for legalization of the allocated land. This is in despite of the factor that it is the aspiration of Kenyan people as community to achieve and maintain a forest cover of 10% of Kenya land area as enshrined in article 69, (1) b of Kenyan constitution (COK 2010). There are efforts by the Kenya government, corporate world and environmentalists to recover the parts of the forests of Ol Arabel and Marmanent forests which were excised (GOK 2019).

Major conflicts in the fishery are between wildlife conservationist, hospitality industry players and fishermen on the other hand. The conservationist's objective is to preserve wildlife and to keep the lake healthy. On the hand, fishermen complain that the large vertebrates (crocodiles and hippopotamus) should be eradicated from the lake as they destroy their fishing gears, maim and kill human beings. Secondly, crocodiles and aquatic birds eat fish already caught in fishing gears reducing catch and income due to fishermen. Thirdly, motorised boats which ferry tourists to view the lake and wildlife destroy their fishing gear. Kenya Wildlife Service (KWS) is in charge of managing Wildlife in the lake. Normally whenever there is loss of livestock or human, KWS manages the situation by compensating the party involved. However, the community feels it takes long to get compensation. Another conflict is the practice of the fisher-folk of exploiting the fishery in unsustainable manner. The overexploitation of the fishery using illegal undersize fishing nets is common in lake. This problem is managed by fisheries department who enforce the fishery laws. Thus, illegal fishing gears are confiscated and if the owner is found he is charged according to the law. Enforcement of the law has not been successful though as it is not done regularly due lack of resources to police the lake. Regular patrols of the lake are usually not done. Theft of fishing gear in lake is another conflict in the lake. Involvement of fisher-folk community through Beach Management Units (BMUs) has reduced the theft considerably.

Water abstraction from rivers by farmers for irrigation farming is another conflict. Most of farmers are not licensed. Therefore, they do it illegally. Whenever they see government officials they normally run and leaving their water pumps. There is no information on how much water can be sustainably abstracted without interfering with health of the rivers and lake. To solve this problem the Water Resources Authority (WRA) has encouraged the involvement of the community in the management of water resources. At moment WRA encourages formation of Water Resources Associations but most Water Resources Associations are not effective due to lack of finance. Thus, a new law regime has been formulated to allow Water Resources Associations to access finance from the government to run their activities (WA 2016).

7. Current Problems, Causes and their Management

7.1. Current Problems and their Management

Sedimentation is threat to the Lake Baringo ecosystem. It reduces both depth and surface area of the lake (Oduor *et al.* 2003). In addition, it destroys the habitat of aquatic fauna. The rate of soil erosion in the lake basin was estimated at 206 mt^{-1} ha yr^{-1}. In total the estimated sediment yield of the Lake Baringo basin is 10.38 mt^{-1} ha yr^{-1} (Onyando *et al.* 2005). There are on-going efforts to control soil erosion especially in the lowlands. Farmers were taught techniques of soil control: how to plant folder grass, pasture management, maintaining sustainable livestock stocking rate and change from local to more productive exotic breeds. Some farmers have adapted these techniques and achieved success. However, there is need to upscale soil erosion control to the extent that every land owner adapts these techniques. The challenge is land in the ASAL in lower catchment region is communally owned (title is in the name of group ranch) thus, there is no individual motivation to control soil erosion. Soil erosion on the edges of roads is also a sediment contributor in the lake's catchment and more so in the ASAL as impacts of climate change continue to be to increase. This problem can be sorted by implementing climate change strategies on how to construct climate change proof roads. It is now about 16 year since last soil erosion of River Perkerra basin was assessed (Onyando *et al.* 2005). The land use/land cover of the basin has since changed. There is need to evaluate the current soil erosion of not only the Rivers Perkerra basin but also for the other rivers basins afferent to Lake Baringo.

The fishery of the lake has been fluctuating over the years due to erratic, unstable lake environment and habitat degradation (Hickley *et al.* 2004, Britton *et al.* 2006). Concurrently, the fish species composition has been changing over time. Previously the main commercial fish species were *O. niloticus* and *C. gariepinus*, but since the introduction *P. aethipicus* in the lake, the dominant commercial fish species fluctuates between *O. niloticus* and *P. aethipicus*. Due to fluctuations in fish stocks in lake, the fish catches dwindle to very low levels in some years (Figs. 12 and 13). Thus, fishermen and fish traders suffer loss of income and county governments lose revenue. To solve this problem scientific research is being undertaken to guide management decision. Scientific research include: identification of the fishing breeding and conservation areas, stock assessment and fish production. The application of results of scientific research is another challenge.

Unsustainable livestock population is another problem in the catchment especially in the ASAL. Since parts of the catchment in lowlands are semi-arid, it has low livestock carrying capacity but the inhabitants still value keeping large livestock herds (Odada *et al.* 2006). The large livestock population destroys the habitat of plants and animals, while cattle tracks cause gullies, creating conducive conditions for soil erosion and sedimentation into the lake. Maintaining sustainable livestock stocking rate and change from local to more productive exotic breeds has been the strategy adopted. Human capacity building has been done and some farmers have adapted exotic breeds in the ASAL. However, to combat the unsustainable livestock population, adoption of exotic breeds needs to be embraced by all farmers. The government can play key role in this line. A possible approach can be for the government to purchase exotic breeds for farmers and also to train them on proper husbandry and also to provide seed fodder. This can be means also to eradicate poverty in ASAL.

Erratic and inadequate discharge in rivers is problem as results in inadequate supply of water for domestic, livestock and irrigation agriculture. The problem has been compounded by climate change and damming of rivers. The effect of climate change is more pronounced in the ASALs of the catchment compared to the highlands (Koskei 2018). Reduced water recharge and damming of rivers pose a threat to the lake ecosystem through reduce stream flows. The main dams in the catchment are Kirandich, Chemasusu, Chemoron and Kimau. As a way to ensure stream flow in rivers in future, before any new dam is built in the catchment, an environmental impact assessment must be done. To address the problems of climate change, the national government enacted the Climate Change Act (CCA 2016) to guide the responses to problems associated with climate change. There is also National Climate Change Response Strategy (GOK 2010), Kenya Climate Smart Agriculture Strategy (GOK 2017) and National Climate Action Plans (GOK 2013) which are in tandem with Climate Change Act and are all meant to tackle problems associated with climate change. County governments are mandate to mainstream the Climate Change Act (CCA 2016) to suit their unique needs. The three counties where Lake Baringo catchment lies have not enacted a law to mainstream the Climate Change Act (CCA 2016).

Livestock rustling is problem in the ASALs which recurs annually. It mainly practiced by the Pokot community against the Kikuyu, IIchamus and Tugen communities. It has reached an unprecedented level with IIchamus being displaced from their ancestral land which forms a whole division of Mukutan. Rustling reduces the resilience of communities affected leads them to extreme poverty. It affects the fisheries sector as fishermen lose livestock which is an alternative fallback. Thus, occupational migration from the fishery is curtailed. The National Government has been fighting to eradicate livestock rustling through police service, military forces and public administration organs. Of late the Police logistics of have been beefed up with introduction of armoured vehicles to tackle the problem more effectively.

The inhabitants of the catchment generally consider wastewater management not to be a major threatening issue (J.R. Muli pers. observ. Based on Ecosystem Service Perceptional Profile survey). However, there are some areas within the catchment where communities feel sanitation, excreta disposal and hygiene issues are quite threatening. These areas include mid-section of River Molo at Mogotio and along the shore of Lake Baringo at Kampi ya Samaki townships. It is our opinion these public perceptions are genuine as per our observations. At Mogotio Township, there is estate in one part of the town were people do not have toilets in residential houses and also there are no public toilets. Thus, there is open defecation. At Kampi ya Samaki Township there is also open defecation though there are the toilets for shops, hotels and residential houses. However, there are no toilets for the public who visit the town. There is too much paper (including polythene) littered all over the town which is an eyesore. During Ecosystem Service Perceptional Profile (ESPP) study in 2016, inhabitants of these two towns pointed this to us. Certainly, there is faecal contamination into rivers and the lake around these towns though; there is no scientific data to back up the claim. Cases of cholera reported in the recent past in public media forcing public health officers to close hotels and all other eateries at Mogotio and Kampi ya Samaki townships further corroborates contamination of rivers.

7.2. Apparent root causes

Management regulations used to manage the lake are not based on science. Moratorium on fishing which was applied in 2002-2003 with aim of recovering the fish production did not yield any positive tangible results (Britton *et al*. 2008). The moratorium was not based on research showing that decline in fish production was caused by unsustainable fishing effort. Indeed, after the moratorium, Britton *et al.* (2008) demonstrated using data collected from 2001 to 2007 that the decline in fish production was not caused by exploitation but by erratic and environmental perturbations.

Exploitation of the stock is not based on fishery science. Entry to fishery is done not based on science. The number of fishermen and quantity of fishing gear authorized to the exploit the fishery is not based on the fishery stock available and how much can be exploited sustainably. Over-exploitation of fishery resources is caused partly by not enforcing the fisheries laws. Illegal fishing gears are used. Fishing is done even in fish breeding zones. Stocking the lake with Tilapia fry was done yearly from 2011 to 2016 (Ogwai, pers. comm.). However, the stocking did not result in restoring the dwelling fish stock. The stocking did not follow the national legal procedure (FA 2012). First environmental impact assessment and environmental impact audit were not done before restocking was done. And even public participation was not done.

Deforestation to give room to agriculture led to the forested area in catchment to decrease by about 50% since 1976 (Odada *et al.* 2006). In addition, the natural forest in this region has also been exploited for timber, wood fuel, charcoal and settlement. This has resulted in decrease in ground water recharge, streams drying up during dry season and flash floods during rainy seasons.

The indigenous communities in semi-arid zones of catchment earn their living through pastoralism and agro-pastoralism. They keep large number of livestock (cattle, sheep and goats) which overgraze the catchment vegetation leading to enhanced soil erosion and sedimentation in streams and the lake and frequent flash floods. Cultural beliefs and perception of livestock as source of wealth creates need to own large number of livestock by all means. Thus, livestock rustling is rampant in the semi-arid zones around the lake; which creates friction between communities in the basin, and consequently limiting collective responsibility in the management of the lake and its basin. The communities are politically marginalized especially the Ilchamus and Pokot and their poverty levels is high. They have limited access to potable water, health facilities and other services. In the catchment there are poor farming methods resulting in soil erosion. For instance, there is overstocking so most of pastureland is bare without grass, deforestation is going on, and farming in the river riparian zone. Land use methods in the catchment are not protecting the land.

7.3. Not Apparent root causes

Conservation of fishery is not a priority for the county government. Very little funds are allocated for conservation purpose. Thus, desired environment conservation efforts are hampered. Second, the county government does not enforce the country laws on conservation of lake water bodies. Third, climate change and/or variation could be cause of change in lake level.

The poor fisher folk, both fishers and fish traders incur loss in revenues as fish stocks dwindle, resulting in low living standards. Similarly, the local communities depend on the lake for fish protein, so when fish stock dwindles there is lack of fish protein. The government also suffers loses in revenue as fish stocks dwindle. With environmental degradation, the aesthetic value of lake decreases and becomes less attractive to tourists and consequently may result in less tourist visiting and loss of revenue.

8. Major "Impact Stories" Regarding the Lake

8.1. Water Hyacinth invasion

The latest major impact thing which has happened to the lake is the invasion of lake by Water Hyacinth (*Eichhornia crassipes* (Mart.) Solms-Labauch (Pontederiaceace) since 2016. The weed has formed large mats in southern zone but in central and northern zone it appears as single stands (plants). It is thought the weed originated from Lake Kichiritith where it was initially reported. Lake Kichiritith is an ox-bow lake in the floodplain of River Molo, located 8 km south of Lake Baringo. It is of recent origin having formed after the *El Nino* rains of 1997-98 (Tarras-Wahlberg *et al.* 2003).

Stocking of the lake with tilapia fry due to declining stock was done annually from 2011 to 2016 to restore the dwelling fish stock (J.R. Muli, pers. Observ.). Unfortunately, the fishery has not recovered. Some of the tilapia fry stocked came from Lake Victoria basin are most probably the species *Oreochromis niloticus* which interbreed with the local endemic *Oreochromis niloticus baringoensis.* The future impact of the interbreeding is not known. In Lake Victoria where *Oreochromis niloticus* was introduced in early 1960s, it out competed the indigenous *Oreochromis esculentus*.

There has been improvement in the public involvement of fisherfolk in management of the fishery. Fishermen involvement was strengthened by legalizing Beach Management Units (BMUs). BMU is the organization through which the fishermen co-manage the fishery with the both national and devolved county government (FA 2012).

Increase in lake depth since last lake brief is major story about the lake. The lake depth level increased from a mean of 3 m in 2003 to mean of 10.6 m in 2013. This was accompanied by submergence of building around the shores of the lake like hotels, hospital, fish landing '*bandas*' and even residential houses.

Research was conducted to identify the fish breeding regions. The identification was research based on both scientific survey of fish egg and larvae survey as local fishermen indigenous knowledge. This resulted in development of maps depicting the breeding zones. Development of fisheries maps was one of the national climate change adaptation measure for the fisheries sector (Government of Kenya 2010).

8.2. Climate change/variability and the recent rise in lake levels

Climate change variation in the basin has an effect on water quality variables of the lake. Annual water quality variables pattern generally follow annual climate pattern of wet and dry seasons. After rainfall seasonal in March–June, lake depth and transparency increases as the season progresses while with turbidity decreases. On the other hand, ionic concentration decreases as reflected by decrease in conductivity. During the dry season the reverse happens (Muli *et al.* 2007). Similar long term pattern in water quality variables occurs as following climate change pattern. There is not enough data to support this conclusion. All the same, comparison of long term ionic composition data suggest a correlation exist between climate change and water physical chemical variables of the lake water.

The recent rise in lake levels had profound effect on physical chemical characteristics of the lake. A summary of some physical chemical of the changes over the years is depicted in Table 4. Depth increased 3-fold from an average of 3.4m in 2004 to 10.6m in 2013 and decreased 1.2 times to 8.7m by 2015. The changes in lake level had a corresponding a 17-fold increase in transparency and 57-fold decrease in turbidity between the period 2004 to 2013. After lake level decreased marginally after 2013, transparency decreased also marginally by about 1.3 while turbidity increased marginally by about 3.2. Chlorophyll a had similar changes as transparency following changes in lake level over the same period. Chlorophyll a had an 1100-fold increase between the periods 2004 to 2013 and after lake level decreased marginally after 2013, it decreased also marginally by about 2.6.

9. Major Lake Basin Governance Issues

The approach to the management of Lake Baringo has been sectorial with each organization implementing its plans according to its mandate (a list of the organizations and their mandates is given in section 9.1. The activities of are not necessarily focused on managing the lake.

First of all, there is no management plan for the lake for all the stakeholders to rally around. Coordination hardly exists between the various institutions mandated in sustainably managing the lake and therefore their activities may not necessary contribute to the sustainable management of the lake. In addition, a national or county strategy or plan for managing the lake does not exist. Although a clear administrative line between national government and county governments and also between various ministries has always existed, however, it has not been effective in sustainably managing the lake. Nevertheless, the need for cooperation is now enshrined in new Kenya constitution promulgated in article 189 (1, 2, 3 and 4) which provide that cooperation between the national and county governments should comprise of information exchange, policies coordination, administration and capacity enhancement (COK 2010). Effective administrative structures need to be established cognizant of the factors which have always inhibited effective cooperation in the past. The governance structure advocated by Integrated Lentic Lotic Basin Management (ILLBM) system is appropriate in this aspect. A draft national strategy has been prepared which incorporate ILLBM and has been shared with stakeholders and is undergoing various stages of development as per the Kenya country guidelines for strategy development.

One major governance issue is related to the enactment and promulgation of new constitution for Kenya in 2010 (COK 2010). The new constitution changed the governance structure by devolving the fisheries from the national government to regional county governments, but the extent of their respective mandates remains unclear. According to the article 22 of the fifth schedule of the constitution, the national government has still the role of protecting the environment and natural resources with a view of establishing a sustainable system of development, and in particular: fishing, hunting, gathering and protection of animals and wildlife (COK 2010). The new constitution did not provide clear administrative framework on governance between the state departments/national statutory bodies and county governments on functions which overlap such as agriculture and fisheries. Thus, working modalities between the national and county governments need to be established on this line.

The laws which currently govern the management of lake are: Fisheries Act (FA 2012), Water Act (WA 2016), Agriculture Act (AA 2016), Forest Conservation and Management Act (FCMA 2016), Land Law (Amendment) Act of 2016 (LLA, 2016) and Environmental Management and Coordination Act (EMCA 1999). These acts are supported by relevant polices for each sector. The laws and policies governing the managing the lake and its basin are not fully implemented. The national policy on management of the lake and fishery has not fundamentally changed since the enactment of the new constitution. And the county government has not come up with a new policy or plans for management of the lake.

There are regular monitoring programs of the lake by KMFRI on limnology and fisheries, and broader ranging research by universities and other research institutions, both local and international. KMFRI is improving its capacity to conduct research by improving its ability to access and monitor lake by purchasing sampling equipment and improving its buildings.

The main financial mechanisms used to facilitate the control of exploitation of lake resources are licensing of fishermen before one is authorized to fish in lake. Fish traders also are required to pay license. Land rates for leasing parcel of land is another tax for those who own plot and/commercial building around the lake. Fisherman and fish trader licenses and land tax are payable to the County Government of Baringo. There are fees imposed by citizens through their own organizations particular the Beach Management Unit (BMU) and Lake Baringo Boat Owners Association (LABOA). County governments are assured to receive not less than fifteen per cent of all revenue collected by the national government which they share equitably among themselves. This is enshrined in the constitution (COK 2010). The funding from the national government is not subject to negotiation and therefore sustainable. Once the funding is received from the national government, county government is free to budget and allocate as per the priorities they deem fit. The only problem is that the magnitude of current funding for lake management is usually very low for any effective sustainable conservation of the lake.

9.1. Institutions

The institutions and agencies which are the key players and their role in management of the lake are listed below:

Ministry of Water and Irrigation: This ministry is operated under water Act 2016 (WA 2016). It is charged with development of legislation, policy formulation, sector coordination, guidelines, monitoring and evaluation in the water sector;
Water Resources Authority (WRA): This is the lead agency mandated with the regulation of the management and use of water resources in Kenya and currently it falls under the Ministry of Water and Irrigation. It formulates and enforce standards, procedures and regulations for the management and use of water resources and flood mitigation; regulates the management and use of water resources; enforces regulations made under the act establishing Water Resources Authority Act (WA 2016), among others;
Water Harvesting and Storage Authority: Created under Water Act 2016 (WA 2016), this agency undertakes on behalf of the national government, the development of national public water works for water resources storage and flood control and among others maintains and manages national public water works infrastructure for water resources storage;
Water Sector Trust Fund: This institution was established through the Water Act 2016 (WA 2016). It provides conditional and unconditional grants to counties and assists in financing the development and management of water services in marginalized areas or any area which is considered to be deserving including-community level initiatives for the sustainable management of water resources in 'alarm' and 'alert' sub catchments;
Water Tribunal: It is creation of Water Act 2016 (WA 2016). Water tribunal arbitrates appeals lodged at the instance of any person or institution directly affected by the decision or order of the Cabinet Secretary, the Authority and Regulatory Board or of any person acting under the authority of the Cabinet Secretary, the Authority and Regulatory Board;
WRA Rift Valley Catchment Area: Representation of WRA at the Basin Area level and performs all WRA mandate at the regional office;
Basin Water Resources Committees (BWRC): Though currently not yet instituted, BWRC is obligated to play advisory role to the WRA and County governments, at the respective regional office concerning; conservation, use and apportionment of water resources; the grant, adjustment, cancellation or variation of any permit, protection of water resources and increasing the availability of water; facilitation of the establishment and operations of water resource user associations;

Ministry of Environment, Energy, Water and Natural resources: This is a ministry of County Government of Baringo and has the mandate of developing legislation, policy formulation, sector coordination and guidance and monitoring and evaluation at the county;

Water Resource Users Association (WRUA): WRUAs are community-based association for collaborative management of water resources and resolution of conflicts concerning the use of water resources;

Water Service Provider (WSP): WSPs are mandated to provide water services within the area specified in the license and the development of county assets for water service;

Kenya Marine and Fisheries Research Institute (KMFRI): This is a statutory research institution mandated to carry out research on marine and freshwater fisheries, aquatic ecology including environmental and ecological studies, marine research including chemical and physical oceanography. It was established in 1979 following the enactment of The Science and Technology Act which commenced in July 1st 1977 (ST Act, cap 250, 2009). In 2013, the act was repealed and replaced by the Science, Technology and Innovation Act (STI Act 2017). Currently all research institutes, including those privately inaugurated, are guided by this act which was not the case before new the act came to effect on 24th June 2013. The establishment of KMFRI in 1979 is not the definite beginning of the institute but rather change of jurisdiction from an East African Community (EAC) owned institution and with operations in Kenya, Tanzania and Uganda, to one solely owned and with operations in Kenya only. The history of KMFRI dates back to the 1940s, when the then British colonial government set a limnology laboratory in Jinja, Uganda. After independence, the institute continued with its mandate and later it was taken over by the EAC after 1967. Following the collapse of East African Community in 1977, each of the each East African countries inaugurated their own institutions. The other five statutory research institutes are: Kenya Forestry Research Institute (KEMFRI), Kenya Agricultural and Livestock Research Organization (KALRO), Kenya Industrial and Development Research Institute (KEMFRI), Kenya Medical Research Institute (KEMRI), Kenya Trypanosomiasis Research Institute (KTRI). These institutes have a similar history and are also governed by the Science, Technology and Innovation Act (STI Act, 2017). They all have role in the management of lake;

Kenya Forestry Research Institute (KEMFRI): This is also a statutory research institution mandated to carry out research on forests and forestry systems to ensure sustainable use and conservation;

Ministry of Agriculture, Livestock and Fisheries: This Ministry was formed after the enactment of new constitution (COK 2010) by merging Ministries of Agriculture and Livestock and Fisheries development. It is responsible for formulating policy on agriculture and livestock. The department of agriculture is responsible for improving food production, while at the same time conserving the resources to ensure a sustainable supply of food needs. Its activities involve carrying out extension services on modern farming techniques, creating awareness on the sustainable use of resources, and educating farmers, among other tasks The Livestock department provides extension services on livestock management and breed improvement (Odada *et al* 2006). The agriculture docket has the highest number of statutory bodies compared to all ministries in the country. The State Department of Fisheries in this Ministry operates under the Fisheries Act (FA 2012). The department's role is to ensure sustainable use and conservation of fisheries resources;

Kenya Agricultural and Livestock Research Organization (KALRO): Like KMFRI and KEMFRI, *KALRO* is a public research institution under the Ministry of Agriculture, Livestock and fisheries. It is responsible for agriculture-based research, including developing variety of crops which are more productive and livestock breeds which are more productive;

Ministry of Environment and Natural Resources: This ministry is responsible for environmental conservation in the catchment, including its rivers and the lake. It advises the Government on the use of natural resources in such a way as to minimize environmental degradation. It also promotes environmentally friendly management interventions. Its activities are enshrined in the Environmental Act (EMCA 1999). National Environmental Management Authority (NEMA) is under the ministry;

Kenya Wildlife Services (KWS): This is a government agency responsible for wildlife management;

County Government of Baringo: This is the devolved government that was formed following new governance order of new constitution in 2010 (COK 2010). It headed by Governor who is the Chief Executive Officer (CEO) and is elected by direct suffrage by the residents of the county. The territory of county of Baringo was formed from the immediate former Koibatek and Baringo districts which existed before 2010. The new county government took over the duties and ownership of Municipal Council of Kabarnet and Baringo County Council. Baringo County Council owned the trust land where the lake is located, and collected taxes from revenue generated from the lake. The taxes are ploughed back, through facilitation of its personnel, who oversee the general management of the lake;

Rehabilitation of Arid Environment Trust (RAE): This is an NGO, which undertakes rehabilitation of eroded lands within the basin by planting pasture grass and proper management thus ensuring regeneration of indigenous trees and pasture. Once bare land has been rehabilitated and fully covered by grass, controlled grazing is practiced by rotation of livestock in different land paddocks and parcels. Thus, the land is not left bare and soil erosion prevented;

World Vision: World Vision is an NGO that is based at Marigat district. It ensures community resilience from climate shocks by assisting recovery from famine, extended droughts and floods which have lost crops and other resources;

Honey Care: This is a Community Based Organization (CBO) responsible for promoting good practices of honey production and marketing so that farmers maximize returns;

Women's Groups: These comprise Community Based Organizations (CBOs) composed of mainly women, with the common goal of improving livelihoods. They operate microenterprises as alternative sources of income. Such enterprises relieve consumption pressures on the lake and its resources, thereby contributing to improved resource management;

Beach Management Units (BMUs): This is organization of fishermen through which the fishermen co-management the fishery together with government. It provides the mechanism for public participation in the governance of the lake and its fishery. It is anchored in law in the fisheries Act;

Hotels and camp sites: These are private enterprises located at the shore of the lake. They provide hospitality facilities to tourists visiting the basin. The tourists are attracted to tour by the lake and its rich biodiversity. The locals participate in tourism in lake by providing boat service and tour guiding. Tourism is source of income to hotel owners as well as well to the local community. The lake is a resource which provides income directly to the local the community, conservation is therefore accepted.

10. Key Challenges to Lake Governance

10.1. Institutions

There is no single institution with authority over all aspects of Lake Basin management. The numerous institutions involved in the lake basin management in one way or another carryout their activities based on their legal mandate. This situation has been further exacerbated by formation of devolved county governments which was as result of enactment of the new constitution in 2010 (COK 2010) which altered the governance structure in country. County governments are independent; decide on their own development programmes, activities and budgets. This means county governments plan and prioritize their development programmes according what they perceive as important to them without consultant with other counties. Lake Baringo catchment falls under the jurisdiction of County Governments of Baringo, Nakuru, and Laikipia. However, out of the three counties, it is only Baringo County which is at moment is managing the lake. This is in spite of the fact that the counties of Nakuru and Laikipia have considerable effect on Lake Baringo given that they are sources of the major rivers which drain into lake and their residents use the lake services. It seems the County Governments of Nakuru, and Laikipia are not aware that an investment in the management of Lake Baringo catchment would benefit to its residents. Thus, there isn't need in investing in management of Lake Baringo as it doesn't give a return. An Ecosystem Service Shared Value Assessment (ESSVA) conducted in 2015 showed that people in upper catchment of the lake in Nakuru perceive that their actions contribute very little in the impairment of nature's functions of the lake. Consequently, citizens of Nakuru and Laikipia cannot lobby their county governments to contribute in the management of lake due to this perception. This is a challenge which can be tackled by building up the capacity of leadership of counties on environment and the need for the counties to cooperate in managing the lake jointly to achieve success.

There is low cooperation between the institutions and agencies which are the key players in management of the lake. Sectorial approach in management is the order of the day as each player implements programmes according to each sector policy (Odada *et al.* 2006). This approach is problematic as the different policies are not aimed at meeting one common goal of conserving the lake. There is negative vertical and horizontal interplay between policies (Atela 2016). The interaction between sector policies of land, fishery, water and forestry in the catchment is a good example to explain the nature of the interplay. Over half of the national land policy negatively affects forestry conservation policy when land policy advocates for human settlement in gazetted forests. There is centralized decision making with land allocation decisions vested in Minister in-charge of land matters and with little provision of cross-sectoral consultation. All these are key drivers of deforestation. In agriculture sector there is the over-arching measure in the act which aims at achieving 6% increase in agricultural production through mechanization. Mechanization in this case involves use of fertilizers, machinery and expansion farm land into forested land (Atela 2016). Thus, the agricultural policy of mechanization is an underlying driver of deforestation and Climate Change given the use of fertilizers and machinery which use fossil-fuel such as diesel to power tractors, combine harvesters etc. are agents of Greenhouse Gases (GHGs). Moreover, the agricultural policy affects water sector given that forests ensure both river flow and water quality. As deforestation occurs it changes the water bodies (river and lake) hydrological regime and consequently biotic cycles (Klein *et al.* 2007). For example, inadequate river water flow or no flow at all during the annual cycle means anadromous and catadromous fish are unable to reproduce. The Government allowed people to settle and create farms in Arabel and Marmanent forests. This resulted in deforestation of large portions of forests. The deforestation probably affected the hydrological regime of River Ol Arabel as river flow into Lake Baringo is no longer continuous through the year as was the case before the deforestation between 1982 and 2001. Another aspect of agriculture policy which negatively interacts with water and fishery sectors is the plan to increase area under irrigation agriculture in Kenya. Newly irrigation areas created are at Marigat which uses water from River Molo and around mouth of River Ol Arabel. Abstraction of water from the rivers results in inadequate water flow into Lake Baringo, thus reducing fisheries production. In order to achieve sustainable management of the lake they is need to harmonize the policies of which guide the activities of various institutions which are involved in the management of various aspects of the lake. This is the essence and challenge of Integrated Lentic-lotic Basin Management (ILLBM).

There is the challenge to lake governance of institutions in charge of lake management not working effectively as per their mandate. An example is role of government to protect water bodies from invasion of foreign weeds and fish from other water bodies. Fisheries officers are mandated to ensure that water bodies are protected from foreign biota such fish and/or invasive weeds. Thus, they are duty bound to inspect boats and fishing gears before they are moved to another water body as per articles 61 (1, 2) of the Fisheries (General) regulation of Subsidiary legislation of fisheries act (Fisheries Act 2012, pp. 17-64). This does not happen and the lake is exposed to invasive weeds and fishes despite legislation and institution being in place.

Another challenge of institutions is not considering the opinion and input of other institution involved in the management of lake. Around year 2002, the fisheries department started to build a modern fish catch landing 'bandas' at Kampi ya Samaki and Loruk in shores of Lake Baringo for the fisherfolk and general public. When the construction started, the fisheries officer in charge then was informed by local elders that he was constructing at site which forms part of the lake area and that he should transfer the construction to higher ground away from the lake shore. However, the information was ignored. Unfortunately, even before construction was complete, the 'banda' was submerged by lake water in 2012. Since then, up to date, the 'banda' has not been used and instead a makeshift 'banda' was constructed in a higher ground to cater for fish catch landing and trading. This is case were public funds are wasted and needs of public for whom a project is meant are not met because of lack of public participation and public opinion is taken for granted.

10.2. Policies and Laws

The issue of not adhering to policies and laws which have been enacted for the governance of lake is challenge for the sustainable management of Lake Basin resources. There are several policies and laws which have been enacted to guide the sustainable use of resources in the basin. These include and not limited to: Fisheries Act (FA 2012), Environmental Management and Coordination Act (EMCA 1999), Water Act (WA 2012), Merchant Act (MA 2009) and above all, the constitution of Kenya (COK 2010). The policies and laws have regularly been reviewed and amended over the years as new needs and better management principles emerge. Following promulgation of the new the constitution (COK 2010), most of acts have been reviewed and amended to confirm to the new constitution.

Despite the good intention of governance principles and regulations, the lake and catchment has continued to degenerate over the years. One of the reasons why the governance principles and regulations have not been so effective is due to largely non-compliance. This situation is dire given the fact that at times senior government officers who ironically are responsible for management of the resources in question are the ones who do not adhere to the law. There are several cases to exemplify this allegation. The first example is that of the stocking of the lake with Tilapia fry from Lake Victoria basin which was done yearly from 2011 to 2016 (Ogwai, Fisheries Officer, pers. comm.). The stocking did not follow the legal procedure as authorization was not given by the Directors of the National Environment Authority (NEMA) and Department of Fisheries, environmental impact assessment and environmental impact audit were not done before restocking was done. This action was contrary to article 42 1(a) of Environmental Management and Coordination Act (EMCA 1999) on introduction of an alien or indigenous animal to river or lake. And also the guidelines given by articles 25 (1, 2) and article 62 (1) of the Fisheries Act (FA 2012). Even public participation was not done as required by article 10 (2)a of the constitution of Kenya (COK 2010). It is not surprising that the stocking did not result in restoring the dwelling fish stock. The second example is the impunity of blocking the lake from natural and normal course.

This happened by construction of fish landing building (Banda), hotels, a dispensary, water tank in drawdown of lake which affects normal use of the lake by citizens. The third example is Fisheries officers abet the fishing in river mouths and breeding zones which is proscribed by articles 47 (1, 2) and 50 (1, 2) of the fisheries Act (FA 2012) in order to allow spawning fish to breed and fish fry to grow.

There is a conundrum of laws which govern the rivers and lakes. They are not harmonious and at times contradict one another. A classic example is the Acts of law that govern conservation of riparian zone of rivers and lakes which were enacted over last six decades since the late 1960s. It seems there was no across sector consultations during the process of enactment of the riparian zone laws in various acts which were meant to guide the operations of different sectors such as physical planning, agriculture, survey, lake management etc. Consequently, the various acts are liable to different interpretation by different professionals depending on the legal framework they belong to. An old Agricultural Act on basic land use (AA 1986, subsidiary legislation, p. 150) stipulates that the riparian zone should be 2 metres were cultivation is not allowed. If the river is greater than 2 metres then riparian zone becomes equal to the size of the river but not more than 30 metres. On the other hand, article 111 of 1994 survey regulations defined riparian zone of tidal rivers as the land not less than 30 metres in width above the highest water mark level (SA 1989, subsidiary legislation, p. 52). Under this act the riparian zone is reserved as government owned land (currently called public land (COK 2010)). The article excludes non-tidal rivers and therefore the river-line is not protected. Another shortcoming is the regulation gives the Minister the authority to vary the width of the riparian zone to less than 30 metres in special circumstances. This provision can be used for political exigencies ignoring scientific knowledge given that Ministers are usually politician. This shorting also applies to lake reservation which is given as not less 30 metres from the edge at ordinary high-water (SA 1989, article 112, p. 52). Further, the lakes reservation article did not mention dams or even man-made lakes which imply that there was no across-sector consultation when the regulations were enacted as 7-folks dams along River Tana had long existed. Some made-made lakes such Masinga (surface area of 120 km^2), Kiambere and Kaburu are larger than most natural lakes in Kenya such as Nakuru (surface area of approximately 5-45 km^2), Elmenteita (surface area 18-20 km^2), Lake Magadi (surface area 100 km^2), Lake Challa (surface area 4 km^2), Lake Jipe (surface area 25 km^2) and Bogoria (surface area 34-49 km^2). The Physical Planning Act of 1996 (PPA, 1996) decreed riparian zone to be less than 10 metres except where there is established flooding. Thus, it added more confusion to the Survey and Agriculture Acts aforementioned. The 2006 Environmental Management (water quality) Coordination Regulations on protection of water resources through article 6 (c) set the riparian zone as minimum of 6 and a maximum of 30 metres from the highest ever recorded flood level, on either side of a river (EMCOR 2006). However, the lake riparian reserve is not mentioned explicitly in the article giving room for people to take advantage and cultivate or undertake development within the riparian zone of lakes. Following the promulgation of new constitution in 2010, the old statutes had to be reviewed to confirm with new constitutional order. So the

Environmental Management and Coordination Act (EMCA 2016) amended the 1999 version (EMCA 1999). On the other hand, the Water Act 2016 (WA 2016) amended the 2002 version (WA 2002). However, the new amendments did not endeavour to solve the legal conundrum of the riparian zone. In 2018, there was demolition of landmark buildings encroaching on the riparian reserves in Nairobi which included among others, South East mall, Ukay mall, Gateway mall. With more than 4,000 building set for demolition in 2019 year there is resistance and people used the courts to delay demolition orders and challenging riparian laws due to lack of legal clarity. An example is the deferred demolition of Seefar apartments which are located in riparian zone of Nairobi dam in the vicinity of Kibra slum of Nairobi (Owino 2019). The court cases challenging demolition would perhaps demonstrate the need and lead to harmonization of the various laws governing riparian zone of water bodies in Kenya.

10.3. Participation

Public participation in the governance of public resources is mandatory in Kenya and is enshrined by articles 10 (2)a and 69 1(d) of the constitution of Kenya (COK 2010). The constitution which is the supreme law of the land and other laws are subject to it. To actualize the public participation there are several sector laws enacted to ensure and guide how the public participates. For example, in the fisheries sector, Beach Management Units (BMU) is the legal public body through which the fisher-folk participate and co-manage the fisheries resources. Fisheries (Beach Management Unit) regulations which came to effect in 2007 (FA 2012, pp. 145-168) regulates and support the activities of BMUs. In water sector, Water Resource Users Associations (WRUAs) are community-based association for collaborative management of water resources and resolution of conflicts concerning the use of water resources. For the forest sector, public participation is legalized in the Forest Conservation and Management Act (FCMA 2016) in part v on community participation by articles 48 to 52.

One challenge for most of the citizen organization which co-manage public resources is lack of finance for them to carry out their activities. WRUAs and Community Forest Associations (CFAs) experience this problem partly because there is no legal provision for funding them (FCMA 2016, pp 29-31). In case of BMUs the national government provides funds to manage some of their activities. Despite the funding there are challenges partly because the funding is channeled through fisheries county offices to ensure accountability of public funds. At times the money does not fund the activities BMUs as it not availed to them by the officers on the ground. And despite complaints from BMUs to higher authorities on misuse of funds allocated for BMUs no corrective action is taken. Since, BMU is under the support and supervision of Director of Fisheries and who supervises technical, legal and financial performance. The Director also delegates his authority to authorized Fisheries Officers to assist him. Thus, the Director or his representative control and can have undue influence on a BMU. Thus there is need to review the success and failures of BMUs with the view of improving accountability.

10.4. Knowledge and Information

Vandalism of scientific equipment used to measure water parameters is a common feature in the basin. This affects mostly equipment for measuring water discharge such water gauges and automatic river water discharge. Human beings are the major culprit of the vandalism but also natural forces such as erosion of river banks also contribute. For example, there is a gauge at Lake Baringo which was submerged by water with increasing lake level; however, a new one has not been installed for years. The end result is gaps in data sets or no data altogether.

Another challenge is not being able to sample enough data to able to make scientifically logical deduction to guide in the management of the lake basin. A classic example is on hydrology and climatology. Data for river discharges is not adequate to estimate the amount of discharge which enters lake because river gauges are not installed near river mouths for at least all the major rivers which drain in the lake. Overall, in the lake basin river discharge started in 1926 and has continued to date with varying levels of success. A total of 26 river-gauging stations have been installed over years in various locations in the rivers afferent to Lake Baringo. However, most are not currently operational. There is a station on River Molo where data has been collected from 1926 to date i.e. for 91 years. Another station on River Rongai which is a tributary of River Molo data was collected for 67 years since 1931, however, after 1998 no data is available for about 19 years (Figs 4, 5 and 6). Data gaps are the norm in discharge data for the basin. This is caused by non-replacement of gauge meters when they get vandalized by humans or natural forces.

The lake water balance has not been determined yet and it might be difficult to establish a water balance based on empirical evidence. This is so due to lack of enough and quality hydrological data for the basin. For example, it now over century since 1903 when rainfall monitoring started in the basin yet the current gauge density of 97 km^2 $gauge^{-1}$ is less than the World Meteorological Organization's recommendation of 17 km^2 $gauge^{-1}$ (Odada *et al.* 2006). In addition, there is no public/government weather monitoring station by the shores of lake. The nearest weather station is 20 km away at Marigat.

The aforementioned status of knowledge of hydrology of Lake Baringo is a challenge in the sustainable exploitation of the water resources. For example, we do not know how much water should be abstracted for irrigation without affecting the fauna and flora in both the rivers and the lake. Thus, there need to invest in acquiring adequate and quality data on hydrology.

Sharing of data between government institutions is challenge. Data has to be bought by scientists from other government agencies yet they all belong to the same government. For example, on river discharge data is collected by WRMA while data on climate data such rainfall, temperature humidity is collected by Kenya Meteorological Services. To access hydrology data and climate data, a scientist from KMFRI has to purchase it.

Collation of data, analysis and presentation in manner useful to stakeholders is not done. The databases are not created and updated as scientists in institutions holding data are not motivated as it not demanded of them by the employers. There is generally poor storage of data by various institution involved in managing the lake. There is possibility in future that data could get lost. All data has not been digitized more so the historical data. Some of the historical data is stored in files in typed hardcopies or handwritten papers and with time due to old age they are getting worn out. There is a possibility of loss in case of fire breakup. There is need to archive data in different places and create databases. This will ensure that the data is secure and can be easily be retrieved. Inaccessibility of contemporary data harbours research in the present and even in future, when there were be need to infer historical trends.

Information dissemination is a challenge due lack of finance for holding frequent and regular meetings of stakeholders. Lack of funds harbours the publication and dissemination of non-technical documents that are easily understood especially by non-professional and various stakeholders. Information dissemination can be improved by first publishing and sharing the published information with local institutions which directly manage the lake. Regular workshops (biannual) among researchers and other professionals would improve information dissemination. A regular workshop, at least annual of all stakeholders on management of lake is also very crucial.

10.5. Technology and Innovation

Construction of conventional pond sewerage system is difficult and expensive due to the rocky and hilly terrain in large part of catchment. For example, Kabarnet town is located on top of Tugen hills with two of sides of mountain range acutely sloping. Some residential areas are sprawled to other hills. A large area of the town is rocky. Construction of conventional pond sewerage system is challenge due to the sloping and rocky terrain. May be the town needs to be served by several sewerage plants to serve the different slopes as pumping upstream wastewater is expensive. Since construction of conventional pond sewerage system is challenge in most parts of the catchment, clearly new innovations are required so that other appropriate systems of waste water purification are used.

Supply of potable water is also challenge due to the hilly terrain. Kirandich dam was built to supply potable water to Kabarnet town. However, the high cost of electricity used in pumping water uphill on a very steep slope has always been issue and many times the water supply company is in electricity charges arrears. The sale of potable water from the dam to the town cannot pay for the cost of supplying water. The challenge is to find an alternative source of power for pumping potable water to the town.

Land has not been set aside for construction of public utilities such as sewer systems in most small townships in the catchment such as Mogotio, Marigat, Kampi ya Samaki and Loruk. In future it will be expense and a long process to acquire land for waste disposal. Thus, when it will become absolutely necessary to construct solid waste disposal infrastructure, land will have to be to be purchased to compensate people so as to give way for construction. The current practice of human waste disposal is through pit latrine. Once a pit latrine is full, usually it is abandoned and a new one is constructed. It is only in big towns such as Nakuru where the services of exhausters are available. It is not clear where exhausters dispose their waste as most towns have not developed the 'Kabata' system as in Japan where such waste is treated. Use of Eco-toilets is cheap and simple technologies which can assist alleviate the problem of filling of pit latrine. But the challenge would be the acceptance as the local population in the catchment does not have the culture of use of human waste as manure in farms. Thus, to implement such system, human capacity development would be necessary for that system to be accepted by the local communities. Another challenge is there is no policy of separation waste material at point of waste generation (e.g. household level, offices, and factories). Hence, biodegradable waste is not separated from non-biodegradable wastes and hazard material is not separated from non-hazard waste. As such, bottles with remains of pesticides and herbicides end up in pit latrines. Over time hazard continues to accumulate and this will continue to be a danger as more water wells continue to be drilled all over the catchment. There is technology in world to recycle waste material which can be adopted. The challenge could be that the technology is expensive as most cases it is owned by private entrepreneurs who are keen on making a return to their investment. There is need for locally based research to develop methods to recycle waste material to meet the needs of the catchment as importing technology is expensive.

The most of Lake Baringo catchment is largely classified as an ASAL and such there is need to use available water resources efficiently as much as possible. This is crucial given that the catchment is experiencing climate change and the concomitant shocks such as erratic rainfall, floods, droughts, wells and rivers drying; and famine which will continue becoming worse (Koskei 2018). Water from the perennial rivers afferent to Lake Baringo is abstracted and used for irrigation agriculture. This is challenge because the rivers dry during part of year and it not been established what is the contribution of irrigation to the drying of the river. In most cases farmers abstract water from rivers illegally and the amount they use is not metered. Whenever farmers are abstracting water from rivers and see any government vehicle they usually ran away at times even leaving their water pumps as they fear being arrested. This demonstrates that farmers are at least aware they are undertaking an illegal action and they are supposed to acquire water abstraction licenses or permits. Farrow irrigation system is the type of irrigation system which is used in most parts of the catchment. Since water is scarce commodity in the catchment there is need to switch from farrow irrigation system to systems which uses little amount of water as much as possible such as drip irrigation system. The challenge is the institutes in charge of irrigation have not internalized the role they play in sustainably managing the resources of Lake Baringo catchment.

There a general problem with maintenance of infrastructure, machine and instrument used in management of water bodies. There is a generally apathy in maintenance which exemplified by instances when a repair which does not require expenditure of money is not done and decay or damage is allowed to continue. For example, a nail used to hold wire on post on fence would get loose, but instead of hammering it back in position, no remedial action would be taken. The nail would finally fall and progressively more nails would get loose and finally the fence falls. Fences are enacted to protect water technological infrastructure such as water purification plants, sewerage plants or weather stations. Once a fence falls, the technology infrastructure falls prey to vandalism and gradually destroyed until finally it stops functioning. Similarly, a malfunctioning instrument would require repair or even cheap spare part replacement. However, repair would not be done and the instrument would be left to rot. Later another machine would be purchased. The net result is work is not done for some time (or even years) before the purchase to replace the machine is done.

Land tenure in the ASALs parts of the catchment is challenge to governance in terms of containing sedimentation into the lake and rivers. In the ASALs there are no individual land titles. Usually land is owned by the clan and if it is registered it has group ranch title. Since the land is owned by group, there is no individual motivation to use the land sustainably. So there is no effort to control soil erosion and sedimentation to the lake and rivers. Grazing of livestock is not controlled and there is overgrazing of pasture leaving land bare exposed to erosion. RAE demonstrated it is possible to rehabilitate degraded land under group ranch land tenure ship. The community surrendered a parcels of their land to RAE for rehabilitation at Kampi ya Samaki near shores of Lake Baringo. The parcels were divided into paddocks and fenced using electric fence powered by solar power to prevent livestock from accessing the protected parcels. Furrows were dug and pasture grass seeds planted before the start of the rainfall season. Within week after the start of rains grass sprouted and it was let to grow without livestock grassing. Most of the bare land was covered within a within season and also indigenous trees started grow. Once the degraded land was rehabilitated and fully covered by grass, controlled grazing was practiced with rotation of livestock in different land paddocks. Thus, the land was not again left bare and soil erosion prevented. A few residents around Lake Baringo have adapted this system of land rehabilitation. Unfortunately, the county or national government did not take up and up-scale rehabilitation of degradation of land in catchment despite the project success.

This is example of the challenge of slow adoption of available technology which has been tested successfully locally and which can be used to improvement the health of lake.

10.6. Financing

Following the enactment of new constitution in 2010 and establishment of County Government of Baringo in 2013, the county government assumed the management of Lake Baringo (COK 2010). However, the County Governments of Nakuru and Laikipia did not follow suit in adopting the management of the lake. Currently, it is only Baringo County which is involved in management of the lake. Probably, ignorance is the challenge which causes the Government of Nakuru and Laikipia not to participate in management of Lake Baringo as they presume that the lake falls entirely in Baringo County, and it is not their business to manage and contribute finance. This is in spite of the fact that the lake catchment also falls in these counties and their residents use the services of lake.

Currently, it is only Baringo County government which has enacted laws and regulation to exploit and manage the resources of the lake. Taxes are imposed for fishermen and fish traders to be allowed to fish and trade in fish. Hotels, campsites and other business premises pay annual land fee and trading licenses. A reptile museum was constructed by the county and earns the county revenue. All monies in form of taxes and revenue including those from other sectors of the economy in the county are banked in one county's consolidated bank account. Then the budget for all county projects and activities is prepared by county government and approved by the County Assembly based what they perceive as their priority. Over the years money allocated for the management of the lake basically covers salaries and emoluments. Recently, the county has been sponsoring annually the boat race at Kampi ya Samaki. Hardly any money is allocated for the development and maintenance of lake resources. There is apathy towards the county government as local citizens who live around the lake argue that they have never seen a return of taxes they have paid in form of investment in development. They allude to the fact that the county government has never built single toilet to serve the local lake users and even tourists. Hence they do not participate in meetings organized by county government for budget making. This further aggravates the situation as their issues are not presented; articulated and county government cannot prioritize and include them in the annual budget. The indifference crystallized and local citizens at Kampi ya Samaki took the law into their own hands. They gathered, demonstrated and forcibly removed the road barrier enacted by county government to enforce tax collection before tourist gain entry into Kampi ya Samaki township. Few people were arrested following orders of the county government and charged in court. However, the county had to withdraw the court cases and removed the road barrier. Though the citizens won, the issue of the barrier still lingers in the governance of the lake. Years have passed and citizens see some positive aspect of the road barrier. They opine that road barrier used serve as place where: i) statistics was collected e.g. on number tourists visiting the lake, ii) inspection of boat and fishing gear to prevent introduction of foreign fish and weeds into lake. Today the entry is free for all iii) to confirm whether fish traders have paid fish levies before transporting fish to sell to other markets iv) there was security check. The only negative issue about the barrier was the tax tourists were paying before gaining access to Kampi ya Samaki Township which they thought was not justifiable. Thus, the taxation could have been annulled by passing a by-law in the County Assembly without removing the barrier. Perhaps the removal of the road barrier was not well thought. The county government should have engaged in dialogue and consultation with various professionals instead of rushing to arrest the local without digging into what the issue the local citizens were complaining about.

The tax paid by fishermen and fish traders is not enough to cater for the management of the fishery. More money has to be sourced from other sectors of the county economy. How much a sector is allocation in the annual county budget depends on return on investment it gives. The more return on investment a sector gives the more money it is allocated. The fisheries and tourism sector has a low return on investment for the County Government of Baringo. Thus, on basis of economic valuation alone, the allocation in the county annual budget for the lake management is expected to be small compared to other sectors of the economy. The challenge is to identify more potential investment options and increase economic value of the Lake Baringo. For example, tourism sector has not been exploited fully as there are numerous sites were hotels can be set.

Economic consideration is not the only factor influencing county budget, political influence is another factor. Political leaders such as Governors can sway budget allocation to the sectors which can give them popularity. Thus, voters in county would vote for a Governor who favours them in terms of development and economic empowerment. The highland regions of the County of Baringo are more populated compared to the lowlands. Further the highland is occupied mainly occupied by one harmonious community compared to lowlands which inhabited several discordant tribes and sub-tribes (clans). The lowland communities are in state of conflict due to competition for land, pasture for grazing, wealth (livestock) and fishing grounds and cannot unite to harmoniously manage their resources. Leadership of the county comes from the highland community as they form a larger voting block compared to divided lowlands communities. Since the leadership of the county is in the hands of highland people who perceive the lake as having minimal monetary value, then allocation of county resources would be more biased toward meeting the needs of the highland communities. All in all, the challenge is to allocate county resources equitably as is the requirement of the constitution, otherwise the citizen have the legal right to demand for their share of development (COK 2010).

Odada *et al.* (2006) estimated that the lake requires an investment of medium size project (MSP) worth US $ 750,000 for time frame of a minimum of three years for an integrated lake basin management programme to achieve results. Since last UNEP/GEF-funded LBCB project concluded in 2003, no new project at that scale has been implemented for the improvement of health of Lake Baringo to date.

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