**Assessment of Management of Lake Malawi Basin through Application of ILBM-Based Tools**

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## 1.0 Introduction

Proper management of lakes and their basins is crucial for the well-being of society and the development of the economies that lakes support as well as the sustainability of the lake basin ecosystems. This is because lake basins, vast and complex as they are, are also very vulnerable to the effects of human activities. Lake Malawi is one of the African Great Lakes and is well known for its fish biodiversity which is the greatest in the world for freshwaters (Ribbink et al. 1983; Bootsma and Hecky 1999). The lake and its basin are shared by Malawi, Mozambique and Tanzania with the largest portions of the lake and basin in Malawi. The lake basin is a valuable resource to the riparian countries. In Malawi, for example, it is important in many aspects including hydro-electric power generation (on its only outlet), fisheries, domestic and industrial water supply, rain-fed and irrigated agriculture, navigation, mineral resources, and tourism. The main problems in the Lake Malawi Basin are deforestation, soil erosion, overexploitation of some fish species, pollution, and excessive extraction of water from some rivers (GoM 1994; Bootsma & Jorgensen 2005; Chafota et al. 2005; Jamu et al. 2011; Ngochera 2014). Emerging threats include increasing mineral resource extraction, industrialization (Jamu et al. 2011), invasive species and climate change.

The management of lake basins is complex as it requires the integration of approaches across various sectors and stakeholders. Integrated Lake Basin Management (ILBM) is a management approach based on the proper understanding of the biophysical characteristics of lake ecosystems and how they interact with humanity (ILEC 2005).

This module explains the indicator framework that was developed and piloted for assessing the management of Lake Malawi basin through application of ILBM-based tools. The module is based on the assessment that was carried out on the Lake Malawi Basin from which several publications and a doctoral thesis ensued. In this module, a step-by-step guide on how the assessment was conducted is given in a summarized synthesis. For more details, the reader is encouraged to see Muhandiki et al. (2014), Chidammodzi and Muhandiki (2015a, 2015b, 2016, 2017), and Chidammodzi (2016 *unpublished doctoral thesis).*

The overall objective for the assessment was to conduct a comprehensive assessment and analysis of the issues, needs and challenges in the management of the Lake Malawi Basin using ILBM-based tools. An indicator-based framework for assessment was developed; status of the Lake Malawi Basin was determined by applying ILBM principles; issues, needs and challenges in the management of the Lake Malawi Basin were identified and analyzed through SWOT analysis; and, critical points requiring management attention were identified through application of systems thinking approach. The following sections give a brief overview of ILBM and then explain the steps followed in the assessment.

## 2.0 A Quick Look at ILBM Principles and Key Concepts

The ILBM concept is a management concept based on six principles/pillars of governance as follows:

1) *Policies* –they establish the foundation for other aspects of management e.g. institutions and legislation.
2) *Institutions* - are at the centre of lake basin management since they implement the measures for management e.g. administer laws, provide a forum for involving stakeholders, gather and store knowledge, sometimes establish policies, etc.
3) *Participation* –active stakeholder and public involvement fosters a better understanding of the implications of lake basin issues and helps gain support for better lake basin management.
4) *Technology* – if appropriately applied, can complement other interventions in addressing lake basin issues.
5) *Information and science* - since lake ecosystems are complex, reliable information is particularly valuable to guide decision-making.
6) *Finance* - long term availability of stable funds is necessary to implement and sustain management activities.

ILBM compliments the Integrated Water Resources Management (IWRM) approach by highlighting the three unique characteristics of lakes and their management implications which need to be considered when formulating management plans. These characteristics are *integrating nature, long retention time* and *complex response dynamics* (see ILEC 2005, for details). The combination of these three characteristics is unique to lakes. ILBM can be considered the ecosystem approach, focused on lake basins

There are several underlying key conceptual tools of ILBM that need to be factored into management programs for lakes. The conceptual relevant to the Lake Malawi Basin are presented below:

*Lake characteristics:* Lake Malawi has a large surface area, is very deep and hosts the world's greatest freshwater fish biodiversity. It has a long flushing time and a long residence time (Bootsma and Hecky 2003).

*Ecosystem services:* The lake and its basin provide a wide diversity of values which include fisheries resources, supporting human settlements, supporting both rain-fed and irrigated agriculture, tourism, supporting diverse ecosystems, moderating local climate etc.

*Basin approach:* Most of the threats that the lake is facing originate from the catchment hence the need for a basin approach to the management of the lake.

*Socio-economic issues:* For management approaches to be relevant and successful, they need to also address some important socio-economic issues that are related to lake basin management. Integrated approaches in water resources management are linked to poverty reduction (Mulwafu and Msosa 2005) and lake basin management therefore, needs to contribute towards enhancing the well-being of society as well.

All these aspects of the lake basin need to be taken into consideration in the management and utilization of the lake basin. Hence, ILBM is a management framework that advocates for lake management approaches that are based on the proper understanding of the biophysical characteristics of lake ecosystems and interactions between lake ecosystems and humanity.

## 3.0 Methodology

Generally, a systems thinking approach was applied and the Lake Malawi Basin was taken as a unit. Mixed methods research design was utilized. The lake basin system was looked at in two dimensions: the socio-economic subsystem and the ecological subsystem. However, due to resource constraints, it was not possible to assess the entire basin encompassing all the three riparian countries. The assessment was therefore limited to the Malawian side of the lake basin. Many of the issues, however, are common across the riparian countries as literature suggests. Nevertheless, a comprehensive assessment encompassing all the three riparian countries is encouraged whenever resources allow.

### 3.1 Analytical Framework

Moving towards better lake basin management is a cyclic process that undergoes constant improvement as progress is made and new insights emerge (Nakamura and Rast 2011). Figure 1 represents the process for improving basin governance through ILBM in the following steps:

1. *Acknowledge the state of the lake basin* – start by understanding the present reality i.e. the physical, chemical and biological characteristics, current uses, etc.
2. *Identify issues, needs and challenges, and envision the future state of governance* – analyze the challenges in relation to the six governance pillars, then foster and evolve a shared vision.
3. *Seek ways to strengthen the governance pillars through monitoring, reconnaissance survey, inventory and databases*.
4. *Assess the governance improvements* – utilize indicators to monitor the impact of resource utilization, conservation and management approaches.
5. *Continue with efforts to eventually reach the long-term goal.*

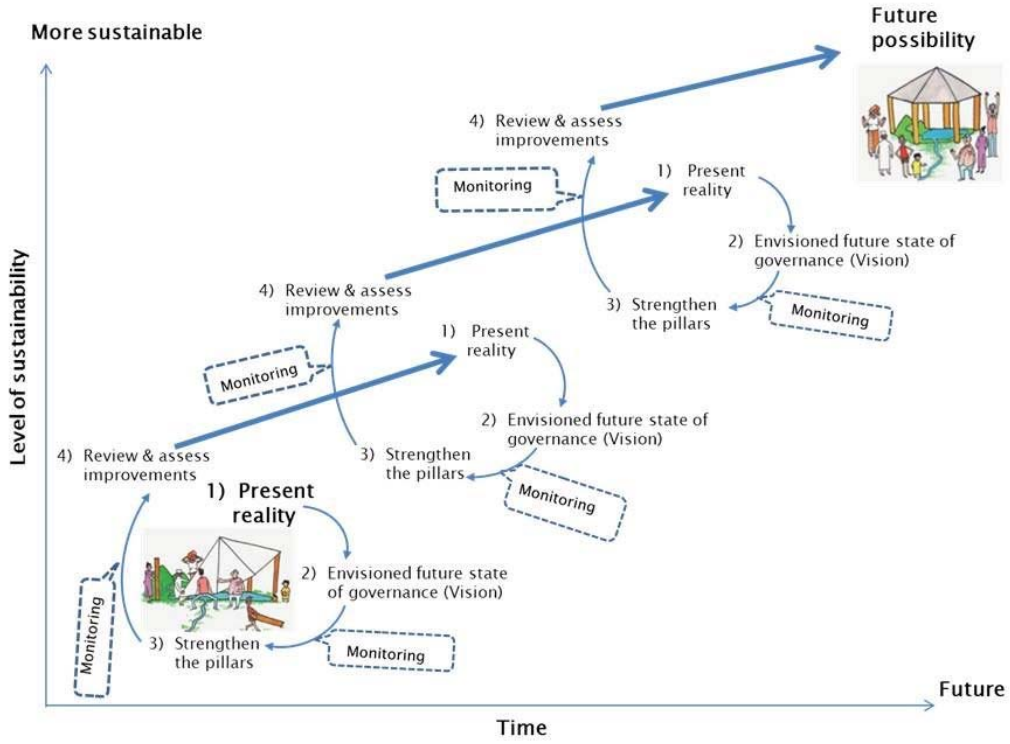


Figure 1. The cyclical process for improving lake basin governance through ILBM (Modified from Nakamura and Rast 2011).

Through this gradual and repeated process, adjustments to the approaches and vision are made taking on board new insights as they emerge. Such cyclic management process allows the governance system to capture and sustain incremental improvements and build on them, ultimately leading to greater sustainability of the lake basin.

### 3.2 Applied Methodology

The procedures that were applied in the study are outlined in Figure 2 and explained in the following sub-sections.

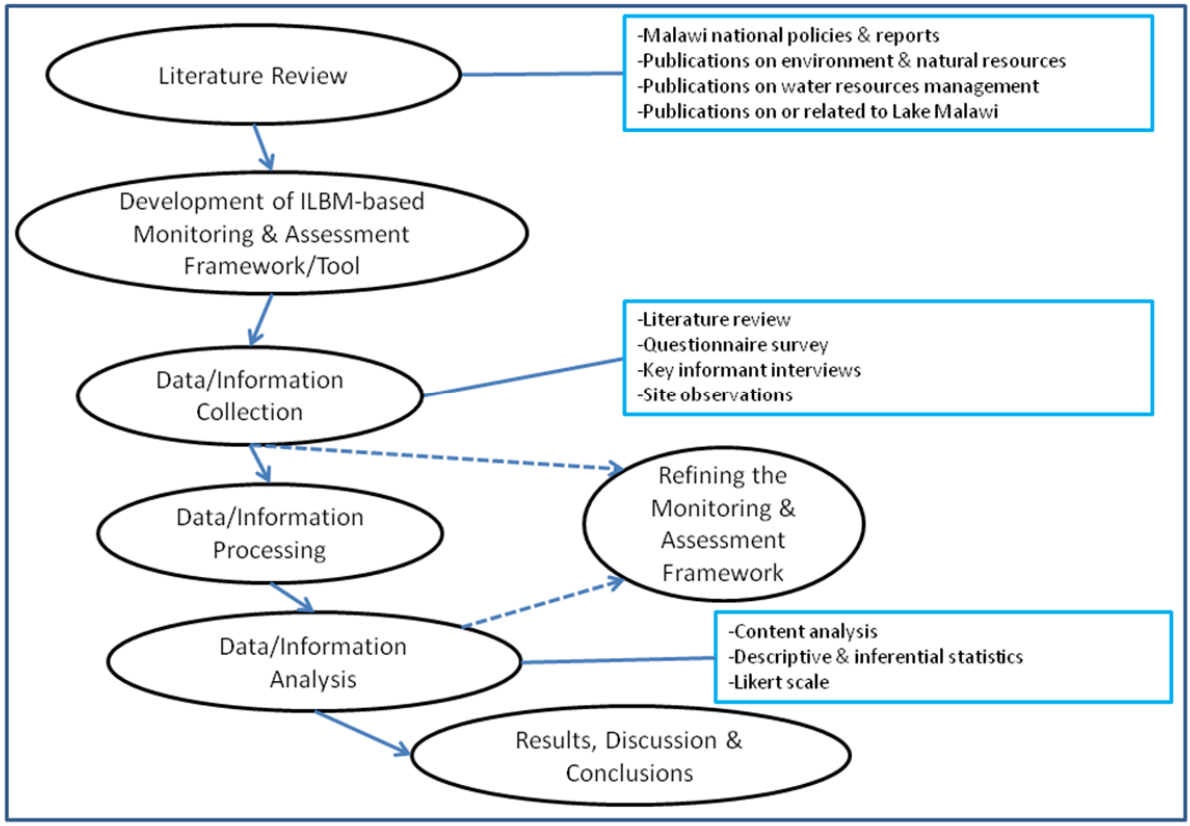


Figure 2. Applied research methodology

#### 3.2.1 Step 1: Initial Literature Review

This was the first step undertaken to provide a theoretical background for the assessment. A wide range of literature was reviewed including;

*Policies and reports for Malawi in the environment and natural resources sector* to understand the country's goals and strategies in the sector.

*Publications on natural resources management in general and water resources management in particular* (such as IWRM, ILBM, journal papers and publications by global and international organizations (e.g. United Nations and the World Bank). This was to understand the global perspective regarding water resources and environmental management in general as well as lake basin management in particular.

This review guided the first cycle in the cyclical process for improving lake basin governance through ILBM as depicted in Figure 3.1-1. The reality of the lake basin was understood, a Lake Malawi vision was deduced, and indicators for monitoring and assessment were identified.

*Deduced Vision for the Lake Malawi Basin*

A shared vision plays a crucial role in moving towards sustainable management and utilization of lakes. The literature reviewed contain descriptions of the conditions that are desirable for water resources in Malawi in general and Lake Malawi in particular. These conditions, expressed explicitly in some cases and implicitly in others, were extracted and integrated into a vision for Lake Malawi, which is presented in six vision statements. Reflection of the lake values, relationship with the identified threats, and linkages with the major issues highlighted in literature (i.e. findings of the Survey of the State of World Lakes etc.) were the criteria used to select the statements. Malawi desires to achieve a state whereby:

1. Every citizen is aware of the importance of the lake and basin to the nation and is motivated to protect their integrity (National Water Policy; World Lake Vision; McKaye et al. 2008 etc.).
2. The lake basin sustainably supports human settlements and activities by providing them with the resources necessary for their well-being (National policies in the natural resources sector; Chafota et al.2005 etc.).
3. Water quantity and quality necessary for sustaining the viability of humans and dependent ecosystems (water for all) is maintained (National Water Policy; Malawi Integrated Water Resources/Water Efficiency (IWRM/WE) Plan; Malawi Growth and Development Strategy (MGDS) etc.).
4. Diversity and sustainable populations of fish are maintained and dependent livelihoods are secured (National Water Policy; National Fisheries and Aquaculture Policy etc.).
5. The lake's buffering capacity is maintained (National policies in the natural resources sector).
6. The nation's pride in the lake is preserved and the inheritance of future generations safeguarded (McKaye et al. 2008).

Development of indicators was guided by the literature review. In addition to the literature indicated in section 3.1, a review was also conducted on lake management approaches in other lakes (the Laurentian Great Lakes in North America, Lake Constance in Central Europe, Lake Victoria in East Africa, Lake Biwa in Japan, Lake Chad in West-Central Africa and the Lake Chilwa Wetland in Malawi). These cases were selected in consideration of size, transboundary nature (for most of them), significance, and management history. Indicator development approaches taken by others around the world were also reviewed to understand the global perspective in the context of water resources and lake basin management and to determine if there are commonalities among various strategies. These were approaches taken by the Global Environment Facility (GEF) (Duda 2002), World bank – Environment Department's Economic and Sector Work (World Bank 2005), Transboundary Waters Assessment Program (TWAP) (ILEC 2011), and the Environmental Performance Index and Pilot Trend Environmental Performance Index of the Yale Center for Environmental Law and Policy (Emerson et al. 2012). A set of indicators for monitoring and assessing ILBM in the lake basin was then developed and published (Chidammodzi and Muhandiki 2015).

This indicator framework was then used in the next cyclical process of moving towards better lake basin management. A next level study was undertaken, using the indicator framework as guide to monitor and assess the Lake Malawi Basin from the perspective of ILBM. The framework underwent several improvements during the assessment as new insights emerged. The final version used is presented is section 4.0. The following section explains how this ILBM-based framework was piloted to actually monitor and assess on-the-ground management situation of the Lake Malawi Basin.

### 3.2.2 Step 2: Assessment of the Management of Lake Malawi Basin Using ILBM Tools

#### 3.2.2.1 Data/Information Collection

Both primary and secondary data/information were utilized. Data and information were collected through document review, questionnaire survey, key informant interviews, and site observations.

*Document Review*

This step is a continuation of the literature review discussed earlier in Step 1. The highlight of the document review at this stage is that it provided information for some of the indicators. In addition, it helped contextualize the findings of the study. Table 1 lists the main documents reviewed with regard to Malawi's policy direction.

Table 1. Major Documents Reviewed in the relevant sectors

| Sector | Documents |
|---|---|
| Environment | National Environmental Policy (2004); Environment Management Act (1996); National Environmental Action Plan (1994); National Biodiversity Strategy and Action Plan (2006) |
| Water | National Water Policy (2005); Water Resources Act (1969; 2013); IWRM/WE Plan (2005) |
| Sanitation | National Sanitation Policy (2008) |
| Agriculture | The Agriculture Sector Wide Approach - ASWAp (2010) |
| Irrigation | Irrigation Act (2001)<br>National Irrigation Policy and Development Strategy, 2000 |
| Forestry | National Forest Policy (1996); National Forestry Program (2001) |
| Fisheries | National Fisheries Policy (2012); Annual Fish Frame Survey Report (2008); Fisheries Conservation and Management Act (1997) |
| Others | Decentralization Policy (1998); Local Government Act (1998); National Strategy for Sustainable Development, NSSD (2004); The Foreign Policy of the Government of the Republic of Malawi (2010); Malawi Growth and Development Strategy MGDS II (2011) |

*Questionnaire Survey*

A questionnaire survey was conducted in five out of the 15 basin districts. It targeted local community institutions in the three categories of farmers, fisherfolk and local forestry management groups. These constitute the majority of the lake basin population and also represent the main users of the lake basin. Judgment non-probability sampling was utilized. This sampling technique relies on the researcher's judgment as to who is most suited to provide information relevant to the research objectives (Kumar 2014). This type of sampling is useful when the study aims to describe a phenomenon or understand something which is little known (Kumar 2014). The technique is appropriate for this study as it has aspects that are descriptive and exploratory.

*Key informant Interviews*

Key informant interviews were conducted at the Departments of Environmental Affairs, Fisheries, Land Resources Conservation and Development (agriculture), Forestry, Water Resources, Irrigation, Energy, and the City Councils of Lilongwe and Mzuzu. Semi-structured questionnaires were used in the interviews. Formulation of the questionnaires was also guided by the indicator framework and questions were organized according to the six ILBM pillars and customized as

appropriate for the sector. Other researchers and sector officials were also interviewed as appropriate throughout the course of the assessment.

*Site Observations*
Site observations were also guided by the indicator framework. Visits were made to seven out of the fifteen basin districts/cities. Field notes and pictures of the situation in the basin (e.g. dump sites, river bank and forest conditions) were taken to enhance understanding of the status of the lake basin.

### 3.2.2.2 Data/Information Processing and Analysis

Data and information were analyzed using both descriptive and inferential statistics. For comparison and indicator scoring purposes raw data values were normalized using a five point Likert-type categorical scale. A scale of 1 to 5 was used where 1 is very low/very weak and 5 is very high/very strong as Table 2 shows.

The collected data/information were arranged into two different data sets, one for key informant interviews, documents review and site observations and the other for questionnaire survey. Through content analysis, responses to open-ended questions (from both questionnaire survey and key informant interviews) were manually coded based on key words contained therein i.e. the data were scrutinized for patterns, inconsistencies and differing views from the different groups of respondents. The data were sorted and categorized to allow quantification of the different patterns that frequently emerged while capturing unique views that appeared to enhance understanding.

Table 2. Rating Scale

| Rating | Interpretation |
|---|---|
| 1 | Very low/very weak (≤ 20%) |
| 2 | Low/weak (21- 40%) |
| 3 | Moderate (41 – 60%) |
| 4 | High/strong (61-80%) |
| 5 | Very high/very strong (≥ 81%) |

The Likert scale aided indicator scoring and was used to obtain averages especially regarding rates provided by key informants and survey respondents. Each indicator has a minimum potential score of 1 and a maximum of 5. The same is true for each pillar. Table 2 shows how the indicators and sub-indicators were scored. Targets were set for some of the sub-indicators based on existing targets either in Malawi or relevant literature. Where an existing target is adopted, the source of the target is indicated after the target value (see the aforementioned doctoral thesis for details). The source is not indicated for the targets the study proposed. Targets were not set for some indicators. This is either because target setting for them requires an analysis of other related aspects which is beyond the scope of the study, or the indicators were only establishing a baseline at this step which will act as a benchmark for future assessments. The sub-indicators were assessed against the targets in relation to the applied Likert scale. This is similar to the proximity-to-target concept applied in the 2012 Environmental Performance Index approach (Emerson et al., 2012). However, for the sub-indicators for which no specific target was set, the rate provided by key informants was applied. Details of how each indicator was utilized in the assessment can be found in the aforementioned doctoral thesis

## 4.0 Results

### 4.1 ILBM Monitoring and Assessment Framework/Tool

The proposed indicators focus on measuring progress in the development of an enabling environment for lake management. The main criterion for selecting the approach was based on understanding the lake and its basin as a unit and therefore the ILBM framework forms the basis of the approach.

One fundamental assumption in the proposed indicator framework is that the following seven sectors are key in the management of Lake Malawi/Nyasa basin; fisheries, agriculture/land resources conservation and development, irrigation, forestry, water, sanitation, and environment. Other sectors that were considered are health, gender, parks and wildlife, industry, mining, energy, education, infrastructure, weather and climate, and information. Most of the indicators in this assessment were developed in consideration of the key sectors. The indicator framework that was developed and used as a guiding tool in the assessment is shown in Figure 3 (a and b).

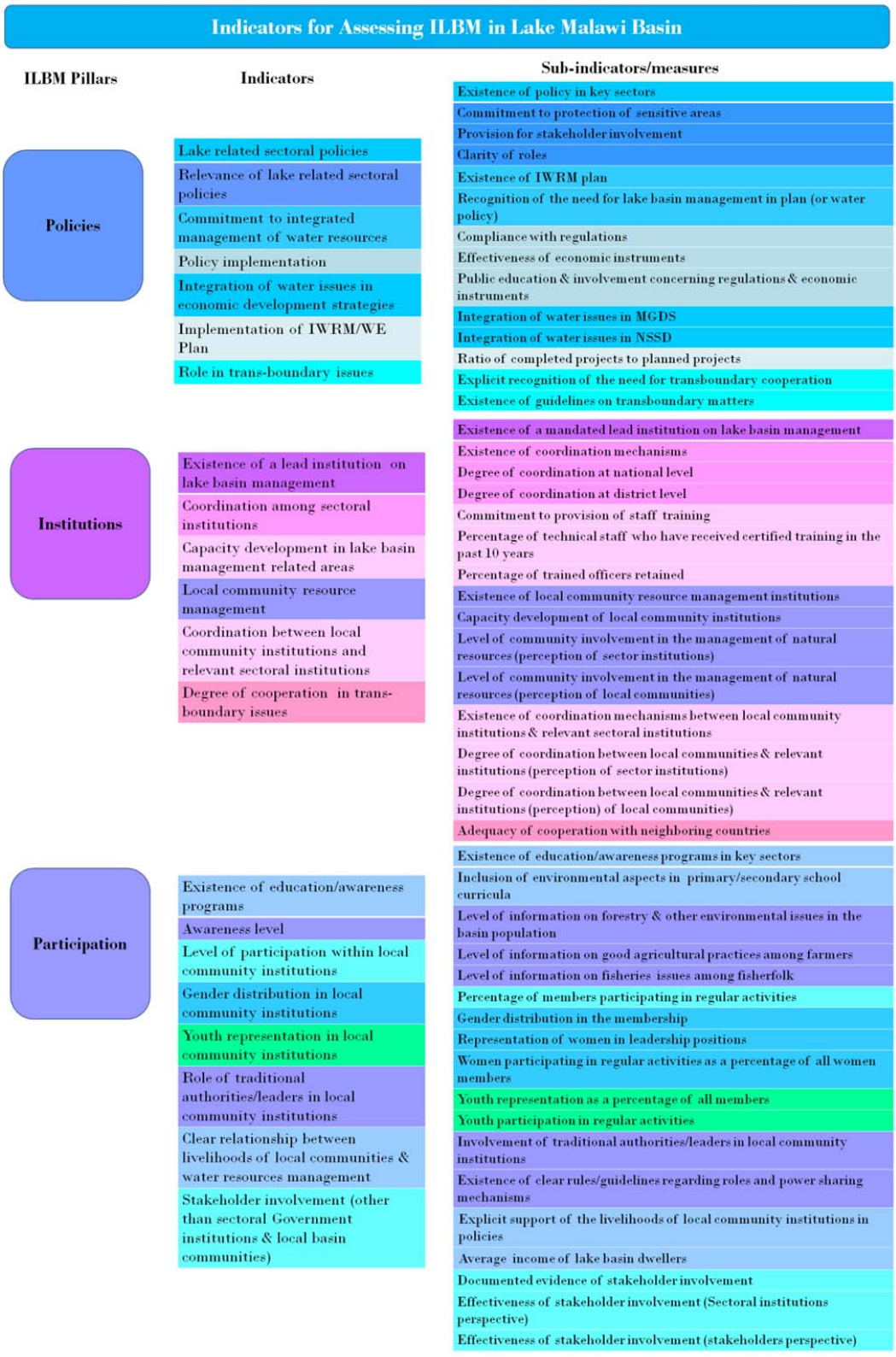


Figure 3 (a) Indicator Framework for Assessing ILBM in Lake Malawi Basin

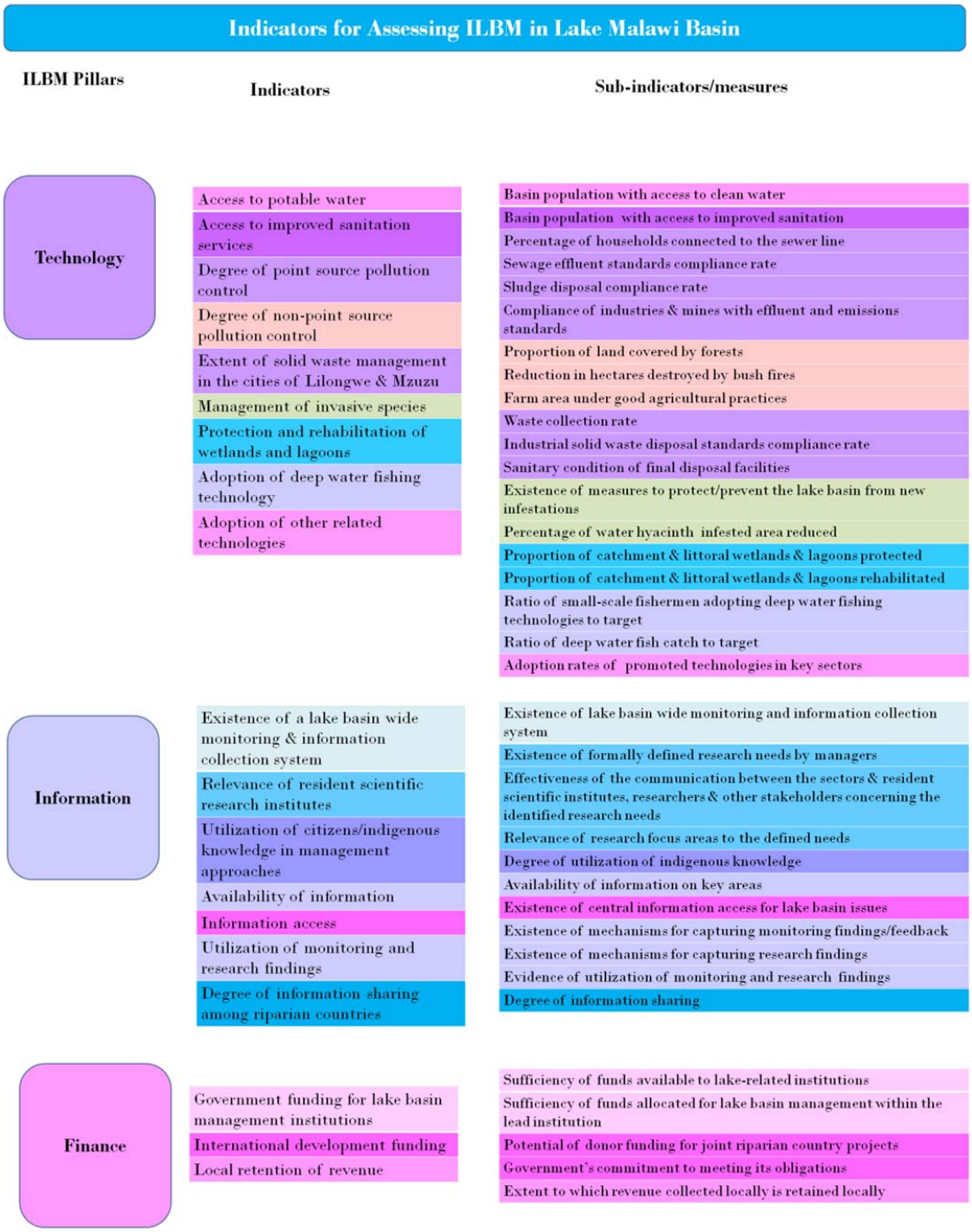


Figure 3 (b) Indicator Framework for Assessing ILBM in Lake Malawi Basin

## 4.2 Status of Current Management of the Lake Malawi Basin in the aspects of the Six ILBM Pillars of Governance

*Policies Pillar*

This pillar was found to be strong with an overall rating of 4.11. Figure 4 below shows the scores of the indicators falling under policies.

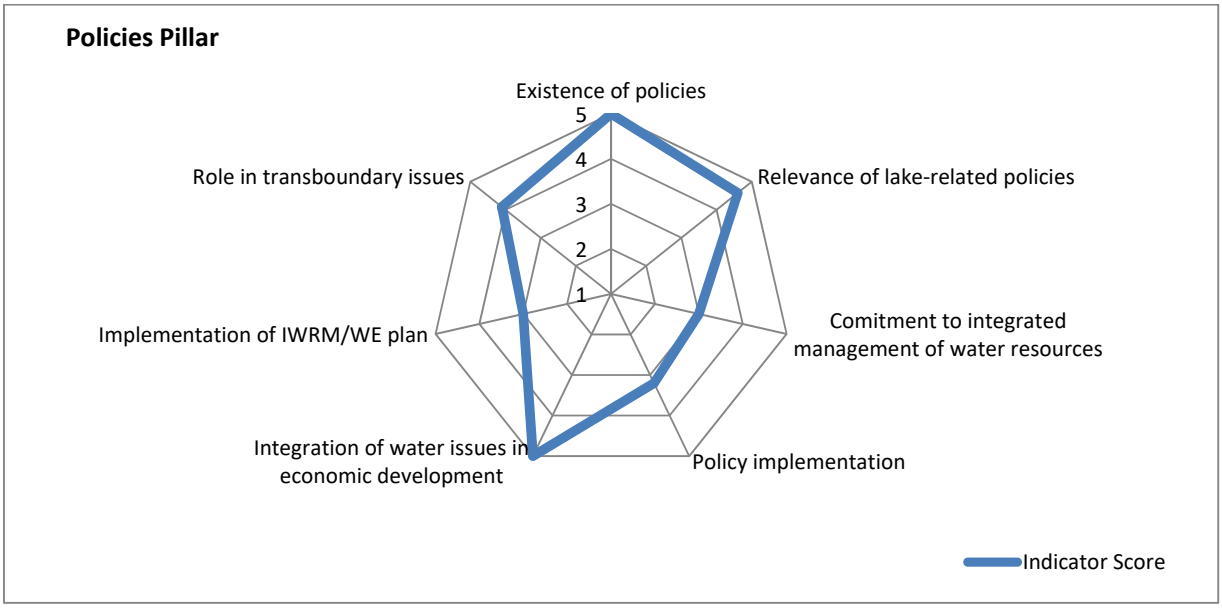


Figure 4. Performance of the policies pillar.

Areas Requiring Attention

- Water related policies need to specifically acknowledge and provide for the management of lakes holistically with their basins.
- The implementation of IWRM needs to be enhanced by ensuring that IWRM implementation is focused on addressing national priorities.

*Institutions Pillar*
The institutions pillar was moderate to Strong with an overall rating of 3.8 (See Figure 5).

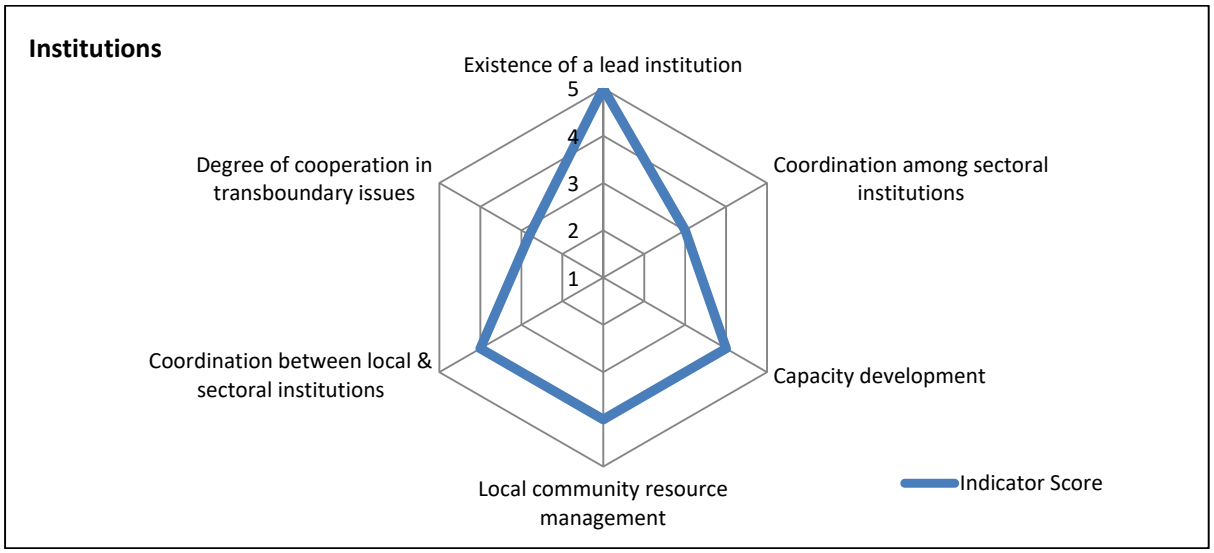


Figure 5. Performance of the institutions pillar.

Areas Requiring Attention

- Cross-sectoral coordination/cooperation at national level needs to be improved (lake issues are handled depending on the relevant sector).
- Cross-sectoral coordination/cooperation at district level also needs improvement.
- Transboundary cooperation needs to be diligently pursued.

*Participation Pillar*
This pillar fared strong to very strong with an overall rating of 4.6 (Figure 6).

Areas Requiring Attention

- Cross-sectoral coordination/cooperation among local institutions needs to be enhanced.
- It is also important to enhance understanding of linkages between the water body and the basin.

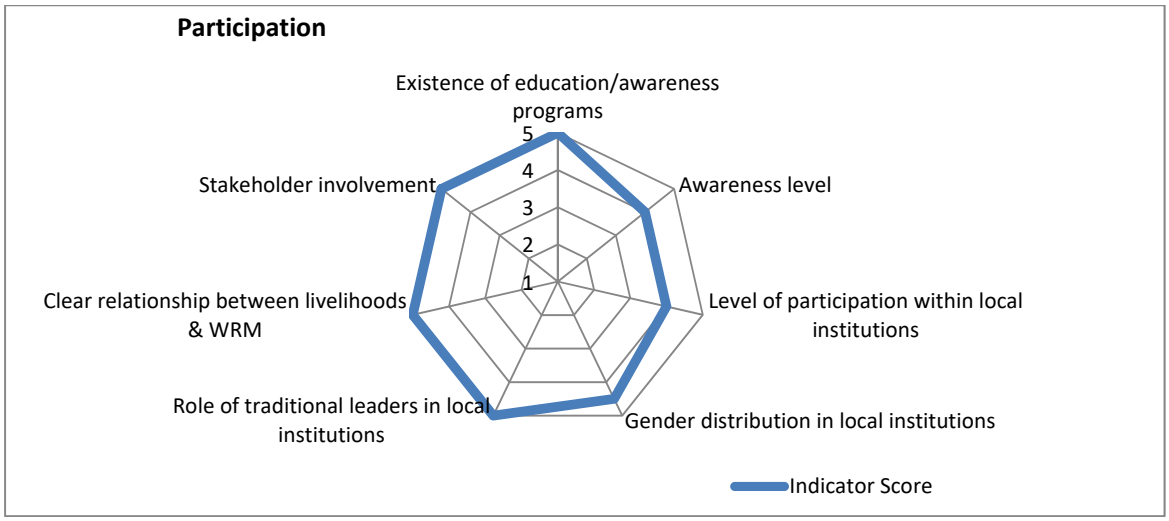


Figure 6. Performance of the participation pillar.

*Technology Pillar*

This pillar was found to be weak to moderate with an overall rating of 2.6 (Figure 7).

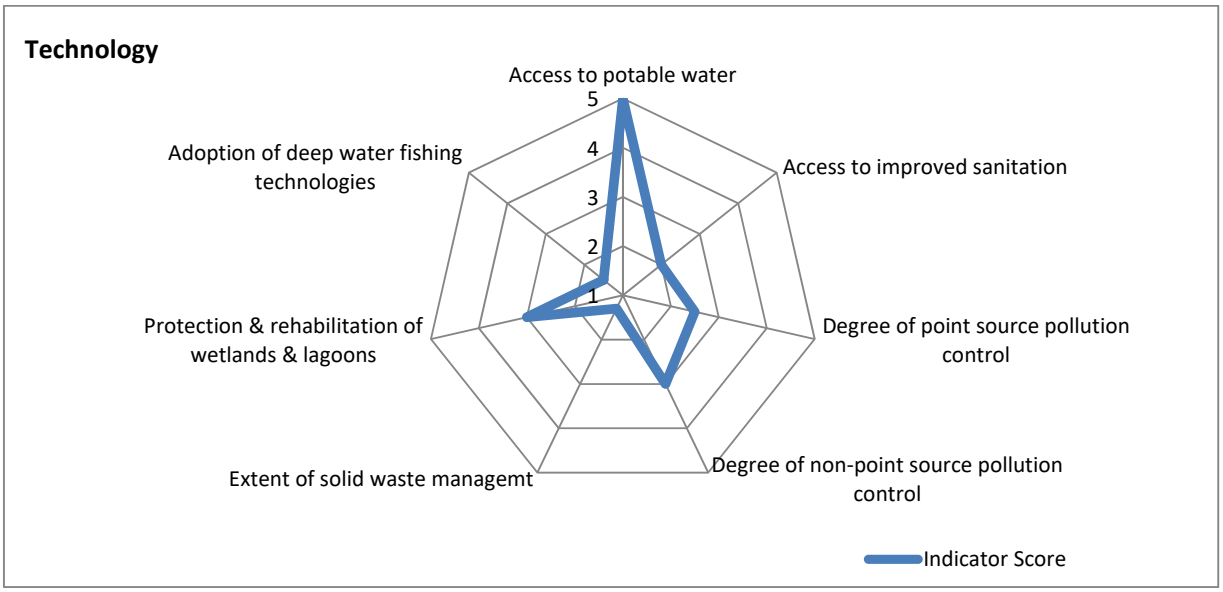


Figure 7. Performance of the technology pillar.

Areas Requiring Attention

- Access to improved sanitation services needs to be increased greatly.
- Control of both point and non-point source pollution needs to be enhanced.
- Waste management needs to be improved.
- There is need for better management of invasive species.
- Adoption of deep water fishing technology needs to be further promoted.

*Information Pillar*

The information pillar was weak with an overall rating of 2.16 (Figure 8).

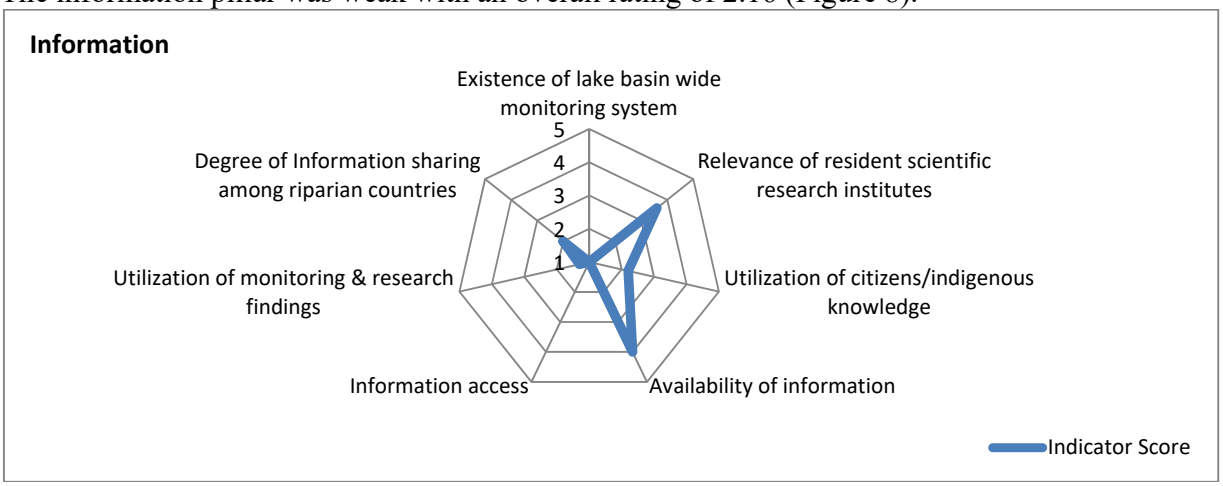


Figure 8. Performance of the information pillar.

Areas Requiring Attention

- A lake basin wide monitoring and information collection system needs to be put in place.
- Access to information needs to be addressed.
- Management plans and strategies need to utilize monitoring and research findings.
- Information sharing among riparian countries needs to go beyond projects and be mainstreamed as a regular activity within natural resources management.
- Mechanisms for capturing and utilizing citizens/indigenous knowledge need to be enhanced to improve their effectiveness.

*Finance Pillar*

The finance pillar was weak with an overall rating of 2.4 (Figure 9).

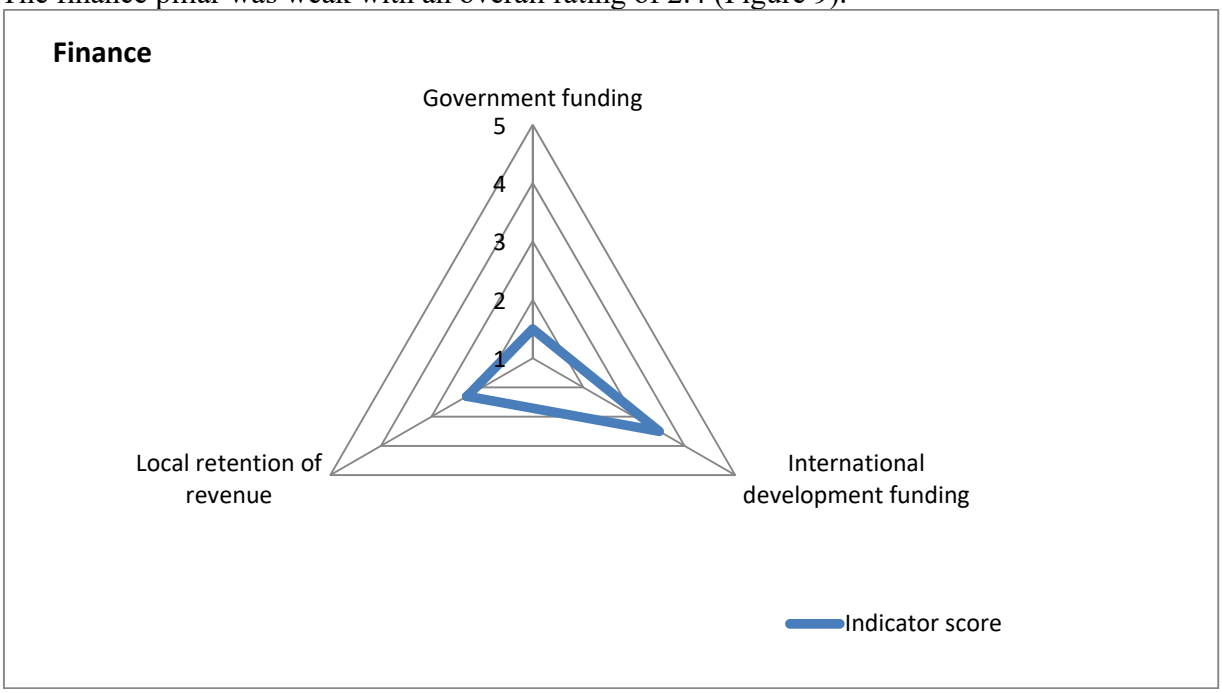


Figure 9. Performance of the finance pillar.

Areas Requiring Attention

- Government needs to commit more towards funding lake basin management.
- There should be mechanisms for retaining locally collected revenue where it is collected for use in addressing local issues and to motivate local stakeholders.

*Overall Performance of the Lake Malawi Basin Management*

Overall, the management of the Lake Malawi Basin was rated moderate with an average score of 3.27. The results show that the pillar performance is split into two distinct rating groups, low and high. The participation and policies pillars fall in the high rating while the institutions pillar fall under moderate-to-high. On the other hand, the technology pillar falls under low-to-moderate while the finance and information pillars are rated low. The results show that the information, finance and technology pillars require more attention than the other three pillars. Figure 10 provides an overview picture of the status of the Lake Malawi Basin.

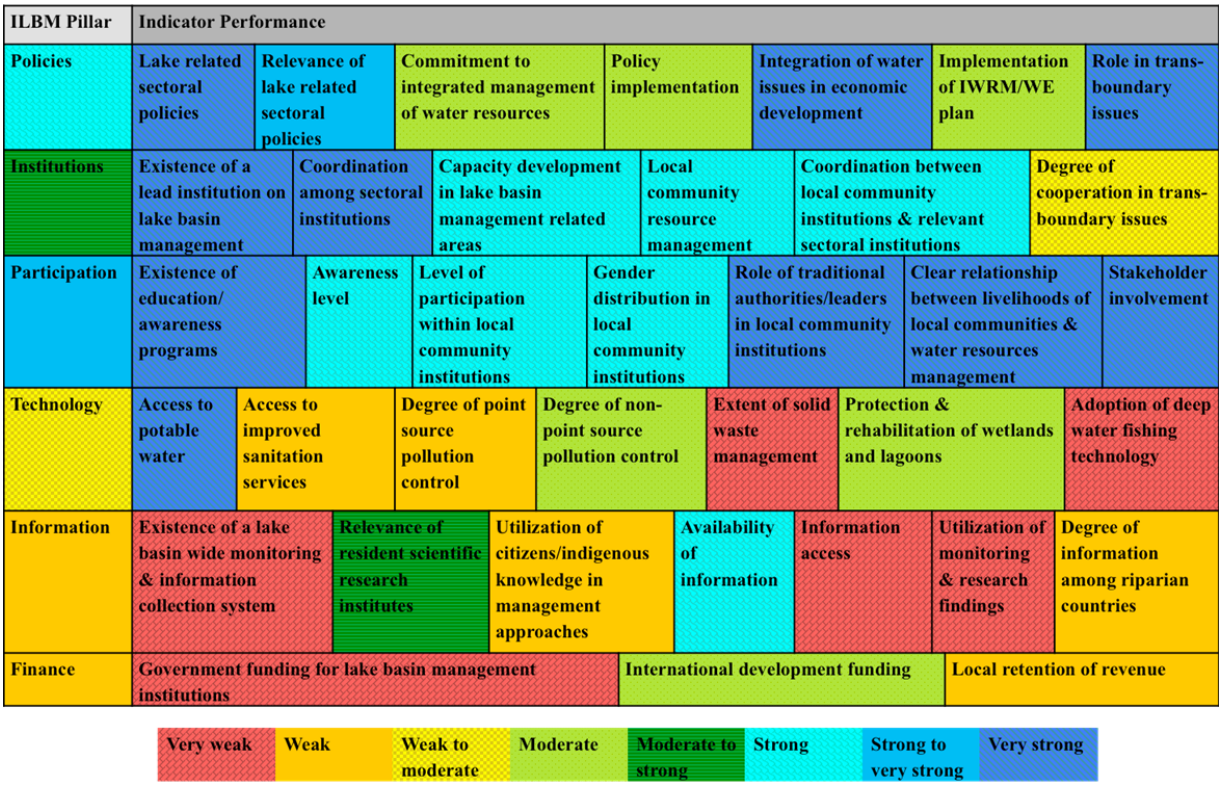


Figure 10. Status of the management of Lake Malawi Basin from ILBM lens.

## 5.0 Synthesis of Findings

This section discusses the findings from a holistic perspective i.e. in consideration of all the six pillars of ILBM. Section 5.1 reinforces the indicator findings by picking up the underlying issues that emerged in the assessment of each pillar. Through a SWOT analysis, the section presents the internal and external factors surrounding the management of the Lake Malawi Basin. Then, section 5.2 ties everything together and aims to demonstrate the interactions between the socio-economic subsystem (represented by the indicator performance) and the ecological subsystem (represented by the ecosystem services provided by the lake basin) and identify critical points requiring attention.

## 5.1 SWOT analysis of findings

To synthesize the findings from all the six pillars of ILBM, the study applied the Strengths, Weaknesses, Opportunities and Threats (SWOT) framework to highlight the issues, needs and challenges in the management of the Lake Malawi Basin. The reader is encouraged to read the doctoral thesis that provides the basis for this training module to appreciate how the issues appearing in the SWOT analysis came about. SWOT is a useful tool in planning and can aid decision making based on the understanding of the internal factors (strengths and weaknesses) and external factors (opportunities and threats) that affect or may affect the sustainable management and use of the lake basin. Studies by Diamantopoulou and Voudouris (2008) and Nouri et al. (2008) are some of the examples applying SWOT analysis in water resources and environmental management. In this way, an understanding of the status of the management of the Lake Malawi basin through ILBM lens is obtained. Table 3 shows the strengths, weaknesses, opportunities and threats identified.

Table 3. SWOT Analysis

| Strengths | Weaknesses |
|---|---|
| 1. Existence of lake related sectoral policies to support sustainable lake basin management | 1. Lack of recognition of the need for holistic lake basin management in water policies |
| 2. Relevance of the lake related sectoral policies | 2. Low access to improved sanitation services |
| 3. Integration of water issues in economic development strategies | 3. Very low proportions of city population connected to the sewer line |
| 4. Established institutional set up – i.e. existence of a lead institution & other relevant institutions at national, regional and district levels and local community institutions in various related sectors | 4. Very weak solid waste management |
| 5. Capacity development in lake basin management related areas | 5. Inadequate protection of wetlands & lagoons |
| 6. Existence of education/awareness programs | 6. Inadequate cross-sectoral coordination/cooperation & fragmented implementation of interventions (e.g. catchment management) |
| 7. Existence of local community resource management institutions | 7. Weak trans-boundary cooperation |
| 8. High level of awareness among stakeholders on some lake basin issues | 8. Slow adoption of good agricultural practices |
| 9. Stakeholder interest (e.g. NGOs & local communities) in lake basin related issues | 9. Very low compliance rate with industrial waste disposal standards |
| 10. High level of women involvement in natural resource management | 10. Very poor condition of final solid waste disposal facilities |
| 11. Very high access to potable water | 11. Very low adoption of deep water fishing technologies |
| 12. Explicit support of the livelihoods of local communities in policies | 12. Lack of lake basin wide monitoring and information collection system |
| 13. High forest coverage | 13. Weak communication between sectors and scientific institutes, researchers & other stakeholders |
| | 14. Low utilization of indigenous knowledge |

Table continues

Table 3. Continued

| Strengths | Weaknesses |
|---|---|
| | 15. Lack of a central information access point for lake basin issues<br>16. Unclear mechanisms for capturing monitoring and research findings<br>17. Low utilization of monitoring & research findings<br>18. Low information sharing with riparian countries<br>19. Lack of specific fund allocation for lake basin management coordination<br>20. Low local retention of revenue collected locally<br>21. Lack of monitoring of policy implementation<br>22. Some required institutions not operational (e.g. NWRA & CMCs)<br>23. Inadequate availability & allocation of resources (human, financial & material) to lake-related institutions<br>24. Weak enforcement of legislation |
| **Opportunities** | **Threats** |
| 1. Availability of information in scientific literature & in institutions<br>2. Harnessing NGO & civil society interest & participation<br>3. Donor funding potential for joint riparian projects | 1. Climate change & climate variability<br>2. Inadequate affordable alternative energy sources |

### 5.2 Sub-system Interactions in the Lake Malawi Basin

The assessment employed the causal loop diagram (CLD) technique to complement the SWOT analysis in synthesizing the findings. One main weakness of the SWOT analysis is that it expresses individual factors without explicitly showing how these factors influence and get influenced by one another. This makes it difficult to systematically identify the critical factors or issues upon which to focus management efforts or interventions. The systems approach as applied in this assessment sought to enhance the SWOT analysis by highlighting critical areas that require attention and so guide prioritization of management action. The findings through SWOT became the factors for developing a CLD so as to capture the dynamics behind cause, effect and feedback. Vensim PLE software was used to develop the CLD.

The following are the steps followed in the systems approach applied:

1) Identification of the components of the system - This was done in Chapter 3 of the doctoral thesis (Chidammodzi, 2016). The six ILBM pillars together with their respective indicators form the key components of the system under study, the Lake Malawi Basin.
2) Identification of key issues – Major weaknesses were extracted from the results of the pillar performance and the SWOT analysis and they are shown in Table 4.
3) Development of a causal loop diagram (CLD).
4) Identification of critical points of action and critical indicators.

Table 4 shows the weak areas as revealed by the results of the indicator performance. These represent the socio-economic subsystem. Out of these issues, four were isolated as key issues considering how they are causally related to the other variables and their connection to ecosystem services in the lake basin. These are waste management, access to improved sanitation services, nutrient loading and pollution control, and protection of biodiversity (i.e. management of invasive species, protection and rehabilitation of wetlands and lagoons, and related aspects). Pollution, for instance, is an effect of many activities in the lake basin across all sectors, while biodiversity is affected by and affects fairy everything going on in the basin, whether positively or negatively. In addition, key ecosystem services provided by the lake basin were isolated to represent the ecological subsystem. These ecosystem services are also reflected in the deduced vision for the Lake Malawi Basin. The key issues and ecosystem services became the variables for the CLD that was developed (Figure 11). The CLD illustrates the relationship between the socio-economic and ecological sub-systems through interaction of the key issues and the ecosystem services and the associated feedback. As necessary, additional variables were included to clarify the causal link between variables. There are several factors with a causal effect on the selected variables. The CLD was drawn using only selected factors that are closely related to the context of this assessment i.e. factors that can be easily related with the indicators and sub-indicators that this assessment used. The intent was to include an adequate number of key variables that enhance understanding of the interactions at play without including too many variables that would make the CLD overwhelming.

Table 4. Major Weaknesses

| Pillar | Indicator | Sub-indicator/Measure |
|---|---|---|
| Policies | Commitment to integrated management of water resources | Recognition of the need for lake basin management |
| Institutions | Degree of cooperation in trans-boundary issues | Adequacy of cooperation with neighboring countrie |
| Technology | Access to improved sanitation services | Basin population with access to improved sanitation services |
| | Degree of point source pollution control | Percentage of households connected to sewer line |
| | Extent of solid waste management in the cities of Lilongwe & Mzuzu | Waste collection rate |
| | | Industrial solid waste disposal standards compliance rate |
| | | Sanitary condition of final waste disposal facilities |
| | Adoption of deep water fishing technology | Small-scale fisherfolk adopting deep water fishing technologies |
| | | Deep water fish catch |
| Information | Lake basin wide monitoring and information collection | Lake basin wide monitoring and information collection |
| | Utilization of citizens/indigenous knowledge | Utilization of citizens/indigenous knowledge |
| | Information access | Information access |
| | Utilization of monitoring & research findings | Extent of utilization of monitoring & research findings |
| | Sharing of information among riparian countries | Degree of information sharing among riparian countries |
| Finance | Government funding | Sufficiency of funds to lead institution |
| | | Sufficiency of funds to lake-related institutions |
| | Local retention of revenue | Local retention of revenue |

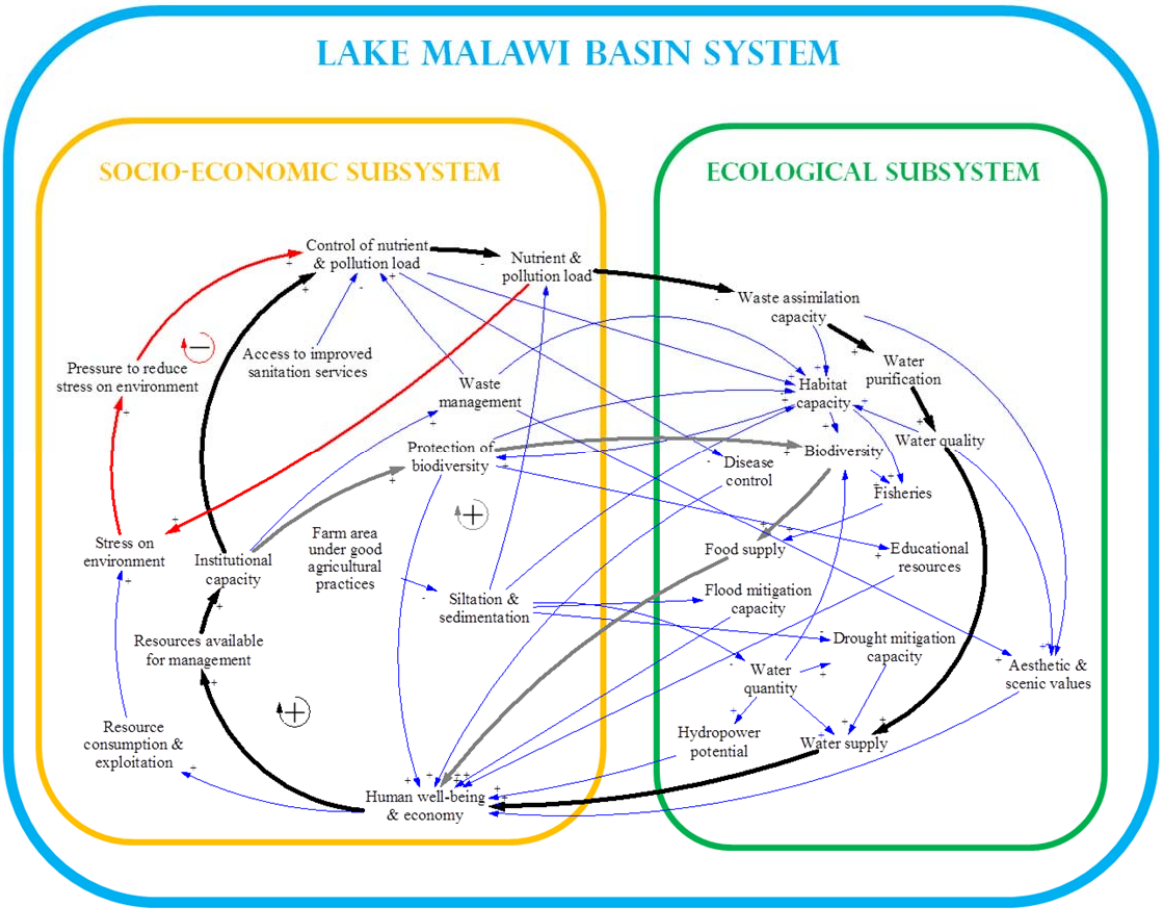


Figure 5. Causal loop diagram illustrating the interaction between the socio-economic and ecological subsystems in the Lake Malawi Basin. The item at the tail of the arrow causes a change in the item at the head of the arrow. A + sign at the head of the arrow indicates that change occurs in the same direction and a – sign indicates that change occurs in the opposite direction. The ⊕ or ⊖ symbols indicate the direction and effect of the loop.

In this module, only one loop is explained for demonstration purposes. For more loop explanations, see the doctoral thesis. The CLD shows clear interaction between the two subsystems as illustrated by arrows crossing from one system to the other. For instance, nutrient and pollution load causes a cascade of effects on several ecosystem services i.e. waste assimilation and water purification, which are regulating services, and water supply, which is a resource provision service. The loop tracing this effect (shown with black arrows) moves from control of nutrient and pollution load to nutrient and pollution load, waste assimilation capacity, water purification, water quality, water supply, human well-being and economy, resources available for management, institutional capacity and back to control of nutrient and pollution load, and has a reinforcing effect. The reinforcing effect indicates that a change in the condition of a variable leads to an amplified change when the effects are traced around the loop. In this case, a decrease in control of nutrient and pollution load (findings show low to moderate pollution

control) will cause an increase in nutrient and pollution load which will cause a decrease in waste assimilation capacity. This will in turn cause a decrease in water purification capacity that will cause a decline in water quality that will eventually cause a decrease in water supply. This will cause a decline in human well-being and economy and in turn cause a decrease in resources available for management that will cause a decrease in institutional capacity. The end result will be a decrease in the control of nutrient and pollution load.

Reinforcing loops make the system unstable and are associated with a high potential for either a rapid upward or downward spiral i.e. if the initial condition is bad, it will keep worsening and likewise if it is good, it will keep getting better. Lake basin management needs to take this into account to avoid continued degradation of the lake basin. In this case, **monitoring of nutrient and pollution load from both point and non-point sources is critical**. This entails keeping an eye on access to improved sanitation services, population proportion connected to the sewerage system, sludge disposal compliance, compliance of industries and mines with standards, forest cover, bush fires, agricultural practices, solid waste management and other issues as relevant**. A lake basin wide monitoring and information collection system is therefore crucial**. Equally important is the utilization of **monitoring and research** findings in management approaches and policy formulation. Coordination across sectors and meaningful stakeholder involvement are also essential. **All this requires availability of adequate and stable resources**. The issue of pollution control falls under the technology pillar but this discussion shows how it is linked with the information, policies, institutions, participation and finance pillars. This example highlights the interconnectedness of the ILBM pillars and why it is important to consider all of them (in varying degrees as appropriate) to ensure lakes are managed for sustainable use.

*Critical Areas Requiring Attention*
*Broad Areas:* Pollution control, biodiversity protection, promotion of scientific research, lake basin wide monitoring and information collection, institutional capacity, and availability of adequate and stable resources.

*Issues connected to the broad areas that require improvement and/or monitoring:* recognition of the need for lake basin management, access to improved sanitation services, population proportion connected to the sewerage system, sludge disposal compliance, regulations enforcement, compliance of industries and mines with standards, forest cover, bush fires, agricultural practices, solid waste management, adoption of deep water fishing technologies, prevention and management of invasive species, access to information, utilization of monitoring and research findings in management and policy formulation, sufficiency of funds available to lake-related institutions, trans-boundary cooperation, cross-sectoral coordination, access to sustainable energy sources, and climate change.

## 6.0 Concluding Remarks

This training module has provided the step-by-step process that was followed in the assessment of the Lake Malawi Basin. Lake basin assessment is often exploratory in nature i.e. one often deals with numerous unknowns and so they endeavor to attain a clear understanding of the issues, establish priorities, develop working/operational definitions as well as methodologies, and contribute towards the improvement of the situation. Sometimes one has to deal with a problem

that is not even clearly defined (lake basins are complex and dynamic). This sometimes entails navigating the process in a trial-and-error manner. The purpose of this module is to provide a guide to lake basin managers and all stakeholders interested in lake basin monitoring and assessment, so that they can have a road map or a reference point, depending on their experiences and needs. Flexibility of approaches in lake basin assessment is fundamental. So readers are encouraged not to be bound by the approaches employed in this assessment but to be open to use a combination of approaches and an integration of disciplines as may be appropriate for dealing with the situation at hand with respect to the objectives and the associated constraints.

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