# AN ASSESSEMENT OF THE ECOSYSTEM HEALTH OF LAKE VICTORIA (EAST AFRICA): CURRENT STATUS, TRENDS AND IMPACTS TO FISHERY

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## ABSTRACT

The paper presents results on the current environmental conditions in Lake Victoria in order to improve understanding on the limnological changes that have taken place over the last four decades and their impacts on fish stocks. Results show that in last four decades, Secchi disc visibility decreased by about 75% (range: 0.5m in the shallow bays around Nyanza Gulf to 5.7m in deep waters). Oxycline depth decreased by 50% indicating that a large body of the lake water in the deeper waters cannot support life. Chlorophyll *a* has increased three times compared to historical values. Results also show that the redfield ratio has decreased to 8.2:1 (N: P) indicating more P and less N in the lake water. Low oxygen conditions in the deep water causes rapid denitrification with subsequent loss of nitrogen. In addition, primary productivity has doubled over the period and algal biomass increased by 8-10 folds. The algal biomass is currently dominated by *Cyanophyta*. Zooplankton communities have also changed to smaller sized species and a dominance of rotifers while the micro-invertebrate *Caridina nilotica* has a higher abundance in inshore waters compared to offshore waters. Changes in phytoplankton and zooplankton biomass and species composition following eutrophication has influenced changes in herbivorous fish species as well as zooplanktivorous resulting in increase of zooplankton fish species such as "Dagaa" *Rastrineobola argentea*, and decline of other species. Changes in other ecological interactions due to species introduction and predation accelerated by the environmental changes and increased fishing pressure have further complicated the ecosystem dynamics of Lake Victoria and pose serious uncertainties about its future stability and sustainability of the fisheries resources. Lake Victoria's future sustainability requires effective management of fishing effort and phosphorous loading. Future research should endeavour to determine an acceptable nutrient loading rate that will sustain/ improve the fishery.

**Key words:** Deoxygenation, Phosphorous, NP ratios, Eutrophication, Fishery

## INTRODUCTION

Since the late 1960s, disruptions of physical and biogeochemical processes have occurred in the Lake Victoria basin caused by intense human activity in the watershed caused by accelerated population growth, intense cultivation, animal husbandry and introduction of exotic fish species (Bugenyi and Balirwa 1989; Hecky 1993; Balirwa *et al.* 2003; Lowe-McConnel 1997). These disruptions have led to over fertilization (eutrophication) which affects water quality and aquatic biota including fish in Lake Victoria (Mugidde 2001; Lungayia *et al.* 2000). The symptoms of eutrophication as characterised by elevated nutrient concentrations, Hypoxia, massive fish kills and algal blooms had become common phenomenon in Lake Victoria in the late 1990s. The interventions by the respective governments and some development partners have reduced the effects but still very far from control.

Changes in the environment involving water quality, especially turbidity, may have brought about dramatic losses in biodiversity. Increased sediments loads and elevated algal biomass have direct effects on the fish habitat as well as fish production. Fish require good light conditions for visual recognition during mating and territorial defense. The changed light environment in Lake Victoria as indicated by increased water turbidity has reduced the effectiveness of colour signals between mates leading to the breakdown of the reproductive barriers and consequent erosion of the cichlid species diversity in Lake Victoria (Seehausen *et al.* 1997). This had direct effect to the other species such as *Rastrineobola argentea* which shared the same ecological niche. The introduced species on the other hand also competed with the endemic species for habitat and food resulting in marked changes in species diversity, composition and the fishery.

Changes in phytoplankton and zooplankton biomass and species composition following eutrophication has influenced the changes in herbivorous as well as zooplanktivorous fish species resulting in an increase of zooplankton fish species such as the *Rastrineobola argentea*, locally named dagaa and decline of other species. Changes in other ecological interactions due to species introduction and predation accelerated by environmental changes and increased fishing pressure have further complicated the ecosystem dynamics of Lake Victoria and poses serious uncertainties about its future stability and sustainability of the resources. The objective of this paper is to present some of the changes and concerns.

## General description of Lake Victoria

Lake Victoria, the second largest fresh-water lake in the world, is shared by three East African countries, with Tanzania having 51%, Uganda 43% and Kenya 6% (4,128 $km^2$) (Figure 1). The Lake has a surface area of 68,800 $km^2$, is located at an altitude of 1134 m above sea level and extends from 2.5 °S to 0.5°N and from 31.5 to 34 °E, thus being approximately 400 km long by 250 km wide. The lake is relatively shallow, reaching a maximum depth of about 79 m, and an average depth of about 40 m.

Lake Victoria is a vital resource on which about 30 million people in the riparian countries are dependent. It is a moderator of climate for the basin and is a source of domestic and industrial water.

The fisheries resources of Lake Victoria are very important to the East African Community (EAC) Partner States. The estimated annual yield for 2006 was 1 million tons valued at US $ 350 – 400 million at beach level. Nile perch exports from the lake are estimated at about 80,000 tones of fillets worth US$ 250 million. Three to four million people in the basin depend directly or indirectly on the fishery. The fishery provides raw material for about 30 factories with a capacity to process about 1,800 tonnes of fish per day. The array of different haplochromine species (over 500 species) and another 28 endemic fish species present before the introductions and other ecological changes had made Lake Victoria a living museum for biodiversity and evolution studies.


**Figure 1:** Lake Victoria and its location in the Africa continent

## METHODS

The Lake Victoria Fisheries Organisation (LVFO) is coordinating resource monitoring and environmental research under Implementation of Fisheries Management Plan (IFMP) project- an EU funded project implemented from 2005 to 2008. Catch Assessment Surveys were conducted thrice and hydroacoustic surveys and trawl surveys, twice a year. Frame surveys to monitor fishing effort were conducted bi-annually. Sampling of environmental variables, both physical and chemical coincided with the acoustic surveys.

The information generated during the different studies is summarized and presented to elaborate the changes in the lake environment and the fisheries.

## RESULTS

### *Water quality status in Lake Victoria*

The beginning of the slow deterioration of Lake Victoria ecology is very much linked to the rapid riparian population growth and consequent livelihood activities associated with farming and urbanization. The increase in population in a 100-km (62-mile) buffer zone around Lake Victoria between 1960 and 2000 outpaced the continental average (Africa Atlas, 2006) (Figure 2). Lake Victoria supports one of the densest and poorest rural populations in the world, with densities of up to 1200 persons per square kilometre in parts of Kenya. An average annual population growth rate of 3% is exerting increasing pressures on the lake's natural resources.

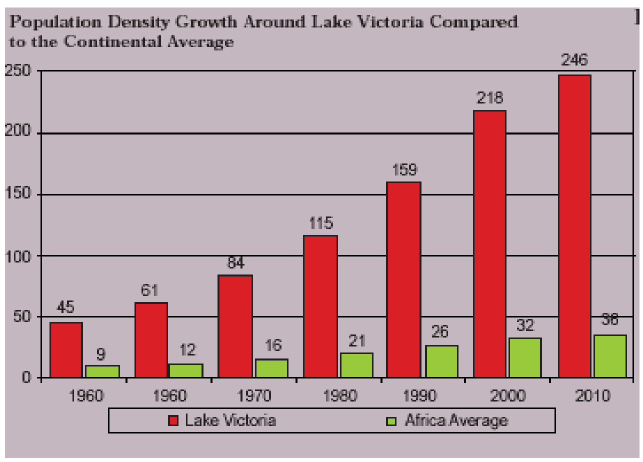


**Figure 2:** Population density growth around Lake Victoria compared to the continent average. Adapted from Africa Atlas, UNEP, 2006

### *Status of eutrophication in Lake Victoria*

### *Indicators of Eutrophication in Lake Victoria*

The indicators of eutrophication Chlorophyll *a*, Transparency *(*Secchi disk depths) and Oxycline depth recorded in 2005/06 were compared with the 1965 readings (Talling 1966) and with fish production which has increased almost ten-fold (Figure 3). Chlorophyll *a* increased three times but with higher variability indicated by wide standard errors as algae blooms are very seasonal and more common in inshore shallow waters. Secchi disc visibility decreased by about 75% (ranged from 0.5m in the shallow bays around Nyanza Gulf to 5.7m in deep waters reading at 70 m depth in Feb 2006). Oxycline depth decreased by 50% as further elaborated by a deep station of 60 m depth in North western sector of Lake Victoria during February-March 2006 sampling where the thermocline and the oxycline was at 32 metres deep (Figure 4). With the increase of ten-folds in fish production, fishing efforts have also increased five-fold from 1970s to 2006.

### *Nutrient loading*

Atmospheric deposition is a major source of pollutants into Lake Victoria (Table 1.). Most of the nutrients are from biomass burning mainly from the slash and burn agriculture (fire is used to clear the land surface, to regenerate nutrients, for hunting as well as for domestic uses) and burning of wetlands to create new growth for pasture which is a common practice in the Lake region. The practice is also common in the national parks such as Serengeti national park. The nutrient laden dust is swept into Lake Victoria by the strong winds, which converge at the centre of the lake. The Redfield ratio for TN: TP is 16:1 and this has decreased to 8:2 in the lake(unclear), indicating more P and less N. Low oxygen conditions (hypoxia) cause rapid denitrification which offsets nitrogen fixation by cyanophyta on an annual basis.

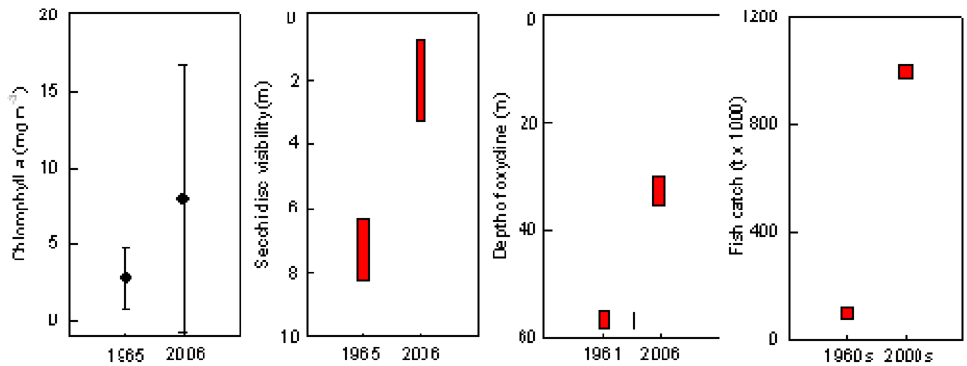


Figure 3: Indicators of Eutrophication recorded in 2005/2006 compared with records in 1965 by Talling (1966)

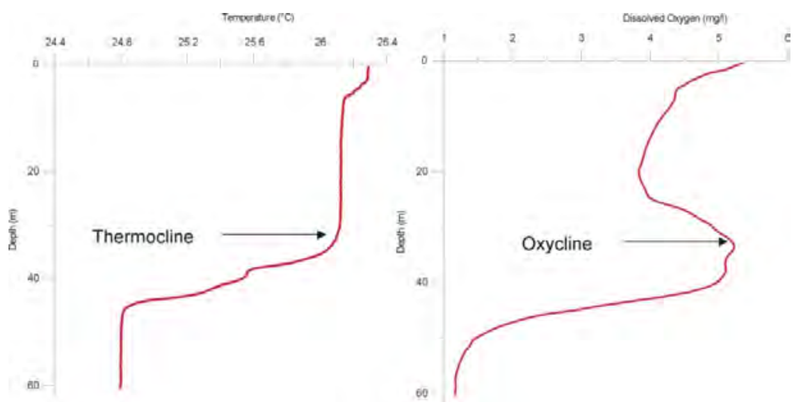


Figure 4: Temperature (left) and Dissolved oxygen (right) profile for a stratified station Off Bokassa (00° 46.950'S; 032°52.105' E) in the North western sector of Lake Victoria during the February –March 2006 sampling

**Table 1 TN: TP ratios for the various localities in Lake Victoria (IFMP- synthesis report 2005)**

| Locality | | Nutrient | | |
|---|---|---|---|---|
| | **Date of sampling** | **TN (ugN/l)** | **TP (ugP/l)** | **N:P ratio** |
| | March-05 | 353.85 | 74.11 | 4.8 |
| Nyanza Gulf | June -July 2005 | 1272.32 | 136.29 | 9.3 |
| Tanzanian waters | June -July 2005 | 709.26 | 76.83 | 9.2 |
| | March-05 | 763.00 | 106.00 | 7.2 |
| Zones 1,2,3 (Uganda) | June -July 2005 | 1006.50 | 95.10 | 10.6 |
| | | | **Average** | **8.2** |

Changes in Primary and Secondary Productiction on******

Changes in dominance of diatoms in the 1960s to blue green algae in 2000s is shown (Figure 5). In the surveys of 2005/06, cyanophytes were the dominant algae by over 50% in all the three national waters (Figure 5 a-c). Data from Talling (1966) indicated a dominance of diatoms by 69% (Figure 5d).

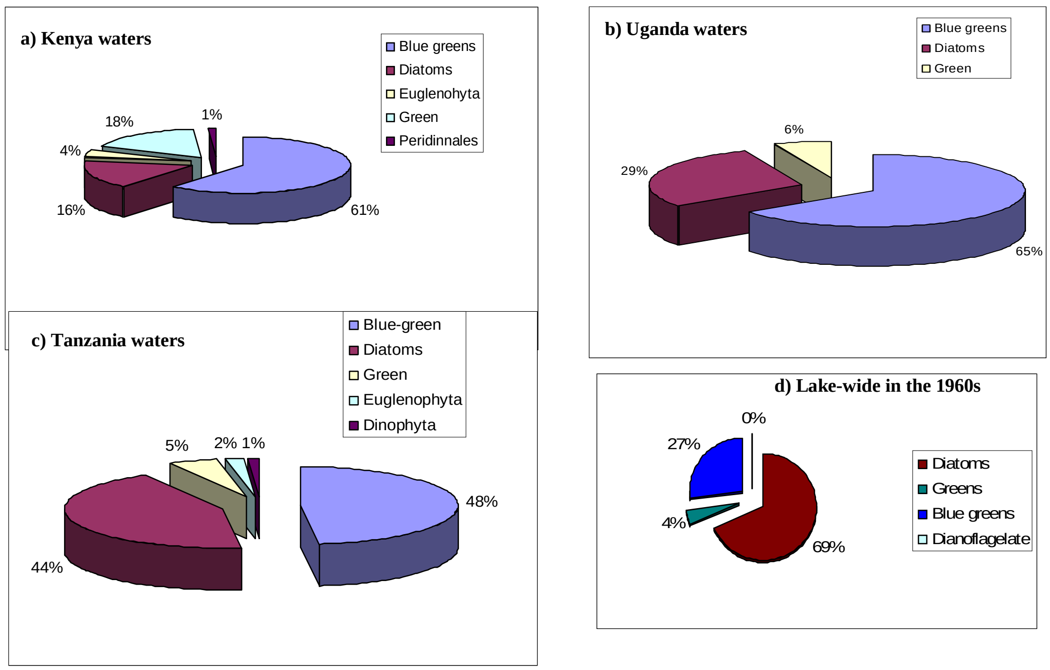


Figure 5: Algal species Composition in (a) Kenya, (b) Uganda, (c) Tanzania compared with (d) Lake-wide compositions in 1960s. (Source: Synthesis Reports of IFMP, 2005)

Zooplankton communities have also changed to smaller sized species and a dominance of rotifers while the micro-invertebrate *Caridina nilotica* has a higher abundance in inshore waters compared to offshore waters (Figure 6)

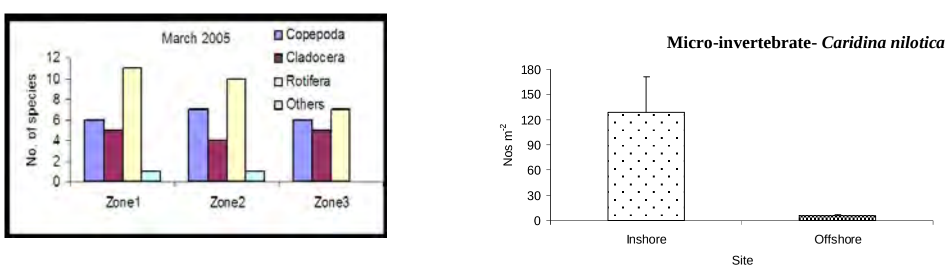


Figure 6: Zooplankton composition and the increase in *Caridina nilotica* in 2005, Lake Victoria

## The status of fish production

Fish production has been increasing with increase of eutrophication as indicated by total landings (Figure 7). However, in early 2000s, Nile perch catches slightly declined or stabilized while the pelagic Dagaa (*Rastrineobola argentea*) is further increasing in the landings. A clear picture of possible declines in the predator Nile perch, and increase of the pelagic dagaa is shown from hydroacoustic survey results (Figure 8).

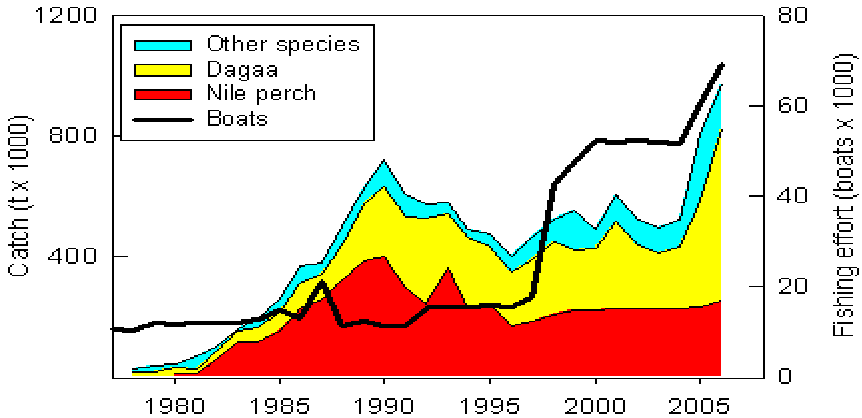


Figure 7: Trends in landings per species from 1980s to 2006 and the corresponding increase in effort

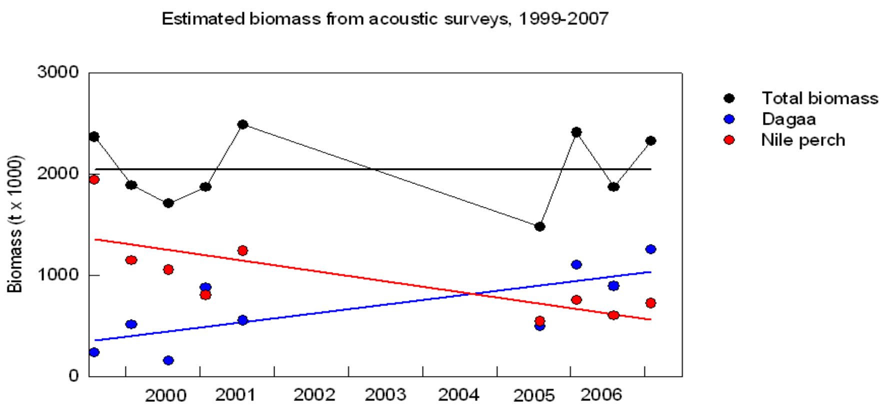


Figure 8: Trends in estimated biomass from lake-wide Acoustic Surveys

## Biological indicators of eutrophication and/or fishing effort

Length-frequency distribution of dagaa catches from 5-mm and 10-mm nets before 2000 and in 2006 indicate that the species now matures more rapidly than before and adults and juveniles are now more difficult to separate (Figure 9).

The same trend was observed in Nile perch catches (Figure 10). In 1983, they exhibited a marked sexual dimorphism with small males and large females but by 2006 males and females were maturing at smaller sizes and occurring in approximately equal numbers over all size ranges, except > 100 cm (only three females of > 100cm were in the 2006 samples).

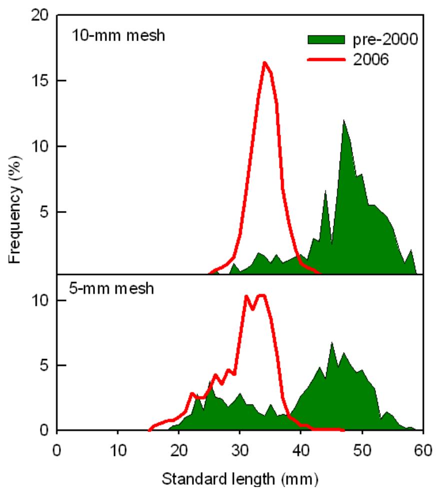


Figure 9: Changes in size structure of dagaa Rastrineobola argentea

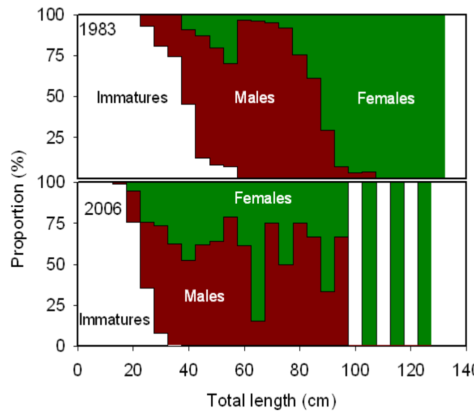


Figure 10 : Changes in the Nile perch demography

## DISCUSSION AND CONCLUSION

The increasing eutrophication in Lake Victoria resulting in changes in plankton communities and composition might be influencing changes in fish species composition and production. The increased water turbidity and reduced transparency (Hecky *et al.* 1996, Mugidde 2001; Gichuki *et al.* 2006; Lungayia *et al.* 2000) are known to have reduced the effectiveness of colour signals between mates leading to the breakdown of the reproductive barriers (unclear) and consequence erosion of the cichlid species diversity in Lake Victoria (Seehausen *et al.* 1997). Increase in the algal biomass has also recently favored the proliferation of fresh water shrimp *Caridina nilotica* (Mwebaza-Ndawula 1994). The juveniles of Nile perch feed largely on the semi-planktonic freshwater prawn, *Caridina nilotica* (Mkumbo & Ligtvoet 1992; Ogutu-Ohwayo 1990; Ogari & Dadzie 1988) but of recent, *Caridina* contributed over 60% to the diet of Nile perch upto 60cm total length. The Nile perch stocks from acoustic surveys indicate a decline in biomass while dagaa is increasing and also haplocromines recovering and becoming an important component again in the diet of Nile perch (IFMP Reports, Mkumbo *et. al.* 2005). Total landings have been increasing but the population structure and size at first maturity have declined while fishing effort kept increasing.

Zooplanktons form the sole food source for the pelagic cyprinid, *Rastrineobola argentea* (Mwebaza-Ndawula 1998) and pelagic haplochromines. The composition and diversity of zooplankton communities changed from dominance of larger types (calanoid copepods; cladocerans) to smaller types (cyclopoid copepods). This simplified the food web and reduced the grazing efficiency of the zooplankton. Is that the only cause of changes observed in dagaa stocks? The recovery of haplocromines might result in competition with dagaa for food and habitat, and probably further reduce grazing efficiency of zooplankton resulting in even more algae blooms. The switch of Nile perch to feed on haplochromines as they re-appear will probably control eruption of haplos to their previous levels and thus continue to favour the increase of dagaa. Increase in fishing effort will also control the dagaa population. Control of eutrophication therefore needs dedicated efforts to recover the health of Lake Victoria ecosystem and ensure a balance in food web and sustainable fish production.

## SUMMARY AND RECOMMENDATIONS

1. Population growth of the Lake Victoria basin is currently estimated at 3.8% which is very high compared to 2.2% for Sub Saharan Africa and 0.5% in many developed countries. Measures to put in place to halt population growth include; population control through educating

communities in family planning and widespread use of immunization and handling of preventable diseases.

2. With regard to pollution and eutrophication results show that phosphorus concentrations have doubled while nitrogen is unchanged thus lowering the NP ratios. Algal biomass has increased four times, changed from dominance of diatoms to blue green algae while phytoplankton production doubled. In addition there is four times decreased in water transparency and also decrease in oxygen concentration in the hypolimnion during the period of stratification and elevation of the anoxic layer in the water column leading to loss in the volume of water habitable to fish. Measures to put in place to reduce pollution include; reduction nutrient emissions associated with human activities, land management – ( proper agricultural practices to reduce soil erosion slush and burn agriculture and regulation of forest fires started deliberately to clear the forest for agriculture), upgrading the industrial and municipal treatment systems to include tertially treatment of waste using constructed wetlands.

3. On fish species introductions, results show that Nile perch *Lates niloticus* and four tilappine species were introduced to improve the fisheries and that *Lates niloticus* introduction was accompanied by a decline and in some cases total disappearance of most of the native hapochromine species. Overall, there was loss of species diversity. Measures to put in place to address this problem include strict regulations and mandatory Environmental Impact Assessments (EIA) on any future species introductions

4. On policies and legal regimes of shared water bodies results show that these policies and legal regimes are sectoral and conflicting e.g. on the use of Lake Victoria waters. There is need to review and harmonize these laws

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