

# Experiences and lessons learned from interventions in the Lake Victoria Basin: The Lake Victoria Environmental Management Project

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## Abstract

The Lake Victoria basin has experienced a myriad of environmental changes leading to its degradation, and necessitating various interventions to be implemented. The purpose of this study was to review early development initiatives, past and ongoing interventions in order to document experiences and lessons learned from them. The methods used in this study include review of published articles, project reports, and personal opinions of experts and project implementers in the lake basin. There are numerous threats to the lake basin, the major ones being poor land use and agricultural practices, catchment deforestation, destruction of wetlands, pollution loading, fishing malpractices and invasion by exotic aquatic weeds. These threats have resulted in rampant land and wetland degradation, leading to poor water quality and consequent water loss, a decline in the diversity of the commercial fisheries, and the lake's biodiversity in general, unsustainable use of natural resources, increased poor human health and food insecurity, with high levels of poverty among the riparian communities. Initiatives for socio-economic development within the lake basin began as early as the turn of the 20th century, while intervention studies started as early as the 1920s. Current lake management intervention projects, such as the Lake Victoria Environmental Management Project (LVEMP), undertaken by the riparian states of the East African Community, have invested heavily in the lake basin, with the goal of addressing the above-noted threats to the lake. Some pilot projects undertaken through the LVEMP include: (i) water quality and quantity monitoring; (ii) industrial and municipal management; (iii) fisheries studies; (iv) water hyacinth control; (v) wetlands; (vi) land use; (vii) catchment afforestation; and (viii) micro-projects to alleviate poverty, to cite a few examples. Phase 1 of the LVEMP was a major effort in the history of the lake basin; hence, its critical examination. To this end, this study highlights, in chronological order, the experiences, achievements, challenges and lessons learned with regard to Phase 1 of the LVEMP.

## Key words

**aquatic weeds, environmental degradation, fisheries production, Lake Victoria, LVEMP, management interventions, socio-economic, water quality.**

## INTRODUCTION

Lake Victoria is the world's second largest freshwater lake by area, and the largest in Africa with a surface area of 68 800 km<sup>2</sup>. Located between the eastern and western rift valleys, it fills a shallow depression in the centre of a great plateau at an altitude of 1134 m. It contains 2760 km<sup>3</sup> of water at an average depth of 40 m, and a maximum depth of 84 m. Its water volume would take 100 years to be replaced by inflows. Situated on the equator, the lake's temperature range is narrow and

warm, with a mean annual water mass temperature of 25 °C. The shoreline is about 3500 km long, being convoluted and enclosing multiple small, shallow bays and inlets, many of which include swamps and wetlands differ considerably from one another, and from the lake itself. The lake is a shared resource among its three riparian countries, with Kenya containing 6%, Uganda 45% and Tanzania 49% of the basin area, respectively (Fig. 1). Rwanda and Burundi also are in the lake's catchment.

Over the past four decades or so, the lake has experienced significant increasing pressures from a variety of inter-linked human activities, including overfishing, introductions

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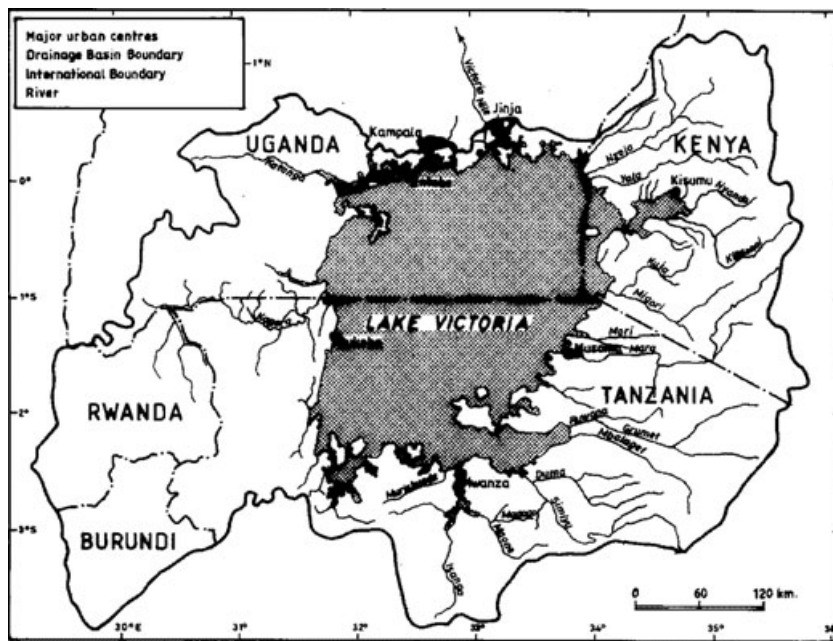


Fig. 1. Location of Lake Victoria and its basin.

of exotic species, industrial pollution, eutrophication and sedimentation (Hecky 1993; LVEMP Water Quality Synthesis Report 2005). The lake provides various resources, both renewable and non-renewable, to its riparian communities. Effective and efficient management of its resource base is essential for the economic and social welfare of any nation, and for its environmental quality. Changes in population size, employment, settlement, consumption patterns, industrialization and resource utilization can affect the sustainability of the resources and environmental quality of a lake basin both positively and negatively.

A shift in Lake Victoria's fauna became noticeable in the 1980s (Ochumba & Kibaara 1989), although the origins of this shift began much earlier (Hecky 1993; Verschuren *et al.* 2002). The bottom waters of the lake appeared to be a dead zone, devoid of dissolved oxygen and fish life. However, the lake was choked with algae, about five to ten times more than observed in the early 1960s (Kling *et al.* 2001). This situation suggested massive eutrophication, an oxygen-depleting condition resulting from high nutrient levels that encourage rapid phytoplankton growth. In fact, the nutrient loads to Lake Victoria have increased at least two- to three-fold since the turn of the century (Talling & Lemoalle 1998). The phosphorus concentrations have increased markedly in the deeper water layers of the lake, while nitrogen concentrations have increased along the lakeshore (Hecky *et al.* 1996), as nitrogen fixation rates have especially increased in the lake's inshore coastal waters (Mugidde

*et al.* 2003). Furthermore, massive algal blooms have developed, becoming increasingly dominated by potentially-toxic blue-green species of algae. Water transparency (measured as Secchi depth) has decreased from 5 m in the early 1930s, to 1 m or less at the present time for most of the year in its coastal waters. Waterborne diseases also have increased in frequency (Muyodi *et al.* 2009). Water hyacinth, which were absent as late as 1989, have since choked important waterways and landings, although its abundance has declined somewhat in recent years in response to biological controls (Williams *et al.* 2005).

### Socio-economic characteristics of Lake Victoria basin residents

The economy of the Lake Victoria basin, which currently supports an estimated population of about 40 million people, should be viewed from the perspective of the totality of the socio-economic, scientific and environmental benefits that accrue not only to its five basin countries, and Uganda in particular, but also to the global community in general. The latter is mainly in regard to its land and water uses, unique land and waterborne biodiversity, wetlands and fisheries products and its immeasurable aesthetic values. The lake basin provides a source of food, energy, drinking and irrigation water, shelter, transport, and is a repository for human, agricultural, municipal and industrial wastes by about a third of the combined populations of the three riparian countries, whose gross economic product is in the order of US\$ 4–6 billion annually.

## METHODS

Methods used in this study included reviews of published literature, project reports, and personal opinions from experts and project implementers in the Lake Victoria Basin. Some parameters presented in LVEMP reports for determining pollution loads from point sources were limited to Biochemical Oxygen Demand (BOD<sub>5</sub>), total nitrogen (TN) and total phosphorus (TP), mainly because of their relevance as water quality indicators, and their contribution to the eutrophication of the lake. In addition to these key parameters, pH, electrical conductivity, Chemical Oxygen Demand, alkalinity, chloride, dissolved oxygen (DO), faecal coliforms, TSS (total suspended solids) and heavy metals often were analysed, and were available in relevant national water quality reports. Most of the methods used in LVEMP studies were standard water quality analytical methods (APHA 1998).

## RESULTS AND DISCUSSION

### Development initiatives

Although administrative responses collected over time by the riparian governments of Uganda, Kenya and Tanzania in regard to changes in the lake's ecosystems and socio-economic problems have resulted in varied degrees of success, they have also resulted in some undesirable socio-economic implications.

### Studies of Graham and his successors (from the 1920s)

Initiatives for socio-economic development within the Lake Victoria Basin began as early as the turn of the 20th Century, while lake-focused intervention studies began as early as the 1920s, with the work of such individuals as Graham (1929), Greenwood (1965) and Beadle (1981). Many of these early studies focused on the lake's fisheries, being done in response to decreasing fish catches (Graham 1929). After completing his research on the fisheries resources of Lake Victoria, Graham (1929) recommended establishment of fisheries management authorities in the three riparian countries, which led to the establishment of the Lake Victoria Fisheries Commission in 1932, under the East African High Commission. Graham and Worthington (Graham 1929; Worthington 1929) highlighted the difficulties of characterizing the state of the lake fisheries in the absence of reliable statistical data. They both urged that efforts be undertaken to collect production statistics from the major fisheries, by systematic recording of fish consignments shipped by road, railway or steamer, and of market transactions in fish at major population centres. Data on the place of

origin, and the weight by species, were deemed to be particularly important. Worthington foresaw that statistics, if collected in this manner from the beginning, will be of considerable value in assessing the progress of the lake fisheries. It also would make any related future fisheries work, which he believed would become necessary if the fisheries were to be exploited to their best advantage, a matter of much greater value. Such detailed record keeping was not formalized at that time, however, and the Second World War also dictated other priorities.

### LVFS, EAFRO and EAFFRO (1947–1960s)

Regular, more useful records began to be collected for Lake Victoria with the creation of the Lake Victoria Fisheries Service (LVFS) of the East African High Commission in 1947. The LVFS and East African Fisheries Research Organization (EAFRO), the latter fully established in 1949, working together fulfilled Graham's recommendation for a Lake Victoria Fisheries Authority that combined both administration and research activities. The LVFS had the responsibility for collecting statistics about the entire lake until 1960, when its role was taken over by the governments of the three riparian territories (Kenya; Tanganyika (now Tanzania); Uganda). The East African Fisheries Research Organization (EAFRO) was renamed the East African Freshwater Fisheries Research Organization (EAFFRO) in 1960. EAFFRO became responsible for managing the fisheries of Lake Victoria. Formation of the earlier East African Community (EAC) strengthened the operations of EAFFRO (Beauchamp 1955; Garrod 1961; EAFFRO 1976).

### The Lake Victoria Fisheries Research Project (1967)

In recognition of the need to strengthen biological and statistical research capabilities in East Africa freshwater fisheries, efforts were undertaken in late 1963 to develop a project for submission to the United Nations. To this end, the joint Lake Victoria Fisheries Research Project (LVFRP) was launched in 1967 by the United Nations Food and Agricultural Organization (FAO) and the United Nations Development Programme (UNDP). Its principal objective was to implement a lake-wide sampling system for collecting resource and fish catch effort data (Bazigos 1971; EAFFRO 1976).

### The Lake Victoria Fisheries Commission (1973)

The next major event regarding development of a fisheries data system in the Lake Victoria Basin was establishment of the Lake Victoria Fisheries Commission (LVFC)

in 1973. The LVFC objectives included the standardization of fishery statistics, and a committee on harmonization and standardization of methods of collection, processing and compilation of fisheries data was created in 1974, being coordinated by EAFFRO statisticians (EAFFRO, 1976). EAFFRO was subsequently abolished after the collapse of the East African Community in June 1977. As a result, Uganda, Kenya and Tanzania formed their own national fisheries research organizations, including the Uganda Freshwater Fisheries Research Organization (UFFRO) for Uganda (UFFRO 1977), Kenya Marine and Freshwater Research Institute (KMFRI) for Kenya and Tanzanian Fisheries Research Institute (TAF-IRI) for Tanzania, respectively.

### **CIFA (1976) and LVFO (2001)**

When the East African Community (EAC) collapsed in 1976, the Sub-Committee of the Committee for the Inland Fisheries of Africa (CIFA), operating under the auspices of FAO, assumed responsibility for the management and development of the Lake Victoria fisheries (Bernacsek 1987), until the three riparian countries replaced it with the Lake Victoria Fisheries Organization (LVFO). Efforts were initiated under the new, strengthened EAC to create a more comprehensive and sustainable legal and institutional framework for the Lake Victoria Basin. The subsidiary socio-economic development programmes within the lake basin by the Nile Basin Initiative, in addition to the initiatives by the EAC under the concept: "Lake Victoria region is an ECONOMIC ZONE," added to the list of development interventions in the Lake Victoria Basin.

A major research effort by the United Nations Development Programme (UNDP) and United Nations Food and Agriculture Organization (FAO) took place between 1966 and 1971, producing the first quantitative information on the Lake Victoria fish stocks. Other initiatives took place between 1971 and 1994, including the UNDP/FAO on fisheries statistics, the European Union (EU) on the supply of fishing gears, the FAO on fish quality control and assurance, and the three riparian governments on various other developments. A more comprehensive development programme, the Lake Victoria Environmental Management Project (LVEMP), was initiated in 1994 as a 5-year project funded through the World Bank, commencing in 1997.

### **Other Lake Victoria Basin Water Resources Management Projects and Programmes**

The Lake Victoria Basin Commission (LVBC), an apex institution for the EAC for the Lake Victoria Basin (LVB), was established in July 2005. The Lake Victoria

Research Initiative (VicRes) funded by SIDA/SAREC was launched in 2002, being coordinated by the Inter-University Council for East Africa (IUCEA). The purpose of VicRes is to identify development-oriented research projects, with the goal of producing new knowledge of importance for sustainable development of the Lake Victoria region.

The International Hydrological Programme (IHP), UNESCO's international scientific cooperative programme in water research, water resources management, education and capacity-building, was founded in 1975. Its primary aim is to bring together scientists worldwide, in order to establish the scientific and technological bases for rational management of water resources, with respect to both water quantity and quality. The Nature Society and Water Project (NWS) is a project under cooperation between Makerere University Kampala, University of Bergen and NIVA Oslo (Larsson *et al.* 2009). The Kagera River Basin Integrated Water Resources Management Project is implemented in Burundi, Rwanda, Tanzania, Uganda, Kenya, Egypt and Sudan under the Nile Basin Initiative (NBI). Its objective is to develop tools and a permanent institution, for the joint, sustainable management of the water resources of the Kagera River Basin, in order to prepare for sustainable development-oriented investments through improving the living conditions of the people and protecting the natural environment. The Malakisi-Malaba-Sio River Basins Development project is a framework for cooperative management of the water resources of the Malakisi-Malaba-Sio River Basins in Kenya and Uganda.

### **Experiences from Past and Ongoing Projects**

Past and ongoing projects have been, and are currently, addressing a number of complex mix of scientific/technical, managerial, legal and institutional issues across the three (and now five, including Rwanda and Burundi) countries regarding the Lake Victoria Basin. These projects involve gathering of information, capacity building, establishing institutions and initiating some developmental action plans to deal with overall socioeconomic and environmental problems. The projects have laid, and continue to lay, a solid foundation and central core around which to coalesce a larger programme of investments to clean up the lake, and to establish sustainable socioeconomic, scientific and environmental development within the lake basin, in the face of increasing population pressures likely to continue.

While the various lake and lake basin interventions have so far all been initiated with good intentions, they

largely focused on individual merit, rather than overall coordination. Thus, there was an immediate need to develop a focused development programme, in which policy coordination for all initiatives and interventions within the lake basin was under close supervision and guidance by the EAC Committee, and the Lake Victoria Development Programme (LVDP). The actual implementation of development activities on the ground, in turn, remain the responsibility of the riparian states, which can delegate the coordination function to a regionally established project implementation coordinating mechanism, such as LVEMP. Being a more comprehensive development programme, the LVEMP was initiated in 1994 as a 5-year project, subsequently commencing in 1997 with funding from the World Bank.

### Lake Victoria Environmental Management Project

The LVEMP was developed and implemented from the period of July 1997 to December 2005, with this period including two project extensions, the first from December 2002 to December 2004, and the second to December 2005. The LVEMP was financed via a grant from the Global environment Facility (GEF), and a loan from the International Development Association (IDA) through the World Bank. Uganda; Kenya and Tanzania are LVEMP partners through a Tripartite Agreement and Program Preparation Framework signed in August 1994. The concept of joint management of Lake Victoria and its basin as a shared ecosystem gained momentum following the conclusion of the Rio Earth Summit in 1992, which was the basis for the preparation and implementation of the LVEMP. Subsequent developments led to the inauguration of the Lake Victoria Development Programme (LVDP) at the EAC Secretariat in 2001 and, more recently, to development of a protocol for sustainable management of the Lake Victoria Basin (LVB) that provides for both the detailed legal framework and the Lake Victoria Basin Commission (LVBC) as a body for regional management of the entire basin.

The LVEMP and other bilateral efforts have generated significant knowledge, as well as developing technical capacity in the national agencies of the three riparian countries, allowing for assessment of the environmental stresses confronting the lake and its basin. The goal of the project was to restore a healthy, varied ecosystem to the lake, one which is inherently environmentally stable and able to sustainably support the various socioeconomic activities taking place in the Lake Victoria Basin.

### Summary of LVEMP achievements and findings

LVEMP achievements include establishing a number of sampling networks for littoral, pelagic and urban monitoring stations, monitoring trends in physical and chemical lake water quality parameters and undertaking joint cruises. Training programmes were designed to strengthen scientists in applied limnology, monitoring and related environmental topics. In addition to training, elaborate infrastructure for water quality monitoring was established in the Lake Victoria region. Laboratories were rehabilitated and equipped in Kisumu, Mwanza, Bukoba and Musoma, while the Entebbe laboratory was equipped with more sophisticated equipment. A regional network for data collection in the inshore and offshore areas now exists, in addition to the establishment of a precipitation network. LVEMP also has emphasized the establishment of internal and regional quality assurance mechanisms, enhancement of laboratory performances and efficiency, and data generation and management.

### Hydro-meteorological conditions of the Lake Victoria Basin

As part of the LVEMP, hydro-metrological data for the period from 1950 to 2004 were analysed, forming the basis for computing pollution loadings from the lake catchment and the atmosphere into the lake, and as well the calculation of the lake water balance. Continuous rainfall and evaporation records were utilized, and data gaps filled, were necessary. The mean annual rainfall over the Ugandan side of the lake is about 62 539 billion cubic metres (BCM), that for Tanzania is about 60 682 BCM, while that for Kenya is about 4 541 BCM (Table 1). There was a 10.7% decrease in rainfall over the lake from the period 1972 to 1993. By contrast, there was a 2.2% increase from the period 1994 to 2004. There also was a decrease of 14.7% in catchment inflows to the lake, with a 1.64 m decrease water level from the period 1998 to 2004, leading to concerns regarding the causes and

**Table 1.** Precipitation input into Lake Victoria, by country

Country	Rainfall (m)	Area (%)	Lake area (km <sup>2</sup> )	Rainfall (BCM)	Percent (%)
Uganda	2.02	45	30 960	62 539	48.9
Tanzania	1.8	49	33 712	60 682	47.5
Kenya	1.1	6	4128	4541	3.6
Total		100	68 800	127 762	100.0

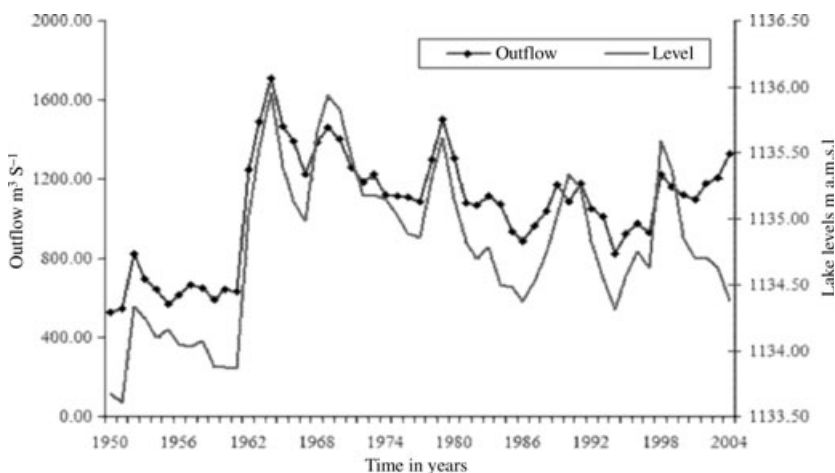
m, metres; BCM, billion cubic metres.

the long-term implications for the lake (Swenson & Wahr 2009).

### River Nile outflow

The Nile River outflow from the period 1950 to 1954 was a natural outflow until the Owens Falls Dam was commissioned in 1954. The Dam was constructed to operate on an ‘‘Agreed Curve’’ Policy that determines the quantity of water to be released, by utilizing the prevailing water levels to maintain natural flows at those levels. The dam does not control the lake’s water levels. The outlet capacity of the lake was subsequently increased with the construction of a new phase of Owens Falls Dam in the 1990s. The Agreed Curve maintained a natural pattern up to the year 2000. From the period 2001 to 2004, disparities began to occur between lake water levels and the Nile River outflow (Fig. 2), with the outflow increasing while lake levels decreased. This observation was attributed partly to increasing water outflows at Jinja, as well as other climatic factors, including decreasing rainfall and river discharges into the lake compared with the historic period (Swenson & Wahr 2009).

The mean inflows to the lake were evaluated by dividing the datasets for catchment inflows into three periods: (i) 1950–2000 (before LVEMP); (ii) 2001–2004 period, in which data collection was carried out under LVEMP; and (iii) 1950–2004 period, illustrating long-term averages. The results indicate that, on average, there was a significant decline in catchment inflows into Lake Victoria for the 2001–2004 period compared with the long-term mean period of 1950–2000. These decreasing inflows contributed to the falling water levels, but under the Agreed Curve discharges also should have decreased, which was not the case. The new outlet capacity at Owen Falls allowed the discharges to remain high.



**Fig. 2.** Relationship between Nile River outflows from Lake Victoria and lake levels, 1950–2004.

### Temporal and spatial patterns in Lake Victoria

Lake Victoria has four hydrodynamic seasons (phases), as illustrated in Table 2. The means of the determinations of the various variables monitored between 2000 and 2005 are summarized by season in Table 3. Nutrient and physical conditions during the LVEMP were compared with historic data for the nearest location for both the littoral and pelagic LVEMP stations, as illustrated in Table 4.

The hydrodynamic seasons were found to affect many water quality parameters throughout the lake, including temperature, Secchi depth transparency and turbidity (Table 3). The physical and chemical water quality properties indicated some strong differences between the littoral and pelagic stations across the lake, and between the surface pelagic stations and deep water stations (Tables 3,4). Most notably, the littoral waters had lower Secchi depths because of high algal biomass (Silsbe *et al.* 2006), whereas the deep pelagic waters Secchi depths >20 m exhibited widespread, persistent hypoxic conditions.

The higher algal biomass (expressed as chlorophyll) in Table 4, particularly of N-fixing cyanobacteria (Kling *et al.* 2001), accounted for the higher total nitrogen (TN) concentrations, as well as the higher chlorophyll and organic matter concentrations at the littoral stations (Mugidde *et al.* 2003). By contrast, the dissolved silicon (Si) concentrations are lower, compared with historical data, for all the in-lake sampling sites, particularly the littoral sites. The decreasing Si concentration is a result of the higher total phosphorus (TP) concentrations at all sampling sites, with the increased availability of regenerated nitrogen (N) a result of N-fixation. The pelagic response to increased phosphorus is muted because of

**Table 2.** The four hydrodynamic phases observed in Lake Victoria

	Months	Water column stability
Phase 1	January–March	Stable deep thermocline
Phase 2 (long rains)	April–May	Beginning of destratification
Phase 3	June–August	Complete mixing
Phase 4 (short rains)	September–December	Warming-stratification establishment

**Table 3.** Average physical conditions in Lake Victoria during different hydrodynamic seasons, 2000–2005

Parameters	Season 1	Season 2	Season 3	Season 4
<b>Littoral waters</b>				
Water temperature (°C)	26.37	25.58	24.16	25.31
Dissolved oxygen concentration (mg L <sup>-1</sup> )	6.01	6.58	7.08	6.42
Electrical conductivity (μS cm <sup>-1</sup> )	116.19	109.69	123.29	117.71
pH	8.45	8.26	8.08	8.53
Secchi depth (m)	1.49	1.15	1.23	1.16
Turbidity (NTU)	13.24	22.96	16.38	6.36
<b>Pelagic water (&lt;20 m)</b>				
Water temperature (°C)	25.39	25.18	24.63	24.88
Dissolved oxygen concentration (mg L <sup>-1</sup> )	6.64	6.64	6.80	7.00
Electrical conductivity (μS cm <sup>-1</sup> )	92.82	97.72	91.53	92.87
pH	8.08	7.26	7.59	8.43
Secchi depth (m)	3.39	2.69	3.08	2.95
NTU	7.64	8.88	2.38	2.25
<b>Pelagic deep water (&gt;20 m)</b>				
Water temperature (°C)	24.8	24.8	24.4	24.4
Dissolved oxygen concentration (mg L <sup>-1</sup> )	4.3	4.9	5.7	4.2
Electrical conductivity (μS cm <sup>-1</sup> )	94.1	91.4	90.8	94.5
pH	7.8	7.3	7.4	7.7
NTU	15.2	9.0	3.7	1.3

light limitation imposed by self-shading in the deep-mixing offshore waters (Mugidde *et al.* 2003).

The soluble reactive phosphorus (SRP) concentrations were high during all seasons, relative to the concentrations that would normally be expected to limit algal growth (i.e., <1 μg L<sup>-1</sup>). The continuous excess of SRP,

and the ability of cyanobacteria to fix atmospheric nitrogen, create nutrient-saturated conditions that result in light being the algal growth limiting factor (Silsbe *et al.* 2006). Diatoms require silicon for their growth, however, and the higher algal growth rates in the littoral areas results in lower biogenic Si concentrations in these areas compared with the lake's pelagic regions.

Historical data, and data during the LVEMP, was compared for some in-lake locations. Chlorophyll-a concentrations in both the littoral and pelagic regions of the lake have increased, compared with Talling's (1965) measurements and other historic observations. This observation also agrees with that of other studies prior to the Lake Victoria Environment Management Project (e.g., Hecky 1993; Gophen *et al.* 1995; see Table 4). The P concentration in the littoral and pelagic regions of the lake has increased considerably over the years, with concentrations being higher in the pelagic region, compared with the 1960s values (Table 4). The TP concentrations appear to be approximately twice as high as those observed in 1960. Table 4 also illustrates comparisons of LVEMP measurements to historical data for other parameters.

Point-source and non-point source pollution contribute to the pollutant loading to Lake Victoria. The municipal effluent load was higher than the industrial load. Nevertheless, they both represent threats to the community immediately downstream of the discharge points and the lake's proximate littoral zone. Atmospheric deposition was the overall dominant nutrient loading source to Lake Victoria, annually contributing about 39 978 and 167 650 tons of TP and TN, respectively, to the lake. The riverine loads are estimated to be 9270 tons TP year<sup>-1</sup> and 38 828 tons TN year<sup>-1</sup>, respectively, in both cases representing 80% of the total non-point load to the lake. The point source loads are estimated to be about 4.3 tons TN year<sup>-1</sup> and of TN and 1.9 tons TP year<sup>-1</sup>. Table 5 presents estimates of the total N, P and suspended sediment loads from the catchment and atmosphere, while Table 6 presents the relative magnitude of the loading sources to Lake Victoria.

The increased turbidity attributed to high total suspended solid (TSS) concentrations and colour has resulted in reduced filter life and increased down time needed to change filters for the water treatment plants. Turbidity also has an effect on water disinfection, as high turbidity levels have been shown to protect microorganisms from the action of disinfectants and to increase the chlorine and oxygen demand. Thus, the water treatment costs have increased over time, with the end user bearing the increased costs. The total extra cost incurred for water treatment chemicals from 1995 to June 2005 was

**Table 4.** Comparison of LVEMP data (2000–2005) and historical data

Station	Source	TP ( $\mu\text{g L}^{-1}$ )	PO <sub>4</sub> -P ( $\mu\text{g L}^{-1}$ )	SiO <sub>2</sub> -Si ( $\text{mg L}^{-1}$ )	NO <sub>3</sub> -N ( $\mu\text{g L}^{-1}$ )	TN ( $\mu\text{g L}^{-1}$ )	pH	EC ( $\mu\text{S cm}^{-1}$ )	Temp. (°C)	Chl-a ( $\mu\text{g L}^{-1}$ )	Secchi depth (m)
KL3	LVEMP	20–113	5–16	2.66–7.138	3–11	892–3090	8.2–9.0	159–165	25.49–26.86	25–35	0.8–1.2
	Talling	67		2.75	29		8.75	145	27.5		
KP1	LVEMP	63–92	3–7	0.04–0.145	1–182	410–860	6.7–8.9	94	24.51–26.84	2–20	1.6–3.6
	Talling	49		2.66					25.9		
KP3	LVEMP	75–92	6–7	0.37–3.63	7–9	440–530	6.4–8.3	94–96	22.59–25.35	3–13	2.8
	Talling	26		2.33					25.9		
Kenya littoral	LVEMP		21				6.7–10	105–181	21.8–28.8	35–40	0.2–2.4
	Mavuti and Litterick (1991)		6.8					120–150	24.35	40.7–50.6	0.7–1.8
Kenya pelagic	Ochumba and Kibaara (1989)						7.42–9.4	85–123			
	LVEMP	63–92	3–7				6.1–9.8	98–104	20.88–27.74	10	1.6–4.2
Kenya pelagic	Gohen <i>et al.</i> (1995)	70–103	4–73		10–30	440–1160					1.8
	Ochumba and Kibaara (1989)						6–8.85	88.1–102			
Mavuti and Litterick (1991)			15.7						23.6	15.8	
	Worthington (1929)										7.8
TL228	LVEMP	74–108	35–83	0.45–1.2	14–279		7.2–8.2	91–92.2	24.7–25.5	7–11	1.5–2.8
	Talling	53		2.15							
TP3	LVEMP	77–141	18–33	0.63–0.99	32–64		7–7.6	82.1–82.5	24.8	6–14	3–4
	Talling	33		1.96				96	25.05		
TP8	LVEMP	82–126	20–31	0.2–0.32	5–75		6.7–7.86	89.9–90.7	24.95–25.61	4–9	4
	Talling	33		2.00					24.9		
TP16	LVEMP	87–107	27–39	0.68–1.13	5–79		6.4–6.91	91.1–91.9	25.12–25.18	5–13	3–4
	Talling	47		2.05			8.5	95	25.4		
TL231	LVEMP	102–107	13–54	0.83–0.93	13–119		7.51–9.25	95.8–97	24.15–26.65	16–111	0.9–1.1
	Akiyama <i>et al.</i> (1977)		0–122	0.6–2.8	0–18	–	6.9–9.0	–	22.0–26.0	2–8.5	1.1–1.9
UP2	LVEMP	50–160	23–60	0.14–0.20	11.9–50		6.76–9.76	92.5–92.8	25.9–26.0	2.4–6.24	2.3–2.7
	Talling	43	5–15	4.05	18				25.1	2–4	
UP3	Hecky (1993)	62–124	12–43	0.1–2.5	1–84	336–448				1–23	1.2
	Talling	45		4	6		8.05		25.1		

Source: LVEMP Water Quality Synthesis Report (2005).

TP, total phosphorus; PO<sub>4</sub>-P, phosphate phosphorus; SiO<sub>2</sub>-Si, silicon; NO<sub>3</sub>-N, nitrate-nitrogen; TN, total nitrogen; EC, electrical conductivity; Temp, temperature; Chl-a, chlorophyll-a concentration; LVEMP, Lake Victoria Environment Management Project.

**Table 5.** Estimated total phosphorus (TP), total nitrogen (TN) and total suspended sediment (TSS) loads from Lake Victoria drainage basin and atmosphere

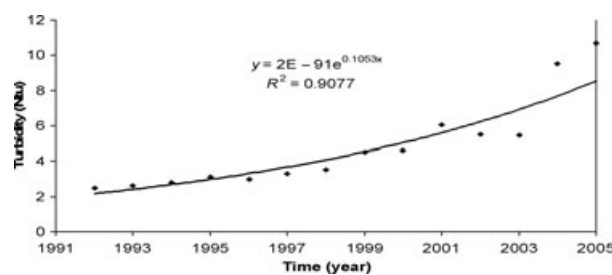
Parameter	Basin (ton year <sup>-1</sup> )	Atmosphere (ton year <sup>-1</sup> )	Total Load (ton year <sup>-1</sup> )	Percent (%)	
				Atmosphere	Basin
TP	9247	39 978	49 225	81.2	18.8
TN	38 828	167 650	206 478	81.2	18.8
TSS	6 511 950	–	6 511 950	–	–

**Table 6.** Relative magnitude of nutrient loading sources to Lake Victoria

Nutrient source	Total nitrogen (TN)		Total phosphorus (TP)	
	(ton year <sup>-1</sup> )	(%)	(ton year <sup>-1</sup> )	(%)
Atmospheric deposition	167 600	17	39 978	79
River inputs	38 800	4	9247	18
Biological N-fixation	757 000	78		
Point sources	4300	1	1690	3
Total load	967 700	100	50 915	100

US\$ 1.7 million (LVEMP Regional Water Quality Synthesis Report 2005), which otherwise could have been used for other beneficial purposes (e.g., extending water mains to the urban poor). The impact of water quality changes for Inner Murchison Bay (IMB) has not only increased costs for water treatment chemicals but also raised the water filtration costs. The increased filter backwash frequency has increased costs by 5% of the total water production costs. Thus, if the daily water production in Gaba costs US\$ 2800, an extra US\$ 140 per day is used to backwash filters. If the water quality degradation is not addressed, the Gaba waterworks will continue to use not less than US\$ 51 000 annually for the excessive filter backwashing. Thus, the annual total extra cost for chemicals and filter backwash is about US \$ 221 000 (LVEMP Regional Water Quality Synthesis Report 2005). Figure 3 illustrates the raw water turbidity trends at the Gaba Waterworks intake, Murchison Bay, Uganda.

Studies to examine the prevalence of water-related diseases, and other health risks at landing beaches in the Lake Victoria region of Uganda, indicated coliforms were generally very high at most of the sampling sites, suggesting high levels of water contamination. The wet seasons exhibited significantly higher coliform counts than the dry seasons for all lakeshore sites, correlating positively with higher waterborne disease incidences during

**Fig. 3.** Turbidity trends for raw water at Gaba waterworks intake, Murchison Bay, Uganda.

the wet season (Muyodi *et al.* 2009). The most prevalent diseases at the lake landing sites include malaria, dysentery, diarrhoea and bilharzia. The vulnerability of lakeside communities to water-related diseases is further aggravated by a low accessibility to health facilities and personnel. Furthermore, in the Lake Victoria Basin, cyanobacteria (potentially toxic to humans and animals) dominated other algal species. These findings suggest that improved water quality, sanitation and hygiene behaviour changes could significantly reduce the prevalence of water-related diseases (LVEMP Water Quality Synthesis Report 2005).

### Wetlands and fisheries

The wetlands in the Lake Victoria Basin have been heavily degraded. A summary of key findings from the wetlands component of the LVEMP included: (i) uncontrolled clearing of wetlands for human settlement and agricultural activities; (ii) irresponsible disposal of human wastes, polythene and other plastics, and over-harvesting of wetland resources including papyrus; (iii) silting, erosion, deforestation and burning; and (iv) drainage for agriculture, settlement construction and brick-making. All these factors have lowered the buffering capacity of the lake's wetlands and the natural wetland functions have been destroyed in the basin (LVEMP Wetlands Lessons Learnt Report 2005).

The most important trends in the Lake Victoria fisheries include: (i) a sudden, abrupt change in the fish

community structure 25–30 years after introduction of Nile perch; (ii) little change in the abundance of Nile perch, with an increase in haplochromines, Nile tilapia, Dagaa and other species, over the past decade; (iii) no changes in any important fish life history indicators (mean size, maximum size, growth, etc.) of Nile perch; (iv) no significant changes in the experimental trawl catch rates of Nile perch over the past decade, while overall fishery catch rates decreased from 7 kg per fisher to 3 kg per fisher since 1990, (v) numbers of fishermen has increased from 35 000 to 165 000 since 1975 and fishing boats have increased in number from 9000 to 52 000 since 1970, at the same time that the total fish catch has remained stable at between 400 000 and 500 000 tons over past levels through the beginning of the new century; (vi) increased value, export and contribution of the fishery to the GDP, while the contribution of the catches to food supply has declined from 80% to 20% since 1980, with the increased fish catches not keeping pace with the fish population growth; and (vii) a large number of illegal fishing gears (especially beach seines) and increased illegal gillnets <5 in. mesh size (LVEMP Regional Fisheries Synthesis Report 2005).

### Major challenges from LVEMP implementation activities

Although the LVEMP made significant achievements in regard to management of Lake Victoria, some of the challenges still facing the project included: (i) little project sustainability, noting that most pilot projects were terminated immediately after expiry of the project life; (ii) high personnel turn-over rates because most of the relevant manpower was from government or established institutions with their own mandates, resulting in little or no control over personnel transfers after they received training using project funds; (iii) inadequate capacity of some institutions to continue using the equipment acquired during Phase 1 of the LVEMP, or else receiving equipment they did not require; (iv) lack of coordination of training throughout all the project components; (v) inability to introduce cost-effective technologies, in combination with incentives and bylaws, so that farmers, especially the poorest, could invest in good land management practices; (vi) land tenure problems affecting adoption of improved land use management on communal lands and lands belonging to absentee landlords, especially in the case of Uganda; (vii) low levels of political commitment to project activities at the local level; and (viii) irregular funding flows from the LVEMP secretariat, as well as weak linkages from other projects, leading to duplication of activities (ICR 2005).

### Lessons learned from LVEMP implementation activities

Key lessons learned from LVEMP phase 1 implementation include the following:

1. A basin perspective is critical to addressing the key environmental issues of Lake Victoria: The project addressed environmental concerns by using an integrated lake basin management approach, which focuses on the lake and its entire watershed.

2. The on- and off-site consequences of land degradation can only be systematically addressed through up-scaling of successful sustainable land management (SLM) in the specific countries and ecosystems: Under LVEMP phase II, successful soil and water conservation interventions piloted in specific countries and ecosystems during LVEMP I must be up-scaled.

3. Environmental benefits must be strongly linked to improved livelihoods for local people and communities: The community-driven development watershed management sub-projects should comprise natural resources conservation interventions, which generate predominantly public goods or benefits, as well as livelihood improvement activities that are largely household-based, and with substantial private benefits.

4. Raising awareness and ensuring the participation of the public, parliamentarians and decision makers are critical for long-term financial sustainability: The LVEMP should include a public awareness and participation component aimed at improving regional and national outreach, and community awareness and participation.

5. Scientific research must be targeted, provide usable information for management decisions, and widely accessible: Adaptive research, aimed at filling knowledge gaps and/or addressing specific lake ecosystem and socio-economic problems, should be adopted.

6. Planning for sustainability of outcomes and activities at both national and regional levels: The project implementation should be mainstreamed in the National Focal Point Ministries and a regional institution such as the Lake Victoria Basin Commission (LVBC).

7. Conflicting government policies are sometimes the cause of natural resources and environmental degradation: the previous government policies in Uganda, for example, allowed acquisition of wetland areas in urban settings and the draining of wetlands for agriculture in rural settings.

Other lessons learned include the following:

8. That capacity building must address both current and projected gaps;

9. That programmes have been successful in building knowledge and introducing new technologies, but not translating that knowledge into policies and management plans;

10. That good lake basin governance requires: (i) institutions to manage the lake and its basin for the benefit of all lake basin resource uses; (ii) policies to govern people's use of lake resources, and their impacts on lakes; (iii) involvement of people who are central to lake basin or watershed management; (iv) technological interventions to address the environmental degradation or environmental concerns of the lake and its basins; (v) both traditional and/or indigenous knowledge, as well as of a scientific nature, for better lake management; and (vi) sustainable finances to fund all targeted activities, and

11. The importance of collaborative investigations and synergies when tackling issues of common interest, and using an ecosystem approach to address issues.

## CONCLUSIONS AND RECOMMENDATIONS

Through the LVEMP, much knowledge has been generated about the physical, chemical, biological, ecological and socio-economic status of Lake Victoria and its basin. Critical lake problems, such as the currently unaddressed eutrophication and biodiversity loss identified during LVEMP phase 1, have yet to be addressed by existing management programmes. There were many challenges, however, faced during implementation of the project. Based on the project results, many lessons were learned that can be used to improve the second phase of the LVEMP, as well as any other lake basin project of this magnitude.

A strategy to facilitate a rapid free flow and exchange of information to the stakeholders relevant to management of shared resources between institutions, both nationally and regionally, must be developed in the next phase of LVEMP, and an integrated approach to managing the lake resources that involves the local communities and all other interested stakeholders is strongly recommended. Focus should be directed to purpose-based water resources management, sensitization of communities around the lake for a participatory approach to lake restoration. Socio-economic and applied research is a priority area for planning coordinated and sustainable utilization of Lake Victoria, its basin and its resources.

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