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Mitigation of Environmental Problems in Lake Victoria, East Africa: Causal Chain and Policy Options Analyses

Lake Victoria is an international waterbody that offers the riparian communities a large number of extremely important environmental services. Over the past three decades or so, the lake has come under increasing and considerable pressure from a variety of interlinked human activities such as overfishing, species introductions, industrial pollution, eutrophication, and sedimentation. In this paper we examine the root causes for overfishing and pollution in Lake Victoria and give possible policy options that can help remediate or mitigate the environmental degradation.

INTRODUCTION

The large lakes of the East African Rift Valley are unique natural resources that are heavily utilized by their bordering countries for transportation, water supply, fisheries, waste disposal, recreation and tourism. The waters of Lake Victoria and its shoreline are shared between 3 countries; Kenya (6%), Uganda (43%), and Tanzania (51%) (Fig. 1). Additionally, the catchment of the principal affluent river, the Kagera, runs through the countries of Rwanda and Burundi. The Nile river outflow is an extremely important freshwater resource for the Nile Basin countries of Uganda, Sudan, and Egypt.

The demographic and physical characteristics of Lake Victoria basin are summarized in Table 1. The human population in the lacustrine basins of the East African Rift Valley lakes subregion is high (about 30 million people) (1),

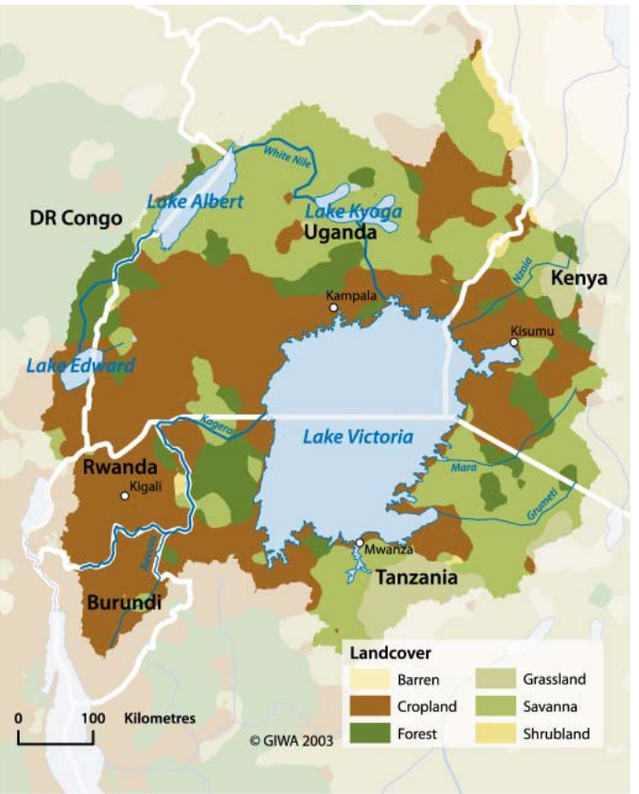

Figure 1. General features of the Lake Victoria basin.

Table 1. Demographic and biophysical characterization of the inlet drainage basins of Lake Victoria (4). (Est. – estimated; Ave. – average).

River basin	Countries sharing basin	Est. basin size (km²)	Ave. est. 2000 pop. density (km⁻²)	Est. total pop. In 2000	Ave. annual rainfall (mm)	Ave. sediment transport capacity index	Ave. % slope
Nzoia / Yala	Kenya	15 143	221 (±154)	3 346 000	1306	0.14	2.3
Nyando	Kenya	3517	174 (±127)	611 000	1360	0.30	5.0
Sondu Miriu	Kenya	3583	220 (±148)	788 000	1415	0.14	2.3
Gucha	Kenya	6612	224 (±183)	1 481 000	1300	0.16	2.0
Mara	Kenya Tanzania	13 915	46 (±56)	640 000	1040	0.15	2.0
Gurumeti	Tanzania	12 290	21 (±26)	258 000	879	0.12	1.6
Mbalaget	Tanzania	5702	37 (±22)	211 000	766	0.05	0.6
Duma / Simiyu	Tanzania	9702	50 (±26)	485 000	804	0.06	0.5
Magoga / Muame	Tanzania						
Isonga	Tanzania	5104	88 (±47)	449 000	842	0.05	0.4
Kagera	Tanzania	8972	48 (±22)	430 000	897	0.04	0.3
	Uganda Rwanda Burundi	59 158	181 (±196)	10 711 000	1051	0.24	3.0
Lake edge	Kenya Tanzania Uganda	40 682	133 (±175)	5 411 000	1077	0.21	1.4

growing rapidly, and heavily concentrated near the lakes (2). The lake basin supports one of the densest and poorest rural populations in the world, with human population density in the Lake Victoria basin being well over 100 km^{-2} (2). It is thus the most heavily populated basin within the East African Rift Valley Lakes subregion. It is multi-ethnic, comprising communities from Kenya, Uganda, Tanzania, Burundi, and Rwanda. The population of the region is expected to double within the next two decades (3).

Lake Victoria is an "international water" that is under considerable pressure from a variety of interlinked human activities; it has undergone enormous environmental changes within the last 40 years or so. Overfishing, siltation from the erosion of deforested watersheds, species introductions, industrial pollution, eutrophication, and climate change are all contributing to a host of rapidly evolving changes in the lake (and the other East African lakes) that seriously threatens its ecosystem function and overall diversity (5, 6). Today, nearly half of the lake floor experiences prolonged anoxia (lack of oxygen) spells for several months of the year compared to 4 decades ago when anoxia was sporadic and localized (7–10). Algal biomass concentration is almost 5 times greater in the surface waters today than reported in the 1960s (11), which indicates higher rates of photosynthesis. Also, the transparency values have de creased to one third, and the silica concentration has gone down to one tenth of what they were about 40 years ago (5, 9, 12). These and other related environmental changes, arising out of natural or anthropogenic causes, have significantly impacted Lake Victoria's fish populations. For example, the extinction of several hundred species of haplochromine cichlid fish in Lake Victoria, primarily as a result of the introduction of the Nile perch, remains a single most dramatic event of vertebrate species extinction attributable to specific human activities (13).

The Lake Victoria basin (LVB) faces far more complex social, economic, political and technical barriers than other transboundary lakes in the region (14). The environmental degradation of LVB over the last 3 decades, due to unsustainable use of natural resources, massive algal blooms, waterborne diseases, water hyacinth infestation, oxygen depletion, introduction of alien fish species, etc., has put the economically important fisheries sector at risk. It has been estimated that if the large export fishery for Nile perch is lost, the riparian communities stand to lose USD 270 – 520 million in revenue (1). The alarm over the accelerated degradation was the key driving force for the approval of the Lake Victoria GEF project in the mid-1990s, as the then largest GEF international waters project at USD 77 million (14). At about the same time, the Lake Victoria Fisheries Organization (LVFO) was formed by Kenya, Uganda, and Tanzania under the Convention of Fisheries. The Lake Victoria 5-year GEF project was the first of several intended interventions over time (14). The transboundary nature of Lake Victoria presents the main challenge to regional management of water and other aquatic resources.

The major concerns (issues) that emerged from the environmental assessment (15) using the Global International Waters Assessment (GIWA) transboundary diagnostic analysis approach were: unsustainable exploitation of fisheries (overexploitation, excessive by-catch and discards, and destructive fishing practices), and pollution (microbiological, eutrophication, chemical and suspended solids). In this paper, we address the root causes of these problems—overfishing and pollution—and suggest mitigating policy options.

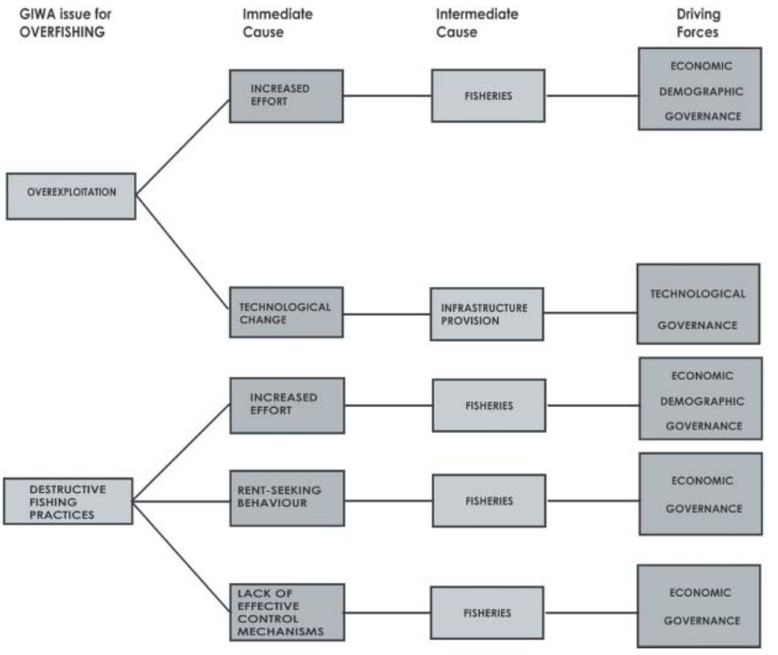

Figure 2. Causal chain analysis diagram for overfishing.

ENVIRONMENTAL PROBLEMS: THE ROOT CAUSES

Unsustainable Exploitation of Fisheries

Overexploitation

Two immediate causes were identified for overexploitation, i.e. increased effort and technological change (Fig. 2).

Increased fishing effort and technological change: Overexploitation is mainly due to increased fishing effort (55 – 75%). As a result of increased total fishing effort, efficiency of fishing gear and extension of fishing grounds to maintain the yield, there has been a progressive decline in catch per unit effort (CPUE) and mean size of fish caught (16, 17). In all 3 countries, efforts in terms of boats and numbers of fishermen have more than doubled in the past 10 years (18, 19). The number of fishermen in Lake Victoria increased from about 84 000 in 1990/1991 to about 122 000 in 2000 (19). With increased fishing pressure, predation, and competition among species, the multispecies fishery of Lake Victoria fishery has changed to only 3 species: Nile perch (*Lates niloticus*), the pelagic cyprinid-dagaa (*Rastrioneobola argentea* Pellegrin), and the introduced tilapiine (*Oreochromis niloticus* L.) (Fig. 3). By 1998, total Nile perch catches were half those at the beginning of the decade despite increased effort, and catches of *Rastrineobola argentea* have also levelled off despite increased effort (20). The unrestricted access status of the lake and lack of enforcement of existing legislation are linked to increasing and crippling fishing effort (21).

Overexploitation is also related to technological change (20–30%). Changes in the efficiency of fishing gears, motorization of canoes and increase in total fishing effort to maintain production have contributed to the decline of the Nile perch since the mid-1990s (21). Most of the region's factories suffer from fish supply problems, attributed to low catches and competition with other fish factories (22) and in order to stay operational, they drive fishermen to catch more fish.

Related sectors and activities: Increased effort has been driven by a much greater demand for fish by recently established fish processing factories that have a large capacity for processed products (23). Nile perch fisheries opened up greater employment opportunities, attracting more fishers (artisanal to large-scale), more fishing gear and vessels to access the resource, and the establishment of fish filleting factories (21). Dwindling fish stocks are necessitating increased effort in order to maintain the same level of catch (24).

Technological change has come about mainly due to a demand for higher fish catches to supply the fish processing factories and consequently the huge export market. A number of fish processing plants have been constructed along the shores of the lake, 11 of which are licensed to operate in the Uganda sector of the lake (25), 12 in Kenya and 12 in Tanzania (26). The large number of processing factories, whose capacity is about 120 000 tonnes (t) *versus* the total landings for the lake being in the region of 210 000 t, is an important driver of exploitation of the fishery (21). Nile perch is purchased and processed mainly by the large-scale processors (21).

The establishment of the Dutch Government sponsored fish meal plant in Mwanza, Tanzania in the 1970s contributed substantially to the decline of the haplochromines in the lake since the factory targeted this fish group (21). Of the factories currently operating in the region, the majority commenced operations after 1990, an indication of the region's relatively recent entry into the global fish market (22). Fifteen out of 25 factories surveyed in the region (22) have been obliged to close down at least once between 1997 and 1998 to carry out modifications so as to comply with EU import regulations (22). Many of the fish processed are small sized because demand from export markets is fillets from small sized individuals, which are less fatty and provide portion-sized fillets (21). The decline of fish catches over time has also necessitated a change in the technology used in fishing to using illegal degrading technologies in order to catch more fish (23, 24).

Root causes for overexploitation of fisheries: The marketing of Lake Victoria's fish was localized within the riparian states during the pre-Nile perch era, but as most fish filleting factories were established in the 1990s, both the regional and international trade expanded (21, 23, 24). The high demand for processed fish products is, therefore, driven mainly by the large export market for Nile perch fillets that emerged in the early 1990s (23). Increasing human populations within the lake basin, poor governance in the fishing industry, and the unrestricted access status of the lake are secondary drivers.

The large export fishery for the Nile perch is estimated at USD 270 to 520 million (14). Fishers annual incomes (per capita) are estimated as follows: Kenyan, USD 3269, Tanzanian, USD 2294, Uganda, USD 1157 (21). The Nile perch is now sold not only to the traditional EU and Middle Eastern countries, but also to Japan, Australia, and northern and southern America (21). The price ranges for fish products such as chilled fillets, frozen fillets, portions, head-on gutted fish, head-off gutted fish and kosher products are from USD 2 to 4.5 kg^{-1} (22). By-products from the factories are numerous and include skins, off-cuts (chips), swim bladders and carcasses (frames). Swim bladders are the most valuable and are exported to the Far East (22).

The gap between the richest and poorest fishers in some coastal areas is widening, and the gap between the benefits obtained from the fishery by vessel owners and employed fishermen is also widening (21). Due to high demand for Nile perch, processors are providing loans to some fishers who then repatriate the outlays through catches to the companies (21, 22). The scarcity of fish has increased fish

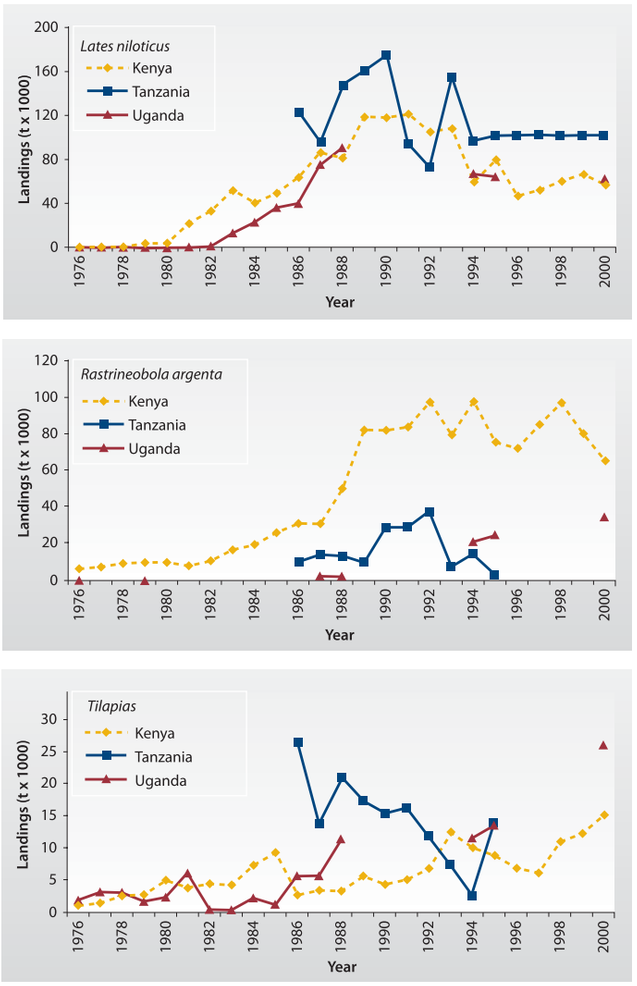

Figure 3. Trends in landings (tonnes (t)) of the major commercial fish species in the riparian countries of Lake Victoria (49).

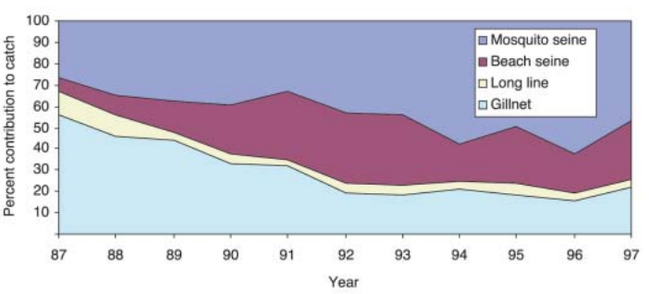

Figure 4. The percent contribution by weight of the 4 major fishing gears to the Kenyan Lake Victoria catches (20).

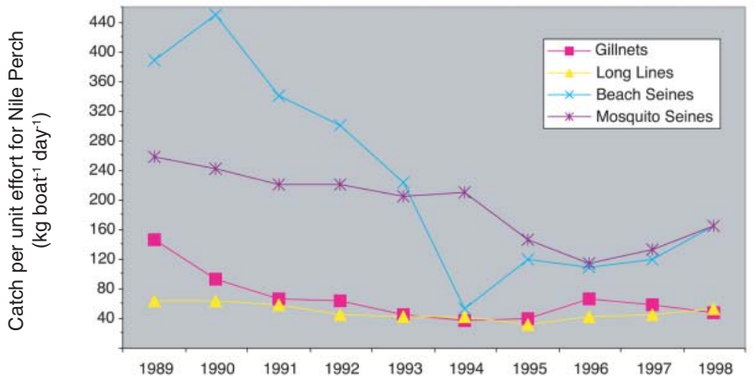

Figure 5. Trends in catch per unit effort for Nile perch in commercial fisheries of Lake Victoria (20, 21, 50).

prices at the landing sites (21). Thus, rich firms are able to displace less-rich processors, some of whom have been forced to close down. This has led to serious impacts in the fisheries sector and has intensified existing conflicts between users (27).

Destructive fishing practices

Destructive fishing practices and reduced capacity to meet human needs: Destructive fishing practices are mainly due to increased effort (55 – 75%). There has been a reduction in mesh size of nets used, and an increased proportion of immature fish in the catches (21). Mesh sizes have progressively declined over the past 10 years or so with 24% of the nets (24, 28) in Uganda now below the recommended mesh size of 5 inches, and now more recent beach surveys (L. Muhoozi, cited in 21) suggest that this is now as high as 50%. In Kenya and Tanzania, 3 and 18%, respectively, of the gillnets are below the legal mesh size limits (21). Trends (1987 – 1997) in percentage contribution by weight of the 4 major fishing gears to the Kenya Lake Victoria catches show that mosquito seine and beach seine landings have increased despite a ban on their use, while the gillnet and long-line contributions have declined (Fig. 4) (20, 23, 24). Rent-seeking behavior probably accounts for up to 20% of the contribution to destructive fishing practices. Beach seines and trawls (10 of which were operating in Kenyan waters until recently) (M. Njiru, cited in 21) are banned gears in the region.

Reduced capacity to meet human needs can account for up to 40% of the destructive fishing practices (Figs 4, 5). As traditional fishing methods are now often considered inadequate for landing a sufficient catch, fishermen increasingly resort to deploying illegal fishing gear such as cast nets, fish poison and weirs to improve their catches (26). Some of the gears used to fish are a fallout from other sectors such as the flower industry, where fine mesh nets that are used to protect flowers from birds are now being used in the fishing industry. In a 1999 LVRFP study of 1066 fishers in all 3 countries of the lake, 33% of respondents linked declines in the stock to the contravention of fishing regulations, 32% felt this was due to excessive fishing effort and 11% to pollution or the presence of water hyacinth (29). In most cases, these reasons provided for catch declines indicate a widespread acknowledgement amongst the lakes fishing communities that effort levels are excessive, that damaging fishing techniques are in use and that regulations are generally ignored (21).

Related sectors and activities: Most of the region's factories suffer from fish supply problems, attributed to low catches and competition with other fish factories (22). Due to the boom in the Nile perch export market, many more people who were never fishermen moved to cash in on the "lucrative" industry. This may have pushed traditional fishermen to resort to the use of destructive fishing methods to sustain their level of livelihood and food requirements. The use of poison, which led to a ban on fishing and the sale of fish in March 1999 (26), was probably largely due to rent-seekers. The remoteness of some of the landing sites and the inadequate transportation infrastructure impose severe constraints on the post harvest sector of the Lake Victoria fishery (21). Handling facilities, ice plants, storage facilities, sanitary conditions (including boats with containers) are either lacking or inadequate at landing sites, contributing to poor fish quality (21).

Root causes for destructive fishing practices: The reduction of taxes on all nets has resulted in more net purchases. The increase in population has resulted in increased demand for fish (particularly Tilapia) for local consumption. The unrestricted access status of the lake and lack of enforcement of existing legislation is linked to increasing and crippling fishing effort (21). There is also a lack of awareness among some of the fisherfolk on the mid- to long-term consequences of destructive fishing methods. The policy of free and unrestricted access to the Lake Victoria fisheries appears to be a major loophole that was exploited by the rent-seekers. With the near disappearance of many food-fish species (30) and signs of decline in *L. niloticus* (Othina and Osewe-Odera, cited in ref. 30), a number of management measures were effected including a ban on beach seines and undersized mesh nets (< 127mm stretched mesh) in 1994, and a ban on trawlers in 1996 (30). Failure in monitoring and enforcement of these bans is evident, e.g. the continued beach seineing in Kenyan waters despite its ban. Overfishing and the use of damaging or illegal fishing gear is only in part a reflection of the failure of centralized management strategies on the lake, and are symptomatic of broader social, economic, and developmental dislocations (21) such as poverty, lack of employment, etc. Theft (of fishing gears, vessels, etc.) and piracy are rampant on the lake, and may become worse as the disparity in distribution of benefits from the fishery becomes more polarized (21).

Table 2. Number of sewered and unsewered people in urban populations (from 33).

	Total population (1000 people)	Urban Population (1000 people)		
		Sewered	Unsewered	Number of Towns
Kenya	10 200	390	630	18
Uganda	5600	210	870	9
Tanzania	5200	27	340	4
Rwanda	5900	-	400	5
Burundi	2800	-	140	4
Total	29 700	627	2380	40

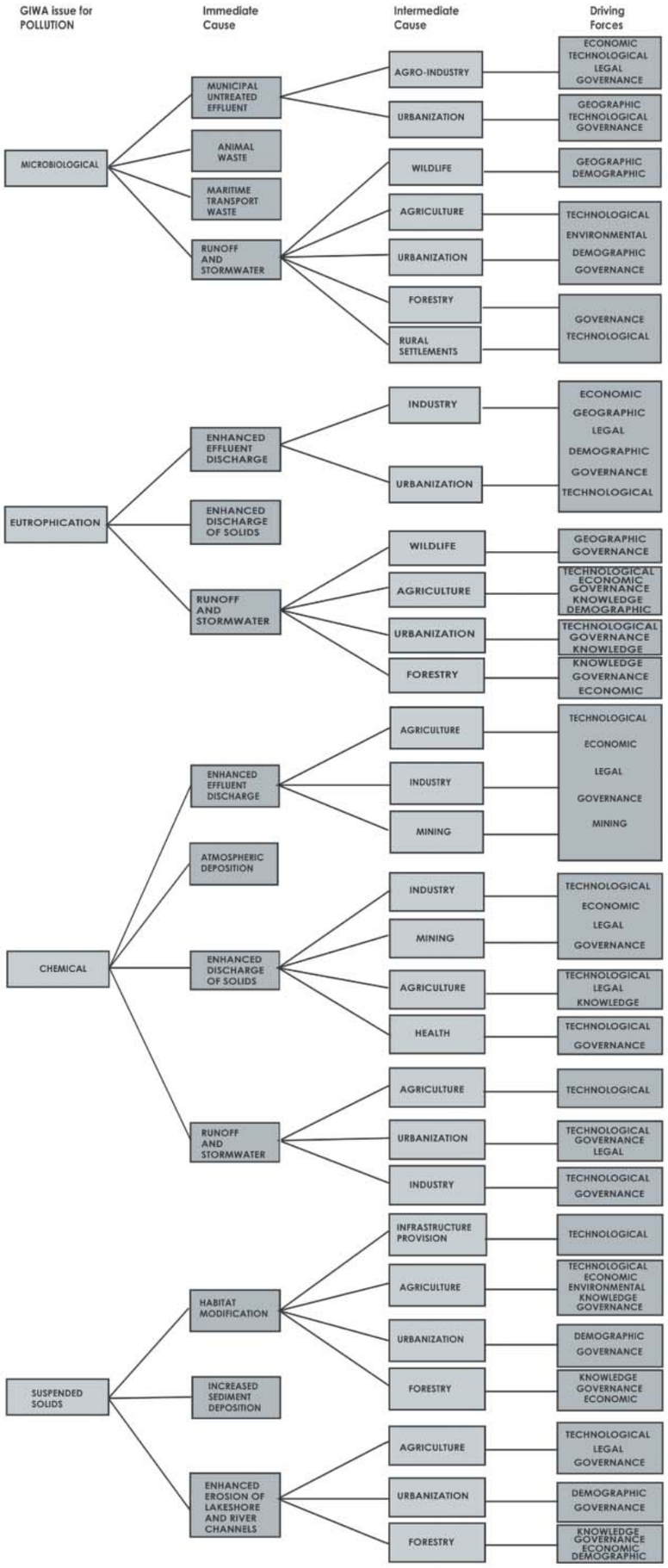

Figure 6. Causal chain analysis diagram for pollution.

Pollution

The following pollution issues; microbiological, eutrophication, chemical, and suspended solids were identified as being the most important. It was noted that suspended solids are part and parcel of the factors that contribute to microbiological, eutrophication and chemical pollution, and that their role is more important in synergies with the other 3 issues rather than on its own. Therefore, suspended solids is nested within the other 3 issues.

Microbiological

Four immediate causes have been identified in microbiological pollution, namely, municipal untreated sewage, runoff, and storm water, animal waste, and maritime transport waste (Fig. 6). Of these immediate causes, the 2 most important are municipal untreated sewage, and runoff, and storm water.

Municipal untreated sewage, runoff, and storm water: Direct discharge of municipal untreated effluent into rivers and the lake directly contribute to microbiological pollution. These have contributed to the degradation of river and lake-water quality for habitats and drinking use (26, 31). The low standards of health in the region are caused by a general lack of awareness of good hygiene practices, direct contamination of beach waters through bathing and washing, and uncontrolled waste disposal around the shore line (32). Reduction of the biological oxygen demand (BOD) load of such effluent can significantly reduce the occurrence of waterborne diseases such as typhoid and cholera which are common in the region. Runoff and storm water collect a lot of animal, plant, and human waste from point and nonpoint sources and channel these to rivers and the lake, creating an environment that supports microbiological pathogens. Harbor and bilge discharges compound the microbiological pollution problem.

Related sectors and activities: There are 2 major sectors from which the municipal untreated effluent is derived, i.e. agro-industry and urbanization. Beer-brewing, pulp and paper production, tanning, fish processing, agro-processing and abattoirs discharge raw/untreated waste to feeder rivers and lakes (e.g. 26, 31). The number of people without sewers in urban populations is high (Table 2), and with an urban population growth over 5–10% yr^{-1} in most of the larger towns (against 2–4% in most parts of the lake basin) (33), the situation is likely to get worse. In rural areas there are no sewers at all.

An assessment of BOD_5 loading of Lake Victoria (corrected for purification in treatment plants, rivers and wetlands) shows that domestic pollution accounts for most of the BOD load, with the contribution of industry (mainly from breweries, sugar-cane factories and soap and

oil factories) being relatively low (33). Kenya contributes a BOD load of 7510 t yr^{-1}, Uganda contributes a BOD load of 4540 t yr^{-1} while Tanzania contributes a BOD load of 3920 t yr^{-1} (33). 75% of the BOD load from Uganda originates from Kampala, while in Kenya, 50% of the BOD load originates from Kisumu (33). Water hyacinth infestations have also been reported to lower the water-quality in Kenya, Uganda, and Tanzania (in terms of color, pH, turbidity of water) and to increase the treatment costs (particularly associated with keeping the water intake points free of water hyacinth) (34).

There are several sectors that contribute to microbiological pollution of runoff and storm water. These include wildlife, agriculture, urban, forestry and rural settlements sectors. During the rainy seasons when runoff and storm water discharge are peaking, the incidences of water-related diseases reach high levels.

Root causes for microbiological pollution: The treatment works in municipalities are either inadequate, using old and obsolete technology, have ageing components, or have simply ground to a halt. They have also not been able to expand to keep pace with the increasingly larger populations. The municipal by-laws, such as those of Kisumu City, did not predict the growth and type of industries existing today, and so there is no capacity to manage the waste from these industries. Industries flout the by-laws and regulations as there is no monitoring and enforcement mechanism. Poor planning, maintenance, and inadequate investment in municipality wastewater-treatment systems have contributed to the increased untreated effluent discharge. If the present treatment plants in Kisumu performed optimally, the BOD loads could be brought down by 50% (33). Water supply to both municipalities and villages is also affected by water hyacinth. In municipalities, water hyacinth interferes with the water-intake points through blockage, which lowers the quantity of water pumped (in Kisumu the water supply has dropped from 20 000 m^3 to 10 000 m^3 day^{-1}) (34). This decline in water supply invariably causes more people to look for alternative, and often untreated, water sources.

Flooding is common in the region, particularly around the lakeshore, during the rainy season and its impact is exacerbated by poor practices when carrying out activities in the above sectors. Contamination of drinking water results from poor sanitation, hygiene, and poor floodwater management. For example, there were 14 275 cholera admissions in Nyanza province, LVB, Kenya, alone between June 1997 and March 1998, with 547 deaths reported (32). One of the major risk factors identified for cholera among a sample of these patients was drinking water from Lake Victoria or a stream (32). The period coincided with widespread heavy rainfall that caused flooding across the East and the Horn of Africa (35).

Eutrophication

Three immediate causes of eutrophication can be identified; i.e. enhanced effluent discharge, runoff and storm water, and enhanced discharge of solids. Enhanced effluent discharge and runoff and storm water are the most important immediate causes of eutrophication.

Enhanced effluent discharge, runoff and storm water: Analyses of sediment cores from the lake show an increasing rate of sedimentation over the past 150 years (6, 36). There are many densely cultivated areas in the LVB, especially in Kenya, Rwanda and Burundi (33). Some rivers, such as the Sio, Nzoia, Yala, Sondu, Nando and Kuja in the LVB Kenya, drain highly productive agricultural areas. The sediment load of the Nyando River, for example, has increased by 7.5 times during the last 16 years, with turbidity measured at 527 NTU in the rainy season of 2001 (36).

Table 3 Agricultural characteristics of Lake Victoria basin (33).

	Catchment land area (1000 ha)		
	Cultivated	Noncultivated	Total
Kenya	1470	3400	4870
Uganda	1400	2100	3500
Tanzania	1500	5540	7040
Rwanda	930	1130	2060
Burundi	670	640	1310
Total	5970	12 810	18 780

Habitat modification through vegetation clearance for infrastructure provision, agriculture, urban settlements and plant harvesting for use as building materials, furniture crafting and fuelwood, etc., enhances erosion and increases the suspended solids load in rivers. Enhanced erosion of the lakeshore and river channels are directly contributing to increased suspended solids in the lake. Soaps and detergents that are being used within the basin are outdated or banned and are contributing to eutrophication. Analysis of nutrients (N and P) in the rainy season of 2001 in the Nyando, Sondu, Nzoia, and Yala rivers indicates that continued addition of input of such high nutrient concentrations into the Winam Gulf will seriously affect aquatic systems and water-quality (36). Nutrient loads to the lake are associated mainly with atmospheric deposition and land runoff, together accounting for about 90% of the phosphorus and 94% of the nitrogen input into the lake (33).

Related sectors and activities: The change from small-scale to large-scale industrial production, and change from small to large farms, etc. have all contributed to enhanced effluent discharge. The agricultural characteristics for the LVB as a whole are as shown in Table 3 below (33).

Human population increase, as well as increased rates of urbanization and agriculture in the region have increased the per capita demand for land (37), and hence more land is cleared to create the additional space required for these sectors, including wetlands (37, 38), leading to increased sediment deposition in the rivers and lake. There is, for example, large-scale draining of the Yala Swamp (LVB - Kenya) to create land for agriculture and settlement (39). Clearing of riparian vegetation has led to erosion and loss of the vegetation that acted as filters (40), while nutrient-rich sediments from agricultural runoff and also low-lying, deforested riparian zones and other areas surrounding the lake contribute to eutrophication, and feed the carpets of water hyacinth (41). The degree to which urban runoff and solid wastes contribute to suspended solids load has not been assessed (26).

Root causes for eutrophication: There has been a lack of monitoring and enforcement of regulations. Those industries that have tried to install recycling facilities in urban areas have not had support from the regulating authorities. The food and cash crops grown on wetlands require application

of fertilizers and pesticides (37). Unsustainable land-use practices lead to increased soil erosion and nutrient land runoff (33). The high atmospheric nutrient loads are attributed to forest burning, and increased dust due to soil erosion (42). Sand harvesting activity is mainly performed 5–10 km away from the lake, particularly in Winam and Ahero Divisions, LVB, Kenya, but some sand harvesting is undertaken right on the shores of the lake (37).

An important source of income, papyrus, is harvested for thatching houses and the making of mats, baskets, furniture (chairs), fishing floats, rafts, etc., while both shrubs and papyrus are used for wood fuel (37). There are farms, roads, fishing camps and housing developments close to or on the wetlands (37). Soil erosion in the wetlands is generally connected with cultivation, but specifically to poor farming practices (37).

Chemical pollution

The identified immediate causes for chemical pollution are: enhanced effluent discharge; enhanced discharge of solids; runoff and storm water; and atmospheric deposition. The latter is currently the least important but, in terms of supply of nutrients such as N and P, it may become increasingly important as land-use in the basin and outside cumulatively reduces the vegetation cover, thus increasing the atmospheric load of fine particulate matter.

Enhanced effluent and solids discharge: Increasing volumes of chemical effluent discharges go directly into the rivers and lake. Leachates from mining tailings that are close to the rivers or lakeshore, industrial wastes such as barley waste and chemicals are dumped into the lake in an uncontrolled manner. There is also disposal of expired pesticides, medical waste, petrol station wastes, bunkering wastes, etc. Some companies have stockpiles of banned substances such as DDT.

Related sectors and activities: Most industry is located in the large towns bordering the lake; Kampala and Jinja in Uganda, Mwanza and Musoma in Tanzania, and Kisumu in Kenya, with the exception of the large sugar factories in Kenya located at some distance from the lake (33). Small-scale mining is increasing in parts of the Tanzanian catchments, leading to contamination of the waterways by mercury. Very few industries have adopted clean technologies. For example, Panpaper Limited in Kenya (discharging into Nzoia River) could use an extra processing step of scrubbing technology to reduce SO_2 and produce sulfuric acid (added value product). Used chlorine has been dumped into the lake killing many aquatic organisms. In Uganda, expired chemicals as well as drugs and partially-treated domestic sewage from the Kampala area are dumped into public waterways, finally ending up in Lake Victoria (43).

The use of agrochemicals is increasing in the lake basin where there are large-scale farms of coffee, tea, cotton, rice maize, sugar, and tobacco (26). Much of Ugandan industrial effluents drain through wetlands before reaching the lake water (33). The urban and peri-urban growth is rapid and largely unplanned; many buildings are erected without authorization, runoff rates are increased due to lack of storm-water drainage to handle urban runoff, and municipal authorities poorly manage waste disposal. Most of the poorly disposed of urban wastes are then washed into watercourses and eventually reach the lake.

Root causes for chemical pollution: In Tanzania and Uganda, industrial wastewater treatment facilities are generally absent, but in Kenya a majority of factories operate a treatment plant (33). Some recent studies have shown that fish in Lake Victoria contain varying levels of organochlorine pesticide residues (44), reflecting the transport of agrochemical residues from farms within the catchment, through rivers to the lake. Only a few industries are connected to an urban sewage system (33). Growth in industries has taken place against a backdrop of no infrastructure development for disposal of effluents. The currently existing sewage infrastructure has not been expanded or improved for decades. However, some of the industries are being allowed to establish their operations in areas that have been designated as "non-industrial", so they lack the infrastructure to handle their waste products. There is no enforcement of existing regulations regarding chemicals use and their disposal, and the current legislations are out-dated and in need of revision. Lack of monitoring and poor scientific knowledge has led to the use of inappropriate or obsolete technologies to the detriment of the environment. The governments of the 3 riparian countries have not taken deliberate actions to put in capital resources to meet the economic development needs of the region.

POLICY OPTIONS

We evaluated the relative likelihood of success of the policy options using the following criteria: effectiveness, efficiency, equity, political feasibility and implementation capacity. The policy options in the LVB were additionally evaluated within the context of the policies that guide the recently re-established East African Community (EAC) (45, 46). The Lake Victoria Development Programme (LVDP) has already established and operationalized National Focal Points in the Partner States' ministries responsible for Lake Victoria development. These ministries include the Ministry of Environment and Natural Resources in Kenya, the Ministry of Water and Livestock Development in Tanzania and the Ministry of Foreign Affairs in Uganda. The other achievements are in terms of studies conducted for facilitating the basis for objective decisions on environmental and natural resources management in implementation of the Treaty. The East African Community therefore offers a good prospect for the success of the policies that have been proposed here in that it provides a conducive environment for Kenya, Uganda, and Tanzania to work together towards common goals.

Overexploitation of Fisheries

Quota for fishing

This has a high probability of success in the medium-term (5 years). There should be involvement of stakeholders (fishers in co-management), with change of attitude from government-driven to community-driven management and ownership of the process. The process should be initiated in areas where the environment favors self-regulation and sustainability. A conducive environment for the success of the instruments that need to be put in place (revision of by-laws; scientific basis for decision-making; education and training; financial and technological assistance; etc.) should be created. This measure should be able to control the number of entrants and efforts to a sustainable level at minimum cost.

Quota for processing

This should go along the same lines as the quotas for

fisheries. It holds the highest possibility of controlling the amount of fish landed due to restricting the main market. Resistance is expected from both sellers and buyers of fish, but with the dwindling stock of fish and reduced supply, in terms of both quantity and quality, it is expected that awareness creation properly publicized will avoid this obstacle.

Review of the rules and regulations and existing policies
In order for co-management to succeed, an environment that is conducive should be provided. This will include recognition of property rights and entitlements. The review of policies, rules and regulations are already being worked out under EAC. This, however, should be carried out in conjunction with effective enforcement. The policy option will have a high probability of success if well implemented in a participatory manner with stakeholders in the fishing communities along the lake shores, as has already begun under co-management through Beach Management Units (BMUs).

Civic education and awareness
It is important to increase public participation in order to enhance effective decision-making and compliance by self-regulation. There is political will at the regional level, as demonstrated by the EAC treaty document and implementation of the intended objectives so far. This option will lead to more popular participation of the communities in the environmental, economic, and development issues that affect their livelihoods. It would also be more inclusive in terms of sharing accruing costs and benefits.

Destructive Fishing Practices

Strengthening monitoring and enforcement of restrictions and rule of law
Monitoring and enforcement of regulations and restrictions puts the risk factor for contraventions high so as to encourage compliance. The effectiveness of this policy is high, especially considering the EAC initiative's political will and intention towards strengthening capacity for the management of Lake Victoria. The move towards co-management should be supported because it involves communities in effective management at a lower cost hence making it possible to achieve the monitoring and enforcement goal.

Provide civic education and awareness, empower and involve more communities in management
The general lack of awareness of both the status of the fishery and the adverse impacts of destructive fishing practices on the fishery may be a contributing factor to the irresponsible behavior. The people's lack of awareness and ignorance of their rights and obligations in bringing about a conducive environment for a sustainable fishery may also undermine their effective participation in the management of their natural resources and fisheries in particular. Empowering the community in both these and other forms of awareness would go a long way towards effective management and consequently sustainable utilization of fisheries resources.

Imposition of size restrictions on fish-processing factories
Fish-processing factories place the highest demand on Nile perch, and prefer small-size fish, which they export to foreign markets. Therefore, by discouraging the purchase of small-size fish, the effect will be to facilitate growth of fish to full size where reproduction will take place to replenish stocks. This policy option is now achievable since most of the owners of the processing plants have realized that the availability of small-size fish for their factories is becoming a problem.

Provision of credit to artisan fishers
Lack of capital to buy the recommended fishing gear hampers compliance by small-scale fishers. Having being dispossessed of their illegal gear, they cannot afford to buy new legal fishing gear. Provision of credit to these fisherfolk will facilitate compliance of restrictions and regulations by enabling them to purchase the required gear, which does not endanger the sustainability of the fishery. With the experience gained by numerous NGOs in credit provision to small-scale entrepreneurs, this policy option has a high probability of success. It has the double advantage of alleviating poverty among the fishing communities while at the same time facilitating sustainable utilization of fisheries resources.

Pollution Policy Options

Accreditation of analytical laboratories for standards enforcement
In order to facilitate water-quality standards enforcement conveniently and relatively cheaply, accreditation of regional and national water-quality laboratories is essential. Implementation of this policy option will go a long way in reducing health costs and increase labor productivity. Under the EAC, programs are already underway to address this situation.

Liberalization of waste disposal activities to involve the private sector and communities
Private sector participation in waste disposal activities is obviously important in order to fill the void left by the public institutions which have failed to render these services. The feasibility and effectiveness of this policy option is that it is a business venture with the capability of generating income. There are, for example, environmental and sanitation companies in Dar es Salaam and other towns that are carrying out the enterprise profitably. In some places there are established community youth groups that engage in waste collection and disposal from residential areas.

Revise regulations in urban planning that have not taken into account environmental issues and improve monitoring and enforcement
Current urban-planning regulations and plans are outdated. Town-planning services have not taken into account the increasing populations which have far outstripped projections made in the 1960s and 1970s. Lack of monitoring and enforcement of building and new settlement developments have resulted in urban centers evolving haphazardly with poor sanitation and lack of essential services. However, the capacity to undertake the revision and corrective measures exists within relevant land offices in EAC partner states.

Improve natural resource management, farming practice through training, governance and technologies in agriculture
Training of farmers around the lake to practice clean production and to avoid bad farming practices, which result in pollution of the lake, is essential. Poor farming practices are mainly due to lack of education and awareness. The implementation capacity of this policy option exists within partner states and the political and technical feasibility is manifested by the existence of LVEMP.

Stronger vetting of technologies that are being promoted by the national and international agencies

Many factories are using old, obsolete and/or inappropriate technologies that do not adequately reduce the pollutant load in effluents before discharge to rivers and the lake. In some cases, prohibited chemicals such as DDT are used. Clean technologies should be promoted alongside better economic incentives, and stronger vetting of prohibited chemicals will reduce the risk of the adverse effects of pollution on human health and the environment.

Strengthen enforcement of regulations requiring effluent treatment in municipalities and industries

While rules and regulations on waste disposal exist in all 3 countries, their enforcement is seriously lacking. In the industrial ordinance of Tanzania, the factory inspector requires all processing plants to have waste-treatment facilities from their factories. However, few industries have "working" treatment plants or ponds for that matter. Wastewater and solid waste is left to spread to streams and residential areas where they affect the health of inhabitants living in the vicinity of these areas or those who use contaminated water from streams and rivers. In other places, the disposal of industrial and municipal effluent results in huge economic losses to the economy through destruction of tourist attractions such as coral reefs. With the enactment of environmental policies and frame law in all the 3 partner states, and establishment of environmental protection agencies, this policy option has a high probability of succeeding.

Incorporate all stakeholders in drafting of regulations and in monitoring and enforcing agreed upon regulations

Participatory approaches have been found to be effective in implementation of policies and decisions, which require the input of the community and where the communities in turn stand to benefit from the process. This is because involvement of the beneficiaries inculcates a sense of responsibility and ownership among others. Because the cost of implementation and the benefit accrues to them, they become effective partners ensuring proper and successful implementation. This policy option has a high probability of success. It provides high dividends in terms of high success rates, as has been experienced across the region in several project implementations.

Integration of institutional framework, regulations and laws at two levels: National and regional

In order to have a consistent and smooth policy implementation for the management of the lake, harmonization of policies, regulations and laws is vital. This work is underway within the auspices of EAC for fisheries, environment and natural resources management.

Legal and economic empowerment of institutions

Given that conflicts occur between people from the partner states over shared resources (e.g. between fishermen), the current practice is such that country rules and regulations and institutions are used to solve these transboundary types of problems. In order to avoid complaints from parties in conflict, an impartial institution is recommended to take care of such occurrences. This will foster harmonious coexistence among inhabitants of the 3 states sharing the same resources through reduction of transboundary conflicts.

Enforce compliance to international conventions, e.g. RAMSAR, CITES, and the Biological Diversity Convention of Agenda 21

All the partner states have ratified many international conventions including the ones mentioned above. However, not all the ratified conventions are implemented as desired. The result of such a state of affairs is to exacerbate environmental degradation and biodiversity decline among others with disastrous effects. With proper awareness, mobilization and commitment, popular participation seems to be one way of facilitating the objectives through putting pressure on relevant authorities.

Strengthening of capacity of National Environmental Protection authorities in order to be more effective

For all its existence to date, the National Environmental Management Council (NEMC) of Tanzania has been a "toothless dog" in that it did not have legal backing to enable it to execute the mandate of an effective environmental protection agency, as we know it. With the work on the Institutional and Legal Framework for Environmental Management in Tanzania nearing completion with the formulation of the environmental framework law, NEMC will have executive powers to monitor and enforce rules and regulations pertaining to environmental management and protection. Such institutions have already been established in Uganda (NEMA) and Kenya (NEMA).

CONCLUSIONS

A comprehensive assessment of the environmental and socioeconomic issues affecting Lake Victoria Basin was carried out following the methodology outlined by the GIWA project (47). This assessment identified overfishing and pollution as the issues of greatest concern (48). The root causes of these environmental problems are many, reflecting the complexity of issues affecting Lake Victoria.

The underlying causes for overexploitation of fisheries include: high demand for fish and fish products in export markets, and improvements in fish handling capacities and technologies used in the fisheries sector. Other causes are related to lack of sufficient controls through regulations and legislation. For example, lack of fishing quotas and the unrestricted access status of the lake has abetted high fish harvesting rates and high influx of fishermen that threatens the sustainability of the fisheries resource. There is a general lack of compliance to and enforcement of

Multifunctional sewage treatment ponds at Webuye Pan Paper Industry. Photo: O. On'gan'a.

regulations and legislation governing the industry that is partly due to corruption, as well as weak regional integration of legal, institutional, and implementing mechanisms. There is a notable lack of involvement of stakeholders in decision-making processes, and a low level of civic education and awareness at all levels on the consequences of unregulated fishing and use of destructive fishing methods. The lack of cross-sectoral harmonization of legislation in closely related industries can lead, for example, to unjustified disjunctions in the requirements for the minimum operating standards.

The factors contributing to the pollution of the lake and influent rivers include: poor urban planning against the backdrop of population and industrial growth, the use of old, dilapidated and inappropriate technologies, poor maintenance of treatment plants, lack of waste treatment and disposal mechanisms, poor sanitation infrastructure, poor agricultural/land-use practices, and inappropriate use and disposal of chemicals such as pesticides, fertilizers, and industrial wastes. Currently, there are poor standards for industrial operations, and there are no incentives to encourage the industries to engage clean technologies. In addition to this, the governments have failed to provide services such as sewage treatment and waste disposal in both urban and rural areas. There is a lack of monitoring and enforcement of existing regulations and legislation, and, in most sectors, lack of resources and will on the part of the governments to mitigate the environmental problems.

On the policy option part, we observe that in several cases, more than one policy ought to be taken up at once in order to obtain the desired impact. This is true with quotas for fishing and processing. Also, the successful implementation of these policy options will not be achieved without involving, in a participatory manner, the communities living on the lakeshores who are involved in fishing as a source of their subsistence livelihood and income generation. Capacity building in terms of civic education and leadership and management skills will enhance this empowerment. Knowledge gaps are identified as being lack of information on quantitative estimates of benefits and costs (in both physical and monetary terms) of the Lake Victoria water and fisheries resources. The EAC has identified natural resource valuation and accounting as very important aspects in planning and development. It is important to know the economic, social and environmental values of these natural resources in order to allocate them efficiently and equitably for the present and future generations.

Immediate further studies/actions are required on the following wider aspects: water-quality assessment; sociocultural issues (holistic rather than focusing within the fisheries sector, encompassing also health, agriculture, education, etc. within the entire lake basin); resource inventory, mapping and use (including mapping of critical resources); assessment and harmonization of legal and institutional status of National Acts, regional and international Treaties and Conventions; the biology and ecology of the Nile perch and other fishes.

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empowerment it means that community responses to issues remain low and, more or less, unfocussed. Part of the reason for this is the lack of ownership of natural resources, linguistic and education barriers to mass media, difficulties in cross border trade and an imbalance in the ownership of the means of production. Additionally, where resolutions and decisions have been made, the speed of implementation is very slow.
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