Cooperation and Competition: Managing Transboundary Water Resources in the Lake Victoria Region

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Working Paper No. 5 2009

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Introduction

The sustainable and equitable management of transboundary water resources poses a host of problems for riparian nations in developing regions of the world. This is highlighted in Africa's Lake Victoria region, where the nations of Kenya, Tanzania, and Uganda are seeking to combat interrelated challenges, including recent problems of water hyacinth infestation and eutrophication, as well as the more far-reaching problem of increasing environmental pressures brought on by burgeoning populations, increased pollution, and climate change. A decline in lake water levels further threatens the environment and economic growth.

To combat these challenges, these East African governments have, both singly and collectively, undertaken numerous projects in the region. Because the scale of the problems is so large and the lake and its catchment basin cross international boundaries, a coordinated set of activities is required to produce the most positive results. To this end, the Lake Victoria Environmental Management Project (LVEMP) was established by Kenya, Tanzania, and Uganda.

In theory, LVEMP should provide a framework for coordination among the governments as well as a forum in which to discuss and implement programs necessary for combating the region's problems. This paper seeks to review the effectiveness of LVEMP-I and analyze the extent to which it has been successful in addressing the Lake Victoria region's numerous challenges. This takes on special importance as preparations are made to begin implementing LVEMP-II projects.

Background

The consequences of failing to address the threats to Lake Victoria are likely to be severe. The lake is the defining feature of the regional ecology, the primary source of livelihood security for the basin's human population, and an important source of revenues and economic growth for the nations of the catchment basin. Ecologically, the importance of the lake is difficult to overstate. It is the second largest lake in the world as well as the source of the White Nile, and its waters and wetlands are home to numerous fish and bird species, some of which already are threatened or endangered. Additionally, Lake Victoria is a major determinant in the region's weather system, with water levels playing a key role in regulating area rainfall patterns. From the perspective of human security, the lake basin's large and growing human population is heavily dependent on the lake and its resources both for water needs and for livelihoods. Finally, Lake Victoria plays an important role in the energy and export economies of the riparian nations. Uganda depends on the flow from Lake Victoria to power its dams at Jinja, which provide much of the country's power. Kenya also has significant hydropower potential, and Tanzania is especially dependent on the lake for its fisheries.

In recent years, these riparian nations began to recognize that the lack of a coherent region-wide strategy had become a major factor in environmental degradation (East African Community [EAC] 2005). One nation's misconceived development plans or flawed environmental management could undermine the conservation and management efforts of other states, thereby threatening development and livelihood security in the entire region.

The Lake Victoria Environmental Management Project (LVEMP) was formed in 1994 by Kenya, Tanzania, and Uganda. LVEMP-I was developed as a five-year program to research issues affecting the lake, design potential solutions, and implement pilot programs to address them. LVEMP-I produced several notable outcomes, including the establishment of a common database for fisheries research and the first comprehensive water quality monitoring program ever undertaken on Lake Victoria. In 2003, program development began on LVEMP-II to build on the tasks initiated under LVEMP-I and further address regional threats.

Despite the achievements of LVEMP-I and the ambitions of LVEMP-II, questions about the efficacy of the initiatives nevertheless remain. There are indications that competing interests and a lack of transparency are hampering cooperative efforts. The need for economic growth also creates incentives for member governments to behave in ways that sometimes contradict natural resource management agreements and strategies.

Overfishing has become a major problem, significantly affecting livelihood security in the region. Pollution also poses major threats to both the environment and the health of basin residents. However, the most salient and well-publicized example of competing uses for water in the lake basin is Uganda's alleged over-release of water at the Kiira and Nalubaale dams. Studies have offered evidence that Uganda is operating in violation of the Agreed Curve, the historical agreement that controls how much water can be released at Owen Falls, and thus how much water can be released at the Kiira and Nalubaale dams (Kiwango and Wolanski 2007; Kull 2006). Although the arrangement is designed specifically to maintain natural water levels in Lake Victoria, at least two studies have concluded that Uganda is releasing much more water than allowed by the Agreed Curve to power its dams, contributing substantially to a drop in water levels that has caused concern among scientists and policymakers alike. Uganda insists that its actions are in keeping with prevailing agreements and attributes lake water level changes to climate change and other environmental factors.

Failure to address adequately the challenges present in the basin will mean significant ecological degradation, resulting in decreased economic performance and deterioration in the quality of life and well-being of millions of people—the result of which may be loss of legitimacy for the riparian governments, as well as declining legitimacy for the institutions that have been developed to help mitigate the challenges. Although to date the region has avoided large-scale, environmentally induced conflict, a confluence of adverse trends would threaten human security, increase social tensions, and increase the possibility of interstate disputes or conflict.

Environmental Significance

Lake Victoria lies within the boundaries of Tanzania, Kenya, and Uganda, accounting for 44 percent, 22 percent, and 16 percent of the basin, respectively (EAC n.d.). Parts of Rwanda and Burundi also lie within the catchment basin, but to a much smaller extent, composing only 11 percent and 7 percent of the basin, respectively (see Figure 1). The area of the lake is 69,000 square miles, and its catchment area encompasses 193,000 square miles. Given its size, it is not surprising that Lake Victoria plays a vital role in the ecology of the entire East African region. Lake Victoria provides habitat for numerous fish and bird species, including the crested crane and the sitatunga, a globally threatened species of water antelope (Kansiime et al. 2007).

Figure 1. Map of Lake Victoria Region

Source: Encarta 2008.

The ecological significance of the lake is heightened by the role it plays in shaping regional weather patterns, especially with regard to rainfall. According to Anyah and Semazzi, the surface temperature of the lake is significantly correlated to the basin-wide spatial distribution of rainfall (2004). This phenomenon occurs because large inland lakes "affect atmospheric circulations…through frictional and thermal contrasts between lake surfaces and the adjoining land areas" (Mukabana and Pielke 1996). Large inland lakes, such as Lake Victoria, also are sources of significant moisture and latent heat, both of which drive tropical climates (Anyah and Semazzi 2004). The relationship between Lake Victoria's surface temperatures and climate is especially strong, even compared to other large lakes, because of its high-altitude location, which contributes to strong wind circulations in the region (Anyah and Semazzi 2004). This link is not just of academic interest; with lake surface temperatures so strongly correlated to regional climate and rainfall patterns, any changes could have a major impact on agricultural productivity and thus the livelihoods of millions of people in the basin area. Additionally, if surface temperature changes cause a significant disturbance to rainfall amounts, it will have a marked effect on the lake itself as rainfall is the primary natural determinant of lake water levels.

Average temperature in the lake varies only slightly from month to month (Anyah and Semazzi 2004). However, temperatures in Lake Victoria have been rising in recent years. According to Anyah and Semazzi, air temperatures on the Ugandan side of the lake were 0.5˚C higher in the 1990s than in the 1960s (2004). While this may not seem like a striking increase, the interactions between lake surface temperature and rainfall amounts and distribution are complex. Research indicates that higher lake temperatures are associated with increased rainfall, with models predicting that some areas of the basin region could receive 100 percent more rainfall when lake temperatures rise by as little as 1.5˚C (Anyah and Semazzi 2004). Anyah and Semazzi acknowledge that the models and simulations derived from their research do not describe the region's rainfall scenario with absolute precision, and other factors also may have consequences for lake levels and rainfall. The main issue to consider, however, is that because Lake Victoria plays a major role in shaping the region's climate, even small changes to the lake can have much larger—and unpredictable—effects on the entire basin area.

Economic Significance

Lake Victoria plays a major role in the economies of the riparian nations. The fishing and fish processing industries generate much-needed income and hard currency earnings. Current annual fish catch estimates for the lake range between 500,000 metric tons and 750,000 metric tons, and account for between US$300 million and US$400 million in annual value, US$250 million of which is exported (EAC n.d.; Uganda Coalition for Sustainable Development 2007; EAC 2006). According to the Uganda Export Promotion Board (UEPB), Uganda's fish exports totaled 36,461 metric tons and accounted for US$145.8 million in 2006 (UEPB 2007). Strong European demand for Nile perch from Uganda led to yearly increases in the value of fish exports from 2002 until 2006 (UEPB 2007).

All three nations also depend on Lake Victoria as a source of power needed for economic development. This is especially true in the case of Uganda, which already relies on two dams near Jinja, the Nalubaale and Kiira dams, to produce a combined 320MW of electricity. According to the 2007 Renewable Energy Policy for Uganda, the country hopes to expand hydropower capacity from the 2007 level of 380MW to 1200MW by 2017 (Government of Uganda 2007). The government is moving ahead with plans to build the Bujagali dam, construction of which began in 2007, and the plant is expected to produce an additional 250MW of electricity (Government of Uganda 2007). Further plans are being developed to add 100MW to 200MW at Karuma, 450MW at Kalagala (EAC 2006), 300MW at Ayago North, 250MW at Ayago South, and 600MW at Murchison Falls. Not all of these sites will affect Lake Victoria, but it is clear that expanding hydropower is the central tenet of the government's strategy to increase electrical production (Government of Uganda 2007).

Although Uganda currently has the most developed hydropower industry of the three nations, Kenya also has significant potential. The EAC estimates that Kenya could generate a total of 278MW of electricity from Lake Victoria tributaries Sondu-Miriu, Kuja, Nzoia, and Yala (EAC 2006). This added capacity also would benefit Kenya's electricity exports, as Uganda seeks to increase its energy imports during periods when the country cannot produce enough to meet national demand (Ministry of Energy and Mineral Development 2006).

In addition to its fisheries, the lake also plays a vital role in regional transportation, with connections running between the major towns of Musoma, Mwanza, and Bukoba in Tanzania, Port Bell and Jinja in Uganda, and Kisumu in Kenya (EAC 2006).

Human Security and Livelihood Significance

The lake and its resources directly impact, and are impacted by, the 30 million people living in its catchment area, 25 million of whom reside in Kenya, Tanzania, and Uganda (EAC n.d.). Catchment area residents rely on the lake for everything from drinking and household water to livelihood opportunities. According to the East African Community, Lake Victoria supplies fresh water to five million people, from some of the region's largest cities to a number of rural villages (2006). The fishing industry, including both commercial operations and artisanal fishing, and the fish processing industry directly supports three million people (EAC 2006). Considering the extremely high incidence of poverty in the basin area, the continued vitality of the fishing industry is especially important to the economic health and livelihood security of the region.

Environmental Challenges

The lake ecosystem is under threat from multiple sources, each posing its own management challenge. Water quality has declined due to water hyacinth infestation, and the resulting eutrophication has negatively altered lake oxygen levels.[1] Rapid population growth contributes to pollution, soil erosion, and run-off triggered by deforestation, wetland destruction, and poor agricultural practices, which further threaten water quality.

Water Hyacinth

Although it is unknown how water hyacinth first entered Lake Victoria, the resulting infestation has become a massive problem over the last two decades. Since first being reported in Ugandan waters in 1988, the infestation has spread across the lake from the likely source, the Kagera River, all the way to the Kenyan border (Wulf and Andjelic n.d.). Water hyacinth infestation blocks major transportation routes, interferes with fishing, and hampers dam operations. Water hyacinth also poses problems for the lake ecology by using available oxygen reserves, resulting in fish kills. Economic losses are significant. The World Bank estimated that the first outbreak in 1997 cost the riparian nations between US$6 million and US$10 million (2000). During this period, there was reportedly a 70-percent decline in economic activity at the Kenyan port of Kisumu (Mailu 2001).

Water hyacinth infestations have a direct effect on local communities. As the World Bank has noted, water hyacinth is a major contributor to poverty and low standards of living in the area because it negatively affects fish catches and increases water pollution. Large mats of water hyacinth—some stretching as far as the eye can see—provide an ideal breeding ground for malaria-carrying mosquitoes, further threatening the well-being of the population (Klohn and Andjelic n.d.).

Addressing the water hyacinth problem has become a major undertaking involving all three nations and numerous international organizations, including the World Bank and the United Nations Food and Agricultural Organization (FAO). The multi-government, multi-agency approach reflects the difficulty of controlling the plant. Water hyacinth is a free-floating plant with an extremely high growth rate, capable of doubling its size every 6 to 18 days (NASA 2007). Complicating matters, water hyacinth seeds can remain viable in silt and lake beds for as many as 15 years, sprouting rapidly when conditions are ideal and spreading quickly across the lake. For this reason, it often has seemed that mitigation methods have been successful in bringing water hyacinth outbreaks under control, only to see them flare up again, reappearing just as quickly as they vanished.

Addressing such a dynamic threat to the lake has required Kenya, Tanzania, and Uganda to work together to combat the infestation, as the treatment options are expensive and depend on simultaneous response. The governments considered and tested three treatment options in the lake, each with its own advantages and challenges. Mechanical control involves using either mechanized equipment to shred, harvest, and remove the plant, dragging it to shore for disposal, or manual removal, which primarily is done close to the shore and requires only simple tools. These methods are quite effective but also very costly. Mechanical removal costs about US$3,000 per hectare, and manual sinking and shredding costs US$1,000 per hectare (World Bank 2000). A second option, chemical control, consists of using aquatic herbicides in open water areas away from the shoreline to minimize the effects on local communities. However, there have been concerns that herbicides could accumulate in fish tissue, threatening those who eat the fish and placing the export industry at risk. As with mechanical control mechanisms, there also are significant costs associated with this option. The World Bank estimates that chemical control of water hyacinth costs between US$100 and US$300 per hectare (2000). In light of these concerns, the governments have decided against using this method.

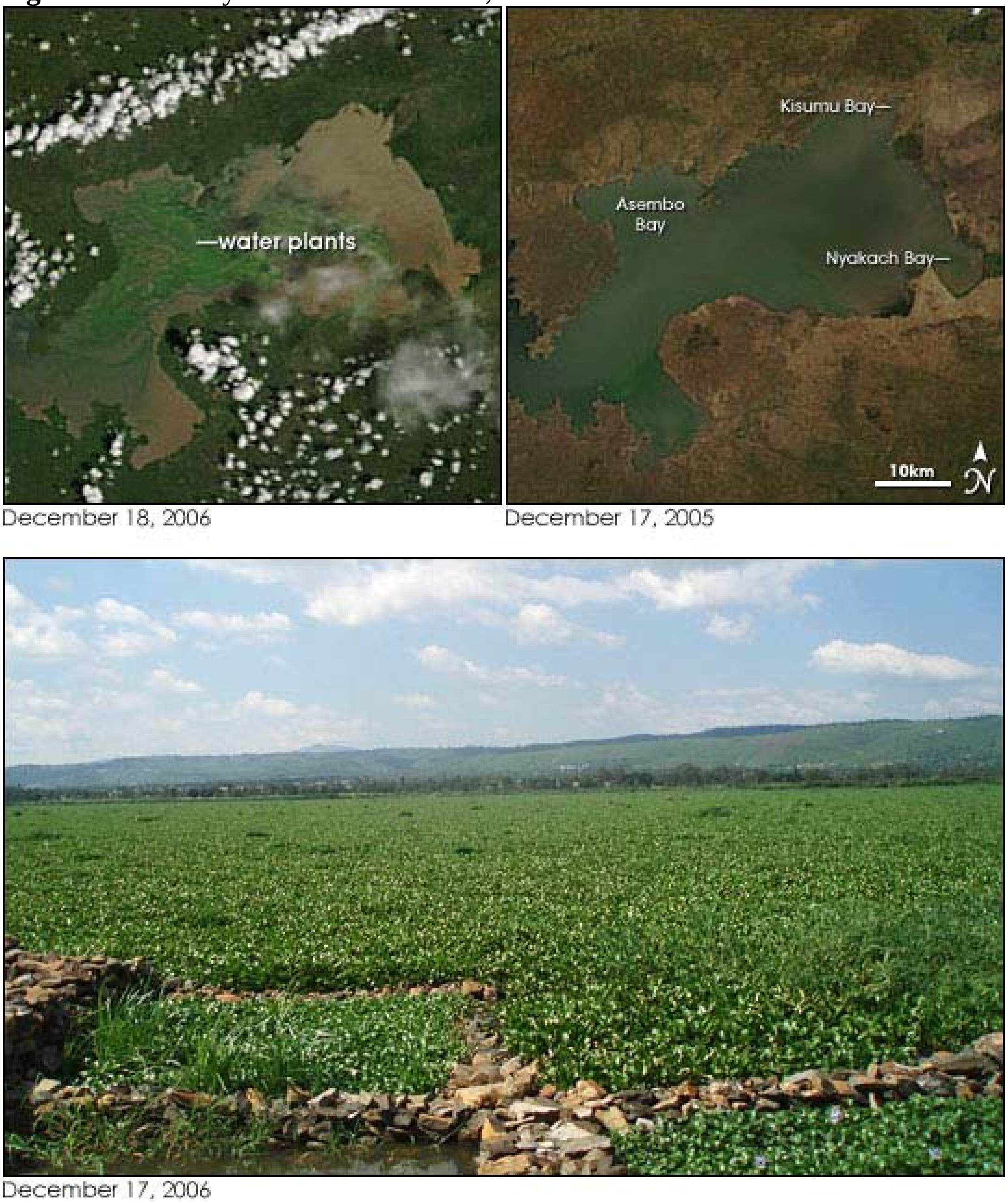
The final option is biological control, which involves raising and releasing two species of weevils (an insect in the beetle family). Adult weevils feed on the leaves of the water hyacinth plant, while the larvae feed on the plant tissue. The stress caused by the weevils render the water hyacinth incapable of flowering and setting seed. This has been the most successful method to date, in some cases reducing the hyacinth population by as much as 30 percent to 50 percent (World Bank 2000). At a cost of US$30 and US$50 per hectare, it also is the most cost effective and has accordingly been adopted as the primary strategy for managing infestations. However, the biological control method requires the greatest degree of coordination between the governments. To be most effective, mass weevil-rearing facilities must be established at multiple locations around the lake and well-coordinated field releases involving local communities must be organized.

To the credit of the riparian governments and the multilateral agencies that have supported these projects, water hyacinth was greatly reduced using these methods after the 1997 outbreak. In fact, the lake was almost completely cleared by 2001, and satellite images taken in 2005 showed no reoccurrence. Although the success was short-lived (satellite images taken in December 2006 indicated that a new outbreak was spreading across the lake), there is reason to be hopeful that through cooperative effort the Lake Victoria basin countries can once again tackle water hyacinth.

Pollution

Both point and non-point source pollution are major problems in the Lake Victoria basin. Industrial facilities discharge effluent directly into the lake, frequently with little prior treatment (Kiwango and Wolanski 2007). This primarily is a problem in the major urban centers of Mwanza, Musoma, and Bukoba in Tanzania (Machiwa 2002). However, adding to the industrial contamination is the non-point source pollution from human and animal wastes entering the lake from urban areas and rural villages alike. Kiwango and Wolanski estimate that 80 percent of the riverine phosphorus entering Lake Victoria comes from municipal and industrial sewage and the dumping of untreated sewage from villages and small settlements (2007).[2] Human and animal wastes also are contaminating lake ecosystems, and contain dangerous bacteria that can negatively affect water quality and sicken communities. While some facilities do exist to treat these streams, they are highly inadequate (Kiwango and Wolanski 2007). In many places they are simply nonexistent (Machiwa 2002). The lack of treatment poses a major risk to public health

Figure 2. Water Hyacinth Re-infestation, 2007



Source: NASA 2007.

because 70 percent of the basin population utilizes raw water in some form or another (Machiwa 2002). Illness associated with contaminated water and poor sanitation practices include typhoid fever, cholera, dysentery, and malaria. The microbial contamination of the lake has increased the risk of waterborne diseases outbreaks (Global International Waters Assessment [GIWA] 2006). Although life expectancy statistics are not available at the basin level, it is likely that in addition to dramatically reducing the standard of living of those who depend on the lake's waters, water pollution also may be reducing their life expectancies (GIWA 2006).

Remediation of non-point source pollution, notably agricultural runoff, is almost nonexistent in the Lake Victoria basin. Although most of the agriculture practiced in the region is undertaken without the use of fertilizers and other chemical inputs, large-scale agricultural operations, including tea, coffee, cotton, rice, sugar, and tobacco plantations, are becoming increasingly prevalent, and their use of chemical inputs is much higher than that of subsistence-level farms (United Nations Environment Programme [UNEP] 2006). Soil erosion, the result of poor agricultural practices such as clear cutting vegetative cover and wetlands, has increased nutrient loads to the lake through sediment loads (Machiwa 2002). In fact, agricultural runoff is the most significant source of high nitrogen loads in Lake Victoria, accounting for as much as 75 percent of the nitrogen flow into the lake (Kiwango and Wolanski 2007). As a result, algae concentrations are three to five times higher today than in the 1960s (GIWA 2006), and the resulting blooms have become a major problem, blocking sunlight and exacerbating anoxic conditions that harm plant life and result in fish kills. Nearly half of Lake Victoria's floor currently experiences prolonged anoxia for several months per year, compared to the 1960s when it was a localized phenomenon (GIWA 2006). Other indicators are similarly bleak; according to FAO, the Secchi water transparency index declined from five meters in the 1930s to less than one meter in the 1990s (Klohn and Andjelic n.d.).

Tropical lakes are especially sensitive to pollution because their naturally lower levels of oxygen, resulting from high regional temperatures, reduce the ability of the lake to absorb pollution loads (GIWA 2006). Healthy papyrus wetlands, which formerly featured prominently in the Lake Victoria region, can help control the effects of nutrient loads and sedimentation by acting as natural sponges, taking up excess nutrients such as nitrogen and phosphorus into their root structures. However, in recent years, Lake Victoria's wetlands have become increasingly degraded, and their ability to continue providing valuable ecological services is threatened (Kansiime et al. 2007). Without action, these problems likely will worsen in the coming decades, with increasingly adverse impacts on the environment and the health of the communities that depend on Lake Victoria.

Estimates vary widely on the amount of soil lost to erosion each year—between 690 million tons and 19,800 million tons per year according to the UN-sponsored Global International Waters Assessment (GIWA)—however, even the lower range of the spectrum is large enough to elicit serious concern (2006). The situation is unlikely to improve in the near term, as current trends indicate that the development of the agricultural sector will continue. Kenya, Tanzania, and Uganda are seeking to expand cash crop production since it brings in hard currency earnings and contributes substantially to exports, especially in the form of coffee, tea, and other large-scale plantation crops. Add to this that 43.5 percent of the lake basin area already is under cultivation (Machiwa 2002) and that 80 percent of the population living in the Lake Victoria basin derive their livelihoods from subsistence agriculture (GIWA 2006) and it becomes clear that it likely will have significant and increasing impacts on the lake environment.

In addition to environmental consequences, eutrophication also may impact the food and livelihood security of the most impoverished communities living along the lake shore. Changes to the lake environment have benefited the Nile perch population to the detriment of the Nile tilapia, the preferred fish for consumption in local communities. Tilapia is relied upon as a vital source of inexpensive protein, and declines in these stocks contribute to food insecurity for communities that depend on it. Switching to a diet based on Nile perch is not an option because the high export demand makes it unaffordable for most of the population.

Finally, the lake basin has pockets of significant mineral wealth, especially in Tanzania near Mwanza and Mare. Tanzania is Africa's third largest gold exporter (Curtis and Lissu 2008), and it continues to grow. Activities include both artisanal and large-scale production, both of which are focused in close proximity to Lake Victoria. Artisanal mining has up to this point contributed little in the way of pollution to the lake. Although there have not been reports of serious environmental accidents as a result of large-scale mining activities, environmentalists have raised concerns about the potential for processing chemicals to pollute water resources. Several large-scale operations have recently been granted permits or commenced operation. Companies include Resolute LTD's Golden Pride Mine, Bulyanhulu, Ashanti Gold, and Geita Gold Mine, all of which have opened since 1999. More recently, in 2003, the North Mara Gold Mine and Tulawaka were opened, and four additional mining operations were set to commence operations the following year (SIDA 2004).

In light of the country's need for hard currency and export earnings, the Tanzanian government has embraced the mineral sector, believing it will "substantially contribute to income generation, employment creation, and social and economic infrastructure development." This push has been reflected in the country's economic profile: in 2003, mineral exports (lead by gold) accounted for US$504.1 million (Yager 2003), and represented 37 percent of Tanzania's exports (SIDA 2004). This is a substantially higher percentage than fish, which accounted for roughly 13 percent of exports in 2003 (SIDA 2004). By 2005, the value of Tanzania's mineral exports, again attributable primarily to gold, reached US$642 million, and represented 42 percent of the country's exports (Yager 2007). There is obvious incentive for the Tanzanian government to encourage development in the mining industry; however, while the government maintains a regulatory role over the industry, it remains to be seen how effective it will be in this capacity, given its dual interest in both promoting economic growth and protecting the environment.

The Role of Population Growth

The Lake Victoria catchment area supports one of the highest rural population densities in the world, with over 100 residents per square kilometer in most places, and reaching densities as high as 1,200 residents per square kilometer in some areas. With population growth rates topping 3–4 percent in all of the basin region, and rates as high as 5–10 percent in urban areas, the population of the Lake Victoria basin is expected to double by 2020 (GIWA 2006). Despite the rapid expansion of urban centers, the population remains largely dependent on agriculture, with subsistence agriculture, pastoralism, and agro-pastoralism providing livelihoods for 21 million people in the basin. Most basin-area residents also are very poor, earning between US$90 and US$270 per year (GIWA 2006). The confluence of these factors has exacerbated or directly caused many of the aforementioned environmental problems as a result of poor agricultural practices and the increasing demand for agricultural land.

As these examples demonstrate, environmental degradation in Lake Victoria and its surrounding watershed must be addressed immediately. Although the riparian nations have undertaken numerous initiatives, they have managed to control only one of the significant problems facing the basin area: water hyacinth. Several projects have been successful in addressing specific, narrowly focused objectives (such as fisheries research); however, they have not eased the worsening patterns of environmental damage that are threatening to permanently undermine the environmental health of the lake.

Multilateral Policy Initiatives

Numerous groups and organizations have taken a keen interest in different aspects of lake management. The East African Community (EAC) in particular has developed an extensive program of activities and has had a major role in shaping the primary lake management initiatives, LVEMP-I and LVEMP-II.

Lake Victoria Environmental Management Project–I

The EAC has identified the lack of a regional strategy for natural resources management as one of the underlying causes of environmental degradation in the basin area. With this in mind, the riparian nations developed the Lake Victoria Environmental Management Project (LVEMP). Beginning in 1992 immediately following the Rio Earth Summit, the governments of Kenya, Tanzania, and Uganda began informal discussions focused on strengthening regional cooperation in environmental management as well as addressing the social issues affecting the basin (EAC 2004). These discussions paved the way for LVEMP-I, which was established with the goal of "defining a vision for the sustainable management of the lake basin as well as compatible individual visions for the future" (EAC 2004). The governments were attempting to create a space for "discussing perspectives, strategies and approaches that have to be in place to set key priorities, initiate agreed actions, and monitor progress toward the goals set" (EAC 2004). The initiative was funded through the Global Environment Facility (GEF), an arm of the United Nations, which provided US$37 million, the International Development Association, a division of the World Bank, which provided US$48 million, and the partner states, which donated a combined US$10 million (Orach-Meza and Okurut 2005).[3]

The LVEMP governments identified the following major concerns in forming the framework and identifying projects:

- Deterioration of water quality in Lake Victoria;
- Declining biodiversity and fisheries due to poor harvesting practices;
- Land degradation resulting from soil erosion and poor agricultural practices;
- Destruction of wetlands and their buffering capacity;
- Water hyacinth infestation;
- Increasing pollution from the lake catchment areas, including pollution from industrial and municipal wastes; and
- Lack of strategic and comprehensive action to address threats to the lake (Orach-Meza and Okurut 2005).

The most notable projects of LVEMP-I have been in the areas of fisheries research and management, water hyacinth control, water quality monitoring, waste management, wetlands management, and reforestation (Orach-Meza and Okurut 2005). Through LVEMP-I, the governments began developing a common fisheries database and established three fish quality assurance labs and numerous Beach Management Units to help shoreline communities better manage their environment (World Bank 2004). LVEMP-I projects also were successful in reducing water hyacinth infestation by 85 percent and establishing 72 weevil-rearing centers.

Additionally, the partner countries established the first comprehensive water quality monitoring program for Lake Victoria, established a database to track long-term regional and basin trends, and rehabilitated a water treatment facility that increased by 30 percent the amount of waste being treated in the lake basin.

From LVEMP-I to LVEMP-II

LVEMP-I was terminated on December 31, 2005, nine years after it was initiated. According to Orach-Meza and Okurut, the member governments realized from the onset of LVEMP-I that most of the LVEMP-I initiatives would be expensive, long-term undertakings with some taking as long as 15 to 20 years to fully implement (2005). With this long-term focus in mind, the member governments began reviewing LVEMP-I projects in 2003 with the purpose of determining the best way to move forward once the initial phase was complete.

Preparations for LVEMP-II began on January 17, 2005 with the goal of applying the relevant knowledge from LVEMP-I to the research and management agenda of LVEMP-II. The new phase is scheduled to begin on March 31, 2009 and will cost US$135 million (EAC 2008). Integral to this process has been recognizing the limitations of the initial framework, which included weak institutional capacity in all three nations, lack of harmonization and synergy between projects, and the failure to translate research into viable action plans (GEF 2008).

To address some of these challenges, LVEMP-II initiatives include an intermediate focus on:

- Building human capacity to ensure the sustainability of the projects that have been initiated;
- Building institutional capacity to ensure that projects can be effectively implemented;
- Creating a reliable baseline and data set to evaluate trends;
- Piloting suitable projects to test their effectiveness; and
- Encouraging the application of proven environmental management practices on a lake-wide basis.

Long-term initiatives include:

- Maximizing sustainable benefits to riparian communities by using basin resources to generate food, employment, and income, as well as to provide clean water;
- Conserving biodiversity and genetic resources;
- Harmonizing national and regional management programs to reverse environmental degradation; and
- Promoting regional cooperation among the partner states.

It is notable that the governments identified the harmonization of national and regional environmental policies and promoting regional cooperation as long-term goals, rather than something that must be accomplished in the near-term. This may pose significant problems for the effective implementation of lake basin initiatives. The EAC has stated that the uncoordinated nature of development and environmental projects "may not holistically contribute to development in the [natural resources] sector" (EAC 2005).

> Each of the three Partner States have national policies on Environment and for different Natural Resources which have been used in providing a framework for action and for the setting of the environmental objectives and targets. At [the] regional level, presently, there is no overarching environment policy framework. Even the current legal instruments under development (Protocol) will rely more on the national frameworks for their implementation (EAC 2005).

To combat this problem, the EAC recommended that the member governments simplify their respective environmental policies and strengthen the appropriate institutional arrangements that are responsible for decision making, monitoring, and evaluation in the natural resources sector.

Other organizations have echoed this need, including the nongovernmental organization Uganda Coalition for Sustainable Development, which has expressed concern that the lack of policy coordination in the region is hampering development efforts. The Coalition also claims that conflicts arising from unclear border demarcations in the basin area have lead to "loss of property, lives, and slow[ed] the building of trust amongst border communities" (Uganda Coalition for Sustainable Development 2007).

<u>Proposed Projects</u>

The first phase of LVEMP focused on building capacity, identifying problems, and developing pilot programs. In addition to project coordination and management, LVEMP-II will be geared toward project implementation in the following three areas:

- Strengthening governance of water and fisheries resources. This component aims to develop regional frameworks for the management of transboundary water resources and fisheries as well as establish mechanisms for resolving disputes over their use. Research projects will be undertaken to generate knowledge and inform policy. The riparian nations also will attempt to harmonize their legal structures and provide incentives to local communities for compliance with fishing laws.
- Investing in pollution control and prevention measures. Projects in this component are focused on reducing environmental stress in the lake basin by addressing non-point source pollution in designated "hotspots" and limiting industrial pollution. Support to existing municipal sewerage treatment facilities will be provided and the development of wastewater treatment facilities in areas where they do not currently exist will be stressed. The component also envisions water and soil conservation projects in nine priority watersheds. Other projects include safety programs to avoid marine accidents.
- Raising public awareness and participation. Elected officials, local communities, and the general public all are targeted for education programs under this component, which seeks to disseminate information about LVEMP projects and any research findings generated.

These project areas form the broad umbrella that unifies the multitude of small initiatives comprising LVEMP-II. The individual interventions are too numerous to list but they have the potential to make a notable difference in the areas of fisheries research, soil and watershed conservation, and other environmental management tasks. However, LVEMP-II project documents fail to mention the most important issue in the Lake Victoria basin: falling water levels. Furthermore, it is unclear whether planned initiatives will be successful in addressing the basin's other major concern, overfishing.

Challenges to LVEMP

The LVEMP-I programs have been credited with bringing Kenya, Tanzania, and Uganda together to address challenges that the governments could not effectively manage on their own. The most successful undertakings—water hyacinth control and carrying out fisheries studies—provided quick wins for the partner states, in which they acted on problems that affected large numbers of their populations. The LVEMP framework has demonstrated shortcomings and flaws in the areas where the riparian nations compete or have a strong incentive to mismanage resources. Falling lake levels, which threaten nearly every aspect of lake functioning and livelihood support, and unsustainable rates of fish harvesting, specifically the commercially caught Nile perch, which comprises the backbone of the region's commercial fishing operations, are the most salient examples. These two issues, arguably the most severe problems currently facing the lake and its basin, largely have gone unaddressed under the LVEMP framework. To be sure, much discussion over these concerns has taken place over the last several years as the governments have attempted to come to agreements and solutions for these challenges. Despite the attention, little progress has been made, in large part because of the competing interests of the riparian governments. This in turn raises the question of whether or not the existing institutions and frameworks, specifically LVEMP-I and II, are capable of providing the necessary structure for addressing the most serious issues facing the lake and basin area. The failure of LVEMP-I to manage these problems, or in the case of the plans of LVEMP II, to adequately address them, demonstrates the difficulty of tackling issues that are likely to lead to conflict.

Falling Water Levels

A dramatic decline in lake water levels has been wreaking havoc on the lake and basin over the last few years. Two factors, one climate-related and one human-induced, have combined to account for a drop of more than two meters in lake water levels since 2002. This reduction has serious environmental and economic consequences. The impacts on fish and wildlife have been striking and well documented in the media and academic literature, as numerous species rely on the papyrus wetlands for breeding ground and shelter from other predatory species. The lake's wetlands have experienced severe degradation, damaging critical habitat for numerous fish, bird, and wildlife species. Water quality has been negatively impacted because reduced water levels increase the concentration of pollutants. Water hyacinth also thrives along the beaches that have been exposed due to receding water levels, threatening to undermine the progress that the nations have made in combating this problem. Finally, the newly created shoreline has allowed malaria-carrying mosquitoes to expand their breeding grounds, possibly causing even greater incidence of the disease (Minakawa et al. 2008).

Low water levels have become a serious economic burden for Tanzania and Uganda. In Tanzania, the Mwanza Urban Water Authority was forced to shut down one of its three water intakes from Lake Victoria and use submersible water pumps to augment supply. Water supply to the city was reduced from 42,000 m^3/day to 38,000 m^3/day, an amount insufficient to meet the city's needs. Shipping and trade routes also have been affected, with large vessels no longer able to dock in previously accessible ports. In some cases, the ships cannot be loaded to full capacity or take trucks on board (Mngodo 2006). The falling water levels also have caused a reduction in the water flow necessary to power the hydroelectric facilities of Nalubaale and Kiira, upon which Uganda is especially dependent. In 2005, Uganda experienced a 30-percent decline in electricity production at the dams, resulting in frequent blackouts for some of Uganda's most densely populated urban areas, and frequent brownouts remain the norm today.

<u>Climate Variables</u>
Dramatic fluctuations in lake water levels have been reported during several time periods. As a general pattern, the lake levels were relatively low—but constant—between 1900 and 1961 (EAC 2006). Beginning in 1961 with a period of unusually high rainfall, lake levels rose substantially, eventually rising by about two and one half meters (USDA 2005). Then, beginning in 2000, water levels began to fall once again, eventually declining by as much as two meters (USDA 2005).

Numerous hypotheses have been suggested to explain the recent decline in water levels, including decreased rainfall, increased temperatures and evaporation, changes in wind patterns, and changes in river flows (EAC 2006). Of these factors, studies have most strongly linked rainfall and temperature to the declining water level. Lake Victoria is different from many other waterbodies in that contributions to water levels from tributary inflow and outflow are minimal. Rivers account for only 15 percent of total inflow, and of this 15 percent, the Kagera River alone is responsible for approximately half (SIDA 2004). The other 85 percent of the water entering the lake comes directly from precipitation, making Lake Victoria's water levels highly sensitive to changes in rainfall patterns, and especially dependent on the yearly seasonal rains, including the long rains, which occur between March and May, and the short rains, which occur between October and December (EAC 2006). Under normal circumstances, outflow is limited primarily to evaporation, which accounts for some 85 percent of the water leaving the lake (SIDA 2004).

The lake's high degree of dependency on rainfall and evaporation rates means that any changes to these variables can have a noticeable impact on lake water levels. Awange et al. demonstrated that even short term droughts can have a marked impact on Lake Victoria and that extended droughts can take years to overcome (Awange et al. 2008). Given this relationship, numerous studies have been conducted to determine the role that drought has played in the recent lake water level drops, and it appears likely that it has made a contribution. According to the EAC, between 2001 and 2004, rainfall decreased by 4.2 percent compared to the period between 1950 and 2000, and scarce rainfall conditions persisted through 2005 (2006). NASA also noted a drought beginning in 2000 (NASA 2009), and regional news agencies have produced myriad stories and reports about drought conditions. However, there is some debate about the presence (and severity) of a regional drought. In their 2007 study, Awange et al. state that rainfall was stable between 2000 and 2006 and that their research did not reveal a significant reduction in rainfall over the lake (2007). The authors do note that the EAC findings differed from their own and called for additional research on the topic. A third study found that drought has indeed played a role and attributed 45 percent of the recent drop to decreased rainfall (Kull 2006).

There have been similar disparate findings with respect to temperature (and thus to evaporation rates). According to the EAC, temperatures in the lake basin have been rising, increasing the amount of water lost through evaporation. The EAC study found that average temperatures in the Lake Victoria region rose 1˚C between 1950 and 2000 (2006). Awange et al. disagree and state in their report that temperatures did not increase dramatically between 2000 and 2006, and thus increased evaporation rates were unlikely (2007). Both studies found that wind conditions, which also have an effect on evaporation rates, did not change over the same period (EAC 2006; Awange et al. 2007).

Over-releasing at Nalubaale and Kiira Dams

The electricity produced at Uganda's Nalubaale and Kiira Dams is important both in terms of supplying Uganda with modern energy and creating export revenues from electricity sales to Kenya and Tanzania (SIDA 2004). Regional integration has become a factor, with the Swedish International Development Cooperation Agency (SIDA) estimating that Kenya will need to double its electricity imports from Uganda (2004). Uganda also has expressed hope that it will be able to export electricity to Tanzania and Rwanda in the coming years (Government of Uganda 2007). However, low water levels in Lake Victoria may not provide sufficient water pressure, without which none of this is possible.

The Nalubaale dam at Owen Falls was completed in the mid-1950s, at which time Lake Victoria ceased operating as a natural lake and essentially became a human-controlled reservoir. Recognizing that lake levels could be manipulated under this new hydrological regime, in 1954 Egypt and Uganda wrote and signed what is known as the "Agreed Curve." The goal of the agreement is to maintain a natural water level in Lake Victoria, based on historical levels of the lake and the amount of recent rainfall. The Agreed Curve states that Uganda may release an amount of water equal to the natural discharge of the lake to the White Nile, which should maintain the natural hydrological balance of the lake system (Kiwango and Wolanski 2007; EAC 2006). The Agreed Curve allows the lake water levels to continue rising and falling according to the natural patterns of rain and evaporation that characterized the hydrological system prior to the dam. In other words, the natural conditions of the lake were given precedence over the production of hydropower (Kiwango and Wolanski 2007).

Theoretically, this system allows Uganda to use water from Lake Victoria to power the hydroelectric facilities while still allowing the lake system to operate naturally. This agreement successfully maintained water levels with the operation of the Nalubaale dam from 1954 until 2000 (NASA 2009).

Hydrology experts have stated that meteorological factors are not enough to explain the lake's recent dramatic water level decline (Kiwango and Wolanksi 2007; Awange et al. 2007; Awange et al. 2008). The mean rainfall data collected at Mwanza over the period of 1985 to 2006 shows periods of drought between 1992 and 1993, and again in 2000. However, lake levels dropped every year between 2000 and 2006, even without the presence of a drought. In fact, uncharacteristically large amounts of rain fell between November 2006 and February 2007, resulting in a one-meter rise in lake water levels (Kiwango and Wolanksi 2007). Awange et al. noted that although the link between climate and lake levels is strong in Lake Victoria, satellite datasets for the period between 2001 and 2006 "revealed no major influence of precipitation on the falling water level" (2008). Kiwango and Wolanksi additionally stated that Lake Victoria's water levels would have remained about constant between 2000 and 2006 if the Agreed Curve had been maintained (2007).

According to Daniel Kull, a hydrologic engineer in Nairobi, even if droughts are factored in, today's lake levels would be 50 centimeters higher if the Agreed Curve had been maintained (2006). In his report, Kull stated that 55 percent of the drop in water levels is attributable to Uganda's actions (Kull 2006). Furthermore, he calculates that the water releases at the Nalubaale and Kiira dams are approximately 75 percent more than the Agreed Curve mandated for the year of 2005 (Kull 2006). Additionally, the Global Environment Facility (GEF), which is financing part of LVEMP-II, noted Uganda's role in falling lake water levels in project documents, attributing 50 percent of the decline to drought and 50 percent to the over-abstraction of water for hydropower (GEF 2008).

Kiwango and Wolanski believe that the over-release of water at the dams is likely due to the difficulty of managing two dams in unison (2007). In order to provide enough water pressure to operate both Kiira and Nalubaale dams, discharge to the White Nile from Lake Victoria was increased by as much as 50 percent (Kiwango and Wolanski 2007). Kull, along with the EAC, has stated that maintaining the lake levels based on the Agreed Curve is no longer tenable, given recent low levels of rainfall and increasing demand for power in Uganda.

Despite the independent studies and data indicating that over-release at the Kiira and Nalubaale dams are at least partially to blame for the decline in lake water levels, Uganda has repeatedly insisted that other factors are behind the changes (IUCN 2006).[4] The Ugandan minister of state for water, Maria Mutagamba, recently stated that the Ugandan government was monitoring the water levels on the lake via engineers at Jinja, and had determined that "the low levels of water in Lake Victoria were…a result of the recent drought in the region" (Kagire 2008). Another high-ranking Ugandan official stressed that climate change, wetland destruction, siltation, and increased irrigation withdrawals in Tanzania and Kenya also have contributed to lake water level declines.[5]

The relationship between lake water levels and the environmental and climatic factors present in the basin are complicated and not perfectly understood. It is likely that a combination of these dynamics has contributed to the current situation. However, the evidence offered on the impact of Uganda's dams has created an uncomfortable disconnect between the data from the scientific community and the official response from the Ugandan government, which has not acknowledged the dams' role in the problem. This raises questions about the efficacy of LVEMP-I, especially as Uganda has been accused of withholding information about water releases at the Kiira and Nalubaale dams. For instance, while Kull was compiling data for his study, he was able to obtain flow rate reports and other critical data for the years between 1946 and 1970 and again from 1973 to 1982. However, no additional or newer information was made publically available. Kull notes that in many countries this data is kept in the public domain, and it is unclear why access was restricted in the case of Uganda (Kull 2006).

Until very recently, the governments of Tanzania and Kenya had been noticeably silent on the role of hydroelectric power production in the lake's falling water levels. There are signs that this may be changing, however. In November 2008, Tanzania raised concerns about a private meeting between Uganda's president and water and environment ministers and their Egyptian counterparts regarding the use of Nile River waters. Also in November, Kenya's water minister, Charity Ngilu, accused Uganda of over-releasing water from its dams and contributing to the decline in Lake Victoria's water levels (Ochola 2008). These examples are relatively few, however, and it is only very recently that they started appearing in the media.

Regional institutions also noted the link between the dams and Lake Victoria's water levels and have—in principle—attempted to address it. In November 2008 at the 19th Extraordinary Meeting of the EAC Council of Ministers, attendees agreed to establish "an independent and transparent mechanism" for monitoring water releases by representatives of the riparian nations (EAC 2008). The purpose of the Water Release and Abstraction Policy, which is to be finalized no later than six months after LVEMP-II comes into force, is to develop a legal mechanism to ensure compliance with the Agreed Curve (Ubwani 2008). Perhaps most importantly, the policy will be woven into the framework of LVEMP-II, including the grant and other financial agreements between the EAC and the World Bank, providing it with additional authority and legitimacy (EAC 2008). It remains to be seen if the riparian governments will indeed be able to agree to such a policy and to what extent it will be successful in increasing transparency surrounding water releases. This is nevertheless a positive first step; transparency and knowledge sharing are critical elements of transboundary water resource management. If Uganda is perceived as withholding important information about the lake and its water levels from the other riparian nations, it could impede further cooperation. If Uganda instead engages cooperatively and makes the necessary information available to the other nations, the country will be taking much-needed action to promote environmental security in the Lake Victoria basin.

Overfishing

Another disappointing aspect of LVEMP-I is the unsustainable rate at which fish, specifically the commercially caught Nile perch, are being taken from the lake. Considering the amount of attention that LVEMP projects have given to fisheries issues and management, it is discouraging that fish catches have decreased in recent years. According to the Lake Victoria Fisheries Organization (LVFO), landings of Nile perch have declined despite increasingly intensive fishing efforts (2008). Surveys conducted by LVFO between 2000 and 2006 showed an increase in the number of fishermen operating on the lake, as well as an increase in the number of boats (with and without engines), nets, and hooks (2007). The increased numbers of fishermen and the use of modern catching equipment have caused a dramatic decrease in the stock of Nile perch. Between 1999 and 2001, the stock of Nile perch was estimated at 1.29 million metric tons. For the period between 2005 and 2006, estimated stocks had fallen to 0.82 million metric tons. The stock of Nile perch as a percentage of the entire Lake Victoria fish stock decreased from 59 percent to 39 percent of the total standing stock between 2001 to 2006 (LVFO 2008).

In addition to the important role that the fishing industry plays in the economies of Kenya, Tanzania, and Uganda, it also plays a significant role in maintaining food and livelihood security for the lake basin's population. It is therefore imperative that the nations manage fish stocks to ensure their continued sustainable use. This will not be possible without first harmonizing the legal structures that govern fishing in the lake, as the current lack of statutory unity is among the primary contributors to overfishing and related conflicts. For instance, although Kenya, Tanzania, and Uganda have agreed to open access for fishermen, meaning that each nation allows fishermen from all nations to fish in their territory provided they follow the applicable local laws, as of 2005, rules controlling catch sizes and allowable equipment, such as net size, had not been standardized (World Bank 2005). This led to several highly publicized cases where fishermen of one country were arrested by the authorities of another for invalidating their fishing permits by breaking the local fishing laws (SIDA 2004). The lack of harmonization also poses problems for sustainability because the danger of overfishing is greatest in the waters belonging to the government with the weakest laws. A population decrease in one part of the lake can have repercussions for the species across the entire lake.

Kenya, Tanzania, and Uganda sought to face these problems by adopting the Regional Plan of Action for the Management of Fishing Activity (RPOA-Capacity) in March 2007. The plan calls on the governments to review their existing national policies and present a harmonized regional fishing framework to their parliaments for ratification (LVFO 2007). It also calls on the governments to "streamline policy and legislation relating to licensing [of] target species, type of fishing gear, type and size of fishing craft, and any other component relating to capacity" (LVFO 2007). However, the three governments have been discussing the need to align their respective laws since at least 1995 when LVEMP-I was being drafted (UNEP et al. 1999). Up to this point, neither of the LVEMP frameworks nor the RPOA-Capacity framework appears to have succeeded in harmonizing the three countries' legislation, and it remains to be seen if the new push of LVEMP-II will bring about these necessary changes. The GEF echoes these concerns in project documents, giving LVEMP-II a "high risk" rating due in part to the complexity of the institutional arrangements necessary for project implementation (GEF 2008).

As these examples show, successful joint management of Lake Victoria runs into significant problems when the interests of one nation are in opposition to the interests of one or more of the other nations. While it is not surprising that this is the case, it nevertheless poses a dilemma. If the partner governments fail to address and manage lake water levels and fish stocks, there will be serious environmental, economic, and livelihood repercussions. At the same time, their need for economic development and hard currency earnings are pushing them to make choices that undermine the long-term sustainability of the lake system in favor of short-term economic gains. By prioritizing water usage for electricity production and allowing unsustainable fishing practices, the governments may be undermining the ability of the lake and basin to provide both the ecological and economic benefits upon which millions of people rely. And while the Lake Victoria region has thus far avoided the environmentally induced conflicts that have befallen many other nations and regions, there is no guarantee that this will remain true, especially if fish stocks and other livelihood needs rapidly diminish and the competition over resources increases. Given the region's high population growth rates, this scenario remains possible.

Conclusion

The challenges facing Lake Victoria and its catchment basin are numerous, complex, and interrelated. Declining water quality, increasing nutrient and pollution loads, wetland degradation, decreasing biodiversity, and water hyacinth infestation comprise a list of serious environmental concerns that threaten to undermine the ecosystem of the lake, as well as the health and livelihoods of the millions of people who depend on its resources. Rapid population growth is transforming the long-term outlook for the lake, simultaneously increasing the pressures on the lake and its resources. Lake water levels already are dangerously low, and there is little doubt that the stresses on the lake will only increase in years to come.

Kenya, Tanzania, and Uganda must work together to address the challenges to the lake and catchment basin. LVEMP-I made notable progress toward managing water hyacinth and collecting baseline data. However, these are the areas where cooperation pays the greatest dividends for the lowest political investment. Everyone already agrees that water hyacinth infestation is a major problem, and there has been little contention about the best way to manage the outbreaks. By working together to establish biological control methods, Kenya, Tanzania, and Uganda were able not only to bring the infestation under control but also to demonstrate their willingness to act multilaterally to manage lake resources, and in doing so, they showed their citizens that they were taking decisive action to address a major problem. The nations shared similar success when LVEMP-I initiatives were used to conduct baseline data research on the lake's ecosystem. While obtaining this data was a necessary first step, there were no competing interests to address. In other words, while these projects were beneficial in the context of lake management, they were win-win undertakings. Because they occurred in areas where the riparian nations had similar goals and management strategies, they did not fundamentally challenge the usefulness of the LVEMP framework.

LVEMP-I has shown weakness in areas where the needs and interests of the riparian nations do not intersect, as in the case of falling lake water levels and overfishing—in other words, where the outcome is (or is perceived to be) a zero-sum problem. It is in this context that questions about the efficacy of transboundary water resource management in the Lake Victoria Basin must be raised. In the worst case scenario, failure to address adequately the decline in water levels will mean worsening environmental conditions, increasing livelihood and food insecurity, and slower economic growth. Decreasing fish yields, increasing environmental degradation, and threats to the local water supply all may contribute to tensions in the future.

In the best case scenario, the riparian governments will take action and use the trust and positive relationships garnered from the win-win projects of LVEMP-I and apply them to LVEMP-II to address the region's more challenging issues, especially falling lake water levels and overfishing. As these issues will require a much greater degree of diplomacy and negotiation, it will be necessary to build upon the success of other lake management projects. However, by engaging in candid discussions about the problems that the nations face in managing the lake and basin environment, the governments would be much better placed to take steps toward reversing environmental degradation. Successful basin management may also reduce the likelihood that resource scarcity will lead to friction and conflict, both between governments and at the local level. The governments would be demonstrating to their citizens that food and livelihood security are issues that they take seriously. On the international level, compromising and working together to solve these more complicated issues would enhance the region's capacity to cope with future environmental changes and challenges. This could become especially important if predictions about long-term climate change, population increases, and resource scarcity come to pass.

Reality rarely follows either the best or worst case scenario. Resource-based armed conflict does not seem imminent in the basin region, either at the community level or the international level. Nevertheless, it is not difficult to imagine a situation in which environmental mismanagement and increasing livelihood insecurity could begin to undermine the progress that LVEMP-I has made. Following a pattern of minimal information sharing and seeking only to cooperate in areas where interests overlap means that increasingly serious problems may remain unaddressed, with potentially severe implications for human security, environmental management, and economic growth in the entire catchment basin. The riparian nations have an opportunity to address these concerns while LVEMP-II initiatives are still under consideration. If they succeed in doing so, it will be a notable step toward improving environmental security in the Lake Victoria basin.

Endnotes

1. Eutrophication occurs in lakes and other slow-moving water bodies when excess nutrient loads, especially from nitrogen and phosphorus, stimulate excessive plant growth. As the plants bloom and then eventually die, the decomposing material reduces dissolved oxygen in the water creating anoxic zones that can be fatal to other lake organisms (USGS 2008).
2. Drainage channels from agricultural areas also contribute phosphorus pollution to the lake environment.
3. Other donors included the European Union, United States Agency International Development, FAO, United Nations Development Programme, UNEP, the World Bank, and several others.
4. Other hypotheses that have been suggested include wetland and forest degradation, water withdrawals, global warming, earth movements that cause changes to the lake bottom, annual changes in the number of sunspots, and siltation resulting from agricultural encroachment (IUCN 2006).
5. Personal communication.

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This report is made possible by the generous support of the American people through the United States Agency for International Development (USAID). The contents are the responsibility of Foundation for Environmental Security and Sustainability and do not necessarily reflect the views of USAID or the United States Government.