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Climate Change and Fishery Sustainability in Lake Victoria*

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Abstract
The fisheries of Lake Victoria have recently undergone rapid ecological and social change. Loss of diversity in terms of species richness and economic opportunity has increased the system's vulnerability to additional economic, ecological, and social stressors predicted with future climate change. This paper discusses the fisheries of Lake Victoria as a complex adaptive social-ecological system and summarises the recent literature on the impacts of climate change on the Lake Victoria Basin. Possibilities for reducing vulnerability and enhancing adaptive capacity in the basin are discussed. The paper concludes that the Lake Victoria Fisheries Organization is uniquely able to address present and future sustainability challenges, but that a re-examination of the sustainability goals of fishery may be appropriate.

Key words: Social-ecological systems, resilience, adaptive capacity, vulnerability, localisation

Introduction

The fisheries of Lake Victoria have undergone rapid ecological and social change in recent decades. Climate change, the still rapid growth of the human population and continued dependence on Nile perch for export, regional and local markets all threaten to exacerbate the ongoing depletion of the Nile perch fishery. In this paper the fisheries of Lake Victoria are discussed as a social-ecological system, the predicted impacts of climate change on the basin are reviewed, and the concept of localisation as strategy to reorient societies around the sustainable local production of food, energy, goods, and governance is introduced.

Lake Victoria as a social-ecological system

The future of Lake Victoria is uncertain. Will current management regimes be able to avoid the collapse of Nile perch stocks? How will shifting climate patters impact the ecosystem functioning of the basin? Will the presently high rates of human populations continue into the future? What is clear is that the future health of Lake Victoria and the more than 30 million people who live around the lake is determined by virtually innumerable social and ecological forces at local, national, regional and international scales. The Nile perch export trade itself is influenced by socio-cultural, economic, political and ecological forces at multiple scales, such as fishing practices, the demand for fish, concerns for fish quality, the need for foreign exchange, the effectiveness of management regimes, the health of the ecosystem and the potential impacts of climate change. Still, the Nile perch fishery, while the most important export fishery, is but one component of the Lake Victoria Basin system as a whole.

Conceptualizing Lake Victoria as a social-ecological system (SES) that is complex and adaptable is a useful framework for analysing the many complex social and ecological dynamics determining the health of the basin as a whole. SESs are complex adaptive systems in which social-ecological factors interact at multiple scales across both time and space (Janssen and fawange, 2006). Change in an ecological dimension of the basin can invoke subsequent change in one or more social dimensions of the system and vice versa. For example, ecological conditions such as stratification, rising water temperature, and shifting species composition interact with social factors such as fishing effort (which is in turn influenced by the demand for fish, the availability of alternative livelihood strategies, and the effectiveness of management efforts) to influence the quantity, quality and value of fish landings. At the same time, the lake and its watershed are central to the survival of tens of millions of people, hundreds of species of aquatic life and provide renewable forest, wetland, and aquatic resources. These complex social-ecological interactions influence the health of the Lake Victoria Basin and are simultaneously

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a source of opportunity and growing concern for sustainability at multiple temporal and spatial scales.

Conceptualizing the fisheries of Lake Victoria complex adaptive SES is a step towards a more holistic, ecosystem-based approach to fisheries management in the basin that considers humans to be a part of "the environment." It also provides a framework for identifying and prioritizing the components of a sustainable future for Lake Victoria, given the potential negative and uncertain impacts of climate change.

Climate change and the Lake Victoria basin

The negative impacts of climate change will increasingly be felt in the waters and on the shores of Lake Victoria. Inter-annual and inter-seasonal variability in rainfall and temperature could affect the survival of aquatic life, increasing the variability of fish catches, while uncertain agricultural yields inland may bring new entrants into the fishery each year. The ongoing influx of political and environmental refugees into the basin and the fishery are likely to increase under all climate change scenarios (Myers, 2002; Awange and On'Gan'ga, 2006).

Detailed studies integrating potential biophysical, ecological and social impacts of climate change have yet to be undertaken, but climate scientists have identified general trends and made predictions about the basin-wide impacts of climate change. The recent application of climate change models to the basin by Sabiiti (2008) suggests that rainfall and temperatures could increase up to 2030, but some microclimates will experience decreasing rainfall and night-time temperatures. Hydrologists applying climate change scenarios to the water balance of the lake predict a fall in lake levels by 2030 and a subsequent rise by 2080 (Tate *et al*., 2004). Recent falls in lake levels illustrate these predictions, suggesting that some models may be too conservative. These fluctuations will not only affect ecological and biophysical processes in the lake, but will also have serious implications for human health with respect to disease outbreaks and the availability of adequate quantities of potable water.

In addition to the declining availability of freshwater, climate change will increase waterborne and vector-borne diseases such as cholera and malaria. A 2006 report coupled climate parameters (precipitation and temperature) from 1978-2002 with hydrological characteristics of the Yala River and related them to outbreaks of cholera. The analysis showed that high peak river flows, occurring predominately in El Niño years, coincided with cholera epidemics resulting in rates of mortality and morbidity several orders of magnitude higher than hygienic cholera episodes (Wandiga, 2006). Additionally, as the severity of storm events increase as predicted under future climate change scenarios, it is likely that the influx of phosphorus-rich sediments into the lake will also increase. This increased nutrient loading will likely exacerbate ongoing eutrophication and decreasing oxygen availability in the lake, providing additional stressors to social-ecological life in the basin (Hecky *et al*., 1994; Stone and Bohannon, 2006).

While climate change science and modelling in the basin are still conducted at relatively coarse scales, it is clear that the basin is vulnerable to the impacts of climate change. More frequent extreme weather events and unpredictable rainfall patterns will continue to threaten human security in already vulnerable basin communities. Such considerations must be brought into natural resource policy and management, especially in fisheries, to ensure a sustainable future for the Lake Victoria Basin.

Conceptualising change in social-ecological systems

Scholars and professionals addressing climate change in SESs have developed useful heuristics to guide the sustainable management of these systems. Two of the most relevant to Lake Victoria's fisheries include vulnerability and adaptive capacity. When faced with uncertainty minimising vulnerability and enhancing adaptive capacity are essential for fostering sustainability in these systems.

Vulnerability, according to the Intergovernmental Panel on Climate Change, is the "degree to which a system is susceptible to injury, damage, or harm." (Ahmad et al., 2001). Vulnerability to climate change is context specific (Adger and Kelly, 2005), with some groups of people, places and species more vulnerable to change than others (Adger *et al*. 2003). In the Lake Victoria Basin vulnerability has both ecological and social dimensions. Ecologically, declines in the production of ecosystem services, including the availability of potable water and species diversity, makes the system more vulnerable to changing climatic conditions. Socially, the lack of adequate educational and social services, gender discrimination and lost bargaining power in the fish trade exacerbate vulnerability. Additionally, technological factors form a subset of the social dimensions of vulnerability. For example, the reliance on fossil fuels in the Nile perch fishery and the lack of adequate sanitation and transportation infrastructures combine with other social factors to potentially compromise future sustainability.

According to Young *et al*. (2006) globalisation may also increase vulnerability to climate change. Communities highly dependent on income generated from a single export commodity, such as Nile perch, are more vulnerable to change than more economically diversified communities. The latter are better able to alternate production and livelihood strategies in response to social or environmental change. These forms of vulnerability combine to increase sensitivity to climate change as well as changes in the global fish trade such as fluctuating market and transportation costs. Understanding how and to what degree SESs adapt to minimize or increase vulnerability is key to managing the system towards sustainability.

Adaptive capacity is another concept used to understand change in SESs. It refers to the ability of SESs to adjust to actual or anticipated climate-driven threats to enhance the integrity of the system. According to Folke *et al*. (2005) "systems with high adaptive capacity are able to reconfigure themselves when subject to change without significant declines in crucial functions of the social ecological system". This does not imply that it is always desirable for a system to maintain its current state when presented with change, but rather that the ecological and social components of a system with high adaptive capacity are able to adjust to experienced changes without severely reducing the services the system provides. SESs with high adaptive capacity are thought to be characterised by high levels of genetic and biological diversity and are managed by formal and informal social institutions that learn and store knowledge, are flexible and balance power among interest groups (Peterson *et al.*, 1998; Scheffer *et al.*, 2001; Brooks *et al.*, 2005). It follows that the ability to diversify livelihoods, as well as species composition, is vital for local welfare and for increasing adaptive capacity.

Defining what these crucial social-ecological functions are is an important step towards conceptualising and managing towards sustainability. Should the primary function of Lake Victoria be defined as consistent exports of Nile perch? Should another be the promotion of vibrant local and regional markets for fish? Are these two incommensurable? The answers to these questions must come from the system's stakeholders. Those analysing stakeholder input must also remember that stakeholder opinions may be as diverse as the options available, while also recognising that all stakeholders do not have the same ability to influence policy and management outcomes to meet their needs. Less powerful stakeholders are no less important than more influential ones to the long term sustainability of the fisheries of Lake Victoria.

Conceptualising change in Lake Victoria's fisheries

Much of the effort in understanding how social-ecological systems adapt to change has focused on identifying thresholds or tipping points that, once crossed, can change the system from one type to another - for better or worse. Holling (2001) provides a visual representation of this cycle with respect to what he calls potential and connectivity (Figure 1). Potential represents the number of "alternative options for the future," while connectivity determines the "degree to which a system can control its own destiny". The movement of the cycle alternates between "long periods of slow accumulation and transformation of resources (from exploitation to conservation, or r to K)" and "with shorter periods that create opportunities for innovation (from release to reorganization, or Ω to α)".

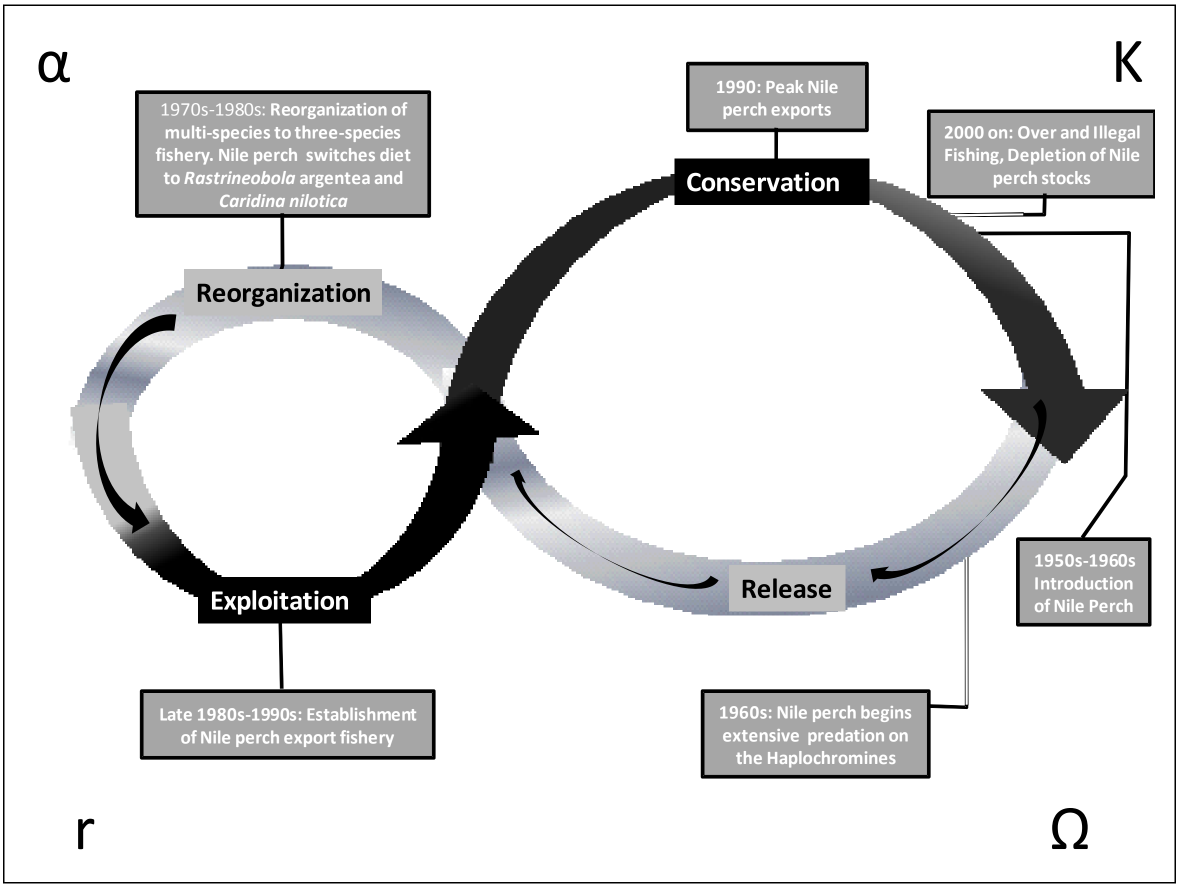

Figure 1. Conceptualizing Change in Lake Victoria as a Social Ecological System 1950's-2000. Adapted from Holling (2001).

In the case of the fisheries of Lake Victoria the introduction of Nile perch in the 1950s and 1960s moved the once multi-species fishery from a long period of conservation (K) to a period of rapid release (Ω) (Figure 1). As a result of Nile perch predation on the haplochromine cichlids, the system moved through a period of reorganisation (α) into the primarily three-species fishery of today. Throughout the 1980s and mid-1990s the system was able to sustain fishing pressure up to 500,000 tons per year and the development of the

Nile perch export industry, while moving from (r) to (K). The reorganisation of the fisheries of the Lake Victoria Basin from a local and regional fishery to the largest source of exported freshwater fish in Africa shortly after the Nile perch began to dominate catches is testament to the past adaptive capacity of this system. Today, management of the fishery is focused largely on maintaining Nile perch exports, keeping the fishery in the conservation (K) phase and avoiding a complete transformation of the fishery at (Ω) and subsequent reorganization at (α). While sensible, given the need for foreign exchange, income-generating activities in the basin and the priorities of international donors, it is possible that even recent efforts to reduce illegal fishing in the lake will be not enough to sustain a fishery dominated by Nile perch into the future.

The Nile perch fishery of today is unsustainable at (K) for a variety of ecological and social reasons, and is likely moving towards a release phase. If recent increases in fishing effort continue, the system will likely reach a new tipping point, moving the cycle back into the release (Ω) and reorganisation phases (α), creating a very different fishery. The threshold will likely be reached in the near term if demand for and harvest of adult and juvenile Nile perch continues at current levels. Presuming that fishing effort is effectively controlled, a long term transformation may still be likely in response to the additional multiple environmental stressors such as as siltation and eutrophication, an increasing human population, and rising and falling lake levels and, temperature increases resulting from climate change.

Predictions of change in biomass made by an ECOPATH/ECOSIM model reflect similar future conditions (Matsuishi *et al*., 2006). They show that adult and juvenile Nile perch populations will continue to fall substantially, while haplochromine and Nile tilapia populations are likely to rise. At the same time, they showed that catch per unit effort declined from over 140 kg of Nile perch per boat per day in 1989 to under 40 kg per boat per day in 2000. While these transformations will negatively impact the export-oriented Nile perch fishery, they may have substantial benefits for fish consumers within the basin as new species emerge for local markets.

Reducing vulnerability and enhancing adaptive capacity in the Lake Victoria basin

Reducing vulnerability and enhancing the adaptive capacity of Lake Victoria as a SES is essential for coping with future climate change. Potential strategies to do so include: protecting and enhancing biological and occupational diversity, reducing pollution, reducing gender disparities, accounting for the social and environmental externalities of Nile perch exports, re-examining the focus on Nile perch exports as an indicator of SES health, and even reducing dependency on Nile perch exports. One strategy alone will not adequately address the future problems of climate change. Approaches to reduce vulnerability and enhance adaptive capacity must be implemented holistically as part of a suite of adaptation strategies. The Lake Victoria Fisheries Organisation, with a history of basin wide collaboration and commitment to co-management is well suited to plan for and implement adaptation strategies in the basin.

Scholars studying adaptation to climate change in Kenya and Tanzania believe that occupational and biological diversity is essential if adaptive capacity is to be increased (Eriksen *et al*., 2005). Strengthening the value of biodiversity through promotion of a multi-species fishery, valuing other species for their economic value *and* their ecological and local nutritional value may reduce vulnerability by increasing local food sources and reducing dependency on Nile perch exports. Contrary to present management strategies, allowing the continued harvest of juvenile Nile perch may be the best way to accomplish this goal. Another is to reduce inputs of pollution into the lake, given that untreated effluent from industry and municipal sanitation is a potential driver of ecological change in the fishery and may have significant human and ecological health impacts. Effluents from mining and other industrial activities such as the fabrication of batteries, metals, corrugated iron sheets, and pharmaceutical, beverage and tannery production can also have substantial impacts on the health of wetlands in the basin (Muwanga and Barifijo 2006). Recent calls for an “Environmental Police” around the basin is a promising sign that toxic pollution is beginning to garner the attention it deserves.

Recognising and working to reduce gender disparities in the fishery is another component of a multifaceted adaptation strategy. While there are some inspiring examples of women profiting from the Nile perch export fishery, many women in fishing dependent communities have been marginalised by the industrialisation of the fishery as they have also been through the industrialisation of other resource bases. As artisanal processing and trade in the pre-Nile perch multi-species fishery was replaced partly by industrial processing and export of Nile perch women were excluded from the monetary benefits of the fishery (Geheb *et al*., 2008). Encouraging profitable alternative livelihoods for women, as well as men, is one way to reduce these gender disparities, as is increasing female representation in governance institutions. In my fieldwork I have observed that fishing communities with local female and male leadership appear to have lower rates of domestic abuse and prostitution than fishing communities with only male leadership. Enabling women to become local economic and political leaders alongside men should be an integral part of any strategy to address climate change in the basin.

Increasing the per kilo value of Nile perch exports by accessing duties on exports and pursuing fair trade and/or sustainability certification are additional strategies to manage towards sustainability in the fishery. Despite the increasing global demand for seafood and decreasing supply of Nile perch, consumers in Europe, Asia and the Middle East receive Nile perch at artificially low prices, in part because Nile perch is easily replaced by other whitefish, such as farmed basa (*Pangasius bocourti*) and tilapia from Asia. Foreign consumers do not pay for the externalities associated with consumption of Lake Victoria Nile perch, including the social-ecological impacts of an already depleted fishery and the transfer of nutritional value from potential basin-based consumers to comparatively wealthy consumers of exported fish. At the same time, most Nile perch-exporting nations, due to the African and Caribbean Free Trade Agreement, are unable to access duties on Nile perch exports to fund fisheries science and management in the basin, as well as other economic development priorities. Actively pursuing the assessment of duties on Nile perch exports and a "fair trade" fishery (as GTZ is experimentally implementing in several beach management units in Tanzania) are two ways to internalise some of these externalities in the prices consumers pay for Nile perch abroad.

These externalities can also be addressed by reconceptualising the way the fishery is valued and oriented. The Nile perch export fishery has indeed contributed to economic development in the basin, but has been accompanied by many well-documented negative ecological and social impacts (Ogutu-Ohwayo, 1990; Witte *et al*., 1992, 1999; Abila and Jansen, 1997). According to many fishermen around the lake, these negative impacts outweigh the positive benefits of the Nile perch export fishery. With the looming problems of climate change, population growth and continued illegal overfishing, it may be time to re-examine the focus on Nile perch exports as the primary indicator and driver of social, ecological, economic health in the basin. Local access to the nutritional and economic benefits from a multi-species fishery may actually better meet the sustainability goals of a larger number of stakeholders in the basin than the maintenance of a three species fishery dominated by the exported Nile perch.

Food systems around the world are beginning reorient themselves away from global food sources towards local production, processing and consumption in response to concerns over the long term unsustainability of the global food trade. As transportation costs and awareness of the links between the global food trade and climate change rise, production and consumption of local food has also increased. This shift, while in its nascent stages, is accompanied by steps towards sustainable local food, energy, goods, and governance sources - what some scholars are calling localisation (Hines, 2000). A "localised" Lake Victoria would not mean completely halting the Nile perch export trade, but would bolster already active local and regional markets to ensure that the lake's fisheries are meeting the needs of East Africans first and global consumers second. The Lake Victoria Fisheries Organisation and Lake Victoria itself with its recent shift towards co-management are well suited to promote localisation, prioritise local economies and support sustainable livelihoods in the basin, in turn reducing vulnerability and enhancing adaptive capacity in the basin.

While the global demand for seafood continues to rise, with the UN predicting a 40 million metric ton global seafood deficit by 2030, so does local demand for fish (FAO, 2009). Household surveys (n = 130) administered in Mwanza, Tanzania in the summer of 2007 show that 79% of all households consumed less fish in 2007 compared with 2002, with 70% of those 79% consuming much less fish in 2007 than 2002. Most respondents gave the rising price of fish as the reason for this decrease in consumption, and stated that they were unable to substitute fish for other animal protein sources such as beef or chicken. A recent study conducted in Western Kenya found that almost 50% of all children under five suffered from stunted growth, yet another impact of the fish deficit (Bloss *et al*., 2004). While the Nile perch export trade is certainly not the only cause of this deficit, it does play a role in limiting local availability of fish.

Recently, the illegal trade in undersized juvenile Nile perch has emerged to meet this local demand with clear consequences for the sustainability of the Nile perch export trade as it is known today. Despite recent efforts to control illegal fishing, the unmet demand for fish protein and the lack of alternative livelihood strategies in the basin are likely to continue to drive illegal fishing efforts and so reducing already dwindling Nile perch stocks (as suggested in Figure 1). At the same time, species once thought to be extinct are re-emerging (Balirwa *et al.*, 2003), providing an opportunity to strengthen the local fish trade and improve human health in the basin.

Localisation is one promising and proactive strategy to increase adaptive capacity and reduce the vulnerability of this system to climate change by fostering ecological and economic diversity. Allowing local and regional markets to flourish legally may help empower women, the primary processors and traders of locally consumed fish, while providing substantial nutritional benefits for many of the 30 million residents of the basin. Increased local processing, trade and consumption of the fish harvested from Lake Victoria will have local economic multiplier effects that may outweigh short-term reductions in foreign exchange earnings. With the commitments made by Uganda, Kenya and Tanzania to collaboration, cooperation and co-management and the scientific and policy expertise of the Lake Victoria Fisheries Organisation, a more basin-based fishery can be fostered in order to reduce vulnerability and increase adaptive capacity to ongoing climate change.

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