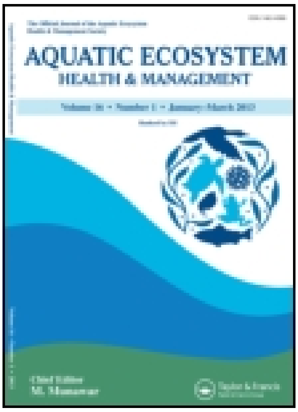

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Management of Lake Victoria fishery: Are we looking for easy solutions?

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Management of Lake Victoria fishery: Are we looking for easy solutions?

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Lake Victoria, East Africa, supports a fishery that yields about one million tonnes per annum consisting predominantly of three species, Nile Perch (Lates niloticus)*, Nile Tilapia* (Oreochromis niloticus) *and a native sardine-like cyprinid called Dagaa* (Rastrineobola argentea)*. The non-native Nile Perch is the most valuable of these species and supports an important commercial export industry; there are fears that overfishing, due to the growth of fishing capacity, is threatening the Nile Perch fishery. Based on its economic importance and the notion that overfishing is threatening the resource, the current fishery management system was developed to control fishing capacity and effort. This system, using the concepts of co-management, where fishing communities and stakeholders participate through community organizations called Beach Management Units (BMUs) to actively manage the fishery in partnership with the central government, has been criticized that it is "fishery-based," focusing on a single species and taking no account of ecological conditions in the lake, nor other species. A more "holistic" approach, which places a greater emphasis on changing nutrient concentrations and primary productivity as drivers of fish populations, has been proposed. Though fishery biologists and managers on Lake Victoria recognize that ecological conditions affect fishery populations, there appears to be two major challenges hindering the implementation of such approaches: first, the lack of a coherent objective of the Lake Victoria fishery, and second, the challenges associated with incorporating and implementing concepts of nutrient information and multiple species into a practical fishery management program.*

This article describes the current fishery co-management program to determine the feasibility of implementing a holistic approach on Lake Victoria. It is concluded that whether a management system should be "holistic" or "fishery-based" is of little importance; what is needed on Lake Victoria are clear objectives and a management plan that will enable those objectives to be achieved, utilizing both ecological and fisheries data where appropriate.

Keywords: Nile Perch, management plans, holistic management, fishing effort, fishing capacity

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Introduction

Lake Victoria is the second largest freshwater lake in the world and the largest in Africa, having a surface area of about 68,800 km^2. It is located in a tectonic basin between the western and eastern arms of the Great Rift Valley in Eastern Africa. The lake is 1134 m above sea level and is relatively shallow, with a mean depth of 40 m (Johnson et al., 2000). The lake's ecosystem underwent dramatic ecological changes that were realized around 1980 with the rapid population explosion of the non-native Nile Perch, *Lates niloticus* (Kaufman, 1992), which was introduced in the 1950s and 1960s. The Nile Perch was introduced to utilize the 500+ species of endemic haplochromines (Cichlidae) which dominated the fish biomass in the lake and were considered to be of little economic value (Anderson, 1961).

The population explosion of the Nile Perch led to the apparent extirpation of most haplochromine species by the early 1980s (Witte et al., 1992a). This was followed by a series of further dramatic ecological changes associated with rapid eutrophication, which included the occurrence of algal blooms, fish kills and an outbreak of Water Hyacinth (Ochumba and Kibaara, 1989; Ochumba, 1990, 1995; Albright et al., 2004). There is evidence that the lake was becoming eutrophic even before the Nile Perch explosion (Stager et al., 2009), but the ecological disruptions that followed the virtually instantaneous loss of most of the fish biomass (Witte et al., 1992b) must have accelerated the process of eutrophication. While these ecological disruptions caused a great deal of concern, there was a remarkable increase in fisheries productivity with the total catch rising from around 100,000 t per annum in the 1970s to about one million tonnes in 2010 (Marshall and Mkumbo, 2011). The dramatic increase in catch was mainly attributed to Nile Perch feeding on the numerous and abundant haplochromine species.

The current fisheries of Lake Victoria are of crucial economic importance to the region as they support around 200,000 fishermen (LVFO, 2013) as well as around 3 million people who are involved in fisheries activities including fish processing, fish trade, and net and boat construction (EAC, 2006), all of which represent a significant contribution to the national gross domestic product (GDP) and the local economies of the riparian states (Odongkara et al., 2009). Around 75% of the Nile Perch catch is exported to Europe, the US and the Middle East with 91,000 t of fillets, valued at USD 319 million, being exported in 2008 and 81,000 t valued at USD 310 million being exported in 2009 (Odongkara et al., 2009); these earnings are a major contribution to economic growth; exports of Nile Perch average USD 350 million per annum.

The state of Lake Victoria's fisheries is a matter of great concern to management authorities, with the state of the Nile Perch fishery being of particular concern because of its high value and subsequent economic importance and its population decline. If the Nile Perch's population decline continues, it could be a serious threat to the GDP and local economies of each of Lake Victoria's partner countries. Declining fishery yields could lead to reduced GDP of each country and to the reduced livelihood security of the fishers around the lake. Indirect effects of the declining Nile Perch populations could result in conflicts on the lake, as already demonstrated by the ownership dispute of the rich fishery resources of Migingo Island, an island situated on the borders of Kenya and Uganda in the lake's waters (Howden, 2009). Other species of critical importance to fishers' livelihoods are the introduced Nile Tilapia and endemic Dagaa. The importance of the native haplochromines in the lake decreased after the Nile Perch population explosion but some haplochromine stocks have recovered and these species may be re-emerging as an important fishery, now contributing about 100,000 t, or about 10%, of the total annual catch (Marshall and Mkumbo, 2011).

The current fishery management practices on Lake Victoria focus primarily on a "fisheries" approach that manages fishing effort and catch of specific species, such as the Nile Perch and Nile Tilapia. It has been suggested that this approach is too narrow and that a more holistic, ecosystem-based approach, which takes into account ecological factors that affect all fish populations, would be more appropriate (Kolding et al., 2009). Furthermore, current management actions are seemingly ineffective, as fishing effort, legal and illegal, appears to be rising again after a period of apparent decline between 2006 and 2010 (LVFO, 2013). Although a co-management system, with all fishermen organized into Beach Management Units (BMUs) has been adopted (Ogwang et al., 2009), BMU members are often unable to conduct effective fishery management due to unclear relationships with higher levels of government (Lawrence, 2013). Also, the fishery on Lake Victoria remains open-access, allowing unfettered access to the fishery; some fish stocks have declined as a result (Van der Knaap, 2013a,b). Additionally, Nile Perch, Nile Tilapia and Dagaa are exhibiting the effects of intensive fishing, such as changes in mean length and length at first maturity (Njiru et al., 2007; Sharpe et al., 2012).

Other effects include increased pollution from towns and cities, and mines and industries, along with the impacts of climate change which are currently unpredictable. Recent climate models suggest that East Africa will experience increased wet season rainfall with more river runoff and fresh water availability (Doherty et al., 2010), however beneficial this seems for inland fisheries, increased rainfall together with increased deforestation, land clearance, and agriculture, could lead to severe problems of erosion, siltation, and nutrient runoff and cancel out the benefit of increased rainfall.

Fish stocks in Lake Victoria

The fisheries of Lake Victoria have a history of changing fishing pressures. Commercial fishing began early in the 20th century and stocks of the most important species, the endemic tilapias *Oreochromis esculentus* and *O. variabilis*, had collapsed by 1940 because of overfishing (Kudhongania and Chitamwebwa, 1995). Attempts were made in the 1950s and 1960s to rehabilitate Lake Victoria's fisheries by introducing non-native Tilapia species such as the Nile Tilapia, *Oreochromis niloticus*, *O. leucostictus* and *Tilapia zillii* (Welcomme, 1966), but only Nile Tilapia became sufficiently abundant to support a fishery. The piscivorous Nile Perch were also introduced into the lake to exploit the haplochromines (Anderson, 1961), which were perceived as "trash fish" by the colonial government, into an internationally viable commercial fishery. The Nile Perch virtually extirpated many of the 500+ haplochromine species, while most other native species populations also declined (Ogutu-Ohwayo, 1990). Since 1980 the commercial fishery of Lake Victoria has been based on Nile Perch, Nile Tilapia and Dagaa which together make up 85–90% of the catch; a major shift from previous observations of 80% haplochromine catches.

After the population explosion of Nile Perch in the early 1980s, international demand for this species also increased. Fisheries infrastructure, such as roads, airports, and processing plants were created to carry the Nile Perch to international markets. The high demand, subsequent high value, and new infrastructure allowed the increasing human populations to increase fishing pressure on this species. This led to decreasing populations of this economically important species.

During the time period 1999 to 2011 a number of fish population and relative fish biomass changes were observed using hydro-acoustic surveys (Figure 1): the relative biomass of Nile Perch declined from 1.3 million t in 1999 to 0.8 million t in 2010–2011 while that of Dagaa rose from 245,000 t (10% of the total) to 477,000 t (23%) between 1991 and 2001, and over 1 million t during 2005–2008 constituting 50% of the lake's total biomass (Kayanda et al., 2009). The biomass of Nile Tilapia could not be estimated by hydro-acoustics because it mostly occurs in water less than 10 m deep, which could not be effectively sampled during hydro-acoustic cruises but catch data indicate the stock has declined. Other species, most of which were haplochromines, accounted for about 24% of the total biomass in 2010–2011, which reflects their resurgence over the last two decades (Witte et al., 2007).

Fishery management on Lake Victoria

The first attempts to manage the fisheries of Lake Victoria began in the 1930s following recommendations made by Graham (1929) who proposed a minimum mesh size of 5 inches (125 mm) in order to protect the endemic Tilapia stocks. The recommendation and implementation of the 5 inches minimum mesh size did not control overfishing, because fishing capacity increased, leading to decline in number and size of fish caught. By 1955 catches were so low that fishermen were illegally shifting to smaller and smaller mesh sizes, thus catching juveniles and disrupting recruitment (Kudhongania and Chitamwebwa, 1995). Larger-meshed nets (5 inches) were once again used on the lake after the Nile Perch population exploded in the 1980s to capture the larger sized perch which fetched higher prices. The high value of the Nile Perch fishery created incentives for an increase in fishing effort on Lake Victoria and therefore a need for stronger fishery management programs.

Recognizing that the "top-down" (i.e. dictated to the fishermen by government officials) management system was failing, the authorities in Lake Victoria's three countries agreed to standardize management

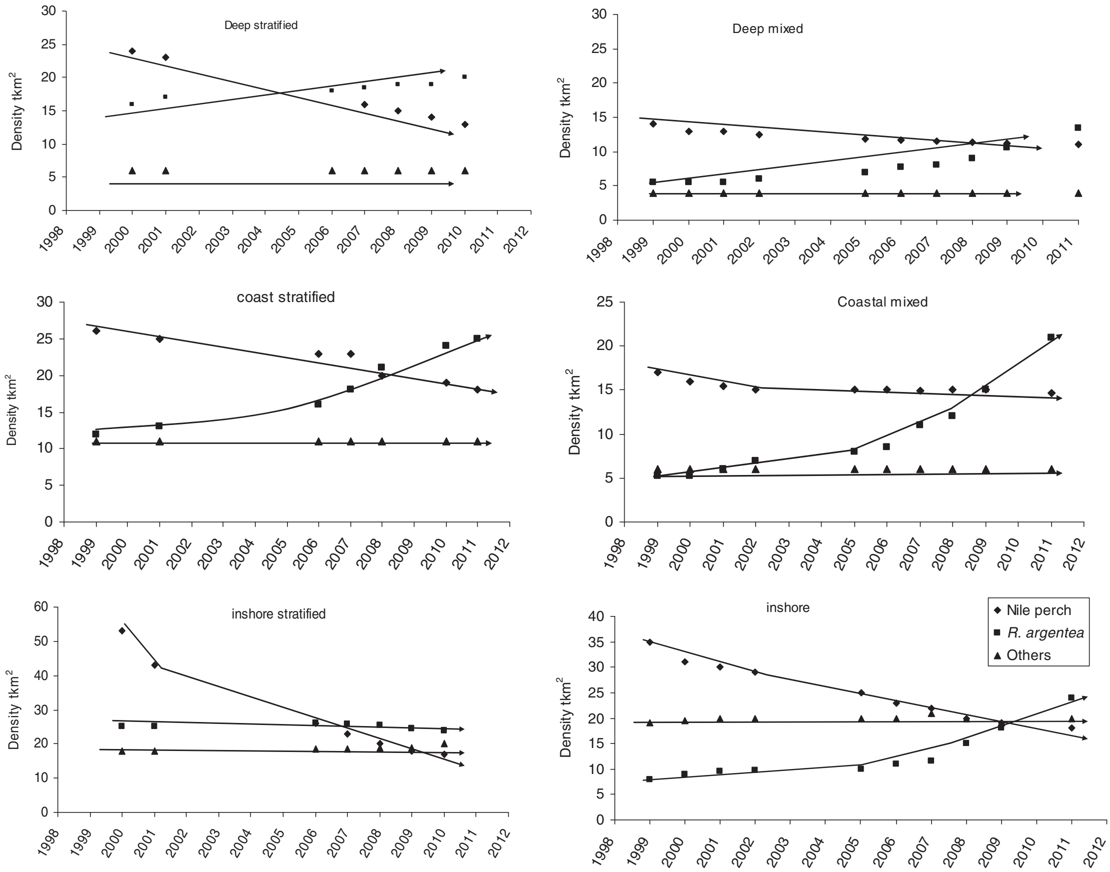

Figure 1. Trends in fitted density (t. km^{-2}) of the major fish taxa estimated through acoustic surveys conducted in February–March (stratified) and August–September (mixed) seasons from 1999–2011 as estimated by the 3 main strata (deep, coastal and inshore). Arrows indicate trends. (Adapted from Taabu-Munyaho et al., 2014.)

on a lake-wide basis with the Lake Victoria Fisheries Organization as the coordinating body. The first output was the Lake Victoria Fisheries Research Project (LVFRP), from 1992 to 2002, which trained fishery scientists, coordinated fishery research in the three countries, and produced a fishery management plan (Bwathondi et al., 2001). The LVFRP reviewed the management issues on the lake in 2001 and discussed various options including ecosystem, adaptive, precautionary and holistic management. It established a framework for fisheries management on the lake and set out six strategic goals:

(1) regulate fishing effort within an adaptive management approach;
(2) harmonise and strengthen the institutional environment for fisheries;
(3) enable local communities to participate in managing the fisheries;
(4) adopt a Code of Conduct for Responsible Fisheries that recognises the complexities of the fishery;
(5) strengthen capacity building and the institutions for management and research; and
(6) develop improved post-harvest methods and infrastructure.

Perhaps the most ambitious and significant of these was strategic goal (3), which led to the establishment of Beach Management Units (BMUs) around the lake. In a subsequent project called the Implementation of the Fisheries Management Plan (IFMP), 2004–2008, more than 1000 BMUs were created, where all the fishermen on the lake were included into the fishery co-management program. These BMUs were organized on a community basis with the intent that all fishery stakeholders be involved and represented (Ogwang et al., 2009). The intention was to develop a partnership between government and fishery stakeholders with, ultimately, the role of the BMUs as primary management entities and the fisheries departments becoming secondary and supportive. To achieve stakeholder participation, fishermen had to be made aware of issues and problems concerning fishery populations and the possible solutions that were being implemented to address these problems. The IFMP made a considerable investment in training stakeholders and developing the institutional framework (the development of fishing rules and the structure of fishery stakeholder involvement of each BMU) needed for the BMUs to function.

The IFMP also produced a new fisheries management plan for the period 2009–2014, which was focused more on fisheries management rather than institutional development (LVFO, 2008a). This plan set out "species-specific" management plans that were, in some respects, more suited to industrial marine fisheries rather than artisanal fisheries on an African lake. The requirements for biological reference points (e.g. defined changes in mortality rates or biomass) and decision rules (specified actions that would be taken once certain biological reference points had been reached) would be difficult to implement since they require very detailed biological and fisheries data. The data that are currently available from the Lake Victoria fisheries are not sufficiently comprehensive and this aspect of the fisheries plan will have to be re-examined when the current plan ends in 2014 and a new one will have to be prepared.

The impetus for the current management program on Lake Victoria was the increasing importance of Nile Perch, especially as an export commodity. The Council of Ministers (composed of fisheries ministers from Kenya, Tanzania and Uganda) has given priority to this fishery and maintaining its productivity is the principal management objective on the lake (LVFO, 2008b). Because of concerns that the Nile Perch stocks might become depleted, the three states around the lake agreed that only fish of slot size between 50 and 85 cm total length (TL) could be caught in order to protect juveniles and large reproducing females (Njiru et al., 2009). The Council of Ministers also agreed that the minimum stretched mesh size for gill nets would be 5 inches (125 mm) but this has created two major problems. The first problem associated with a minimum mesh size concerns the overlap of methods used to catch other species on Lake Victoria and the second problem concerns the peak selectivity in 5 inches nets was at 49 cm (Asila et al., 2000) which meant that >50% of the fish caught in these (legal) nets were smaller than the 50 cm (and therefore illegal). Subsequently the Council of Ministers, in 2009, adjusted the minimum mesh size for Nile Perch gillnets to 7 inches (175 mm).

The problem associated with minimum mesh size and overlapping methods

Gill nets are used to catch Nile Tilapia, and fishermen often resort to illegal nets with a mesh size smaller than 5 inches in order to maintain their catches, as they did in the 1950s and 1960s when Tilapia stocks were declining (Fryer, 1972; Kudhongania and Chitamwebwa, 1995). Fishermen who target this species will inevitably catch under-sized Nile Perch. Similarly, the fishers targeting Dagaa use nets with a legally mandated mesh size of 10 mm (although smaller meshes are commonly, illegally used) and also inevitably catch under-sized Nile Perch; there have been proposals to reduce the mesh size to 5 mm (LVFO, 2007a). The Dagaa nets may also catch the juveniles of other species and the fear that Nile Perch and Nile Tilapia will be caught in Dagaa nets has led to proposals to control Dagaa fishing in inshore waters. A closed season for Dagaa is enforced in the Kenyan part of the lake from 1 April to 31 August which appears to be its peak breeding season (Njiru et al., 2005). The effectiveness of this closure has not been assessed but Dagaa is increasing throughout the lake (Kayanda et al., 2009) and it would be interesting to know if the closed season is contributing to this increase. However, the closure may be more important in protecting juveniles of other species that may be caught incidentally in the Dagaa nets. Finally, those fishers who target haplochromines often use beach seines, which are illegal because they cause damage to fish breeding grounds and are usually small meshed-sized, and indiscriminately catch species other than the targeted haplochromines. Nonetheless, beach seines are still in use around the lake in great numbers. With the increasing importance of the haplochromine fishery, it will be necessary to determine what impacts it might have on other species, such as small tilapias and Nile Perch.

The problem associated with minimum mesh size and peak selectivity

The peak selectivity in 5 inches gillnets, which also leads to capture of immature fish, was rather contradictory (Asila et al., 2000). This approach made it very difficult to separate legal from illegal fish, and data from factories in Kenya and Uganda in 2008 showed that up to 70% of Nile Perch processed were below the legal slot size. In Tanzania, more than 80% of the Nile Perch caught in 5-inch gill nets were below 50 cm (Msuku et al., 2011). These findings demonstrate that the slot size is not strictly adhered to by either the fishers or the processors (Njiru et al., 2009).

Two problems associated with minimum mesh size and overlapping methods of the Nile Tilapia, Dagaa, and haplochromine fisheries highlight the need of a comprehensive fishery management program, where other fisheries are considered in the management of individual species; the Nile Perch stock cannot be managed without taking other species and their specific rules into account. In this regard, the fisheries management plan for 2009–2014 will need to be revised to include a thorough consideration of what kind of fishery should exist on Lake Victoria.

The question of management approaches on Lake Victoria must be further assessed as fish populations, and thus, efforts toward other species shift. In Lake Victoria, the decline of Nile Perch has been matched by an increase in Dagaa and haplochromines; the removal of the top predator, therefore, may be having a positive ecological impact on those species. The fishery, therefore, has shifted towards one based on lower trophic levels, targeting Tilapias and haplochromines, as described by Witte et al. (1992a), and towards a "food security" fishery, targeting Dagaa. These small fish are more productive than large predators and this is desirable because it guarantees a more reliable source of protein and so contributes to food security. But as these fish are less valuable than Nile Perch, this development may not be welcomed by fishermen who could see their incomes reduced as their catches of Nile Perch are reduced.

Sustainability of the Nile Perch fishery

Recent data suggest that the biomass of Nile Perch is stabilizing (Kayanda et al., 2009), but the stock has declined to 50% of what it was in the early 2000s and is now around 800,000 t. How far this species can resist intensive fishing is unknown and concern about this species is justified as top predators are usually the first to decrease in most fisheries. From an ecological point of view, managing a fishery based on the top predator is inefficient because of energy lost while being transferred from lower trophic levels. Many marine ecosystems have been disrupted by the selective removal of top predators (Heithaus et al., 2008; Palkovacs et al., 2011). Examples of this include the predatory catfishes in Lake Victoria in the pre-Nile Perch era (Marten, 1979; Goudswaard et al., 1997), and the endemic *Lates* spp. of Lake Tanganyika (Coulter, 1970). The presence of juvenile Nile Perch in the population suggests that there is adequate recruitment despite the intense fishing pressure (Taabu et al., 2005), but it is unrealistic to imagine that the fishery that existed in the 1980s, based almost entirely on a top predator, is sustainable. Van der Knaap and Ligtvoet (2010) estimated that the Nile Perch fishery was sustainable at the beginning of the millennium, in 2002, with the prevailing fishing capacity at the time. Since then the fishing capacity has increased sharply (LVFO, 2013), and the sustainability of the fishery has come into question.

The dramatic increase of fishing effort, from about 35,000 fishermen in 1972–1973 (Reynolds et al., 1995) to more than 200,000 in 2012 (LVFO, 2013), raises the question: how have Nile Perch sustained viable populations so far? The evolutionary history and biological characteristics may contribute to an explanation. Nile Perch inhabits and may have evolved in highly seasonal river systems along the southern fringes of the Sahara, such as the Senegal and Niger Rivers, Lake Chad, the Chari-Logone system and the Nile itself (Daget et al., 1986). These are extreme environments which flood during the rainy season, sometimes over very large floodplains, and then shrink during the dry season until they are sometimes reduced to little more than a series of pools. The fish in these systems spawn prolifically during the flood period to produce large numbers of fry, most of which die as the river recedes and they become exposed to predators (Welcomme, 1985). Fish that inhabit these types of stressful systems, such as Nile Perch, are therefore well-adapted to withstand a changing environment and high mortality rates.

These attributes have probably enabled Nile Perch to survive the increasingly intensive fishery on Lake Victoria thus far but it is not clear for how much longer they can do this. Evidence of overfishing, such as the loss of large individuals and a consequent decline in biomass, is causing concern about the sustainability of the fishery and the social and economic significances of a collapse.

Fishing capacity

Measuring fishing capacity on Lake Victoria is difficult because of the complexity and diversity of fishing approaches including operating different gear for the exploitation of the same species. There are multiple types of fishing vessels, some propelled by paddles and therefore limited to inshore waters, others with sails or outboard motors that can travel further into offshore waters. These vessels carry a wide variety of fishing gears, some of which target particular species (e.g. hooks) while others might be more general in their selectivity and catch more than one species (e.g. fine meshed gill nets). As a result, a standardized measure of effort in the Nile Perch fishery remains elusive and attempts to estimate catch per unit effort and incorporate it into fishery models have not been a success.

Biannual frame surveys, however, have been carried out on the lake since 2000 and indicate that fishing effort reached a peak in 2006, declined until 2010 but has begun to increase again. The number of fishermen on the lake rose from 129,000, with 43,000 boats, in 2000 to 200,000 fishermen with 70,000 boats in 2012 (LVFO, 2013). Over the same period, the total number of legal gillnets (≥5 inch mesh) rose from 537,000 in 2000 to a peak of 1,100,000 in 2004 but then declining to 832,000 in 2012. These values may not be a good indication of effort since fishermen often join gillnets together, either longitudinally or vertically and these might not be enumerated separately (attempts to do so may partly explain the increase in gillnet numbers in the 2012 frame survey [LVFO, 2013]). Finally, long lines with hooks, baited with haplochromines or small African catfish, *Clarias gariepinus*, are the only gear that specifically target Nile Perch (Mkumbo and Mlaponi, 2007). Hook sizes are graded according to size, with size 1 being the largest and size 15 the smallest; the smallest hooks (sizes 10–15) are illegal. The total number of all-sized hooks on Lake Victoria increased from 3.5 million in 2000 to 13.3 million in 2012 (LVFO, 2013) representing a 300% increase in fishing effort targeting Nile Perch. Additionally there has been a shift towards smaller, illegal-sized hooks, sized >10 increasing from 37% of total hooks in 2006 to 65% of total hooks 2012. This may reflect the fact that the proportion of large Nile Perch has decreased and fishermen are forced to use small-sized hooks in order to maintain their catches of smaller fish, many of them below the legal slot size of 50–85 cm TL. The number of illegal nets (<5 inch mesh) followed a similar trend, rising from 113,000 in 2000 to 215,000 in 2006 before falling to 159,000 in 2010 but then rising again to 200,000 in 2012; the reasons for this are unclear but may relate to more effective enforcement between 2006 and 2010, or it may reflect the fact that illegal nets are, for obvious reasons, much harder to count accurately. Other illegal gears, such as beach seines, cast nets and monofilament gillnets, are still widely used on the lake.

"Holistic" versus "fishery-based" management

Fisheries management that is based on the regulation of harvests of an individual species is recognised as insufficient because of the interactions of species within a system, a holistic management approach, therefore, is advocated (Fowler et al., 2013). A holistic approach should include the critical principles of an "ecosystem-based fisheries management" program. An ecosystem-based approach should include food webs, trophic structure, complex population dynamics, and numerous predatory and competitive interactions, along with processes and interactions that involve evolution, co-evolution, extinction, and interactions among species, including extinction and its selectivity, and their contributions to the structure and functioning of ecosystems (Fowler et al., 2013). The current fisheries management system on Lake Victoria has been criticized by Kolding et al. (2009) that fisheries management was "based purely on classical fisheries theory, with effort as the only driver". Kolding et al. (2009) asserted that fishery managers had paid little attention to the work done by limnologists and ecologists and that, (a) all changes in the fish stocks were driven by "bottom-up" processes (i.e. changes in nutrient concentrations and primary productivity) and (b) there was no evidence of overfishing in the lake. These claims seem unfounded since most fishery biologists are well aware of the ecological processes on the lake and no one would deny that nutrients and primary productivity influence fisheries. But to imagine that 200,000 fishermen, employing one million gill nets, 13 million hooks, 15,000 Dagaa nets, 4,400 beach seines and

35,000 monofilament nets to remove 1 million t of fish per annum, have little impact on the stocks, is surely unrealistic.

Kolding et al. (2009) concluded: "It is apparent that . . . environmental and fisheries research and management activities need integration, and that a holistic Ecosystem Approach to Fisheries (EAF) management is adopted." This was certainly one of the objectives of the fisheries plan drawn up in 2001 and the fisheries departments in each country employed limnologists and recognized the importance of limnological data. The challenge, however, is how can limnological and ecological data be incorporated into a fishery management plan? Managing conditions external to the fishery which cause ecological changes to the lake (e.g. agricultural runoff, industrial runoff, invasive species) is a major challenge in fisheries management approaches; even if the ecological processes are known and understood, they are not easily managed. Proponents of the ecological approach, such as Kolding et al. (2009), have simply called for more data, better integration, and the development of a wider array of ecological indicators, but they have not provided any practical or implementable proposals for fishery management that address the reduction in fish biomass due to ecological disturbances.

The question of whether a "holistic" or "fishery-based management" program should be implemented may be the wrong question; a more realistic question might be, "What are the objectives of the Lake Victoria fisheries, and what has to be done to achieve those objectives?" Once fishery planners and stakeholders can agree on this, they may be better able to draw up a plan that could include both fishery-based and ecological approaches, whichever would be most effective in achieving the objective(s).

Conclusions

Lake Victoria supports one of the world's largest inland fisheries and is a major contributor to the economies of the riparian countries' GDPs and to the development of the communities who rely on the fisheries. Maintaining the productivity of this fishery is of vital importance, but accomplishing this is a major challenge owing to the size of the lake, the increasing number of fishermen and increasing capacity, the variety of gears in use, and environmental conditions—ecological changes—which affect fish populations and growth. Additionally, managing a fishery is complicated by social and political variables. For example, it is widely accepted that fishing effort will need to be reduced if the Nile Perch stocks are to recover (LVFO, 2007b); however, many methods suggested for decreasing effort, such as reducing the number of fishing boats or gear, changing net and hook sizes, or establishing quotas, closed seasons or closed areas, will have a serious effect on the incomes of many fishermen. In case the Nile Perch stocks collapse, the fishermen will tend to change to other fishing gears and methods to exploit the commercially less attractive Dagaa and as a result the fishermen will lose part of their incomes. Inhibiting a fisher's livelihood often reduces his ability to follow the rules and therefore it is expected that the use of illegal fishing gears and methods will continue.

Effort reduction can only be achieved with the cooperation of the fishing community and the establishment of the BMUs within Lake Victoria's fishery co-management program, was meant to overcome failures of past top-down management programs. One objective of the BMUs was to keep the fishermen informed of fishery problems and enable them to contribute to their solution. However, the BMUs have experienced many problems, including obstruction by various government agencies, and have not yet been able to play a substantial part in fisheries management (Lawrence, 2013). It is essential that the BMUs be more effective if the co-management programme is to succeed and national governments should commit themselves more fully to the BMUs, for instance, by clearly defining their authority and responsibilities and ensuring that obstructive behaviour of some government agencies (Lawrence, 2013) is controlled.

The management of the fisheries will become increasingly difficult because of the growth of the human population; the combined population of Kenya, Tanzania and Uganda was estimated to be 126.3 million in 2012 and is projected to reach 303.4 million in 2050 (Population Reference Bureau [PRB], 2012). The impacts of this on freshwater resources will be especially dire as access to clean water and their resources become limited. This enormous increase in population will also increase the demand for fish and the management problems currently being experienced are likely to be greatly magnified. The need to redefine the objectives of Lake Victoria's fishery management approach is necessary to address the oncoming challenges of higher human populations and the environmental and other anthropogenic forces they will have on the fisheries.

The direct impacts of higher human populations will likely result in the increased demand for fish, also driving an increase in the numbers of people seeking to make a living from fishing. Failure to make a living from agriculture could drive more people to seek a living from fishing thereby increasing fishing effort even further. There is an urgent need, therefore, for a robust and effective fisheries management system that can deal with current and future problems. Whether this is called a 'holistic' or 'fishery-based' system it will not be easy to implement. The reasons for the lack of implementation vary and include a lack of resources, political will, or often, the impracticability of certain approaches (e.g. nutrient information). The size of the lake and the number of fishermen means that it is difficult to successfully implement Monitoring Control and Surveillance strategies and here the BMUs should play an important role. Ineffective regulations are no better than no regulations and without political and financial support the fishery administrations and BMUs will be unable to implement any management plans.

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References

Albright, T.P., Moorhouse, T.G., McNabb, T.J., 2004. The rise and fall of water hyacinth in Lake Victoria and the Kagera River basin, 1989–2001. J. Aquat. Plant Mgmt. 42, 73–84.

Anderson, A.M., 1961. Further observations concerning the proposed introduction of Nile Perch into Lake Victoria. E. Afr. Agri. For. 26, 195–201.

Asila, A.A., 2000. Optimizing gill net mesh sizes for the Lake Victoria Nile Perch fishery. p. 118–123. In: Proceedings of the Lake Victoria 2000 a new beginning conference, 2000 May 15–19. Lake Victoria Fisheries Organization, Jinja, Uganda.

Bwathondi, P.O.J., Ogutu-Ohwayo, R., Ogari, J., 2001. Lake Victoria Fisheries Management Plan. Lake Victoria Fisheries Research Project, Technical Document 16.

Coulter, G.W., 1970. Population changes within a group of fish species following their exploitation. J. Fish Biol. 2, 29–53.

Daget, J., Gosse, J.P., Thys van den Audenaerde, D.F.E. (Eds.) 1986. *Check-list of the freshwater fishes of Africa, Vol. 2.* ISNB Brussels, MRAC Tervuren, ORSTOM Paris.

Doherty, R.M., Sitch, S., Smith, B., Lewis, S.L., Thornton, P.K., 2010. Implications of future climate and atmospheric CO_2 content for regional biogeochemistry, biogeography and ecosystem services across East Africa. Global Change Biol. 16, 617–640.

EAC, 2006. Special report on the declining of water levels in Lake Victoria. UNESCO Water e-Newsletter No. 169: Lake Victoria. http:// www.unesco.org/ water/news/ newsletter/169. shtml.

Fowler, C.W., Belgrano, A., Casini, M., 2013. Holistic fisheries management: combining macroecology, ecology and evolutionary biology. Mar. Fish. Rev. 75, 1–36.

Fryer, G., 1972. Conservation of the Great Lakes of East Africa: a lesson and a warning. Biol. Conserv. 4, 256–262.

Goudswaard, P.C., 1997. The catfish fauna of Lake Victoria after the Nile Perch upsurge. Environ. Biol. Fish. 49, 21–43.

Graham, M., 1929. *The Victoria Nyanza and its fisheries.* Crown Agents, London.

Heithaus, M.R., Frid, A., Winsing, A.J. Worm, B., 2008. Predicting ecological consequences of marine top predator decline. Trends Ecol. Evol. 23, 202–210.

Howden, D., 2009. Migingo: big trouble on small island. 23 March 2009. The Independent. http://www.independent.co.uk/news/world/africa/migingo-big-trouble-on-small-island-1651736.html (consulted on 13 June 2013)

Johnson, T.C., Kelts, K., Odada, E., 2000. The Holocene history of Lake Victoria. Ambio 29(1), 2–14.

Kaufman, L.S., 1992. Catastrophic change in species-rich freshwater ecosystems: The lessons of Lake Victoria. Bioscience 42, 846–858.

Kayanda, R., Taabu, A.M., Tumwebaze, R., Muhoozi, L., Jembe, T., Mlaponi, E., Nzungi, P., 2009. Status of the major commercial Fish stocks and proposed species-specific management plans for Lake Victoria for Lake Victoria. Afri. Trop. Hydrobiol. Fish. 12, 15–21.

Kolding, J., Van Zwieten, P., Mkumbo, O.C., Silsbe, G., Hecky, R., 2009. Are the Lake Victoria fisheries threatened by exploitation or eutrophication? Towards an ecosystem based approach to management In: G. Bianchi, H.R. Skjoldal (Eds.), *The Ecosystem Approach to Fisheries*, pp. 309–354. FAO, Rome and CABI International, Wallingford, UK.

Kudhongania, A.W., Chitamwebwa, D.B.R., 1995. Impact of environmental change, species introductions and ecological interactions on the fish stocks of Lake Victoria. In: T.J. Pitcher, P.J.B. Hart (Eds.), *The Impact of Species Change in African Lakes*, pp. 19–32, Chapman and Hall, London.

Lawrence, T., 2013. Taking the 'co' out of 'co-management': the deligitimization of fishing communities on Lake Victoria, E. Africa. In: G. Krantzberg, V. I. Grover (Eds.), *Water Co-Management*, pp. 168–196. CRC Press, Boca Raton, FL.

LVFO, 2007a. Options for management of the *Rastrineobla argentea* (Dagaa/omena/mukene) fishery of Lake Victoria.

Dagaa Regional Working Group, Lake Victoria Fisheries Organization, Jinja, Uganda.

LVFO, 2007b. Regional Plan of Action for the Management of Fishing Capacity in Lake Victoria (RPOA-Capacity). Lake Victoria Fisheries Organization, Jinja, Uganda.

LVFO, 2008a. The fisheries management plan for Lake Victoria, 2009–2014. Lake Victoria Fisheries Organization, Jinja, Uganda.

LVFO, 2008b. Joint Communique of the Council of Ministers of the Lake Victoria Fisheries Organization, Kampala, 29 October 2008. Lake Victoria Fisheries Organization, Jinja, Uganda.

LVFO, 2013. Regional status report on Lake Victoria biennial frame surveys between 2000 and 2012. Lake Victoria Fisheries Organization, Jinja, Uganda.

Marshall, B.E., Mkumbo, O.C., 2011. The fisheries of Lake Victoria: past present and future. Nat. Faun. 26, 8–13.

Marten, G.G., 1979. Impact of fishing on the inshore fishery of Lake Victoria (East Africa). J. Fish. Res. Board Can. 36, 891–900.

Mkumbo, O.C., Mlaponi, E., 2007. Impact of the baited hook fishery on the recovering endemic fish species in Lake Victoria. Aquat. Ecosyst. Health Mgmt. 10(4), 458–466.

Msuku, B.S., Mrosso, H.D.J., Nsinda, P.E., 2011. A critical look at the current gill net regulations meant to protect the Nile Perch stocks of Lake Victoria. Aquat. Ecosyst. Health Mgmt. 14(3), 252–259.

Njiru, M., Budeba, Y., Wandera, S.B., 2005. Reproduction and growth of commercially important fish species, In: *The State of the Fisheries Resources of Lake Victoria and their Management*, pp 85–96. LVFO Secretariat, Jinja, Uganda.

Njiru, M., Getabu, A., Othina, A., Wakwabi, E., 2007. Are the management measures successful in Lake Victoria, Kenya? The case of Nile Perch and Nile Tilapia Fishery. Afr. J. Ecol. 45, 315–323.

Njiru, M., Getabu, A., Taabu, A.A., Mlaponi, E, Muhoozi, L. Mkumbo, O.C., 2009. Managing Nile Perch using slot size: is it possible? Afr. J. Trop. Hydrobiol. Fish. 12, 9–14.

Nunan, F., 2013. Wealth and welfare? Can fisheries management succeed in achieving multiple objectives? A case study of Lake Victoria, East Africa. Fish and Fisheries. doi: 10.1111/faf.12012

Ochumba, P.B.O., 1990. Massive fish kills within the Nyanza Gulf of Lake Victoria, Kenya. Hydrobiologia 208, 93–99.

Ochumba, P.B.O., 1995. Limnological changes in Lake Victoria since the Nile Perch introduction. In: T.J. Pitcher and P.J.B. Hart (Eds.). *The Impact of Species Changes in African Lakes*, pp. 33–43, Chapman and Hall, London.

Ochumba, P.B.O., Kibaara, D.I., 1989. Observations on blue-green algal blooms in the open waters of Lake Victoria. Afr.J. Eco. 27, 23–34.

Odongkara, K., Abila, R.O., Luomba, J., 2009. The contribution of Lake Victoria fisheries to national economies. Afr. J. Trop. Hydrobiol. Fish. 12, 47–51.

Ogutu-Ohwayo, R., 1990. The decline of the native fishes of lakes Victoria and Kyoga (East Africa) and the impact of introduced species, especially the Nile Perch, *Lates niloticus* and the Nile Tilapia, *Oreochromis niloticus*. Environ. Biol. Fish. 27, 81–96.

Ogwang, V.O., Nyeko, J.I., Mbilinyi, R., 2009. Implementing co-management of Lake Victoria's fisheries: achievements and challenges. Afri. J. Trop. Hydrobiol. Fish. 12, 52–58.

Palkovacs, E.P., Wasserman, B.A., Kinnison, M.T., 2011. Eco-Evolutionary Trophic Dynamics: Loss of Top Predators Drives Trophic Evolution and Ecology of Prey. PLoS ONE 6(4): e18879. doi:10.1371/journal.pone.0018879

PRB, 2012. *2012 World Population Data Sheet*. Population Reference Bureau, New York.

Reynolds, J.E., Greboval, D., Mannini, P., 1995. Thirty years on: the development of the Nile Perch fishery in Lake Victoria. In: T.J. Pitcher, P.J.B. Hart (Eds.), *The Impact of Species Changes in African Lakes*, pp. 181–214. Chapman and Hall, London.

Sharpe, D.M.T., Wandera, S.B., Chapman, L.J., 2012. Life history change in response to fishing and an introduced predator in the East African cyprinid *Rastrineobola argentea*. Evol. Applic. 5, 677–693.

Stager, J.C., Hecky, R.E., Grzesik, D., Cumming, B.F., Kling, H., 2009. Diatom evidence for the timing and causes of eutrophication in Lake Victoria, East Africa. Hydrobiologia 636, 463–478.

Taabu-Munyaho, A., Steinarsson, B.Æ., Hjörleifsson, E., 2005. Assessment of the status of the stock and fishery of the Nile Perch in Lake Victoria, Uganda. United Nations University - Fisheries Training Program (UNU-FTP), Reykjavik, Iceland: pp: 53

Taabu-Munyaho, A., Nyamweya, O., Sitoki, L., Kayanda, R., Everson, I., Marteinsdóttir, G., 2014. Spatial and temporal variation in the distribution and density of pelagic fish species in Lake Victoria, East Africa. Aquat. Ecosyst. Health Mgmt. 17(1), 52–61.

Van der Knaap, M., 2013a. May we eat biodiversity? How to solve the impasse of conservation and exploitation of biodiversity and fishery resources. Aquat. Ecosyst. Health Mgmt. 16(2), 164–171.

Van der Knaap, M., 2013b. Comparative analysis of fisheries restoration and public participation in Lake Victoria and Lake Tanganyika. Aquat. Ecosyst. Health Mgmt. 16(3), 279–287.

Van der Knaap, M., Ligtvoet, W., 2010. Is Western consumption of Nile Perch from Lake Victoria sustainable? Aquat. Ecosyst. Health Mgmt. 13(4), 429–436.

Welcomme, R.L., 1966. Recent changes in the stocks of Tilapia in Lake Victoria. Nature, London. 212, 52–54.

Welcomme, R.L., 1985. *River fisheries. Technical Paper*, vol. 262, 330 pp. FAO Fisheries, Rome.

Witte, F., Goldschmidt, T., Wanink, J.H., Van Oijen, M., Goudswaard, K., Witte-Maas, E., Bouton, N., 1992a. The destruction of an endemic species flock: quantitative data on the decline of the haplochromine cichlids of Lake Victoria. Env. Biol. Fish. 34, 1–28.

Witte, F., Goldschmidt T., Goudswaard, P.C., Ligtvoet, W., Van Oijen, M.J.P., Wanink J.H., 1992b. Species extinction and concomitant ecological changes in Lake Victoria. Nether. J. Zool. 42, 214–232.

Witte, F., Wanink, J.H., Kishe-Machumu, M., Mkumbo, O.C., Goudswaard, P.C., Seehausen, O. 2007. Differential decline and recovery of haplochromine trophic groups in the Mwanza Gulf of Lake Victoria. Aquat. Ecosyst. Health Mgmt. 10(4), 416–433.