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Status of the Major Commercial Fish Stocks and Proposed Species-specific Management Plans for Lake Victoria★

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Abstract
The fishery of Lake Victoria is dominated by four species, the introduced Nile perch (*Lates niloticus)* and Nile tilapia, (*Oreochromis niloticus)*, the native dagaa, (*Rastrineobola argentea*) and haplochromines. Recently, there has been a concern about the state of these fish stocks and their current status is reviewed by examining trends in biomass, catch, catch per unit efforts and biological indicators. The Cadima model was used to predict the MSY of Nile perch and dagaa and the Nile perch was shown to be under intense fishing pressure. The biomass has considerably reduced with catches being higher than the predicted *MSY*. In contrast, the dagaa fishery was well below the predicted *MSY* and there is still scope for expansion. The fishery for Nile tilapia is also under pressure as a result of increased fishing effort and illegality, but little is known about the haplochromines. The current status of the fisheries threatens the benefits which the lake has been providing for decades and it is recommended that management options outlined in this paper are implemented to avoid the collapse of the fisheries.

Keywords: Lake Victoria, biomass, Nile perch, *Rastrineobola*, recovery plan, species specific management plan

Introduction

Lake Victoria, with a surface area of 68,800 km^2 is the world's second largest freshwater body and it supports one of the world's most productive inland fisheries with a total catch of around one million tonnes per annum. It supports about 200,000 fishermen and the catch is valued at more than US$ 400 million which includes some US$ 250 million in exports which is 3-5% of the total GDP of the three countries around the lake (Ogutu-Ohwayo and Balirwa, 2006).

The fish stocks in the lake have changed dramatically since the introduction of Nile perch *Lates niloticus* (L.) during the late 1950s and early 1960s. These changes included the apparent destruction of the endemic haplochromine species flock, which made up about 80% of the fish biomass in the lake in the 1970s (Kudhongania and Cordone, 1974), but less than 4% by the early 1990s while Nile perch became the dominant species (Okaronon, 2004). Currently, the fishery is dominated by two introduced species, Nile perch and Nile tilapia *Oreochromis niloticus* (L.), and the native pelagic cyprinid *Rastrineobola argentea* (Pellegrin),commonly referred to as 'dagaa' (also 'omena' or 'mukene'), and haplochromines. The recovery of the haplochromines is a striking feature of recent catches but it is not clear which species are involved and how many may have been lost. The Nile perch fishery is the most valuable since it provides most of the export earnings, but concerns about over-exploitation have been expressed (Matsuishi *et al.*, 2006) and signs of overfishing, such as a decline in the biomass and a decrease in the age of first maturity, are now evident (LVFO, 2007, 2008a).

This paper summarises current knowledge about the status of the fish stocks and reviews the need for species-specific management plans for the major commercial fish species of Lake Victoria. It also outlines a recovery plan for the Nile perch fishery where fishing effort may now be almost twice the optimal level needed for a sustainable yield (Arnason, 2009).

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Methods

Data for this assessment were obtained from biennial frame surveys carried out from 2000 to 2008, catch assessment surveys from 2005-2008, acoustic surveys carried out from 1999-2001 (Getabu *et al*., 2003: Tumwebaze *et al*., 2007) and again from 2005-2008, and bottom trawl surveys undertaken from 2005-2008. These surveys were carried out concurrently in all three countries, using standardised methods, and are among the first to provide information on a lake-wide basis.

A wide variety of stock assessment models are available (Sparre and Venema, 1992; Jennings *et al.*, 2001) but many of these require data which are not readily available from Lake Victoria. In particular, adequate long-term data are lacking while inconsistency in datasets and fragmentation of data as a result of interruptions in sampling are a major problem. Two projects funded by the European Union, the Lake Victoria Fisheries Research Project (LVFRP) which ran from 1997 to 2001 and the Implementation of Fisheries Management Plan Project (IFMP) which began in 2003 and will be completed in 2010 have provided consistent lake-wide data.

The current assessment is based on a simple but robust form of surplus production model, the Cadima equation, in which

$$MSY = 0.5 * (Y + M\overline{B})$$

where MSY = maximum sustainable yield, Y = yield, M = natural mortality and $\overline{B}$ = mean biomass. This model was chosen because models that rely on catch and effort are difficult to use owing to problems in estimating a standardised measure of effort since a wide variety of fishing methods are used in Lake Victoria.

Results

Biomass and relative abundance

The average biomass of fish in the lake was estimated to be 2.1 million tonnes (range 1.6 million to 2.6 million tonnes) over the period from August 1999 to August 2008 (Figure 1a). The Nile perch biomass declined from 1.9 million t in August 1999 (82% of the total biomass) to 227,000 t (15%) in August 2008. On average, it accounted for 59% of the total biomass in 1999-2001 but only 26% in 2005-2008. It made up only 37% and 15% of the stock in August 2005 and August 2008. The biomass of *Rastrineobola argentea* has risen considerably over the last decade (Figure 1b). In 1999 its biomass was only about 245,000 t (10% of the total) although this rose to an average of 477,000 t (23%) during 1999-2001. Its biomass continued to rise throughout 2005-2008 with an average of just over 1 million tonnes or 50% of the total. Its population fluctuated quite considerably, however, with the lowest estimate during this period being recorded in August 2005 (500,000 t or 34%) and the highest in February 2008 (1.5 million tonnes or 57%).

The Nile tilapia is the most important tilapia in the lake (Ojuok *et al.*, 2007) but its biomass could not be determined as it mostly lives in water < 10 m deep where it cannot be adequately sampled by acoustic methods. Similarly, there are no direct data available on haplochromine biomass although their populations are evidently increasing (Table 1). Stock assessment of this group will be very difficult because the stock consists of a number of species, not all of which can be easily distinguished and treating it as a single unit could mask significant changes within the community.

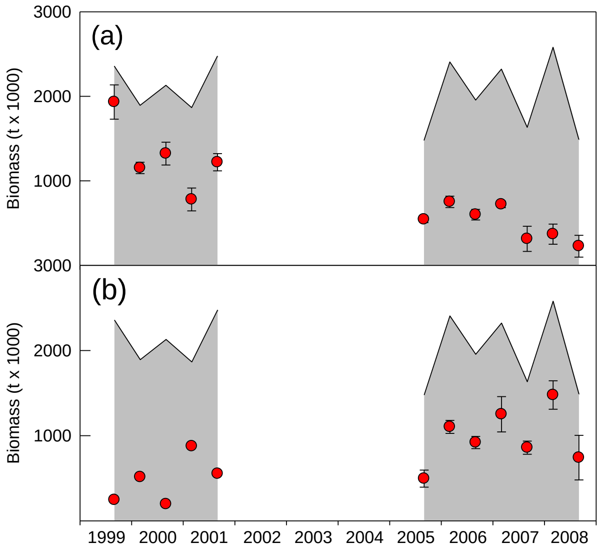

Figure 1. Changes in the biomass of (a) Nile perch and (b) *Rastrineobola argentea* (dagaa) in Lake Victoria, 1999-2008, in relation to the total fish biomass. Grey shading = total biomass, points = biomass (± standard deviation). No surveys were carried out between August 2001 and August 2005. Data from Getabu *et al.* (2003), Tumwebaze *et al*. (2007) and IFMP surveys, 2005-08.

Table 1. The proportion (%) of major inshore species collected in trawls during the acoustic surveys, 2005-08. Dagaa are not effectively sampled with bottom trawls.

	Nile Perch	Tilapia	Haplo-chromines	Others
Aug 05	81.4	4.8	7.2	6.6
Feb 06	86.2	6.7	3.4	3.7
Aug 06	66.8	12.6	12.9	7.7
Aug 07	83.6	0. 7	12.7	3.0
Feb 08	75.0	3.5	14.0	7.5
Aug 08	71.1	1.7	21. 9	5.3

Biological indicators

The mean length of Nile perch in trawl catches did not change much between 1994 and 1999 although there was a marked increase from around 18 cm in 1999 to about 32 cm in 2002 (Figure 2). This may be a result of the export bans that were imposed at various times between 1997 and 2000, which led to a reduction in the total catch and, presumably, a decrease in fishing effort. This increase in mean length was not sustained and it fell back to about 18 cm by 2007. The mean maximum length of Nile perch detected by single target detection during the acoustic surveys carried out during the IFMP was around 50 cm between August 2005 and February 2007. Thereafter, it fell sharply to about 27 cm by August 2008 and this corresponded significantly with a reduction in its biomass (Figure 3).

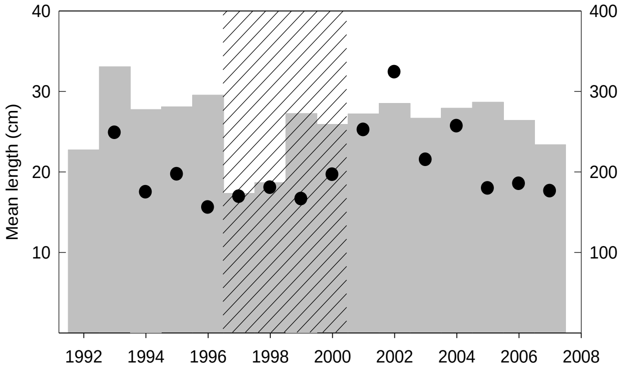

Figure 2. Mean length of Nile perch in trawl samples, 1993-2007 (points) The grey shading denotes the annual catch while the cross-hatched area indicates the period when export bans were in force at various times. Data from Yongo *et al*. (2005), Payne *et al.* (2006) and IFMP surveys.

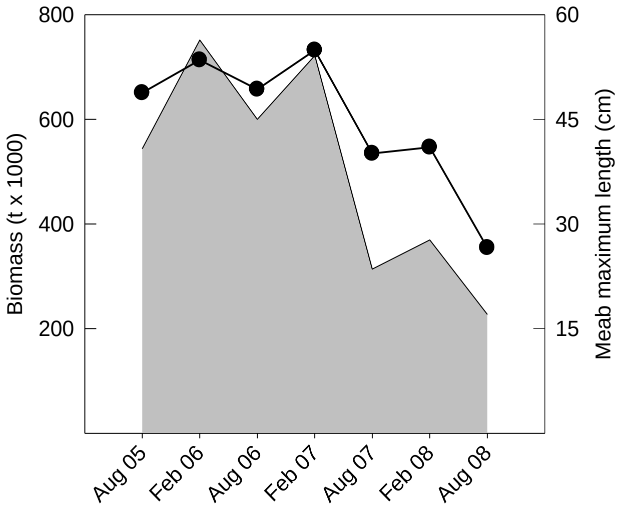

Figure 3. The relationship between the mean maximum length (points) and l biomass (grey shading) of Nile perch during IFMP acoustic surveys, August 2005-August 2008. There was a significant correlation (r = 0.94, p < 0.01) between the two variables.

Table 2. Size at first maturity (total length, cm) in male and female Nile perch in Lake Victoria, 1964-2007.

	Females	Males	Source
1964-67	45.3	32.2	Okedi (1970)
1968-77	54.7	41.9	Ogutu-Ohwayo (2004)
1982	93.3	46.8	Ogutu-Ohwayo (2004)
1988-92	93.3	62.2	Ogutu-Ohwayo (2004)
2001	75.8	57.7	UNECIA (2001)
2007	58.0	52.5	LVFO (2007a)

The size at first maturity of Nile perch has fluctuated over time (Table 2). These data suggest that it matures relatively early when its population is small, i.e. in the 1960s and 1970s when it was still expanding, and again more recently when its biomass has fallen as a result of overfishing. The length at first maturity was greatest in females, at about 93 cm in the period from 1982-92 when Nile perch were probably most abundant in the lake.

The decrease in size of dagaa is reflected by changes in the size at first maturity. In the pre-Nile perch era dagaa matured at around 60 mm TL but by the 1990s this had fallen to around 35-40 mm (Table 3). In the Kenyan waters of Lake Victoria the mean length at first maturity of *Oreochromis niloticus* was reported to be 35 cm TL (Getabu, 1992) while Ojuok *et al.* (2007) reported that it was 35.0 cm TL for males and 31 cm TL for females. By 2004-05 their length at first maturity had decreased further to 22.0 cm TL in females and 25.0 cm TL in males (Njiru *et al*., 2006).

Table 3. Estimates of length at first maturity (standard length, cm) in *Rastrineobola argentea*. The data for 1973 have been converted from total length using the relationship SL = (TL – 0.33)/1.22 (Wanink, 1994).

Females	Males	Source
51.4	44.0	Okedi (1973)
40.0	41.0	Wandera (1992)
34.0	36.0	Manyala *et al*. (1992)
33.0	46.0	Wanink (1998)
40.0	40.0	Wandera *et al*. (2005)
41.6	40.2	Wandera *et al*. (2005)

Fishery indicators

A decline in the catch per unit effort (CPUE) of Nile perch was noted in paddled sesse boats using gillnets in Tanzania, and in sesse boats with motors/sails and gillnets in Kenya, and amongst paddled sesse boats with longlines in both Kenya and Tanzania (Figure 4). The number of fishermen and the number of fishing boats rose by 54% and 63% respectively between 2000 and 2008, but the relative number of boats remained more or less constant at 0.3 per fisherman. Fishing gear increased considerably, however, and in each case the numbers per fisherman also increased. This was especially evident in long lines, which target Nile perch almost exclusively, where the number of hooks rose from 27 per fisherman in 2000 to 56 in 2008 with the total number increasing by 322% over the same period. The most significant increase was in the number of small hooks (i.e. size 10 or above) which increased by 77% from 2006 to 2008, reflecting the decrease in the average size of Nile perch.

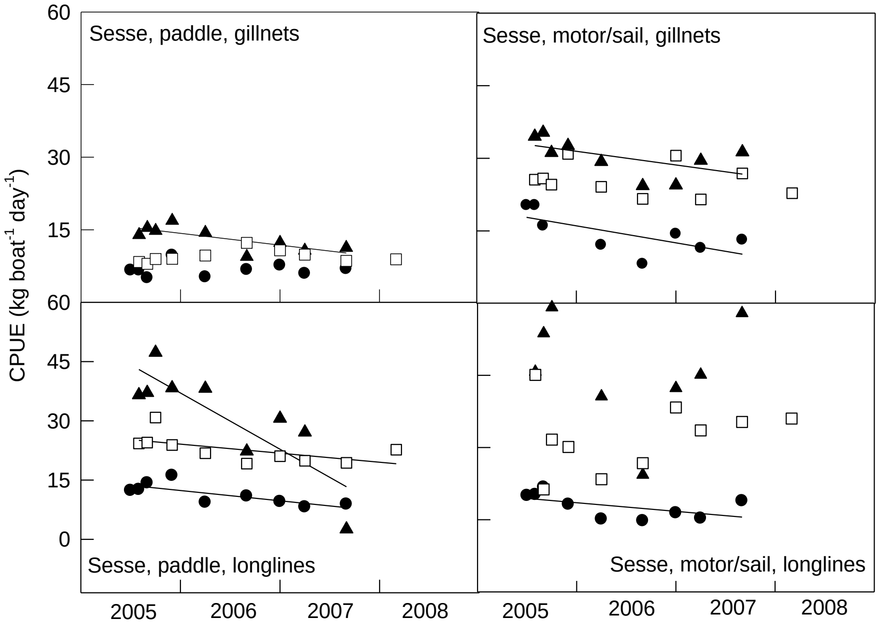

Figure 4. Catch per unit effort (kg boat^{-1} day^{-1}) of Nile perch in the main vessel-gear combinations. ● = Kenya, ▲ = Tanzania, □ = Uganda. Only significant (p < 0.05) relationships are indicated by a regression line. Data from IFMP catch assessment surveys.

The catch rates of dagaa in all vessel-gear types fluctuated to a considerable extent with no clear pattern (Fig. 5). The mean catch rate for paddled sesse boats averaged about 220 kg boat^{-1} night^{-1} in all three countries but catches lowest from Kenya (122 kg boat^{-1} night^{-1}) and highest in Tanzania (282 kg boat^{-1} night^{-1}). Catch rates from sesse boats propelled by sails or motors were only reported from two countries and again, those from Kenya were much lower (mean = 106 kg boat^{-1} night^{-1}) than those from Tanzania (523 kg boat^{-1} night^{-1}).

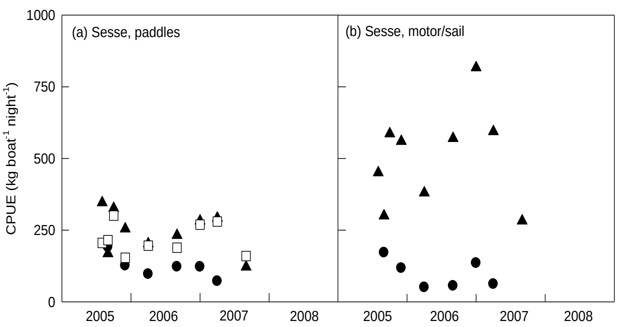

Figure 5. Catch per unit effort (kg boat^{-1} night^{-1}) of dagaa in the two main gear-vessel combinations: (a) Sesse boats with paddles and small seines, and (b) sesse boats with a motor or sail and small seines. ● = Kenya, ▲ = Tanzania, □ = Uganda. Data from IFMP catch assessment surveys.

The catch rates of *Oreochromis niloticus* made by sesse boats with hand lines decreased significantly (p <0.05) in Tanzania while the reduction in catch by sesse boats with gillnets in Uganda was nearly significant (p < 0.10). There was no clear pattern in the catch rates from parachute boats with gillnets and hand lines (Figure 6).

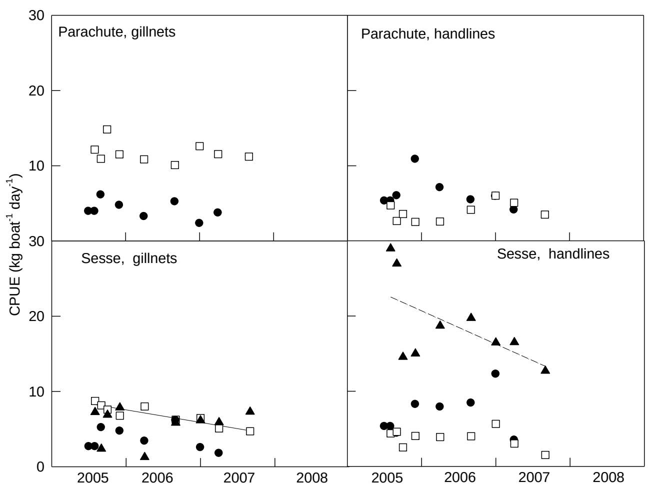

Figure 6. Catch per unit effort (kg boat^{-1} day^{-1}) of *Oreochromis niloticus* fishery of Lake Victoria in relation to the principal gear-vessel combinations. ● = Kenya, ▲ = Tanzania, □ = Uganda. Data from IFMP catch assessment surveys.

Stock assessment and reference points

During the period 1999-2001 the yield of Nile perch ranged from 58-86% of the predicted maximum sustainable yield (*MSY*) and from 12-23% of the mean biomass ($\overline{B}$) recorded during the surveys at that time (Table 4). This had changed dramatically a few years later and by 2005-07 the proportion of *MSY* taken by the fishery was over 100% while the yield exceeded 40% of the mean biomass which was considered to be the maximum for a species with the characteristics of Nile perch (LVFO, 2008b).

Table 4. The mean performance of the Nile perch fishery in relation to predicted MSY and biomass in 1999-2001 and in 2005-07. $\overline{B}$ = biomass (t), Y = yield (t), MSY = predicted maximum sustainable yield (t) using data from LVFRP and IFMP. In all cases natural mortality (M) was taken to be 0.3.

	1999-2001	2005-2007
$\overline{B}$ (x 1000)	1,390	579
Y (x 1000)	229	249
MSY (x 1000)	323	212
Y/MSY	0.73	1.18
$Y/\overline{B}$	0.18	0.44

Table 5. The effects of reducing yield by on the *MSY* and *Y/B* ratio in the Nile perch fishery, 2005-07. Symbols and units are given in Table 4.

	Year	2005	2006	2007
Biomass	$\overline{B}$	544	676	518
Effort -10%	*Y*	259	208	205
	MSY	211	205	180
	$Y/\overline{B}$	0.4	0.31	0.4
Effort - 20%	*Y*	230	185	182
	MSY	197	194	169
	$Y/\overline{B}$	0.42	0.27	0.35
Effort -30%	*Y*	202	162	160
	MSY	183	182	158
	$Y/\overline{B}$	0.37	0.24	0.31

An assessment of the dagaa fishery suggests that the yield is lower than maximum sustainable yield (Table 6). Therefore, the current fishing effort could be increased to bring the $Y/\overline{B}$ ratio to 100% which should be sustainable in a short-lived species like dagaa (LVFO, 2008b).

Table 6. The mean performance of the dagaa fishery in relation to predicted MSY and biomass in 1999-2001 and in 2005-07. Symbols and units as in Table 4. In all cases natural mortality (M) was taken to be 2.0

	1999-2001	2005-2007
$\overline{B}$ (x 1000)	468	856
Y (x 1000)	194	395
MSY (x 1000)	565	1,054
Y/MSY	0.34	0.37
$Y/\overline{B}$	0.41	0.46

Of the three variables in the Cadima model, only the yield (Y) can be influenced directly by management through increasing or decreasing the fishing effort. Given the present state of the Nile perch stocks, the only management measure available is to reduce fishing effort, which would also reduce the yield. If the effort reduction was adequate a decrease in the $Y/\overline{B}$ ratio would be expected and the stock could begin to recover. An indication of how yield reduction could affect the fishery can be obtained by changing Y in the 2005-07 data by varying amounts (Table 5). It would require a 30% reduction of effort to bring the yield to below 40% of the mean biomass as recommended by LVFO (2008b).

Discussion

The fisheries of Lake Victoria directly support around three million people (EAC, 2006) and make a significant contribution to the GDP of the countries around the lake (Ogutu-Ohwayo and Balirwa, 2006). The reduction in the biomass of Nile perch is therefore of concern as a potential threat to the local economy. Some benefits that have already shown signs of being affected include incomes and employment owing to the closure of some fish processing factories, while those currently operating are working at reduced capacity (Onyango, 2006).

While the total biomass of Nile perch has decreased, the catch is higher than the predicted *MSY* in most years. This is the result of increased fishing effort which has led to reduced numbers of larger fish in the population. The reduction of the spawning stock could impair the ability of the stock to replenish itself, although this has been offset by a reduction in the size of first maturity. Nevertheless bioeconomic models suggest that fishing effort is too high for a sustainable fishery (Arnason, 2009) and draw attention to the need to reduce effort and a regional plan of action has been drawn up to accomplish this (LVFO, 2007b).

If an *MSY* of 225,000 t is to be maintained then, assuming that 30% of the biomass can be removed, then the target biomass would come to 750,000 t. This can be achieved by a 30% reduction of effort and for practical purposes the allowable catch should therefore not exceed 30% of the mean biomass in the previous year. Various options exist for reducing effort and these have been set out in the Regional Plans of Action for (a) Capacity and (b) Illegal, Undocumented and Unlicensed Fisheries, and the full implementation of these plans should have an impact on the stocks. Other possible actions include the establishment of closed areas to protect stocks in key habitats or even closed seasons for as long as 3 months per year to allow for the stocks to recover.

The dagaa fishery seems to be capable of further expansion with yield being substantially lower than maximum sustainable yield and a relatively small proportion of the biomass. As a small, rapidly-growing species it has a high P/B ratio (probably > 2.0) and the catch can exceed the mean biomass. At present there is no obvious need to set limits for this fishery but if the Nile perch stock recovers this it may reduce the dagaa stock and the need to control fishing may have to be re-examined.

The development of specific management plans for other species is hampered by a lack of data. Little is known of the biomass of Nile tilapia because they inhabit shallow water where they cannot be sampled adequately by trawl or acoustic surveys. Some declines in catch per unit effort have been noted in Uganda (sesse boats with gillnets), Tanzania (sesse boats with long lines) but more data are needed. The reduction in their since the late

1980s suggests a degree of overfishing and highlights the need to manage this species using mesh size regulations, the protection of breeding areas, and the control of illegal regulating gears that disrupt nests and destroy nests and young fish.

The management of haplochromines has been hampered by a lack of taxonomic knowledge and therefore an inability to separate the stocks. Haplochromines are taken as a by-catch in the dagaa fishery so, possible management measures for that fishery should take haplochromines into account. Fishing in littoral waters can affect specialised species, such as those restricted to rocky habitats, which are heavily fished for bait for long lines targeting Nile perch (Mkumbo and Mlaponi, 2007). There may be a need to control these activities.

The development of fishery-specific management plans is a new concept in Lake Victoria which aims at managing fish species individually, but taking into consideration their biology and ecological interactions. The major focus is on the promotion of sustainable exploitation to achieve effective fisheries management for sustainable development. Therefore, we recommend that species-specific management options outlined above be implemented to reverse the current trend in the Nile perch stocks, the most immediate management issue in the lake.

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