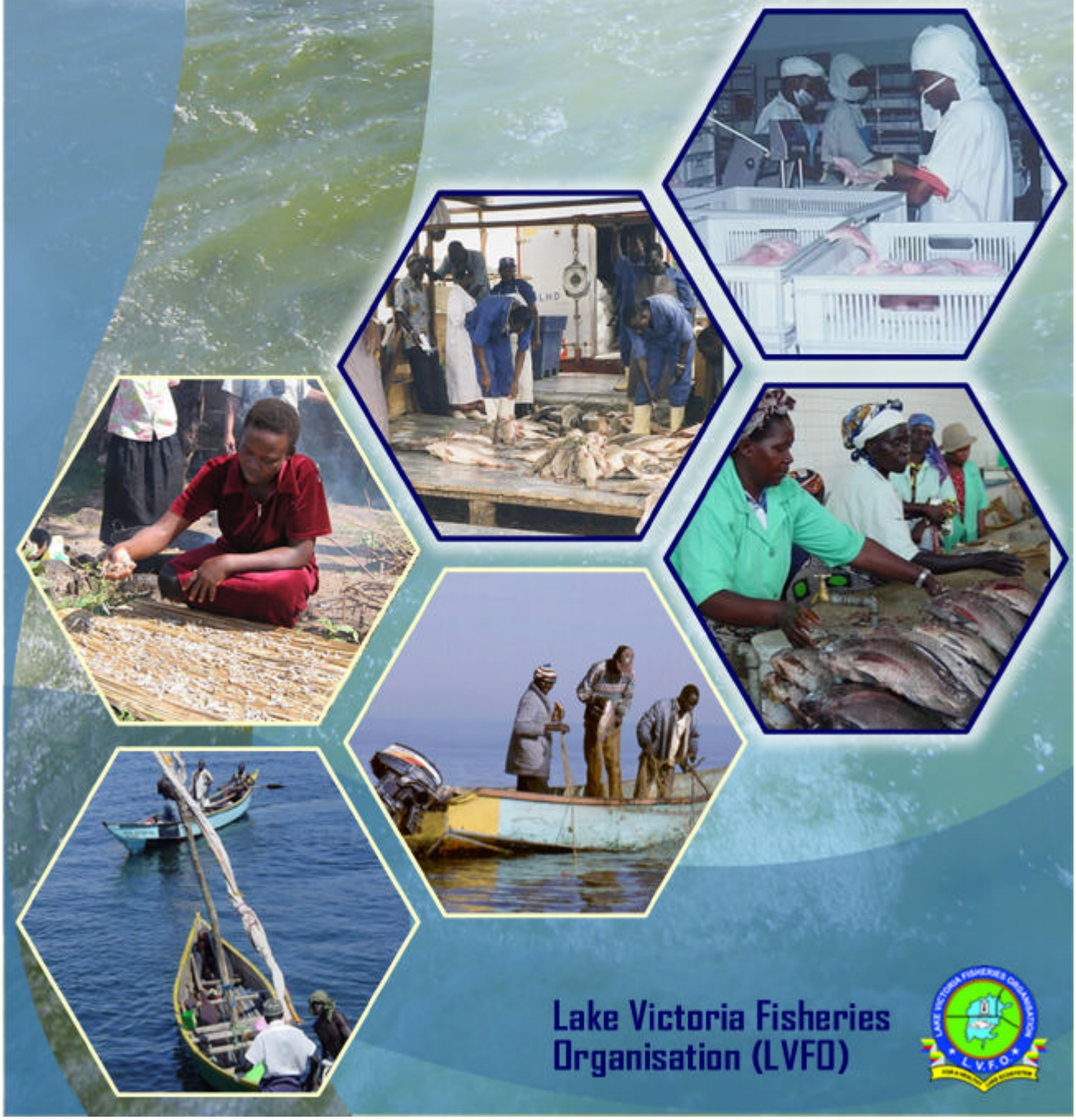
Proceedings of Lake Victoria 2000 A New Beginning Conference

15 - 19 May 2000, Jinja, Uganda



Lake Victoria Fisheries Organisation (LVFO)

Proceedings of Lake Victoria 2000
A New Beginning Conference

15 – 19 May 2000
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Preface

The Lake Victoria Fisheries Organization (LVFO) is an Inter-governmental Organization formed by three Contracting Parties of Kenya, Uganda and Tanzania on 30th June, 1994 in Kisumu, Kenya. The main objectives of the LVFO are to foster co-operation amongst the Contracting Parties in matters relating to Lake Victoria fisheries; harmonise national measures for the sustainable utilisation of the living resources of the lake; develop and adopt conservation and management measures to assure the lake's ecosystem health and the sustainability of the living resources, and to provide information on the lake and its resources.

The Lake Victoria Fisheries Organization (LVFO) organized an International Conference "***Lake Victoria 2000: A New Beginning"*** in Jinja, Uganda from 15th to 19th May, 2000. Major Objectives of this conference were: to share experiences from research undertaken in the past; to present accumulated results from research; to identify gaps in knowledge of the changing fisheries of the lake, and, to deliberate on emerging management and conservation issues in the fisheries of the lake. The Conference thus brought together more than 200 Scientists representing at least three generations of researchers who had experience on the lake from the 1930s to 2000. Some of these researchers had worked through the 1930s to 1940s when the East African Fisheries Research Organization (EAFRO) was formed; others had worked on the lake from the 1950s to the 1960s under the East African Freshwater Fisheries Organization (EAFFRO), a period that coincided with species introductions of the Nile perch and tilapiine fishes into Lake Victoria. The third category comprised of researchers from the mid-1970s through the 1980s to the present, and who witnessed the transition from a multi-species artisanal fishery to a three-species commercial fishery dominated by two introduced species (*Lates niloticus*, the Nile perch and Nile tilapia, *Oreochromis niloticus*), and the native pelagic *Rastrineobola argentea* (Dagaa/Mukene/Omena). The conference was thus one of the LVFO's initiatives to collate information in management issues and involve stakeholders on the status and conservation of the lake's resources and ecosystem. Five conference themes categorised the scope of issues from the diverse papers presented. These are summarised as:

1. Multiple resource use and ecosystem health of the Lake Victoria basin

This theme identified shifts in use of land and aquactic resources over time as a major factor defining the current status of the resources. The impact of population growth in the basin and increased human activity along the lake shores were highlighted as major forces of degradation.

2. The role of Science, economics and politics in fisheries management

The effectiveness of science in improving the status of the lake environment and its resources depends on the socio-economic environment which also influences fisheries management policies. The theme thus made it clear that effective fisheries management requires

consideration of both bio-physical and socio-economic impacts on the resource. It was therefore considered important for sustainability to integrate the different ecosystem and socio-economic components into a fisheries management system.

3. Development of the Fisheries sector

This theme analysed the status of the fish stocks and trophic interactions. Issues related to exploitation of the resources, existing policies and regulations aimed at sustainable utilization of the resources were highlighed. Development of aquaculture technologies was considered as a viable means of reducing fishing pressure on wild fish stocks, and as an alternative livelihood strategy for fishery dependent communities.

4. Roles of conservation in biodiversity and fisheries sustainability

The theme addressed the status of biodiversity and its role in maintaining ecosystem integrity. The impact of introduced species (Nile perch and tilapiines) on biodiversity and fishery yield were analysed in relation to overall environmental quality. The need to include water quality standards for fisheries in the lake, its tributaries and associated lakeshore wetlands, and to reverse the increasing eutrophication were emphasized as measures that would enhance biodiversity conservation especially in satellite lakes in the basin.

5. Integrated Lake Basin management

The theme emphasised a trans-sectoral approach where fisheries is one of the elements to be addressed in the planning, development and management of the Lake Victoria Basin (LVB). It was also realized that any plans and derived strategies to manage the fisheries resources and the basin must involve all stakeholders. This was considered to be the cornerstone for Human Resource Development (HRD) programes in the Lake Victoria Basin (LVB).

The recommendations from the plenary discussions under each theme which served as a guide and reference on the way forward for Lake Victoria were published in December 2000 as ***'Lake Victoria 2000: A New Beginning, The Jinja Recommendations on the Way Forward'.***

This document presents a record of the proceedings of the conference. Some of the key issues identified and recommended for action are also included under the section '***Workshop Recommendations***'. It was imperative that the papers presented be packaged to provide opportunity for the stakeholders of the resources of Lake Victoria and its basin to reflect back and assess progress and achievement based on the information presented during the conference. 89 papers including key note papers in each of the five themes were presented. However, some authors did not submit their final copies while others had their papers published before the production of these proceedings. The proceedings collate a total of 42

manuscripts presented during the '***LV 2000 A New Beginning Conference***'.
I believe the information in this publication will be of use for us all to reflect back and assess the success of our interventions under the LVFO Institutions. The lessons presented in 2000 on the status of the fisheries resources and the ecosystem health, and recommendations made by the stakeholders should act as a mirror as we assess our management achievements over the five years from 2000 to 2005. It is fortunate that in 2005 we had another conference but this was regional and the proceedings of that 'Lake Victoria Stakeholders' Conference' held in Entebbe in February 2005, should be used closely with the proceedings of 2000 conference as we map a way forward for the sustainability of the resources of Lake Victoria.

I wish once again to thank individuals, organizations and institutions that contributed in all ways to make the Lake Victoria 2000 Conference successful and in the production of these proceedings; 'L***V 2000: A New Beginning' Conference Proceedings*** which is a bench-mark of our efforts in monitoring and managing the Lake Victoria Fisheries resources and the ecosystem heath. This explains why the LVFO Secretariat had to ensure the proceedings are published.

Executive Secretary,
Lake Victoria Fisheries Organization.

Conference Recommendations

1. The Health of the Ecosystem

The changes in fish stocks structure and dynamics were reported to be mainly a result of changes in resource use and ecosystem health. To ensure sustainability of the resources and the health of the ecosystem the following was recommended:

a) States should put measures in place to control eutrophication by addressing the excessing nutrient loading caused by poor agriculture practices, deforestation and the input of untreated industrial and domestic wastes. These inadequately controlled practices result in high algal population and blooms which cause high water treatment costs, algal toxins and alteration of food webs which in turn affect fish habitats and loss of biodiversity resulting to unstable ecosytem;

b) States should take measures to ensure responsible fishing is practised to avoid over-exploitation by harmonizing regulations and enforce them for sustainability of the resources.

2. Institutional Framework

The following were recommended in improving the institutional framework and policies for the management of Lake Victoria resouces:

a) States should ensure that an appropriate policy, legal and institutional framework is adopted to achieve the sustainable and integrated use of Lake Victoria basin (LVB) resources, taking into account the needs of the communities, the fragility of the ecosystem and the finite nature of its natural resources.

b) States should ensure that representatives of all sectors (and stakeholders) are consulted in the decision-making processes and involved in other activities related to planning, development and management of the Lake Victoria basin.

c) States should develop, as appropriate, institutional and legal frameworks in order to determine possible uses of resources and to govern access to them taking into account the rights (custodianship and proprietorship) of the Lake Victoria basin fishing communities and their customary practices to the extent compatible with sustainable development.

d) States should promote the establishment of procedures and mechanisms at the appropriate administrative level to settle conflicts, which arise within the fisheries sector and between them and other users within the Lake Victoria basin.

e) States should limit new fish processing plants and pirate processing plants created prior to or in violation of licensing.

f) The potential in commercial aquaculture the region is high, but is very far from

being achieved. It is recommended, however, that States should adopt a precautionary approach to large scale aquaculture development because such initiatives can impact biodiveristy through acceleration of sedimentation rates, the accrual of uneaten food increases eutrophication and antibiotics and antifouling compounds can lead to local toxic pollution. There are also risks of contamination and introductions of species and genetic varieties that are foreign to the lake. The development should therefore be closely monitored.

k) Riparian States should offer members of commnities' opportunities for education and training sufficient to provide access to alternative means of employment, and/ or material assistance in relocation.

l) States should preserve typical refugia areas through protected area or as part of integrative co-management programs. A coherent plan for conservation and rehabilitation of the lake basin fish faunas should also be developed without delay on the following basis:

i) Provisions for the setting up of reserves typifying the various habitats of the lake, its tributary rivers, associated wetlands and satellite lakes, after an apropriate inventory has been conducted;
ii) Human aspects of such reserves should be agreed through consultations with local groups;
iii) Formulation of strategies to reinforce conservation, financial and social value on the resources to be protected;
iv) Education programmes addressed to all levels of society aimed at clarifying the benefits from conservation and defining the processes needed to achieve it.

3. Policy Measures

a) States should promote the creation of public awareness of the need for protection and management of resources and participation in the management process by those affected.

b) States should promote the assessment of the respective value of the wetlands taking into account social, economic and cultural factors.

c) States should address the risks and uncertainities and adopt a precautionary approach in setting policies for the management of the Lake Victoria basin.

d) States should establish or promote the establishment of systems to monitor the Lake Victoria basin environment, as part of the management process, using social, economic, physical, chemical and biological criteria.

e) States should promote multidisciplinary research in support of management of Lake Victoria basin with respect to social, economic, legal, political, environmental, administrative, technical and biological criteria.

4. Regional Co-operation

a) States of the Lake Victoria basin should co-operate to facilitate sustainable use of its resources and conservation of biodiversity (and its environment).

b) In the case of activities that may have an adverse effect upon the Lake Victoria basin environment, States should:

(i) Provide timely information and, if possible, prior notification to potentially affected States;

(ii) Consult with those States as early as possible.

c) States should strengthen existing regional mechanisms (e.g. of East African Community (EAC), LVFO) in order to facilitate co-operation and co-ordination among agencies involved in the planning, development and management of the Lake Victoria basin.

d) The LVFO should be the lead organization, responsible for facilitating collaboration and co-operation with respect to the development and harmonization of activities affecting the Lake Victoria basin.

e) The LVFO should collaborate with stakeholders, relevant inter-governmental and non-governmental organizations and financial institutions to promote the effective integration of management for Lake Victoria basin.

Assessment of Pollution Sources and Socio-economic Circumstances related to the Eutrophication of Lake Victoria

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SUMMARY

Pollution resulting from increased human activities is threatening Lake Victoria, its effects being characterised by advanced levels of eutrophication and the occurrence of low dissolved oxygen levels in parts of the lake. A three-step pollution assessment was conducted, consisting of a qualitative screening stage, a quantitative pollution sources assessment, and an assessment of forcing functions. The assessment revealed that nutrient input originates mainly from atmospheric deposition and land runoff, together accounting for more than 90 % of phosphorous and nitrogen input into the lake. The increase in eutrophication is probably due to an increase in nutrient flux via these avenues as a result of increased human activities in the lake surroundings. BOD loading was found to be predominantly from domestic sources.

The study investigated the socio-economic parameters influencing the nutrient fluxes, for the case of Tanzania. At the root of the problem is the high increase of population (3.2 % annually), under influence of various cultural, social and economic factors. The resulting influence on eutrophication reveals itself in two main categories: (i) Increasing soil erosion, nutrient runoff and leakage to surface waters as a result of unsustainable and growing land exploitation for agricultural production, overgrazing, and deforestation for firewood and construction material; (ii) Increasing release to the atmosphere of nutrients from biomass burning, and consequent deposition to surface waters. In order to counteract these adverse effects, Lake Management strategies should be directed at the introduction of sustainable land-use practices, the introduction of high efficiency stoves and control over forest burning.

INTRODUCTION

With a surface area of 68,800 km^2 and an average depth of 40 m, Lake Victoria is the second largest water body in the world and of crucial socio-economic importance to its riparian population. The three surrounding countries Tanzania, Uganda and Kenya control respectively 49%, 45% and 6% of the area of the lake and make use of its resources for fishery, freshwater and avenues of transportation. The lake's 194,000 km^2 catchment area stretches further across Rwanda and

Burundi. The lake's water balance is dominated by evaporation and precipitation, its single outlet being the Victoria Nile at Jinja, Uganda. Some basic morphometric and hydrological data on Lake Victoria is presented in Table 1.

Table 1 : Morphometric and hydrological data for Lake Victoria. Data taken from Akiyama *et al.* (1977), Kite (1981; 1982; 1984) and Piper (1986).

Surface area (km^2)	68 800
Mean depth (m)	40
Maximum depth (m)	97
Volume (km^3)	2 740
Inflow (km^3yr^{-1})	29
Outflow (km^3yr^{-1})	39
Precipitation (km^3yr^{-1})	114
Evaporation (km^3yr^{-1})	109
Hydraulic detention time (yr)	70

In the last few decades, the lake has undergone large changes in chemistry and biology as a result of growing human interference. Threats to the lake's ecosystem include overfishing, the introduction of exotic fish species such as the notorious Nile perch (*Lates Niloticus*) accompanied by a drastic reduction in endemic species (e.g. Goldsmith *et al.*, 1993; Gophen *et al*., 1993; Kaufman, 1992; Witte *et al*., 1992a; 1992b), and the large scale infiltration of the water-hyacinth (*Eichhornia crassipes*). Pollution from domestic, industrial, and agricultural activities have lead to a deterioration of water quality, characterised by algal blooms, even off-shore (Ochumba & Kibaara, 1989), and periodic massive fish kills caused by oxygen depletion (Ochumba, 1988; Hecky et al., 1994). Widespread water-borne diseases and reduced benefits to riparian people result.

This study presents an assessment of pollution sources and their contribution to the changes taking place in Lake Victoria. It will furthermore evaluate the socio-economic parameters that are at the core of the pollution problem. The assessment makes use of the scattered and mimnimal amount of data available, applying a set of methodologies for translation of this data into conclusions that could contribute to the design of effective pollution control approaches. Data was gathered both through literature survey and field surveys in the period 1993 to 1999, building upon earlier work, though less extensive, of others (Calamari *et al*., 1993; Scheren *et al*., 1994, 1995a & 2000; Kirugara & Nevejan, 1996).

The methodology followed has proven to be effective for pollution assessment in situations where extensive monitoring programs can not be executed, such as often the case in developing countries. In view of the catchment area's characteristics, with organic pollution from industries, farming and basic consumption patterns prevailing, the results presented in this paper are limited to three

major organic pollution parameters: The 5-day Biological Oxygen Demand (BOD) load, as an indicator for the pollution load of industries and domestic effluents to bays and near-shore waters (often associated with water born diseases), and nitrogen (N) and phosphorus (P) as nutrients associated with the eutrophication of the lake.

METHODS

The assessment hereafter described is subdivided into three stages:

a) A qualitative screening stage, which includes an assessment of relevant characteristics of the lake's catchment area, in order to determine the most relevant parameters for assessment;

b) A quantitative pollution sources assessment, based on what is often referred to as 'rapid assessment' method (World Health Organization, 1982; Economopoulos, 1993; Scheren *et al.*, 1994 & 1995a), applying penetration factors to incorporate the effects of 'natural purification' by rivers and wetlands, and the 'enforced purification' of treatment facilities, and an error analysis to evaluate the reliability of conclusions;

c) An assessment of forcing functions, which includes an evaluation of the relative contribution of pollution sources to the lake's nutrient balance; and an assessment of the socio-economic parameters at the core of the pollution problem.

Reference year for the assessments is 1995.

A. Screening

The qualitative screening stage involved mainly the evaluation of relevant Lake basin principal characteristics often related to environmental pollution, such as demographic and industrial developments, agricultural land-use practices and atmospheric deposition.

B. Pollution Sources Assessment

The standard procedure used to estimate pollution from the various land-based pollution sources is based on the following general formula:

Waste Load = Functional Variable * Pollution Intensity

In which the pollution intensity represents the characteristic amount of waste produced per unit of a certain functional variable. A suitable selection of parameters allows estimation of waste loads on the basis of more easily measurable data, such as population, production and land-use figures. Table 2 presents functional variables and pollution intensities as proposed in this study.

Table 2. Functional variables and pollution intensities for the principle pollution sources

Pollution source	Functional variable	Pollution intensity
Industries Households Agriculture Atmospheric Deposition	Annual production Population number Area of (non) cultivated land Surface area	Waste production per unit product Annual waste production per person Annual export coefficients of nutrients Annual deposition per unit of surface area

In Table 2 atmospheric deposition was added to the commonly used sources (Economopoulos, 1993), because this in cases is an important factor in the nutrient balance of lakes (Bootsma *et al.* 1996). Human activities in a wide area around the water body, such as biomass burning and land cultivation resulting in erosion, are known to be of potentially large influence to nutrient flow via this avenue (Crutzen & Andreae, 1990; Galloway *et al.*, 1982; Goldman *et al.*, 1990; Lewis 1981).

The actual assessment demands firstly the collection of baseline data on the functional variables chosen. Data may be collected through field surveys, but often also extracted from available statistical reports, data from local, national and regional governmental and non-governmental institutions, scientific literature, and other written and non-written resources.

In using the above procedure, the choice of characteristic pollution intensities becomes very delicate, since factors like export coefficients and waste per unit product or person vary widely across cases. Due attention should therefore be given to the selection of these parameters, demanding a review of literature data from cases as similar as possible to the one surveyed. A range of possible values for each parameter may be defined.

Penetration factors

The actual pollutant load to a given water body may not be equal to what leaves the source at its origin. Wastewater treatment facilities and self-purification in rivers and wetlands may reduce the actual load. An elaboration of the standard formula allows for such effects to be incorporated in the assessment:

Waste Load = Functional Variable * Pollution Intensity * Penetration Factor(s)

where the value of the penetration factor may vary between 0 and 1.
The most common penetration factors are efficiency factors for domestic and industrial wastewater treatment facilities. Typical performances of normally operating plants are reported by Economopoulos (1993), although bad operation may require estimations of treatment efficiencies to be made on the basis of site visits and effluent analysis data. Furthermore, natural purification effects of rivers and streams reduce BOD from a distant source. The breakdown of BOD in

rivers can be described as a fist-order decay process, as elaborated by Scheren (2000).

Nutrient and oxygen demanding waste concentrations in rivers and sewage outlets may also be drastically reduced when draining through swamp areas. The purification capacity of wetlands is related to various aspects of wetland hydrology such as water depth, retention time and degree of channelization. Appropriate wetland penetration factors should therefore be assessed for each individual case (Scheren, 2000).

Error Analysis

Errors in the calculation of waste loads may be caused by either variability or bias (Reckhow and Simpson, 1980). In our case, variability may result from fluctuations inherent in a characteristic of the pollution source, represented by the 'functional variable'. Bias may result from the fact that the estimate may not fully represent the characteristic that it was selected to estimate. Uncertainty in this regard is for example introduced when values for 'pollution intensities' generated from other cases (e.g. watersheds in temperate climates) are applied to the Lake Victoria basin.

In the case of this study, the danger of bias errors originating from the selection of pollution intensities is much larger than that caused by variability, since the latter refers to primary data collected and verified in the field. To account for bias in the assessment parameters, a range, represented by 'high', 'most likely', and 'low' values may be selected by the analyst. For pollution intensities, these values may be based on reported ranges in literature. The width of the selected high-low interval expresses the confidence of the analyst in the most likely value. The procedure applied here is based on first-order analysis (Benjamin & Cornell, 1970). A modification of the Chebyshev inequality results in confidence limits for the estimated total waste load W, as follows:

Equation 1. $$P[(W_{ml} - h \times s^{-}) \leq W \leq (W_{ml} + h \times s^{+})] \geq 1 - \frac{1}{2{,}25 \times h^{2}}$$

Equation 2. $$s^{+} = \frac{W_{high} - W_{ml}}{2}$$

Equation 3. $$s^{-} = \frac{W_{ml} - W_{low}}{2}$$

Equation (1) states that the probability that the true waste load (W) lies within certain bounds around the most likely value ($W_{ml)}$, defined by a multiple (h) of the estimation error (s), is greater than or equal to 1-1/2.25 h^2. For a theoretical elaboration on the procedure we refer to Reckhow and Simpson, 1980. It is important to state, that with this procedure it is not required that the error term be normally distributed, which contrary to many other methods implies that low and high intervals need not necessarily be symmetric.

C. Assessment of forcing functions

Nutrient balance assessment

To assess the overall nutrient budget of a lake, a one-dimensional input-output model is proposed. Although such a model averages concentrations over the lake, and is therewith not suitable to predict local deviations and fluctuations, it is a useful tool to assess the overall nutrient balance. Under steady-state conditions (when nutrients concentrations are relatively constant), and assuming that lake volume and outflow are constant and that all processes involving nutrients (e.g. sedimentation) are linearly related to the nutrient concentration, the lake's nutrient balance can be described as:

Equation 4. $$W_A = C_A \times \left(Q_E + V \frac{v_S^A}{H} \right)$$

in which *WA* represents input of nutrient A [g yr^{-1}], CA is the concentration of nutrient A [g m^{-3}], Q_E is the river outflow [m^3 yr^{-1}], V is the lake volume [m^3], *vSA* is the sedimentation velocity for nutrient A [m yr^{-1}], and H is the average lake depth [m]. Since the assumptions made are generally valid approximations for a large water body such as Lake Victoria (Scheren, 1995b elaborates on this), equation (5) thus provides an estimation of the total nutrient load W_A.

Assessment of socio-economic circumstances

The assessment of economic circumstances related to the pollution of Lake Victoria evaluates the driving forces behind the increasing input of pollutants into the Lake, whether of domestic, agricultural, industrial or natural origin, attempting to quantify as much as possible conclusions. The assessment presented in this paper concerns solely the nutrient input and eutrophication aspect of the pollution problem.

RESULTS

A. Screening of relevant lake basin characteristics

Industrial pollution - Most industry is located in the larger towns bordering the lake; Kampala and Jinja in Uganda, Mwanza and Musoma in Tanzania, and Kisumu in Kenya. Exceptions are the large sugar factories in Kenya located at some distance from the lake. Table 3 presents an overview of the industrial production characteristics of the region, listing types, production and number of establishments. Although in Tanzania and Uganda industrial wastewater treatment facilities are generally absent, a majority of the Kenyan factories does operate a treatment plant. A minority of industries is furthermore connected to an urban sewage system. Although treatment efficiencies are generally low, their effect should not be neglected. Much of Ugandan industrial effluents furthermore drain through wetlands before reaching the lake surface water.

Table 3. Estimated 1995 production of major industries in the catchment area of Lake Victoria by country and industrial (sub)sector

ISIC	Industry	Shared production of major factories [t yr^{-1}] (number of major factories)		
		Kenya	Uganda	Tanzania
3111	Slaughter Houses	3000 (1)	14000 (3)	-
3112	Dairy Factories Fish	-	25000 (1)	-
3114	Factories Vegetable	18000 (6)	12000 (4)	6630 (2)
3115	Oil Refineries	-	3300 (2)	31400 (4)
3118	Sugar Factories	640000 (6)	-	3500 (1)
3131	Distilleries	18000 (1)	460 (1)	-
3133	Breweries	60000 (1)	17000 (1)	-
3134	Bottleries	41000 (1)	40000 (2)	11100 (2)
3211	Cotton Mills Leather	1500 (1)	-	1320 (2)
3231	Tanneries Paper	270 (1)	60 (1)	220 (1)
3411	Mills	94000 (2)	-	-
3523	Soap Factories	-	40000 (2)	15000 (1)

Sources: Kenya: Calamari (1994), Kirugara and Nevejan (1996), Ministry of Planning & National Development (1994), Oerlemans (1985), selected industrial site visits; Uganda: Droruga (1990), Ministry of Natural Resources (1995), Ministry of Finance & Economic Planning (1993), selected site visits; Tanzania: Höjlund and Marwa (1993a and 1993b), Regional Trade Office Mwanza (1991), Scheren et al. (1995a).

Domestic pollution - With an approximate population of 30 million, the Lake Victoria catchment area is one of the most densely populated parts of Africa. Annual population growth is 2-4 % in most parts of the lake basin but urban population growth is over 5-10 % per year in most of the larger towns. Table 4 summarises population statistics for the lake basin. A minority of the population lives in 40 urban settlements, which remain largely unsewered.

Table 4. Domestic characteristics of the Lake Victoria catchment area (1995)

Total population (1000 pple)		Urban Population [1000 people]		
		Sewered	Unsewered	Number of towns
Kenya	10200	390	630	18
Uganda	5600	210	870	9
Tanzania	5200	27	340	4
Rwanda	5900	-	400	5
Burundi	2800	-	140	4
Total	29700	627	2380	40

Sources: Kenya: Ministry of Water Development (1992); Uganda: Ministry of Finance & Economic Planning (1992), National Water and Sewerage Corporation (1995), Ministry of Natural Resources (1993); Tanzania: Matowo (1992), Scheren et al. (1995a); Rwanda and Burundi: Verlinden, P. (1996).

Land runoff - There are many densely cultivated areas in the Lake Victoria basin, especially in Kenya, Rwanda and Burundi. Important staple crops are maize and bananas. The main cash crops are sugarcane, coffee and tea. Artificial fertilizer use is very limited, while livestock breeding is extensive in the region. Agricultural characteristics are summarised in Table 5. Most values are extrapolations from recent surveys, assuming a 2% annual growth rate for the area of cultivated land (Ministry of Water Development, Kenya, 1992).

Table 5. Agricultural characteristics of the Lake Victoria catchment area, 1995

	Catchment land area [1000 ha]			Livestock population [1000 heads]			Fertilizer use [t/yr]	
	Cultivated	Non-cultivated	Total	Cattle	Sheep & Goats	Chicken	N	P_2O_5
Kenya	1470	3400	4870	4890	3140	11400	9000	14900
Uganda	1400	2100	3500	1630	1590	3750	420	210
Tanzania	1500	5540	7040	2800	1900	1300	420	130
Rwanda	930	1130	2060	480	310	-	300	80
Burundi	670	640	1310	200	180	-	1000	800
Total	5970	12810	18780	10000	7120	16450	11140	16120

Sources: Kenya: Lake Basin Development Authority (1987), Ministry of Water Development (1992), Kirugara and Nevejan (1996), Kenya Grain Growers Cooperative Union (1991); Uganda: Ministry of Natural Resources (1996), Ministry of Agriculture (1992, 1995), World Bank (1993), Bank of Uganda (1995); Tanzania: Scheren et al. (1995a); Rwanda and Burundi: Bullock et al. (1995), United Nations (1995).

Atmospheric deposition - Average rainfall over Lake Victoria is 1450 mm yr^{-1} (±10%), equivalent to approximately 100 km^3yr^{-1}. Regional rainfall varies between 895 mm yr-1 in Musoma (Tanzania) and 2216 mm yr^{-1} in Kalangala (Uganda) (Crul, 1993; Piper *et al.*, 1986).

Wetlands - The largest wetland area in the Lake Victoria basin is in western Uganda. The entire drainage of the Katonga and Ruizi-Kibali river basins is through river channels that used to be more rapidly flowing in history but which are now sluggish, choked with swamps and in places flooded out to form small swampy lakes (Beadle and Lind, 1960). Other important wetlands in Uganda are the small swamps on the lakeshore receiving the domestic and industrial wastewater from Kampala and Jinja (Ogaram & Kalema, 1995). Furthermore, the Kagera river basin, draining through Rwanda, Burundi, Tanzania and Uganda, is covered with large areas of wetlands.

Important swamps on the Kenyan side are at the mouths of the rivers Yala and Nyando.

B. Pollution sources assessment

Definition of pollution intensities

Industrial Pollution - World Health Organization (1982) and Economopoulos (1993) present pollution intensities for industrial waste loads, averaged from data all over the world. Table 6 presents values for estimation of BOD loads from industries typical to the region. Although the individual values may be biased, the overall waste load estimation for a large batch of sources may be expected reasonably accurate (Economopoulos, 1993). An error estimation would therefore not be required.

Table 6. Pollution Intensities for industrial BOD5 load, classified according to the International Standard Industrial Classification (ISIC)

ISIC	Industry	BOD_5 [kg t^{-1}]	ISIC	Industry	BOD_5 [kg t^{-1}]
3111	Slaughter Houses	6	3134	Bottleries	2.1
3112	Dairy Factories	3.2	3211	Cotton Mills	155
3114	Fish Factories	7.9	3221	Coffee Factories	-
3115	Vegetable Oil Refineries	12.9	3231	Leather Tanneries	89
3118	Sugar Factories	2.9	3411	Paper Mills	8
3131	Distilleries	220	3521	Paint Factories	-
3133	Breweries	18.8	3523	Soap Factories	6

Sources: WHO (1982), Economopoulos (1993).

Domestic Pollution -Table 7 presents ranges and most likely values for waste generated by both sewered and unsewered urban domestic population, based on reviews by World Health Organization (1982), Economopoulos (1993), Iwugo (1990), Jørgensen (1980), and Vighi and Chiaudani (1987). Unlike the population in cities and towns, often located directly on the lake shores or its adjacent bays and streams, rural households are scattered (in the case of lake Victoria over an area up to 250 km from the lake) and their waste streams for the major part not directly linked to watercourses. Their contribution to the overall inputs would be accounted for within the overall land-runoff stream.

Table 7. Selected pollution intensities for urban domestic liquid waste generation

Sanitation	Interval	BOD_5 [kg $pers^{-1}yr^{-1}$]	N [kg $pers^{-1}yr^{-1}$]	P [kg $pers^{-1}yr^{-1}$]
Sewered	Low	8	2.2	0.2
	Most likely	16	3.3	0.4
	High	20	4.4	1.6
Unsewered	Low	7	2.2	0.2
	Most likely	8	3.3	0.4
	High	11	4.4	1.6

Land runoff - The method applied for the estimation of nutrient land runoff employs the export coefficient approach of Jørgensen (1980), a procedure widely used in many studies (e.g. Scheren, 1995b; Mattikalli & Richards, 1996). The loss of N and P to watercourses is estimated as a function of area and export coefficients, where export coefficients may vary for different categories of land-use. Many characteristics control nutrient export, including precipitation runoff, soil texture, slope, type of crop cultivated and fertiliser application. The selection of suitable and universal export coefficients therefore introduces major uncertainty. The range of values reported in various extensive reviews of nutrient-export relations (Beaulac & Reckhow, 1982; Ritter 1988; Thomann & Mueller, 1987), as summarised in Table 8, expresses this uncertainty.

Table 8. Selected nutrient export coefficients

Interval	Unit	Cultivated land		Non-cultivated land	
		N	P	N	P
Low	kg $ha^{-1}yr^{-1}$	0.5	0.1	1	0.1
Most likely	kg $ha^{-1}yr^{-1}$	1.4	0.3	1.4	0.3
High	kg $ha^{-1}yr^{-1}$	12	1.4	7	0.9

Unfortunately, data on nutrient export in the vicinities of Lake Victoria, and in fact for the African continent as a whole, is very rare, and where available represents loss of nutrients from plots of agricultural land, rather than the actual amount eventually ending up in watercourses (Aroya & Juo, 1982; Omoti *et al.*, 1983; Walters & Malzer, 1990). Smaling *et al.* (1993) and Lijklema (1995) report values for Kisii in Western Kenya and Rwanda respectively, where nutrient loss through leaching and erosion from arable land range from 4,5 to 10 kg $ha^{-1}y^{-1}$ for P and 40 to 45 kg $ha^{-1}y^{-1}$ for N.

That the actual amount ending up in Lake Victoria would be substantially smaller may be shown by comparing data for Lake Malawi, whose catchment area has similar soil texture and

precipitation characteristics as Lake Victoria. Bootsma *et al.,* (1996) report values for nutrient input via rivers flowing through the catchment area, which translated into actual input per area of land lead to export factors of 1,4 kg $ha^{-1}y^{-1}$ for N and 0,3 kg $ha^{-1}y^{-1}$ for P. Although land-use practices vary between the two catchment areas, Table 8 indicates that the difference in export coefficient for different types of land-use would probably not be of dramatic influence to a rough calculation. In the absence of more reliable data, therefore, export coefficients calculated for Lake Malawi are applied as a first estimate. However, keeping in mind the higher population density and more intensive land-use around Lake Victoria, these values should be considered within the lower range when applied to Lake Victoria.

Atmospheric deposition - As a consequence of both natural and human factors, atmospheric nutrient loading varies widely. As reviewed by Bootsma *et al.* (1996) and Lewis (1981), for remote non-marine tropical watersheds, values reported in literature range from 0.3 to 1.7 kg $ha^{-1}y^{-1}$ for P and 7,5 to 19 kg $ha^{-1}y^{-1}$ for N. Rare data on nutrients in atmospheric deposition in the region is given by Bootsma *et al*., (1996), and Bootsma and Hecky (1993), who report values measured in non-populated areas of Lake Malawi to be 0.53 kg $ha^{-1}y^{-1}$ for P and 12,43 kg $ha^{-1}y^{-1}$ for N. In the absence of more reliable data, their data are used as most likely values, with the full literature range of values (Bootsma et al. 1996, Lewis 1981) as upper and lower limits.

It should be noted that Bootsma & Hecky (1993), Scheren (1995b), Visser (1961) and ICRAF (1995) report data on rainwater analysis for samples taken on the shores of Lake Victoria. Values range from 0.58 to 0.92 mg/l for N and from 0.07 to 0.11 mg/l for P, which is substantially higher than values reported for other remote tropical data sets (Galloway *et al.*, 1982), and does suggest large interference with the effects of human activities on the lake shores. Although most probably therefore not representative for the open lake, discussion exists as to whether these high nutrient concentrations might be caused by the extensive forest burning in the adjacent Rwanda and Burundi highlands (Bootsma and Hecky, 1993; Scheren, 1995b), a phenomenon also described by Crutzen and Andreae (1990) and Goldman *et al.,* (1990).

Determination of penetration factors

The treatment efficiencies of individual industrial wastewater treatment facilities were estimated, where available on the basis of effluent analysis data, and otherwise upon judgement of the auditor, using as a starting point the efficiencies for optimum operation as reported by Economopoulus (1993). Penetration factors were rated between 0.3 and 0.7 (corresponding to 30 and 70% efficiency). The factory-by-factory results of this data intensive exercise have been reported elsewhere (Scheren *et al.,* 1994 & 1995a; Scheren, 1995b; Zanting, 1996). Central treatment facilities for the treatment of domestic effluents were rated similarly, with penetration factors estimated from 0.3 at reasonably effective operation for example in Jinja and Kampala, up to 0.9 for some of the Kenyan plants. 50% reliability intervals were adopted because of the uncertainty imposed by the judgements. For those industries and towns not located on the lakeshores, distance penetration factors were defined (Scheren, 2000). Resulting BOD penetration factors are presented in Table 9.

Table 9. Selected distance penetration factors for BOD5

Distance [km]	Low	Most likely	High
0 - 10	0.90	1.00	1.00
10 - 50	0.50	0.90	0.95
50 - 100	0.15	0.75	0.85
100 - 150	0.05	0.60	0.70
150 - 250	0.00	0.45	0.65

Wetland penetration factors were applied for domestic and industrial sources draining through wetlands. BOD penetration factors as reported by Richardson and Nichols (1985), ranging from 0.30 to 0.05, with 0.20 as most common value, were adopted. Richardson and Nichols (1985) furthermore present relations between P and N removal rates and loading, based on studies on several (North American) wetlands. The results of applying these relations the wetlands around Lake Victoria are presented in Table 10. 50% uncertainty intervals were adopted.

Table 10. Nutrient penetration factors through wetlands (selected most likely values)

Loading [g(N/P) $m^{-2}yr^{-1}$]	N	P
2	0.3	0.4
10	0.7	0.6
50	0.9	0.75
500		0.8

BOD loading estimates

Organic waste loads, represented by a BOD load, were assessed for domestic and industrial (point) sources. As the study focuses on the pollution of the lake, the estimated generated BOD loads were corrected for purification in treatment plants, rivers and wetlands. Table 11 shows the results.

Table 11. Results of the Lake Victoria BOD_5 loading assessment

Unit: t yr^{-1}	Kenya			Uganda			Tanzania		
Source	Most likely	s-	s+	Most likely	s-	s+	Most likely	s-	s+
Industrial	1810	850	1260	540	50	75	820	90	0
Domestic	5700	2250	2900	4000	760	1500	3100	490	560
Total	7510	2410	3160	4540	760	1500	3920	500	560
Prob >55%	5100 - 10700			3800 - 6000			3400 - 4500		
Prob >90%	2700 - 13800			3000 - 7500			2900 - 5000		

The probability intervals presented in Table 11 result from the high-low intervals for domestic pollution intensities, distance and wetland penetration factors and wastewater treatment efficiency. High-low intervals for industrial production figures and pollution intensities were not selected, as argued before (section 2). However, its contribution to the overall BOD load being relatively small, this has minor influence on the overall result. Breweries, sugar cane factories and soap and oil factories display the largest amount of industrial BOD load.

Most likely BOD loads are presented in Fig. 1. The error analysis understates the conclusion that domestic pollution accounts for most of the BOD load. 75% of Uganda's domestic BOD load originates from its capital Kampala, while in Kenya 50% originates from Kisumu. Further calibration of the Kenyan results shows that, in case all the present treatment plants would perform optimally BOD loads could be brought down with 50%.

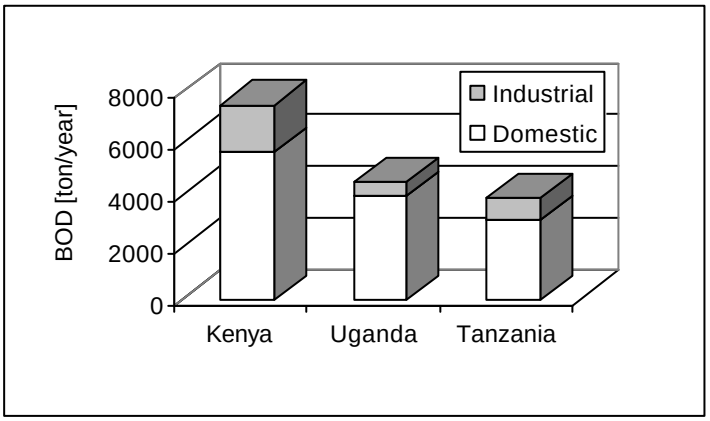

Fig. 1. Most likely BOD loads to Lake Victoria

N and P loading estimates

The results of the assessment of N and P loads to Lake Victoria are summarised in Table 12 and Figure 2. Land runoff and atmospheric deposition are the most important sources of both N and P, together accounting for approximately 90% of P and 94% of N input into the lake. Domestic liquid waste plays only a minor role in nutrient loading. The highest uncertainty is equally in the land runoff and atmospheric nutrient load estimates.

Table 12. Results of the Lake Victoria nutrient loading assessment

Unit: t yr^{-1}	Total Nitrogen			Total Phosphorus		
Source	Most likely	s-	s+	Most likely	s-	s+
Urban Domestic	7600	1800	2100	920	280	1650
Agriculture	26292	3756	67509	5634	641	4565
Atm. Deposition	85513	16958	22599	3647	791	4025
Total	119405	17500	71200	10201	1100	6300
Prob >55%	102000 - 191000			9100 -16500		
Prob >90%	84000 - 262000			8000 - 23000		

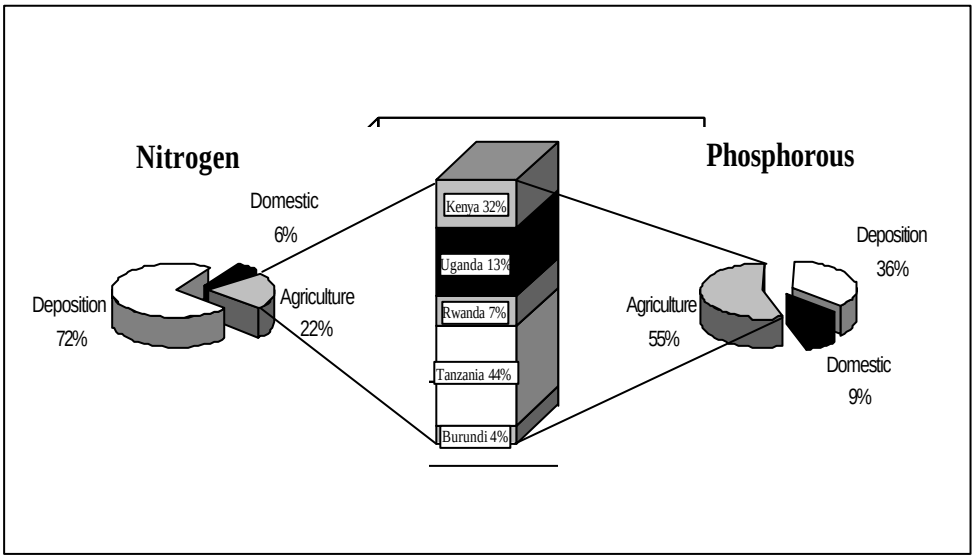

Fig. 2. Most likely nutrient loads by source and agricultural loads by country

The most likely values for N and P loads are presented in Fig. 2. The picture shown is that N originates primarily from atmospheric deposition, while in the case of P atmospheric deposition and land-runoff are more balanced. Clearly, the uncertainty intervals do not allow for a definite conclusion on these outcomes, but what is shown is that both sources of nutrients definitely play a significant role in the lake's nutrient balance.

C. Assessment of forcing functions

The nutrient balance of Lake Victoria

Average lake water concentrations of 0.640 mg l^{-1} for N and 0.074 mg l^{-1} for P, where applied, based on reported sampling studies from Gophen *et al.*, (1995) and Lehman and Brandstrator (1994). Combined with a lake volume (V) of 2,760 $km^{3,}$ an average depth (H) of 40 m, a river outflow (Q_E) of 23.5 km^3 yr^{-1} (Kite, 1981, 1982 & 1984; Piper, 1986), the nutrient input (W_A) was calculated. The net settling velocity was calculated by applying: $vS = r_S * S_A / C_A$, with r_S representing the sedimentation rate [g m^2 yr^{-1}] and S_A the concentration of nutrient A in the sediment S_A [mg g^{-1}]. Hecky (1993) reports values for rS and SA taken from a single sediment core sample of Lake Victoria. The resulting settling velocities are 2.3 m yr^{-1} for both N and P. The resulting WA are 117,000 and 14,000 t/yr for N and P respectively. In spite of data limitations, specifically with regard to the settling velocity, which is based on a single sediment core sample, the outcome of this simple nutrient balance assessment provides a good idea of the order of magnitude of the total nutrients load to Lake Victoria. Its results are well in correspondence with the results from the pollution sources assessment.

Assessment of socio-economic circumstances

Atmospheric deposition and land runoff having been defined as the principal sources of nutrients, the question remains what is at the core of these apparently high nutrients inputs. A schematic representation of the related socio-economic circumstances is presented in Fig. 3.

Quite obviously, human influences on the lake's ecosystem are principally determined by the high population growth in the region, averaging at 3,2 %. This population growth itself is determined by various cultural and economic factors, inducing large household sizes. The increasing pressure on natural resources resulting from the population growth reveals itself in various aspect, of which the following are most relevant in terms of the principal sources of nutrients:

i) Increasing soil erosion and nutrient runoff and leakage to surface waters as a result of unsustainable and growing land exploitation for agricultural production, and deforestation for firewood and construction material;
ii) Increasing release to the atmosphere of nutrients from biomass burning, and consequent deposition to surface waters.

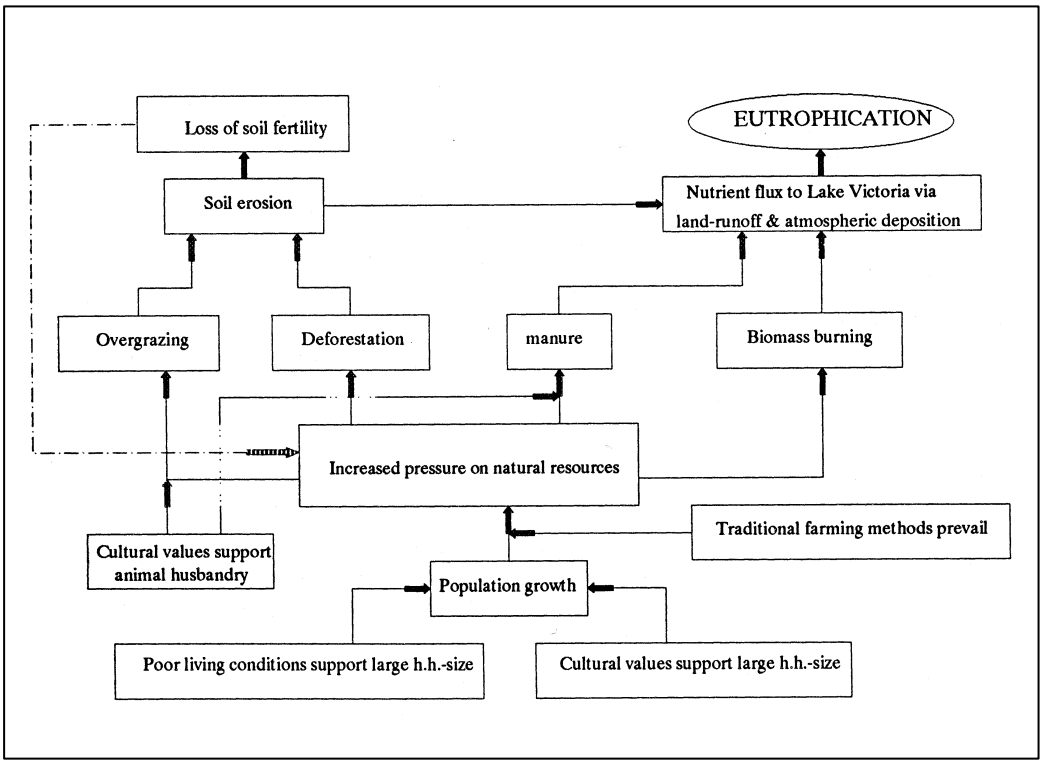

Fig. 3. Schematic representation of socio-economic circumstances related to increasing nutrient inputs into Lake Victoria

The average annual increase in cultivated land in the Lake Victoria catchment area follows more or less the population trends. Inefficient traditional cultivation methods prevail. Technical knowledge is limited, and the use of fertilizers and pesticides (in itself a positive effect in terms of the reduction of leaching and runoff to the environment), is very limited, mainly as a result of economic constraints to the prevailing small-scale farmers, but also as a result of logistical constraints and lack of awareness. Furthermore, of the manure produced by livestock in the region, only a part arrives on agricultural fields, and what arrives is largely insufficient to fertilize the land. Table 13 provides estimates for the annual production of manure and corresponding fertilizing agents for the Lake Region, based on data in Table 5. The estimation assumes an average production of 730 kg of dry manure per livestock unit (LU), where each LU represents one head of cattle or five heads of sheep or goats, of which 475 kg is dropped in the 'kraal', and where dry manure is assumed to contain 0.5% N, 0.3% P and 1.3% K (Budelman *et al*., 1995). Taking that an average of 40 kg/ha yr of N is needed to substantially increase crop yields, an average of less than 10% of the cultivated land in the Lake Victoria could theoretically be fertilized from manure.

Much of the manure produced does furthermore not end up on fields, mainly due to logistical restrictions on the part of the farmers. Consequently, agricultural yields are often poor, causing a prevailing 'horizontal' growth of the sector and increasing the demand for more land cultivation. In the absence of 'technological' changes (production increasing measures), the clearing and burning of the natural soil-protecting coverings of savannah, forests and woodlands, for cultivation reasons, will continue.

Table. 13. Manure from livestock in the Lake Victoria region (1995)

	LU[1000 head]	Manure in kraal [1000 t/yr]	Cultivated area[1000 ha]	Fertilizing content [kg/ha yr]			% of N recommended
				N	P	K	
Kenya	5 518	2 621	1 470	8,9	5,3	23,2	22,3
Uganda	1948	925	1 400	3,3	2,0	8,6	8,3
Tanzania	3180	1 511	1 500	5,0	3,0	13,1	12,6
Rwanda	542	257	930	1,4	0,8	3,6	3,5
Burundi	236	112	670	0,8	0,5	2,2	2,1
Average				3,9	2,3	10,1	9,7

Livestock furthermore plays an important role in food security (Table 5) in the region. As assessed by Meertens & Lupeja (1994), the carrying capacity of grazing area in the Lake zone varies from 3 to 5 hectares per livestock unit. From Table 14 follows can be deducted that sustainable grazing rates are exceeded by a factor of 4 or more in Mwanza region, typical for much of the Lake zone. Consequently, as grazing area is insufficient, livestock keepers tend to penetrate non-grazing areas, including forests and woodlands (Tanzania Forestry Action Plan, 1990a). Also, under pressure of fodder shortage, livestock feeds on crop residues, which would otherwise have been left to serve as humus on agricultural land.

At the same time, forests and woodlands are under large pressure from an increasing demand for fuel wood from the ever-growing population. Approximately 95% of the population depends on woody biomass for domestic purposes. Tanzania Forestry Action Plan (1990a, 1990b and 1990c) and Maagi *et al.,* (1996) estimate that annual fuel wood consumption for the Kagera, Mara and Mwanza region are respectively 2.0, 0.8 and 1.3 m^3 per capita (or the equivalent in charcoal), while consumption for construction purposes is estimated at 4 m^3 per 1000 capita, and for industrial activities 6 m^3 per 1000 capita. Based on their estimates, which include an analysis of production potential and allowable cuts, Table 15 provides an assessment of the potential deforestation in the Tanzanian part of the Lake, based on an existing deficit. The situation is alarming, especially in Mwanza where demand for wood exceeds the sustainable exploitation rates by more than 300%, or 16% of forest resources annually. Fortunately, part of this gap is filled through the use of alternative sources of energy, such as cow dung and agricultural residues, and through supplies from pastures and grazing areas, and as a result the actual deforestation for the Lake region in Tanzania was estimated at approximately 5% in 1988/89.

Table 14. Grazing - overgrazing in the Mwanza region (1991/1992 season), Tanzania

District	Number of cattle	Number of goats and sheep	Grazing area	Average grazing area per LU [ha]
Mwanza rural	31 648	17 201	15 400	0,44
Ukerewe	60 023	30 353	25 100	0,38
Magu	334 340	200 492	149 800	0,40
Sengerema	212 126	147 823	154 700	0,64
Geita	309 000	200 868	251 400	0,72
Kwimba	575 302	325 784	352 200	0,55
Mwanza region	1 522 439	922 521	948 600	0,52

Table 15. Wood consumption and deforestation in the Tanzanian part of the Lake Zone 1988/1989.

	Productive forest, plantations & woodlands			Demand		Potential deforestation	
	Area[ha]	Potential [m^3]	Allowable cut [m^3/yr]	Consumption [m^3/yr]	Deficit [%]	Rate [ha/yr]	Rate [%]
Kagera	1 110 554	36 648 282	1 315 734	2 652 366	102	40 504	3,6
Mara	457 650	9 153 000	541 550	776 754 43	11	760	2,6
Mwanza	350 457	11 214 624	585 308 2	441 752 317	58	014	16,6
LV Region	1 918 661	57 015 906	2 442 592	5 870 872	154	110 278	7,6

All the above developments have led to increasing soil erosion, with the loss of soil fertility increasing as through a vicious circle the pressure on land.

Estimations of the quantities of nutrients released to the atmosphere from biomass burning were made on the basis of an approach of the International Panel on Climate Change (IPCC/OECD, 1995). The results displayed in Table 16, for domestic burning, show that N released forms a substantial contribution to the atmospheric loading to the Lake. The industrial contribution was found to be very limited, but land clearing and slash-and-burn practices in the agricultural sector would probably add substantially to N emissions. P emissions would be more difficult to estimate, in the absence of any stable gaseous form for P, but particulate releases from smoke and dust would probably also add substantially to the atmospheric deposition of P, specifically in the direct surroundings of the source.

Table 16. Nitrogen emissions from household biomass burning in the Lake Victoria region (1995)

	Consumption [kg/d/cap]		Carbon release		Nitrogen release	
	Urban	Rural	Fraction	Total [t/yr]	N/C	Total [t/yr]
Fuelwood	2,18	2,79	0,39	11 580 262	0,010	115 803
Charcoal consumption	0,60	0,00	0,77	503 570	0,010	5 036
Charcoal production	0,60	0,00	0,36	238 708	0,010	2 387
Crop residue	0,19	0,75	0,36	2 711 080	0,015	40 666
Cattle dung	0,05	0,20	0,31	611 445	0,020	12 229
Total				15 645 065		176 121

DISCUSSION

This paper presents a methodology for rapid assessments of sources of water pollution. The methodology has proven to be effective in the case of Lake Victoria, where data and resource scarcity object a more detailed and accurate assessment. The effects of uncertainty in data have been evaluated by using an error analysis. The use of penetration factors furthermore not only refines the method, but also provides insight into the potential reduction of waste loads by artificial and natural treatment processes. Although weakness in data and associated uncertainties in results do not always allow absolute conclusions, the outcome of the assessment form a useful basis for the evaluation of strategic policy options, and for identification of areas requiring further research.

The outcome of the Lake Victoria assessment determines domestic pollution as opposed to industries as the major source of BOD loads, and the Kenyan part of the lake as its largest contributor. Reduction of BOD loads, often associated with the occurrence of water born diseases, should therefore be through better control over domestic sources. It was calculated that, through efficient management of existing treatment facilities only, BOD loads in Kenya could be reduced by 50%. Of the industries, breweries, sugar cane factories and soap and oil factories display the largest load, and would therefore deserve most attention in terms of control measures.

Nutrient loads to the lake are associated mainly with atmospheric deposition and land runoff, together accounting for approximately 90% of P and 94% of N input into the lake. Domestic inputs are negligible. In the case of N, atmospheric deposition is most probably in excess over land runoff, not even mentioning the observed high nitrogen fixation rates (Hecky, 1993). This conclusion, coupled with the suggested N limitation in lake Victoria (Bootsma and Hecky, 1993; Lehman *et al.*, 1994), corresponds with the observed increase in chlorophyll-a concentration and algal blooms during rainy seasons, which can only partly be linked to nutrient upsurge from sediments (Ochumba and Kibaara, 1989). In the case of P, runoff and atmospheric deposition are more balanced, although reported high concentration of P in rainwater on the shores of Lake Victoria (Bootsma and Hecky, 1993; Scheren, 1995b; Visser, 1961; ICRAF, 1995), make suspect a larger contribution of atmospheric deposition to the P balance. Anthropogeneous

influences in the area, such as forest burning and increased dust due to soil erosion, have been liased to this phenomenon (Bootsma and Hecky, 1993; Scheren, 1995b).

In spite of the uncertainties remaining, the assessment allows for certain management options counteracting the apparent increasing nutrient input into Lake Victoria to be defined. The increasing population pressure in the region causes a high rate of land clearing for cultivation, and forest burning for this purpose as well as for provision of biomass for household burning. Together with unsustainable land-use practices, the results are increased soil erosion and nutrient land runoff, with biomass and forest burning having as a direct effect also its influence on the atmospheric deposition of nutrients.

Apart from a control over population growth, often difficult to realise, policies should therefore be directed at an introduction of sustainable land-use practices, the introduction of high-efficiency stoves and a control over forest burning. Improved agricultural practices would not only ensure food supply to the growing population, but also counteract the soil erosion and land runoff, as well as decrease the need for forest clearing, with its here reported influences on the ecosystem.

For future research, parameters of highest uncertainty remain pollution intensities for land runoff and atmospheric deposition. Further in-depth study on these topics, and in specific also the factors influencing their intensities, would allow for a fine-tuning of management options for preservation and rehabilitation of Lake Victoria's so highly valued but now pressurised ecosystem.

Observations on the Limnology of Kenyan Waters of Lake Victoria in Relation to Fisheries

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SUMMARY

Data on physical and chemical parameters were collected in the Kenyan waters of Lake Victoria at designated points from October 1997 to January 2000 with the main objective of relating them to fish survival and catches. The parameters sampled included Secchi depth, Chlorophyll-a concentration, conductivity, pH, Dissolved oxygen concentration, temperature, phosphates, nitrates and silicates. The study area was divided into four ecological zones: the Nyanza Gulf, Rusinga Channel, Open waters offshore and open waters inshore. Reduced water transparency was pronounced in the Gulf zone and near river mouths than in the open waters, Chlorophyll-a and nutrient concentration were higher in the Gulf than in the open waters, an aspect related to anthropogenic inputs from the catchment areas. Dissolved oxygen concentrations in all four zones examined were as low as 0.84 mgL^{-1}.at Kisumu pier, station [10] and 1.5 mgl^{-1} at Awach River Mouth, station [3] at particular periods. These were sampling stations that were infested by the water hyacinth. Results of temperature obtained from all sampled station showed little variation between stations.

INTRODUCTION

In the last 30 years, the waters of Lake Victoria have been progressively enriched with nitrogen and phosphorus (Ochumba & Kibaara 1989). This has led to the accumulation of organic matter in the water and changes in its chemical properties. Ecological studies in the Lake Victoria, especially those related to physical and chemical characteristics of the water have received less attention in comparison to studies on alien fish introductions (Ogutu-Ohwayo 1990), macrophytes (Gichuki & Odhiambo 1994), changes in fish compositions (Okemwa 1984) and algal blooms (e.g. Ochumba & Kibaara 1989). This is considered a narrow focus, and to understand the dynamics of the fisheries, there is a fundamental requirement to determine how physical and chemical parameters affect the distribution and abundance of the fish stocks. This paper presents preliminary findings of limnological studies in the Kenyan sector of Lake Victoria, as a precursor to more in-depth analysis of the way physical and chemical parameters affect the fish stock dynamics.

MATERIALS AND METHODS

The Kenyan part of Lake Victoria is at 1134 m above sea level and is located between 0°04'S-0° 32'S 34° and 13'E - 34°52'E. Sampling sites were selected to be representative of the Kenyan waters of the lake and indicative of the experimental trawling stations.

18 sampling sites were selected in four ecological zones (Fig. 1). The Nyanza Gulf zone was represented by ten sites: Kisumu Pier [10]; Sondu Miriu [2]; Awach River Mouth [3]; Homa Bay Pier [9]; Asembo Bay [26]; Gingra Rock [4] Ndere[31]; Bala Rawi; Maboko [30]; and Madundu [6]. The Rusinga Channel [34] was the second zone. The third zone was in the open waters outside the Nyanza Gulf, and was sampled at Bridge Island [32]. The fourth zone comprises the Yala River mouth [54], Sio River mouth[50] and Nzoia River mouth [53], in the north of the lake, Matara Bay, Kuja River mouth [105] and Muhuru Bay, in the south.

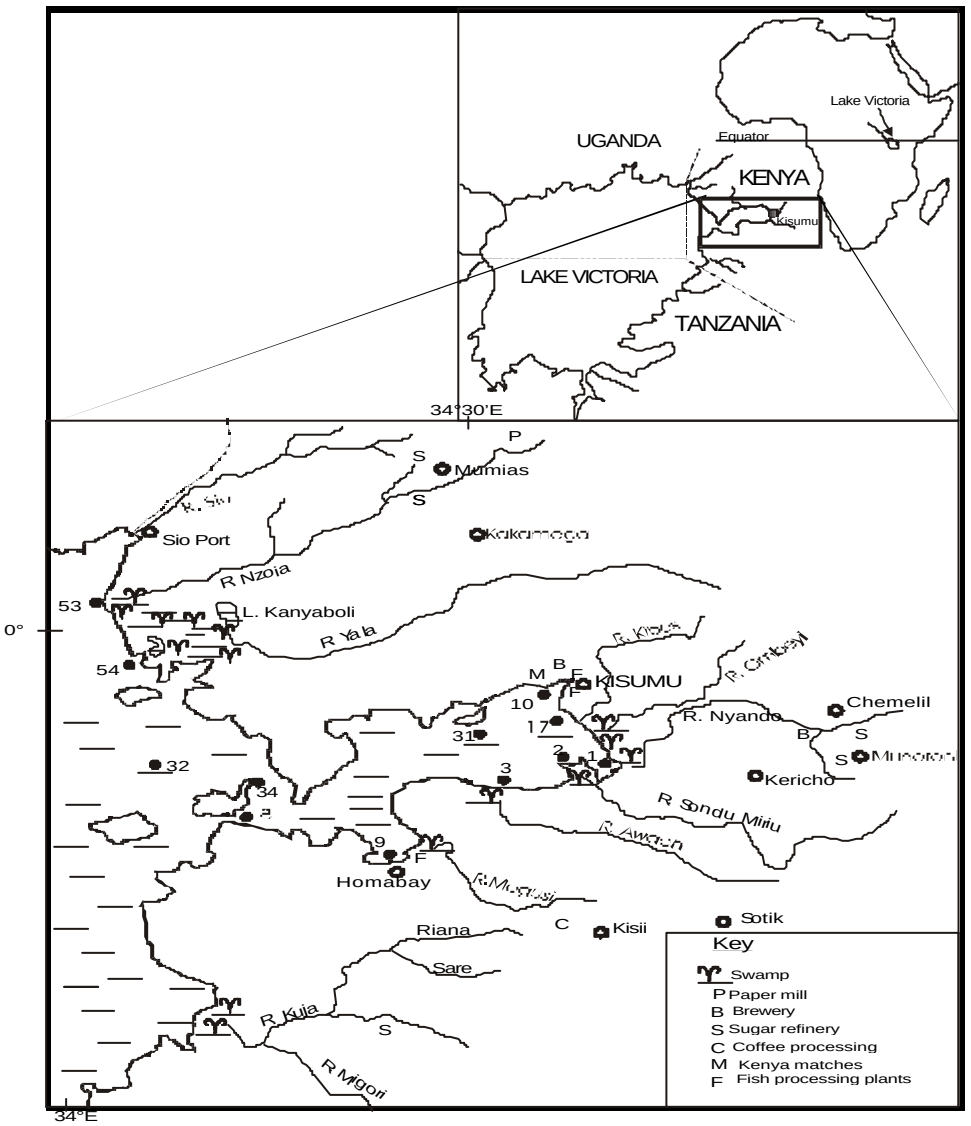

Fig. 1. Map of Lake Victoria Kenyan waters showing sampling sites

Samples were collected, where possible, on a monthly basis between October 1997 and March 2000 to obtain information on the main physical and chemical characteristics. *In situ* measurements for temperature and dissolved oxygen were made using a YSI model 57 oxygen meter, pH was measured using a digital mini-model 49, and conductivity measured using a microprocessor conductivity meter LF 96. In instrument addition, redox potential was measured automatically using a Hydrolab Surveyor II connected to an SVR 2 -DU display and 401-CA circulator assembly. Turbidity was measured using a Hatch turbidimeter 2100P. Light penetration was taken as extinction of a 20-cm black and white secchi disc. Total alkalinity and total hardness were determined by titrating 100ml of each sample against a standard solution of a strong mineral acid and ammonium hydroxide respectively.

At each station, and on each occasion, water samples were collected in polyethylene bottles for nutrient analysis. They were preserved with 1ml mercuric chloride and stored at 4°C in the laboratory. The samples were filtered through a cellulose acetate membrane with nominal pore size of 0.45 mm. The filtrate was saved for analysis of dissolved chemical species as recommended by GEMS (1992) and Mackereth *et al*. (1978).

RESULTS

Marked differences in the mean dissolved oxygen concentration [0_2] (mg L^{-1}) profiles were found between sampling stations and sampling zones (Fig. 2). Three sampling stations had [0_2] levels below 3 mgL^{-1}, which is considered the critical level for survival of the major commercial fish species. (The optimum [0_2] for fish survival is 5 mg L^{-1}, critical [0_2] is 3 mg L^{-1} and levels below 3 mg L^{-1} are considered lethal). These sampling stations in the Nyanza Gulf zone were Kisumu Pier [10], Awach River mouth [3] and Homa-Bay pier [9], both of which were characterised by extensive coverage of water hyacinth (*Eichhornia crassipes*) and shallow depths.

Maboko [30] station in the Gulf zone had mean [$0_{2]}$ of >5 mgL^{-1} at the surface but critical (3 mgL^{-1}) at the bottom. The remainder of the sampling stations in the Gulf Sondu Miriu [2], Gingra Rock [4], Madundu [6], Ndere [31], Bala Rawi and Asembo Bay [30] Fig.2. had mean dissolved oxygen concentrations of 5 mgL^{-1} or more.

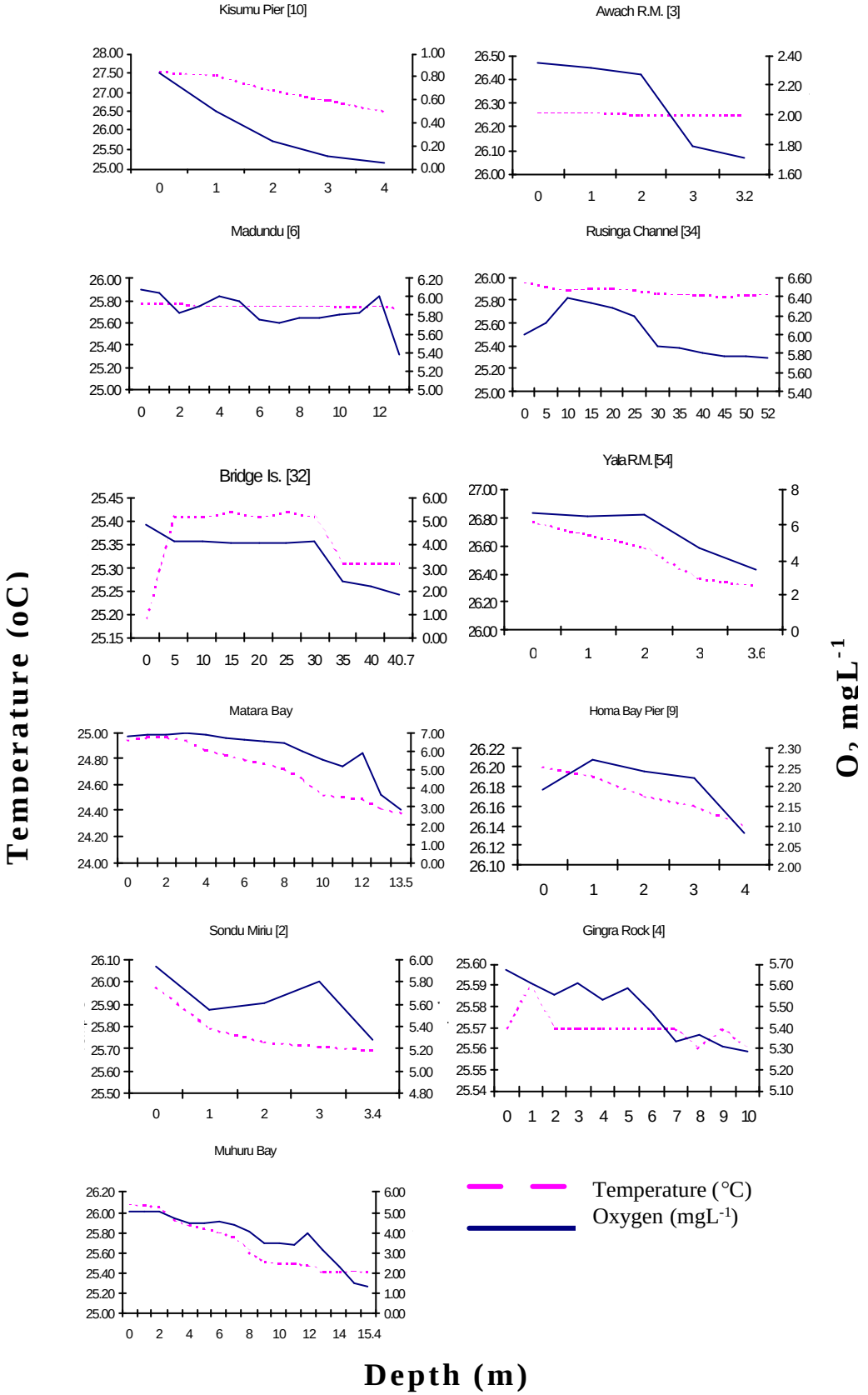

Fig. 2. Temperature and Oxygen Profiles

Stations in the inshore region of the open lake that exhibited a decrease in [0_2] to critical levels as depth increased were Muhuru Bay and Yala River mouth [54] Muhuru Bay is a deep sampling station (16 m deep) and exhibited thermal stratification, hence the decrease in the level of oxygen in deeper waters. However, Yala river Mouth [54] is no deeper than 5 m, and the low [$0_{2]}$ is probably linked to the influence of the river discharges which carry considerable organic effluent and have high suspended solids loadings.

Bridge Island, another open water zone is a deep water station (41.2 m), it exhibits the effect of thermal stratification, with a sharp drop in [0_2] from 5 mg L^{-1} to <3 mg L^{-1} around the thermocline at about 30 m. Although Rusinga Channel is a deep-water station (52 m), there was no evidence of thermal stratification or a degradation of the [0_2] with increasing depth. This was probably because the water currents between the inner Gulf region and the open water of the lake continually mixed the waters.

Mean chlorophyll-a (mg L^{-1}) and conductivity (uS/cm) concentrations and secchi disc depth (m) showed contrasting results between the Nyanza Gulf sampling sites and those in the open waters (Table 1 & Figs. 3 & 4). Considerably higher values were found within the gulf, especially around urban centres, possibly reflecting nutrient input and cultural eutrophication. Secchi disc depths in the open water zones were generally high, the exception being where major rivers discharge into the lake.

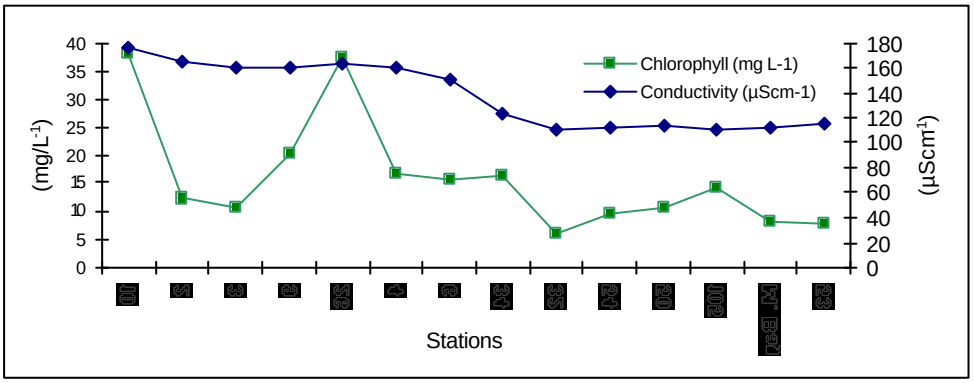

Fig. 3. Mean chlorophyll-a and conductivity

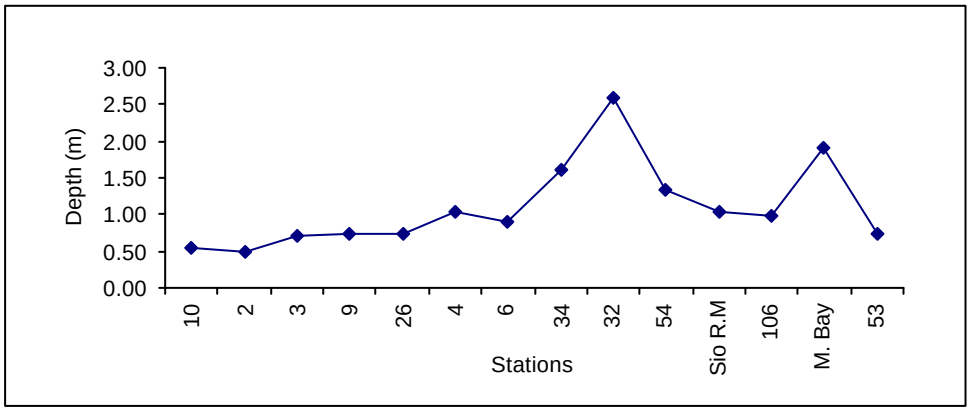

Fig. 4 Mean Secchi depth (m)

Table 1. Mean nutrient concentrations and secchi depths for limnological sampling sites in Kenyan waters of Lake Victoria.

Station	Position GPS)	Sil (mg L^{-1})	Ni (mg L^{-1})	P (µg L^{-1})	Chl (mg L^{-1})	Sec (m)	Cond (µScm^{-1})
Nyanza Gulf							
Kisumu Pier [10]	00°06'09"S 34°44'32"E	4.10	0.05	41.17	38.07	0.55	176.89
Sondu Miriu [2]	00°17'00"S 34°44'42"E	7.14	0.33	44.75	12.35	0.50	165.42
Awach river mouth [3]	00°20'17"S 34°38'45"E	6.30	0.13	77.25	10.68	0.70	161.18
Homa Bay Pier [9]	00°30'53"S 34°27'41"E	4.87	0.03	77.25	20.04	0.75	160.25
Asembo Bay [26]	00°12'35"S 34°24'33"E	5.20	0.03	22.84	37.45	0.75	163.98
Gingra Rock [4]	00°20'37"S 34°26'30"E	3.23	0.11	52.63	16.44	1.03	161.10
Madundu	00°25'32"S 34°19'59"E	5.03	0.15	36.00	15.60	0.90	150.95
Rusinga Channel							
Rusinga Channel [34]	00°20'57"S 34°13'54"E	2.17	0.11	74.92	16.31	1.6	124.05
Open Lake							
Bridge Island [32]	00°20'34"S 34°06'30"E	1.03	0.11	89.71	6.30	2.60	110.97
Open lake - inshore							
Yala river mouth [54]	00°03'36"S 34°02'19"E	0.67	0.02	32.21	9.77	1.34	111.52
Sio river mouth	00°13'47"N 34°00'15"E	1.89	0.03	22.42	10.80	1.03	113.08
Kuja river mouth	00°55'20"S 34°07'41"E	1.73	0.08	74.71	14.13	0.98	110.97
Muhuru Bay	00°57'49"S 34°06'08"E	3.59	0.18	75.13	8.13	1.90	111.26
Nzoia river mouth [53]	00°03'46"N 33°56'40"E	1.53	0.02	41.35	7.86	0.75	115.22

Sil = Silcon, Ni = Nitates, P = Phosphates, Chl = Chlorophyll, Sec = Secchi depth, Cond = Conductivity

Mean nitrate (mg L^{-1}) and silicate concentrations in the different zones (Table 1& Fig.5.) showed similar trends to those of chlorophyll-a, secchi disc depth and conductivity, with the highest levels of nitrates (0.33 mg L^{-1}) in the Gulf waters below the Sondu Miriu mouth, and the lowest concentrations (0.02 mg L^{-1}) in the open waters around the Nzoia river mouth. The highest and lowest silicate levels (7.14 and 0.67mgL^{-1}) were also found within the same locality. Diatom activity has probably contributed to this trend in the silicate concentrations. Mean phosphates (mgL^{-1}) concentrations (Table 1 & Fig.5) showed no obvious trend, although higher levels were again found around urban centres and around discharge points of the major rivers, the latter possibly indicative of fertilizer run-off.

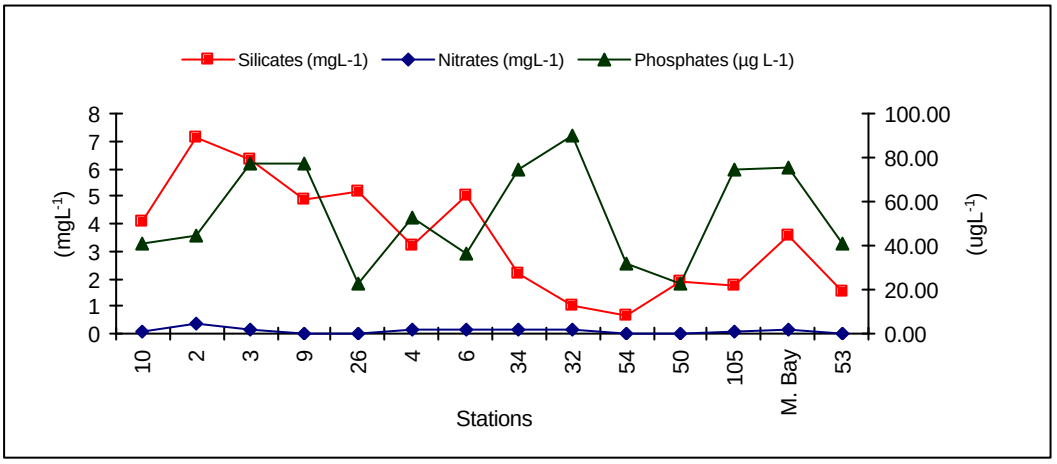

Fig. 5. Nutrients

Annual mean alkalinity and hardness concentrations (mgL^{-1}) per sampling station for the years 1997, 1998, 1999 and 2000 (Fig.6&7). showed no obvious trends although slightly higher values were found in the gulf area.

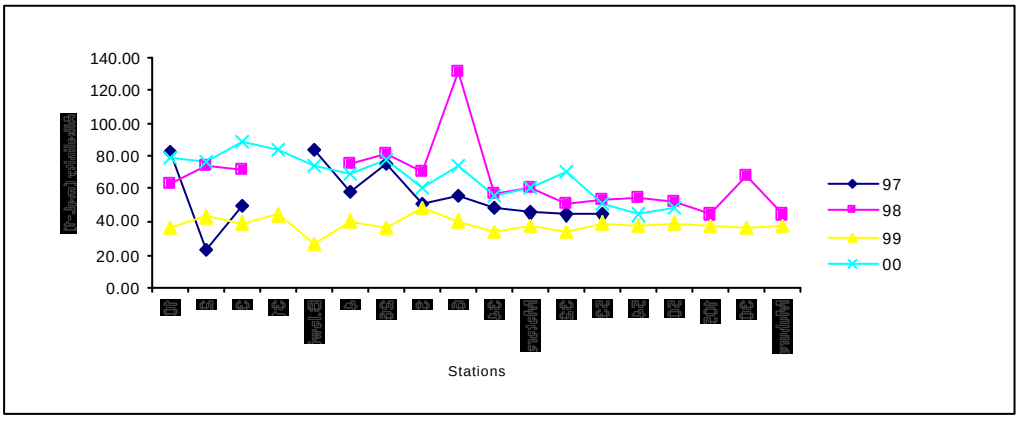

Fig. 6. Mean Annual Alkalinity (mgL^{-1}) for 1997, 1998, 1999 and 2000

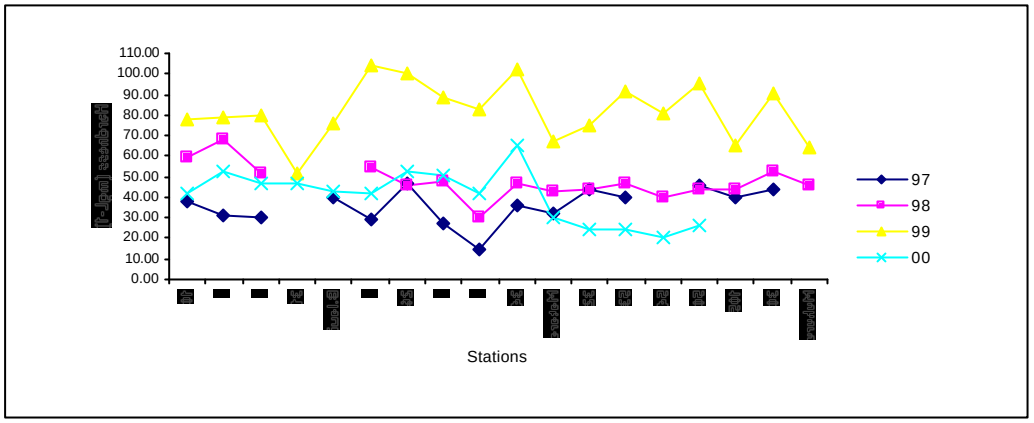

Fig. 7. Mean Annual Hardness (mgL^{-1}) for 1997, 1998, 1999 and 2000

DISCUSSION

Thermal stratification only occurs in the deeper waters and was most prevalent around Bridge Island and to a lesser extent at Yala river mouth and Muhuru Bay. Rusinga channel, which is also a deep-water site, did not exhibit stratification, presumably because of the continuous mixing of waters between the open lake and the Nyanza Gulf. Depleted oxygen concentrations were prevalent throughout the lake but fell to critical levels for survival of fish around Homa Bay and Awach River mouth. These sites were characterised by extensive coverage of water hyacinth, which is known to deplete oxygen below the vegetation.

The mean concentration of chlorophyll-a in the water, an indicator of primary productivity, also varied between regions. Chlorophyll-a levels were highest in the Gulf zone and declined towards open waters. It is important to note that this trend is not reflected in the nutrient (PO_4 and NO_3) levels, suggesting that the latter are not limiting factors to primary production. This is probably more a reflection of nutrient enrichment, which is continually taking place around the inshore waters from urban and agricultural sources. This is particularly noticeable around the mouths of the major rivers which drain agricultural land, e.g. the Sondu Miriu, and large urban centres like Homa Bay and Kisumu.

The high chlorophyll concentrations around the Gulf area are also characterised by higher densities of diatoms and dinoflagellates, and a depleted silicate concentration in the open waters. Diatoms require silicon for the manufacture of their shells and since they constitute a very prominent and strategic group in the plankton at large, the available supply of silicon in the water is regarded as a matter of real consequence. These variations in dissolved oxygen concentrations, nutrient availability and phytoplankton abundance all have implications for the fisheries production of the lake. The loss of the many phytoplankivorous haplochromines following the introduction of Nile perch, has left a food niche in the lake which has been occupied by the *Rastrineobola argentea* and the resurgence of *Yssichromis fusifornis* and *Y. laparogramma*, two haplochromines which appear to be able to tolerate the predation pressure of Nile perch. There is thus a need to

continue to monitor the limnological characteristics of the lake both in Kenyan waters and the other countries, to fully understand the trophic dynamics of the system.

ACKNOWLEDGEMENTS

The survey was funded by the European Union Lake Victoria Fisheries Research Project (Ref: ACP-RPR 227). Other thanks go to the Director, Kenya Marine and Fisheries Research Institute for both laboratory space and moral support. I also extend my thanks to all researchers and technical staff of Kenya Marine and Fisheries Research Institute without whom it would not have been possible to produce the paper.

The chemical environment of Lake Victoria (Kenya) with special reference to nutrient dynamics

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SUMMARY

This paper reports on the results of an investigation on the chemical environment of L. Victoria, Kenya undertaken during the period March 1994 to March 1995. An inventory of the major point sources of pollution in the urban centres is presented. Results obtained indicate that the effluents from the urban, industrial and municipal establishments failed to meet the WHO standards for wastewater for most of the parameters analyzed. Regarding the dissolved nutrients, values were significantly high during the rainy season for stations at the river discharge points. Rain falling directly on the lake water contributed 1242 and 66.2 g km^{-2} yr^{-1} of nitrate nitrogen (NO_3-N) and soluble reactive phosphorous (PO_4-P) respectively. We report herein massive fish kills in the shallow bays and deep waters and attempt to explain the causes of this frequent enigma, which leads to massive loss of exploitable fish stocks. This study emphasizes the need to re-evaluate the health of low lying riparian areas around the lake as "filters" and "sinks" of nutrients since they may serve as crucial hotspots in managing the pollution problem of Lake Victoria.

INTRODUCTION

Lake Victoria, the second largest lake on earth, provides protein, freshwater, employment, hydroelectric power and a mode of transport to about 30 million people who live in the Lake Victoria basin.

That lake Victoria is dying is no longer in doubt. A lethal cocktail of toxic waste and nutrients derived from industry, agriculture and new housing is causing serious damage to the lake ecosystem. Particularly serious is the process of eutrophication- water pollution caused by excessive nutrients especially phosphorous. Besides triggering blooms of toxic algae and causing massive fish kills, eutrophication is associated with the spread of the water hyacinth (*Eichhornia crassipes*), an aggressive floating weed that nearly covered 700 square kilometres of the lakes surface in less than a decade. The weed starves fish and plankton of oxygen and sunlight and reduces the diversity of other aquatic plants. The fast growing weed further chokes everything in its path, crippling the fishing industry and threatening the food supplies, trade, transportation, and hydroelectricity for millions of the lakeside residents.

Though the understanding of nutrient supplies is crucial to rational management of a water resource, little information exist on the chemical aspects of the Lake Victoria waters. Instead, researchers have focused on alien fish introductions (Ogutu Ohwayo, 1990a), changes in fish compositions (Okemwa, 1984), organic matter flow in wetlands (Gichuki & Odhiambo, 1994; Gichuki *et al.*, 2001), algal blooms (Ochumba & Kibaara, 1989). An environmental baseline study of Lake Victoria, Kenya was carried out in 1987 (Mavuti & Litterick, 1990). The work of Nyamu (1986) in Kisumu bay was limited in scope as it considered basic parameters and avoided crucial ones such as nutrients

Most of the knowledge on the chemical aspects of Lake Victoria have been based on studies based on samples taken in only one season or at infrequent intervals and as such little information on seasonal and spatial variations exist.

The aim of the present study was to describe the temporal and spatial variability of the chemical parameters of the Lake Victoria (Kenya) ecosystem and to compare this with previous investigations. Talling (1965, 66) classic studies are considered as the benchmark against which any changes in this study are assessed.

MATERIAL AND METHODS

Description of the study area

The Kenyan part of L.Victoria is at an altitude of 1134 m above sea level and is located 00° 32'S 34°13'E 34° 52'E (Fig.1).

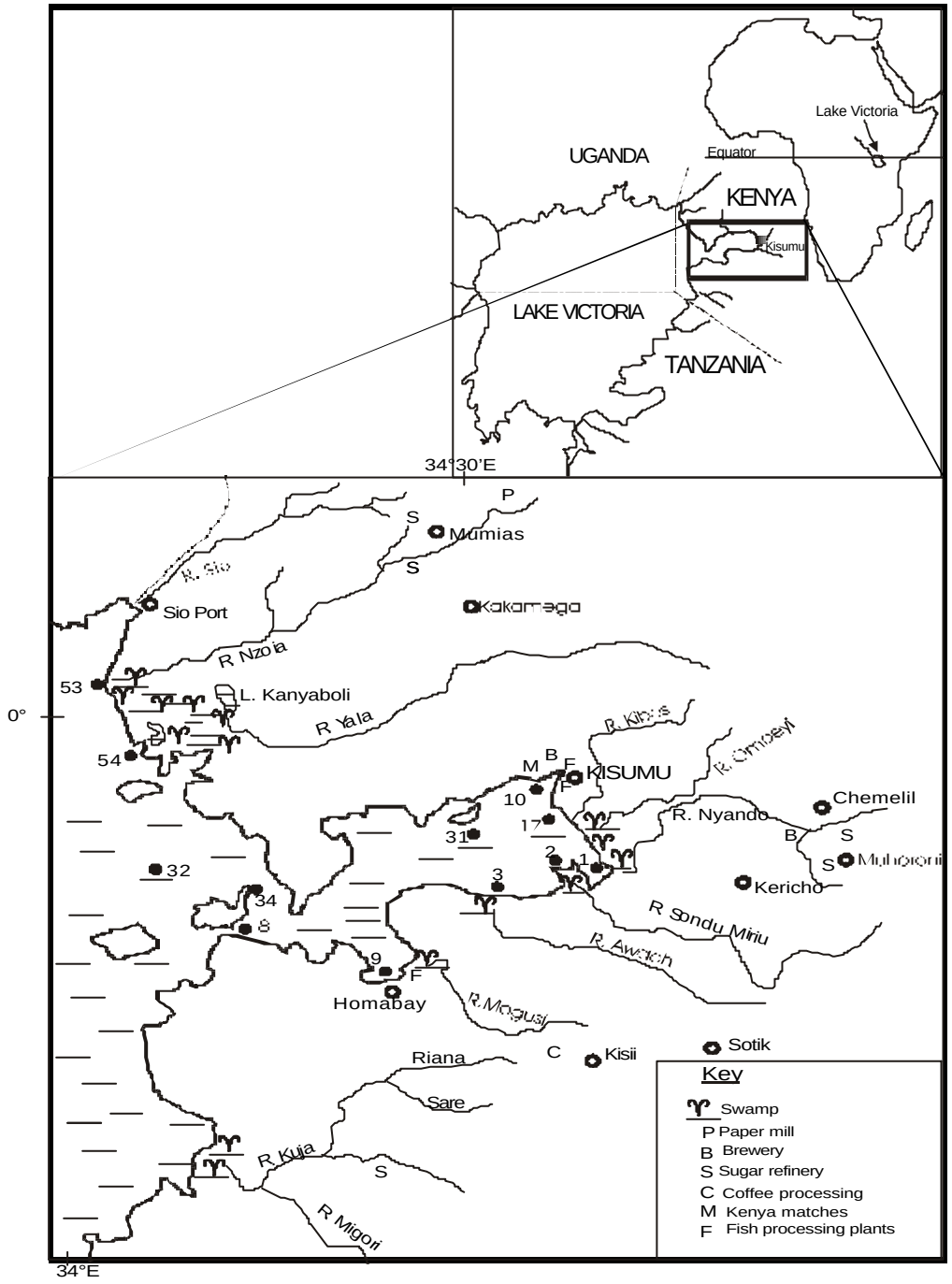

Fig. 1. Map of Lake Victoria Kenyan waters showing sampling sites

Measurements were carried out during the period March 1994 to March 1995 (10 cruises) of KMFRI research vessel R/V Fwani equipped with Radar (Rytheon), compass and echo sounder. Stations were located via satellite using a satellite navigator - Magellan GPS Meridian.

In total 12 stations were monitored. A messenger collected samples for Lake Water at predetermined depths using a 2-litre plastic Van dorn sampler, which closes at desired depths. Samples for rainwater and from point sources of pollution were collected in polyethylene bottles. They were subsequently preserved with 1m conc. $H_2 SO_4$ per litre of sample and stored at 4°C. Prior to chemical analysis (in the lab 7 days after the collection of the samples), the samples were filtered through a cellulose acetate membrane with nominal pore size of 0.45 µm. Spectrophotometric methods were employed to determine the soluble reactive phosphorous (SRP) and nitrate nitrogen as outlined by Mackereth *et al.*, (1978) and silicates according to APHA (1985).

Insitu measurements were also made at predetermined depths for temperature and dissolved oxygen using YSI model 57 oxygen meter. Light penetration was estimated with a 20 cm diameter, black and white Secchi disk. Turbidity was measured with a Hach Turbidimeter 2100P. pH was determined with a pH meter model 49 and Conductivity with a Microprocessor conductivity meter LF96. Portion of the water samples (50 mls) were analyzed for total alkalinity and total hardness by titration with 0.02N HCl to final pH of 4.5 using methyl orange indicator and with 0.02 N EDTA respectively as outlined in GEMS (1992).

RESULTS

The monthly variation in rainfall and evaporation during the study period is presented in Fig. 2. The highest rainfall was recorded in the period March to May 1994 and also in November 1994. High evaporation rates were observed in January, August 1994 and March 1995. Results of the physico-chemistry of the rainwater are displayed in Table 1. In total 5 samples were collected at sampling stations whenever it rained during the cruises. The variability of the values is wide and this was associated to the seasonality. Dillon and Rigler model (1974) was used to compute the contribution of rainwater to the nutrient input in to the lake thus;

$I\ (mg\ km^{-2} yr^{-1}) = P.C.A$ ……(Equation 1)

Where P = Total annual rainfall (mm)

C = Mean nutrient concentration ($mg\ l^{-1}$)

A = Surface area of waterbody in km^2 (6% of 68,800 km^2)

Total annual rainfall at Kisumu (March 1994-95)=		1769.5 mm
Contribution of Nitrate nitrogen from rain	=	1242 g km^{-2} yr^{-1}
Contribution of S.R.P from rain	=	66.2 g km^{-2} yr^{-1}

An inventory of the major point sources of pollution in the urban centres of Kisumu and Homabay and the chemical composition of their effluent are displayed in Table 2.

Table 1. Chemical composition of rain onto L. Victoria, Kenya during the period March 1994 to March 1995.

Parameter	Conductivity (µS/cm)	pH	Tot. hardness (mg/l) as $CaCO_3$	Tot.alkalinity (mg/l) as $CaCO_3$	PO_4-P (μgPO_4-P/l)	NO3-N (μgNO_3-N/l)	Reacitve silica (RSi)($mgSiO_2$/l)
Range	(6.29-31.5) 17.9	(8.2-8.3) 8.25	(5-17)	(5-24)	(6.3-50.3)	(0-607.5)	(0-2.5)
Mean value			11	14.5	9.1	170.2	0.944

Table 2. Ranges of chemical composition of point sources of chemical pollution in the urban centres of Kisumu and Homabay. Values in parentheses indicate the mean. *(-indicates no data).*

Parameter	Conductivity (µS/cm)	pH	BOD (mg/l)	Tot.hardness (mg/l -$CaCO_3$)	Total alkalinity (mg/l -$CaCO_3$)	PO4-P (µg PO_4-P/l)	NO_3-N (µg NO_3-N/l)	Reacitve silica (mg SiO_2/l)
Capital communications	216-810 (513)	8.2-8.3 (8.25)	-	48-94 (71)	66-70	28.3-610 (319.2)	8-9 (8.5)	0-0.17 (0.085)
Conventional treatment works	1080	7.2	440	83	330	63.3-200.3 (131.8)	1027-1178 (1402)	6.5
Nyamasaria lagoons	1234	9.41	10	76	118	-	-	-
Kenya matches	1044	9.52	60	80	408	-	-	-
WHO standards	100	6.5-8.5	20	500	-	-	-	-

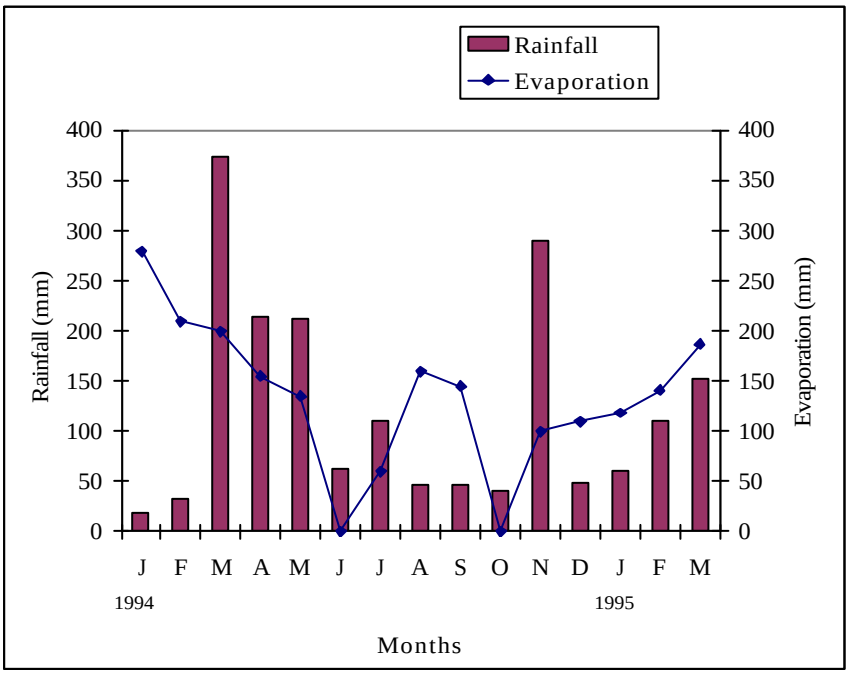

Fig. 2. Monthly variation in Rainfall (mm) and Evaporation (mm) at Kisumu (1994). (*Source. Meteorology Department, Kisumu airport)*

The results of the depth profiles of the dissolved oxygen, temperature and conductivity for stations 32, 34 & 31 are shown in Fig. 3 (a, b and c) respectively. The depths of the sampled stations were observed to vary slightly with months. This was associated with changes in the water levels.

DISCUSSION

The chemistry of rain

Rain falling directly over the lake water had low conductivity values compared to the lake water (Table 1). Of the nitrogen and phosphorus forms in rainwater, nitrate nitrogen (NO_3-N) and SRP (PO_4-P) dominated respectively.

We postulate that the sources of nitrates and SRP in rainwater originate from combustion of fossil fuel, soil dust, burning of vegetation to create space for agriculture and from automotive exhausts. Other sources according to Visser (1964b) are electrical fixation of atmospheric nitrogen, which constitute 80% of the air, photo-oxidation of ammonia and meteor traits. It was noted during this study that a heavy storm in Kisumu was normally preceded by strong winds, which whirled up large amount of nutrient rich dust into the atmosphere, which is washed by rain into the lake. Our results suggest that direct rainfall may provide a large part of nutrient supply with respect to NO_3-N and SRP (PO_4-P) to the African lakes especially where the lakes have a large surface area.

Point sources of pollution

Other than the point sources displayed in Table 2, other crucial sources of chemical pollution were blocked manholes, open sewers and storm drainages of which the most important in Kisumu is "Auji" discharging raw sewage directly into Lake Victoria without any form of treatment. The conventional treatment system at Kisumu originally constructed to cater for 50,000 people now caters for over 500,000, people and excess sewage of over (7,000 cubic meters) is by passed without any form of treatment into Kisat river which drains into L. Victoria after about 1km. The fish factory at Homabay (Capital communications Limited) uses heavy doses of chlorine (disinfectant) and detergent (to clean floors). Added to this are fish trimmings and slime from the processed fish. The end result is an effluent high in conductivity, PO_4-P and NO_3-N. This is discharged into Lake Victoria near the Homa bay pier without any form of treatment (Table 2).

It is evident from the data obtained herein that the effluent from the urban, industrial and municipal establishments failed to meet the WHO standards for wastewater for most of the parameters. The efficiency of municipal establishments has been hampered by lack of maintenance incase of Nyamasaria lagoons and burglary which crippled the digesters and sludge pumps at the conventional treatment system. We observed that industries dotting the coastline lacked treatment plants and hence were flouting the water act.

Depth profiles of Temperature, Dissolved oxygen and Conductivity

Depth profiles for Temperature, Conductivity and Dissolved oxygen are displayed for the deep stations; Stn. 32 and Stn. 34 and for one shallow station (Stn. 31). Of significance were the massive fish kills observed at Stn. 32 on May 19th 1994 and at Stn 31 on May 17th and May 21st 1994. This corresponded to two striking oxygen peaks (0.0 mg/l) observed at Stn. 31 at the bottom (6 m) and at 3 m, indicating severe oxygen depletion even at shallow depths. The fish kills contributed to massive losses of exploitable fish stocks. We aver that the fish kills observed could have been caused by severe deoxygenation of hypolimnetic water at the stations named. When dissolved oxygen decreases to below the critical concentration of 4 mg l^{1} (Golterman, 1975), it ignites a series of chemical reactions as shown in Table 3 which could result to release of nitrite nitrogen, ammonia and hydrogen sulfide which are toxic to fish. These gases acting synergistically with anoxic conditions may have possibly caused the massive fish kills observed.

We did not record hypolimnion temperatures lower than 23.5°C over the whole sampling period. According to Graham (1929) reported by Talling (1966) patches of cold water (20.5°C) were recorded near Kisumu and parts of Jinja.

Owing to its location at the tropics, Lake Victoria does not experience cool seasons, which would result in drop of temperature during circulation. This leaves the wind as the only alternative driving force in water circulation but according to Getabu (Pers. comm), the winds have been very weak. From profile results there is some evidence suggesting a high physical stability of Lake Victoria waters, which may have been caused by climatic variability, and thermal stability. From the oxygen profiles there is evidence suggesting that anoxia is now occurring even at shallow depths. Apart from the month of September 1994 when mixing occurred at Stn 34, anoxia is now frequent in the hypolimnion. According to Talling (1966, 65) anoxia in Lake Victoria was infrequent in the early sixties and when present, it only occurred within the vicinity of the bottom sediments. For example, the lake mixed completely to the bottom two times during the period September 1960 and September 1961 (Talling, 1966; See also Table 4).

Table 3. Reduction of some compounds and apparent redox potentials and prevalent O_2 concentrations (*Adapted from Golterman, 1975).*

Reduction reaction	Apparent redox potential (MV)	Prevalent oxygen concentration (mg/l)
NO_3 - NO_2	450 400	4.0
NO_2 - NH_3	400 - 350	0.4
Fe^{3+} - Fe^{2+}	300 - 200	0.1
$SO4^{-2}$ - S^{-2}	100 - 60	0.0

Spatial and temporal variation in pH and Total alkalinity.

The pH values of the surface water varied between 6.9 and 8 but were higher at stations 1 and 2 (stations with river influence). Values exceeding 7.48 and 8.3 were recorded for station 1and 2 respectively in July 1994. pH values for August 94 were 8.3 and 8.5 for station 1 and 2 respectively. Alkalinity values were 78 and 79 in July 94 and 85 and 58 mg/l in August 94 for station 1 and 2 respectively. This corresponded to the periods of high algal biomass in these stations (Getabu pers.comm).

Nutrient dynamics

We investigated seasonal changes in surface concentration of SRP (soluble reactive phosphorous), nitrate nitrogen and dissolved silica (RSi) with stations. Values were significantly high during the rainy season (March to June 94) and March 95 for stations at the river discharge points.

High concentrations of nitrate nitrogen observed during the rainy season may indicate its leachability into the water body immediately after the first rainy season (March, 94 and March 95). This is consistent with previous findings from Sub-saharan Africa, which show that riverine inputs are loaded towards the first rainfall flush (Ochumba and Kibaara, 1989). This normally corresponds to the first planting season when heavy doses of fertilizers are applied to the soils to enhance productivity. Sediments are also washed down from the farmlands and into the lake in the first heavy rains.

The current status of water quality in Lake Victoria, Kenya

The stratification cycle over Lake Victoria has been documented by Worthington (1930), Fish (1952; 1957), Newell (1960), Talling (1957; 1966), Kitaka (1972), Akiyama *et al.,* (1977), Melack (1979), Ochumba and Kibaara (1989). During the 1950's and 1960's, Lake Victoria lacked a permanent hypolimnion. The lake underwent two cycles of stratification and mixing that corresponded to the long and short rainy seasons. The oxygen was found at 50 m beneath which oxygen levels dropped occasionally to as low as 1 mg l^{-1}. Fish life flourished in the lakes deeper water at all times of the year (Kudhongania and Cordone, 1974). In 1994 the situation for June-September mixes seemed worse than that of 1950's and 60's. Severe deoxygenation was documented at shallow depths and this may be an indicator that a large volume of Lake Victoria water is now incapable of sustaining fish life (Table 4).

Bottom trawling carried out in May 94 by the team from the E.E.C project at Stn 32 revealed only dead Haplochromine species and large quantities of the fresh water shrimp Caridina nilotica, which is insensitive to low oxygen concentrations (Asila pers. comm). Earlier research using remote operated vehicle revealed the similar results. The prolonged stagnation of anoxic water in Lake Victoria is damaging to water quality and fisheries. It seems that the oxygen supply to the deep water has been insufficient to prevent occurrence of anoxia in the deep hypolimnion (supply of oxygen to the hypolimnion is via mixing initiated by strong winds such as the trade winds and locally due to offshore and onshore breeze). Apparently organic matter now produced in surface

waters into the hypolimnion decomposes and settles on sediments uncropped. The deposits consist of vegetable matter, plankton and detritus derived from higher plants and faecal remains. According to one hypothesis these are odorless, contain few bacteria and show little tendency to decompose under aerobic or anaerobic conditions. The hypothesis further states that fleshly precipitated phytoplankton contain antibiotic substances, which inhibit the growth of bacteria. Under tropical conditions, this is not expected but under a continuous rain of phytoplankton carrying antibiotic substances, the bacteria flora will never be able to establish itself in the same way as it does under conditions where the winter season brings about cessation of plant growth (Beachump, 1953; Hesse, 1956). The suppression of vertical mixing due to low wind activity (Getabu, pers. comm.) may have a decisive effect on anoxic conditions in the hypolimnia.

Table 4: Summary of comparative limnological data from various authors on L. Victoria

Feature	Talling (1966)	Akiyama *et al.* (1977)	Melack (1979)	Hecky & Mungoma (1990)	This study
Phosphate -P (µgPO_4-P/l)	7-120	0.1-122	-	0.1-19	1-277.6
Nitrate N (µgNO_3-N/l)	10-112	0.5-122	0.16-18	1-30	0-2038.4
Sulphates-S (µgS/l)	0.4-40	-	0.1- 50	-	-
RSi (mg SiO_2/l)	4-8	0.2-3	0.1-7.6	0.06-72	0-87.75
Secchi depth (m)	1-3.9	1.2-2	-	-	0.15-2.25
Anoxia		Infrequent - when present only in the bottom			Permanent at the bottom

CONCLUSIONS

(a) This study has identified the main sources of pollution influent into Lake Victoria, Kenya and has ranked them in a descending order of importance as;
   (i) Point sources, which are mainly discharges from the municipal establishments in the urban centres, industrial and from fish processing plants dotting the coastline
   (ii) Direct precipitation
   (iii) Discharge from rivers especially during the first rainfall flush

(b) We have documented that anoxia which was infrequent at the bottom in the early sixties is now permanent at the bottom. This is associated with suppressed vertical mixing due to low wind activity. We have noted further that increased anoxia has significantly reduced the volume of water that is habitable to life.

(c) We have noted further that soluble reactive phosphorous (PO_4-P) and nitrate nitrogen (NO_3-N) concentration have risen in the surface waters

(d) And finally that increased flow of nutrients into the lake is resulting to eutrophication

RECOMMENDATIONS

a) Present conditions and operation of facilities affecting the water environment such as sewage wastes in towns and municipalities, sanitary facilities in rural areas, wastewater treatment facilities of various factories have to be evaluated and quantified in a bid to improve on their performance.
b) There is need to re-evaluate the role of low-lying riparian areas around the lake, since if they are healthy, they serve as a filtering system between the rivers that flow down from the hillsides and the lake. In this way, pollution from non point sources is abated. Their capacity as "sinks" of nutrients needs to be quantified as well.
c) There is need to catch up with the most basic infrastructure for water management
d) Lake Victoria is a valuable resource that requires a rational management to protect it from pollution and degradation

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An Observation on Diatom Species Composition in the Kenyan waters of Lake Victoria

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SUMMARY

Planktonic diatoms were investigated in the Kenyan waters of Lake Victoria in September 1997. A total 82 diatom taxa were recorded. Among the centrales, Aulacoseira was the most diversified genera followed by Cyclotella, and, among the pinnates, Nitzschia and Navicula were the most diversified. Diatom abundance ranged from 2.51 x 10^5 to 5.42 x 10^5 frustules l^{-1} in the Nyanza Gulf and from 1.58 x 10^5 to 8.61 x 10^5 frustules l^{-1} in the open lake. Nitzschia acicularis and N. lacustris were the most dominant in the open lake and they were prevalent in most parts of the lake. N. gracilis and Cyclotella radiosa were also important in the open lake. Aulacoseira nyassensis var. victoriae, Navicula digitoradiata, Nitzschia palea, Cyclotella ocellata and C. meneghiniana predominated in the Nyanza Gulf. The spatial patterns indicate recent changes in species composition and abundance of dominant taxa. Species richness, diversity and equitability were higher inshore than offshore. Diversity was related to Secchi transparency, conductivity and concentration of silicate.

BACKGROUND

Talling (1966, 1987) reported clear seasonal succession of phytoplankton groups in Lake Victoria in early 1960s and he observed that during periods of isothermal mixing of the water column, diatoms replaced cyanobacteria (blue-green algae) as the dominant group. Recent studies indicate that this succession has diminished and the cyanobacteria seem to persistently dominate and diatoms and other phytoplankton groups have declined (Hecky & Bugenyi, 1993; Ochumba & Kibaara, 1989; Lung'ayia, *et al.*, 2000). Besides, diatoms mainly of the genus *Aulacoseira*, formed a major source of food for detritivorous and phytoplanktivorous fish species (Greenwood, 1953; Welcomme, 1968).

Diatoms are sensitive to many environmental variables and have been considered as ecological indicators of environmental perturbations such as acidification, eutrophication and climatic changes (Dam *et al.*, 1994). The shifts in communities of diatoms in Lake Victoria are manifestations of a changing environment that has implications on water quality, biological and fish production. Studies on the distribution and composition of diatoms can be one of the first steps in providing a biological means of assessing environmental conditions as well as natural variability and production in the lake.

The objectives of this study were to describe planktonic diatom species composition, especially spatial distribution in abundance and diversity in the Kenyan waters of Lake Victoria and their relationship to some environmental factors.

MATERIALS AND METHODS

Study area

Investigations were carried out at 10 sites in the Kenya waters of Lake Victoria (Fig. 1) in September 1997. The sites were selected from among stations established by Kenya Marine and Fisheries Research Institute (KMFRI) for routine limnological sampling and were used by Lake Victoria Fisheries Research Project (LVFRP) for fish stock assessment studies. The sites represented inshore, mouths of major rivers and offshore in both the Nyanza Gulf and the open lake. The geographic, hydrological and physical characteristics of the lake, including the Nyanza Gulf have been summarized by Mavuti & Litterick (1991) and Crul (1995).

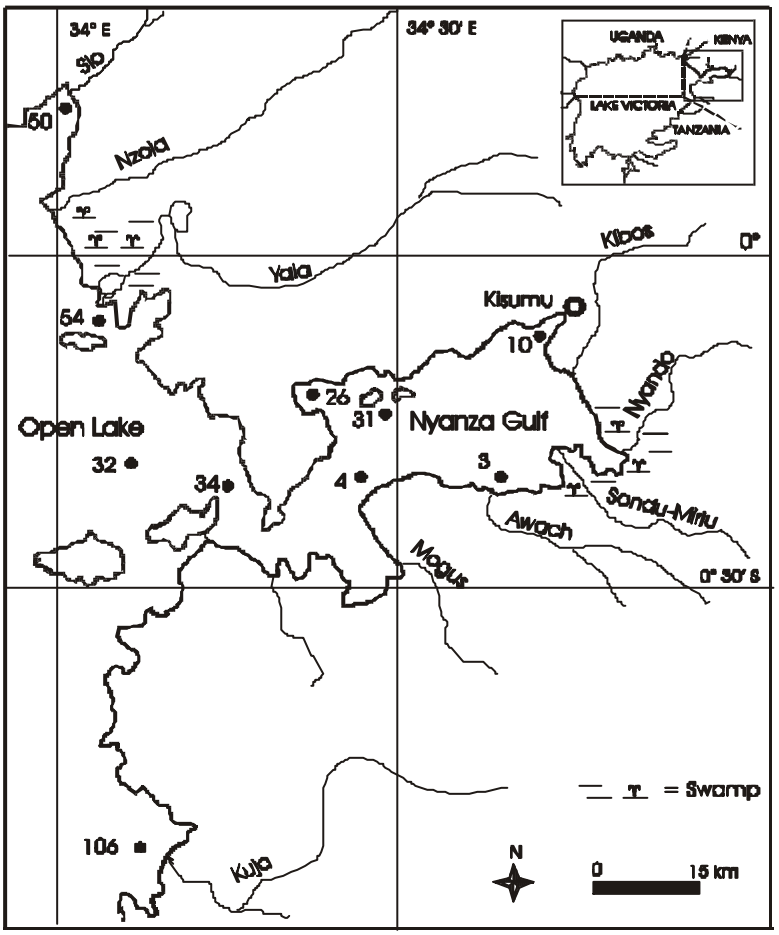

Fig. 1. Location of the sampling stations (3-106) in the Kenyan part of Lake Victoria.

Secchi transparency was estimated with a 20 cm diameter black-white sectioned Secchi disk. Turbidity was measured with a 2100 P Hach Turbidimeter. Water temperature, dissolved oxygen, pH, and conductivity were measured *in situ* with a Hydrolab Surveyor II Multi-parameter Water Quality Monitoring System. Alkalinity was determined by titration with acid as described by Heron & Talling (1978). Chlorophyll a was determined after cold (refrigerated) 90% acetone extraction followed by spectrophotometric analysis and calculated according to Strickland & Parsons (1968). Water samples for analysis of nutrients were preserved with mercuric chloride, stored in ice and transported to the laboratory. The samples were filtered through cellulose-acetate membranes (pore size 0.45 mm) and subsequently analysed for nitrate-nitrogen i.e. NO_3-N (cadmium reduction, diozoic complex), phosphate-phosphorus PO_4-P (SRP, ascorbic acid) and silicate SiO_2 (heteropoli blue) using methods based on those described by Mackereth *et al.*, (1978).

Diatom samples were collected with a 3 l Kemmerer water sampler from the surface (0-0.5 m depth). 250 ml of water were put in polyethylene bottles and preserved with Lugol's solution and 5% formalin. The samples were concentrated by settling for 48 hours to a final volume of 20-30 ml. Diatom frustles were cleaned with sulphuric and nitric acids and mounted in Styrax (Gum storax). Examinations were done on a light microscope using oil immersion lens at 1000 X magnification. Taxonomic identifications were made following Krammer and Lange-Bertalot (1986, 1988, 1991a, b). Counting 300-500 frustules in a known surface area on each permanent slide made quantitative estimates. The counts were recorded as number of frustules l-1. Species richness (d) was calculated by equation of Margalef (1951), diversity (H) by Shannon and Weaver (1963) index and species equitability (J) or evenness by the equation of Pielou (1975). Pearson correlation coefficients between diatom abundance, diversity and environmental factors were calculated using STATISTICA computer program.

RESULTS

Table 1 gives the data on environmental characteristics for the 10 sites sampled. When the different parts of the lake are compared, the Nyanza gulf had lower Secchi transparencies than the open lake. Trends in turbidity were the inverse to those of transparency and turbidities were higher in the gulf than the open lake. There was little variation of water temperature whereas pH was slightly alkaline. Dissolved oxygen was generally high at all stations. On the whole, alkalinity, conductivity and algal biomass, as indicated by chlorophyll-a, were higher in the gulf than in the open lake. Concentrations of PO_4-P showed no clear variations except at Stations 34, at Rusinga Channel and 32 in offshore open lake, where the highest values were recorded. Concentrations of NO_3-N were higher in the gulf where the highest value was recorded at station 10. Slightly higher concentrations of NO_3-N were recorded in the open lake. Similarly, the gulf had higher concentrations of SiO_2 and they decreased to very low values in the open lake.

Table 1. Environmental characteristics of the 10 stations sampled. (NTU = Nephelomet -ric Turbidity Units).

	Station									
	3	**4**	**10**	**26**	**31**	**34**	**32**	**54**	**50**	**106**
Secchi transparency	0.8	1.3	0.7	0.8	0.8	1.3	1.6	1.0	1.0	1.3
Turbidity NTU	13	9	27	12	15	8	4	11	11	8
Temperature °C	27	27	28	28	26	27	26	28	27	27
Dissolved oxygen mgO_2 l^{-1}	8.3	7.5	7.6	8.4	6.3	9.4	6.7	8.3	6.4	7.9
pH	7.8	8.3	7.8	8.3	8.1	7.5	7.9	8.7	7.7	8.1
Alkalinity mg l^{-1} as $CaCO_3$	78	76	84	80	84	72	48	42	44	42
Conductivity µS cm^{-1}	195	191	213	238	236	138	133	126	128	128
PO_4-P µg l^{-1}	36	27	31	22	28	48	47	31	29	50
NO_3-N µg l^{-1}	17	7	169	34	23	37	53	58	27	16
SiO_2 µg l^{-1}	2.6	1.6	4.1	3.5	3.9	0.3	0.3	0.7	0.7	0.2
Ch a µg l^{-1}	9	33	23	51	31	22	8	28	23	7

A total 82 taxa of diatoms belonging to 24 genera (from 6 orders) were recorded (Table 2). The most important order was Biraphidales, which comprised 68% of the total number of taxa, followed by Coscinodiscales (16%), Araphidales (9%) and Monoraphidales (5%). Rhizoseniales and Rhaphidioididales accounted for 1% each. Among the centric diatoms (Centrophycidae), *Aulacoseira* was the most diversified genera comprising 46% of the taxa in this group followed by *Cyclotella* (23%), and *Stephanodicus* (15%). The most diversified genera among the pinnates (Pennatophyicidae) were *Nitzschia* accounting for 22% followed by *Navicula* (20%), *Pinnularia* (13%) and *Gomphonema* (9%). Higher numbers of taxa per station were observed in the littoral and inshore shallow waters particularly in the Nyanza Gulf and they decreased offshore. Numbers of taxa varied from 12 at Station 4 in mid-gulf to a maximum 36 at Stations 3 and 54 near the mouths of Awach and Yala respectively.

Spatial abundance of diatoms ranged from 2.51 x 10^5 to 5.42 x 10^5 frustules l^{-1} in the Nyanza Gulf and from 1.58 x 10^5 to 8.61 x 10^5 frustules l^{-1} in the open lake (Fig. 2). The highest abundance was observed at Station 54 and was mainly constituted by *Nitzschia acicularis* that accounted for 36% of the total diatom population, and, *N. lacustris* 21% (Fig. 2, Table 3). A second maximum occurred at Station 34 and was dominated again by *N. acicularis* accounting for 67%. These two species, *N. acicularis* and *N. lacustris*, were among the most predominant in other parts of the open lake together with *N. gracilis* and *Cyclotella radiosa*. In the gulf, the highest abundance occurred at Station 10 and *Aulacoseira nyassensis var. victoriae* was the most important taxa, others included *Navicula digitoradiata, Aulacoseira nyassensis, Nitzschia palea, Cyclotella ocellata* and *C. meneghiniana, Nitzschia acicularis* and *N. lacustris.*

Table 2. Taxonomic list of diatoms recorded in the sampled area.

Centrophycidae

Coscinodiscales
Aulacoseira agassizii (Ostenf.) Sim.
A. ambigua (Grun.) Sim.
A. granulata (Ehr.) Sim.
A. italica (Ehr.) Sim.
A. nyassensis (O. Müll.) Sim.
A. nyassensis O. Müll. var. *victoriae* O. Müll.
Caloneis bacillum (Grun.) Cl.
Cyclotella meneghiniana Kütz.
C. radiosa (Grun.) Lemm.
C. ocellata Pantocksek
Stephanodiscus astraea (Ehr.) Grun. var *astraea*
Stephanodiscus sp.
Thalassiosira weissflogii Grun.
Rhizosoleniales
Rhizosolenia victoriae Schröd.

Pennatophycidae

Araphidales
Asterionela formosa Hassall.
Diatoma elongatum (Lyngb.) Argardh.
Fragilaria construens (Ehr.) Grun. var. *construens*
F. construens (Ehr.) Grun. var. *exigua* (W. Smith) Schulz.
F. construens (Ehr.) Grun. var. *subsalina* Hust.
F. capucina var. *capucina* Desmaz.
F. intermedia (Grun.) Grun.
Raphidioididales
Eunotia pectinalis Rabh.

Monaraphidales
Achnanthes hungarica (Grun.) Grun.
A. clevei Grun. in Cl. & Grun.
A. ploenensis Hust.
Cocconeis Ehr. var. *placentula*

Biraphidales
Amphora commutata Grun.
A ovalis (Kutz.) Kütz. var. *ovalis*
A. pediculus (Kütz.) Grun.
A. veneta Kütz.
Anomoeoneis follis (Ehr.) Cl.

Cymatopleura solea Bréb. W. Smith var. *solea*
Cymbella sesatii (Rabh.) Grun.
C. turgida (Greg.) Cl.
C. ventricosa Kütz.
Gomphonema acuminatum Ehr. var. *turris*
G. angustatum (Kütz.) Rabh.
G. clavatum Ehr.
G. clevei Frieke
G. gracile Ehr.
G. oliveceum (Hornemann) Bréb.
Gyrosigma acuminatum (Kütz.) Rabh.
Hantzchia amphioxys (Ehr.) Grun. var. *amphioxys*.
Mastogloia smithii Twaites
Navicula clementis Grun.
N. cuspidata Kütz.
N. cryptocephala Kütz.
N. digitoradiata Greg.
N. gastrum Ehr.
N. gottlandica Grun.
N. gracilis Ehr.
N. oblonga Kütz.
N. pupula Kütz.
N. rynchocephala Kütz..
N. viridula Kütz.
N. variostriata Krasske
N. vulpina Kütz.
Navicula sp.
Nitzschia acicularis W. Smith
N. amphibia Grun.
N. dissipata (Kütz.) Grun.
N. gracilis Hantsch.
N. hantzschiana Rabh.
N. intermedia Hantsch.
N. lacustris Hust.
N. linearis W. Smith
N. microcephala Grun.
N. nyassensis O. Müll.
N. palea (Kutz.) W. Smith
N. paleaceae Grun.
N. pusila Grun.
N. vermicularis (Kütz.) Grun.
Nitzschia sp.
Pinnularia alpina W. Smith
P. cardinalis (Ehr.) W. Smith
P. divergens W. Smith
P. leptosoma Grun.
P. subcapitata Greg. var. *subcapitata*

P. viridis (Nitzsch.) Ehr.
Rhopalodia gibberula (Ehr.) O. Müll. var. *heurckii* O. Mull.
Stauroneis anceps Ehr.
S. obtusa Lgst.

Table 3. Percentage contribution of the most quantitatively important (≥5%) diatom taxa to the total count in the various stations

Taxa	Station									
	3	4	10	26	31	34	32	54	50	106
A. granulata					26					
Aulacoseira nyassensis var. victoriae			38							5
Cyclostephanos dubius				7		5				7
Cyclotella meneghiniana	16									
C. ocellata	7			7						
Navicula digitoradiata	12		12	48	23				67	
N. oblonga					5					
Nitzschia acicularis	11	46	7			67	67	36		71
N. gracilis				5	5			11		
N. lacustris	14	36	6	5		19	24	21	7	8
N. microcephala					7					
N. palea	18		25	10	7			11	8	

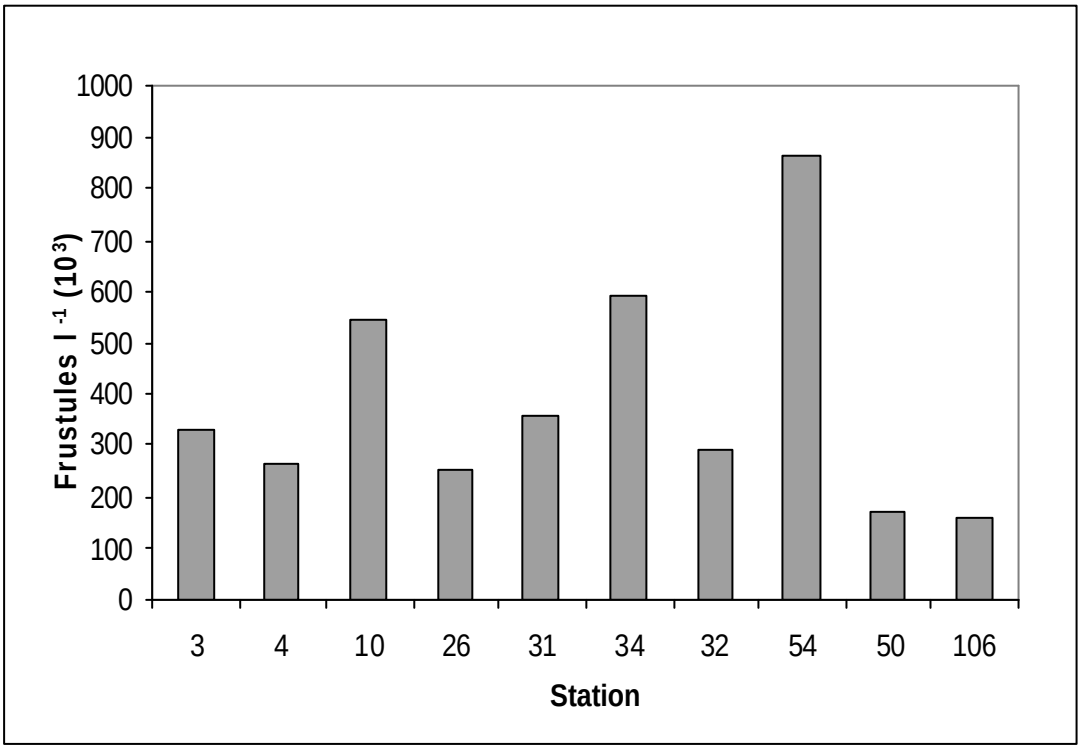

Fig. 2. Variations in diatoms abundance

Higher species richness were observed in the inshore shallow waters of the Nyanza Gulf (Fig. 3) whereas, maximum densities but lower numbers of species occurred offshore and in the open lake. The highest species richness in the gulf 2.8 was recorded at Station 3 and the lowest 0.9 was at Station 4 in mid-gulf. A minor peak of species richness occurred at Station 54 in the open lake. Spatial variations in species diversity index (H) followed similar patterns to those of species richness. The highest diversity was observed at Station 3, owing to presence of a large number of species with higher equitability (J) contributing to the total abundance (Table 3). A minor peak in diversity was observed at Station 54 while the lowest diversity at Station 4 was due to a few dominant species with a high percentage contribution to the total diatom population. Diversity was significantly correlated to Secchi transparency, conductivity and silicate ($p<0.05$) (Table 4). There was no significant correlation between abundance and any of the measured environmental factors.

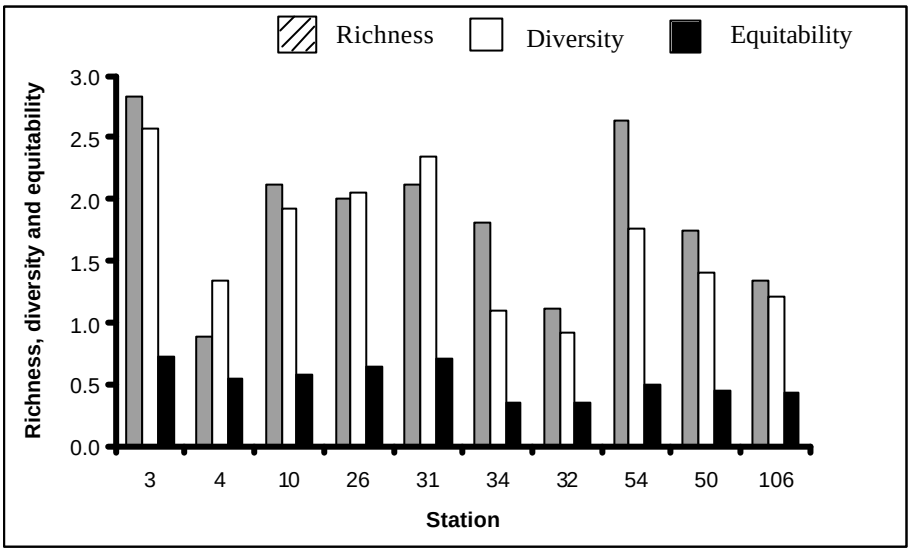

Fig. 3. Variations in diatom species richness (D), diversity (H) and equitability (J)

Table 4. Correlation coefficient 'r' and significant 'p' values calculated between diatom abundance and diversity, and environmental factors (* Significant at 5% level).

Environmental factor	Abundance		Diversity	
	r-value	p-value	r-value	p-value
Secchi transparency	- 0.164	0.651	- 0.892	0.001 *
SiO_2	- 0.016	0.964	0.806	0.005 *
Conductivity	- 0.149	0.681	0.732	0.016 *
PO_4-P	0.009	0.098	- 0.577	0.069
Turbidity	0.253	0.480	0.595	0.070
Alkalinity	0.005	0.990	0.592	0.071
pH	0.399	0.254	0.316	0.374
Chlorophyll a	0.106	0.771	0.304	0.393
Temperature	0.424	0.222	0.228	0.527
NO_3-N	0.451	0.191	0.083	0.819
Dissolved oxygen	0.451	0.191	- 0.003	0.996

DISCUSSION

In Lake Victoria, diatoms were quite diverse and quantitatively important in the phytoplankton in early 1960s (Talling, 1966, 1987). Unpredictable weather changes in the lake's basin is causing variations in thermal structure of the water column and according to Hecky, *et al.*, (1994), there is an increase in stability that has reduced mixing of the water column. Consequently, this has reduced redistribution of nutrients, accumulated in bottom sediments, particularly silicate required for structural growth of diatoms. The decrease in silicate in the epilimnion (Hecky & Bugenyi, 1993) may have lead to a decline in diatoms and in addition, increased their photosynthetic activity as reported by Mugidde (1993). Higher rates of photosynthesis may partly explain the higher concentrations of dissolved oxygen at stations with large populations of diatoms.

In our study, concentration of silicate remained low except in shallower waters in the Nyanza Gulf, particularly near mouths of rivers where higher concentrations were recorded. These areas were also characterized by lower transparency (except at mouth of Yala) mainly due to suspended sediments, and, they had higher ionic content (higher conductivity). Most of the diatom species that were dominant in the shallower waters, such as *Aulacoseira nyassensis, Navicula digitoradiata, Nitzschia palea,* and *Cyclotella meneghiniana*, are tolerant to low light conditions and that is why they contributed greatly to the higher diversities seen, for example at Station 3. This could also be why diversity was significantly correlated to secchi transparency, conductivity and silicate. Our findings agree with those of Lung'ayia *et al*., (2000) who report that silicate and turbidity influenced significantly the distribution of phytoplankton, in general, in Lake Victoria. Elsewhere, in the gulf, lower transparency could be attributed to high algal biomass mainly contributed by other algal groups as shown by higher concentration of chlorophyll a but lower abundance of diatoms, for example at Stations 26 in Asembo Bay, 4 and 31 in mid-gulf.

Minor peak diatom abundance in the Nyanza Gulf at Station 10 in Kisumu Bay, was accompanied by relatively high NO_3-N. On the other hand, the peak of diatom abundance in the open lake coincided with higher transparency and a fairly rich nutrient environment (higher PO_4-P and NO_3-N). Lower SiO_2 in the same areas could be due to exhaustion by the large populations of diatoms. Talling, op cit. reported low concentrations of silicate during and after periods of diatom abundance and associated this to depletion of silicate by the diatoms. As a whole, concentration of PO_4-P and NO_3-N remained higher than the 10 $\mu g\ l^{-1}$ reported by Talling (1966) confirming the increasingly eutrophic nature of Lake Victoria. Long-term trends of major nutrients in the lake indicate that, while concentrations of phosphates have not changed significantly since 1960s, nitrates have increased and silicates have reduced. According to Hecky (1993), the N: P ratio has reduced and this has favoured cyanobacteria that are now persistently dominating the phytoplankton.

In the inshore shallow waters, the diversity of littoral habitats and high amounts of nutrients seem to encourage the floristic richness and growth of different species. This is in agreement with Rao, *et al.*, (1988) who related higher diversity of plankton in general in Lake Rangasagar, India, to high temperature and nutrients. On the other hand, lower concentration of silicate in offshore Lake Victoria results in a decrease in diversity, although also, the concentration of silicate seems

to be sufficient enough to support large numbers of *Nitzschia acicularis* and *N. lacustris*. The coupling between diatoms, and phytoplankton in general, and herbivorous zooplankton and fish in Lake Victoria is not known and needs to be studied. Although the decline of detritivorous / phytoplanktivorous fish species in the lake is blamed on the introduced predatory Nile perch *Lates niloticus* (L.) (Ligtvoet & Witte, 1991), it appears that the changes in phytoplankton composition where cyanobacteria are persistently dominating and other groups are becoming lesser could also have contributed to the decline of the fish species. This is probably due to reduction in availability of certain food items including species of diatoms. According to Greenwood (1953) and Welcome (1968), many detritivorous and phytoplanktivorous fish species fed mainly on diatoms, particularly Aulacoseira that used to be among the most dominant genera.

The abundance of diatom species reported by Talling (1966) as dominant appears to have changed. These included *Aulacoseira nyassensis* (1011 cells l^{-1}), *A. agassizzi* (10^4), *Nitzschia acicularis* (10^5) *Surirella nyassae* (10^3) and *Stephanodiscus astraea* (10^4). The maximum that we recorded for some of these species were: *A. nyassensis* (2.1×10^5 *frustules* l^{-1}), *A. agassizzi* (4.7×10^2), *Nitzschia acicularis* (4×10^5) and *S. astraea* (1.4×10^4). If we compare our data with those of Talling *op cit*., it is possible that *Nitzcschia* may have replaced *Aulacoseira* as the most important diatom particularly in the open lake.

CONCLUSIONS AND RECOMMENDATIONS

From 1997 up to 2000, more data have been collected but it is still predominantly an irregular sampling stream and most of the data is yet to be examined. Until there is complete data collection at regular intervals and covering different seasons, clear relationships, more than the type demonstrated here will be inconclusive and will remain descriptive. However, our data are still sufficiently inclusive to reveal spatial distribution that is governed by environmental factors, since the samples were taken from areas representing different habitats of the lake.

Water quality monitoring programs on Lake Victoria are mostly based on environmental variables. Considering that there is growing interest worldwide on assessment methods on water quality, based on biological organisms such as diatoms, our data may provide baseline and useful information to examine the controlling processes as well as the potential of ecosystem production. Research on diatoms and other organisms as biological indicators of the state of the aquatic environment should be pursued further.

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Distribution of phytoplankton and feeding of Nile tilapia, *Oreochromis niloticus* in Lake Victoria, Kenya

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SUMMARY

Waters samples collected from Lake Victoria between 1998 and 1999 showed that inshore (gulf) and offshore (open waters) algal species are differentiated. Nyanza Gulf had higher species diversity than open water stations. All the major groups of algae (blue green algae; diatoms and green algae) were present throughout the lake. The commonest algae as indicated by Shannon-Weaver index of diversity (H) in the gulf varied with stations. Microcystis aeruginosa (Kütz.) Kütz., Aulacoseira nyassensis (O. müll), and Anabaena circinalis Rabh. ex Born. & Fl. were the most encountered. In the open waters of the lake, Nitzschia acicularis Kütz. W. Smith var. acicularis and A. circinalis were the most abundant. Oreochromis niloticus (L) feeding behaviour indicated active selection. The most preferred food items as indicated by Ivlev's index of electivity (E) in both Nyanza Gulf and offshore stations were A. nyassensis and Oscillatoria spp. though blue-green algae and green algae were more abundant.

INTRODUCTION

Lake Victoria phytoplankton is largely made of green algae (Chlorophyceae), diatoms (Bacillariophyceae) and blue-green algae (Akiyama *et al.*, 1977; Talling, 1987; Lung'ayia *et al.*, 2000). Flagellate groups are scantily represented with the most conspicuous being *Ceratium brachyceros* Dad. (Talling, 1987). There has been a shift from seasonal succession predominated by diatoms, green algae and blue green algae in 1960s to the present domination of blue greens (Hecky, 1993; Lung'anyia *et al.*, 2000). There also has been an increase in primary productivity and algal biomass which are associated with changes in the water quality (Ochumba and Kibaara 1989; Hecky, 1993; Mugidde, 1993; Lung'anyia *et al*., 2000). These changes are also associated with climatic, physical, chemical and biological processes together with human activities taking place in the catchment areas (Crul, 1995).

Introduction of exotic species mainly Nile perch, *Lates niloticus* (L) and Nile tilapia, *O. niloticus* led to reduction of indigenous species especially haplochromines due to predation and competition (Ogutu-Ohwayo 1990). This has contributed to reduction in algal grazing and increase in algal biomass in the lake (Witte *et al.*, 1992). Alga blooms mainly of blue greens are now common (Ochumba and Kibaara 1989). The introduced Nile tilapia, *Oreochromis niloticus* (L.) has been described as mainly herbivorous feeding mostly on algae and plant material in Lake Victoria

(Moriarty and Moriarty 1973; Getabu 1994; Balirwa 1990; Trewavas 1983). This study was taken in attempt to establish the present algal composition in Lake Victoria, and feeding behaviour by *O. niloticus,* and the implication it has on the future water quality.

MATERIALS AND METHODS

Study area

The Kenyan part of Lake Victoria comprises the main lake and semi-enclosed Nyanza Gulf also known as Kavirondo or Winam Gulf. The lake receives its main inflow from several rivers originating from the East Africa Rift Valley highlands. The main geographical, hydrological and physical characteristics of Lake Victoria and Nyanza Gulf have been summarised by Burgis *et al*., (1987), Mavuti and Litterick (1991) and Crul (1995). Nyanza Gulf, which comprises the major part of the lake, lies within the equatorial region. The water temperature and solar radiation are relatively constant throughout the year (mean values of 22±3 ^{0}C and 1200±140 mE m^{-1} s^{-1} respectively).

Food and feeding habits

Samples of *O. niloticus* for food analysis were obtained from several sites by bottom trawls in offshore (open waters) and inshore (Nyanza Gulf) in August 1998-June 1999 (Fig.1). Immediately after capture, fish stomachs were removed and preserved in specimen bottles containing 4% formalin. In the laboratory, stomach contents were examined under a compound microscope (1000x) and the contents identified to the lowest taxonomic level possible. The following keys were used: Huber-Pestalozzi (1938) for Cyanobacteria, Hustedt (1942) for Bacillariophyceae, Ettl and Gartner (1988) for Chlorophyceae. Species identified were cross-checked against a checklist of Lake Victoria given by Cocquyt *et al*., (1993).

Phytoplankton species diversity

While collecting fish, samples for plankton studies were taken using a 3.5-L water sampler. Samples were then transfered to 500 ml plastic bottles and preserved in Lugol's solution. In the laboratory, the perserved samples were mixed thoroughly by tilting the bottle a couple of times. 250ml of a sample from each bottle were transfered to reagent bottles and allowed to stand for 48 hours. The upper supernatant layers were siphoned off with a fine tubing leaving 20-25 ml. The sedimented algae were examined under a compound microscope at various magnification and algae present identified.

Data analysis

Percentage of abundance = $(Fi/\sum Fi)$ 100.
Fi = number of food type i counted in the stomach
Ivlev's index (E) = (ri-pi)/ (ri +pi) and Linear index (L) = ri - pi
ri = proportion of i food item in fish stomach,
pi = proportion of food item i in the sample.

Shannon - Weaver index H = ∑ (pi Ln pi), pi = Ni/N,
N = total no of individuals in a sample, Ni = number of species I. The index was used to determine phytoplankton species diversity.

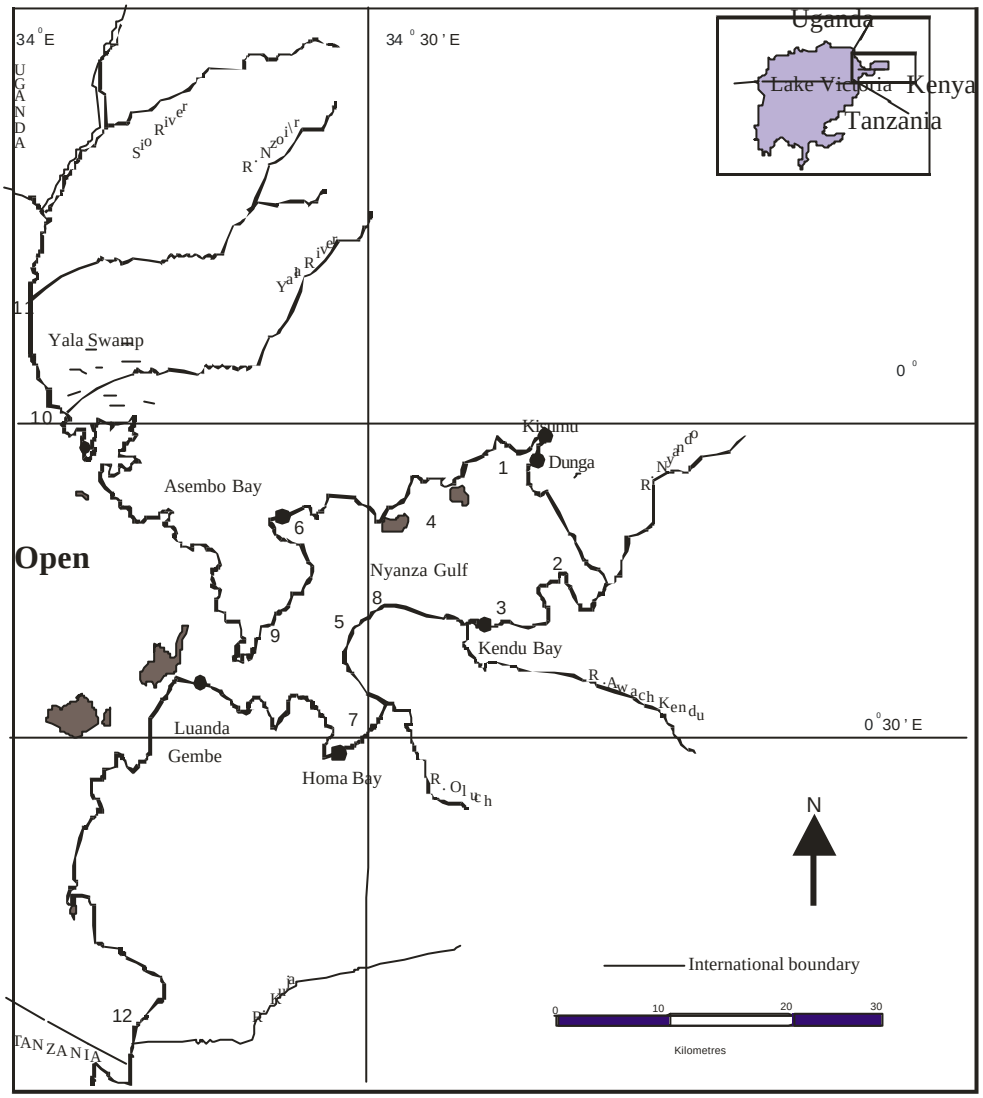

Fig. 1. Map of Nyanza Gulf and open waters of lake Victoria Kenya, showing sampling points.

RESULTS

Species composition

A total of 82 species belonging to 64 genera were identified (Table 1). Chlorophyceae (green algae) had 23 species, Bacillariophyceae (diatoms) 29, Cyanobacteria (blue green algae) had 28, and Dinophyceae (dinoflagellates) two species. Species composition per station revealed that Cyanobacteria were dominant both in open waters and Nyanza Gulf stations (Table 1).

Table 1. Phytoplankton species composition in inshore (Nyanza Gulf) and offshore (open waters) of Lake Victoria, Kenya

Group	Nyanza Gulf	Open waters
Cyanobacteria	30	22
Bacillariophyceae	**21**	**19**
Chlorophyceae	19	17
Dinopyceae	2	1
Total	72	59

Phytoplankton diversity

Shannon-Weaver index of diversity for various algal species showed that Microcystis aeruginosa (Kütz.) Kütz. and Nitzschia acicularis (Kütz.) W. Smith var. acicularis constituted the most abundant algae in Nyanza Gulf and open waters respectively (Table 2). Other commonly encountered algal species in Nyanza Gulf were: *Aulacoseira nyassensis* (O. Müll.) *var. Victoria* O. Müll. and *Anabaena circinalis* Rabh. ex Born. & Fl. while in the open water stations, A. circinalis and M. aeruginosa were the most encountered. Flagellates were rare but occurred in all the sites with *Ceratium, brachyceros* Dad. and *Glenedium* spp as the only identified species.

Distribution of the commonest algae in the gulf and offshore stations varied monthly (Fig. 2). N. acicularis increased gradually from August, peaking in March and reducing again in May. *M. aeruginosa* distribution was more irregular with a peak in May.

Table 2. Shannon-Weaver Index of diversity (H) for the commonest algae species in Lake Victoria, Kenya.

	Shannon-Weaver index (H)	
Food items	Nyanza Gulf	Open lake
Nitzschia acicularis	0.13	0.33
Aulacoseira nyassensis	0.29	0.01
Synedra cunningtonii	0.01	0.07
Oscillatoria sp.	0.01	0.01
Microcystis aeruginosa	0.34	0.09
Anabaena circinalis	0.24	0.15
Lynbya circumcreta	0.09	0.05
Merismopedia glauca	0.08	0.01

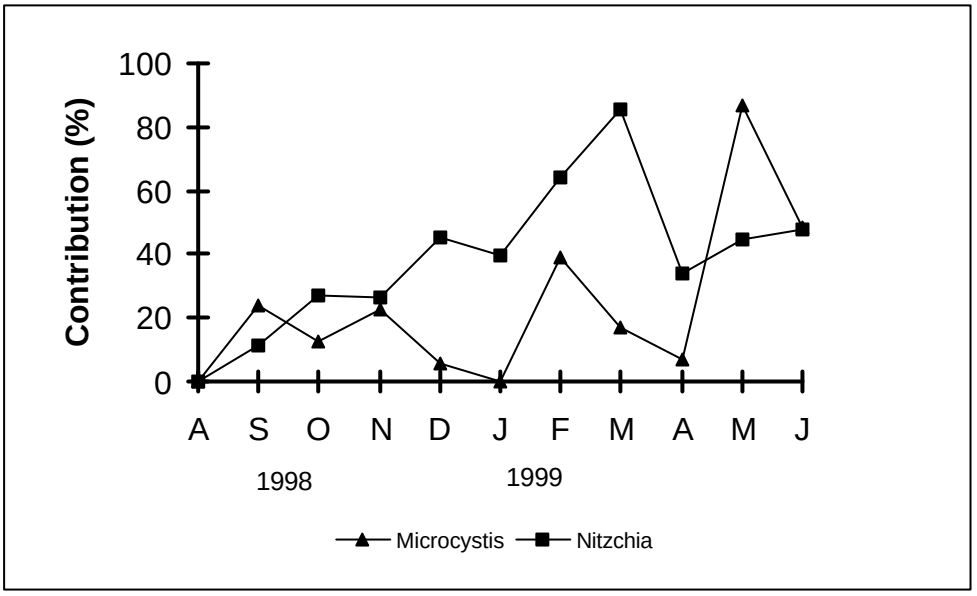

Fig. 2. Percentage abundance of the commonest algae, Nitzschia acicularis in the open waters and Microcystis aeruginosa in Nyanza Gulf of Lake Victoria, Kenya.

Feeding habits

Table 3 shows various algal species fed upon by *O. niloticus* both in Nyanza Gulf and in the open lake. The most abundant species in the lake were not the ones commonly preferred by *O. niloticus*, indicating active selection. The most preferred algae both in Nyanza Gulf and open waters of Lake Victoria as indicated by Ivlev index of electivity (E) were *A. nyassensis* and *Oscillatoria* spp. The least taken species in Nyanza Gulf were *Synedra cunningtonii* G. S. West and *Merismopedia glauca* Ehr. Näg. In the open waters, *M. aeruginosa* was the least taken.

Table 3. Ivlev's index of electivity (E) for the commonest algae species ingested by *Oreochromis niloticus* in Lake Victoria, Kenya.

Food items	Ivlev's index of electivity (E)	
	Nyanza Gulf	Open lake
Nitzschia acicularis	-0.01	+0.33
Aulacoseira nyassensis	+0.42	+0.90
Synedra cunningtonii	-0.35	+0.48
Oscillatoria sp.	+0.42	+0.70
Microcystis aeruginosa	-0.25	-0.48
Lynbya circumcreta	-0.02	+0.11
Merismopedia glauca	-0.68	+0.31

DISCUSSION

The phytoplankton of Lake Victoria was dominated by Cyanobacteria, followed by diatoms, green algae and the flagellates. Lung'anyia *et al*., (2000) found the same groups to dominate algae in Nyanza Gulf of Lake Victoria. There is a pronounced differentiation between the communities of offshore (open waters) and semi-enclosed regions (gulf), with species characteristics of each.

The main diatom offshore was *N. acicularis* and inshore *M. aeruginosa*. *A. nyassensis* dominated the diatoms in 1970s and 1980s. The replacement of *A. nyassensis* by *N. acicularis* is attributed to decline in silicon in the lake (Hecky, 1993; Lung'anyia *et al*., 2000). *N. acicularis* has a thinner silicate skeleton than *A. nyassensis* and requires moderate to low Silicon (Kilham *et al*., 1986). Lung'anyia *et al*., (2000) further found that *N. acicularis* in Lake Victoria showed a negative correlation to Sio_2 concentration especially in rainy season when Sio_2 increases in Nyanza Gulf more than open lake.

Blue green algae mainly, *M. aeruginosa* was the commonest in the gulf. The dominance of blue-greens in the Nyanza is mainly attributed to changes in water quality (Ochumba and Kibaara, 1989: Hecky 1993; Mugidde 1993). Nyanza Gulf is more enclosed and get effluents from several rivers passing through rich agricultural and municipal areas. Open water stations have fewer rivers and no major town influence.

M. aeruginosa have the ability to form blooms on the surface of water because of their buoyancy. Cyanobacteria have large amounts of carotenoids as accessory pigments in photosynthesis and provide protection to chlorophyll from photoxidation (Pear *et al*., 1983). Thus, cyanobacteria are adapted to areas with high illumination attaining high photosynthesis efficiencies. This factor in addition to high temperatures and high nutrient concentrations in the lake gives *M. aeruginos*a a competitive advantage, and the species is likely to continue dominating (Lung' anyia *et al*., 2000).

O. niloticus selected *A. nyassensis* and *Oscillatoria* spp though blue green algae were more abundant. Getabu, (1994) in the same locality found *O. niloticus* to select diatoms though blue-greens were more abundant. *O. niloticus* feeding rates are generally low on both small green and blue-green algae (Moriarty and Moriarty 1973; Robinson *et al*., 1995). Though *O. niloticus* can efficiently digest blue green algae (Moriarty and Moriarty, 1973), species like Anabaena filaments clog the filter decreasing the effective mesh size. *O. niloticus* also has low assimilation efficiency on diets of green algae (Moriarty and Moriarty 1973) and do not actively feed on them and if the algae is entrapped passively it is rejected in a bolus of mucus. Small algal species or low concentrations on the other hand may not be energetically worthwhile for *O. niloticus*, because energy gained from feeding cannot match energy expended in active pumping (Seale and Wassersug, 1979; Robinson *et al*., 1995). Robinson *et al*., (1995) further found that the feeding rate of *O. niloticus* increased with particle size. Overall the maximum particle dimension was important in stimulating active feeding rather than the particle volume. Diatoms like *N. acicularis, A. nyassensis* have a larger particle dimension than *M. aeruginosa* cells and could have led to selection of diatoms instead of blue greens and green algae.

Among flagellates, only *C. brachyceros* and Glenedium occurrence of limited flagellate groups is common in East Africa (Talling 1976) and is a tropical attribute and may depend on local chemical conditions of competition from often more abundant smaller blue-green algae.

Implications of the study

Fresh water phytoplankton feeding fish like *O. niloticus* suppress larger phytoplankton species encouraging blooms of smaller algae producing a monoculture which are not easily suppressed (Robinson *et al*., 1995). In such a case the fish would likely switch to a more available food item. This has been demonstrated in this study, where *O. niloticus* presently the main phytoplanktovore fish in Lake Victoria actively selects larger algal species like diatoms leaving blue green and green algae even when more abundant. Balirwa (1998) further found that, the once herbivorous *O. niloticus* has diversified its food to include a variety of food items like plant material, detritus, insects and fish remains.

Nutrient loading is increasing in Lake Victoria (Ochumba and Kibaara, 1989; Hecky, 1993; Mugidde, 1993; Lunga'yia *et al*., 2000) coupled with decreased grazing pressure (Ogutu-Ohwayo, 1990; Witte *et al.*, 1992). Introduced *L. niloticus* (L) has continued to suppress recovery of phytoplantktivorous haplochromines (Ogutu-Ohwayo, 1990). The main phytoplanktovorous fish in the lake, *O. niloticus* is diversifying its diet leaving Lake Victoria with no major phytoplantktivorous fish.

Nyanza Gulf, which consists of the major part of Kenyan waters of Lake Victoria, is shallow, and heavy storms can stir bottom sediments and distribute it throughout the water column (Fish, 1957; Talling, 1966; Ochumba, 1990). This organic mud added to the nutrients from the storm run-off could support heavy algal blooms. Bacterial breakdown of algal biomass leads to production of Carbon dioxide subsequently a low pH and oxygen deficiency. Cholorophyll-a has also increased from 1.2-2 mg m^{-3} in 1960-1961 (Talling, 1966) to 2.0-71.5 mg m^{-3} in 1994-1995 (Lung'anyia *et al.*, 2000). Increase in chlorophyll-a and buoyant Cyanobacteria have resulted into a decrease in transparency from 7.3-7.9m in offshore stations and 1.3-1.5 m in Nyanza Gulf in 1927 (Worthington 1930) to 1.1-1.4 and 0.6-1.38 in 1994-1995 in both areas respectively (Lung'ayia *et al*., 2000). Low pH, oxygen deficiencies and algal blooms which clog fish gills lead to fish deaths. Unless there is a recovery of phytoplanktivorous fish especially haplochromine cichlids, a reduction in nutrients loading in the lake, algal blooms accompanied by devastating effects on Lake Victoria fishery could be a frequent occurrence.

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Taxonomic Composition and Distribution of Zooplankton in the Nyanza Gulf of Lake Victoria, Kenya

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SUMMARY

Studies on the taxonomic composition and distribution of zooplankton were carried out in the Nyanza Gulf of Lake Victoria. Qualitative samples were collected by vertical hauls using a Nansen type plankton net of 76 µm mesh size. Samples were sorted under a dissection microscope and specimens identified up to species level under high power of a compound microscope. The zooplankton community was dominated by Rotifera with 31 species followed by Cladocera (17 species) and Copepoda (12 species). Certain organisms were restricted to macrophytic, littoral or limnetic habitats while others occurred in all the stations. Mesocyclops leuckarti reported by earlier investigators could have been a misidentification of M. kieferi.

INTRODUCTION

Zooplankton play a vital role in energy transfer by grazing on phytoplankton and epithilic communities thereby converting plant material into animal protein which is transferable to higher trophic levels in the aquatic food chain. In addition to the transfer of energy in an ecosystem zooplankters especially Rotifera, can be used as indicators of water quality (Sladecek, 1983). Abundance and species composition of rotifers can reflect the trophic status of a lake (Nogrady, 1980).

Zooplankton of Lake Victoria is not well documented. The earlier studies were mostly descriptive (Weltner, 1897; Daday, 1907; Delachaux, 1917). The first quantitative study was that by Worthington (1931) on vertical distribution, followed by that of Rzoska (1956) on species composition and distribution. The most recent studies in the lake were those by Mavuti and Litterick (1991) in the Kenyan portion of the lake and Mwebaza-Ndawula (1994) in the Ugandan sector. Gaps in the knowledge of the lake's zooplankton still exist as certain habitats, particularly the littoral, have not been studied in detail. In this study, an attempt was made to identify the zooplankton species which occur in the Nyanza Gulf of Lake Victoria and their distribution and provide basic taxonomic information, which can be used in future specialised investigations.

Study area

The study was carried out in the Nyanza Gulf of Lake Victoria, which comprises about 70% of the Kenya part of the lake and has a shoreline of approximately 500 km. The gulf experiences eutrophic conditions due to agricultural, urban and industrial activities in the riparian areas. Seven

stations (Fig. 1) were sampled between 1995 and 1997. These included most of the ecological zones considered by Mavuti and Litterick (op.cit).

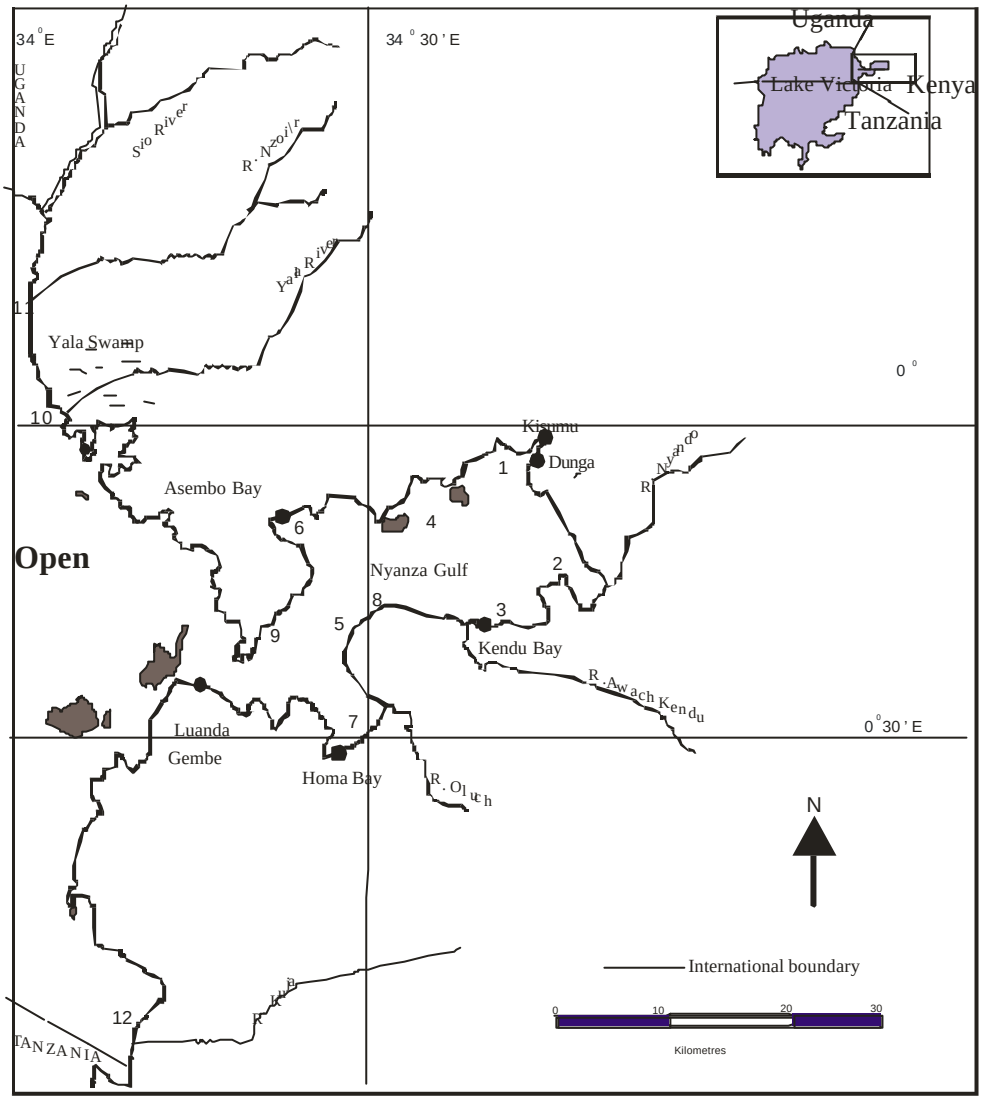

Fig. 1. Map of Nyanza Gulf showing sampling sites

MATERIALS AND METHODS

Zooplankton samples were collected with a 1.0 m long Nansen type plankton net of 76mm mesh size and 30 cm diameter mouth opening. Vertical hauls were obtained as outlined by Tonolli (1971). Within the macrophytes, in station 1, a small hand net with a screen at the mouth was used. Samples were preserved in 5% formaldehyde solution. In the laboratory successive aliquots of every sample were examined under a Wild M3 dissection microscope. Ultra fine capillary tubes were used to sort rotifers while Copepoda and Cladocera were sorted with the aid of fine needles. Trophi of illoricated rotifers were used for identification after dissolving the organisms in sodium hypochloride. External morphological characteristics of the lorica were used to identify

loricated Rotifera. Copepoda and Cladocera were dissected and all specimens identified using morphological features under high magnification (X1000 oil immersion) of a Kyowa Medilux M12 compound microscope. The following taxonomic keys were used for specimen identification: Lindberg (1955, 1957), Van de Velde (1984), Herbst (1986), Smirnov (1996), Korovchinsky (1992), Segers (1995), Koste (1978) and Koste and Shiel (1987, 1990).

RESULTS

A total of 60 species of zooplankton were recorded: 17 copepods, 12 cladocerans and 31 rotifers (Table 1). These were composed of 2, 6 and 13 families respectively.

Table 1: Zooplankton identified from the Nyanza Gulf, Lake Victoria (*- indicate species not recorded by Mavuti and Litterick, 1991).

COPEPODA	**Sampling stations**
Ca**lanoida**	
Diaptomidae	
Diaptominae	
Tropodiaptomus stuhlmanni Mrazek, 1895*	1,2,3,4,5,6,7
Thermodiaptomus galeboides (Sars, 1901)	2,3,4,5,6,7
Cyclopoida	
Cyclopinidae	
Cyclopinae	
Cryptocyclops linjancticus (Kiefer, 1928)*	1
Mesocyclops ogunnus Onabamiro, 1957*	3,5,7
M. kieferi Van de Velde, 1984*	3,7
M. aspericornis (Daday, 1906)*	3
M. major Sars, 1927*	3,4,5,7
M. equatorialis equatorialis (Kiefer, 1927)	2,5,7
Microcyclops varicans (Sars, 1927)*	1
Thermocyclops decipiens (Kiefer, 1929)*	2,3
T. emini Mrazek, 1895	2,3,4,5,6
T. incisus Kiefer, 1932*	1,2
T. neglectus (Sars, 1909)	1,2,3,4,5,6,7
Eucyclopinae	
Ectocyclops rubescens Brady, 1940*	1
Eucyclops serrulatus Fischer, 1851*	1
Macrocyclops albidus Jurine, 1820*	1
Tropocyclops confinis (Kiefer, 1929)*	1,2,3,4,5,6,7
CLADOCERA	
Ctenopoda	
Bosminidae	

Bosmina longirostris Muller, 1885	1,2,3,4,5,6,7
Chydoridae	
Alona davidi Richard, 1895*	1
A. guttata Sars, 1862*	1
Chydorus parvus (Daday, 1898)*	1,3
Dunhuvedia colombiensis Stinglen, 1913*	1
Daphnidae	
Ceriodaphnia cornuta Sars, 1885*	1,2,3,4,5,6,7
Daphnia barbata Weltner, 1898	1,3
D. lumholtzi Sars, 1885	1,2,3,4,5,6,7,
D. longispina Muller, 1785	5,7
Macrothricidae	
Macrothrix spinosa King, 1853*	1
Moinidae	
Moina micrura Kurz, 1874	1,2,3,4,5,6,7
Sididae	
Diaphanosoma excisum Sars, 1885	1,2,3,4,5,6,7
ROTIFERA	
Asplanchnidae	
Asplanchna brightwelli (Gosse, 1850)	7
A. sieboldi (Leydig, 1854)*	5
Brachionidae	
Brachionus angularis (Gosse, 1851)*	3,4,5,6,7
B. bidentata Anderson, 1889*	1
B. caudatus Barrois & Daday, 1894	2,3,6,7
B. falcatus Zacharias, 1898	2,5,7
B. quadridentatus (Herman, 1773)	2,3,4
B. rubens Ehrenberg, 1838*	1,2,3,4,5,6,7
Keratella cochlearis (Gosse, 1851)*	1,2,3,4,5,6,7
K. tropica (Apstein, 1907)*	2,3,4,5,6,7
Plationus patulus (Muller, 1786)*	2,3
Platyias quadricornis (Ehrenberg, 1832)*	1,2
Epiphanidae	
Epiphanes clavulata (Ehrenberg, 1832)*	5,6,7
E. macrourus (Barrois & Daday, 1894)	5
Euchlanidae	
Dipleuchlanis propatula (Gosse, 1886)*	2
Euchlanis triquetra Ehrenberg, 1838*	2
Filinidae	
Filina longiseta (Ehrenberg, 1898)*	2,7
F. opoliensis (Zacharias,1898)	2,7
F. terminalis (Plate, 1886)*	7
Flosculariidae	
Sinantherina socialis Linnaeus, 1758*	2,3,45,6,7

Hexarthridae	
Hexarthra mira (Hudson, 1831)*	2,4,7
Lecanidae	
Lecane bulla Gosse, 1851	1
L. ungulata (Gosse, 1837)*	1
Mytilinidae	
Mytilina ventralis (Ehrenberg, 1832)*	1
Philodinidae	
Rotaria neptunia (Ehrenberg, 1832)	2,3,4,5,6,7
Synchaetidae	
Polyathra vulgaris Carlin, 1943*	2,7
Testudinellidae	
Testudinella emerginula (Sternoos, 1898)*	2
Trichorcercidae	
Trichorcerca braziliensis (Murray, 1913)*	2,3,4,5,6,7
T. elongata (Gosse, 1886)*	3,4,5,7
T. longiseta (Shrank, 1802)*	3,7
T. rattus (Muller, 1776)*	7

Copepoda was represented by two orders Calanoida and Cyclopoida. All the 16 species of Cyclopoida belonged to the family Cyclopinidae and two subfamilies Cyclopinae and Eucyclopinae. Cyclopinae dominated with 12 species of which *Mesocyclops* and *Thermocyclops* were the most common genera.

Cladocera was dominated by the families Chydoridae and Daphnidae each with four species. Other families were: Bosminidae, Macrothricidae, Moinidae and Sididae. The cladoceran species found all over the gulf included: *Bosmina longirostris, Moina micrura, Ceriodaphnia cornuta, Daphnia lumholtzi* and *Diaphanosoma excisum*. *Daphnia longispina* was only recorded in the two deep stations, 6 and 7.

Brachionidae dominated Rotifera with 10 species followed by Trichorcercidae with four species. Families represented with only one species were: Flosculariidae, Hexarthridae, Mytilinidae, Philodinidae, Sychaetidae and Testudinellidae.

DISCUSSION

More zooplankton species were recorded in this study than those of previous studies. Mavuti and Litterick (op. cit.) found 47 species in the Kenyan sector of Lake Victoria (25 rotifers, 10 copepods and 12 cladocerans) while Mwebaza-Ndawula (op. cit) realised 9 copepods and 5 cladocerans in the Northern Lake Victoria. The distribution of zooplankton is governed by several factors among them; physical and chemical conditions, food, predation and means of dispersal. Whereas Mavuti and Litterick (op.cit) found only two species of Mesocyclops, in this study the

genus contributed the highest number of copepod species. *M. leuckarti* reported by the former and other earlier investigators from the lake was probably a misidentification of *M. kieferi.* All the species of *Eucyclopinae* seemed to be littoral except for *Tropocyclops confinis* which was recorded in all the stations in the gulf. Among the Cyclopinae, *Cryptocyclops linjancticus* and *Microcyclops varicans* are also littoral organisms while *Thermocyclops incisus* appears to be an inshore species. Occurrence of copepods within aquatic plants is one way of evading their predators. Other adaptations towards this goal include the change of colour as was seen in *Tropocyclops confinis* and the ability of copepods to escape from predators. Copepod species recorded by earlier studies from the lake but were not encountered in this study include: *Thermocyclops oblongatus, T. hyalinus, Tropodiaptomus neumanii, T. banforanus* (Mavuti and Litterick, *op. cit*) and *Eucyclops agiloides* (Mwebaza-Ndawula, *op.cit*.).

The families Chydoridae and possibly Macrothricidae were restricted to the littoral zone colonised by *Echinocloa* sp and resident water hyacinth while the others occurred in all the stations sampled. Occurrence in such habitats enables the organisms to avoid their predators by using the macrophytes for protection. Due to their large size Cladocerans, are favourite prey of many invertebrate and vertebrate predators. Limnetic forms reduce their liability by reduction in size or by development of defensive morphological structures as in the helmeted *Daphnia lumholtzi*. *D. barbata* was only found at the river mouths and this probably explains why it has not been recorded in the Uganda waters of Lake Victoria in the recent years where such habitats have not been sampled (Mwebaza-Ndawula pers. comm.). Cladocera species, which occur in all the stations, are *Bosmina longirostris, Ceriodaphnia cornuta, Daphnia lumholtzi, Moina micrura* and *Diaphanosoma excisum*. Daphnia longispina was only recorded in the two deep stations showing that it is a limnetic species.

The results of our study show that Rotifera had the highest number of taxa recorded. This corroborates the earlier findings in the lake by Mavuti and Litterick (op.cit.) and elsewhere in Lakes Kariba (Green, 1971) and Naivasha (Mavuti, 1983). The general richness in Rotifera in the deeper stations in contrast to Cladocera could be explained by preference to predation on the latter by juvenile Nile perch, haplochromines and *Rastrineobola argentea*. Moreover, rotifers are known to reproduce rapidly and usually can account for 50% or more of the zooplankton production (Herzig, 1987). In this study the species recorded in the inshore waters were: *Brachionus bidentata, Plationus patulus, Dipleuchlanis propatula, Euchlanis triquetra, Lecane bulla, L. ungulata* and *Testudinella emerginula* whereas typical offshore species were: *Asplanchna brightwelli, A. sieboldi, Epiphanes clavulata* and *E. macrourus*. However, as Preisler (1977, 1980) showed, the horizontal distribution of rotifers is not solely governed by the population growth due to favourable physical and chemical but certain rotifers actually avoid inshore waters while others are attracted to such waters.

CONCLUSIONS

All the specimens in this study were identified to species level. However, due to the seasonality of the organisms, some taxa could have been missed considering that our sampling did not cover all seasons. Robinson and Robinson (1971) noted seasonality in *Brachionus calciflorus, Hexarthra* sp. and *Epiphanes macrourus* among others in Lake Chad.

ACKNOWLEDGEMENT

We wish to thank Drs Mass, Segers and Korovchinsky for confirmation of specimens identity. Appreciation also goes to the entire crew of Utafiti and colleagues at KMFRI. The study was funded by KBJP, KMFRI, LVFRP and ABOS.

Invertebrate communities in northern Lake Victoria (Uganda) with reference to their potential for fishery production

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SUMMARY

The zooplankton community of Lake Victoria was constituted by crustaceans, largely copepods and cladocerans. Non-crustaceans included rotifers and aquatic insect larvae. Macro-invertebrates comprised both benthic (i.e. chironomid larvae, molluscs) and semi-benthonic (i.e. chaoborid larvae, freshwater prawns, Caridina nilotica) forms as the main taxa and other minor groups. Most taxa exhibited wide distribution in the lake with the exception of rotifers, which were rare in deep offshore waters. Cyclopoid copepods dominated the zooplankton community numerically in both inshore and offshore areas. A historical perspective indicated a substantial increase in relative abundance of cyclopoids and a corresponding decline in proportions of diaptomids and Cladocera. Seasonal change in abundance showed attainment of peak abundance of most zooplankton taxa during May; thereafter declining gradually until December.

Zooplankton numerical abundance ranged from <100,000 to >4 million ind.m^{-2} and areal densities increased from the shallow inshore towards deep offshore waters. Among macro-invertebrates, high areal concentrations were observed among chaoborid and chironomid larvae and gastropods.

The diet of the pelagic Rastrineobola argentea (Pisces: Cyprinidae) and larval Lates niloticus (Picses: Centropomidae) was dominated by cyclopoid copepods while larval cichlids ingested mostly adult insects. The sustained dominance of cyclopoids in the zooplankton community despite high predation pressure by zooplanktivorous fishes, offers good prospects for the pelagic fishery in Lake Victoria.

INTRODUCTION

Aquatic invertebrates constitute a major link in energy flow culminating into fish production. So far relatively little research has been done on invertebrates especially their relation to fishery production. Few early workers carried out limited but useful preliminary investigations on both macro-invertebrates (EAFFRO Annual Reports 1950-1970, MacDonald 1956) and zooplankton (Daday 1907, Sars 1909, Delachaux 1917). These early works provide a basis for tracking community changes by comparison with recent investigations (Mbahinzireki 1992 & 1993, Branstrator *et al.*, 1996, Mavuti and Litterick 1991, Mwebaza-Ndawula 1994 & 1998). Nevertheless, these early invertebrate studies were largely descriptive and restricted to the shallow sheltered bays, gulfs and channels. Variability in both species composition and abundance both in

time and space was not adequately examined. Although invertebrates are known to constitute an important prey category in pelagic, larval and juvenile fishes, only one major study (Corbet 1961) has so far examined fish-invertebrate trophic link in Lake Victoria.

This study presents results of field sampling from selected areas in northern Lake Victoria over a period 1994 to 1997. Faunistic lists of aquatic invertebrates, their distribution and abundance patterns, comparison of modern and historical communities and fish-invertebrate trophic interactions are given.

MATERIALS AND METHODS

Sampling sites for invertebrates were located along fish sampling grids of the EU-supported Lake Victoria Fisheries Research project in the Uganda portion of Lake Victoria.

Zooplankton were sampled with Nansen type nets of 50 and 100um mesh and 0.25 m mouth diameter. Four vertical hauls were taken to make a composite sample preserved in 4% sugar-formalin. Macro-benthos were sampled with a Ponar grab and four grabs constituted a composite sample which was preserved in 4% formalin. The invertebrate samples were taxonomically identified and the different taxa counted under compound and binocular stereomicroscopes respectively.

Fish were sampled with a small, canoe-towed, mid-water trawl net described by Mwebaza-Ndawula (1998). The Napoleon Gulf (NG: 0^0 24' N; 0^0 33'E) and Bugaia (BG: 0^0 03'S; 33^0 17'E) represented inshore and offshore areas respectively. Samples were preserved in 10% formalin. Each fish was dissected, the gut removed, the contents spread out on a petri dish and examined under a compound microscope. Prey organisms were identified to broad taxonomic groups and counted. Prey biomass was computed from existing length-weight regressions (Botrell *et al.*, 1976). Historical zooplankton and fish samples were obtained from field collections of Jack Talling and the Fisheries Resources Research Institute (FIRRI) Museum respectively.

RESULTS

Zooplankton taxonomic composition

The zooplankton community of Lake Victoria was composed of cyclopoid and diaptomid copepods, cladocerans, rotifers, aquatic insect larvae/pupae and water mites (Table 1). Copepods were composed of *Thermocyclops, Mesocyclops* and *Tropocyclops* (Cyclopoids), *Thermodiaptomus* and *Tropodiaptomus* (Diaptomids). Cladocera comprised *Diaphanosoma, Daphnia, Ceriodaphnia, Bosmina, Moina, Chydorus* and *Alona*. Rotifers were the most important non-crustacean group especially around the shallow inshore areas and consisted of several genera and species.

Table 1. Occurrence of zooplankton taxa from inshore (NG), offshore (BG) and historical (off Dagusi Is.) samples, Lake Victoria

Taxa	Number of species	Occurrence		
		Inshore	Offshore	Historical
Rotifera:				
Brachionus	7	P	P	
Filinia	2	P	A	
Keratella	2	P	P	
Polyarthra	1	P	A	
Lecane*	++	P	A	
Asplanchna	1	P	P	
Trichocerca	1	P	A	
Aneuropsis	1	P	A	
Euclanis	1	P	A	
Hexathra	1	P	A	
Pompholyx	1	P	A	
Cyclopoida:				
Thermocyclops	4	P	P	P
Mesocyclops	2	P	P	P
Tropocyclops	2	P	P	P
Calanoida:				
Thermodiaptomus	1	P	P	P
Tropodiaptomus	1	P	P	P
Cladocera:				
Daphnia	2	P	P	P
Ceriodaphnia	1	P	P	P
Diaphanosoma	1	P	P	P
Bosmina	1	P	P	P
Chydorus	1	P	A	P
Alona	1	P	A	P
Moina	1	P	A	P
Decapoda:				
Caridina	1	P	P	
Insecta:				
Chaoborus larvae/pupae	1	P	P	
Arachnida:				
Acarid mites	1	P	A	A

*Several unidentified Lecane species

Zooplankton relative abundance

Comparison of taxa between inshore (NG) and offshore (BG) areas (Figs.1a, 1b & 2) showed numerical and biomass dominance of cyclopoids in both areas. Diaptomids and Cladocera were much less abundant in both inshore and offshore waters. Rotifers were more abundant inshore relative to offshore waters.

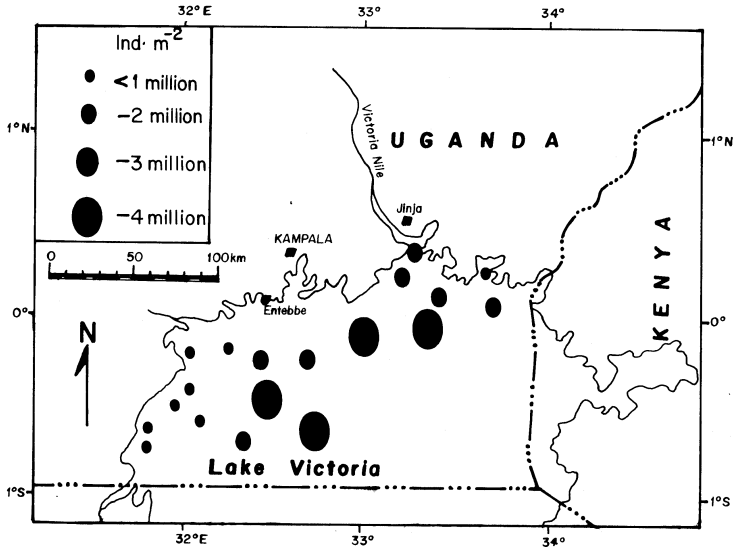

Fig.1a. Map of the Ugandan water of Lake Victoria showing concentrations of zooplankton, represented by (o) at the sampling sites, with relative abundance indicated by the size of the circles

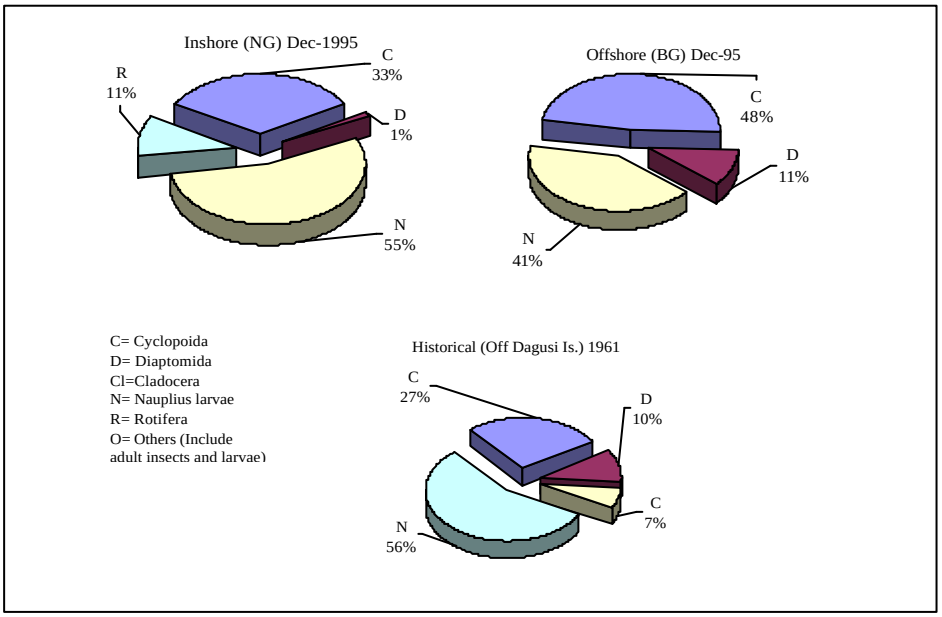

Fig. 1b. Zooplankton relative abundance from inshore (NG), offshore (BG) and histori cal (off Dagusi Is.) samples, Lake Victoria.

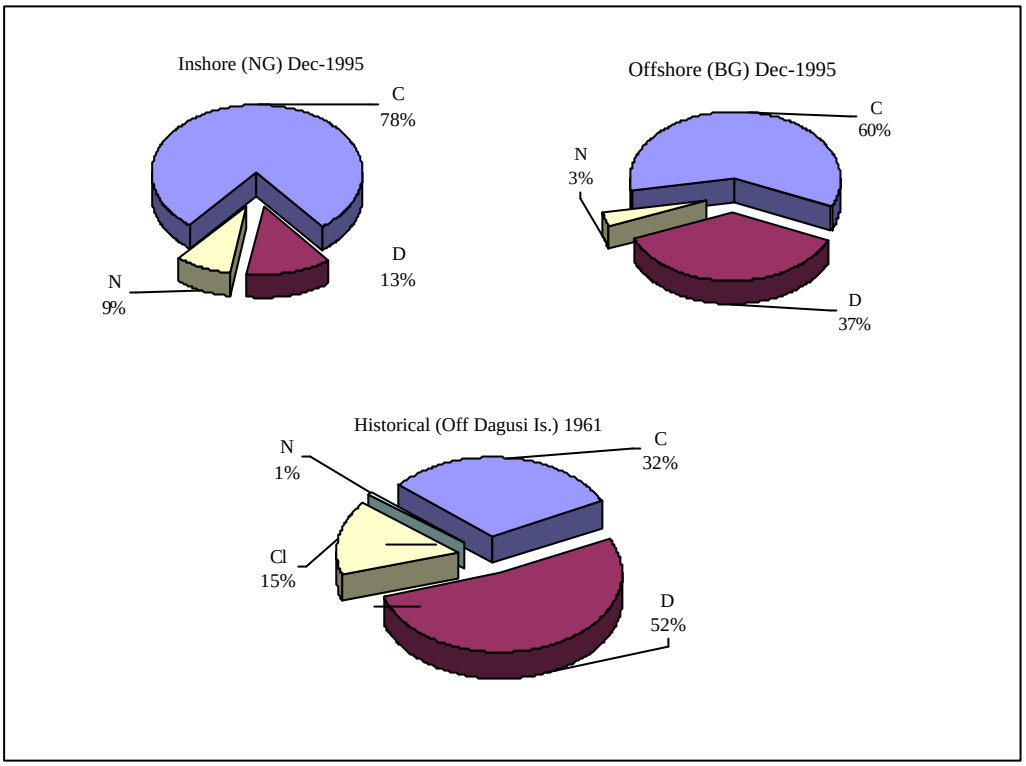

Fig. 2. Zooplankton biomass (%) from inshore (NG), offshore (BG) and historical (off Dagusi Is.) samples, Lake Victoria.

Historical changes in zooplankton relative abundance

Relative abundance and biomass of different taxa from the Napoleon Gulf, (1995) and off Dagusi island (1961) indicated remarkable changes between the 1960s and 1990s communities (Fig. 3A and B). Cyclopoid copepods showed a substantial increase from 56% in the 1960s, to 82% in the 1990s. In contrast, Cladocera and diaptomids showed a drastic decline from 30% and 13% in the 1960s to 2% and 3% respectively in the 1990s. Corresponding dry weight data (Fig. 3B) showed similar changes.

Seasonal changes in zooplankton abundance

Seasonal variation of abundance showed a build-up of populations from January (ca >1 million ind.m^{-2}) through February, March and April culminating into a peak abundance (up to 6 million ind.m^{-2}) during May (Fig. 4). Thereafter, a gradual decline ensued until December. This pattern of seasonal change was generally similar among the major zooplankton taxa.

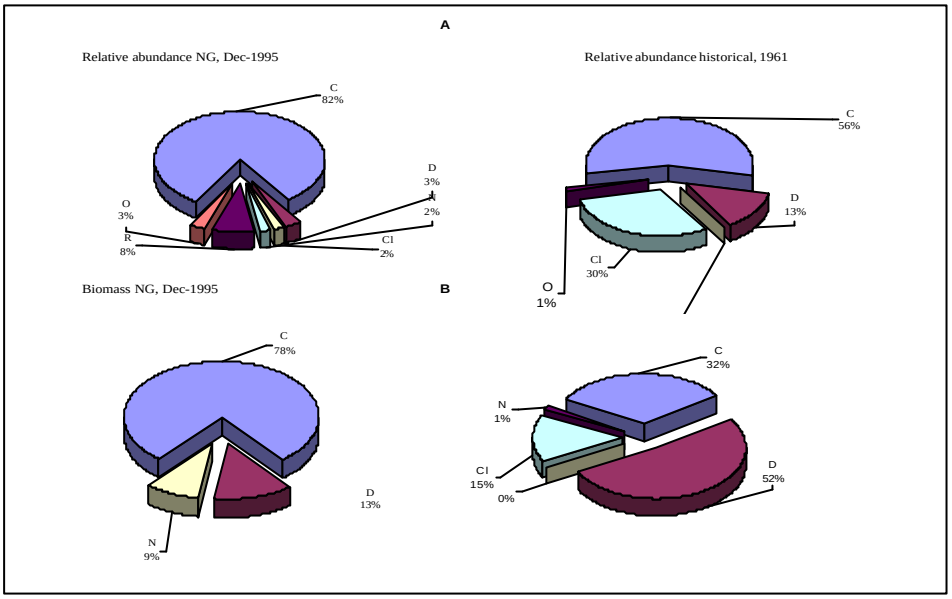

Fig. 3 a&b. Relative abundance and dry weight of zooplankton taxa from inshore (NG) and historical (off Dagusi Is.) samples, Lake Victoria

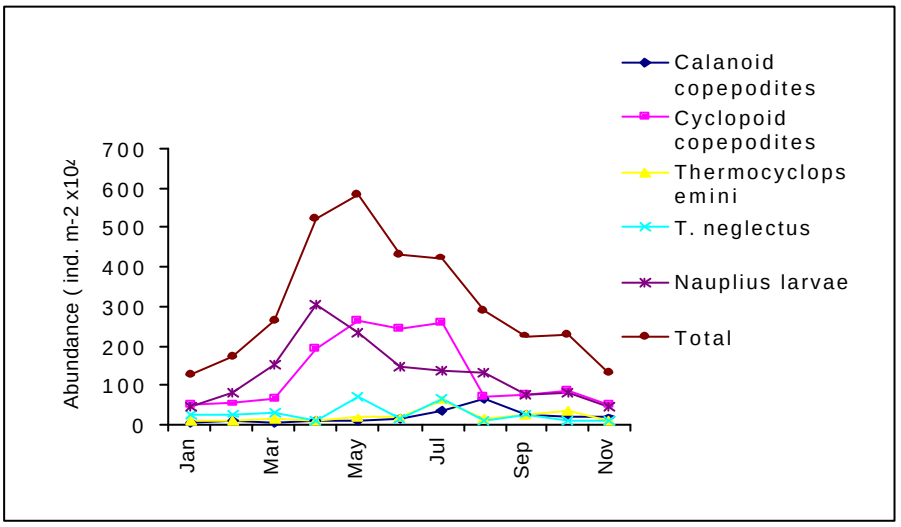

Fig. 4. Seasonal variation in abundance (no/m^2) of zooplankton taxa at Bugaia offshore station, Lake Victoria.

Horizontal distribution patterns

An increasing gradient of densities from the shallow inshore areas to the deeper open waters of the lake over a range of <0.1 to >4 million ind.m^{-2} was observed. This trend represents an inverse relationship with the distribution of fish in general as shown by Kudhongania & Cordone (1974) and Okaronon *et al.*, (1999). Zooplanktivorous fishes have also been shown to decrease along an inshore-offshore gradient (Mwebaza-Ndawula 1998).

Macro-invertebrate occurrence and densities

Macro-invertebrate organisms were composed of chaoborid and chironomid larvae, oligochaetae, nematodes, gastropods, *Caridina nilotica* and other aquatic insect nymphs i.e. Trichoptera and Ephemeroptera (Table 2). Macro-invertebrates also exhibited wide distribution in the lake (Table 2). In terms of occurrence and density, chaoborid and chironomid larvae and gastropods were the more important taxa. Oligochaetes, chaoborid and chironomid pupae, *C. nilotica*, Trichoptera, Ephemeroptera, bivalves, and nematodes were either rare or absent in most areas.

Table 2. Occurrence and density (ind.m^{-2}) of macro-invertebratess in sampling stations in northern Lake Victoria November 1995 to October 1997

Sampling station:	Location	Date	Depth (m)	Chaoborid larvae	Chironomid larvae	Oligochaeta	Gastropoda	*Others
Sari-Kasuri	00 10'S; 320 13'E	Oct-95	13	82	143	41	1286	143
Mweza-Kasayi	00 23'S; 320 09'E	Feb-96	15	82	20	367	102	61
South Banga	00 19'N; 330 20'E	Feb-96	29	306	367	286	163	367
Sigulu	00 08'N; 330 43'E	Apr-96	17	265	0	41	265	122
Sigulu	00 08'N; 330 43'E	Sep-97	17	775	388	0	0	41
White stony	00 34'S; 320 08'E	Mar-97	22	408	163	48	490	82
Itome Bay	00 12'N; 330 15'E	Aug-97	19	2285	143	82	20	224
Itome Bay	00 12'N; 330 15'E	Apr-97	29	2836	1857	20	41	0
Dagusi	00 09'N; 330 36'E	Aug-97	16	347	122	0	102	20
Mvuja	00 08'N; 330 22'E	Aug-97	18	551	1387	0	265	20
Mvuja	00 08'N; 330 22'E	Oct-97	39	1388	82	0	41	40
Frequency of occurrence				11	10	7	10	

** 'Others' include: chaoborid and chironomid pupae, Caridina, Tricoptera, Ephemeroptera, Bivalves and Nematoda*

Zooplankton in the diet of *Rastrineobola argentea*

The frequency of different zooplankton taxa in the diet of *R. argentea* from inshore and offshore waters and historical sample (off Dagusi Is.1966) showed cyclopoid copepods as the main prey item (Fig.5). In the offshore sample, nearly 100% cyclopoid consumption was attained. Greater consumption of Cladocera and diaptomid copepods was evident in the historical (1960s) fish diet compared to that of the 1990s, corresponding to their greater abundance in the historical zooplankton community (Figs. 1 and 2).

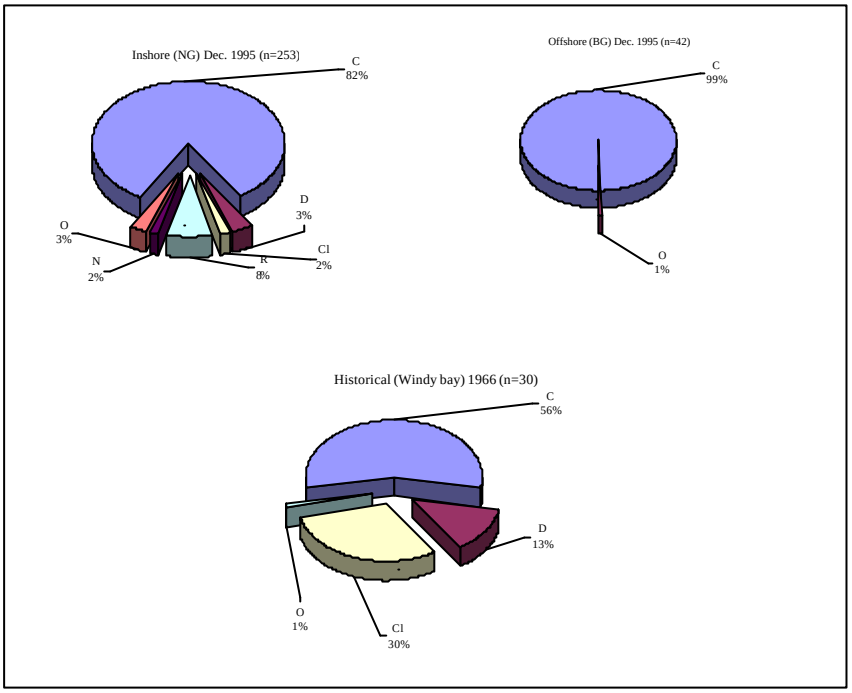

Fig. 5. Relative abundance of prey taxa in the diet of *Rastrineobola argentea* from modern (inshore NG, offshore BG) and historical samples, Lake Victoria. Taxa with <1% are not shown. (C, D, CL, N, R, and O as in Fig. 1).

Invertebrates in the diet of other commercial fish species

Larval *Lates niloticus* ingested mostly cyclopoids (70%) and Cladocera (17%) compared to larval cichlids in which favourite prey items were Chaoborus larvae (48%), adult aquatic insects and cyclopoid copepods (Fig. 6). Supplementary prey for larval *L. niloticus* included diaptomid copepods, and other minor items while cyclopoids and cladocerans supplemented the diet of larval cichlids.

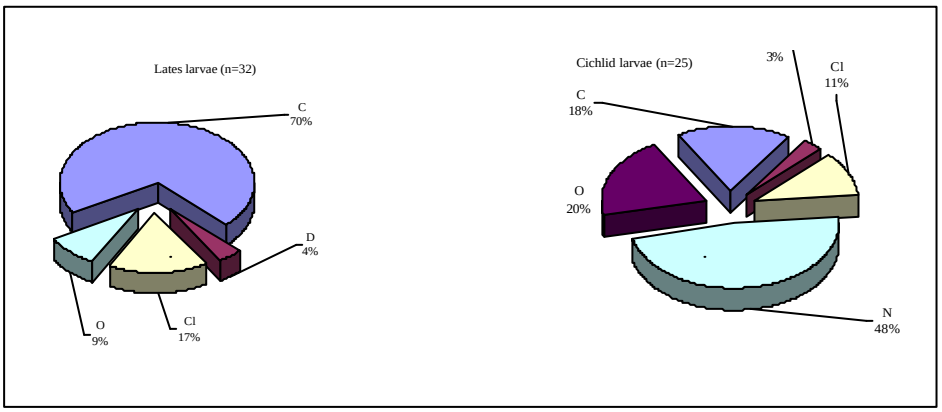

Fig. 6. Relative abundance of prey taxa in the diet of larval *Lates niloticus* and cichlids, Lake Victoria. Taxa with <1% are not shown. (C, D, CL, N, R, and O as in Fig. 1).

DISCUSSION

The seasonal regime of zooplankton abundance observed (Fig. 4) is an annual event previously reported by Branstrator *et al*., (1996) and Mwebaza-Ndawula (1998). However, minor differences in the timing of peak concentrations and the on-set of the build-up of populations may be expected. Planktivorous fishes including *R.argentea* and larval fishes are probably part of the driving forces of the observed seasonal pattern of zooplankton abundance resulting from predation impacts. Mwebaza-Ndawula (1998) found low zooplankton densities in the Napoleon Gulf to coincide with high stocks of larval *R. argentea* during the month of July while at the deep offshore waters where the pelagic fish densities are very low, high zooplankton abundance occurred.

Comparison of modern (1990s) and historical (1961) zooplankton samples (Table 1) showed no recognisable changes in species composition of major taxa (Copepoda and Cladocera) despite drastic changes in the lake's physical-chemical character (Hecky, 1993) and fish fauna (Witte *et al.,* 1992) since the 1960s. Observed absence of Rotifera in the historical sample (Table1) may have been due to use of a large mesh net sampler. Changes in relative abundance have, however, occurred between Cyclopoida, Diaptomida and Cladocera (Mwebaza-Ndawula 1994, 1998; Fig. 3). Such shifts in abundance are probably associated with eutrophication processes (Hecky 1993; Green, 1976) in the lake and concomitant changes in algal species composition and abundance reported by Mugidde (1993). Decline in abundance of the large-bodied Cladocera such as daphnids may suggest substantial increase in fish predation associated with drastic changes in fish species composition over the past four decades. Large-bodied, Daphnia lumholtzi 'monacha' is confined to the deep offshore waters (Branstator et al., 1996) where planktivorous fish stock densities are low (Mwebaza-Ndawula 1998).

The atyid prawns, *Caridina nilotica* have increased tremendously in recent decades (Lehman *et al.,* 1994) notwithstanding the low densities recorded in the present study (Table 2). Timing, frequency of sampling operations and the type of gear used (Ponar grab) may have led to underestimation of the prawns. They currently constitute a major forage item for juvenile and sub-adult stages of the Nile perch in the lake (Ogutu-Ohwayo 1990).

Figure 6 is the findings of Corbet (1961) indicate that aquatic invertebrates constitute key forage items for various fishes and are therefore key elements in the flow of energy in the ecosystem and subsequent fish production. High consumption of cyclopoids, which is the most abundant zooplankton group in the lake (Mwebaza-Ndawula 1998, Figs. 1 and 2) by *R. argentea* and larvae of other fishes (Figs.6) suggests that choice of prey may be partly influenced by relative abundance of prey items in the environment. Low consumption of Cladocera and diaptomids by *R. argentea* of the 1990s compared to the 1960s may therefore relate to their current low numerical abundance in the environment (Fig. 3). Flexibility in prey choice as the food environment changes is a useful survival strategy in a fast changing environment like that of Lake Victoria. An additional strategy relating to food resource sharing involves consumption of different proportions from the same combination of prey items as depicted in the diets of larval *R. argentea* (Fig. 5), *Lates niloticus* and cichlids (Fig.6).

The high densities of zooplankton observed in the deep open waters (Figs. 4) do not seem to be efficiently utilised in fishery production as the pelagic fish stock densities offshore are very low (Mwebaza-Ndawula 1998). However, there are indications of recovery of pelagic haplochromines (Tumwebaze 1997) which may channel the offshore zooplankton into fish production.

From food consumption trends observed in the three key zooplanktivores: *R. argentea* larval Nile perch and cichlids, predation pressure is likely to be high on cyclopoid copepods. However, close examination of the composition, abundance and size structure of modern and historic zooplankton (Mwebaza-Ndawula 1998) indicates a measure of stability of copepods and the zooplankton community in general despite profound ecological changes in the lake (Kaufman 1992, Hecky 1993, Witte *et al.*, 1992) since the 1960s. Such ecological stability offers good prospects for sustainability of the pelagic commercial fishery in Lake Victoria.

The Population Structure of the Macro-Zooplankton Community in Southern Lake Victoria (Tanzania)

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INTRODUCTION

Lake Victoria has undergone considerable changes following successful introductions of exotic species, the impact of human activities in the lake basin and climatic changes (Kudhongania & Chitamwebwa 1995, Ochumba 1995). Through the Nile perch predation on the indigenous fish stocks, the original food web has been disrupted- most of the zooplanktivorous fish went missing (Witte *et al.,* 1992). Consequently planktonic food is not fully utilized at present and signs of eutrophication are imminent (Hecky & Bugenyi 1992, Mugidde, 1993).

Because of the changing conditions in the lake corresponding changes in biotic communities are expected to occur, in accordance with their sensitivity and tolerance to the changing abiotic factors.

Unlike the northern part of Lake Victoria where substantial studies on zooplankton have been carried out (e.g. Worthington 1931; Rzoska ,1956 and Mwebaza-Ndawula, 1994), our knowledge on zooplankton in the southern part of the lake rests on the sole study carried out by Akiyama *et al.*, (1977) in the first half of 1970s.

Because of our meagre knowledge of the zooplankton community in the southern part of Lake Victoria and the important role of the this community in the trophic interactions, the Fisheries Research Component of the Lake Victoria Environment Management Project (LVEMP) has included the study of zooplankton as one of the most important subjects of investigation in understanding the functioning and biodiversity of the lake.

The present work was carried out during the biodiversity study cruises done in the southern half of Lake Victoria (mostly in bays and gulfs) where most biodiversity exists) in March, June and September, 1999. Data collected give us an overview of the population structure of the copepods at the time and place where samples were collected and also on the common species. Note that the June cruise took place in only two zones.

MATERIALS AND METHODS

Samples were collected aboard R/V TAFIRI II - a 16-metre boat powered by 150 HP engine equipped with a radar and digital echo sounder. A 118 mm mesh size conical plankton net having an opening of about 25 cm diameter and about a metre in length was used to collect the zooplankton samples. The graduated towing rope and weight attached to the bottom of the net helped to keep the it in vertical position. The net was lowered until it just touched the bottom so

that the upper opening was about a metre off the bottom to avoid collection of mud. The water column through which the net was towed was then estimated from the markings on the tow rope together with the boat`s echo sounder reading. As the net did not have the special collecting device, a glass tube was tightly attached and detached every time a sample was taken. Samples were transferred into plastic bottles (approx. 125 ml) and preserved with 5% formalin.

In the laboratory, the preserved samples were shaken gently by rotating the bottles upside down several times to ensure uniform distribution of the organisms in the bottles before withdrawing a fixed amount of volume that was introduced onto a counting chamber. The animals were examined and counted using an inverted microscope at low magnification and a counting device. Three groups of animals were identified: cyclopoids, calanoids and cladocerans. Furthermore, cyclopoids and calanoids (copepods) were classified into adult females and males, ovigerous females and juveniles (copepodites and nauplii), the latter two being counted together to represent juveniles. Counts from stations in the same sampling zone were averaged and their percentage contribution by group and state (i.e. adult males, females, etc.) calculated.

Identification of animals was carried out much later, during a short course on the subject offered by Dr. L. Mwebaza-Ndawula on a couple of samples.

RESULTS

Tables 1 to 3 present the numerical percentage composition of the copepods and cladocerans from the sampled zones in March, June and September, 1999. Cyclopoids contributed the most, followed by calanoids and cladocerans contributed the least in abundance. During March, the highest contribution of cladocerans was observed in Zone III (Mwanza Gulf), but in September the zone had the least cladoceran contribution. Tables 4 to 6 give the population structure of the copepods with regard to deveolpment stages and sex, during the three surveys. In both groups females generally outnumbered males. In cyclopoids, females were more numerous than both males and juveniles; while in calanoids, the juveniles were the most numerous, as expected. Table 7 gives the common species of the copepods and cladocerans seen.

Table 1. Percentage composition (numerical) of zooplankton groups in southern Lake Victoria in March, 1999.

Zone	Percentage Composition		
	Cyclopoids	Calanoids	Cladocerns
I	77.5	19.6	2.9
II	63.3	33.9	2.8
III	70.9	23.6	5.5
IV	72.3	24.1	3.5
V	70.2	27.8	2.0

Table 2. Percentage composition of zooplankton groups in south eastern Lake Victoria in June, 1999.

Zone	Percentage Composition		
	Cyclopoids	Calanoids	Cladocerans
I	72.8	25.5	1.7
II	79.7	18.5	1.8

Table 3. Percent composition of the three groups of marco-zooplankton during September, 1999.

Zone	Percentage composition		
	Cyclopoids	Calanoids	Cladocerans
I	76.6	22.2	1.2
III	65.7	33.5	0.8
IV	88.4	10.5	1.1
V	80.4	18.3	1.3

Table 4. Population structure (numerical percentage) of copepods southern Lake Victoria in March, 1999

Zone	Percentage Contribution							
	Cyclopoids				Calanoids			
	M	F	OV.	Cop/Np	M	F	OV.	Cop/Np
I	14.9	40.3	3.9	40.9	9.3	18.9	3.0	68.8
II	13.4	36.2	2.6	47.8	12.4	21.0	1.0	65.6
III	25.1	43.8	5.0	26.1	18.7	24.3	3.7	55.3
IV	15.6	41.1	2.1	41.1	4.2	7.6	0.4	87.8
V	27.0	48.2	6.7	18.1	32.0	28.3	8.9	30.8

Table 5. Population structure (numerical percentage) of copepods in southern eastern Lake Victoria in June, 1999

Zone	Percentage Contribution							
	Cyclopoids				Calanoids			
	M	F	Ov	Cop/Np M	M	F	Ov	Cop/Np
I	10.7	50.0	3.5	35.8	12.5	27.3	7.6	52.6
II	12.9	53.0	3.4	30.7	12.8	32.0	5.6	49.5

Table 6. Population Structure of the Copepods in the surveyed zones during September, 1999

Zone	Percentage Contribution							
	Cyclopoids				Calanoids			
	M	F	Ov	Cop/Np	M	F	Ov	Cop/Np
I	17.7	36.2	4.1	42.0	22.0	9.6	2.5	65.9
III	60.4	13.8	1.0	24.8	6.0	7.2	1.2	85.6
IV	20.7	46.9	4.1	28.3	11.8	11.5	2.4	74.3
V	12.7	34.4	2.7	50.2	7.7	7.3	2.5	82.5

Cop/Np = Copepodites/Nauplii
F = Adult Females
M = Adult Males
Ov = Adult Females bearing eggs

Table 7. Some species of macrozooplankton in southern Lake Victoria sampled in March 1999 cruise.

Group	Species
Cyclopoida:	*Thermocyclops* spp. *Tropocyclops* *Mesocyclops*
Calanoida:	*Thermodiaptomus galeboides* *Tropodiaptomus struhlmanni*
Cladocera:	*Ceriodaphnia cormuta* *Bosmina ligirostris* *Diaphanosoma* sp. *Moina dubia* *Alona* sp.

DISCUSSION

An earlier study of zooplankton in the southern Lake Victoria showed that the copepods (cyclopoids and calenoids) were the most numerous; the cladocerans were the least in abundance (Akiyama *et al.*, 1977). The present results show that the same trend still holds and seems to be a lakewide phenomenon (Mavuti and Litterick 1991, Mwebaza-Ndawula 1994). Comparing recent (1990s) data with historical (1930s and 1950s) ones, Mwebaza-Ndawula (1994) noted that there have been some changes in the zooplankton composition. There has been a decline in abundance of the cladocerans and calanoids- the former drastically from a contribution of about 50% to the less than 5% in offshore waters. In the southern part, Akiyama et al. (1977) obtained a count of up to 30 individuals of cladocerans per litre. No such density was encountered in this study but the highest cladoceran contribution (5.5%) among he studied zones was obtained from the same area (Mwanza gulf) in the March survey.

The juvenile cyclopoids, which are the most numerous elsewhere (Mwebaza-Ndawula 1994), did not feature so prominently in this study (Tables 4 to 6). Obviously, the large meshes (100 µm) of the net used did not effectively retain the small cyclopôid nauplii. Hence the dominance of the females instead of juveniles as it happened to the larger calanoids.

From the common species list (Table 7), although the cladocerans are numerically the least, they are potentially more or less diverse as the other groups on the generic level. With regard to the numerical dominance of the small cyclopoid species, Mwebaza-Ndawula (1994) attributes this to the changes in the trophic structure in the lake, following successful introductions of exotic fish species and eutrophication resulting from increased human activities within the lake's catchment area. These changes favour the dominance of small-bodied organisms over the large-bodied ones. To monitor these changes, sampling stations ought to be established in the area in order to carry out regular, long-term monitoring work.

In conclusion, the present study shows that the macrozooplankton community in southern Lake Victoria is dominated by the cyclopoid copepods and that the cladocerans are the least abundant group like elsewhere on the lake.

Daily Phytoplankton Intake by Fish Before the Ecological Changes in the Mwanza Gulf, Lake Victoria

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SUMMARY

Biomass and trophic composition of fish in the sublittoral area of the Mwanza Gulf before the ecological changes in the 1980s were estimate. The calculations were based on catch data from bottom trawls and from gill nets covering the whole water column. The standing fish stock in the total column was approximately 580 kg ha^{-1} and more than twice as high as the demersal stock. Haplochromine cichlids accounted for 96 % of the standing stock. Phytoplanktivores and detritivores made up respectively ca. 17 and 30 % of the total ichthyomass. The total phytoplankton intake of fishes was estimated at ca. 230 mg dry weight m^2 day^{-1}. It was not possible to estimate the impact of grazing by fish on phytoplankton densities due to the lack of data on phytoplankton production in the area. However, after the 1980s the densities of phytoplanktivorous fish were so low that the impact of grazing was negligible.

INTRODUCTION

In the 1980s, dramatic changes occurred in the fish community of Lake Victoria. In the sublittoral and offshore waters, the Nile perch Lates niloticus (L.), an introduced predator, increased in abundance until it made up more than 90% of the demersal fish catches. Simultaneously, the haplochromine cichlids, which used to make up more than 80% of the catches, almost vanished (Ogutu-Ohwayo 1990, Barel *et al*., 1991, Witte *et al*., 1992a). In the sublittoral waters of the Mwanza Gulf, the standing stock of bottom dwelling fish dropped by a factor of five and the trophic diversity of the fish fauna decreased strongly (Witte *et al*., 1999). The phytoplanktivores and detritivores that had previously dominated the ichthyomass in sublittoral areas disappeared almost completely (Goldschmidt *et al*., 1993, Witte *et al*., 1999).

Due to human activities, eutrophication of the lake has increased since the 1920s (Hecky 1993). During the past two decades in particular, algal blooms and shifts towards Cyanobacteria (blue-green algae) dominance have been observed (Ochumba & Kibaara 1989, Lehman & Branstrator 1993, Mugidde 1993, Verschuren *et al*., 1998). Decomposition of algae that had sunk to the bottom caused a serious decrease in dissolved oxygen concentration and occasional mass fish kills (Ochumba & Kibaara 1989, Kaufman 1992, Hecky *et al*., 1994). In the Mwanza Gulf, increased algal blooms and decreased water transparency and oxygen concentrations were observed a few years after the Nile perch upsurge (Witte *et al*., 1992b, 1999, Wanink *et al*.,

2001). It has been suggested that, in addition to eutrophication, the eradication of phytoplanktivorous fish by overfishing and Nile perch predation may have caused the increase in algal blooms (Kilham & Kilham 1990, Hecky & Bugenyi 1992, Goldschmidt *et al*., 1993, Ochumba 1995, Ogutu-Ohwayo 1999). However, thus far no attempt has been made to quantify the original biomass of phytoplanktivorous fish and their potential impact on phytoplankton. In the present study we determine the trophic composition and biomass of the major fish taxa in the entire column of the sublittoral waters of the Mwanza Gulf. We estimate the daily intake of phytoplankton by fish in the area using these data and data on the ingestion rate of related fish species from Lake George (Moriarty *et al*., 1973).

MATERIALS AND METHODS

We used the following sources to estimate biomass and trophic composition of the fish stocks in the sublittoral areas of the Mwanza Gulf before the ecological changes:

1. Bottom trawl catches by MV Mdiria (120 hp, head rope 25 m, cod end mesh 20 mm). 30 hauls of 45 min were made during daytime between January 1978 and February 1979 in the northern part of the Mwanza Gulf (depth range 6-18 m) Fig 1. Samples of 2-2.5 kg, containing 400-600 fishes, were sorted to species and trophic group.
2. Gill net catches during eight days and nights between 17 August 1981 and 18 July 1982 at the 14-15 m deep station G. Fig 2. A fleet of normal gill nets consisted of a bottom, a mid-water and a top set net, each of 60 m long and 1.5 m deep. The nets were composed of 6 panels of 10 m each, with mesh size of 2.5 cm (1"), 3.8 cm (1.5"), 5.1 cm (2"), 2.5 cm, etc. In addition a vertical gill net covering the entire water column was used. This net had a height of 15 m, a width of 5 m and a mesh size of 2.5 cm (Goudswaard *et al*., 1995). Gill nets were set between 10.00-16.00 h during the day, and between 22.00-04.00 h at night.

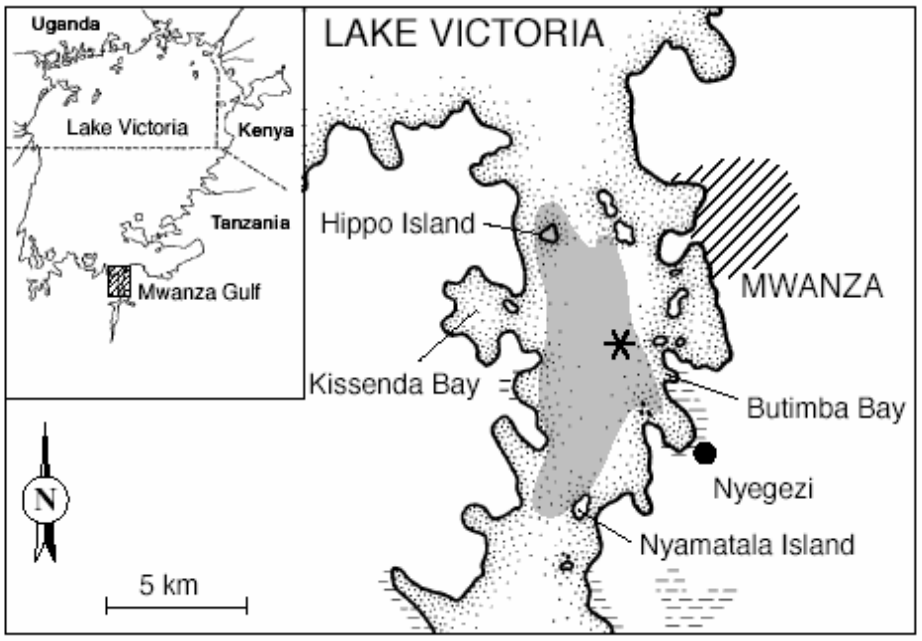

Fig. 1: Map of the study area in the Northen part of the Mwanza Gulf. Shaded area was fished with bottom trawls from January 1978 - February 1979. Asterisk indicates station G where gill nets were set between August 1981 and July 1982.

MV Mdiria fished with a head rope of 25 m and made a speed of 3.5 nautical miles per hour (1 nautical mile = 1852 m). The swept area was calculated as:

(25 x 0.33) x (3.5 x 1852) = 53476.5 m^2 h^{-1}

The correction factor 0.33 for the net opening is based on estimates that have been made for the gear of MV Kiboko in the same area (W. van der Hak, pers. comm.). The effective net opening of bottom trawls is considerably smaller in the soft mud bottom of the Mwanza Gulf than on more firm bottoms.

The trophic composition of the catches was estimated by splitting up the haplochromine and other fish species according to the main components in their diet (e.g. Corbet 1961, Witte 1981, Goldschmidt *et al*., 1990, 1993, Witte *et al.*, 1992b). The mean weight of individuals per trophic group was calculated from 15 samples from bottom trawl catches. This resulted in correction factors that were used to convert percentage trophic composition groups based on numbers to percentage composition by weight.

We calculated the trophic composition in both vertical and normal gill nets from the numbers of haplochromine cichlids in the catches per 24-h session. The mean of the percentages over eight 24-hour sessions (n = 16, 8 for each net type) was used as the percentage composition in the entire column. As in the bottom trawls this was converted to percentage weight composition, using the above mentioned correction factors.

RESULTS

Bottom trawls

The mean catch rate of haplochromines with MV Mdiria during 1978/79 was 1138 kg h^{-1}, which is 212.8 kg ha^{-1}. Detritivores made up about 60% of the total number of fish in these catches, zooplanktivores about. 30%, insectivores 3% and the other groups each less than 1% (Table 1).

Table 1. Haplochromine composition in bottom trawls in the sublittoral area of the Mwanza Gulf in 1978/79. The percentage of the number (% nr) of fishes in the catch was transformed into percentage of weight (% wt) by a correction factor (corr.) for weight per trophic group. The catch rate per hour (kg h^{-1}) and the biomass per hectare (kg ha^{-1}) were calculated from the percentage of weight.

Group	% nr	corr.	% wt	kg h^{-1}	kg ha^{-1}
Detritivores	63.1	1	54.6	620.9	116.1
Phytoplanktivores	0.2	1	0.2	2.0	0.4
Zooplanktvores	30.4	1	27.1	307.9	57.6
Insectivores	3.1	3.5	9.7	109.9	20.6
Molluscivores	0.7	3.5	2.2	24.8	4.6
Piscivores	0.9	3.5	2.8	31.9	6.0
Prawn eaters	0.1	2	0.2	2.0	0.4
Rest	3.8	1	3.4	38.5	7.2
Total				**1138**	**212.8**

Individuals of species belonging to phytoplanktivores, detritivores and zooplanktivores, had a mean weight between 5 and 6 g. Mean individual weight of the prawn eaters was approximately twice as high. That of insectivores (of the '*empodisma*' group, Hoogerhoud & Witte, 1981), molluscivores and piscivores about three and a half times as high. Correction for weight revealed a contribution to the catch of 2-3% for piscivores as well as molluscivores and of almost 10% for insectivores (Table 1). Zooplanktivores and detritivores made up, respectively, ca. 27 and 55% of the catch weight. From these weight percentages and the mean catch rate for all haplochromines together, the demersal biomass ha^{-1} per trophic group was calculated.

Table 2. Total fish biomass in the sublittoral area of the Mwanza Gulf calculated from the trophic composition in the total column in 1981/82 and the demersal biomass derived bottom trawl catches in 1978/79 (see text). The biomass of the other demersal taxa (the phytoplanktivorous *Oreochromis* spp., the molluscivorous *Protopterus* and the piscivorous *Lates, Bagrus* and *Clarias*) is based on bottom trawls only. The biomass of the pelagic zooplanktivore *Rastrineobola argentea* is based on data from Wanink *et al*. (this volume).

	Haplochromines			Other taxa	Total
Group	% No. in column	% weight	kg ha^{-1}	kg ha^{-1}	kg ha^{-1}
Detritus	37.7	31.1	174.2		174.2
Phytoplankton	21.6	17.7	99.9	1.9	101.8
Zooplankton	30.0	24.8	138.7	5.2	143.9
Insect	5.1	14.7	82.5		82.5
Molluscs	0.9	2.6	14.6	7.2	21.8
Piscivorous	1.9	5.5	30.7	6.6	37.3
Prawn	1.3	2.1	12.0		12.0
R. argentea	1.6	1.3	7.4		7.4
Total			560.0	20.9	580.9

In the above calculations we only considered haplochromine cichlids, which made up 93.1% by weight in the bottom trawl catches in 1978/79. The biomass of the demersal, non-haplochromine trophic groups, derived from the same trawl catches are given in Table 2. The contribution of the small, pelagic, zooplanktivorous cyprinid *Rastrineobola argentea* (Pellegrin) has been estimated with other gear at 5.2-kg ha^{-1}.

Gill nets

Compared to the trawl catches, which were estimated to cover only the bottom 1 - 2 m of the column, the gill net catches revealed a relatively large group of phytoplanktivorous haplochromines (Table 2). These fish were living near the surface (Fig. 2; Witte 1984, Goldschmidt *et al*., 1993) and, consequently, were rarely caught in bottom trawls. A considerable part of the zooplanktivores also occurs in the column outside the range of bottom trawls (Witte 1984, Goldschmidt *et al*., 1990).

The catchability per trophic group differed depending on gill net type and time of the day. (Fig. 2) Vertical nets had higher catches at night (total 2388) than by day (total 326). The reverse was observed in the normal gill nets (totals 1628 v 2660 respectively). This might be caused by differences in migration direction: more horizontal during the day and more vertical at night, when many fish occur higher into column. Diurnal and nocturnal activity patterns also differ between trophic groups (F. W. pers. obs.). Therefore, both the horizontal and vertical gill net catches from day and night were used to calculate the mean percentage composition (in numbers and weight) of the haplochromine trophic groups in the entire column (Table 2).

The bottom dwelling detritivores, which dominated the trawl catches by day, were used to calculate the biomass of the haplochromine trophic groups in the entire column. From the vertical distribution in the gill net catches, it was estimated that, during daytime, bottom trawls (up to 2 m above bottom) caught approximately two third of the detritivores in the area covered. Therefore, the total biomass of this group was estimated at:

$$3/2 \times 116.1 \text{ kg ha}^{-1} = 174.2 \text{ kg ha}^{-1}$$

The biomass of detritivores comprised 31.1% of the total haplochromine biomass in our study area (Table 2). From the fractions of the other trophic groups we calculated their biomass as well as the total standing stock of the haplochromines (560 kg ha^{-1}). By adding the biomass of the non haplochromines, the total fish biomass in the Mwanza Gulf was established at 583.3 kg ha^{-1}.

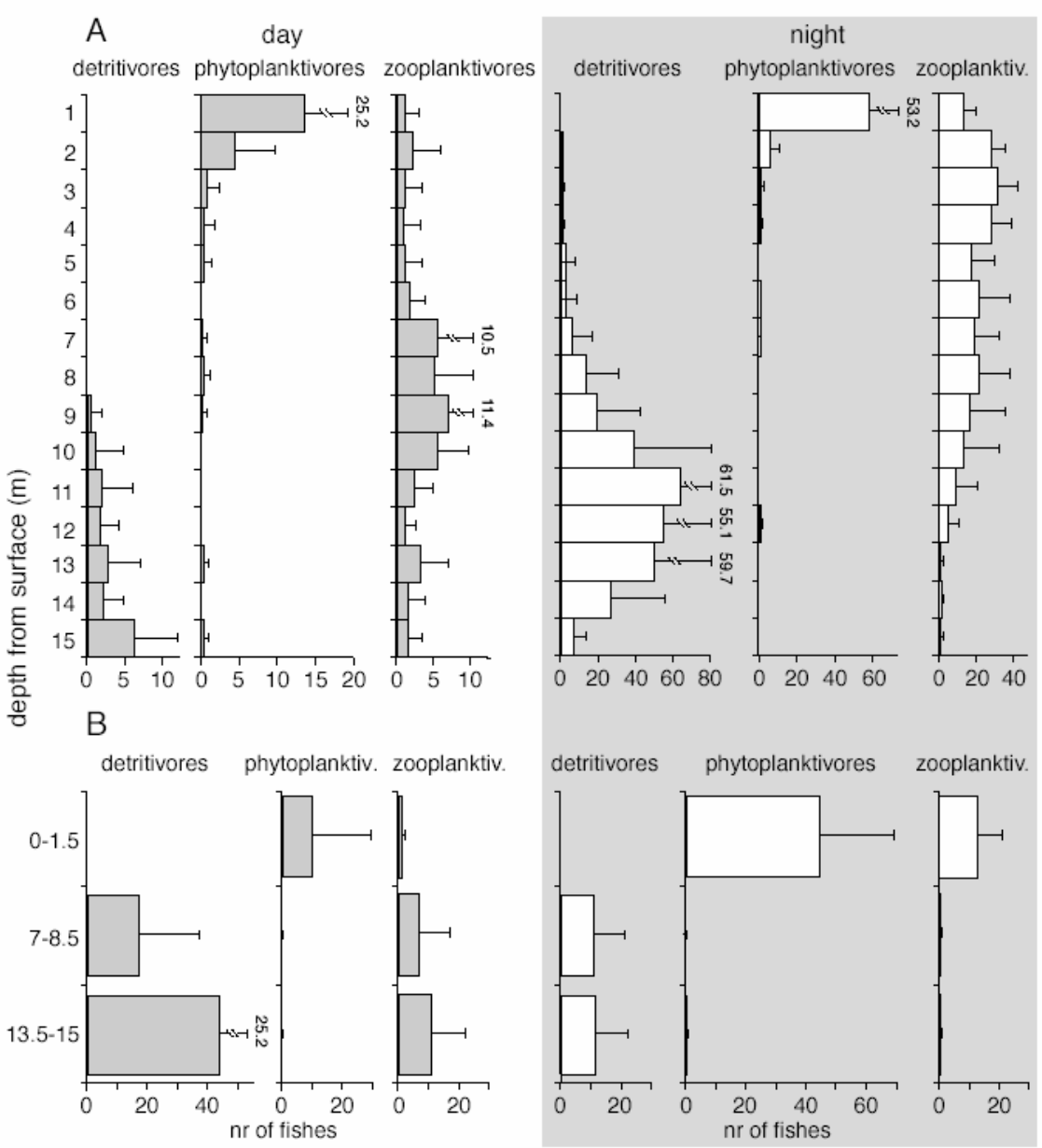

Fig. 2. Mean catch rates and one standard deviation in gill nets during 8 days and 8 nights between August 1981 and July 1982. Mean number of fishes at each depth, are given per 10 m^2 in (A) vertical gill nets covering the whole column and (B) horizontal gill nets at three depths in the column.

Phytoplankton consumption

To estimate phytoplankton consumption we used the formulae of Moriarty et al., (1973) who calculated ingestion rates based on diurnal changes in dry weight of stomach and intestine contents, for the two main phytoplanktivorous fish species of Lake George: H. (*Enterochromis*) *nigripinnis* Regan and *Oreochromis niloticus* (L.). The ingestion (I) in mg dry weight was established as:

I = - n29.6+21.9B, for *H. nigripinnis* from 5-8 cm total length (TL)

I = n271 +13.3B, for *Oreochromis niloticus* from 15-23 cm TL

In which n = number of fish, B = biomass (fresh weight) in g. The detritivorous and phytoplanktivorous haplochromines of Lake Victoria are similar to *H. nigripinnis* in both size and shape. According to Kudhongania & Cordone (1974b), the *Oreochromis* catches in the 1970s in the Mwanza Gulf were a mixture of *O. esculentus* (Graham), *O. variabilis* (Boulenger) and *O. niloticus*. Their mean length was 25 cm (Goudswaard *et al*., unpublished), which is larger than in Lake George.

The number of fish per m^2 (n) was calculated from the mean weights of the different groups and their biomass per m^2 (B) (Table 3). When calculating the ingestion rate we took into consideration that phytoplankton was only a part of the diet in most species. The detritivores in bottom trawls consisted for 63% of so-called curved heads (a group of closely related species including H. (E.) *cinctus* Greenwood & Gee; see Goldschmidt *et al.*, 1993), and for 37% of H. (E.) "*nigrofasciatus*". The respective diets of these species comprised about 10 and 25% phytoplankton, mainly *Aulacoseira* (= *Melosira* in Goldschmidt *et al.*, 1993). The diet of phytoplanktivore H. (?) "*kribensis*" was made up of about. 90% phytoplankton (the Cyanobacteria *Microcystis* and *Anabaena* and the diatom *Aulacoseira*; Goldschmidt *et al*., op. cit). The same percentage was estimated for the *Oreochromis* species, which are reported to feed predominantly on phytoplankton, either from the column or after sedimentation (Lowe-McConnell 1956, Welcomme 1967, Fryer & Iles 1972, Trewavas 1983). The most common zooplanktivore H. (*Yssichromis*) heusinkveldi Witte & Witte-Maas, that made up 46% of the zooplanktivores in the bottom trawls, included a considerable amount (20-40%) Cyanobacteria in its diet (Goldschmidt *et al.*, 1990). Therefore, we included it in our calculations. The total ingestion rate of phytoplankton by all species mentioned above is estimated at 230.4 mg dry weight m^{-2} day^{-1}.

Table 3. Parameters for calculation ingestion rate (see formula in text). From indi vidual fresh weight and biomass m^{-2} (B) the number of fish m^{-2} (n) was calculated. The ingestion rate was corrected for the volume percentage of phytoplankton present in the diet of the different taxa.

Trophic group/ species	Indiv. wt (g)	Biomass (B)g m^{-2}	No. of fish (n) m^{-2}	% phyt. in diet	Ingestion (I)mg dry wt $m^{-2}d^{-1}$
Detritus Curved head group	5.8	10.97	1.89	10%	18.4
H. (E.) "nigrofasciatus"	5.8	6.45	1.11	25%	27.1
Phytoplankton H. (?) "kribensis"	5.8	9.99	1.72	90%	151.0
Oreochromis spp.	300	0.19	0.0006	90%	2.1
ZooplanktonH (Y.) heusinkveldi	5.6	6.38	1.14	30%	31.8
Total		230.4			

DISCUSSION

Sources of error

The assumptions on the gape of the trawl net may strongly influence the biomass estimates. We used a correction factor 0.33. During a lake-wide bottom trawl survey with MV Ibis (Kudhongania & Cordone 1974a,b) the effective fishing width of the most frequently used net, with a headrope of 24 m, was about 9 m (Bergstrand & Cordone 1971), implying a correction factor of 0.37. However, it has been suggested that a correction factor of 0.67 should be used (G. Kukowski, unpublished). Using the latter value in our study would imply a reduction of the fish biomass and the phytoplankton ingestion rates by a factor two. The height of the net opening of ca. 2 m, is also an assumption. The fact that even in water of 2 m depth the floats of the net did not reach the surface supports this assumption. Bergstrand & Cordone (1971) suggested a gape height 2.3 m for the nets of MV Ibis, which does not differ much from our estimate.

Our assumption that 2/3 of the detritivores were caught in bottom trawl nets during the day, is conservative. In the normal gill nets this value approached 2/3. It should be noted, however, that these nets did not sample the depth range of 8.5 - 13.5 m. In the vertical net at daytime about half of the detritivores were caught in the bottom 2 m, and about 2/3 in the bottom 3 m.

We also took a conservative measure of the speed of MV Mdiria. Most studies used a speed of 2.5-3 nautical miles h^{1} (Bergstrand & Cordone 1971, Muller & Benda 1981, Goudswaard 1988). Kukowski (unpublished) estimated the speed of MV Mdiria at 3.5 nautical miles h^{1}, which we used here. Using a speed of 3 miles would increase all results by 14%.

We did not consider possible differences in encounter rates with gill nets, nor differences in selectivity for different trophic groups. Detritivores and phytoplanktivores are probably slower moving fish than zooplanktivores, and may thus have lower encounter rates with gill nets. This may be balanced by the fact that zoplanktivores are somewhat more slender and consequently have a greater chance to pass through the smallest (2.5 cm) mesh.

Moriarty *et al.*, (1973), remarked that the equation for the ingestion rate of phytoplankton in *H. nigripinnis* is only an approximate guide because insufficient data were available for one of the parameters on the rate of stomach emptying. Further, the mean size of the *Oreochromis* species in Lake Victoria was larger than the size range for which Moriarty *et al*., (1973) established the equation, which may underestimate their ingestion rate. The total grazing rate of phytoplankton in the Mwanza Gulf was likely to be higher than calculated because: (1) Many species allocated to other trophic groups included some phytoplankton in their diet (Witte 1981, 1984, Witte & van Oijen 1990). (2) In 1978/79 the *Oreochromis* densities, and thus their grazing rates, in the Mwanza Gulf were approximately ten times lower than at the end of the 1960s (Kudhongania & Cordone 1974b). (3) The haplochromines in the bottom trawl catches of MV Mdiria had decreased by 17%, from 1370 kg h^{-1} (1974/75) to 1138 kg h^{-1} (1978/79).

The importance of including fish stocks from the entire column

The fish biomass in the sublittoral area of the Mwanza Gulf (212.8 kg ha^{-1} for the demersal and

580.9 kg ha^{-1} for the total ichthyomass) is rather high compared to other estimates for Lake Victoria. Kudhongania & Cordone (1974a) estimated 102.8 kg ha^{-1} for the demersal stocks in Tanzanian waters at the end of the 1960s. The difference is probably caused by the fact that Kudhongania & Cordone also included deep, offshore waters in their calculations. Further, they partly used 38 mm mesh size cod ends, which miss part of the small detritivores and zooplanktivores. In the shallow (<4m) Lake George the mean total fish mass was estimated at 22.7 g fresh weight m^{-2} (Burgis *et al*., 1973), which is less than half that which we found for the Mwanza Gulf (58 g f.w. m^{-2}). Also the biomass of phytoplanktivorous fish (8.3 g f.w. m^{-2}) was lower in Lake George (Greenwood 1976) than in the Mwanza Gulf (Table 3).

In contrast to most other studies dealing with composition and standing stocks of fish taxa in Lake Victoria (e.g. Kudhongania & Cordone 1974ab, Benda 1981, Muller & Benda 1981, Witte 1981, Goudswaard 1988, Okaronon 1994, but see Goldschmidt *et al*., 1993), we considered the fish in the entire column. Many researchers regarded the abundant haplochromines as strictly demersal fish. However, research in the Mwanza Gulf showed that this is not correct (Witte 1984, Goldschmidt *et al*., 1990, 1993). Including the fish from the entire column results in a 2.6 times higher biomass and a remarkable increase in phytoplanktivorous haplochromines. This knowledge is essential for a proper understanding of the pre-Nile perch ecosystem. This does not only hold for the situation before the 1980s, but also for the current system. Recent studies revealed that some species of zooplanktivorous haplochromines are recovering and are now common in the catches of the *Rastrineobola* fishermen (Witte *et al*., 2000).

The impact of grazing pressure

The major part of the diet of pelagic phytoplanktivorous cichlids consists of cyanobacteria, which were shown to be digestible at stomach pH values below 2.0 (Moriarty *et al*., 1973). The foregoing estimates on the biomass and ingestion rates of the haplochromine cichlids in the 1970s makes it unlikely that they had no impact on phytoplankton densities and composition in the lake. However, as we have no data on the phytoplankton production in dry wt m^{-2} day^{-1}, it is not possible to estimate the degree of impact. In Lake George the total daily intake of phytoplankton has been estimated at 34 mg cm^{-2} for the fish and 504 mg cm^{-2} for zooplankton (Moriarty *et al*., 1973). Thus the impact of fish was small compared to that of zooplankton. Our results show that the daily intake by fish in the sublittoral waters of Lake Victoria (230.4 mg dry wt m^{-2}) was more than twice as high as in Lake George (103 mg dry wt m^{-2}). The standing crops of phytoplankton in Lake Victoria were, and still are, much lower (chlorophyl-a 1.2-15 mg m^{-3} in the 1960s and 8.4-67.1 mg m^{-3} in 1989/90; Mugidde 1992) than in Lake George (chlorophyl-a 150-350 mg m^{-3}; Greenwood 1976). This suggests that the relative impact of phytoplankton grazing by fish in the Lake Victoria before the 1980s may have been greater than in Lake George.

Whatever the impact of grazing by fish may have been in the past, after the ecological changes it seemed to be negligible. By the end of the 1980s, the only phytoplankton feeding fish in the study area was *O. niloticus*. The mean catch rate in the bottom trawls was 0.8 kg h^{-1} (Ligtvoet *et al*., 1995), which equals to 0.24 kg ha^{-1} and to a phytoplankton intake of only 0.3 mg dry wt m^{-2} day^{-1}. In this calculation the proportion of phytoplankton in the diet of *O. niloticus* was kept at 90%.

However, studies in the northern part of the lake showed a strong reduction in this proportion (Balirwa 1998). Experimental manipulation of crustacean abundance in 1992 in the northern part of the lake failed to produce any detectable effects of grazing by zooplankton as well (Lehman & Branstrator 1992). Thus, whereas eutrophication increased, grazing rates of both fish and crustaceans seems to be extremely low currently. Unless other organisms make use of the phytoplankton in Lake Victoria, the current fate of a major part must be decomposition in deep water or in the surface sediments.

CONCLUSIONS AND RECOMMENDATIONS

a) Including pelagic and surface dwelling fish in ecological studies strongly affects the estimates of standing stocks and trophic composition and is therefore crucial for a proper understanding of Lake Victoria's ecosystem.

b) Considering the whole column in the sublittoral area of the Mwanza Gulf revealed a high biomass of phytoplankton feeding fish. These fishes virtually disappeared after the ecological changes in the 1980s. Because they may show some recovery with the decline of Nile perch, they should be monitored.

c) For firm conclusions on the degree of impact of phytoplankton grazing by fish in the past, a proper knowledge of the phytoplankton production and the daily intake by other organisms, such as zooplankton and benthic organisms is needed.

d) Currently the impact of phytoplankton grazing by fish in the Mwanza Gulf is negligible.

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Changes in Biomass and Predation Pressure of Zooplanktivorous Fish in the Sublittoral Waters of the Mwanza Gulf of Lake Victoria

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SUMMARY

The biomass of zooplanktivorous fish in the Mwanza Gulf of Lake Victoria decreased considerably between 1973 and 1989. The decline in haplochromine cichlids, following increased fishing effort and upsurge of the introduced predatory Nile perch, was not counterbalanced by the rise of the cyprinid dagaa (Rastrineobola argentea). Zooplanktivorous juvenile Nile perch accounted for only a negligible fraction of the total biomass. Hence, the overall predation pressure on zooplankton will have decreased. However, the changed species composition of the zooplanktivorous fish community may have affected the various zooplankton groups differently through selective predation.

INTRODUCTION

Between 1978 and 1982, more than 110 haplochromine cichlid species were found in the sublittoral part of Lake Victoria's Mwanza Gulf (Witte, 1981; Witte *et al*., 1992). At least 15 of these were zooplanktivores (Witte 1984; Goldschmidt & Witte, 1990; Goldschmidt, *et al*., 1990), forming about 25% of the local bottom trawl catches (Witte, 1981; Witte & Goudswaard, 1985). The only non-haplochromine zooplanktivore in the lake, the cyprinid dagaa, *Rastrineobola argentea* (Pellegrin), was also common in the Mwanza Gulf, though less abundant than the haplochromines (Goldschmidt *et al*., 1993).

In 1983 the numbers of the introduced Nile perch, *Lates niloticus* (L.), started to rise in the Mwanza Gulf, after which an explosive increase occurred during 1984-1985 (Barel *et al*., 1991). The upsurge of this large predator coincided with a strong decline of the haplochromines, and by 1987 almost 100 species had vanished from the sublittoral waters (Witte *et al*., 1992). By then, dagaa were practically the only native zooplanktivores found in this area, while juvenile Nile perch had appeared as a new zooplanktivorous species (Ligtvoet and Witte, 1991; Wanink, 1991). The numerical abundance of dagaa had increased by a factor of ten, due to a combination of factors including competitive release and earlier reproduction (Wanink, 1999).

The increase in dagaa in the lake has been assumed to be greater than the decrease in haplochromine zooplanktivores, causing intensified predation on zooplankton (Gophen *et al*., 1995). This could explain changes in the zooplankton community, which was formerly dominated by large calanoids and cladocerans, while small cyclopoids contributed more than 95% after the Nile perch boom (Mavuti & Litterick 1991; Mwebaza-Ndawula, 1994; Gophen *et al*., 1995). No support for this assumption above was found in the Mwanza Gulf, where the increase in dagaa biomass did not compensate for the loss of haplochromines (Wanink, 1998), even though biomass (expressed as kg h^{-1}) was estimated from trawling without accounting for variations in the vertical distribution of the fish. In this paper we estimate the total biomass of zooplanktivorous fish (expressed as kg ha^{-1}) in the sublittoral waters of the Mwanza Gulf between 1973 and 1989, with haplochromines, dagaa and small Nile perch as separate components. We discuss possible effects of species composition changes in the zooplanktivorous fish community on the predation pressure on individual groups of zooplankton.

MATERIALS AND METHODS

Biomass (fresh weight; kg ha^{-1}) of haplochromine zooplanktivores was calculated from daytime bottom trawls, using the swept area method. Day- and night-time gill net catches over the whole water column were used to partly correct for pelagic distributions. Details of the methods are given in a companion paper.

During 1973-1983 data were collected on a weekly basis by MV Mdiria (120 hp, speed 3.5 knots, head rope 25 m, cod end mesh 20 mm, 2-3 hauls of 45-90 min per trip) in the northern part of the Mwanza Gulf (depth 6-18 m). After 1983, MV Kiboko (105 hp, speed 3 knots, head rope 18 m, cod end mesh 20 mm, at least 4 hauls of 30 min per trip) sampled on a monthly basis at station G (depth 14 m), inside the operational area of MV Mdiria. A constant value (27.1%) was used for the weight proportion of zooplanktivores in the haplochromine catches before 1984. Thereafter, annual values were calculated from catches made during March-May (Wanink, 1991).

Zooplanktivorous Nile perch (TL ≤ 5 cm; Ogari and Dadzie, 1988; Katunzi *et al*., unpublished data) in the trawl catches were counted per 1-cm size class. Numerical catch rates (n h^{1}) were converted to dry weight (DW), using the formulas TL = 1.22 SL + 0.17 (TL and SL in mm) and in DW = 3.349 in SL - 6.777 (DW in mg, SL in mm), which are based on small (8-99 mm SL) Nile perch (Wanink & Goudswaard, 1994). Next, fresh weights were calculated from FW = 4.464 DW (Douthwaite, 1976). The vertical distribution of zooplanktivorous Nile perch was estimated from catches with monofilament gill nets of 12.5 mm stretched mesh, which caught sizes ranging between 4.0 and 6.7 cm TL (n = 528; mode: 4.7 cm; 52% ≤ 5 cm). Nets were set at station G during daytime for periods of 2-4 h between 12 May and 13 September 1987. Normal gill nets (height 1.5 m; length 15 m), set at the surface, mid water and the bottom, were used three times, and vertical nets (height 14 m; width 5 m), covering the whole water column, five times.

Dagaa used to be a pelagic species, but the adults became daytime bottom dwellers after the collapse of the haplochromines. Since no change was observed in their surface dwelling behaviour at night, dagaa were sampled by nightly surface trawls, using a small boat (25 hp, speed 3 knots, beam 4.5 m, cod end mesh 5 mm) at station G. A total number of 79 hauls of 10 or 15 min was made between December 1981 and April 1989. The sub-adult part of the population moves away from the surface at night (Wanink, 1998). To correct for this, the contribution of nightly surface trawls to lumped day- and night catches by the same gear was calculated. This was done for 6 days between 1982 and 1988 on which both day- and night-time surface trawls were made. To correct for the fraction of the adult population missed by the nightly surface trawl, which fished the top 1 m only, we used catch results of the vertical gill nets set at station G on six nights in 1987 and 1989. Although it is known that the sub-adults concentrate in the upper part of the water column by day (Wanink, 1998), the exact vertical distribution could not be measured. We have assumed that the daytime distribution of the sub-adults resembled the nightly distribution of the adults and used the same value for the fraction present in the top 1 m.

RESULTS

Vertical distribution of zooplanktivorous fish

Most haplochromine zooplanktivores and adult dagaa occupied the upper part of the water column at night, but there was a difference in their relative abundance in the layer sampled by the surface trawl net. Catches in vertical gill nets showed that 7.6 ± 5.4% (n = 8; total number of fish = 904) of the haplochromines and 31.0 ± 13.7% (n = 6; total number of fish = 6859) of the adult dagaa were dwelling in the top 1 m at night. Comparison of day- and night trawls revealed that 56.4 ± 10.1% (n = 6; total number of fish = 21476) of the total number of surface dwelling dagaa over the 24-h cycle was present in the nightly catches.

Since only 15 Nile perch were caught during five daytime fishing runs with vertical gill nets, the data were pooled before analysis. The proportion caught in those three parts of the net comparable to the normal gill nets (set at the surface, midwater and the bottom) was 73.3%. This was used as a correction factor for the catches of the normal gill nets. Sixty percent of the total catch in the vertical nets was caught in the lower 1.5 m. This was used as an additional estimate to the three catches of the normal gill nets. The average proportion of zooplanktivorous Nile perch present in the lower 1.5 m of the water column by day amounted to 53.7 ± 10.2% (n = 4; total number of fish = 41).

Changes in zooplanktivore biomass

Between 1973 and 1983 the bottom trawl catches gradually decreased. Assuming a constant proportion of 27.1% zooplanktivores in the haplochromine catch during this pre-Nile perch period (Witte et al., this volume), the biomass of haplochromine zooplanktivores decreased from about

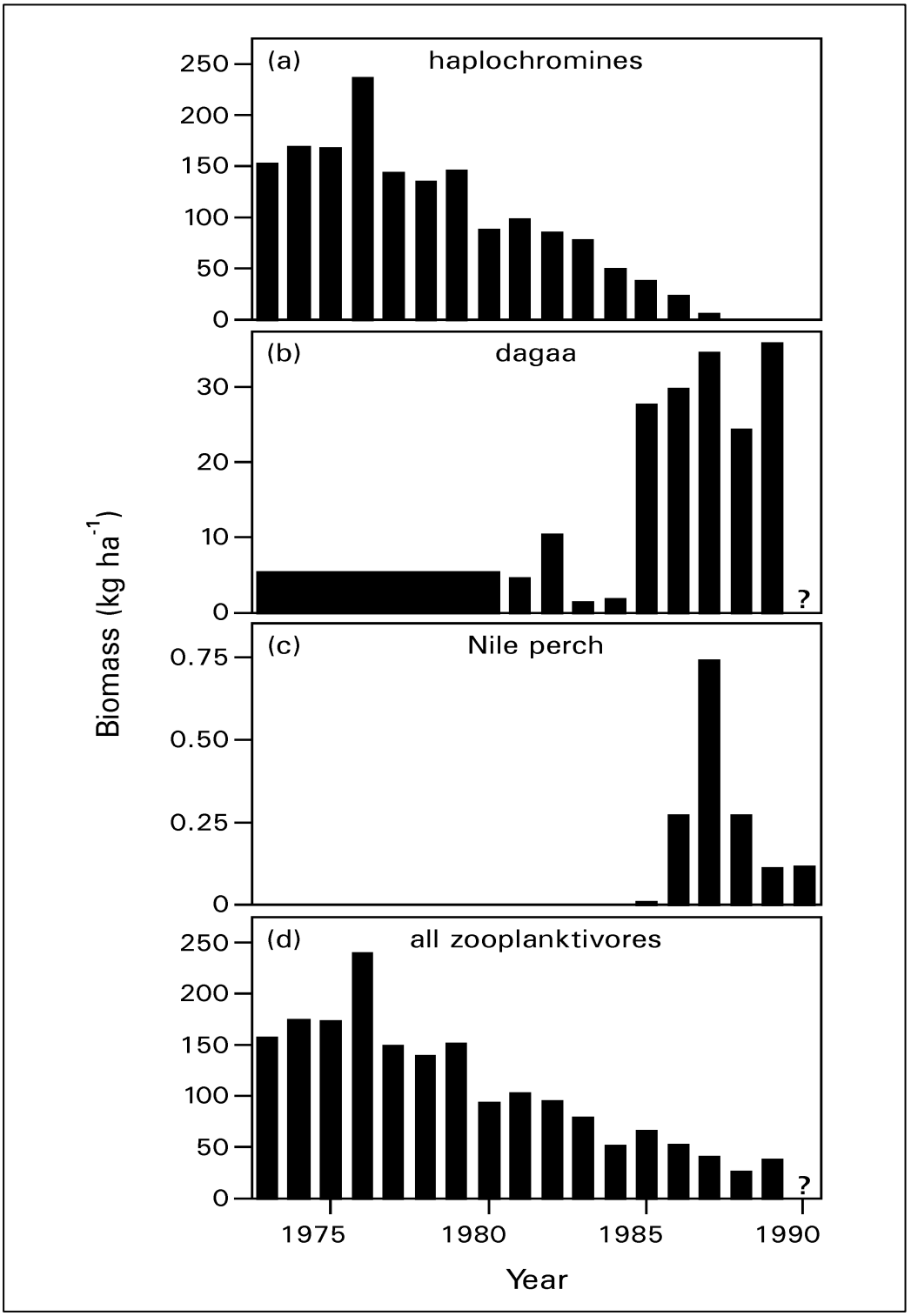

Fig. 1. Changes in the biomass of zooplanktivorous fish in the sublittoral waters of the Mwanza Gulf between 1973 and 1990.

160 to 80 kg ha^{-1} (Fig. 1a). From 1984 till 1987 the mean annual proportion of zooplanktivores in the haplochromine catches increased to 30, 34, 50 and 98% respectively. However, in spite of this relative increase, there was a rapid decline in biomass until virtually no haplochromines were caught anymore between 1988 and 1990 (Fig. 1a).

The weight of dagaa in one floating trawl made in 1981 and two made in 1982 was 16%, 50% and 34% of that of the zooplanktivorous haplochromines respectively. Dagaa biomass in those years was estimated from these percentages and the calculated values for haplochromine zooplanktivore biomass, 64.2 kg ha^{-1} in 1981 and 55.5 kg ha-1 in 1982 (Fig. 1a), corrected for the proportions of haplochromines (7.6%) and dagaa (31.0%) dwelling in the top 1 m at night and the proportion of surface dwelling dagaa present in nightly trawl catches (56.4%). For 1981, the thus calculated dagaa biomass amounted to $(0.16 \times 0.076 \times 64.2) / (0.564 \times 0.31) = 4.5$ kg ha^{-1}. Using the same method, an average value of 10.1 kg ha^{-1} was obtained for 1982. Combining the biomass estimates for 1981 and 1982 with the published increase in the catch rate of dagaa (kg h^{-1}) in nightly surface trawls made in the study area (Wanink, 1999), gave the annual biomass data for the period 1981-1989 (Fig. 1b). Assuming that there was no consistent trend in dagaa biomass before the explosive population increase of Nile perch in the area during 1984, the average biomass over the period 1981-1983 (5.2 kg ha^{-1}) was taken as an estimate for the period 1973-1980 (Fig. 1b).

Zooplanktivorous Nile perch first appeared in the study area in 1985. Their biomass increased strongly, from 0.003 kg ha-1 in 1985 to a peak value of 0.74 kg ha^{-1} in 1987 (Fig. 1c). Thereafter, the biomass decreased to 0.11 kg ha^{-1} at the end of the study period in 1990. Notwithstanding the appearance of Nile perch as an additional zooplanktivore and a six-fold increase in dagaa biomass, the total zooplanktivore biomass decreased between 1973 and 1989 (Fig. 1d). This was due to the relatively low contributions of dagaa and Nile perch. The highest biomass figures for these two species during the study period were only about 20 and 0.5% respectively of the biomass of haplochromine zooplanktivores in the early 1970s.

DISCUSSION

Sources of error

As discussed in a companion paper (Witte *et al*., this volume), our assumptions concerning the gear used to sample haplochromines up to 1983 suggest that the estimates of their biomass are conservative. In contrast, comparing the weight of dagaa in nightly surface trawls during 1981-1982 to the weight of haplochromine zooplanktivores may have resulted in overestimation of the *dagaa* biomass. Direct calculation from the swept area by the surface trawl gave a lower value. The mean catch rate was 1.83 kg h^{-1}. With a net opening of 4.5 m and an estimated speed of 3 nautical miles, correcting for the catchable proportion of the population, this would result in a biomass of 4.2 kg ha^{-1}. Our estimate from the same three samples amounted to 8.2 kg ha^{-1}. However, with the floating trawl only the top meter, or even less, was sampled, and disturbance by the engine may have influenced the catches negatively.

Our assumption that the depth distribution of sub-adult dagaa by day resembles that of the adults by night may have caused another error. In our calculations we have used a value of 31% for the proportion of the sub-adult population dwelling in the top 1-m by day. Using a value of 100% would reduce the estimated dagaa biomass by a factor 2.1. A value of 5% would increase the estimates by a factor 1.7.

Zooplanktivore biomass and predation pressure

No support was found for the hypothesis that the rise of dagaa has increased zooplanktivore biomass and, subsequently, the predation pressure on zooplankton (Gophen *et al.*, 1995). Mean dagaa biomass during 1987-1989 was 31.5 kg ha^{-1}. Even if this were a five-fold underestimation, total zooplanktivore biomass would not have increased, as the average value for haplochromine zooplanktivores in the early 1970s amounted to 160-kg ha^{-1}. The five-fold drop in zooplanktivore biomass between 1973-1975 and 1987-1989 (Fig. 1d) implies a comparable reduction in overall predation pressure on zooplankton. However, there are no indications for a change in overall zooplankton densities in the Mwanza Gulf during our study period.

Effects of changed species composition

Despite a reduction in overall predation pressure, individual groups of zooplankton may have been affected differently by the changed species composition of the zooplanktivores, due to interspecific differences in selective predation. There are some indications for selective predation on calanoids by haplochromine zooplanktivores in the sublittoral part of the Mwanza Gulf (Goldschmidt, 1989; Goldschmidt *et al.*, 1990; Wanink, 1998). During 1983-1984, dagaa at station G showed a slight preference for cladocerans, avoided calanoids and mainly took the most abundant cyclopoids (W. Hoogenboezem unpublished). At that location, dagaa took cyclopoids almost exclusively during 1987-1988 (Wanink,1998). In the same period, zooplanktivorous Nile perch in the Mwanza Gulf took copepods mainly and showed an ontogenetic shift in main prey type from cyclopoids to calanoids (Katunzi *et al.*, unpublished).

From the decline of the haplochromines, the concomitant rise of dagaa, and the minor role as a zooplanktivore played by Nile perch, an increase in the relative predation pressure on the cyclopoid copepods may be expected. Unexpectedly, the proportion of cyclopoids in the zooplankton of Mwanza Gulf increased from 71% in 1973 to 88% in 1989, while the calanoids decreased from 24% in 1973 to 8% in 1989 (Wanink, 1998). However, the level of 88% cyclopoids had been reached already by 1983, before the rise of dagaa. Also on a lakewide scale, the reported shift in the zooplankton composition from calanoids and cladocerans to cyclopoids (Mwebaza-Ndawula, 1994; Gophen *et al.*, 1995) appeared to be well on the way long before the changes in the zooplanktivorous fish community (Wanink, 1998). Conceivably a better knowledge of the food preferences of haplochromine zooplanktivores and dagaa might have provided an explanation for the relative increase of cyclopoids in the Mwanza Gulf. The recent resurgence of two formerly common species of haplochromine zooplanktivores in the Mwanza Gulf (Witte *et al.*, 2000) offers a possibility to fill some gaps in our knowledge.

CONCLUSIONS AND RECOMMENDATIONS

a) After the disappearance of the haplochromine zooplanktivores from the sublittoral waters of the Mwanza Gulf during the 1980s, the increase in dagaa and the appearance of zooplanktivorous Nile perch did not counterbalance the decline in zooplanktivore biomass.

b) The increase in *dagaa* could not explain a reported shift in zooplankton composition.

c) Although the changes in the zooplanktivorous fish community apparently had little effect on the zooplankton, knowledge of food preferences of the different species is too limited to be conclusive.

d) The resurgence of two haplochromine zooplanktivores should be used to study the food preferences of haplochromines, dagaa, and their possible interactions and their combined effects on the zooplankton.

ACKNOWLEDGEMENTS

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Recent Changes on the Artisanal Fishery of Lake Victoria, Kenya with Emphasis on Spatial Distribution of Catch and Effort

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SUMMARY

Catch and effort assessment surveys to determine trends in the landings, species composition, effort and methods of fishing on the artisanal fishery of Lake Victoria (Kenyan sector) was carried out between 1976 and 1999 on five to fifteen sampled boats. Sources of bias are assessed and corrections are discussed. Total landings reached a maximum of 200 000 t annually between 1989 and 1991 and CPUE increased to 180 kgs boat day-1 in 1989 but decreased thereafter with increasing effort. A Schaefer model for gillnets suggests the MSY for Kenyan waters is 48 000 t for 580 000 boat days and 86 000 t at an effort of 445 000 boat days for mosquito seines implying a 30% on gillnet effort.

Increase in effort was stimulated by expanding Nile perch stock and partly by demand. Evidence on niche changes of the fish species in the lake suggests that stability has not yet been realised. The sources of bias were; unstratified non-random sampling and inadequately trained enumerators.

INTRODUCTION

Management of fisheries relies on an underlying knowledge of stock abundance and population parameters (Cowx 1996), for which a well organized catch data collection system is required. This needs knowlegde of the structure of the fishery, proper design of the survey, auditing checks and accurate reporting of the results. Catch assessment surveys to determine trends in the landings, species composition, methods of fishing and demand for fish and their products are vital for management of fisheries.

Lake Victoria, shared by Tanzania, Uganda and Kenya, lies between longitude 0^0 30' N and 2^0 20' S and latitudes 31^0 40' and 34^0 50' E. The lake has a surface area of 68,680 km^2 , with a catchment area of about 200,000 km^2. In the early 1980s changes in the Lake Victoria fishery occured by (Okemwa 1981 and Ssentongo & Welcomme 1985). The lake's fisheries have subsequently become dominated by catches of *Lates niloticus* (L) and *Rastrinebola argentea* (Pellegrin) (Rabour 1989, 1991; Othina & Osewe 1995, 1996).

To assess the dynamics of the fishery for management purposes, a catch assessment survey was established by EAFRO but has been undertaken by KMFRI since late 1970's. This has provided catch data since 1976 but these are considered biased because of a number of problems with the system put into place. The present study reviews catch trends since 1976, examines trends found for the future management of the fishery.

METHODS

On each day of sampling catches were recorded from 15 boats selected randomly from the targeted landing site. 23 of the 256 Kenyan landing sites (Fig. 1) were covered by the survey. Selection of the landing sites was influenced by factors such as presence of infrastructure and accommodation for enumerators and bicycles were also provided for sites which did not have these facilities. Parameters recorded for each sampled fishing boat were the number of crew, gear type, and size, time and duration of fishing. Catches were sorted into species and weighed (nearest kg).

After data auditing in the KMFRI office, monthly catches were estimated as follows:

AC = CPBD x FD x B / 1000, where AC is the average monthly catch (t), CPBD is the mean catch per boat-day (kg), FD is the number of fishing days in a month (i.e. 28, 29, 30 or 31), and B is the mean number of boats fishing daily (i.e. mean ratio of number of boats landing on beach divided by number of boats recorded on beach in the previous frame survey, multiplied by total number of fishing craft recorded on the Kenyan coastline in the frame survey).

Effort in boat days by the different fishing gears was calculated by raising sampled boat days to total annual figure as above, and CPUE, as mean catch per boat per day, was estimated as the arithmetic mean of sample CPUEs. Prior to 1989 there were no raw data available and effort and CPUE, which were not separately calculated at the time of collection and reporting, could not be estimated retrospectively.

RESULTS

Total landings in the last two decades changed markedly, reaching a maximum of 200,000t annually between 1989 and 1991 (Fig. 2). This was followed by a downward trend in *L. niloticus* catches, while those of *R. argentea* leveled off. Other species, including tilapiines and haplochromines have shown small increases in recent years (Fig. 2).

Effort, expressed in boat days, increased for all gears (Table 1), but CPUE showed consistent declines (Table 2). CPUE increased to 180 kg boat-day^{-1} in 1989, but in recent years has dropped to a mean of about 80 kg-day^{-1}. Mosquito seines landings increased from 25% of the total catch in 1987 to 50-60% since 1994, while the gillnet contribution declined from over 50% to 20% in the same period (Fig. 3). The long line contribution halved, while the contribution of beach seines continued to be high despite a ban on their use.

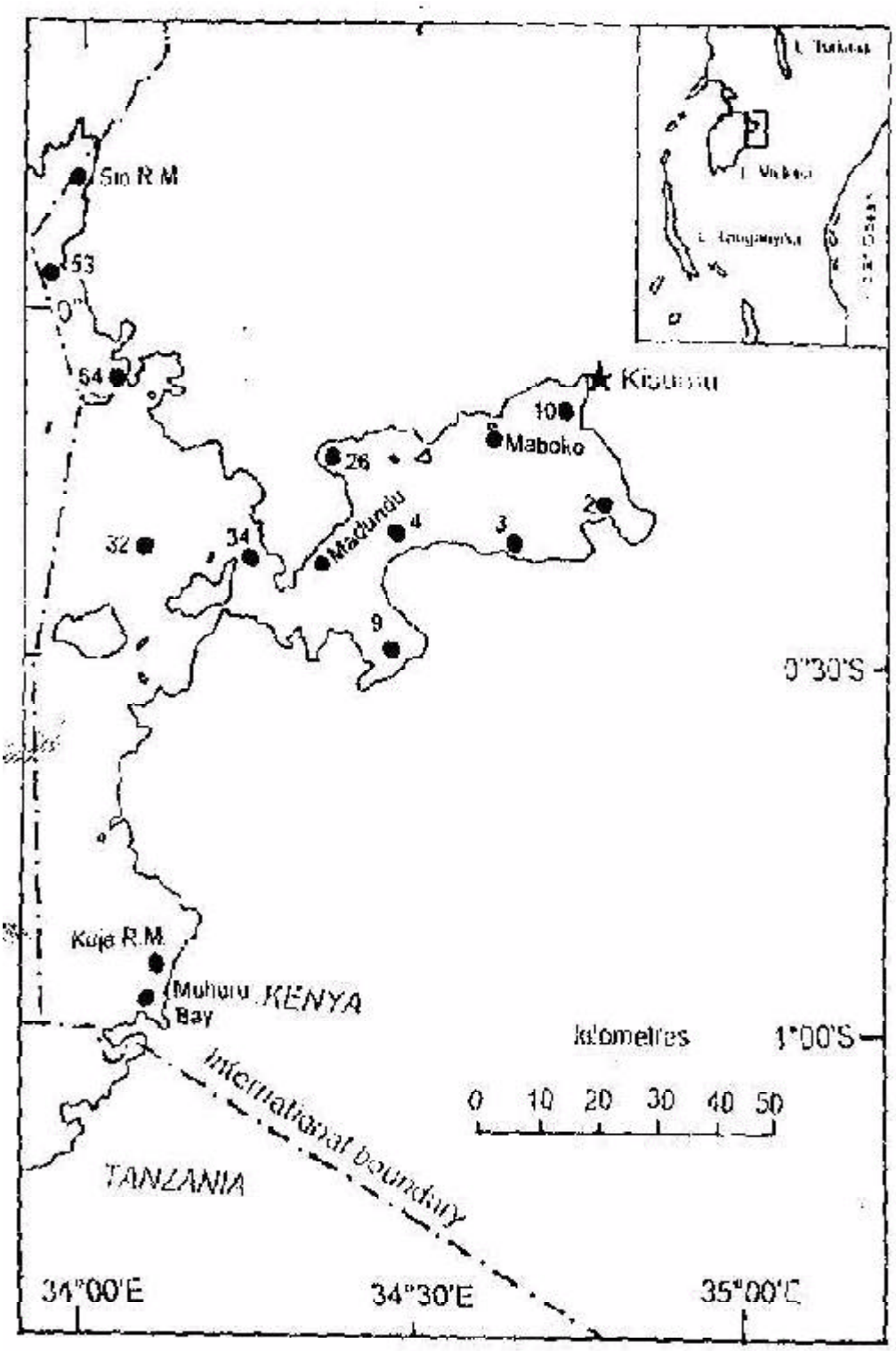

Fig. 1. Map of Kenyan waters of Lake Victoria showing the sampling grid used in the trawl survey.

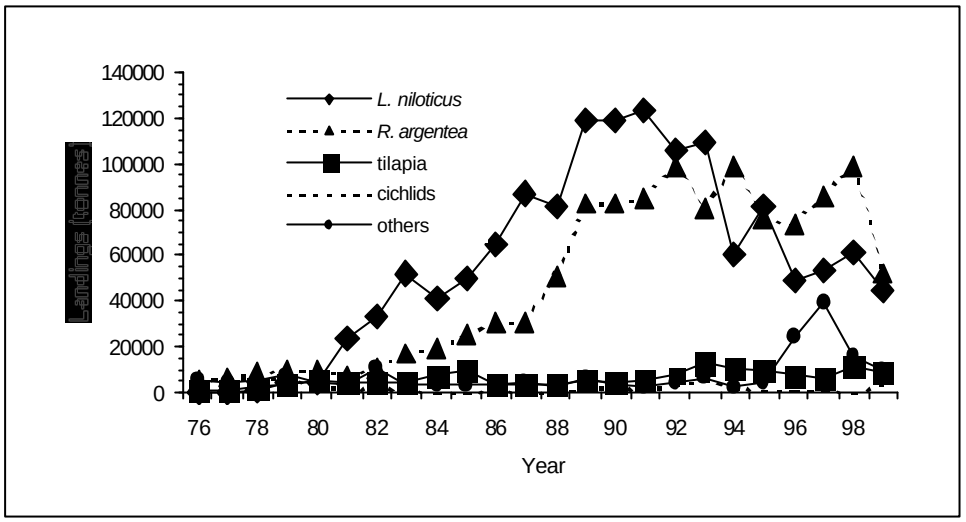

Fig. 2. Total landings in metric tonnes for the major commercial species

Table 1. Annual effort (boat days x 1000) for the main gears used in Kenyan Lake Victoria fisheries.

Year	Gillnet	Long line	Beach seine	Mosquito Seine	Total
1989	677	79	161	336	1250
1990	742	102	194	349	1387
1991	670	217	243	366	1496
1992	743	232	206	425	1606
1993	901	256	223	482	1862
1994	1295	295	209	629	2428
1995	795	362	226	625	2007
1996	833	207	432	499	1971
1997	781	337	242	647	2008
1998	828	338	368	657	2190
1999				535	1781

There were marked declines in CPUE in the gill net and mosquito seine fisheries with increasing effort (Fig. 4a, b). In the mosquito seine fishery, which targets *R. argentea*, the catch and effort trends were investigated using the biomass dynamics model (Punt & Hilborn, 1996) to fit the Schaefer model, using the catch and effort data from 1989 to 1998. The model suggests the MSY for Kenyan waters is 86,000 t with a corresponding effort of 445,000 boat days. The gill net data were more difficult to evaluate using the biomass dynamic model but suggested an MSY of 48 000t at an effort of 580,000 boat days.

Table 2. Annual CPUE (kg boat day $^{-1}$) for the main fishing gears used in Kenyan Lake Victoria fisheries.

Year	Gillnet	Long line	Beach seine	Mosquito Seine
1989	151.2	67.4	402.8	266.3
1990	92.3	63.9	449.8	240.8
1991	66.9	59.8	339.2	221.4
1992	64.6	44.3	301.7	220.2
1993	45.5	43.1	222.3	203.8
1994	36.4	64.8	68.3	274
1995	41.0	30.9	118.7	147.4
1996	67.3	42.5	108.7	113.8
1997	58.9	45.5	120.6	133.7
1998	47.3	53.8	164.7	164.4
1999	44.0	35.3	118.1	148.6

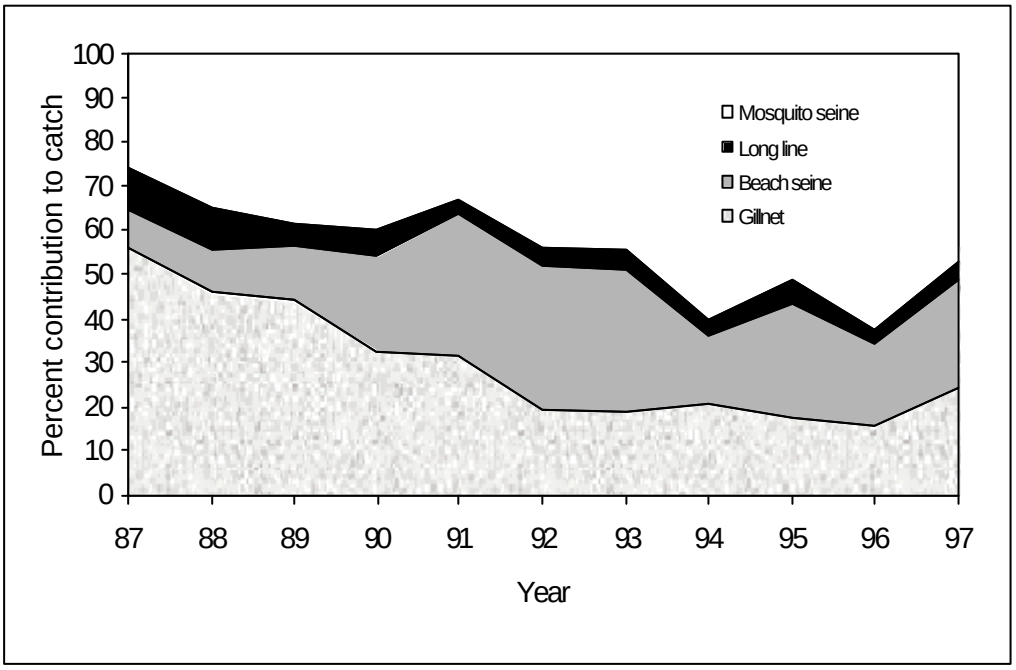

Fig. 3. Percentage contribution by major fishing gears

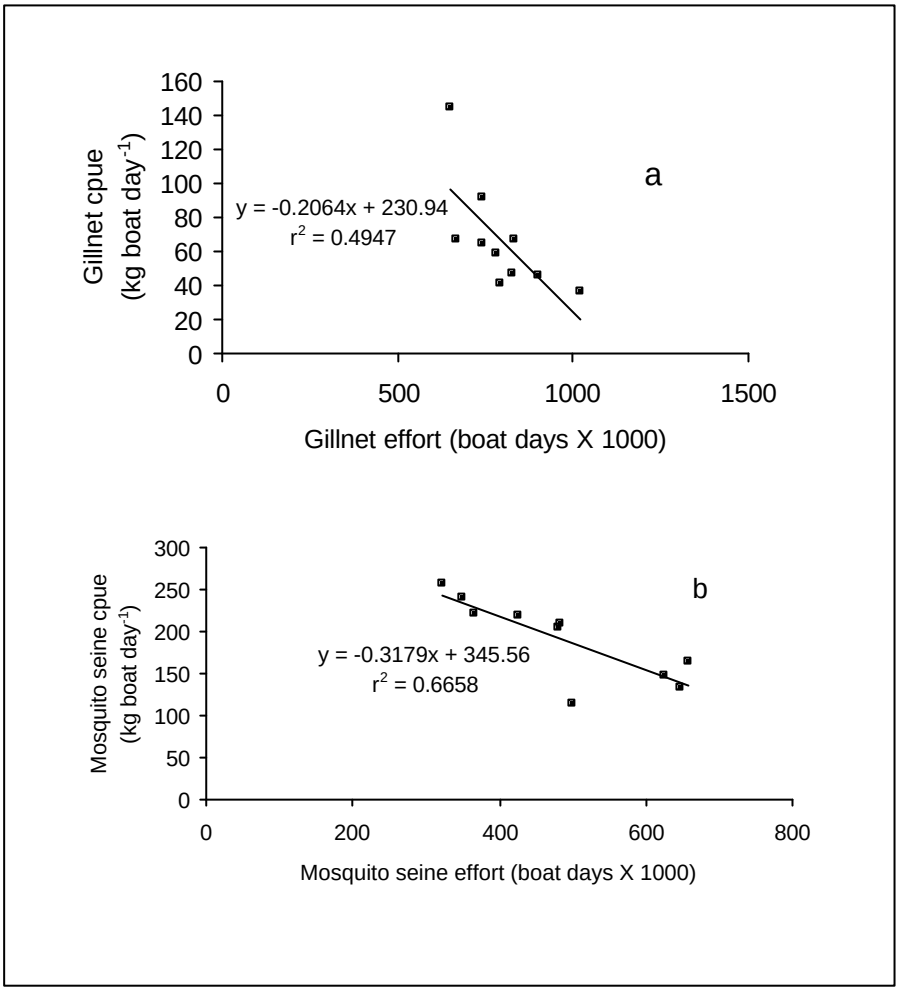

Fig. 4a & b. Effort against landings for the major fishing gears

DISCUSSION

The catches in the Kenyan waters of Lake Victoria have changed since the Nile perch population explosion in the early 1980s. The increase in the Nile perch catches has been well documented (Okemwa, 1981; Ssentongo & Welcomme, 1985; Rabuor 1989, 1991). Rabour & Polovina (1995) also showed the increase in landings upto 1991 which they attributed entirely to increasing effort, and they expressed concern about the expanding fishery. They stated that the fishery stock were not in equilibrium and suggested that a substantial decline in catches could be expected. The scenario of increasing effort leading to increased catches did indeed take place but the direct link to fishing effort is an over-simplification. Whilst effort did increase (detailed effort and CPUE data prior to 1989 have been lost but records show that CPUE increased annually from 82kg boat day^{-1} in 1986 to 180kg boat day^{-1} by 1989), it was stimulated by the expanding Nile perch stock at that time. The trends found show that the concerns of Rabour and Polovina (1995) were well founded (Fig. 2). Catches declined despite a continued increase in effort and by 1998 were half those of the beginning of a decade.

The situation in the gillnet fishery is worse than the data suggest. Effort is expressed in boat days and does not consider the amount of gear per boat. Rabour and Polovina (1995) noted that mesh sizes were getting smaller, nets were longer and soak times were increasing. These changes in fishing strategies are responses to declining catch rates and trends have continued although evidence to support this is anecdotal. In addition, gillnets are now actively fished by drifting. Increased overall effort and decreased mesh sizes tend to lead to increased fishing mortality and reduce the size and age at recruitment, but it is not possible to show this in the effort and CPUE data collected up to the present.

The extent to which the various factors have contributed to the decline in Nile perch catches is difficult to assess. There has been a measurable decline in CPUE in terms of catch per boat coupled with the increase in effort. Unfortunately, detailed information on number and type of gears in use is poor. The stock expansion of Nile perch in the 1980's resulted in very high, but unsustainable catches by the end of the decade, and it is not yet known whether the ecology of the lake and the fish population structure are approaching relative stability or are still in astate of flux after the radical and rapid changes in the ecology of the lake in the 1980s. Evidence on niche changes of the fish species in the lake (Agullo 1999; Njiru 1999) suggests that stability has not yet been realised. Further empirical evidence is being gathered under the LVFRP to investigate the trophic status of the lake.

The extent of fish migration between Kenya and the other two riparian countries, and hence the impact of fishing effort in those countries on the stocks in Kenya, is unknown. An additional factor in the assessment of the Kenyan fishery is the unknown extent of cross-border fish trade with Uganda and Tanzania. Some fish caught in Ugandan and Tanzanian waters may be recorded landing on Kenyan beaches because of differences in pricing policies and market demand between the countries.

Because of these uncertainties, which are currently under investigation, only tentative conclusion can be drawn. There is, however, no doubt that the Nile perch fishery is overfished. The tentative estimate of effort to produce MSY i.e. 580 000 boat days, was exceeded by an average of 50% annually since 1993. As an initial step in controlling the gillnet fishery, the number of gillnet-carrying boats needs to be reduced by about 30% and a minimum mesh size of 127mm (5") must be enforced (Schindler *et al*., 1998).

A common trend in heavily exploited fisheries is a decline in use of large meshed gears used to catch adult , larger, high valued species and an increase use of small-meshed gears for smaller, less valuable species. The fisheries of Lakes Malombe and Malawi are examples from African lakes which show similar fishery changes (Tweddle *et al*. 1994, 1995; Turner 1995). The Kenyan Lake Victoria fishery exhibits these classical changes associated with overfishing (Fig. 3). The contribution of the two gears targeting large fish, gillnets and long lines has declined, while the small-meshed beach seine and mosquito seine fisheries have increased in importance. The beach seines catch large quantities of juveniles of the larger commercial species. They are also used in

important inshore breeding and nursery areas and are thus particularly destructive. Despite a lake-wide ban on beach seines, their use continues to increase in Kenya.

The mosquito seine targets the small pelagic cyprinid *R. argentea*. Mosquito seine fishery effort continues to increase but catches have stabilised and CPUE has declined. The biomass dynamic model suggests that effort is now about 40% higher than the 445 000 boat days which produces MSY. A spread in the use of mosquito seines to previously unfished grounds has been observed since 1994. This may affect assessments of yield if fish migrations are limited in this species, thus caution is needed in interpretation of the results. No further development of this fishery should be considered in those areas already exploited, while expansion to unfished areas should be carefully monitored.

The catch data (Fig. 2) for 'other species' suggests a marked rise in 1996/97 and a decline in 1998. The 1998 decline may be partially attributed to the revised system for sub-sampling mixed juvenile catches and attributing the catches to the correct species. Also included in 'other species' are the lungfish, *Protopterus aethiopicus* (Heckel), and the air-breathing catfish, *Clarias gariepinus* (Burchell). It is believed that these species have benefited through being able to take refuge under the large mats of water hyacinth, *Eichhornia crassipes* (Mart.) Solms, as a result of their tolerance of low oxygen levels under the mats. This hypothesis is under investigation.

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Assessment of catch and effort for *Lates niloticus* (L.), *Oreochromis niloticus* (L.) and *Rastrineobola argentea* (Pellegrin) using fisheries-dependent data from Tanzania waters of Lake Victoria

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SUMMARY

A study on the catches, effort, exploitation rates and size structure of three commercially important fish species, Lates niloticus, Oreochromis niloticus and Rastrineobola argentea that are potentially fished by artisanal fishermen of Lake Victoria, Tanzania part was carried out in Kagera, Mwanza and Mara beaches from October 1997 to July 1999.

Beaches for sampling were selected based on prior knowledge of their importance of the fish landings. Total number of boats on the beach and those that went out fishing were recorded. The catches were sorted into species and size compositions and grouped by regions.

The poorest catches were found in Mwanza region, whilst higher catches were recorded in the other two regions (Kagera and Mara). Oreochromis niloticus was caught by 1"-9" mesh sized gillnets, handlines and longlines with hook size 7 to 12. There was a modal progression from 29-30 cm in April to 36-37 cm TL in July. A considerably greater number of smaller fish were caught in June 1998 and June 1999. Lates niloticus were caught by gillnets with mesh sizes ranging from 4.5" to 7" and longlines of hook size numbers 7 to 13. There was a decline in the modal length of the fish landed, in June 1998 and June 1999. The mean length of fish captured by gill netting was 46 cm TL, and 55 cm by long lining. Rastrineobola argentea was caught by seine nets and lift nets. The fish landed exhibited a modal length of 52-mm TL. Around July to September more than one peak was observed from 45 mm to 58 mm TL respectively.

The use of encircling gillnets and splashing to capture O. niloticus should be prohibited. The majority of L. niloticus caught were below the size at first maturity. This shows that overfishing was prevalent in the fishery. It is suggested that longlines should be encouraged rather than the gillnets of less than 7". The size distribution of R. argentea exploited by the gear (lift nets and seine nets) had modal length above 50 mm TL, which is the size of mature R. argentea observed in Uganda waters. A more detailed research on R. argentea fisheries and its biology in the Tanzanian part of the lake is needed.

INTRODUCTION

The best approach to management of inland fisheries depends heavily on the availability of some

measures of fish stock abundance or associated population parameters on which to formulate the decision-making process or evaluate the impact of a particular management activity (Cowx, 1996). Stock assessment is considered necessary to gauge the effects of activities such as the impact of overfishing, pollution event, land drainage improvement works, river regulation, habitat restoration, stocking, introduction of new species or to merely respond to requests for advice on the management of waters.

Traditionally, two methods of stock assessment are used, based on fishery dependent and fishery independent data. Beach surveys, based on the former, are complimentary to experimental, fishery independent surveys as a method of collecting data to assess the impact of fishing on the stock size.

For statistical reasons, the Tanzania Fisheries Department collects fishery-dependent data. However, the strategy lacks rigor and the data exhibit deficiencies which make their use questionable. Irrespective of the use of fishery-dependent methods, data collection is extremely valuable for identifying exploitation patterns and catch characteristics. Consequently, a pilot study was set up to investigate the exploitation of the three main commercial species in the Tanzania part of Lake Victoria (Nsinda & Mrosso, 1999).

As a result of this pilot study a more comprehensive catch assessment programme was established. The paper provides the output for the first few months of the revised programme and is the forerunner to annual reports on the fishery.

MATERIALS AND METHODS

During the pilot survey, three beaches, Kayenze, Chole, and Igombe (Fig.1), were selected for sampling on the bases of accessibility and their importance for the *Lates nuloticus*, *Oreochromis niloticus* and *Rastrineobola argentea* fisheries. Four trips were made to each beach in October 1997, and February, June and September 1998. The number of boats, number that were idle and those that went out fishing were recorded. For each beach as many active boats as possible were sampled to determine the type of gear, means of propulsion, number and mesh size of the nets. The catch of each boat was sorted into species and recorded. Length (to the nearest cm below) and weight (to the nearest g) measurement of the entire sample or sub sample of *L. niloticus* and *O. niloticus* were taken from each sampled boat. For *R. argentea,* a sample of 0.125 kg was taken and preserved in 5% formalin for analysis in the laboratory.

The revised beach surveys were conducted in three areas: A - Mwanza to Bunda; B - Mara, and C - Kagera between April and July 1999. Five beaches in Kagera area, and seven each from the Mwanza and Mara areas were selected (Fig. 1) on the basis of their importance either for *Lates niloticus*, *Oreochromis niloticus* or *Rastrineobola argentea* fisheries. Due to resource limitations, the surveys were done on a quarterly basis; i.e. all the beaches in a particular area were sampled on a three-monthly rotation. In this complementary survey, sampling on the beaches was the same as in the pilot survey.

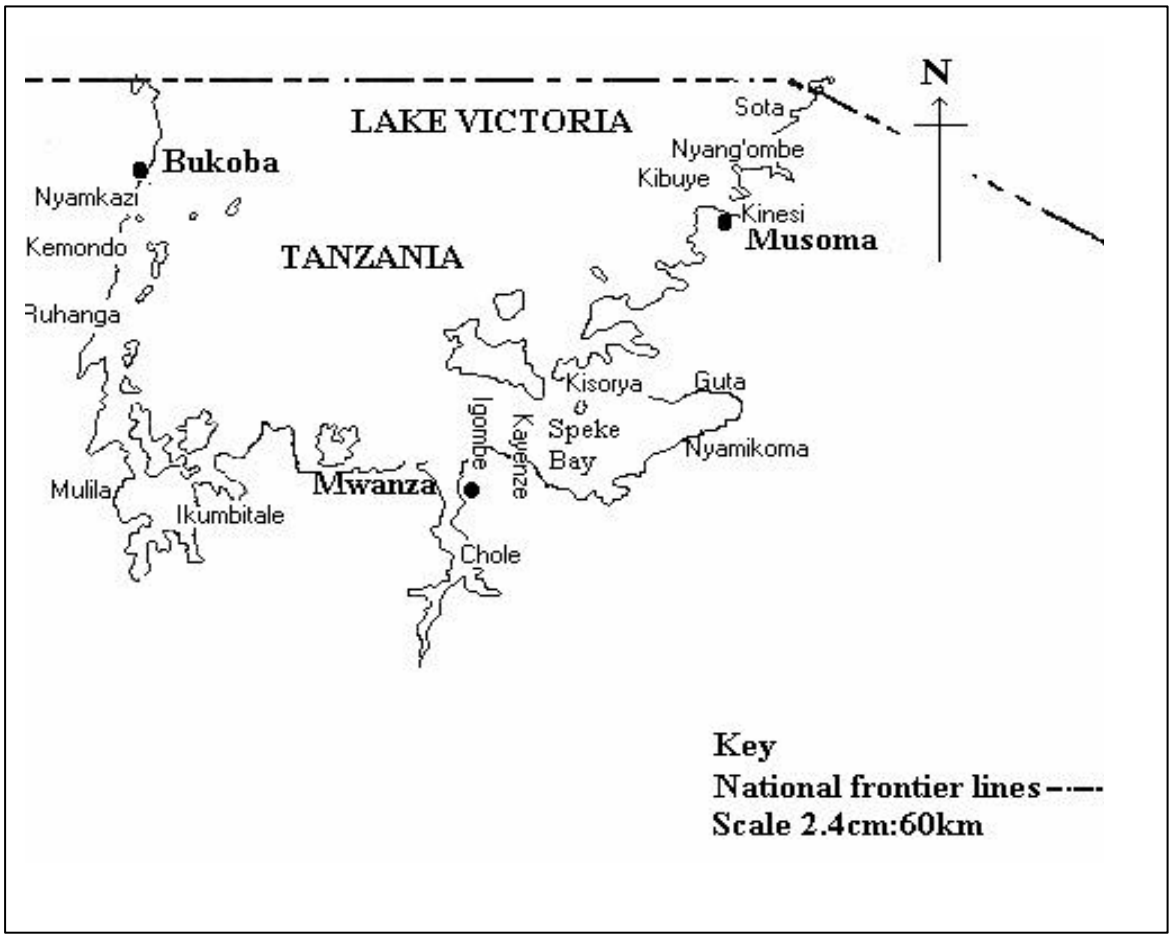

Fig. 1. Sampling beaches on a Tnzanian side of Lake Victoria

RESULTS

Catch by Region

Catch rates varied between months and regions. The poorest catches were in Mara region for *O. niloticus*, Mwanza region for *R. argentea* and Kagera for *L. niloticus*. The catch rates for the three species also varied between regions and months (Table 1).

The modal length for *O. niloticus* caught by 1" - 9" mesh sized gillnets; handlines and longlines with hook size 7 to 12, varied between months. When more consistent data were collected, there was a modal progression from 29 - 30 cm in April to 36 - 37cm TL in July (Fig. 1). A considerably greater number of smaller fish were caught in October 1997 and June 1998.

Lates niloticus were caught by gillnet with mesh sizes ranging from 4.5" to 7" and longlines of hook size numbers 7 to 13. There was a decline in the modal length of the fish landed, in the June 1998 and June 1999 (Fig. 2).

Table 1. Estimated daily landings (kg day^{-1}) for the three major commercial fish species at monitored landing beaches between (a) October 1997 to April 1998 (for Mwanza) and (b) from May to July 1999 for Kagera, Mwanza and Mara region

Region	Species	Effort (No. of boats)	No. of boats sampled	CPUE (kg boat^{-1})	Estimated catch (kg day^{-1})
(a)Mwanza	*Oreochromis niloticus*				
	October 1997	24	25	5.7	143.3
	February 1998	9	7	2.5	16.3
	June 1998	22	13	3.1	40.3
	September 1998	26	18	2.7	70.4
	April 1999	30	13	9.5	282.9
	Rastrineobola argentea				
	October 1997	107	84	125.0	10500.0
	February 1998	78	76	160.8	12542.0
	June 1998	72	36	20.3	1461.0
	September 1998	68	34	141.1	9594.1
	April 1999	34	10	89.1	3029.9
	Lates niloticus				
	October 1997	96	82	41.5	3403.0
	February 1998	42	33	101.2	3333.7
	June 1998	46	46	55.6	2559.3
	September 1998	88	83	64.5	5671.3
	April 1999	41	10	40.7	1668.7
(b)					
	Oreochromis niloticus				
Mwanza	May 1999	10	2	20.0	193.0
Mara	June 1999	16	12	5.0	59.0
Kagera	July 1999	16	8	37.0	1248.0
	Rastrineobola argentea				
Mwanza	May 1999	5	5	33.0	166.0
Mara	June 1999	14	8	172.0	2541.0
Kagera	July 1999	12	7	187.0	2242.0
	Lates niloticus				
Mwanza	May 1999	89	9	134.0	11926.0
Mara	June 1999	26	7	98.0	2479.0
Kagera	July 1999	24	10	56.0	1278.0

Rastrineobola argentea caught by seine nets and lift nets exhibited a modal length of 52-mm TL. Around July to September more than one peak were observed from 45 mm to 58 mm TL respectively (Fig. 3).

Other species encountered in the catches on the surveyed beaches included *Bagrus docmak*, Clarias gariepinus, Protopterus aethiopicus, *Labeo victorianus, Synodontis afrofischeri, Synodontis victoriae, Schilbe intermedius*, *Brycinus jacksonii, Mormyrus kannume* and haplochromine cichlids. The greatest fish species diversity was recorded in Mwanza and Mara regions, whilst only the three species, and haplochromines, were recorded in Kagera area.

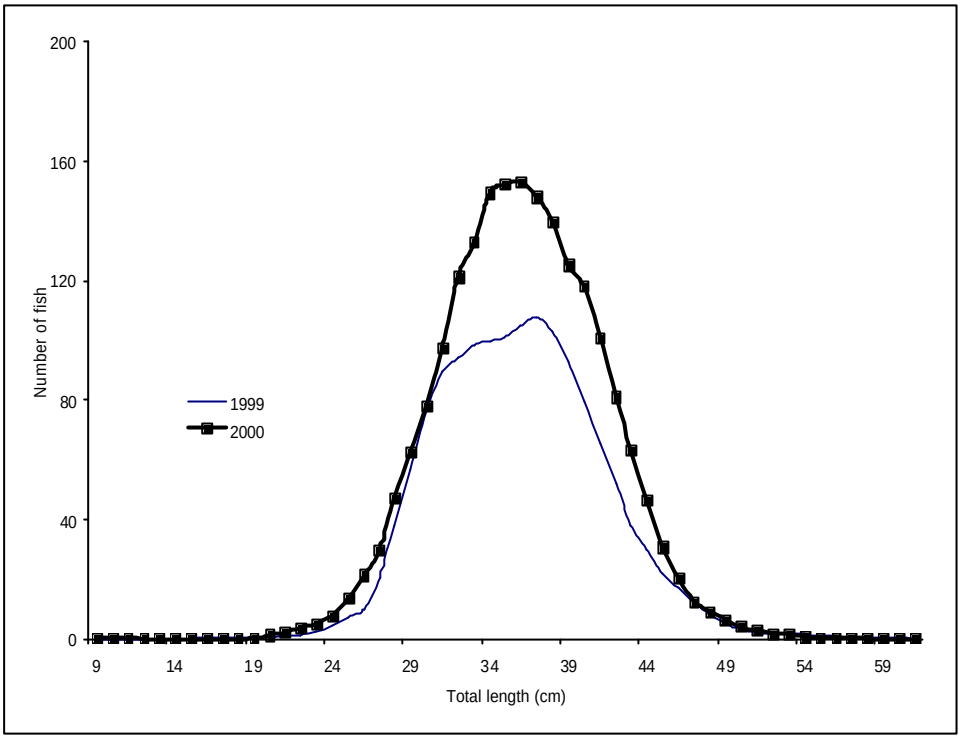

Fig. 2a. Size distribution of *Oreochromis niloticus* caught in gill nets of mesh size 5-7" from Lake Victoria, Tanzania

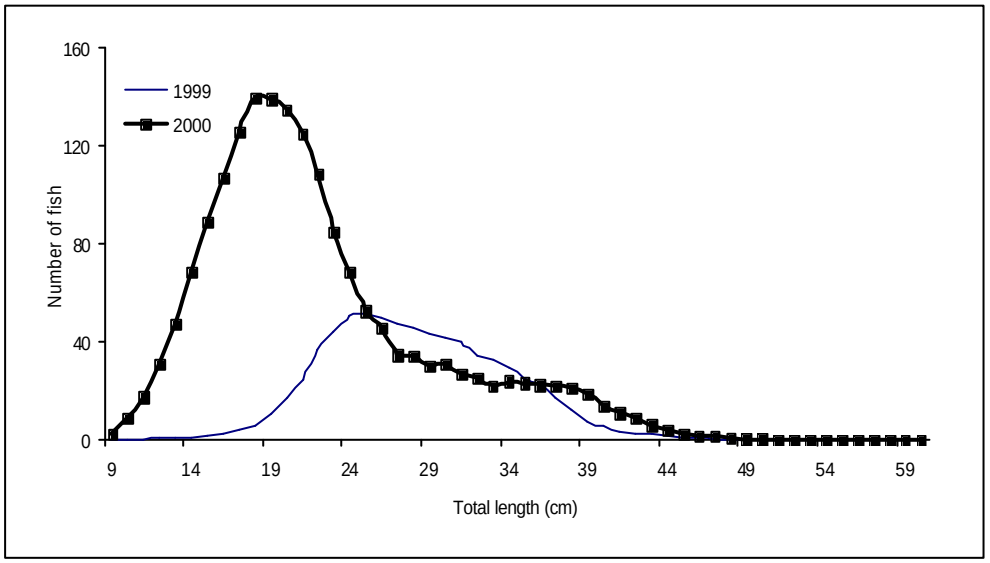

Fig. 2b. Size distribution of *Oreochromis niloticus* caught by handline in gill of size number 9-12 from Lake Victoria, Tanzania

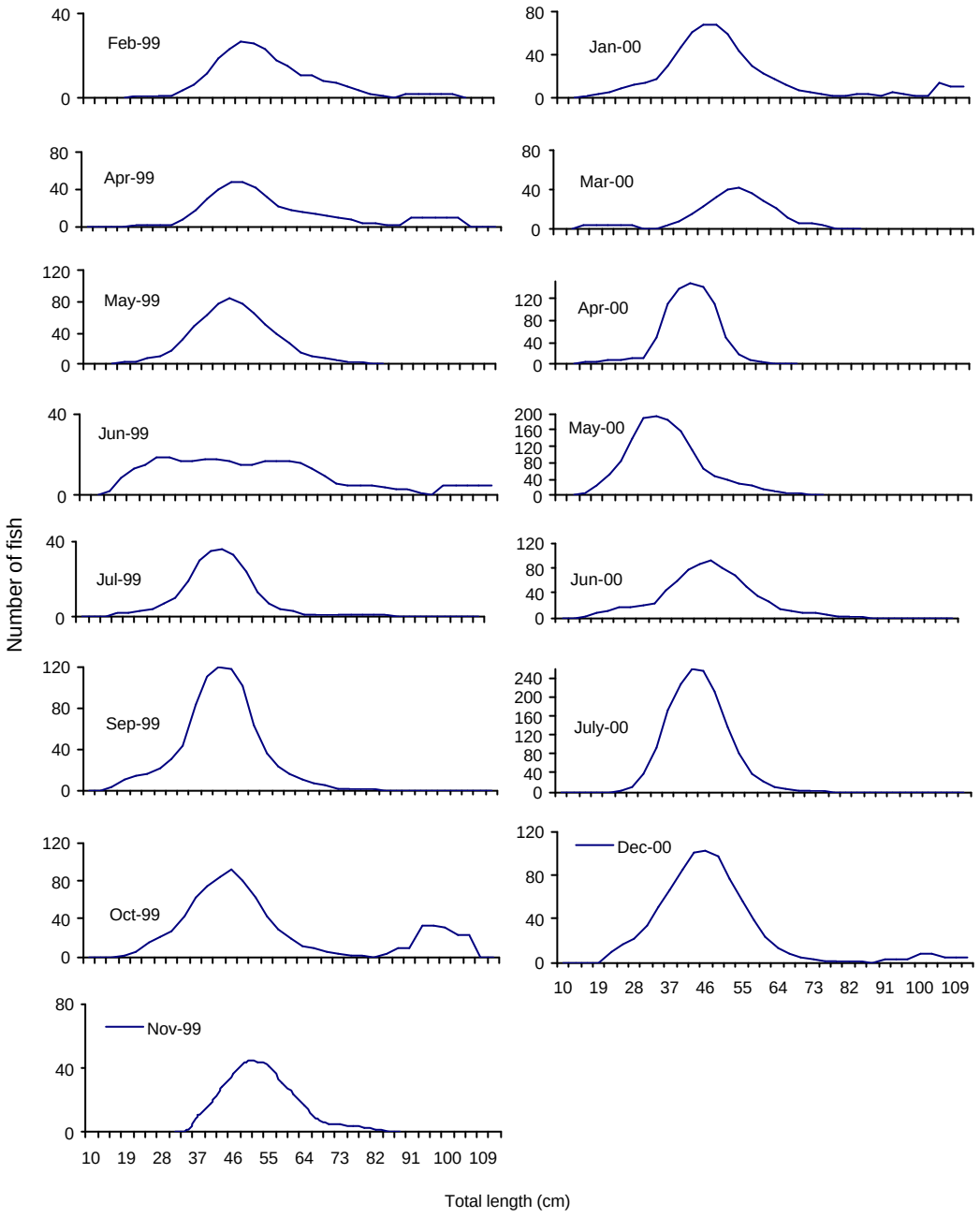

Fig. 3a. Nile perch caught in gill nets of mesh sizes 5-7.5" for 1999 and 2000 from Lake Victoria, Tanzania

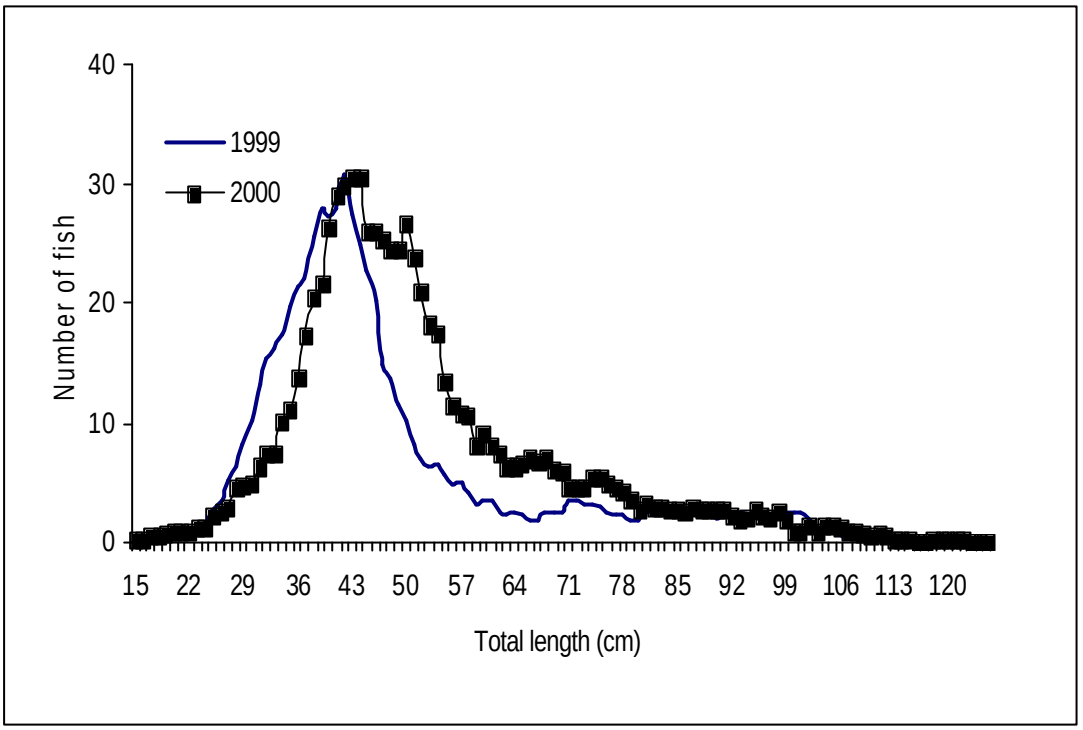

Fig. 3b. Size distribution of *L. niloticus* caught by longline from Lake victoria, Tanzania

Catch by gears

The catch distribution of the various fish species by different gears exhibits some marked differences. **Gillnetting (i.e. 1"- 9" stretched meshed), was the predominant gear used for** *reochromis niloticus*.

The encircling gillnet catch distribution was distributed around a mode of 37 cm TL with few fish caught <29 cm TL. By contrast the majority of *O. niloticus* landed from hand lining were <45 cm and as small as 12 cm TL. The modal length was around 21 cm TL, considerably lower than fish caught by netting (the largest had 52.5 cm TL).

The size composition of *L. niloticus* caught by gillnetting and longlining similarly exhibited marked differences. The mean length of capture by gill netting was 46 cm TL but 55 cm by long lining.

Few fish <30 cm were landed. However, long lining caught considerably larger fishes greater than 80 cm TL.

Landing from the two main gears used to capture *R. argentea* showed marked differences. A bimodal distribution (modes at 45 and 60 mm TL) was found for the lift net catches with a negatively skewed distribution at a mode around 55 mm TL.

DISCUSSION

The preliminary assessment of the commercial landings from the Tanzanian fishery exhibits some prominent characteristics, which will have a bearing on the management of the fishery in the future.

Catch

Catch rates varied considerably between months, and regions. The poorest catches were in Mwanza region, whilst reasonably higher catches were recorded in the other two regions. Once a full year's data have been collected these will be used to estimate the total catch from the fishery based on raising factors collected from the recently completed frame survey. The catch rates for the three species also varied between regions and months, possibly reflecting seasonal/regional variation in the fishery. This will be examined more fully after receiving supporting information from limnological data.

Oreochromis niloticus

Active fishing for *O. niloticus* using encircling and splashing gill nets is illegal in the lake but is commonly practised. However, size distribution of the catch from the netting operation was of larger fish because the encircling nets used were 5" - 6" mesh size. The majority of the nets employed were >5" and presumably contributed to the bulk of the landings which were >30 cm TL. Thus, the damage done by this method is largely one of increasing capture efficiency and not necessarily exploiting smaller individuals. It must borne in mind this scenario may change if catches decline and the fishermen reduce the mesh sizes employed.

Perhaps of more concern is the high proportion of smaller fish caught by the hook and line methods, especially hand lining. The majority of these fish are below the age at first maturity for Nile tilapia (*Oreochromis niloticus*) which is >30 cm TL (Ojuok 1999). Thus, an effort must be made to check on the expansion of the fishery particularly in known nursery areas. Importantly, the majority of Nile tilapia landed by gill netting is >30 cm TL and efforts must be made to ensure the mesh sizes are not reduced when catches decline.

Lates niloticus

Nile perch (*Lates niloticus*) catch statistics again exhibited variation in size distribution of landed fish between gears used. Long lining tended to catch large fish. The majority of fish caught by gill netting was below 50 cm TL. The majority of these fish are below the size at first maturity (55 cm TL in Tanzania waters, Mkumbo & Ezekiel 1999), suggesting that overfishing is prevalent in the fishery and action must be taken to reduce the problem.

Rastrineobola argentea

The size distribution of the exploited stock of *Rastrineobola* varied between gear, probably as a result of seasonal variability in the monitoring. It is possible that the records either covered recruitment of a cohort of juveniles entering into the fishery, especially from July to October

sampling which was more prevalent in the lift net catches (i.e. 5 and 10 mm mesh). Irrespective of the size distribution of fish exploited by the fisheries, the majority was above 50 mm TL, the size of mature *Rastrineobola* in Ugandan waters of Lake Victoria (Wandera 1999).

CONCLUSION

The output of the beach survey studies on Tanzanian waters of Lake Victoria show the importance of integrating fishery dependent data with both biological and limnological information. It also justifies the need to continue collecting data, which will be required in determining the exploitation characteristics of the three major fisheries using stock assessment tools.

ACKNOWLEDGEMENTS

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Changes in the life parameters of Mukene *Rastrineobola argentea (P.)* and implications to the management of the fishery in Lake Victoria.

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SUMMARY

*Changes in growth parameters, size at first maturity and fishing gears and practices for Mukene Rastrineobola argentea (P.) over the last decade in Lake Victoria are outlined. Management measures designed for sustainable exploitation of the fishery are suggested. The species has undergone changes in asymptotic length (*Lx) *and instantaneous growth rate (*K) *from 64.5 mm and 0.92 respectively in 1987 to 54mm and 1.76 in 1999. Over the same period, size at first maturity of the females of the species has reduced to 42 mm SL from 44 mm SL. Populations of R. argentea have also reduced in average lengths from 48 mm SL in 1987 to 44 mm SL in 1999. The 10 mm mesh net recommended for Mukene exploitation is now unprofitable considering the changes that have occurred to the stocks. A mesh size of not less than 5 mm is suggested as suitable for use on Lake Victoria.*

INTRODUCTION

Until about two decades ago, the fishery of Mukene *Rastrineobola argentea* on the Ugandan side of Lake Victoria was not very important. The fishery was then based on the endemic Tilapiines, *Oreochromis (Oreochromis) esculentus* G. and *Oreochromis (Nyasatilapia) variabilis* B.; the catfishes, *Bagrus docmac (F.)* and *Clarias (Clarias) gariepinus* B. and the lungfish *Protopterus aethiopicus (H)*. With the introduction and the subsequent establishment of foreign fish species the Nile perch, *Lates niloticus* (L.) and the Nile tilapia, *Oreochromis (Oreochromis) niloticus* (L.), the indigenous species have almost disappeared from the catches. *R. argentea* is the only endemic species landed in significant quantities. It is second to the Nile perch in the Ugandan waters of Lake Victoria and coming up fast on Lake Kyoga. It is however not yet being fished on Lake Nabugabo. The species is exploited for both human consumption and animal feeds manufacture.

Increased pressure on Mukene has over time resulted in changes in the life history of the species. Such changes therefore require appropriate, management measures for rational exploitation of the fishery. It is for example recommended that *R. argentea* should be fished by a 10 mm mesh sized net. This was proposed at the beginning of Mukene exploitation on the Ugandan side of Lake Victoria before the species' biological parameters had stabilized. This paper outlines changes that have occurred in biological parameters of populations of *R. argentea* on the Ugandan sector of Lake Victoria following increased exploitation. In light of these changes, appropriate management measures are suggested for the exploitation of the species.

EVOLUTION OF MUKENE FISHERY IN THE UGANDAN WATERS

Fishing for *R. argentea* in Uganda was introduced from the Kenyan side of the lake in the early 1980's. On the Ugandan side of Lake Victoria, the fishery can be categorized into three recognizable phases of development namely:

a) *The pre-perch period:* The period prior to the establishment of the Nile perch when there was no significant pressure on the Mukene commercial fishery.
b) *The transition period:* This period was in the early 1980's, characterized by rapid perch colonization of the lake and the beginning of Mukene fishery. Stocks of Mukene were now subjected to pressure from both the artisanal fishery and predation by the Nile perch. In response, life parameters of *R. argentea* populations began to change.
c) *The period of relative stability* – After the 1990's, the fishery was well established on the lake. Populations of the Nile perch were stabilizing (Ogutu-Ohwayo, 1994) and biological parameters of *R. argentea* had also stabilized.

The Mukene fishery based at Lingira was among the first in the Jinja waters of lake Victoria. In 1987 ten canoes with two beach seine nets were fishing at Lingira. At the beginning of 1990 a boat seine (lampara) net was introduced. Because this method eliminated the need for a beach, it enabled a rapid increase in of fishing fleets to more than twenty. This also led to the spread of the fishery to other parts of the lake. Now with the exception of the very deep open waters, Mukene is exploited from all over the lake.

Changes in population size structure

During the pre-perch period, *R. argentea* grew to a large adult size. The population of *R. argentea* caught in August 1970 shows a mean length of 60 mm SL. This size reduced to 48 mm in 1989 and by 1992 had shrunk to 44 mm. Over the same period growth parameters of the species have also changed. In 1988 the asymptotic length of the species was calculated as 64.5 with a growth constant (K) of 0.92 yr^{-1} (Wandera and Wanink 1995). This had by 1992 changed to 54.0 with a K of 1.76 yr^{-1} (Wandera 1999). The combined effect of predation by the Nile perch and human exploitation could be responsible for these changes.

Changes in size at first maturity

In 1988 size at first maturity was calculated at 44mm SL for females while males matured at 41 mm SL. All fishes would be mature by 47 mm SL. Five years later in 1993, it had stabilized at 42 mm SL for females. Males remained at 41mm SL (Wandera 1999). While no data is available on size at first maturity of the species during the pre perch period, it was larger [as inferred from changes in the smallest mature individuals, which were 44 mm in the 70's (Okedi 1981), 36 mm in 1987 (Wanink 1988) and 34 mm in 1992 (Wandera 1992)].

The impact of fishing gears

R. argentea is exploited by light attraction (Okedi 1981, Witte & van Densen, 1995) Fishing gears used in the capture of Mukene in Ugandan are scoop nets, beach seines and lampara (boat seines). Initially, the beach seine nets in use were of stretched mesh size10 mm. With the introduction of the lampara boat seine net, the mesh size reduced to 5 mm. At present, especially on Lake Kyoga, nets with meshes as small as 3 mm are in use. Length frequency of Mukene retained by nets of mesh size 10 and 5 mm is shown in (Fig.1). The 5 mm mesh net captures a high proportion of immature fish between April and May when young fish are recruited into the fishery.

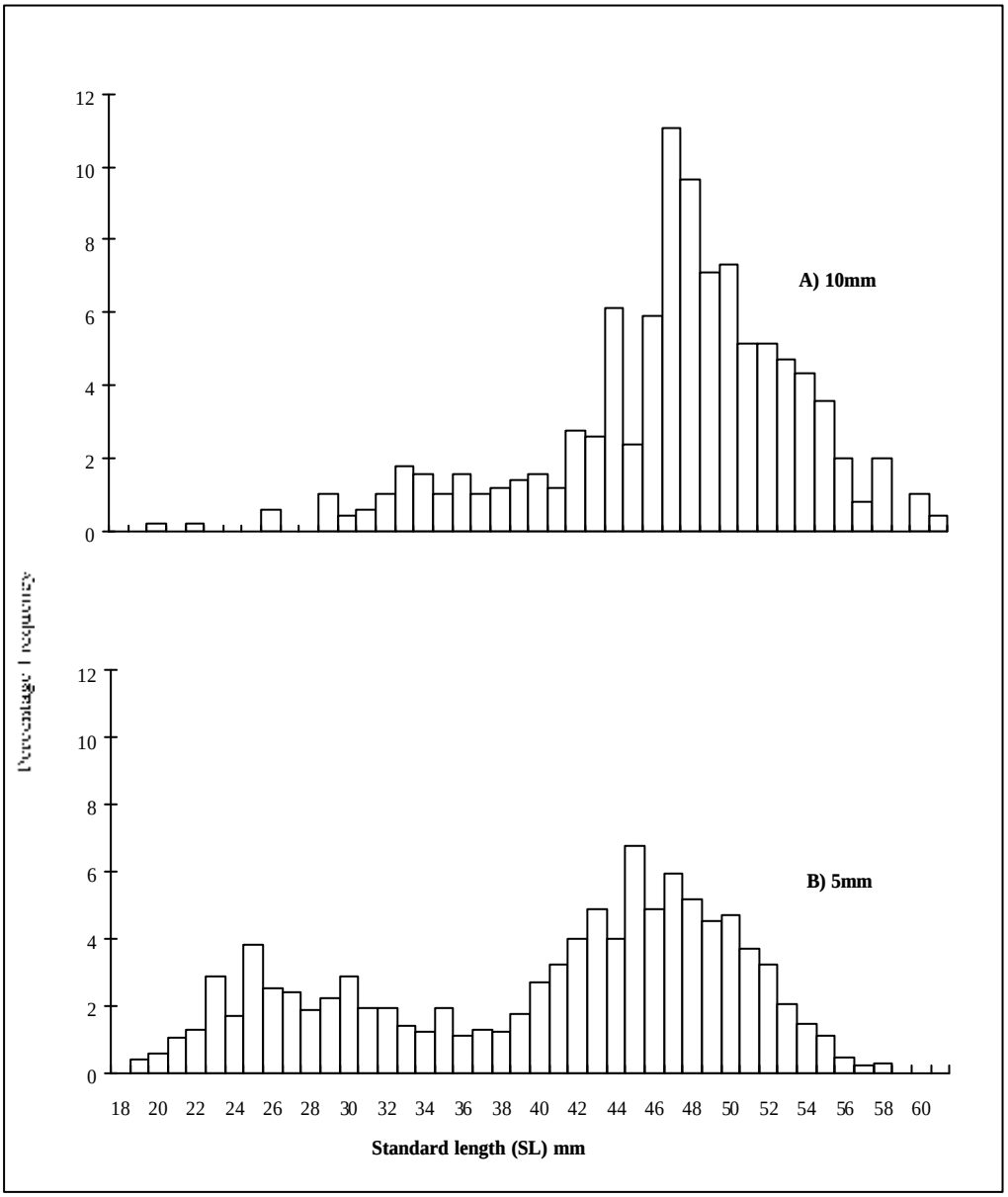

Fig. 1. Length frequency distribution of *R. argentea* caught by: A) 10mm and B) 5mm mesh net

Management of the fishery of *R. argentea*

Rational exploitation of *R. argentea* in Lake Victoria can be maintained if strict management measures are put in place. The most vital intervention points have been identified as:

a) Establishment of closed fishing grounds and seasons

Many fish species especially their juveniles occur in sheltered bays and very close to the shores. Light fishing operated in these waters catches these bye-catch species and juvenile Mukene in large numbers. Mukene catches from fishing grounds further out in the open contain fewer immature individuals (Fig.2). Open waters are the best grounds for Mukene fishing. These waters however tend to be very rough and therefore unsafe to the types of canoes currently in use. Mukene biomass in these waters is also not yet established. Recruitment periods, when high numbers of juvenile Mukene occur should be closed to fishing. While sheltered bays have high numbers of juveniles the whole year round, island zones experience recruitment only in November to December. Closed seasons are however not necessary in the open waters.

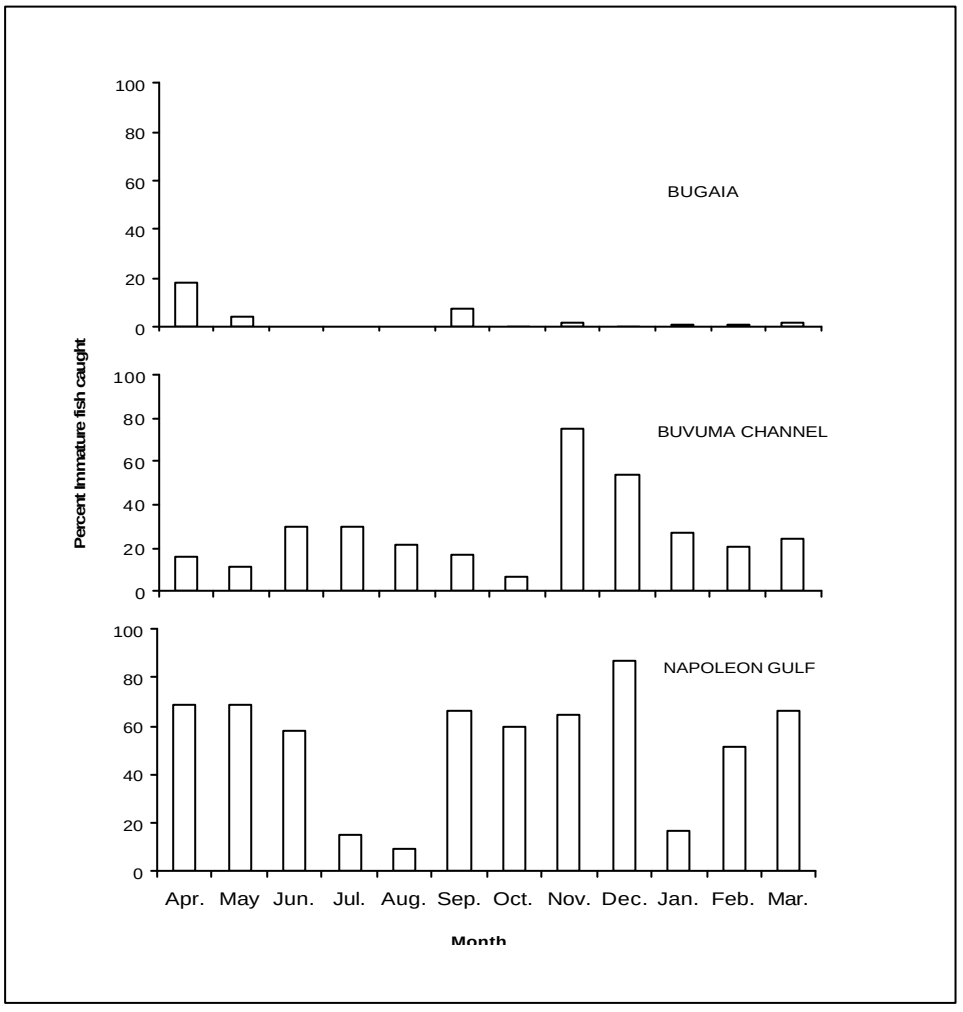

Fig. 2 Monthly percentage of immature *R. argentea* caught by artisanal fishermen in Napoleon Gulf, Buvuma Channel and Bugaia

b) Control of fishing methods

Beach seines capture many bye-catch fish species. Juveniles of non-target species occur very close to the shore and tend to be dragged along during beach seining. Beach seine nets should therefore be discouraged. The lampara (boat seine) is a better gear since it avoids these shore dwelling fishes.

c) Control of mesh size of nets used.

Based on data collected in 1988, a 10 mm mesh net had been recommended as ideal for Mukene exploitation (Ogutu-Ohwayo *et.al.* 1998). With changes in the population structure of *R. argentea*, this size of net might now not be appropriate.

The present mean size of the Mukene at 44 mm SL is small compared to 48 mm SL in 1988. Most fish would now not be retained in the 10 mm mesh net making it unprofitable for the fishermen. Growth parameters indicate that Mukene now grows faster, quickly attaining maturity and asymptotic length. With the reduction in the overall size at first maturity of *R. argentea,* the mean percentage of immature Mukene retained by a 5 mm mesh net has now reduced to 31.4% compared to 47.4% the same net would recover in 1988. Catches during the recruitment period (May) contained 66.3% and 11.4% immature fish respectively for the years 1989 and 1992. This mesh now exerts a lower toll on the juveniles of the species than at the time it was condemned. Considering the above changes to Mukene populations, the 5 mm mesh net could be allowed to operate on Lake Victoria. Further reduction to a smaller size should however be discouraged.

CONCLUSION

The study shows a gradual decline in size of Mukene caught from Lake Victoria between the pre-perch days and the present. Other biological parameters have also changed over the same period. The recommended net of mesh size 10 mm for the capture of Mukene is now inefficient and 5 mm is suggested as a replacement. Beach seines capture high percentages of juvenile Mukene and other bye-catch species when operated very close to the shores and in closed bays. These are juveniles of the three most important commercial fish species in the lake namely; the Nile perch, Nile tilapia and Mukene. Fishing should therefore be done in the open waters away from the shoreline.

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Optimizing gill net mesh sizes for the Lake Victoria Nile perch fishery

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SUMMARY

A shift from one type of fishery in Lake Victoria to another has been largely dependent on relative earnings as well as the rise in costs of initial investments. This study estimated the relative economic profits attained by different mesh sizes as a measure of viability of the Nile perch (Lates niloticus) gill net fishery. Catches from different mesh sizes were summed over the time of the experiment; mean catch per day by mesh size was determined and the relative profits by mesh size were derived. 50% selection points for the composite curves fell at 17 cm TL and 84 cm TL corresponding to the modal lengths for 127 mm and 178 mm meshes, respectively. Optimal yield was observed in 4" and 5" meshes. Optimal relative profits were obtained at mesh sizes equal to or greater than 127 mm (5"). The mesh size recommended on biological grounds for the Nile perch fishery is 7" (178 mm).

INTRODUCTION

Historically, excellent fish catches were obtained in Lake Victoria using simple fishing gear, basket traps, hooks and seine nets, with little fishing effort (Kudhongania *et al*., 1988). However, demand for fish from the lake has been stimulated by the development of urban centres and commercialization on a global scale. Intensified fishing pressure led to localized overfishing, especially of indigenous fish species such as *Oreochromis esculentus* (Kudhongania *et al*., 1988). Despite this, the unit yield for the Lake Victoria increased from 40-80 to 234 kg ha^{-1} between the 1970s and 1985 (JICA 1987a). This was primarily because of the meteoritic rise in Nile perch catches from 300 333 000 t between 1975 to 1990 (Gréboval and Mannini 1992; Jansen *et al*., 1999). The catch is currently dominated by Nile perch, *Ratrineobola argentea* (Pelligrin) and Nile tilapia, *Oreochromis niloticus* (L.). There are some 30 000 fishermen utilising 7800 canoes (wooden planked with 2-8 crew) to land fish at 256 beaches. Fishing gears in use include gill nets, mosquito net seines, beach seines, long lines and hand lines, but gill nets are the most popular for catching Nile perch and tilapia (Hoekstra *et al*., 1990).

To maintain catch per unit effort with intensifying fishing effort, fishermen have reduced the mesh sizes of their nets, but this is leading to overfishing. To overcome this problem, appropriate

management policies can be formulated for gill net fisheries by examining their selectivity. Gill net selectivity studies can be used to determine the minimum mesh size appropriate for a particular fishery. Such proposals can be made in line with biological criteria, especially age/size structure at first maturity, growth rate and spawning stock biomass to sustain subsequent recruitment processes. Gill net selectivity can also assist in correcting bias created by other gears in sampling, for example, bottom trawling. It is a characteristic of gill nets that specific mesh sizes will harvesting particular sizes of fish. However, no assessment of gill net selectivity has been carried out for Nile perch on Lake Victoria. Thus control of mesh size remains a priority in the Nile perch fishery, where there is a tendency to reduce mesh size (Asila *et al.*, 1990; Greboval & Mannini, 1992).

Earnings from gill net fishing in Lake Victoria have been a concern to fishermen in the lake. They have shifted from one type of fishery to another because of relative earnings as well as the rise in costs of initial investments (Asila *et al.*, 1990). This shift has led to increased use of different forms of seine net (beach seine and mosquito net seine) catches in Kenya waters (Othina & Odera, 1996). Such bad fishing methods often result in over-exploitation of fish stocks, which exacerbates the problem by causing further reduction in mesh sizes and eventually the collapse of the fishery. However, when the correct mesh sized gill nets are used this may improve production and in turn give better financial returns. There is need for fishermen to select optimal mesh size for production and financial return, but at the same time conform to biological criteria. The objective of this study was to establish optimal mesh size of gill net for maximum profit. The paper uses relative economic revenue achieved by different mesh sizes to determine the viability of the gill net fishery. It also evaluates the most the appropriate mesh size selection range.

MATERIALS AND METHODS

A gang of gill nets with mesh sizes ranging from 1" (25 mm) to 8" (203 mm) was used. Each gang contained a replicate of the mesh sizes. The order of arrangement was determined at random. Selectivity was determined from the variance of individual mesh size and the mean length of fish caught. Selectivity for each length and mesh size was determined from:

$$S_m(Li) = (L_{ij} - L_m)^2 / \text{var}\,(L_i)$$

where S_m (Li) is the selection factor at length Li at a specific mesh size, L_{ij} is the jth length at the ith mesh size, L_m is the mean length at the mesh size and var (L_i) is the variance of distribution at the mesh size. Thereafter composite selection curves were derived for the four gangs of gill nets.

15 gill nets of different mesh sizes were used in fishing. Each mesh size had eight replicates in four gangs. Catches from different mesh sizes were summed over the survey period. Catch per day by mesh size (8 nets) was determined. Relative revenue by mesh size was derived from the product of mean catch per day, price per kg, weight at that size and the number of settings (= 100). The number of settings is viewed as the life span of the gill nets. Costs of the nets were derived from the price of net plus accessories and labour. Only fixed costs were considered not variable costs. Relative profit was calculated from relative revenue less the cost of nets at the particular mesh size.

Relative profits = Relative revenue from catches - cost of nets (fixed costs only).

RESULTS

Selectivity curves for different gill net mesh sizes (Fig. 1) show increased spread with mesh size. Composite selection curves indicated that the 15% points fall at 17 cm TL and 84 cm TL. 19% selection points occurred between 46 cm TL and 64 cm TL. These points corresponded to modal lengths for 127 mm and 178 mm respectively. Optimum length for 5" (127 mm) was 49 cm TL while the optimum length for 6.5" (165 mm) was 64 cm TL fish. Variance was directly proportional to mesh size, expressed as: Variance = 0.127 x mesh size - 0.109. Yield by mesh size (yield of Nile perch per 100 gill net settings) was high for 4" and 5" mesh sizes at 43.2 kg and 41.1 kg respectively, while the highest was at 8" mesh size with a yield of 46.3 kg (Fig. 2). Lowest catch was observed at a mesh size of 2" with a yield of 5.4 kg.

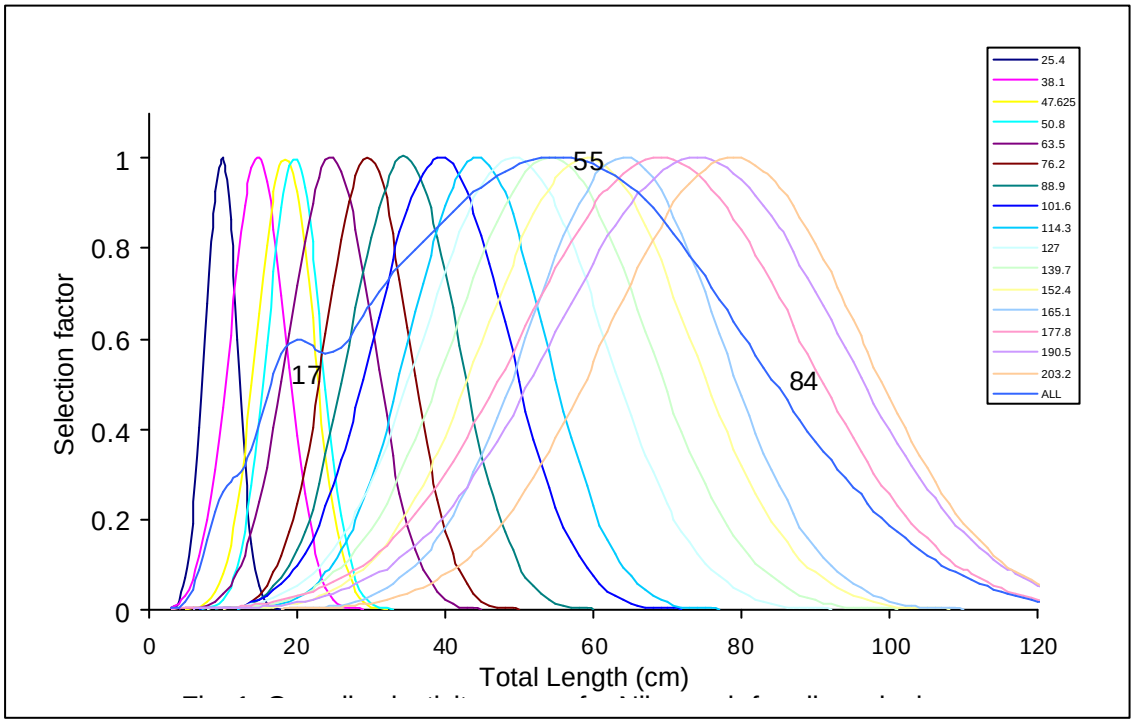

Fig. 1. Overall selectivity curves for Nile perch for all mesh sizes

Peak returns in relative revenue were observed for mesh size of 127 mm (5") at KES 246 680 with the lowest revenue observed at 3" (76 mm) with KES 5410 (Table 1, Fig. 3). A second peak was observed at 8" (203 mm) with KES 277 900. The local minimum between the two peaks was at 6.5" (165 mm) with KES 125 430.

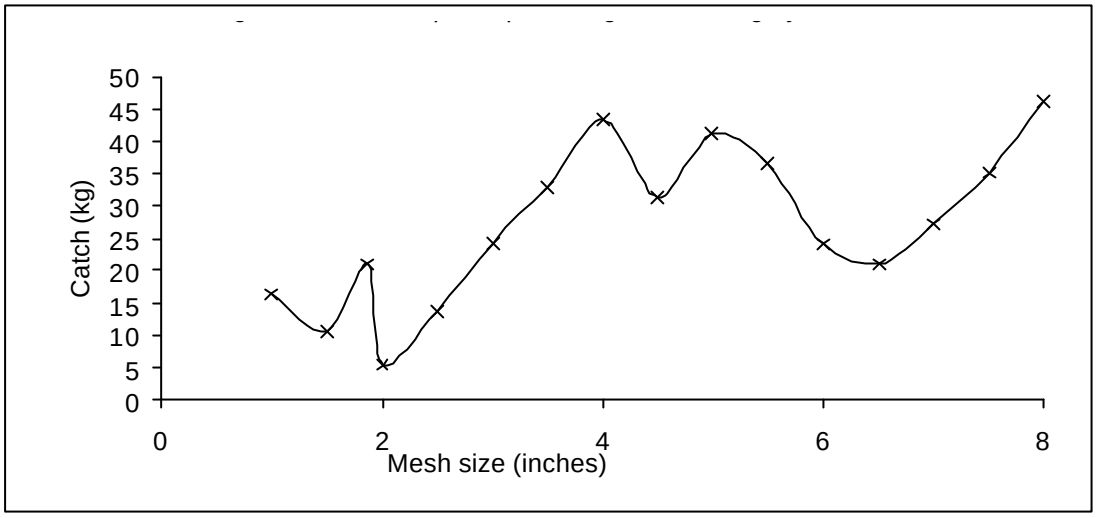

Fig. 2. Yield of Nile perch per 100 gill net setting by mesh size.

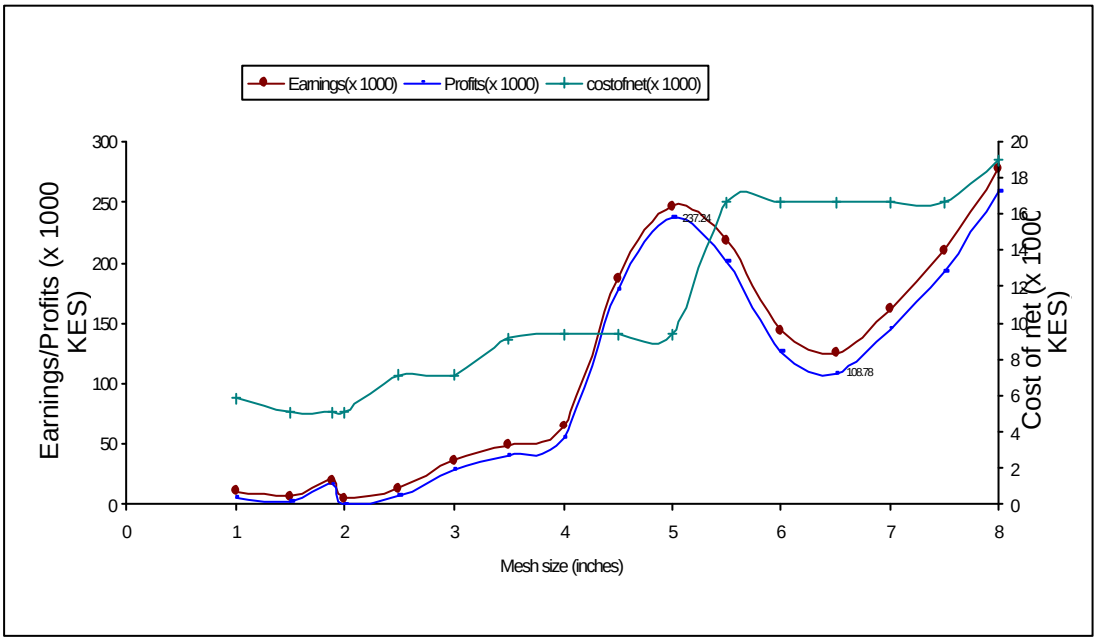

Fig. 3. Earnings, cost of nets and profits by mesh size

Table 1. Economic returns by mesh size by Nile perch

Mesh size	Mean wt	No. net^{-1}	Wt net^{-1}	Wt net^{-1} (kg)	Price	Earnings (x1000)	Cost of net (x1000)	Profits (x1000)
1	25	650	16250	16.3	7	11.38	5.85	5.52
1.5	54.17	191	10346.47	10.3	7	7.24	5.02	2.22
1.875	91.67	227	20809.09	20.8	10	20.81	5.02	15.79
2	90.2	60	5412	5.4	10	5.41	5.02	0.39
2.5	196.88	69	13584.72	13.6	10	13.58	7.13	6.46
3	298.78	81	24201.18	24.2	15	36.30	7.13	29.17
3.5	342.55	96	32884.8	32.9	15	49.33	9.10	40.23
4	561.59	77	43242.43	43.2	15	64.86	9.44	55.42
4.5	867.92	36	31245.12	31.2	60	187.47	9.44	178.03
5	1027.83	40	41113.2	41.1	60	246.68	9.44	237.24
5.5	1515.39	24	36369.36	36.4	60	218.22	16.66	201.56
6	2171.88	11	23890.68	23.9	60	143.34	16.66	126.69
6.5	2613.16	8	20905.28	20.9	60	125.43	16.66	108.78
7	3857.5	7	27002.5	27.0	60	162.02	16.66	145.36
7.5	5001.85	7	35012.95	35.0	60	210.08	16.66	193.42
8	5789.58	8	46316.64	46.3	60	277.90	19.02	258.88

DISCUSSION

The selection ranges indicated that a mesh size above 127-mm (5") would be preferential for optimizing catches (beyond 50% selection point). Fishermen often use a mix of gill net mesh sizes in the fishery, but it would be most appropriate to enforce the current minimum mesh size in the fishery of 5" (127 mm) to maintain yield. This is further supported by the relative revenue which indicated that the optimum mesh size that yields best financial returns is 127 mm (5"). However, the size at first maturity for Nile perch reported in Kenyan waters has reduced from 74 cm TL a decade ago to 55 cm TL for males and 102 cm TL reducing to 70 cm TL for females (Asila and Ogari, 1988, 1992; Asila, 1992). Similarly, size at first maturity has declined in Tanzanian and Uganda waters and is currently around 60-70 cm TL for females and 55-65 for females (O. Okumbo & Okaronon, unpublihsed data). With the fifty per cent selection points observed from this study, females would be heavily exploited with the mesh size of 5" (127 mm), although less so for males, thus potentially leading to recruitment overfishing. Thus the best mesh size on biological rounds, would be around 7" (178 mm), based on the optimum length that falls at 69 cm while the 50% selection point falls at 47 cm and 91 cm, if mature females are to be allowed escapement. Shifting the minimum mesh size from 5" to 7" will shift the optimum length from 49 cm to 69 cm, effectively shifting the mean fish weight from 1028 to 3858 g.

Conversely, it might be argued that given the high fecundity of females of between 3 and 15 million eggs (Asila & Ogari, 1988), it is possible the spawning stock could be maintained by a small number of females in the population, thus such regulations are not necessary. However, survival rate from age 0 to 1 is quite low (Asila, 1994), and this could possibly lead to demise of Nile perch. Also the processors demand fish sizes ranges from one kilogram upwards which acts as an incentive to the fishermen to lower their mesh sizes.

Irrespective of the arguments presented for or against an optimal mesh size above, actions will have to be taken in the near future if the fishery is to remain viable. The current exploitation patterns are leading to a drop in catch per unit effort and this will probably ultimately lead to a further reduction in mesh sizes. This must be avoided at all costs and management measures need to be put into place to regulate the mesh size at least above the current legal size (5"), but preferrably moving towards the biological optimum mesh size (7") to conserve stocks and maintain yield.

Demersal Biomass, Distribution, Growth and Mortality of Fish in Kenya waters of Lake Victoria

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SUMMARY

Bottom trawling was conducted in the Kenya waters of Lake Victoria from September 1997 to November 1999 to study fish distribution, growth and abundance. Growth parameters and mortality were estimated from length frequency data using FISAT. Demersal fish biomass was estimated using the swept area method. A mean standing stock of 98.7 kg ha^{-1} was estimated for the Kenyan sector of Lake Victoria with mean standing stocks of Lates niloticus (L) and Oreochromis niloticus (L) at 75.6 and 9.88 kg ha^{-1} respectively. The biomass of the minor species was 13.38 kg ha^{-1}. Catches of L. niloticus were higher in deeper water while those of O. niloticus were higher in shallow water. Stock sizes and habitat ranges of bottom feeding fishes increased following invasion by water hyacinth.

INTRODUCTION

The Kenya sector of Lake Victoria covers an area of 4 100km^2, representing 6% of the total surface area (Melack, 1979). The Nyanza Gulf covers an area of 1 400 km^2 (Fig 1). The latter has a mean depth of 12 m offshore and 4m inshore. The fishery is mainly artisanal and has until recently been concentrated in inshore waters of 0 - 25 m. The gulf and the northern coast are heavily fished due to a high population density in the hinterland (Wanjala & Marten, 1974; Dache, 1994). A few fishermen with motorised craft venture into relatively less fished distant open waters. Since the last lake-wide survey by Bergstrand and Cordone in (1971); Kudhongania, and Cordone (1974), a number of localised bottom trawl studies have been undertaken Wanjala and Marten (1974); Muller and Benda (1981); Okemwa (1981); Asila and Ogari (1988); Asila (1994); and Dache 1994). Their observations indicated a declining trend of stocks of indigenous fishes and an increasing trend of catches of *L. niloticus*. However the catches of this species have been in decline after peaking in 1989.

Bottom trawling is banned in Nyanza Gulf and within 5 km from the shoreline anywhere in the Kenya waters of Lake Victoria. This is aimed at protecting artisanal fishermen and tilapiine species from adverse harvesting effects of trawlers (i.e. destruction of fishing gear and inshore breeding grounds). Catches are dominated by three commercial fish species: *L. niloticus, O. niloticus,*

and *Rastrineobola argentea* (Pellegrin), which contribute over 96% of the total landings. The major problems facing fishermen include a high fishing effort, which has driven most of the fishermen from the Nyanza Gulf and inshore waters to fishing grounds around the islands and deeper offshore waters in search of better catches.

METHODOLOGY

Studies on demersal fish biomass and distribution

30 hauls were made at sampling points in alternate 2.5 n.mi2 grid squares using a trawl net with a head rope of 24.5 m. The sampling points were established using a Geographical Positioning System (GPS). A cod end bag of mesh size 5 mm was used to obtain samples of smaller sized fish. Sampling at predetermined sites was hampered by the spread of water hyacinth in Nyanza gulf from September 1997 to November 1999. Efforts were made to sample as close as possible to blocked sites. The sampling points are depicted in Fig. 1.

Demersal fish biomass was estimated using the swept area method (Witte & van Densen, 1995; Pauly, 1983; Sparre *et al*., 1998). Fish were sorted on board into species and length frequencies were generated from measurements made on individual fish (TL to the cm below). Where catches of *L. niloticus* were large, a sub-sampling procedure was used whereby all large fish >35 cm were sorted out and measured. The remaining smaller fish were sub-sampled by measuring a representative sample of about 200 fish and then raising the numbers to estimate what was in the sample.

Studies on growth and mortality

Estimates of growth and mortality were made using FISAT. For *L. niloticus*, there was a scarcity of specimen >70 cm. Therefore, growth parameters estimated by Asila and Ogari (1988) together with the length frequencies generated during this study were used to estimate the instantaneous rate of total mortality (Z) using catch-curve analysis. Occurrence of minor species was highly seasonal. Their growth parameters were estimated using the Powell-Wetherall method (Pauly & Morgan, 1997; Sparre *et al*., 1998).

RESULTS

Biomass and distribution of catches

A mean standing stock size of 98.7 kg ha^{-1} was estimated with that of *L. niloticus* being 75.6 kg ha^{-1}, *O. niloticus* 9.98 kg ha^{-1} and other species 13.38 kg ha^{-1}. The highest overall biomass was obtained in the depth range 10 - 14 m (Fig. 2).

Higher catch rates of *L. niloticus* were obtained from areas deeper than 10 m. *L. niloticus* catches varied from 32.26 kg ha^{-1} to 81.29 kg ha^{-1} in the depth range 0 - 24 m, (Table1).

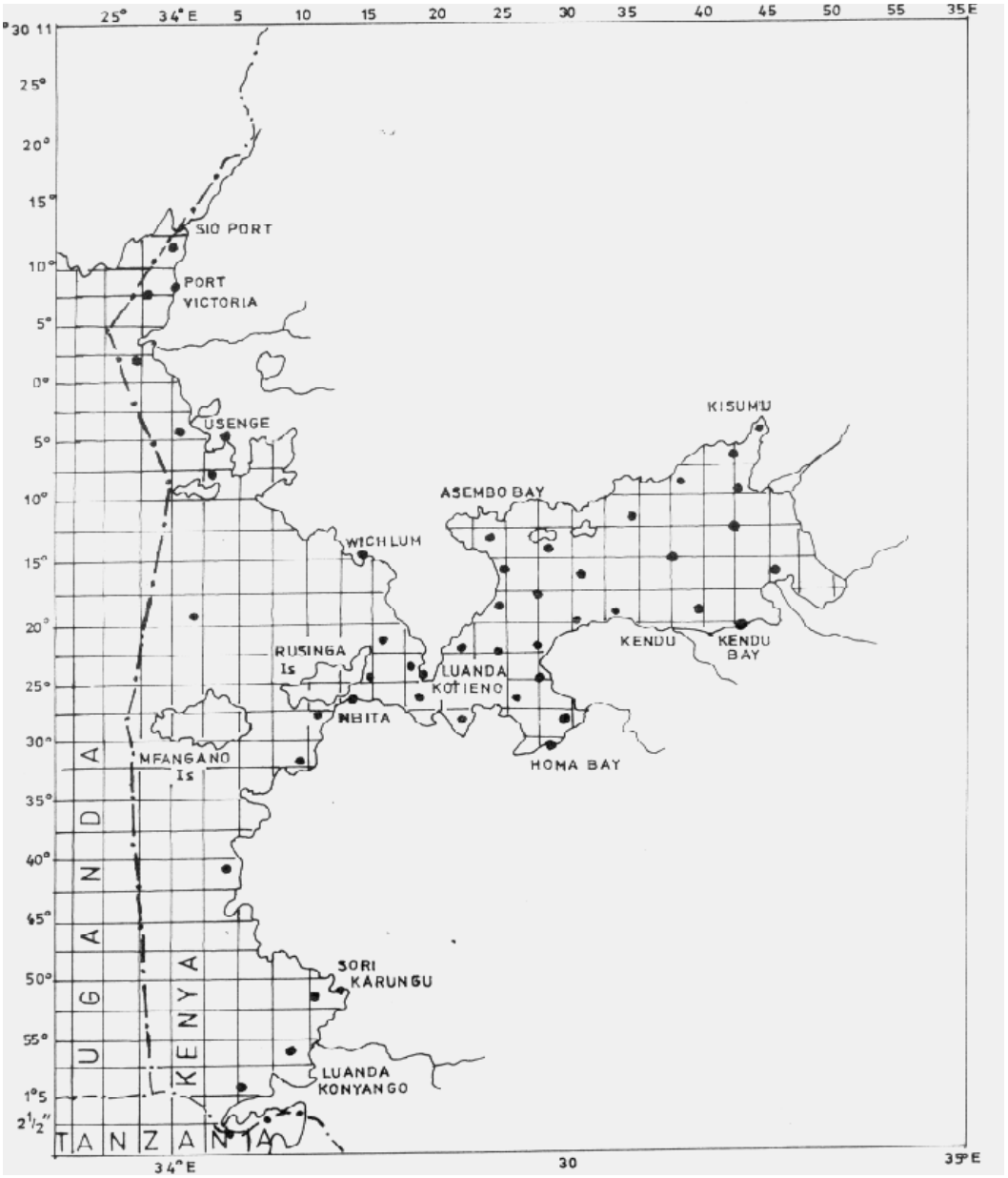

Fig. 1. Map showing sampling sites in the Kenya sector of Lake Victoria

Catches were low in areas covered by water hyacinth. Catches of *O. niloticus* were higher in shallower areas particularly those covered with hyacinth. They decreased with increase in depth from 6.52 - 20.90 kg ha^{-1} in the depth range 0 - 24m. catches of *O. niloticus* showed a drastic increase starting in October 1998 following invasion of the lake by water hyacinth (Fig. 3).
The combined contribution of minor species to the total stock size was 13.38 kg ha^{-1}. These included *Synodontis* spp., *Clarias gariepinus*, *Protopterus aethiopicus*, haplochromines, *Brycinus sadleri* (Boulenger) and *Schilbe intermedius*, (Table 2). Catches of these species were higher in areas invested with hyacinth (Table 3).

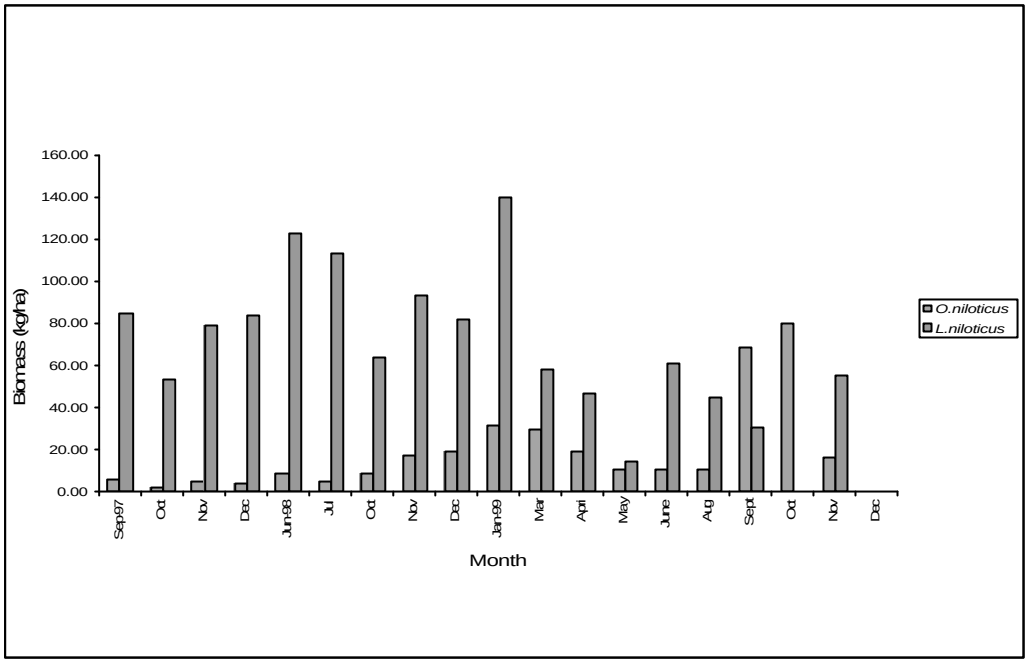

Fig. 2. Variations in demersal biomass of *Lates niloticus* and Oreochromis niloticus in the Kenyan sector of Lake Victoria.

Table 1. Variation in mean catches of *L. niloticus* and *O. niloticus* (kg ha^{-1}) with depth in Kenya sector of Lake Victoria

Species	Depth (m)				
	0 - 4 m	5 - 9 m	10 - 14 m	15 - 19 m	20 - 24 m
L. niloticus	32.26	67.92	79.17	78.07	81.29
O. niloticus	20.90	14.65	17.06	6.52	-
Total	52.16	82.55	96.16	84.595	81.29

Growth parameters and mortality rates

Nile perch of lengths greater than 70 cm TL were rare. Thus, its total mortality was estimated using growth parameters presented by Asila and Ogari (1988) as 3.772. Using Modal Progression Analysis and the Gulland-Holt plot, growth parameters estimated for *O. niloticus* were $L\infty$ = 59.2 cm TL and the intrinsic growth rate K = 0.409yr^{-1}. The Powell-Wetherall method gave $L\infty$ = 59.3 cm and Z/K =3.608. The ELEFAN method gave $L\infty$ =61.7 cm and a K = 0.382 yr^{-1}. Using the above parameters, the instantaneous rate of total mortality for *O. niloticus* estimated from catch curve analysis ranged from 1.76 - 1.88 yr^{-1}. The growth performance index ∅'

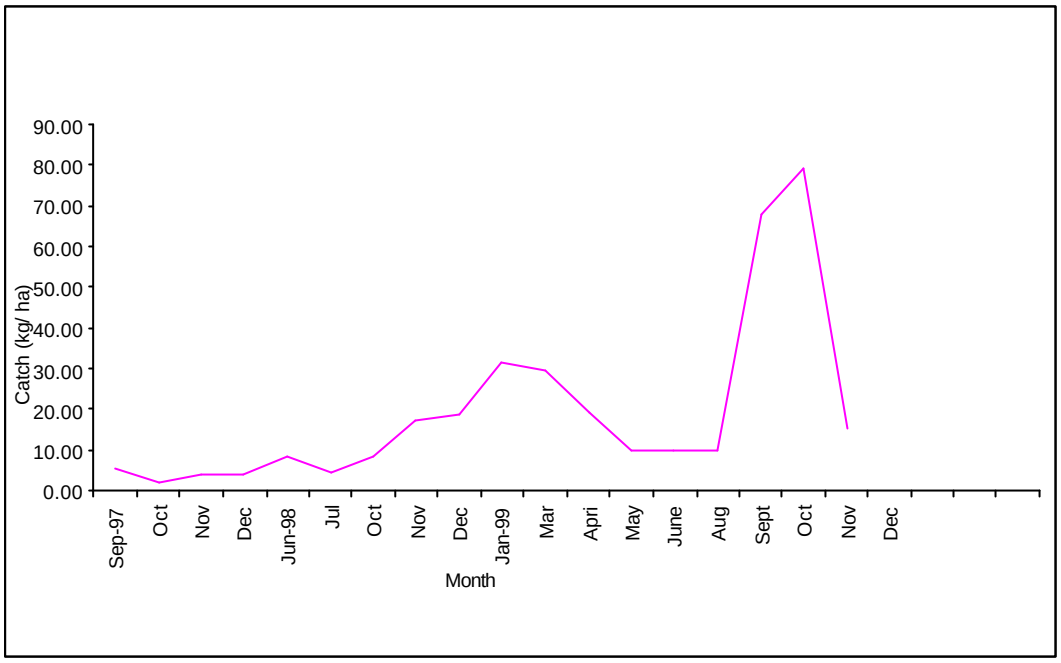

Fig. 3. Growth parameters of minor fish species in the Kenya sector of lake Victoria.

Table 2. Variation of biomass (kg ha^{-1}) of minor species with depth in the Kenya sector of Lake Victoria

Sampling site	Quantity of rotting hyacinth material at the bottom of the lake	
	Kg (30min haul)	Kg ha^{-1}
Awach River mouth	29.6	14.8
Kowuor	12.0	6.0
Mirunda Bay	75.6	37.8
Gudwa	10.0	5.0
Kopiata	349.4	174.7
Awach Maboko	14.8	7.4
Ochieng' Aneko	121.6	65.8
Ndere Is	12.4	6.2

estimated using ELEFAN was 3.6. Estimates of growth parameters and mortality from earlier studies using catch landings (Getabu, 1992) were $L\infty$ = 64.6 cm, Z/K = 3.129, K = 0.254 yr^{-1}, Z = 0.818 yr^{-1} and $\varnothing'$ = 3.025. Dache (1994) using bottom trawl data mainly in the Nyanza Gulf obtained the following estimates: $L\infty$= 61.3 cm, K = 0.35 yr^{-1}, Z = 1.71 yr^{-1} and $\varnothing'$ = 3.12.

Occurrence of minor species was seasonal. It was not possible to obtain continuous monthly

samples. Their growth parameters were therefore estimated using the Powell-Wetherall method (Pauly & Morgan, 1987) and are presented in Table 3. Quantities of *C. gariepinus* and *P. aethiopicus* were very low to warrant estimation of growth parameters and mortality.

Table 3. Growth parameters of minor fish species in the Kenyan sector of Lake Victoria.

Fish species	L∞ (mm)	Z/K	N
Synodontis sp	239.1	2.65	10281
Pinktail haplochromine	120.8	1.059	20363
Barbus profundus	88.5	4.659	45444
Brycinus sadleri	118.833	6.532	3193
Oreochromis niloticus	593.0	3.608	21049

DISCUSSION

The low catches of fish in inshore areas are a result of high fishing pressure due to easy accessibility. Most fishermen operate paddle-propelled canoes and cannot venture far into the open lake. Hence areas in the open gulf and the immediate outside have higher catches. Wanjala and Marten (1974) reported declining catches due to over-fishing in shallow inshore areas.

The distribution of fish in the Nyanza Gulf has been affected by the water hyacinth. Previously after the introduction of L. niloticus in the late 1950s and early 1960s, the distribution of *O. niloticus* and the indigenous fishes was confined to inshore areas of depth <5 m. After the invasion by water hyacinth in 1997, these fishes (*C. gariepinus, Synodontis* spp., *P. aethiopicus* and haplochromines) became more common and started appearing in catches from areas >5 m deep. One of the reasons for this is that *L. niloticus* their main predator has been over-fished and the other is the presence of water hyacinth in the gulf. As the hyacinth spread from inshore areas to open water these species followed suit. The hyacinth introduced a lot of decomposing organic matter at the bottom (Table 3). This stimulated the decomposer food web activity resulting in abundance of fish food organisms. The decomposing hyacinth material caught in trawl-nets contains a wide range of organisms such as gastropod and bivalve molluscs, trichopteran and odonata larvae, oligochaeta and in most cases *Caridina nilotica* (Roux). These constitute the food of the minor bottom feeding fishes, which have shown recovery with the introduction of hyacinth.

L. niloticus does not prefer the anoxic conditions associated with areas under hyacinth hence the low catches of the species encountered in these areas. The hyacinth therefore serves as a refuge from predation by *L. niloticus* as well as a feeding niche for minor species.

There has been an increase in fishing effort in the Kenya sector of Lake Victoria, which has resulted in a higher instantaneous rate of total mortality (Z = 3.77) on *L. niloticus* and the observed low levels of mature fish particularly females. Fish of sizes >70 cm are rare and it is known that females mature at about 85 cm TL. This has caused a reduction in the landings of *L. niloticus*. Catches of this species peaked in 1989 at 215,000 mt annum^{-1} and have since then reduced to about 50,000 mt annum^{-1}. Due to this, the replenishing rate of *L. niloticus* has been reduced and this has resulted in the recovery and extension of ecological ranges of *O. niloticus* and minor species. It is known that fish under intense exploitation grow faster, hence in *O. niloticus* the observed increase in the growth parameters K and $\varnothing'$ from 0.25yr^{-1} to 0.41yr^{-1} and from 3.3 to 3.6 respectively and the reduction in the asymptotic length ($L\infty$) from 64.6 cm TL to 59.2 cm TL from 1992 to this period (Getabu, 1992; Dache, 1994).

CONCLUSIONS

The stocks of *L. niloticus* show signs of decline particularly in the low levels of mature fish, which can sustain recruitment from year to year. Appropriate steps should be taken to avoid collapse of the Nile perch fishery. Currently the majority of fish landed are immature, indicating illegal gear is being used. Mesh size restrictions should be enforced to curtail the harvesting of immature fish. The stocks of *O. niloticu*s and other minor species have shown signs of recovery.

RECOMMENDATIONS

i) The stocks of *L. niloticus* need continuous monitoring to study recruitment and standing stock sizes to obtain information for managing the fishery now that the stocks are threatened.

ii) Studies should be conducted to elucidate factors responsible for the current higher catches of *O. niloticus* in the Nyanza gulf with a view to finding ways of sustaining or improving the catches further.

iii) The role of the spread of the water hyacinth in the recovery of indigenous fish species needs to be investigated. The catches of the species have improved since invasion by the hyacinth. Studies with appropriate gear need to be undertaken to determine their biomass.

iv) Limnological factors and high fishing effort are responsible for the recent changes in catch composition in the Nyanza gulf. The contribution of each of these factors towards this effect needs to be elucidated.

ACKNOWLEDGEMENTS

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The Fishery of Lake Victoria, Tanzania: Pre - Post Nile perch era and the Future

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SUMMARY

Trawl surveys to define the fish stocks of Lake Victoria in terms of biomass and yield, together with the establishment of distribution and exploitation patterns, are being undertaken under the Lake Victoria Fisheries Research Project. Similar, but more localised surveys were carried out by HEST/TAFIRI between 1985 and 1989, and by TAFIRI in 1996 and 1997. These findings are being compared with a lake-wide bottom trawl survey in 1969/70. Marked differences, both spatial and temporal, are depicted in catch rates, biomass and in species composition and distribution. Abundance has been stable with depth although few fish were found deeper than 40 m. Mean catch rates have oscillated over time. At present the fishery is declining, but with indication of recovery in species diversity when compared to 1985 and 1989 findings. The future of Lake Victoria fisheries is argued in relation to existing efforts in management of the fishery and recovery of species diversity so as to restore previous established food webs.

INTRODUCTION

The fishery of Lake Victoria has exhibited considerable change over the last 50 years. Evidence of decline in catches started as early as the 1950s and resulted to the introduction of Tilapia *rendalii*, *Tilapia zillii*, *Oreochromis leucostictus* and *Oreochromis niloticus* (Welcomme 1988). Overfishing was reported as early as 1972. Haplochromines, which contributed 80% of the demersal fish stocks were not utilised until late 1970s when fish meal processing factories were established. The introduction of Nile perch (*Lates niloticus*, L.) in late 1950s and early 1960s altered the fishery of the lake and, with other factors, resulted to changes in the lake's ecosystem and the food web (Ogutu-Ohwayo 1990a; Witte, Goldschmidt *et al*., 1992; Mkumbo & Ligtvoet 1992). Increased pollution and clearing of the peripheral wetlands (Hecky 1993; Kaufman 1992; Mugidde, 1993), which served as fish nursery grounds, may be seriously affecting the fisheries and the lake resources in general.

Despite of a continuous decline of many endemic food species such as *Oreochromis esculentus*, *Bagrus docmak*, *Clarias gariepinus* and *Labeo victorianus* there has been a rapid increase in total landings from early 1980 to a peak in early 1990s. Catches increased five times from 85,914 t to 567,660 t and Nile perch contributed over 70% of the total landings, and up to 97% in trawl catches (Bwathondi, 1990; Ligtvoet *et al*., 1988). Catches for the other fish species decreased even further and others like the haplochromines almost disappeared in bottom trawls (Ligtvoet & Mkumbo, 1992). With increased fishing pressure, predation and competition among

species, the multispecies fishery of Lake Victoria fishery changed to only three species of Nile perch, the pelagic cyprinid, *R. argentea* and the introduced Nile tilapia.

In the mid-1990s Nile perch, the most important fish in the fishery showed signs of decline. Changes in the efficiency of fishing gears, motorization of canoes and increase of total fishing effort to maintain the yield have been observed. Extension of fishing grounds is also evident but all against a continued decrease in catch per unit effort and mean size of fish caught (Othina, 1999; Mkumbo & Cowx, 1999).

Changes in the species composition of the catches had a profound impact in the food web and eventually to the ecosystem in general. The haplochromines encompassed many trophic specialisations (Greenwood, 1974; Van Oijen *et al*., 1981; Witte & Van Oijen, 1990). These include the detritus/phytoplanktivores, molluscivores, zooplanktivores and the piscivores. With the present decline of Nile perch and the implementation of some management measures there are signs of recovery of species diversity in the lake.

In addition, there is a general belief that there are non-exploited off shore and deep waters stocks. The 1969/70 lake wide stock assessment survey was before the Nile perch boom and other ecological perturbations in the lake. The present study under the EU Lake Victoria Fisheries Research project is aiming at establishing the status of the present fishery and exploitation patterns for management purposes. Species distribution, composition, abundance indices and biomass estimates as well as population parameters for Nile perch and thus yield estimates and recruitment patterns are to be established. Fecundity, food and feeding studies are also being conducted.

This paper summarises some of the findings from the Tanzanian part. Species distribution, composition and abundance is given and is compared with past research findings

MATERIALS AND METHODS

Sampling

The Tanzanian part of Lake Victoria was divided into three areas (Fig. 1). Area A stretches from Kome and Buhiru islands in the south west, north eastwards to the south west of Ukerewe island, including Speke Gulf and Mwanza Gulf. Area B is from the Tanzania-Kenya border southwards to the north west of Ukerewe islands. Area C covers the Kagera waters from the Tanzania-Uganda border southwards to Kome island, including Emin Pasha Gulf.

The sampling stations were allocated using gridlines of five nautical mile squares based on degrees and minutes of latitude on hydrographic charts. In each square, one sampling station is allocated depending on depth. In very deep waters, squares of ten to fifteen nautical miles were sampled. Different depth ranges were covered depending on the actual depth of a given square. A total of 133 stations were established.

The research vessel, RV Victoria Explorer, length 17 m and a 250 HP engine, was used for the present surveys with a net of 22.6 m head rope and a codend of 25 mm mesh. Towing speed was 3-3.6 knots and trawling duration was 30 minutes.

Historical data collected by three different research vessels are used for comparison and assessment of any trends.

a) RV Ibis, length 17 m and a 180-HP engine, used in 1969/70 bottom trawl surveys with two standard nets of 24 m and 19 m head rope, and codends of varied mesh sizes but mainly 64, 38 and 19 m mesh sizes. Average towing speed was 3 knots and fishing duration was 60 minutes.

b) RV Kiboko, length 15 m and a 150 HP engine, used in 1985/89 bottom trawl surveys with a net of 18 m head rope and a codend of 25 mm mesh. Towing speed was 3 knots and fishing duration was 30 minutes.

c) RV Tafiri II, length 16m and a 175 HP engine, used in 1995/96 bottom trawls in area A with a net of 13.5 m head rope and a codend of 38 mm Trawling speed was 2.5 knots.

Data recording

Treatment of the catch depended on its size. If it was small, the entire catch was sorted into species, weighed, and every fish measured (TL cm) and weighed (g). If the catch was too large to handle in the time before the following sample was landed, the largest fish above about 35 cm TL were sorted from the catch and measured individually. The remaining small fish, <35 cm TL, were sub-sampled by taking three shovelfuls of fish from the thoroughly-mixed heap of fish on deck. Depending on the average size of fish in the sample, the number of shovels could be increased to have a minimum of 200 fish. The weights of the sub-sample and complete sample from which the sub-sample was taken were used to obtain a raising factor. Specimens of Nile perch from one or two hauls in a day (depending on size of the catch) were gutted for sex/ maturity and dietary analysis.

Data analysis

a) Monthly catch rates (kg hr^{-1}) from the three sampled areas, A, B & C were treated separately to assess the temporal distribution of the fish stocks.

b) Mean catch rates from different depth ranges were used to determine the batho-spatial distribution of the stocks. These were then compared to the historical data from Kudhoghania and Cordone (1974) to establish changes.

c) Changes in species composition was determined using the mean catch rates of the different species separately for the three areas, and this was again compared with historical data from RV, Ibis and RV Kiboko assess the change in fish diversity in the lake.

d) Changes in fish stock abundance were assessed using the mean catch rates of the four

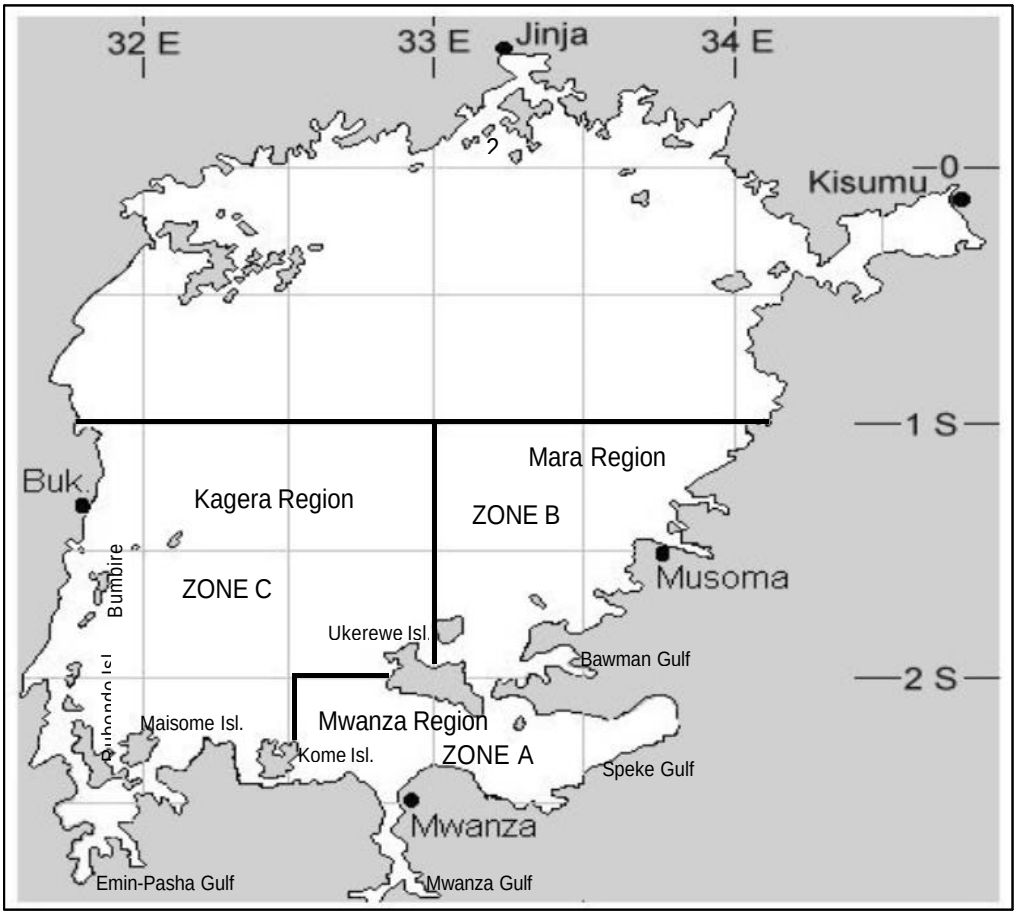

Fig. 1. Map of Lake Victoria indicating the three zones sampled in the Tanzanian side (Buk - Bukoba).

research vessels. It is recognised that the capture efficiency and selectivity of the vessel and the years used may vary but is expected that the output will illustrate trends in stock abundance.

e) Dietary analysis was done using the point method (Hopson, 1972), but for this paper relative occurrence of prey items is used.

RESULTS

Temporal distribution of fish stocks

Catch rates recorded from bottom trawl surveys for two months in 1997, one month in 1998 and monthly from March 1999 to April 2000 indicated varying temporal patterns between zones (Fig.2). Area A had more stable catches over the different months sampled compared to area B and C. The mean catch varied from 197.17 kg hr^{-1} in March 1999 to a highest mean catch of 273.0 kg hr^{-1} in October 1999.

Area B catch rates showed a decreasing trend over the period sampled for the different quarters,

although within the same quarter catches in the other areas were relatively high. Mean catches decreased from 287.7 kg hr^{-1} in Dec 1997 to 80.0 kg hr^{-1} in March 2000. Catches in area C increased from 74.9 kg hr^{-1} in Jan 1998 to a peak of 415.9 kg hr^{-1} in Sept. 1999 and then decreased again to 230.7 kg hr^{-1} in April 2000.

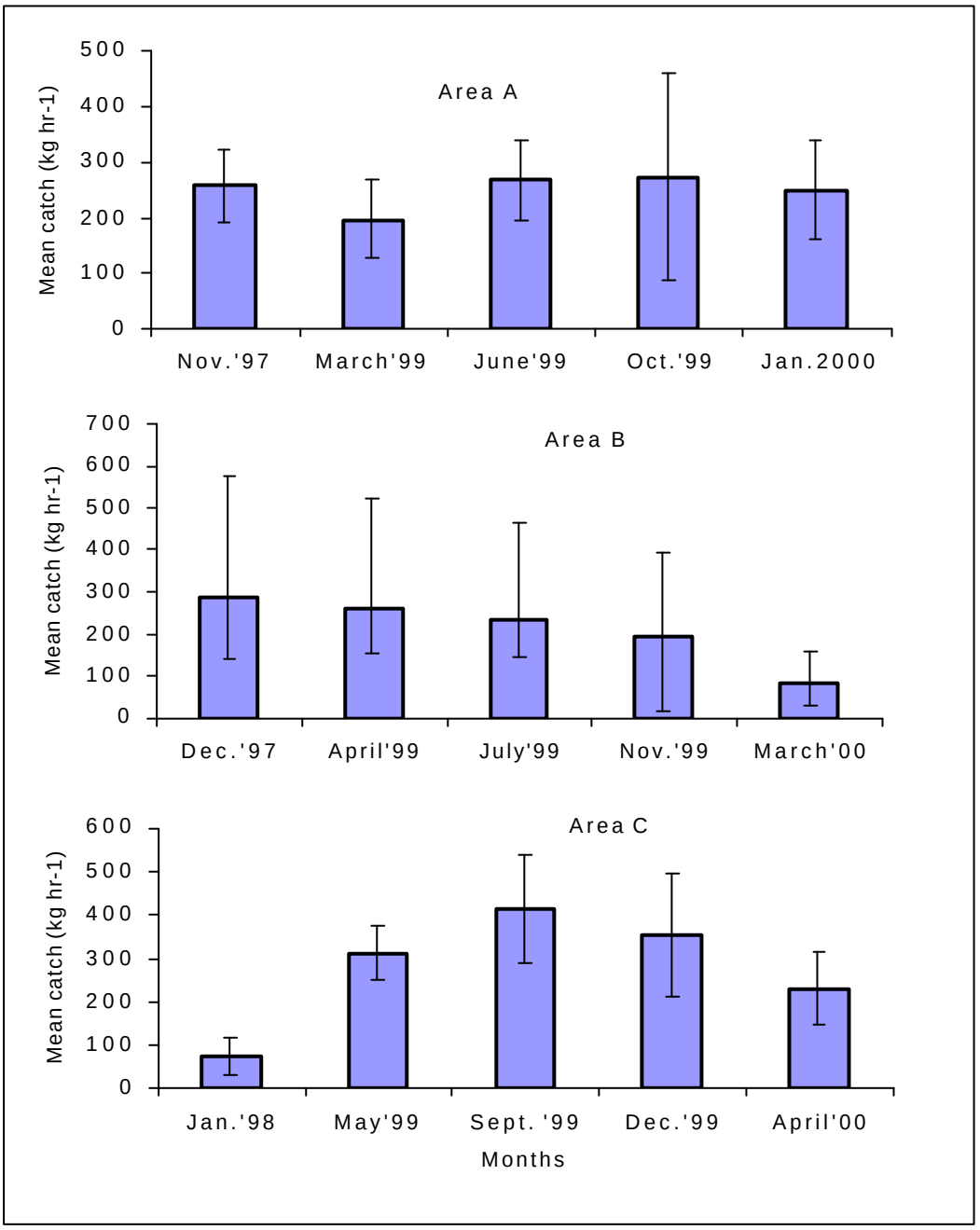

Fig. 2. Monthly mean catch rates from the three areas (A, B & C) sample quarterly from Nov. 1997 to April 2000. Vertical bars show mean ±SD.

Batho-spatial distribution of fish stocks

Catch rates exhibited little variation with depth to 40 m although there was a drop at below 50 m both from the present bottom trawl surveys (Fig. 3a) as well as the 1969/70 surveys (Fig. 3b).

Catches in the inshore waters of less than 20 m deep were the highest in both the surveys. The mean catch rates were 298.7 kg hr^{-1} and 282.3 kg hr^{-1} in 0-10 m and 10-20 m respectively for the 1999/2000 surveys, while they were 644.0 m and 935.3 m for the 1969/70 surveys. Mean catch rates in 1969/70 surveys were almost double those of the present survey. At a depth of 60-70 m the catches are comparable to the present catches in the depth ranges 0-50 m.

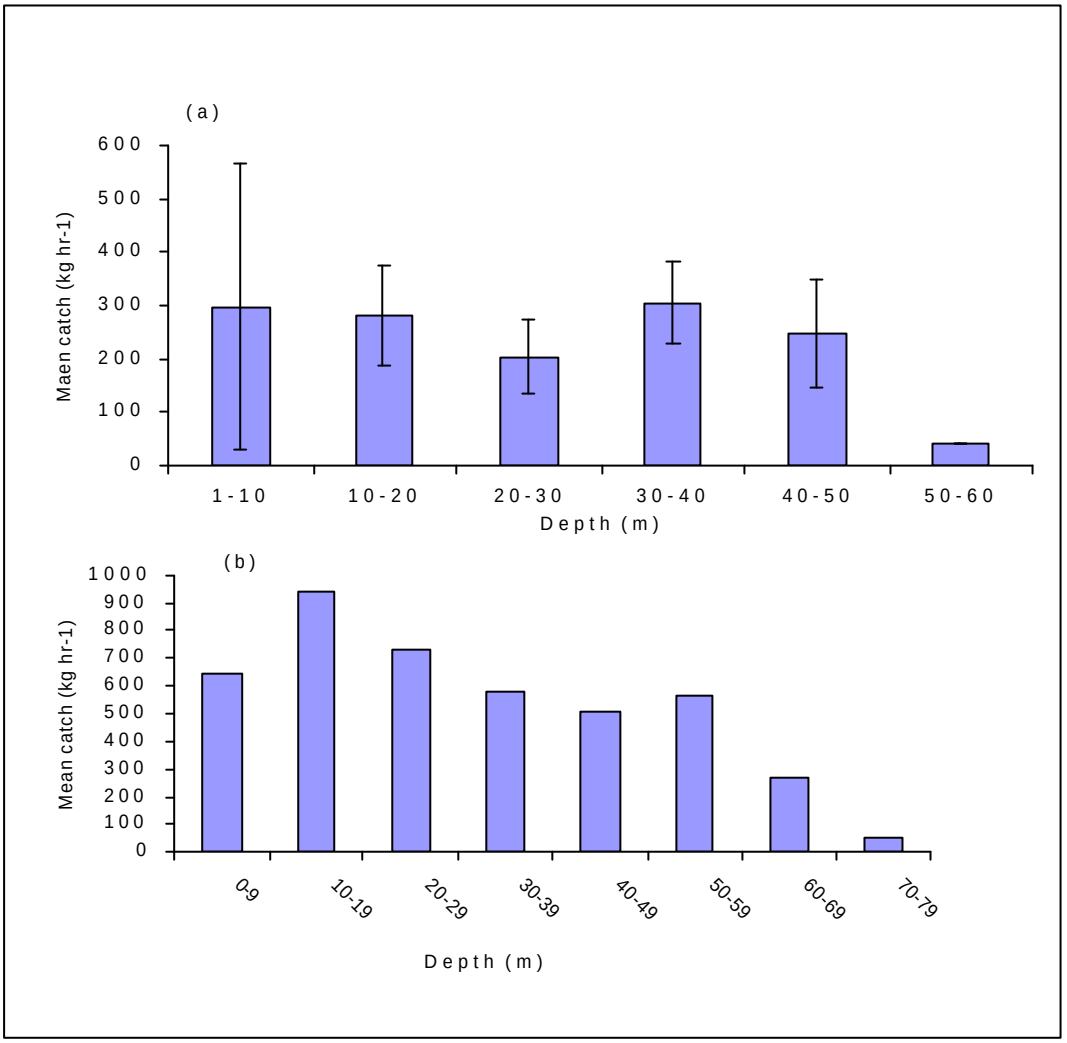

Fig. 3. Mean catch rates (kg hr^{-1}) from bottom trawl surveys in Tanzania waters in (a) 1997 - 2000 R.V. Explorer surveys and (b) 1967/70 R.V. Ibis surveys. Vertical bars show mean ±SD.

Fish species composition

Nile perch dominated the catches from 1989 to 2000; before these time it was haplochromines (Table 1).

For Tanzanian waters, 1969/70 (R.V. Ibis) surveys, haplochromine catch was 450.17 kg hr^{-1} constituted 71% of the total catch. Twenty-four other species were caught; Nile perch was recorded but was only 1 kg hr^{-1}. Other species like, *Oreochromis esculentus, Bagrus docmak, Clarias gariepinus, Protopterus aethiopicus* and *Synodontis victoriae* contributed > 10 kg hr^{-1} in the catches.

Table 1. Species composition by mean catch (kg hr^{-1}) sampled by the three re search vessels *R.V. Ibis, R.V. Kiboko R.V. TAFIRI II, R.V. Victoria Explorer*

	RV. IBIS	RV. Kiboko		RV. TAFIRI II		RV Vic/Expl.
SPECIES	69/70	1985	1989	1995	1996	99/2000
Haplochromines	**450.2**	**219.1**	**0.0**	**0.0**	**10.4**	**18.8**
Oreochromis esculentus (Graham)	17.5	0.0	0.0	0.0	0.0	0.0
O. variabilis (Boulenger)	0.7	0.0	0.0	0.0	0.0	0.0
O.niloticus (L.)	2.7	0.1	0.8	0.0	3.4	3.2
O. leucostictus (Trewavas)		0.0	0.0	0.0	0.0	0.0
Tilapia zillii (Gervais)	0.1	0.0	0.0	0.0	0.0	0.0
Bagrus docmak (Forsskall)	29.4	3.7	0.2	0.0	0.0	0.1
Clarias gariepinus (Burchell)	21.0	1.8	0.9	0.0	0.0	0.5
Xenoclarias eupogon (Norman)	0.3	0.0	0.0	0.0	0.0	0.0
Protopterus aethiopicus Heckel	11.9	16.8	1.5	0.0	0.0	1.3
Lates niloticus (L.)	1.0	75.3	94.6	191.2	279.9	246.2
Synodontis victoriae Boulenger	12.5	0.0	0.0	0.0	0.0	0.0
S. afroficheri Hilgendorf	0.1	0.0	0.0		0.0	0.0
Barbus profoundus	0.0	0.0	0.0	0.0	0.0	0.3
Barbus altianalis Boulenger	0.3			0.0	0.0	0.2
Labeo victorianus Boulenger	0.2	0.0	0.0	0.0	0.0	0.0
Mormyrus kannume Forsskall	0.3	0.0	0.0	0.0	0.0	0.0
Schilbe intermedius(L.)	0.6	0.0	0.0	0.0	0.9	0.6
Brycinus spp.	0.0	0.0	0.0	0.0	11.9	0.1
Aethiomastacembelus frenatus (Boulenger)	0.0	0.0	0.0	0.0	0.0	0.0
Gnathonamus longibarbis Hilgendorf	0.0	0.0	0.0	0.0	0.0	0.0
Rastrineobola argentea	0.0	0.0	0.0	0.0	0.0	2.6
Caridina nilotica	0.0	0.0	0.0	0.0	0.0	0.1

In the 1985, surveys in Mwanza Gulf, haplochromines catch rates were 219.1 kg hr^{-1} representing 69% of the total, and Nile perch had increased to 75.3 kg hr^{-1} (24%). Only four other species were recorded, *Protopterus aethiopicus, Bagrus docmak, Clarias gariepinus* and *Oreochromis niloticus* (Table 1). Catches by the same vessel in the same area in 1989 comprised 94.6% Nile perch while haplochromine was not found. All the other species recorded earlier were less than 2%.

In 1995/96, Nile perch increased from 191 kg hr^{-1} (almost 100% of the catch), to 279.9 kg hr^{-1} (91%). Other species, haplochromines *Schilbe intermedius* and *O. niloticus* were found in catches (Table 1).

Nile perch mean catches contributed 89.8% of the catches (246 kg hr^{-1}) in 1999/2000 while haplochromines catch rates were 18.8 kg hr^{-1} (6.7% of the total catch). Thirteen other species were recorded, *O. niloticus, Rastrineobola argentea, P. aethiopicus, Schilbe intermedius, C. gariepinus, Barbus profoundus, Barbus altianalis, B. docmak, Brycinus* spp., *Synodontis* spp. and *Labeo victorianus*.

Stock abundance over time

Mean catch rates have decreased by almost half between 1969/70 (R.V. Ibis) to 1999/2000 (R.V. Victoria Explorer). There was a progressive decrease to less than 20% in 1989, when the haplochromines almost disappeared from the catches. This was then followed by an increase during the Nile perch boom to 1996 and then a slight decrease (Fig. 4).

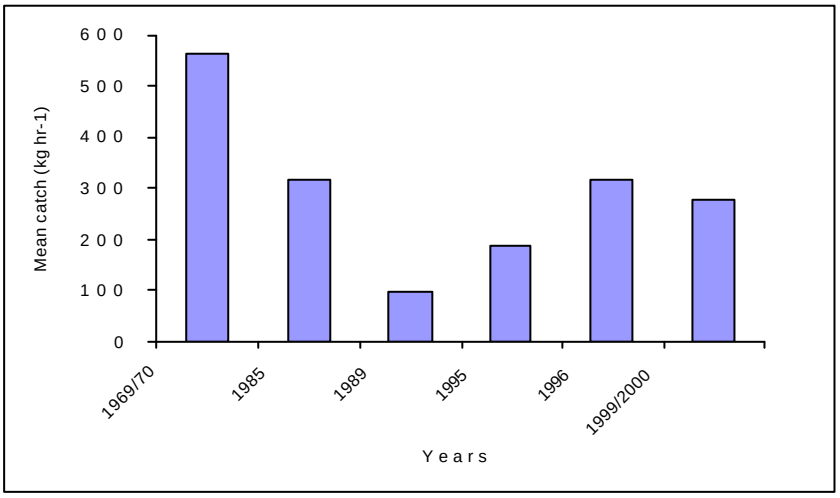

Fig. 4. Changes in mean catch rates of the different research vessels used at different periods in L. Victoria.

Dietary composition of the Nile perch

A total of 3474 fish were gutted for diet analysis. The diet of Nile perch is found to change with **size of fish (Fig. 5).** *Caridina nilotica* was the predominant food of the smaller size groups contributing more than 70% to fishes of less than 40 cm TL total length, and decrease in importance to only 14% in fishes of 80 cm TL. With increasing size haplochromines become important prey item contributing from 32% to 75% in fishes of size 40 cm to 70 cm TL. Above that size *R. argentea* and juveniles of Nile perch become significant each contributing less than 30% to the diet.

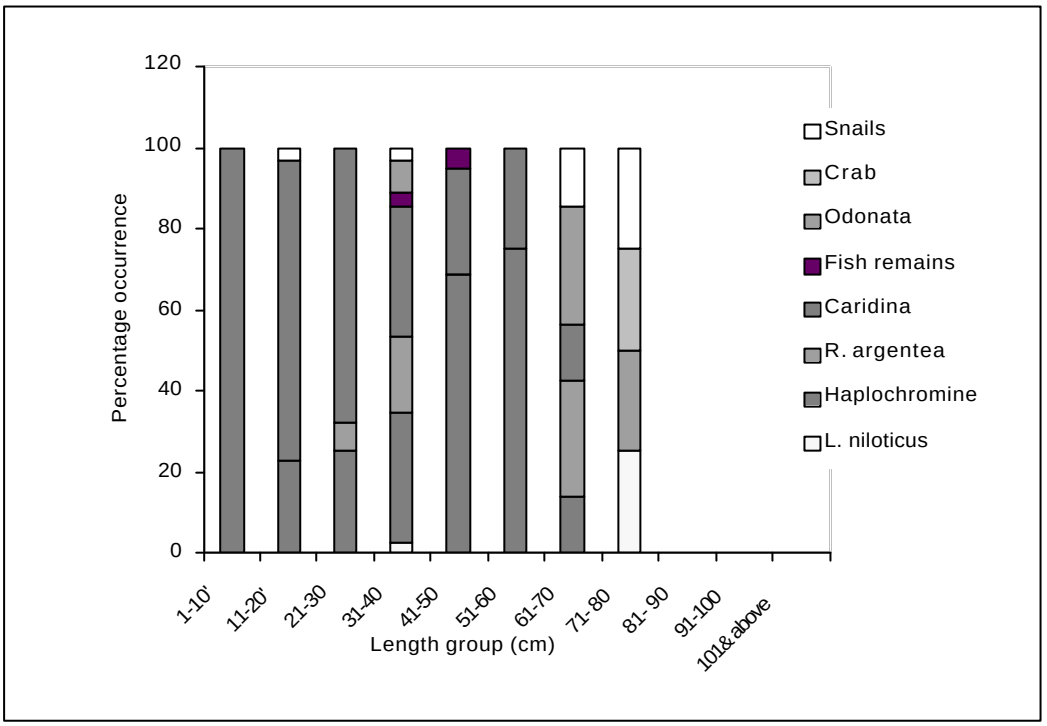

Fig. 5. Percentage composition of the food items in the stomachs of Nile perch of different size groups in the Tanzanian waters of L. Victoria.

Caridina niloticus had an overall contribution of 42% followed by haplochromines (30%), *R. argentea* (10%), Snails (6%), Odonata (5%), Nile perch (3%) and Crabs (3%) (Fig. 6). Thus Caridina and haplochromines are supporting the Nile perch stock.

DISCUSSION

The distribution and abundance of demersal fish stocks of Lake Victoria.

Distribution of fish stocks in Lake Victoria have varying temporal patterns between regions. Area A being relatively shallow with many vegetation fringed bays seem to have almost stable catches over the different seasons This is because thermal stratification and deoxygenation of the lower parts of the water column last for very short periods of relatively low wind speed (Talling, 1966, Hecky & Bugenyi, 1992). It is rather difficult to explain the trend in B without limnological data.

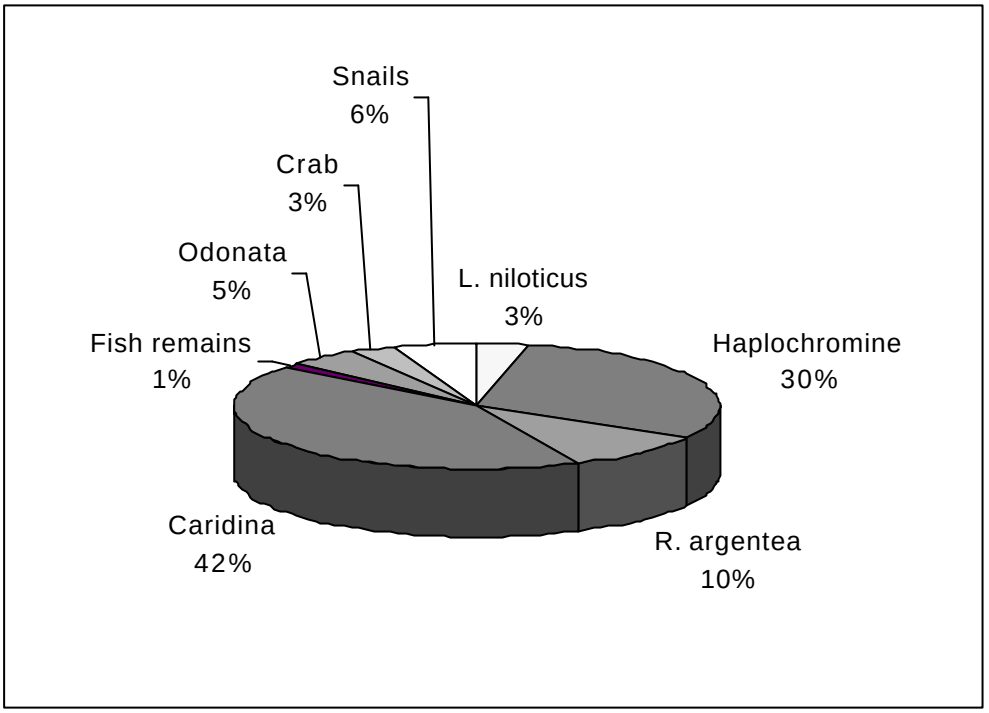

Fig. 6. Percentage contribution of different prey items in the diet of Nile perch in the Tanzanian waters of L. Victoria.

July and November would be expected to have high catches due to total mixing of the water column. It is possible that thermal stratification and oxygen levels are not the key factors influencing fish distribution in this area. The extreme low catches in area C in January 1998 could probably be explain by the effect of *El'Nino*, and being relatively deep with very few bays, the pattern of distribution seems to comply with the periods of mixing and stratification of the water column (Hecky & Bugenyi, 1992).

The batho-spatial distribution pattern is more evident as during the 1969/70 surveys although the trend is clear with consideration of area and time of sampling separately (Mkumbo & Ezekiel, 1999). Below 50 m deep an abrupt drop of mean catch rates is observed unlike the 1969/70 surveys where the drop was below 70 m deep. This is explained by the changes in the physical/ chemical characteristics of the lake and existing hypoxic layer below 50 m (Hecky *et al*. 1994). Haplochromine, the dominant stock in 1969/70 are relatively more tolerant to low oxygen levels than Nile perch (Fish 1956, Ochumba 1987) and this can also explain the difference in depth distribution for the two surveys.

Considering mean catch rates for the experimental trawlers, abundance remarkably decreased with time. Although catches increased five folds in early 1990s (Bwathondi, 1990, Ogari & Asila, 1990, Orach-Meza, 1991), still the abundance of the demersal stocks was lower than the pre Nile perch period. The present decline in catch rates both in experimental surveys as in

commercial landings could probably be due to predation by the Nile perch. Due to under-representation of pelagic stocks in bottom trawl, and also in fishery statistics, there is an under estimates of abundance and biomass. *Rastrineobola* is recorded to have increased considerably over the period (Ligtvoet *et al.,* 1995), and is now the second important in fishery. Nile tilapia is equally under represented due to its' habitat restriction in shallow non-trawled areas but is the third important in the fishery of the lake (Ogutu-Ohwayo, 1995, Ligtvoet *et al*., 1995).

Fish species composition and changes in the diet of Nile perch

The diet of Nile perch have been changing following the dominance of the prey species in the habitat. On the onset, Nile perch predominantly preyed on haplochromines (Okedi, 1971). With changes in abundance Nile perch switched to *Caridina nilotica, Rastrineobola* and cannibalism (Ogari & Dadzie, 1988, Mkumbo and Ligtvoet, 1992), Juvenile Nile perch contributed more than 60% of the diet in 1996, but in the present surveys, it is only 3%. *Caridina* which contributed 42% of Nile perch diet reduced to 30% following recovery of haplochromines. Despite of the abundance of *Rastrineobola* it is contributing only 10% to the diet possibly due to habitat differences. *O. niloticus* is almost missing in the diet of Nile perch although it has increased in abundance.

The future of the fishery and recommendations

The boom of Nile perch fishery was immediately followed by decline in mid 1990s and with signs of over fishing (Ogutu-Ohwayo, 1995, Mkumbo & Cowx, 1999). Management measures were immediately implemented; control of minimum mesh size, barn on trawling and beach seines as well as closed fishing areas and seasons, to protect the spawning stock and ensure recruitment to the fishery. All these measures were being based on the traditional concepts in fisheries management. It is obvious that the prey-predator interaction is an important regulatory mechanism in any natural populations. There has been a tendency of fishing down the trophic levels and as a result sustainability can never be achieved.

Nile perch the present most important fishery stock is the top predator, feeding on a number of trophic levels, mainly primary (juveniles feeding on planktons, cladocera and cyclopoids, then insect larvae) and secondary levels (*Caridina* and haplochromines and *Rastrineobola*), and the bigger ones are tertiary consumers. *Caridina* occupying the niche left by haplochromines, have built up in population numbers and currently supporting the Nile perch as food. The released predation pressure on haplochromines has given the population room to expand once again.
Other fish species are also given room to expand as man, the top-most predator is exerting pressure on the Nile perch, which over-competed the endemic predators like *Clarias* and *Bagrus*. Fishing pressure is also directed to *Rastrineobola* and *Oreochromis*, the other two important stocks in the fishery, but measures must be taken to ensure the trophic levels are not over-exploited to levels which can not support the transfer of energy. Although there are signs of restoration of the former trophic relations, the energy flow from the different levels and the actual biomass needed at each level so as to support another level has to be found for a stable ecosystem and a sustainable fishery of Lake Victoria. Thus an ecosystem-based fisheries management approach is the goal.

Current State of the Fish Stocks in The Ugandan Waters of Lake Victoria

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SUMMARY

A total of 561 hauls were taken during experimental bottom trawl surveys in the Uganda sector of Lake Victoria during the period November 1997 to December 1999 to estimate composition, distribution and abundance of the major fish species in waters 4-60 m deep. Seventeen fish groups were caught with Nile perch, Lates niloticus (L.), constituting 90.0% by weight. Haplochromines and L. niloticus occurred in all areas sampled while Nile tilapia, Oreochromis niloticus (L.), and other tilapiines were restricted to waters <30 m deep. The mean trawl catch rate in the zone where artisanal fishermen operate (i.e. in waters <30 m depth) was 169.94 kg hr^{-1}, of which 90.2% was L. niloticus. Species diversity and relative abundance of the fish caught decreased with increasing water depth.

During the lake wide bottom trawl survey of 1969-1971, 24 fish species belonging to 21 genera were encountered and haplochromine cichlids were the most abundant. The Haplochromis species complex contributed 83% by weight, Bagrus docmak 4.2%, Clarias gariepinus 4.1%, Oreochromis esculentus 3.8%, Protopterus aethiopicus 2.8%, Oreochromis niloticus 0.5% and Synodontis victoriae 0.4%. Lates niloticus catches were insignificant (<0.1%). A mean catch rate of 797 kg hr^{-1} was estimated for waters between 4 m and 30 m deep. Haplochromines in the trawl declined from 91.4% in 1981 to almost zero in 1985, while the contribution of L. niloticus increased from 5% to 96% during the same period. The mean catch rates for all fish species combined declined from 595 kg hr^{-1} in 1981 to 355 kg hr^{-1} in 1983 and to 155 kg hr^{-1} in 1985. During the survey of May 1993 to October 1997, Lates niloticus contributed 96.5% of the total catch by weight.

INTRODUCTION

Until the 1970s, Lake Victoria had a multi-species fishery dominated by the tilapiine and haplochromine cichlids. There were important subsidiary fisheries for more than 20 genera of non-cichlid fishes, including catfishes (*Bagrus docmak, Clarias gariepinus, Synodontis* spp and *Schilbe intermedius*), the lungfish (*Protopterus aethiopicus* and *Labeo victorianus* (Kudhongania & Cordone 1974). Stocks of most of these species declined and others disappeared following the introduction of four tilapiines (*Oreochromis niloticus, Oreochromis leucostictus, Tilapia rendalli* and *Tilapia zillii* and Nile perch (*Lates niloticus*) during the

1950s. Since then the fishery has been dominated by Nile perch, Nile tilapia and the native cyprinid species, *Rastrineobola argentea* (Mukene).

Lake Victoria is an important source of fish not only for local consumption but also for export. A number of fish processing plants have been constructed along the shores of the lake, 11 of which are licensed to operate in Uganda (Odongkara & Okaronon 1999). The fishing capacity in the Uganda sector increased from about 3 200 fishing canoes in 1972 to 8 000 by 1990 (Okaronon 1994) and was estimated to be about 10 000 canoes in 1998 (C. Dhatemwa, personal communication).

This increase in fishing effort and investment was made without clear knowledge of the magnitude of the stocks. There are indications that the fishery yield has declined from 135 000 tons in 1993 to 107 000 tons in 1997 (Odongkara & Okaronon, 1999). The only previous extensive stock assessment exercise undertaken was from 1969 to 1971, before the Nile perch upsurge (Kudhongania & Cordone, 1974). Some other bottom trawl surveys were conducted from 1981 to 1985 (Okaronon J.O., Acere T.O. & Ocenodongo D.L., 1985; Okaronon & Kamanyi 1986) and from 1993 to 1997 (Okaronon, 1994; Odongkara & Okaronon, 1999). The current stock assessment programme, which commenced in 1997, is designed to generate information to underpin management decision making for the fishery. This includes estimating the current composition, distribution, abundance, population structure and biomass of the major fish species. The objective of this paper is to provide an overview of the current state of the fish stocks in the Ugandan portion of Lake Victoria.

MATERIALS AND METHODS

The Ugandan sector of the lake was divided into 3 zones: I - Tanzania/Uganda border to Bugoma Channel (Bukakata), II - Bukakata to Rosebury (Kiyindi), and III - Kiyindi to Uganda/ Kenya border. These zones were further subdivided into grids for sampling purposes; on the Ugandan sector the grids measuring approximately 5 nautical miles square were used. The fixing of grids was based on minutes of Latitude and Longitude.

Experimental bottom trawling surveys, each lasting about 10 days, were carried out monthly between November 1997 and December 1999 using the research vessel R.V. IBIS. Each of the three zones was surveyed once every quarter to take account of the four climatic seasons in the area. Hauls of 30 minutes duration were taken using a 25.4 mm codend stretched mesh trawl in the various grids. The bottom trawl surveys using these grids became operational during 1999. The grids surveyed included those with transects surveyed in earlier operations (1993-1998).

A trawl net is a large wide-mouthed net dragged along the lake-bottom by a boat. The net (trawl) has a head rope (where the floats are attached) of about 20-metre length and a footrope (where the chains or sinkers are attached) of about 28 metre length; the depth/opening of the net is estimated at 1.5 metres. The codend is the closed bag part of the net tied at end of the net. The net was dragged, during the trawling operation, by the research vessel a MV IBIS that is 17 metre long and has a 4.9 metres beam and a 2.4 metres draft. The vessel is powered by a marine

diesel engine rated at 180 hp and attains a maximum speed of 9 knots. The trawling speed was maintained at about 3 knots.

Fish catches were sorted into species. Fish weights and lengths were taken and recorded. The weights were in kilograms (kg) to the nearest 50 grams (g) for fish greater than 2 kg, the nearest 5 g for fish between 100 g and 1 kg and to the nearest 1 g for fish less than 100 g. The lengths are in centimetres (cm) to the nearest millimetre (mm).

For large quantities of fish retained, subsampling was used especially for smaller/juvenile specimen less than 35 cm total length for *L. niloticus*. The heap (of smaller/juvenile fish) was mixed thoroughly, a sample of known weight (3 spades) relative to the heap was taken and analysed for lengths and/or weights and the results raised accordingly

Of the 561 hauls made from November 1997 to December 1999, 48% were taken in Zone II, 40% in Zone III and 12% in Zone I (Table 1). The low number of hauls in Zone I was primarily because of breakdown of the research vessel and, to a certain extent, rough weather. The majority of the trawl hauls (72%) were made in waters between 10 m and 30 m deep, while 18% were in shallower waters (Table 1).

Length frequency analysis of *Lates niloticus* was carried out on 29 345 fish caught between November 1997 and June 1999.

RESULTS

Fish species composition and distribution

During the current survey of November 1997 to December 1999, 17 species groups (14 genera) were recorded (Tables 2 and 3). These groups included species complexes such as haplochromine cichlids. *Lates niloticus* dominated the catches (90.0% by weight) followed by *Oreochromis niloticus* (5.1%) and haplochromines (3.2%); all other species together contributed less than 2% (Table 4).

The highest catches were obtained in Zone II, where an average of 191.7 kg hr^{-1} was recorded, followed by Zone I (142.4 kg hr^{-1}) and Zone III (135.4 kg hr^{-1}) (Table 5). Species diversity was greatest in the depth range 10-20 m, and declined markedly with increasing depth (Table 2). A high proportion of the fish (94%) was found in waters <30 m deep (Tables 4 and 5). *L. niloticus* and haplochromines occurred in all areas sampled while *O. niloticus* and other tilapiines were restricted to waters less than 30 m deep (Tables 2, 3`4 and 5). Few fish were caught in depths greater than 40m and these were restricted to *L. niloticus*, haplochromines and *Barbus* spp.

Relative abundance of the fish stocks

The mean catch declined from 208.3±37.0-kg hr^{-1} in the 4-10 m depth zone to 2.9±3.5-kg hr-1 at 40-50 m depth (Table 4, Fig. 1). A mean catch rate of 168.3± 26.0-kg hr^{-1} was calculated for the 4-30 m depth range where the artisanal fishermen operate.

Table 1. Distribution of hauls during bottom trawling at the various depth ranges in the Uganda sector of Lake Victoria, 1997-1999.

Period		Depth interval (metres)														
		Zone I					Zone II					Zone III				
		4-10	10-20	20-30	30-40	40-50	4-10	10-20	20-30	30-40	40-50	4-10	10-20	20-30	30-40	40-50
1997	Nov						7	12	9	3	5					
	Dec											4	11	10	5	1
1998	Jan															
	Feb	1	15	6	4		1	1								
	Mar						6	9	10	3		1	1			
	Apr											2	14	6	1	
	May															
	Jun						13	15	14							
	Jul															
	Aug											3	12	11	3	1
	Sep											1	24	1		
	Oct						3						5			
	Nov						1	2	8		2					
	Dec		12	4	2		8	9	1							
1999	Jan											3	10	18		1
	Feb															
	Mar						6	13	5	3						
	Apr		4				9	9	10	4	1					
	May											3	6	7	3	
	Jun						12	10	12	3	1					
	Jul			2	3											
	Aug											1	12	1	1	
	Sep	3	5	8			1	2								
	Oct															
	Nov						7	6	9	2	1					
	Dec											6	20	11		1
Total		4	36	20	9		74	88	78	18	10	24	115	65	13	4
By zone:				69					268					221		

Table 2: Species distribution of fish caught by bottom trawling at various depth ranges in three different zones (see Fig. 1) the Uganda sector of Lake Victoria, November 1997 to December 1999.

Fish Species	Water depth (m) Zone I 4-10	10-20	20-30	30-40	40-50	Zone II 4-10	10-20	20-30	30-40	40-50	Zone III 4-10	10-20	20-30	30-40	40-50		
Aethiomastacembelus frenatus																	
Bagrus docmak							+										
Barbus spp			+		+		+	+	+	+		+	+	+	+		
Brycinus spp							+										
Clarias gariepinus			+				+						+				
Haplochromis spp			+		+	+		+	+	+	+	+	+	+	+	+	+
Labeo victorianus			+														
Lates niloticus	+		+		+		+	+	+	+	+	+	+	+	+	+	
Mormyrus kannume														+			
Oreochromis leucostictus								+					+				
Oreochromis niloticus			+		+			+	+				+	+			
Protopterus aethiopicus									+								
Schilbe intermedius											+						
Synodontis afrofischeri								+	+	+	+		+	+	+		
Synodontis victoriae									+	+	+	+		+			
Tilapia rendalli								+									
Tilapia zillii							+					+	+				

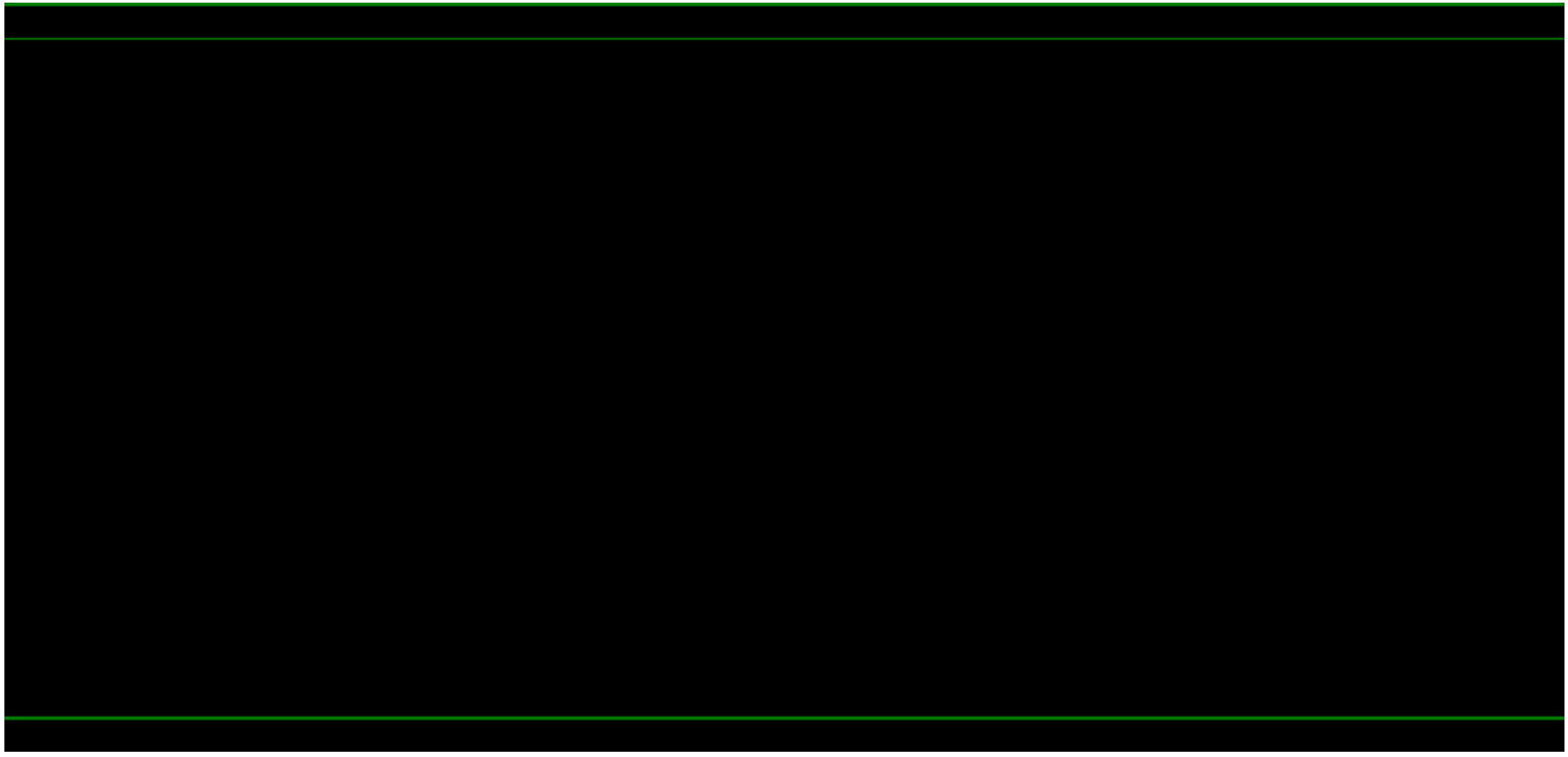
Table 3: Species distribution of fish caught by bottom trawling at the various depth ranges in the Uganda sector of L. Victoria between 1969 & 1999. (Water depth (10 m intervals): 4=4-10 m, 10=10-20 m, 20=20-30 m, etc) Maximum water depth sampled were: 80 m in 1969-1971, 50 m in 1994/97 and 60 m in 1997/99.



Table 4. Mean catch rates (kg hr-1) by depth for fish caught by bottom trawling in the Uganda sector of L. Victoria between November 1997 to December 1999. (0.00 = present in trace quantities of less than 16 g). (mean catch rate=total catch/total number of hauls*60 minutes)

Fish species	Depth interval (metres) 4-10	10-20	20-30	30-40	40-50	50-60	Overall mean	Percentage
Aethiomastacembelus frenatus	0.00						0.00	0.00
Bagrus docmak	0.01						0.01	0.01
Barbus spp	0.03	0.01	0.03	0.03	0.08	0.01	0.02	0.01
Brycinus spp	0.00					0.00	0.00	
Clarias gariepinus		0.09					0.04	0.02
Haplochromis spp	4.43	4.11	8.35	1.22	0.98	0.05	5.12	3.20
Labeo victorianus		0.00					0.00	0.00
Lates niloticus	173.72	139.45	160.00	116.93	1.68	4.83	146.37	91.44
Mormyrus kannume		0.01					0.00	0.00
Oreochromis leucostictus	0.01						0.00	0.00
O. niloticus	24.81	8.63					8.25	5.15
Protopterus aethiopicus		0.39					0.16	0.10
Schilbe intermedius					0.00		0.00	0.00
Synodontis afrofischeri	0.04	0.02	0.01	0.00			0.02	0.01
S. victoriae		0.00	0.01	0.24	0.13		0.03	0.02
Tilapia rendalli		0.02					0.01	0.01
T. zillii	0.01	0.12					0.05	0.03
Number of species caught	9	13	5	5	5	3		
Mean of total catch rate	203.06	152.85	168.40	118.42	2.87	4.89	160.08	
95% confidence limits	±37.27	±22.37	±38.85	±66.31	±3.46	±12.45		
Number of hauls	104	237	165	39	13	3	561	

Table 5. Mean catch rates (kg hr-1) by fishing zone during bottom trawling in the Uganda sector of Lake Victoria between November 1997 and December 1999) (mean catch rate=total catch/total number of hauls*60 minutes)



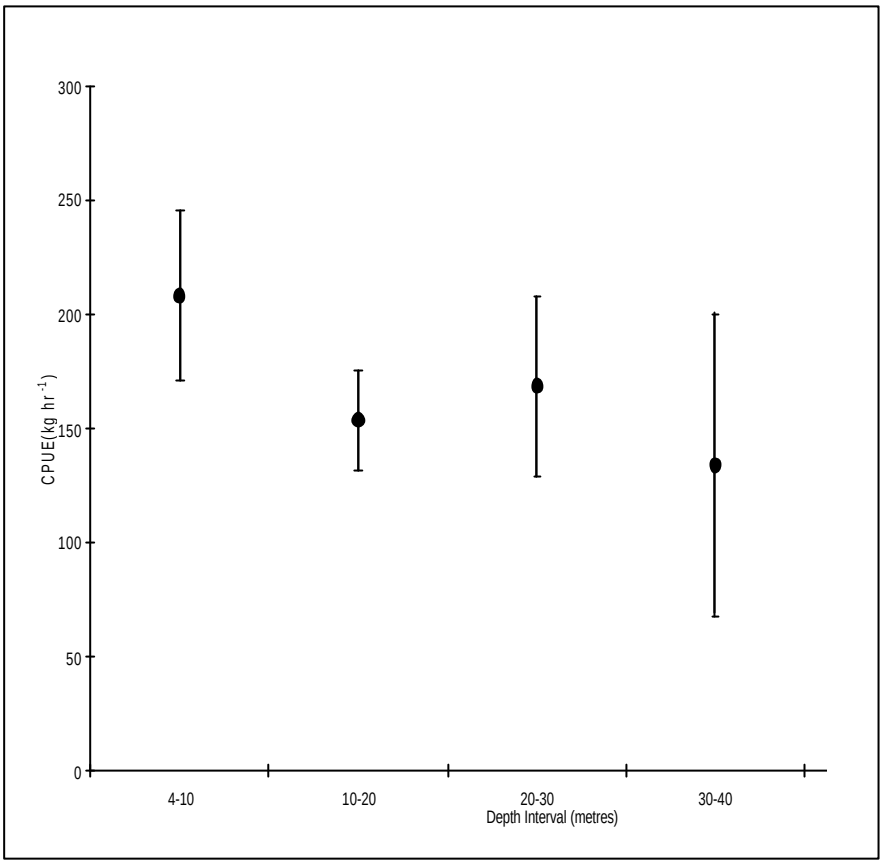


Fig. 1. Mean catch rate (and 95% confindnce limits) from bottom trawling in Lake Victoria (Uganda), November 1997 to December 1999

The mean catch rate of bottom trawling in the artisanal fishing zone showed a marked decline since the surveys of 1969 (Fig. 2). This decline was most rapid in the early 1980s when catches dropped from 595 kg hr^{-1} in 1981 to 155 kg hr^{-1} in 1985.

Population characteristics of *Lates niloticus*

The length range of the 29 345 fish measured was 2 - 137 cm TL. 50% of the fish had a TL of 4 - 16 cm and 73% of 5 - 26 cm. The modal length was 10 cm.

DISCUSSION

During the lakewide bottom trawl survey of 1969-1971, 24 fish species belonging to 21 genera were encountered and haplochromine cichlids were the most abundant. There were remarkable changes in species composition by depth with the maximum species diversity in the shallow waters. The *Haplochromis* species complex contributed 83% by weight, *Bagrus docmak* 4.2%, *Clarias gariepinus* 4.1%, *Oreochromis esculentus* 3.8%, *Protopterus aethiopicus* 2.8%, *Oreochromis niloticus* 0.5% and S. victoriae 0.4%. *Lates niloticus* catches were insignificant (<0.1%). A mean catch rate of 797 kg hr^{-1} was estimated for waters between 4 m and 30 m deep (Fig. 2). The mean total length of some fishes (*Haplochromis* spp, S. victoriae, and *Xenoclarias eupogon*) increased with depth.

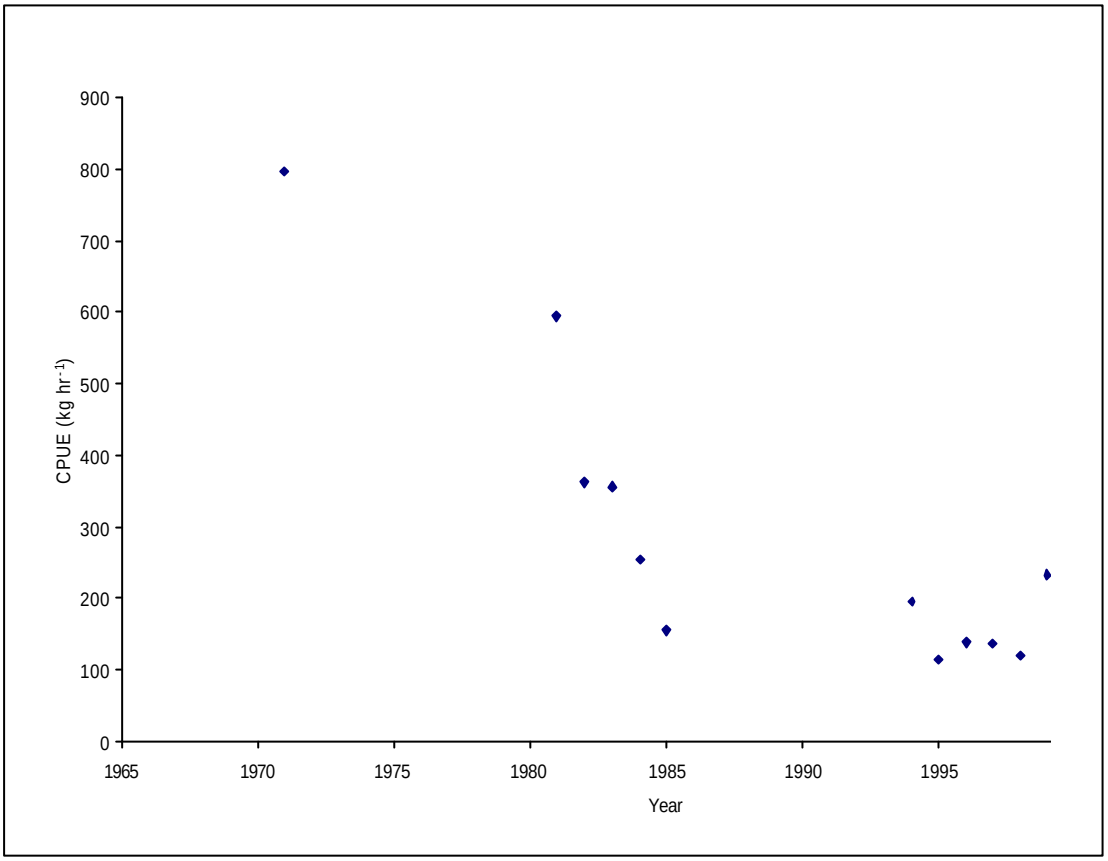


Fig . 2. Change in mean catch per unit of effort from experimental trawling in the 4-30 m depth zone since 1969.

Bottom trawling in the Ugandan waters of Lake Victoria during 1981-1985 (Okaronon J.O., Acere T.O. and Ocenodongo D.L., 1985; Okaronon and Kamanyi 1986) yielded all but two of the non-cichlid species *Gnathonemus longibarbis* and *Brycinus* sp. found in the 1969-71 surveys. Haplochromines in the trawl declined from 91.4% in 1981 to almost zero in 1985, while the contribution of *Lates niloticus* increased from 5% to 96% during the same period. The mean catch rate for all fish species combined declined from 595 kg hr^{-1} in 1981 to 355 kg hr^{-1} in 1983 and to 155 kg hr^{-1} in 1985 (Fig. 2).

During the survey of May 1993 to October 1997 (Okaronon 1994, Odongkara & Okaronon 1999), *L. niloticus* contributed 96.5% of the total catch by weight. Fish diversity and abundance decreased with increasing water depth. About 60% of the total fish catch was in waters less than 30 m deep. The mean annual catch in the 4-30 m depth zone was 150 kg hr^{-1}.

Three fish species recorded during the 1993-97 survey (*Barbus altianalis, Oreochromis variabilis* and *Xenoclarias eupogon*) were not caught in 1997/98, suggesting a further decline in species diversity. More fish (about 95% of total catch by weight) were recorded in waters less than 30 m deep during 1997/1998 compared to about 60% during 1993-1997. During 1999 surveys, three additional fish species, *Aethiomastacembelus frenatus, Schilbe intermedius* and *Tilapia rendalli*, were found. These species were absent during the 1997/98-survey period.

The experimental trawl CPUE has shown a continuous marked decline since the trawling survey of 1969-1971. CPUE in waters less than 30 m was on the average 797 kg hr^{-1} over the 1969-1971-survey period and declined to 115-kg hr^{-1} in 1997/1998. The average catch in 1999 increased to 225±60 kg hr^{-1}, but this increase was probably due to the change of experimental trawl gear effective November 1998 coupled with heavy rains during 1998/1999.

The fish species composition in 1969-1971 was very different from 1999 survey. The different **behaviour and possible net avoidance of** *Lates niloticus* presently targeted by the trawl net may be partially responsible for the decline in fish stocks in the experimental trawl catches. The 72% decline in catch rates in 1999 compared to that for 1969-71 is of major concern.

ACKNOWLEDGEMENT

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Exploitation of the Fish Stocks of the Sondu Miriu Wetlands and Adjacent River and Lake Waters of Lake Victoria (Kenya)

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SUMMARY

A study of the fish stocks of the Sondu Miriu wetlands, adjacent river and the lake waters of Lake Victoria (Kenya) was conducted from January1996 to January 1997 with the aim of understanding the impact of various gears to the recruitment of commercially important fish species to the reproductive stocks. The catch composition by various gears was also investigated.

A total of twenty-nine fish species belonging to twelve families were identified, the majority of which are indigenous. The percentage catches by gear were as follows: gillnets 57.6%, traditional traps 28.7%, hook and line 10.5% and mosquito seine 3.2%. The riparian community depends mainly on this resource to satisfy their protein needs.

Most of the gears that are used in this area exploit fish that are yet to spawn. They are also destructive, as they are used in the spawning and nursery grounds of most of the fish species, therefore interfering with the recruitment of the fish to the reproductive stock. This paper discusses the implications of this kind of fishery and suggests management options for the sustainable utilization of this resource.

INTRODUCTION

Lake Victoria Fishery

Lake Victoria the second largest fresh water lake in the world covers an area estimated at 68800 km^2. It is a source of livelihood for over thirty million people in the riparian states of Kenya, Uganda and Tanzania Kaufman (1992). The earliest fisheries of this Lake were mainly at the subsistence level. Fishing gear consisted of locally made basket traps, hooks and seine nets of papyrus. Initial fishing effort was low, but it began to increase with the introduction of more efficient flex gillnets in 1905. Ogutu-Ohwayo (1990). The major contributors to the commercial landings were *Oreochromis esculentus* Graham, *Oreochromis variabilis* Boulenger, over 250 species of haplochromines, mormyrids, catfish and cyprinids (Graham, 1929), Fryer & Iles (1972). In the 1950s *Oreochromis leucostictus* Trewavas, *Oreochromis niloticus* L. and *Tilapia zillii* Gervais were introduced into Lake Victoria to increase fish production. However, these species

have similar ecological requirements to those of the native species and are likely to have competed with them Ogutu-Ohwayo (1990). High rainfall during the 1960s submerged and destroyed extensive beds of littoral vegetation, eliminating important spawning grounds for native species. This natural occurrence must have contributed to the decline of at least those native species dependent on near shore habitats Kaufman (1992).

The Nile perch *Lates niloticus* L. was introduced into Lake Victoria in the early 1960s (Fryer, 1960). Nile perch persisted as a minor component of the fauna for two decades. By 1983 in Kenya and 1986 in Tanzania, the native fish community had been virtually destroyed and Nile perch comprised more than 80% of the catch Kaufman (1992). Lake Victoria which at one time harbored the world's second largest ichthyofaunal assemblage has now been reduced mainly to a three species scenario, comprising the exotic Nile perch *L. niloticus*, the endemic cyprinid *Rastrineobola argentea* Pellegrin and the introduced Nile tilapia *O. niloticus* Kaufman (1992). The rest of the endemic fish species are endangered, a phenomenon mainly brought about by high predation of Nile perch, overfishing, increased eutrophication and more recently the proliferation of the water hyacinth *Eichhornia crassipes*.

Riverine Fishery

The fisheries of the affluent rivers of the Nyanza Gulf, Kenya, were once important Whitehead, (1959), but have been declining since 1940 (Van Someren, 1959; Cadwalladr, 1965b; Benda, 1979; Marten, 1979; Kibaara, 1981; Ogutu-Ohwayo, 1990). The annual catch of 2500t Whitehead (1959) from the Nyanza rivers is no longer possible. The fishery yield from River Sondu Miriu has dropped from 668 t in 1959 to the current 81.5 - 108 t Ochumba & Manyalla **(1992). The species** *Schilbe intermedius* and *Synodontis victoriae*, have replaced the once abundant *Barbus altianalis* and *Labeo victorianus*. The decline in these species can be attributed to overfishing Van Someren (1959), papyrus encroachment and habitat degradation Balirwa and Bugenyi (1980), introduction of the Nile perch and Nile tilapia Ogutu-Ohwayo (1990), poor management Ochumba & Manyalla (1992) and pollution Kibaara (1981).

The lower Sondu Miriu region receives low and unreliable rainfall, thus making most of the local people, who are mainly poor to rely on the river, swamp and lake for their livelihood. Fish forms an important source of protein for the local community. Fishing is therefore done intensively using small meshed gears, which pose a threat to the fishery of this area.

This paper examines the impact of various gears used for the exploitation of commercially important fish species to the recruitment of these fish to the reproductive stocks and suggests management options for rational utilization of this resource.

MATERIALS AND METHODS

Study Area

This study was conducted at Sondu Miriu wetlands and the adjacent river and the lake waters of Lake Victoria, which lies between latitudes O^o 17'S and O^o 22'S and longitudes 34° O4'E and

34° 49'E. This swamp has an estimated area of 5 km^2. It is served by River Sondu Miriu, which has a total length of 170 km and a catchment area of 3470 km^2 Ochumba & Manyala (1992). The description of the sampling sites is given below.

River (Station 1):
This being the lower course, the river has a lot of meanders. The depth was1 - 3 m. Bottom substratum consisted of mud, rocks, stones, pebbles and sand. Phragmites spp, exotic trees and shrubs covered the western bank of the river. Subsistence farming and livestock farming takes place in this area.

River /Lake Interface (Station 2):
This is the interface between the river and the lake. Depth was 1 - 2 m. Bottom substratum consisted of mud, sand and pebbles. *Phragmites* spp and *Cyperus papyrus*. Water hyacinth occasionally covered this area during the period of sampling.

Lake (Station 3):
Depth of the sampling area was 2 - 4 m. Bottom substratum consisted of pebbles, sand and mud. Water hyacinth occasionally covered this area during the time of sampling.

Swamp (Station 4):
Cyperus papyrus, water hyacinth, water lily and submerged macrophyte covered this area during the time of sampling. Depth was 2 - 3 m. Bottom substratum consisted of mud. Entrance to the sampling site was obtained through a former river channel that eventually became blocked, causing the river to follow another channel to reach the lake.

Sampling

Fish samples were collected by means of mosquito seines of 10mm stretched mesh size (used in the swamp and interface), gillnets of 38 - 63.5 mm stretched mesh size (used in the river, swamp, lake and interface), hook and line (used in the interface and river), and traditional traps (used in the swamp and interface) on a monthly bases from January 1996 to January 1997. The samples were then identified to species level using keys provided by Eccles (1992) and Witte (1995). Thereafter the specimen were measured to the nearest cm SL and TL by means of a measuring board and weighed to the nearest gram using a sensitive balance. They were then dissected and their gonadal status determined.

RESULTS

29 fish species belonging to 12 families were identified (Table 1). Most of the fish caught are endemic and consisted of prey fish. The most dominant species were *Clarias gariepinus* (16.7%), *Synodontis victoriae* (13.9%), *S. afrofischeri* (13.1%), *Protopterus aethiopicus* (11.8%), *Schilbe intermedius* (11.6%,) *Labeo victorianus* (10.5%), *Clarias alluaudi* (9.2%) and *Oreochromis niloticus* (7.4%). The other fish species contributed less than 2% each.
The percentage of fish caught by different gears is illustrated in Figure 1. The bulk of the fish were caught using gillnets (57.6%) while mosquito seine caught the least (3.2%).

For the following commercially important fish species (*Synodontis victoriae, S. afrofischeri, S. intermedius* and *L. victorianus*), the mean length of individuals caught by different gears was determined. (Fig. 2). Small meshed gillnet (38mm) caught the smallest mean length of the four species considered (12.2 cm) followed by mosquito seine (13.3 cm). Large meshed gillnet (63.5 mm) caught the largest mean length of fish (18.9 cm). Observations made to ascertain the impact of these gears to the habitat of the fish, showed that most of the gears are used in the spawning and nursery grounds of these fish species, hence destroying most of the vegetation in these habitats, as the fishermen drag these nets to haul the fish. For example the gillnets and mosquito nets were being used as active gears in the floodplains (swamp) and at the edges of the swamp and in man made channels going into the swamp. However the traditional gears (passive gear), mainly used in the swamp and the interface, had little effect on the habitat of these fish.

Table 1. Inventory of fish species of Sondu Miriu wetlands, adjacent river and the lake.

FAMILY	SPECIES	LOCATION			
		River	Interface	Swamp	Lake
MOCHOKIDAE	*Synodontis afrofischeri* Hilgendorf	x	x	x	
	S. victoriae Boulenger	x	x	x	
CLARIIDAE	*Clarias gariepinus* Burchell	x	x	x	x
	C. alluaudi	x			
CYPRINIDAE	*Brycinus sadleri* Boulenger	x			
	Barbus altianalis Boulenger	x			
	B. neglectus Boulenger	x			
	B. jacksonii Gunther	x			
	Labeo victorianus Boulenger	x	x		
	Rastrineobola argentea Pellegrin		x		
MORMYRIDAE	*Hippopotamyrus grahami* Norman	x	x	x	
	Pollimyrus nigricans Boulenger	x	x	x	
	Petrocephalus catastoma Gunther	x	x	x	
	Gnathonemus longibarbis Hilgendorf	x	x	x	
	Marcusenius victorie Worthington	x	x	x	
	Mormyrus kannume Forsskall	x	x	x	
CENTROPOMIDAE	*Lates niloticus* Linnaeus	x			x
CICHLIDAE	*Oreochromis niloticus* Linnaeus	x	x	x	x
	O. variabilis Boulenger	x	x	x	x
	O. leucostictus Trewavas	x	x	x	x
	Tilapia zillii Gervais	x	x	x	x
	Pseudocrenilabrus multicolor Hilgendorf	x			
	Haplochromis spp.	x			
PROTOPTERIDAE	*Protopterus aethiopicus* Heckel		x		
MASTACEMBELIDAE	*Aethiomastacembelus frenatus* Boulenger	x		x	
SCHILBEIDAE	*Schilbe intermedius* Linnaeus	x	x		
BAGRIDAE	*Bagrus docmak* Forskall	x			
ANABANTIDAE	*Ctenopoma murei* Boulenger	x			
AMPHILIDAE	*Amphilu s jacksonii* Boulenger	x			

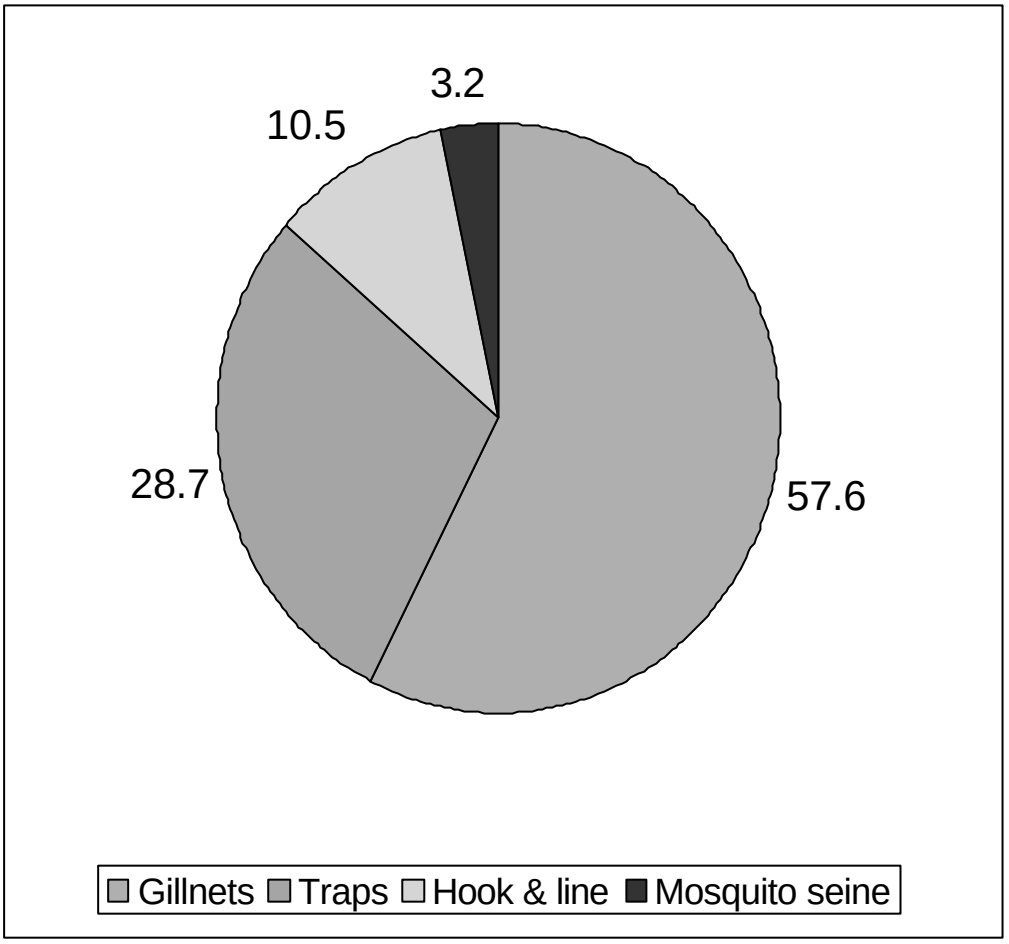

Fig. 1. Catch distribution by gear type in percent of the number of fish caught

The length at 50% maturity for *Synodontis victoriae, S. afrofischeri, Schilbe intermedius* and *Labeo victorianus* is shown in Fig. 4. In *S.ynodontis victoriae* and *S.chilbe intermedius* males mature at smaller size than females, while in *S. afrofischeri* both sexes mature at the same size.

DISCUSSION

The potamodromous fishes, mainly *L. victorianus* and *S. intermedius* of the Sondu Miriu wetland, adjacent River and lake ascend upstream during the rainy season March - June and October - November to breed. These fishes are a delicacy and are usually caught in large numbers at the river mouth and side pools using various sizes of gillnet, seine nets and traditional traps. *L. victorianus* was the most important potamodromous fish species in the first half of the 20th century Graham (1929). However by the late 1950s its population had declined due to the exploitation of sexually mature fish at the river mouth (thus before spawning) using drifting gillnets (Cadwalladr, 1965a). In the Sondu Miriu wetlands this kind of exploitation still continues using undersized nets such as 38 mm gillnets which catch fish that are not mature. The size at 50% maturity for this species is 11 and 13 cm SL for males and female, respectively while this gear catches fish with a mean length of 12.2 cm, Cadwalladr (1965a) found ripe to running fish of 12 cm, SL which is comparable with our results.

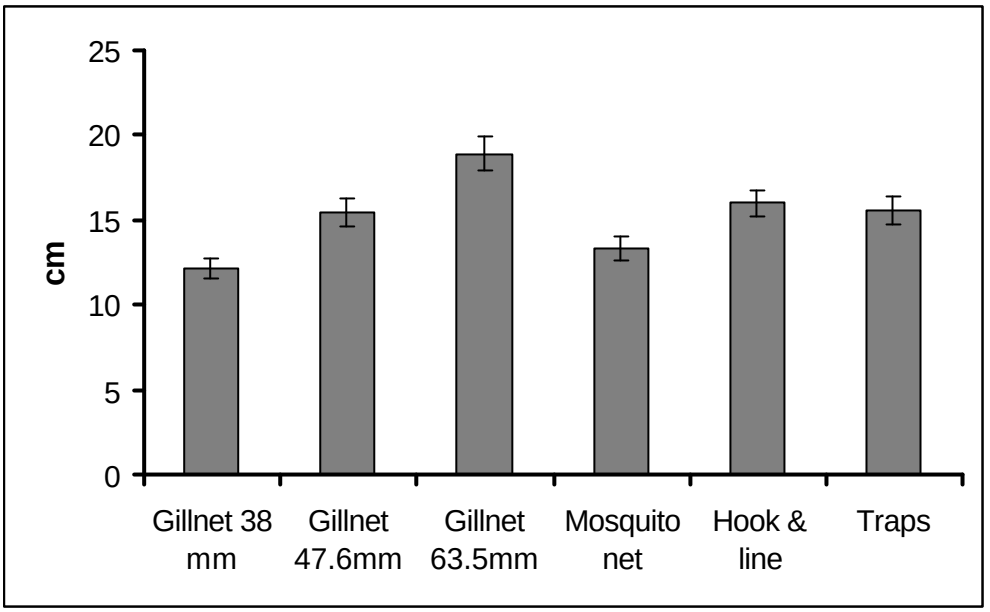

Fig. 2. Mean length (SL, to the nearest cm) by fishing gear of the commercially impor tant fish species in the Sondu Miriu wetland, adjacent river and the lake.

The size at 50% maturity for *S. Intermedius* in the Sondu Miriu wetlands, adjacent river and the lake was 14 cm and 18 cm SL for males and females respectively. All the gears except large meshed gillnets (63.5 mm) caught fish of less than 18 cm mean length. These are therefore, undersized gears that catches females which are yet to spawn. Ochumba & Manyala (1992) found ca 80% of males and 45% of females mature between 12 and 16 cm SL in the Sondu Miriu River.

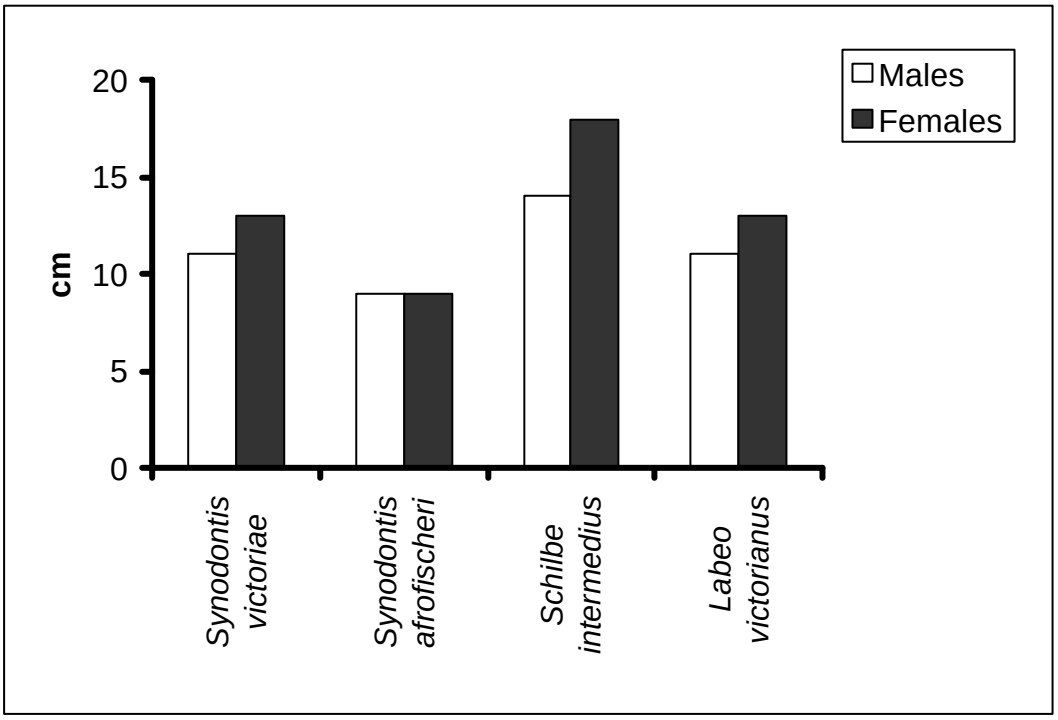

Fig. 3. Size (SL) at 50% maturity for the commercially important fish species in the Sondu Miriu wetlands, adjacent river and the lake.

The size at 50% maturity for *S. victoriae* in the Sondu Miriu wetlands, adjacent river and lake was 11 cm SL and 13 cm SL for males and females respectively. Small meshed gillnet (38 mm) and mosquito seines caught fish of less than 13 cm mean length. These gears, therefore, catches females that are yet to spawn Ochumba & Manyala (1992) found more than 50% of the females mature between 10 and 12 cm SL in the Sondu Miriu River.

The size at 50% maturity for *S. afrofischeri* was 9 cm SL for both sexes in the Sondu Miriu wetland, adjacent river and lake. The mean length of the fish caught using all the gears under consideration, was above 9 cm, thus most of the fish were caught when they had already spawned. Ochumba & Manyala (1992) found ca 50% of both sexes mature between 10 and 12 cm SL, while Rinne & Wanjala (1983) found ca 50% of both sexes mature at 9 cm FL.

CONCLUSION AND RECOMMENDATIONS

Most of the gears that are used in the Sondu Miriu wetland, adjacent river and the lake caught fish which are yet to spawn. These gears are, therefore, destructive and interfere with the spawning and recruitment of these potamodromous fish species, which are important to meet the protein needs of the local population mainly composed of poor people.

There is thus a need for an integrated approach to the management of this resource. This can possibly be achieved through community training, with the emphasis on the rational, wise and non-destructive utilization of the fish stocks, and by discouraging the use of undersized gears, especially mosquito seine and 38 mm gillnets. Other options include the possibility of evoking traditional rules enacted by a council of elders. This could include the use of closed seasons and areas to protect these fish during their breeding period. In the past these rules have served well in the protection of wetland resources.

ACKNOWLEDGEMENT

We wish to thank the Lake Victoria Fisheries Research Project (LVFRP) phase II and the Kenya Belgium project on fresh water ecology for sponsoring the work; the Director of the Kenya Marine and Fisheries Research Institute (KMFRI) for providing facilities and logistics for data collection and analysis and all the technical staff who assisted in data collection. Special thanks are due to the people of Lower Sondu-Miriu for their co-operation.

Gonadal Patterns and Reproductive Strategy of Nile tilapia, Oreochromis niloticus (L.) in the Nyanza Gulf of Lake Victoria, Kenya

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SUMMARY

The reproduction of Nile tilapia Oreochromis niloticus (L.) in the Nyanza Gulf of Lake Victoria was studied from June 1998 to May 1999. Males dominated the population structure for the majority of the year and for the population as a whole. Females were significantly fewer in the larger length classes (>36 cm TL) and were absent in samples >52 cm TL. Length at 50% maturity (Lm_{50}) was at 31 cm TL for females and 34 cm TL for males. Intra-ovarian egg diameter frequencies indicated recruitment of oocytes in the ovary of O. niloticus is asynchronous. The trends in gonadosomatic index (GSI) and the occurrence of gonad maturity stages both point to a protracted breeding period (December - June) and post spawning period with low reproductive activity (July to October). The overall reproductive strategy of O. niloticus in the Nyanza Gulf is discussed and evidence to suggest that it displays a 'r'-selected life history strategy is presented.

INTRODUCTION

The Nile tilapia, *Oreochromis niloticus* (L.) is a cichlid of the tilapiine group (Trewavas, 1983). It was introduced into Lake Victoria first in 1954, and on several occasions between 1956 and 1962 (Odero, 1979). Since then stocks have rapidly increased to become the most dominant species in the tilapia fishery (Ogutu-Ohwayo, 1990).

There is limited information on reproductive bionomics and spawning times of *O. niloticus* in the Kenyan waters of Lake Victoria (Lowe-McConnell, 1959; Welcomme, 1967; Fryer & Iles, 1972). Lake Victoria has undergone several environmental changes associated with species extinction (Witte, *et al*., 1992; Witte *et al*., 1995), eutrophication (Hecky, 1993), shoreline degradation (Balirwa, 1995) and invasion by water hyacinth, Eichhornia crassippes (Martius) Solms-Laubach. Information available on the reproductive biology of the Nile tilapia was either done before these environmental changes or before the species became fully established in the lake, hence cannot be considered indicative of present reproductive patterns. This study examined the gonadal and reproductive patterns of *O. niloticus* in the Kenyan waters of Lake Victoria, including annual cycle of condition, sex ratio, size at maturity, spawning time and seasonal cycle of gonad development.

MATERIALS AND METHODS

Fish samples were collected monthly from both seine net and trawl catches. For each fish, total length (TL, nearest cm below) and total weight (g) were measured. The relative condition factor, *Kn* (Le Cren, 1951) was obtained using $Kn = W/W^{\wedge}$, where W is the total weight of the ungutted fish and $W^{\wedge}$ is the expected weight of fish calculated from the length weight relationship. Each fish was opened and the maturity stage assigned to each gonad following Ntiba and Jaccarini (1990). According to this scheme six stages are recognised namely: Stage I - virgin; stage II - developing virgin/resting (recovering spent); stage III - developing (active); stage IV - mature; stage V - ripe and sometimes running; stage VI - spent.

The gonads were then removed and weighed (nearest 0.01g). The weight of the gonad relative to the body weight (*W*), i.e the gonadosomatic index (GSI), was calculated as: *GSI* = (*Weight of ovary/Weight of fish*) x 100

For female fish, a small piece of the ovary, representing a complete cross-section of the gonad was weighed and preserved in Gilson's fluid for oocyte diameter determination and fecundity counts. The rest of the ovary was preserved in Bouin's fixative for histological study. To account for intra-ovarian egg development, measurements (to the nearest mm) were taken of whole oocytes from six separate ovaries at each maturity stage. Length - weight relationships were determined for each sex by the method of least squares using log - log transformed data. Maturity gives for both sexes were fitted using solver computer programme.

RESULTS

Length - weight relationship and condition factor

Length-weight relationships were determined as:

Males	$W = 0.013 \times TL^{3.13}$	$r^2 = 0.99$, n = 536;
Females	$W = 0.012 \times TL^{3.15}$	$r^2 = 0.97$, n = 351.

No significant difference was found between the gradients of the relationships for the two sexes (t test, P >0.05), so the data were pooled. The resulting relationship was:

Combined sexes $W = 0.0128 \times TL^{3.14}$ $r^2 = 0.98$, n = 887

Seasonal changes in condition factor exhibit little variation (Fig. 1).

Sex ratio

Males dominated the population structure for the majority of the year and for the population as a whole (Table 1). The overall sex ratio for the population was significantly different from the

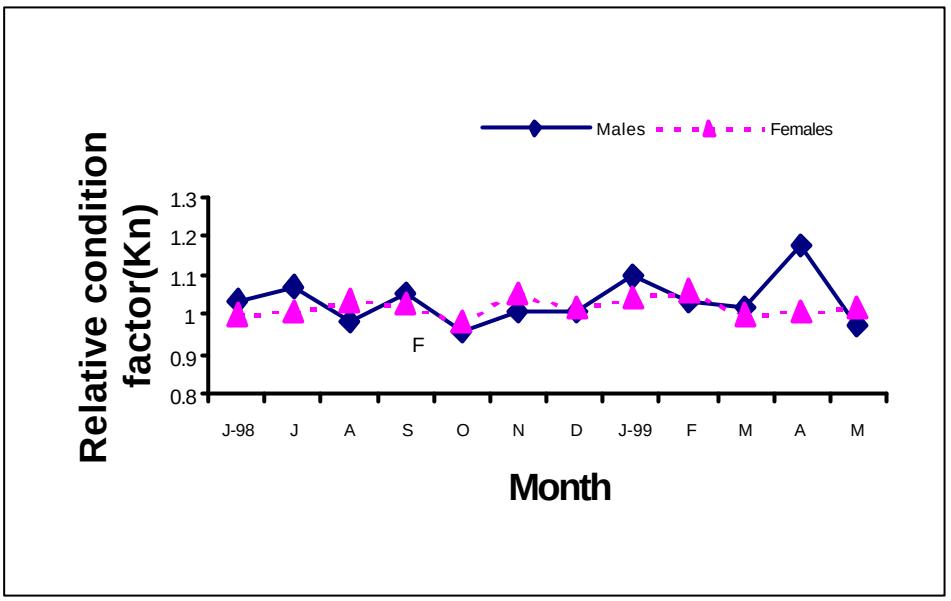

Fig. 1. Seasonal changes in condition factor

expected 1:1 ratio ($\chi^2 = 67.6$, $P > 0.05$). Females were more prominent in the size range 20-30 cm TL (Table 2). The proportion of females declined significantly ($P<0.05$) above 36 cm TL, and no female *O. niloticus* >50-cm TL were caught.

Table 1. Seasonal variation of the sex ratio in *Oreochromis niloticus* from the Nyanza Gulf of lake Victoria, Kenya. *(Numbers of males and females: greater values bold; X^2 significant at the 5% level: italics; at the 0.1% level: bold.).*

Month	No. of males	No. of females	Male: female ratio	χ^2
1998 June	**80**	56	1.43	*4.24**
July	18	29	0.62	2.57
August	**40**	25	1.60	3.46
September	**17**	**18**	0.94	0.03
October	**35**	33	1.06	0.06
November	**46**	33	1.39	2.14
December	**108**	74	1.46	*6.35**
1999 January	**107**	93	1.15	0.98
February	**107**	60	1.78	**13.23**
March	**321**	134	1.72	**25.78**
April	**169**	102	1.66	**16.56**
May	**67**	29	2.31	**15.04**
Total	**1,025**	686	1.49	**67.60**

Table 2. Occurrence of males and females in different size groups of Oreochromis niloticus from the Nyanza Gulf of Lake Victoria, Kenya (n = sample size; greater percent ages bold)

Size group (TL,cm)	n	Males (%)	Females (%)
12-14	9	33	**67**
14-16	15	**60**	40
16-18	25	48	**52**
18-20	67	**58**	42
20-22	72	44	**56**
22-24	62	50	50
24-26	54	50	50
26-28	52	48	**52**
28-30	62	45	**55**
30-32	34	50	50
32-34	33	**54**	46
34-36	40	38	**62**
36-38	50	**52**	48
38-40	41	**51**	49
40-42	51	**65**	35
42-44	35	**71**	29
44-46	28	**71**	29
46-48	33	**82**	18
48-50	31	**97**	3
50-52	25	**100**	0
52-54	1	**100**	0

Size at first maturity

The length at first maturity (Lm50), defined as the mean length at which gonadal development had advanced to at least stage IV in 50% of individuals, showed substantial differences between **males and females (Fig. 2). The smallest mature male** *niloticus* found was 26.2 cm TL while the smallest mature female was 24.3 cm TL. Fifty percent maturity was at 31 cm TL for females and 34 cm TL for males (Fig. 2).

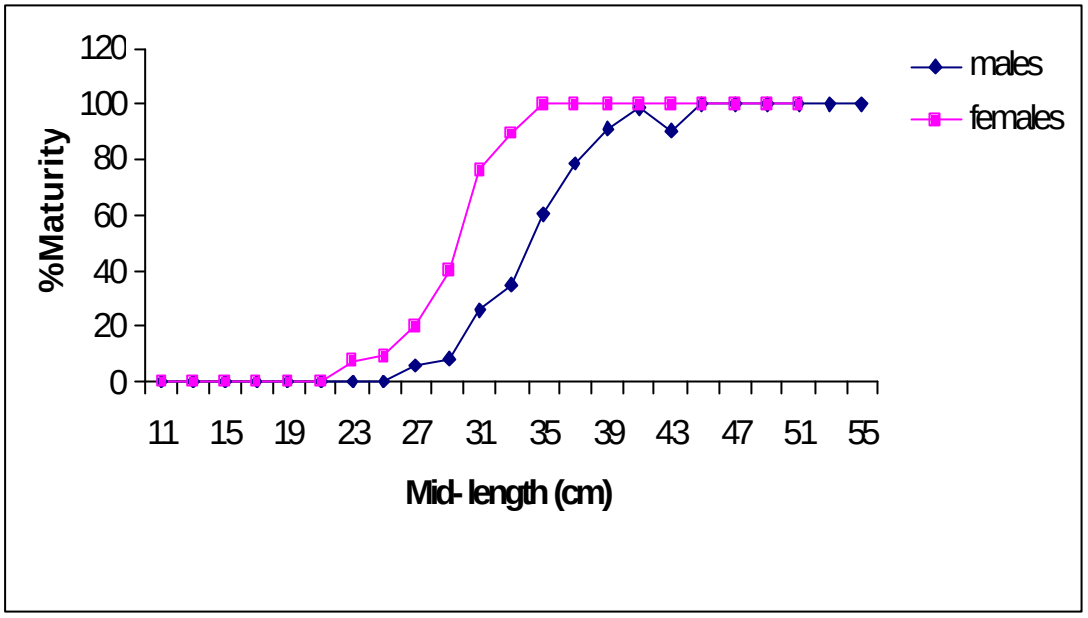

Fig. 2. Maturity ogive for male and female *O. niloticus* in Kenyan waters of Lake Victoria

Ovarian egg diameters

The egg diameter frequencies of ovary development stages (excluding stage I) are shown in Fig. 3. The progressive maturation to spawning condition (stage II - V) was evident from the increasing egg diameters of the most advanced mode at each stage. The advanced mode of stage V with the egg diameter range of 1.50 - 1.80 mm was the ultimate egg development stage when spawning is imminent.

The multiplicity of modes indicates egg batches are continuously matured and shed during a protracted spawning season.

Seasonal reproductive cycles

Seasonal variation in the gonadosomatic index was evident (Fig. 4). In males, the GSI rose from a low in June to August to a peak in November, followed by a slight fall through December and January to peak again in April. For females, a similar trend was found except the peaks occurred later, in January and May.

The monthly proportion of each maturity stage confirms the reproductive cycles depicted by the GSI. There was a lower proportion of mature fish between July and September. However, the high presence of stages IV and V between October and May is indicative of maturation. There was an increase in the proportion of fish at stage VI in July and again in November and January, suggesting that spawning had taken place. Spent fish were found in most of the months indicating continuous spawning.

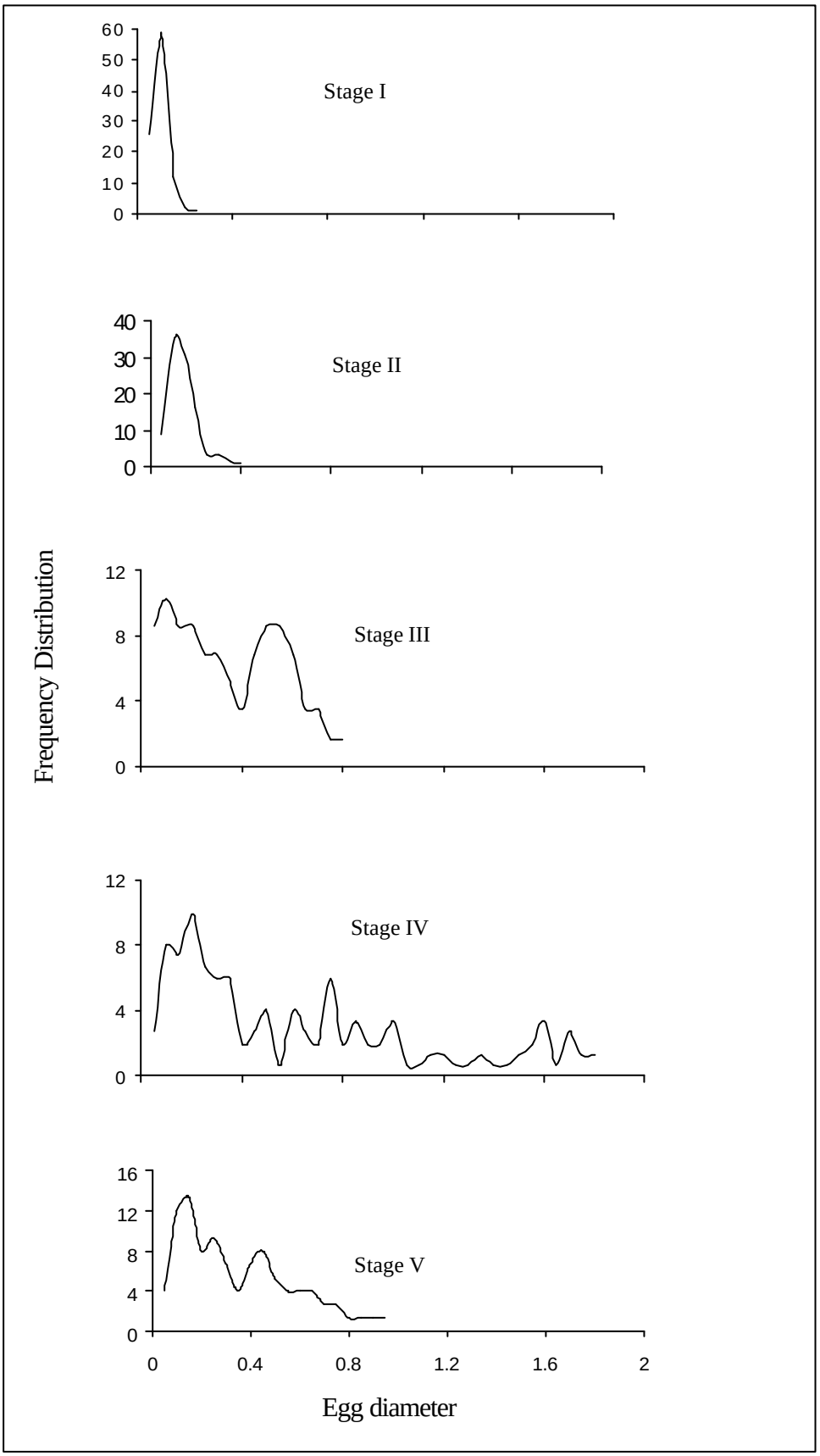

Fig. 3. Frequency distribution of oocyte distribution for each maturity stage (shown by Roman numerals)

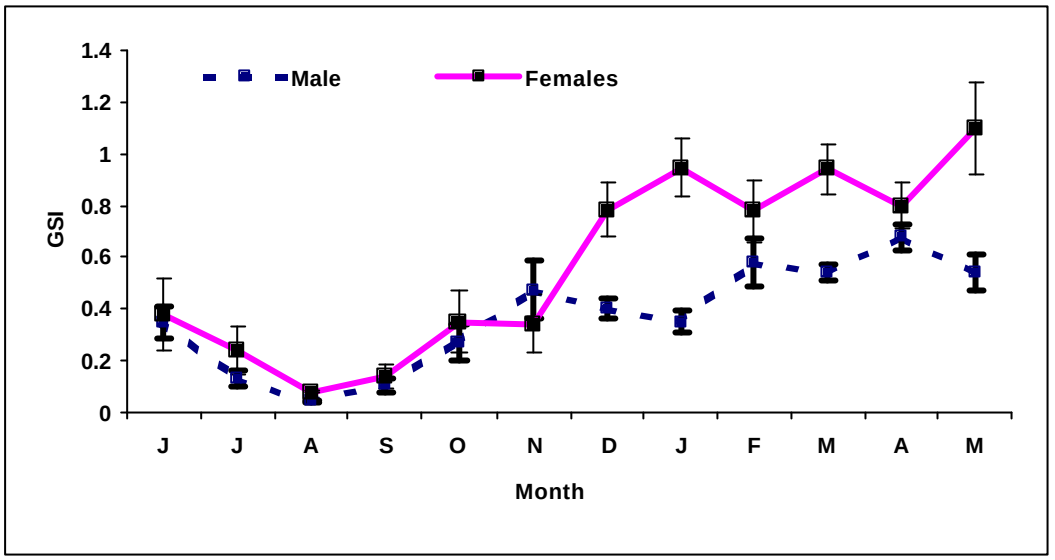

Fig. 4. Monthly variation in Gonadosomatic Index (GSI) of *Oreochromis niloticus* in Kenyan waters.

DISCUSSION

Males, especially between December and June, dominated catches at the main spawning period. During this time, males congregate in nesting arenas. Ripe females visit the arena to spawn but leave quickly and disperse. Active fishing methods such as trawls and seines used on nesting arenas result in catches being highly biased towards males. This is a frequent occurrence in the cichlid trawl fisheries on Lake Malawi (D. Tweddle, pers. com.).

The protracted spawning period (December-June) and the asynchronous (oocytes of all stages are present without dominant populations) intra-ovarian oocyte development confirm the species is a batch spawner. This multiple spawning behaviour has advantages in highly stressed environments. Recruitment in the population is a relatively high-risk event through predation, especially on the juvenile life stages, which could potentially wipe out the reproductive output if only one spawning event occurred each year. To spawn on more than one occasion reduces this risk. Also individual fecundity is increased, by evading a trade-off between the volume of body cavity and fecundity (Nikolski, 1963), and it may allow for an optimum egg size selection avoiding the possible conflict between egg number and egg quality (Miller, 1979).

The maturation of females in Kenyan waters at smaller size contrasts with the findings of Balirwa (1998) in the Ugandan sector of the lake where males first spawn at about 28 cm TL and females at 32 cm TL. It also represents a reduction in size at first maturity since 1986, when *O. niloticus* was reported to mature for the first time at an average length of 35-cm (Getabu, 1992). The observed maturation of the females in the Kenyan sector in recent years is again a tactic to maximise reproduction success (Charlesworth & Leon, 1976; Stearns, 1976), possibly linked to a population response to overfishing. This is a common response in fish populations and it is

used as an indicator of overfishing (Getabu, 1992). Early maturing populations tend to grow quickly to reproductive size and then divert energy away from somatic growth to reproduction. As a consequence, they do not reach such a large size. This could explain the dearth of females in the larger size groups, a phenomenon also found for Nile tilapia in Lake Turkana (Lowe-McConnell, 1959). This tactic has been adopted by many animals living in unstable environments where adverse biotic (competition, predation or overexploitation) and abiotic factors are prevalent (Charlesworth and Leon, 1976), and could explain why Nile tilapia successfully colonised the lake. This tactic contrasts with that adopted for stable environments where smaller fish put more effort into somatic growth and less into gonad development compared with larger counterparts, a mechanism that is more likely to increase their chances of survival and reproduction in subsequent years (Mann & Mills, 1985; Cowx, 1990).

There is thus evidence to suggest that Nile tilapia in the Kenyan part of the lake displays a 'r'-selected life history strategy (Pianka, 1970; Mann & Mills, 1985) to survive the stressful conditions prevalent. The more intensive reproductive effort employed by females fits the theories of life history strategy expounded by Pianka (1970) and Stearns (1976), where natural selection has caused different fish forms to adapt to maximise fitness in specific habitats/environments. It could also be a mechanism to compensate for the intensive fishing pressure in the area.
*O. niloticus i*n Lake Victoria thus shows a well-defined reproductive strategy, which has probably contributed to the success of the species in the lake.

ACKNOWLEDGEMENTS

We would like to express our gratitude to Dr. Ian Cowx for his helpful criticism and his detailed suggestions that greatly improved this manuscript. The European Union through Lake Victoria Fisheries Research Project funded this survey. We are both grateful to the Director, KMFRI and University of Nairobi for their total support for this research work.

Population Characteristics of *Oreochromis esculentus* (Graham 1929) in the Victoria and Kyoga lake basins

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SUMMARY

Oreochromis esculentus is endemic to the Victoria and Kyoga lake basins. Not until the introduction of gill-nets (1905 to 1916), it was the most important commercial fish species but declined and became very rare in the main water bodies. New data were collected from December 1997 to June 1999 through experimental fishing and examination of commercial catches. The fish examined were 7.7- 38.7 cm TL with a modal size of 16.0-20.9 cm TL. The overall mean condition factor K was 1.79±0.024. O. esculentus fed on phytoplankton, mostly cyanobacteria (Microcystis). O. esculentus from those lakes in which it fed on Aulacosira were the largest and had the best condition factor, showing that Aulacoseira was an important food item. Fish from these lakes appear to be the best sources of O. esculentus for restocking and farming.

INTRODUCTION

Oreochromis esculentus (Graham, 1929) is endemic to lakes Victoria and Kyoga and a few satellite lakes in the basins of these lakes (Ogutu-Ohwayo, 1993). During the period 1905 to 1916, when gill nets were introduced into different parts of Lake Victoria, coupled with the growth of urban centers and communication around the lake, fishing industry assumed a commercial role with *O. esculentus* as one of the main target species (Mann, 1969). From the 1930s to the 1950s the catch dropped and the fish became smaller due to increased fishing pressure (Fryer & Illes, 1972) and increasing use of small-mesh gill nets (Witte and van Dansen, 1995). This made *O. esculentus* one of the most threatened fish species leading to its eventual disappearance from the main lakes Victoria and Kyoga.

Impact of the introduction of other fish species on *O. esculentus*

After 1954, *Tilapia zillii*, *Oreochromis niloticus* and *Oreochromis leucostictus* were introduced in lakes Victoria and Kyoga (Lowe-McConnell, 1956), which might have competed with the native tilapiines for food, space and nursery grounds or through hybridization (Welcomme, 1968; Lowe Mc-Connell, 1987; Ogutu-Ohwayo, 1990).

Predation by Nile perch, *Lates niloticus*, may also have contributed to the depletion of *O. esculentus* stocks. This large predator was introduced into the main water bodies of Lake

Kyoga in 1955-56 and Lake Victoria in 1960. Its stocks increased rapidly and these increases were concurrent with a reduction and in some cases total disappearance of the native species (Ogutu-Ohwayo, 1993).

According to Greenwood (1966), the modal adult size was 30-32 cm TL, although specimens of 40-50 cm TL were caught in the southern waters of Lake Victoria (Graham, 1929). In Lake Kyoga *O. esculentus* never exceeded 26 cm. The condition factor K was 2 in Lake Victoria (Worthington 1929).

In Lake Victoria, *O. esculentus* fed on planktonic material collected from suspension (Fryer and Iles, 1972), especially diatoms. Schools of *O. esculentus* followed concentrations of diatoms in the lake (Fish, 1951; Lowe-McConnell, 1956), suggesting that this was its preferred food item, although maximum growth in aquaria could be obtained on an unnatural diet of chopped worms (Stuhlmannia spp.; Cridland, 1964). *Aulacoseira* was usually the most abundant item in the gut contents and made up 48.75 % of the total cells present in all fish stomachs (Graham, 1929).

This paper focuses on length frequency distribution, condition factor and food of *O. esculentus* in the satellite lakes of the two main water bodies and aimed at finding out which lake has the best stocks of this species for restocking and farming.

MATERIALS AND METHODS

The study was carried out on lakes Kachera, Mburo, Kayanja and Kayugi in the Victoria lake basin and lakes Lemwa and Kawi in the Kyoga lake basin.

Three fleets of identical multifilament nylon gill nets were set. In total, 1262 specimens of *O. esculentus* were examined, 378 from lakes Kachera, 76 from Kawi, 290 from Kayanja, 143 from Kayugi, 188 from Lemwa and 87 from Mburo. The specimen were measured (to the nearest centimeter) and weighed (grams) then dissected to determine stomach fullness, and stomachs which had any food were preserved in 5 % formalin. A total of 438 stomachs of *O. esculentus* were examined, 126 from Kachera, 87 from Kawi, 71 from Kayanja, 16 from Kayugi, 116 from Lemwa and 22 from Lake Mburo. Food analysis was done using the point method according to the scheme showed below, being modified from that of Hynes (1950).

Fullness	State	Points
Full	(1) Stomach distended with food up to the pyloric sphincter	16
Three quarter	(3/4) food up to about 3/4 of stomach volume	8
Half	(1/2) food up to about 1/2 of stomach volume	4
Quarter	(1/4) food up to about 1/4 of stomach volume	2
Empty	(0) Stomach empty and collapsed	0

The importance of each of the food items was obtained from these points by calculating the percentage relative importance of the food in the stomachs for example a food item contributing 80 % in a three quota full stomach the score would be: 80/100x8= 6.4 pts. The condition factor K was calculated according to the formula K= 100 W/L3 where W= individual weight of the fish, L= total length.

RESULTS

The *O. esculentus* examined ranged from 7.7 to 38.7 cm TL. The biggest individual was found in Lake Kayugi (38.7 cm TL). Most fish belonged to the size class 16.0-20.9 cm TL (46 %), followed by 11.0-15.9 cm (25.1 %) and 21.0-25.9 cm (18.8 %) Fig. 1).

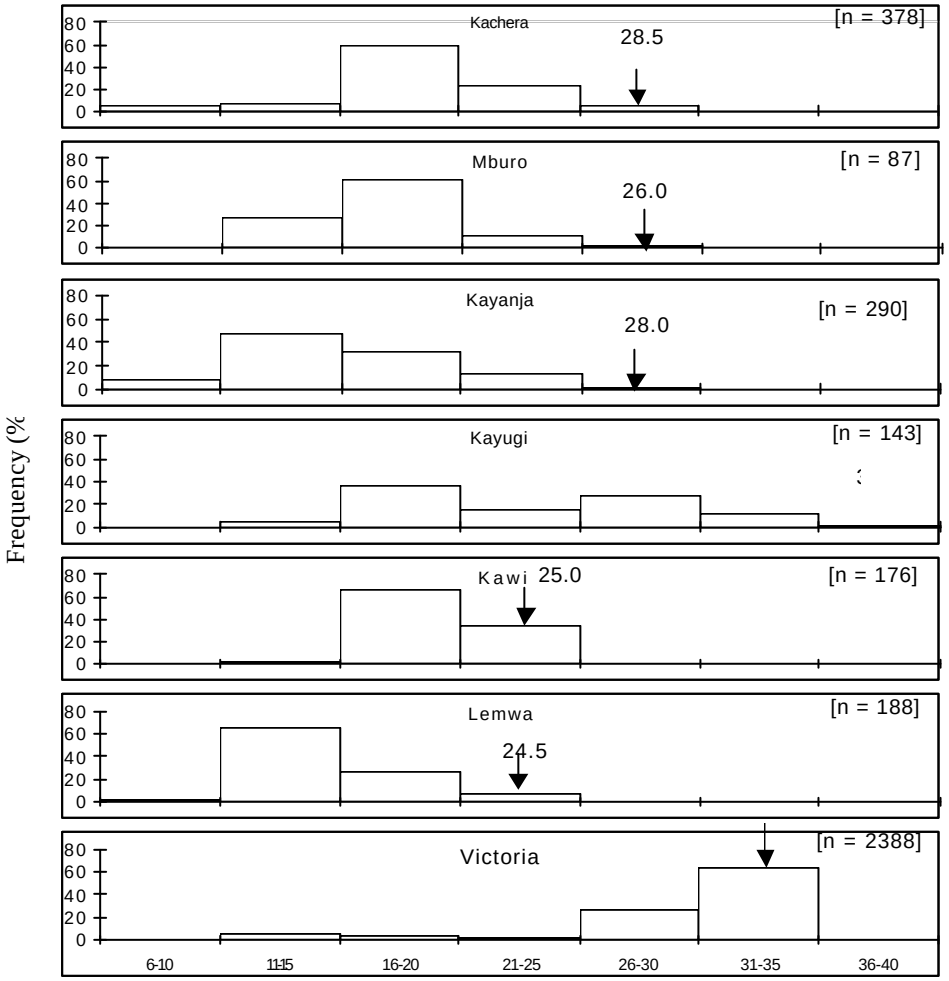

Fig. 1. Length frequency distribution of *Oreochromis esculentus* from the sampled lakes (1997-99) compared with Lake Victoria (Graham, 1929). The arrows show the size class with the largest fish sampled

There was a general increase in the condition factor K with the size of the fish. The overall value was K had a mean ± SE of 1.79±0.02. K was highest in Lake Kawi 2.02 ± 0.03, followed by Lake Kayugi 1.89 ± 0.05, Kachera 1.85 ± 0.06, Mburo 1.83±0.04, Lemwa 1.79 ± 0.04 and lowest in Lake Kayanja 1.51 ± 0.03 (Fig. 2).

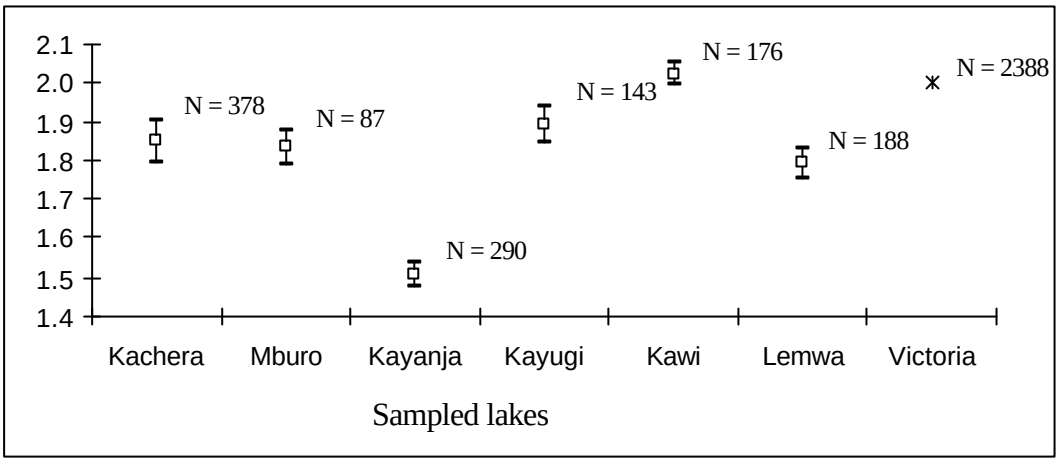

Fig. 2. Mean condition factor K of *Oreochromis esculentus* from the sampled lakes. The value for Lake Victoria (asterics) was from Graham (1929). The interval show standard error

Overall, *Microcystis* was the most important food item (26.6 %), followed by *Aulacoseira* (19.4 %) and *Anabaena* (15.7 %) (Fig. 3). Microcystis was the dominant food item in lakes Lemwa (42 %) and Kachera (26.2 %) while in Lake Kayanja it was *Planktolyngbya* (41.2 %), *Aulacoseira* in lakes Kayugi (93.1 %) and Kawi (49 %) and chironomides in Lake Mburo (32 %).

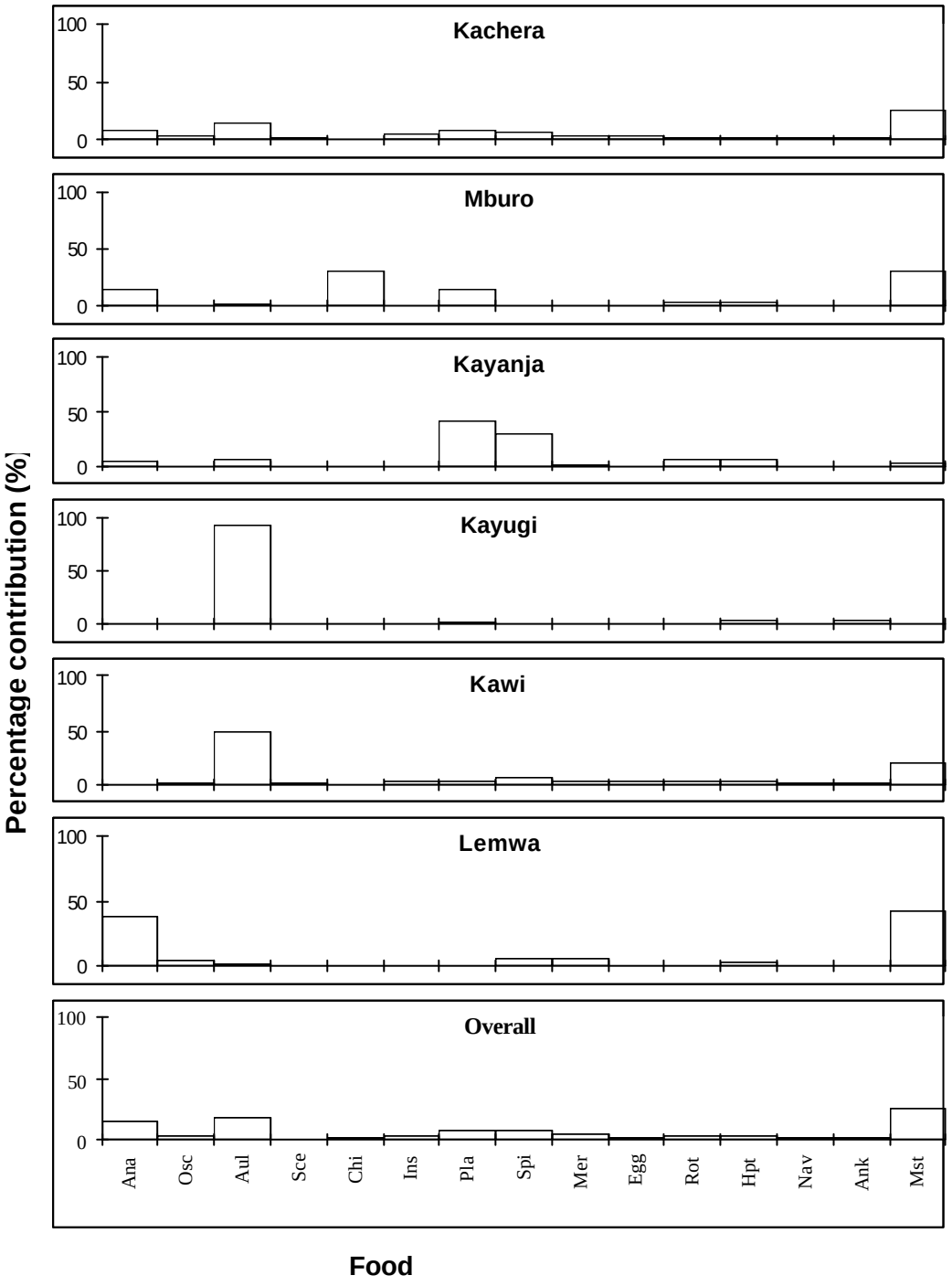

Fig. 3. Relative importance of the food items encountered in stomachs of *O. esculentus* from the sampled lakes

Ana	= An*abaena*	Ins	= Insect remains	*Rot*	= *Rotifers*
Osc	= *Oscillatoria*	Pla	= *Planktolyngbya*	Hpt	= High plant material
Aul	= *Aulacoseira*	Spi	= *Spirulina*	Nav	= Navicula
Sce	= *Scenedesmus*	Mer	= *Merismopedia*	*Ank*	= *Ankstrodesmus*
Chir	= Chironomides	Egg	= Fish eggs	Mst	= Microcystis

DISCUSSION

Marked differences occur in the different populations of *O. esculentus* present in the satellite lakes as compared with the former situation in lakes Victoria and Kyoga. Greenwood (1966) reported maximum TL of 40-50 cm and a modal size of 30-32 cm. During our investigations the largest fish had a TL of 38.7 cm and the modal size was 16.0-20.9 cm. The reduction in size may be due to limited food resources and space available attributed to the much smaller size of the satellite lakes as compared to the main lakes.

The overall condition factor was K 1.76, which is lower than K of 2 reported by Graham (1929) in Lake Victoria. This may be due to limited space and the digestibility of the type of food (algae) available.

Blue-green algae (*Microcystis*) were the most dominant food item as compared with the past when diatoms (*Aulacoseira*) prevailed in the diet. The change may be due to the change in algal growth and this in turn could be a consequence of eutriphication.

There was an increase in nutrient inputs, especially phosphorus and nitrogen, into lakes Victoria and Kyoga mainly from the atmosphere and from changes in land use in the catchment area. Silicon concentration which is vital for diatom growth (*Aulacoseira*), decreased by a factor of 10 (Hecky, 1993; Talling, 1966). The decrease in Aulacoseira which was important food for *O. esculentus*, may have contributed to its apparent disappearance.

CONCLUSION AND RECOMMENDATIONS

Based on the relatively large size, the high condition factor and the presence of *Aulacoseira*, Lake Kayugi appears to be the lake with the best living conditions for *O. esculentus*. This lake should, therefore, be considered for the introduction of adequate conservation measures.

ACKNOWLEDGEMENT

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Population characteristics of Nile tilapia *Oreochromis niloticus* (L.): the future of the fishery in Nyanza Gulf of Lake Victoria, Kenya.

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SUMMARY

Length frequency data collected from commercial fish landings collected in 1998 to 1999 were used to estimate growth parameters, mortality (Z, F, M), growth performance index (j'), exploitation (E) and selection of Nile tilapia, Oreochromis niloticus from Nyanza Gulf (L.). The asymptotic length (L¥) was 60 cm TL, weight infinity (W¥) of 4158 g and growth coefficient (K) of 0.7 yr^{-1}. Total mortality (Z) was estimated as 2.4 yr^{-1}, natural mortality (M) of 1.1 yr^{-1}, fishing mortality (F) of 1.3 yr^{-1}, E of 61% and j' of 3.4. Length class at maximum possible catch in weight per recruit is at 39.5 cm.

A comparison with previous population parameters in the Gulf indicates O. niloticus is caught at a lower mean size, growth rate has increased and the fish is maturing earlier. These changes may point to a fish in a stressful environment, but still the fish exhibits high growth performance and grows to a large size. Remedial measures to sustain the fishery include ban on illegal fishing methods, limiting entry to the fishery and encouraging farming to reduce pressure on the fishery.

INTRODUCTION

Nile tilapia, *Oreochromis niloticus* (L.) a cichlid of the tilapiine group is widely distributed in Africa and many parts of the world (Trewavas, 1983). The first introduction of *O. niloticus* into Lake Victoria occurred in 1950s together with other tilapiine like *Oreochromis leucostictus* (Trewavas), *Tilapia zillii* (Gervais) and *Tilapia rendalli* (Boulenger) (Welcomme, 1967; Trewavas, 1983). *O. niloticus is* currently the third commercial important fish in the lake after *Lates niloticus* (L.) and a native cyprinid, *Rastrineobola argentea* (Pellegerin) (Witte & Van densen, 1995). The increase in *O. niloticus* is attributed to over fishing of endemic tilapiines thus reducing competition while swamps clearance could have increased its spawning areas (Welcomme, 1967). *O. niloticus* can also survive a wide range of pH, resists low levels of dissolved oxygen (Balarin & Hatton, 1979) and feeds on a variety of food items (Balirwa, 1998).

In Kenyan waters of Lake Victoria *O. niloticus* is slow growing and the majority of the fish harvested corresponds to the portion taken by gill nets below the recommended mesh size of 5 inches (Getabu, 1994; Balirwa, 1992). Studies further show that the fishery is operating beyond maximum sustainable yield, indicating overfishing (Getabu, 1994). This paper examines demographic parameters of *O. niloticus* using length frequency data. The results are compared with previous studies to assess the future of this fishery.

MATERIALS AND METHODS

Study area

The Nyanza Gulf has an area of approximately 1920 km2 with a length of 60 km and a width varying between 6-30 km (Fig 1). The Gulf is shallow with a mean depth of 6 m and lies at an altitude of 1134 m above sea level. A short description of the Gulf was given by Rinne and Wanjala (1982), Ogari and Dadzie (1988) and Okach and Dadzie (1988), while a detailed description was given by Ogari (1984).

Sampling

Monthly length frequency data on *O. niloticus* based on commercial catches were collected between July1998 and December 1999 at five landing sites in the Nyanza Gulf of Lake Victoria, viz, Dunga, Kendu Bay and Asembo Bay, Homa Bay and Luanda Gembe (Fig. 1). The samples were representative of the stock from the outer, mid, and inner Gulf. Random samples were taken from commercial fishermen at each station once per month. All fish sampled were measured (Total length (TL) nearest cm) and weighed (nearest g). The samples were grouped into 2-cm class intervals, ranging from 2 to 56 cm TL. The surface water temperature was recorded for each station every month for the purpose of estimating natural mortality (Pauly, 1980).

Data analysis

Data analysis was based on length-frequency analysis methods (Pauly *et al.*, 1984; Sparre & Venema, 1998). The Electron Length Frequency Analysis (ELEFAN I and II) computer programs incorporated in FAO- ICLARM Stock Assessment Tool (FISAT) (Pauly 1987; Gayanilo *et al.*, 1996) were used to estimate population parameters. Asymptotic length (L_∞) was calculated using the Powell-Wetherall's plot while growth coefficient (K) was computed following von Bertalanffy generalised model. Total mortality coefficient (Z) was estimated using length converted catch curve, a regression analysis on the descending right hand arm of the catch curve. Total mortality was thus estimated from the slope as follows Z = -b.

Natural mortality coefficient (M) was estimated following Pauly's empirical formula (Pauly, 1980), linking the natural mortality with the von Bertalanffy parameters, K (yr^{-1}), L_∞ (cm) and mean annual temperature (T ^oC) of water in which fish stock live (in this case 25 ^oC).

$$\text{Log}_{10}(M) = -0.0066 - 0.279 \log_{10} L\infty + 0.6543 \log_{10} K + 0.463 \log_{10} T.$$

Fishing mortality coefficient (F) was computed from the relationship F = Z+M, while exploitation rate was calculated from the relationship $E = F/Z$. The growth performance index was computed according to the Pauly and Munro (1984) formula;

$\varphi' = \text{Log10 } K + 2 \text{ Log10 } L_\infty$.

Weight infinity, W_∞. was calculated using the length - weight formula advanced by LeCren (1951):

$W_\infty = a(L_\infty)^b$

Where, a is a constant (the y - intercept) and b is an exponent describing the slope of the regression line. Maximum yield which is the length class a fishery would obtain maximum possible catch weight per recruit (Beverton, 1992) was estimated as follows;

$Lopt = L_\infty (3/(3+M/K)$

where M is the natural mortality and K is growth coefficient.

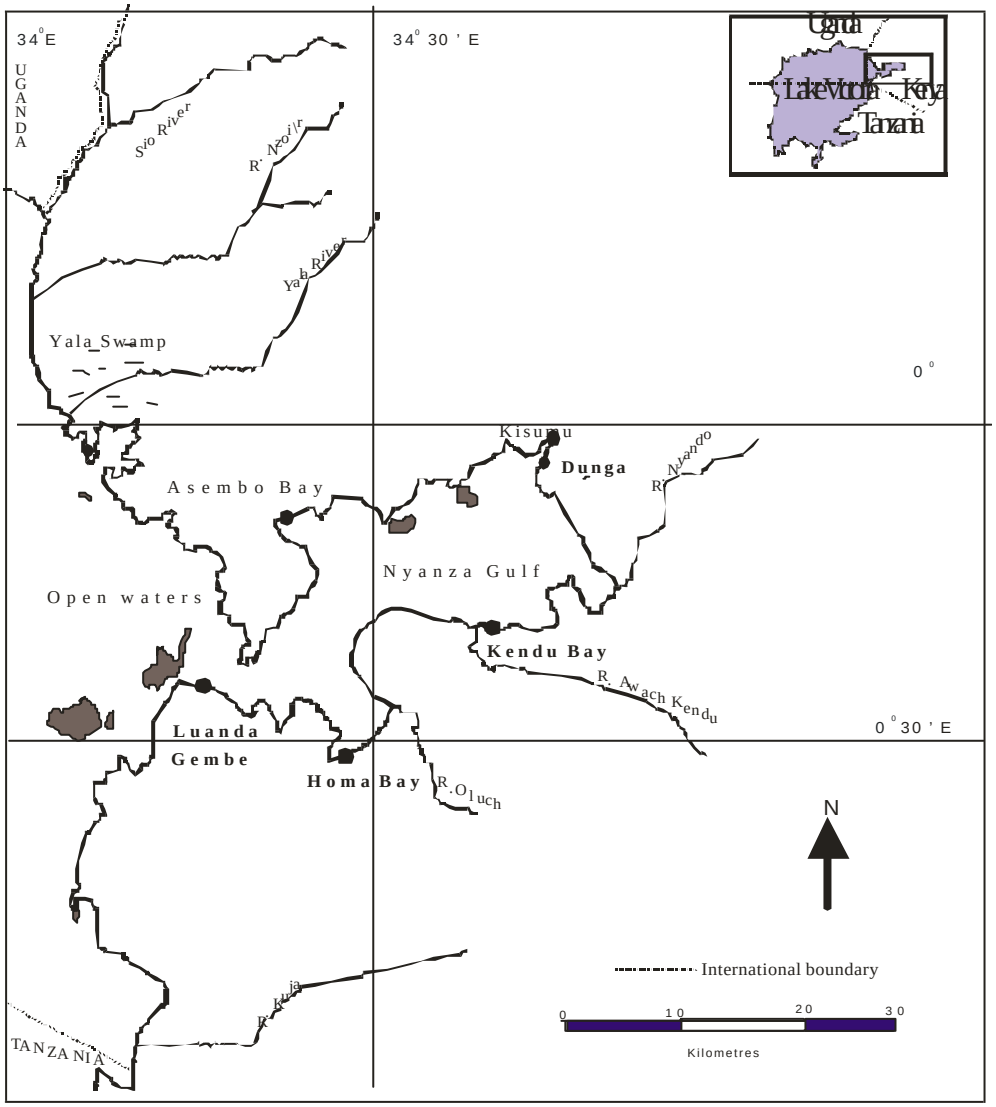

Fig. 1. Map of Nyanza Gulf showing sampling sites

RESULTS

The length-frequency data used for estimation of growth parameters and mortality is present in Fig. 2. Asymptotic length (L_∞) was estimated as 60 cm TL, a growth coefficient (K) of 0.7 yr^{-1} and phi prime (φ') computed as 3.4. Weight infinity (W_∞) was computed as 4158g and maximum yield (L_{opt}) at 39.5 cm TL. Total mortality (Z) was estimated as 2.4 yr^{-1}, natural mortality (M) of 1.1 yr^{-1}, fishing mortality (F) of 1.3 yr^{-1} and exploitation rate (E) of 61 %.

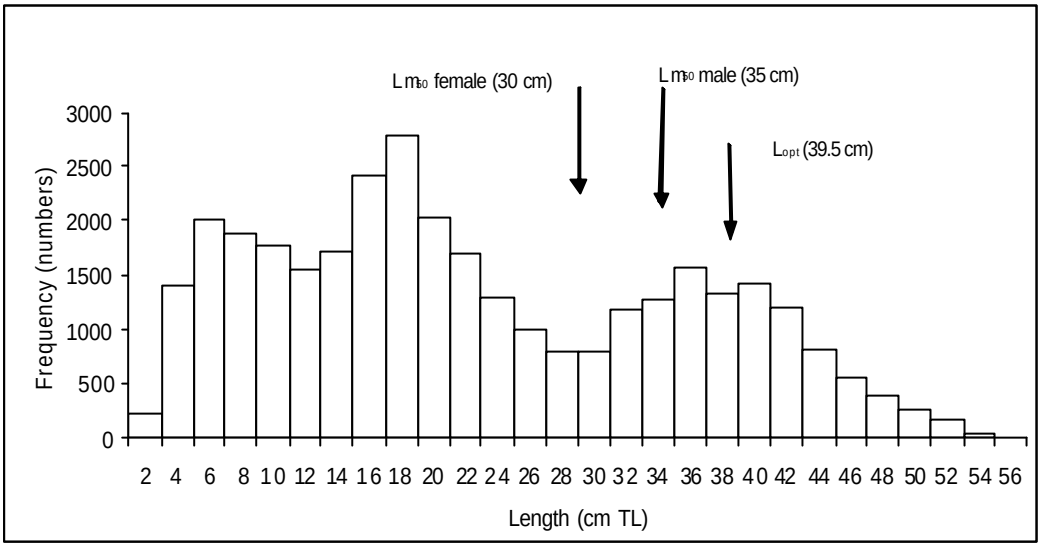

Fig. 2. Length frequency data of commercial *Oreochromis niloticus* catches in Nyanza Gulf indicating, Lm50 and L_{opt}

DISCUSSION

The asymptotic length (L_∞) and weight (W_∞) of *O. niloticus* from Nyanza Gulf shows a general reduction, an increase in growth coefficient (K) and total mortality (Z) over the years (Table 1). Kenya portion of Lake Victoria constitutes only 6 % of the entire lake, but it has the highest concentration of boats (8 000) and fishers (30 000) (Abila and Jansen 1997). The fishery is open access and there is no limitation of boats and the number of gears used in the lake. The recommended gill mesh size for *O. niloticus* fishery is 5 inches (Balirwa, 1992), but 2-3 inches were commonly encountered in this study. Destructive beach seine and trawling though ban in the shallow areas of Kenyan part of the lake were still operational in the lake. Our survey revealed 7 trawlers in the Gulf and all landing sites used beach seine, leading to illegal exploitation in the lake. Available records shows that *O. niloticus* in the Ugandan waters of Lake Victoria start to mature at 32 cm TL for females and 28 cm for males (Balirwa, 1998). Ojouk (1999) found males to first mature at 26.2 cm TL and females at 23.3 cm TL in the Nyanza Gulf. This represents a reduction in size at first maturity since early in 1990s when *O. niloticus* was reported to mature first at 35 cm TL in the Kenyan waters (Getabu, 1992). This earlier maturation of *O. niloticus* in Kenyan waters is in contrast to Ugandan sector may further points to a fish in a stressful environment.

This study reveal that majority of the Nile tilapia caught in Lake Victoria are juveniles (Fig. 2). Majority of fish in the class length 2-5 cm TL were encountered where beach and mosquito seine were targeting *R. argentea* and juveniles of *L. niloticus* were common. Maximum yield (L_{opt}) for Nile tilapia in the Gulf is 39.5 cm TL and the length at first maturity (Lm50) is 35 and 30 cm TL for male and female respectively (personal observations), although majority of the fish caught are below these sizes.

The growth performance index value also shows an increase trend (Table 1). Intensive fishing, genetic makeup and diet type and its utilisation may determine growth potential of a species (Ssentongo and Welcomme, 1985; Pullin, 1988). Illegal fishing methods may results in reduction of the average size of fish caught and the resultant is faster growth in the population. An increase K results in high growth performance index. Tilapia consumes food material that is most suitable for its optimal growth (Bowen 1982). *O. niloticus* in the lake feeds on a wide range of food items including insects, detritus, zooplankton and fish remains (Balirwa, 1998) which could be contributing to this high performance index.

Table 1. Growth parameters (*K* yr^{-1}, W_{oo} g, L_{oo} cm), mortality (*Z*, *M*, *F* yr^{-1}), phi prime (...') and exploitation (*E*) estimates of *O. niloticus* from Nyanza Gulf of Lake Victoria, Kenya

W_{∞} (g)	L_{∞}(cm)	Kyr^{1}	φ'	*Z*	*M*	*F*	*E*	Data collection and source
5930	64.6	0.3	3.0	0.8	-	-	-	July 1985-June 1986 (Getabu 1992)
-	63.1	0.4	3.2	1.7	0.7	1.0	60	1989-1990 (Dache 1994)
4158	60.0	0.7	3.4	2.4	1.1	1.3	61	July 1998-1999 (This study)

CONCLUSION

Continual use of smaller mesh sizes and destruction of breeding grounds will lead to further reduction in *O. niloticus* size/length at first capture. The fishers in turn will reduce their mesh sizes and result to unorthodox fishing methods to target the smaller fish. This will decrease long term catches of the species. Beverton (1959) had predicted a similar trend due use of smaller mesh gill nets to capture the dwindling stocks of *Oreochromis esculetus* (Graham), *Bagrus docmak* (Forsskåll) and Barbus altianalis (Boulenger), once traditional species in Lake Victoria.

O. niloticus stocks occurs mainly in shallow nearshore waters easily accessible by professional and full-time fishers but also to numerous laymen (Witte and Van densen, 1995). Catches of *L. niloticus* the major commercial species is on the decline in the lake (Witte and Van densen, 1995; Othina and Tweddle, 1999) and fishers are shifting more to *O. niloticus* fishery. EU ban on *Lates* export due to poor hygienic conditions has also places more pressure on *O. niloticus*, which fetches the highest price locally.

But, even under this stressful environment *O. niloticus* maintains a high growth performance index attaining large sizes and if well managed production can be increased. Higher production would continue to supply protein and income to people living around the lake who depend so much on fishing due to unpredictable rains. But if allowed to collapse, *O. niloticus* fishery would not only be disastrous to Lake Victoria ecosystem, but also to the economy of the people depending on the lake.

To sustain the fishery, ban on beach seining, trawling, use of illegal mesh sizes and other disastrous fishing methods need to be addressed to by the authority concerned urgently. Entry to the fishery, which is now open, should be limited and licensing of nets in addition to registration of boats should be done to help monitoring the effort exerted on the fishery. Fishers should be provided with cold storage through cooperatives or community based organisations which will enable them to fetch higher prices for their products. To have better bargaining power fishers should be encouraged to form co-operatives societies for sale of their produce. Law enforcers should double their effort and political interference in the running of the fishing industry should be reduced. Alternative source of livelihood like aquaculture and farming should be encouraged to reduce pressure on the lake fishery.

ACKNOWLEDGEMENT

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Food of Surviving Haplochromine Cichlids from Napoleon Gulf, Lake Victoria

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SUMMARY

Specimen of some surviving haplochromine cichlids from Lake Victoria were examined for food to determine their role in the present trophic ecology of the lake. Eight food categories were recorded from the stomachs of the haplochromines examined. Insects were the dominant food category. The other food items included molluscs, plant material, fish remains, leeches, detritus and zooplankton..

The study showed that the number of trophic groups among haplochromines has reduced from ten or more groups originally identified from the lake to only 3. These were insectivores, molluscivores and prawn-eaters with very little planktivory and detrivory. This implies that L. Victoria ecosystem is inefficient since most of the primary production is not utilized. Steps should be taken to reduce nutrient loading in the lake so as to reduce on algal production.

INTRODUCTION

The haplochromine cichlids were originally the most abundant fishes in Lake Victoria comprising more than 80% by weight of the demersal stocks of the lake (Kudhongania & Cordone, 1974). There were over 300 haplochromine species, of which more than 99% were endemic (Witte *et al.*, 1992). Each species had its own unique combination of food and habitat preference (Goldschmidt *et al.*, 1990). Up to eleven trophic groups were identified in the Mwanza Gulf. These were phytoplanktivores, detritivores, algal grazers, plant eaters, molluscivores, zooplanktivores, insectivores, piscivores, parasite eaters, paedophages and scale eaters. Greenwood (1974) had earlier identified five trophic groups in the Napoleon Gulf. These were insectivores, piscivores, molluscivores, plant-eaters and scale-eaters.

Haplochromines disappeared rapidly following establishment of the introduced Nile perch *Lates niloticus* (L.) in L. Victoria (Ogutu-Ohwayo, 1990a). There were differences in the rate of decline, within as well as between, trophic groups (Witte *et al.*, 1992). Molluscivores, insectivores and epiphytic algal grazers survived in the shallow littoral zone where catches of Nile perch were relatively low (Witte op. cit.).

The disruption and reduction of the diverse and trophically complex haplochromine community by the Nile perch seems to have initiated changes in food web structure of the lake. Algal biomass in Lake Victoria increased four to five times and water transparency decreased (Mugidde, 1993). Algal composition has changed and is now dominated by blue-greens. The blue-green algae were the major food source of the detritivorous/phytoplanktivorous haplochromines and the pelagic phytoplanktivores. Together these two trophic groups constituted about 50% of the total haplochromine biomass in the lake (Witte & van Oijen, 1990). Their depletion could have led to reduction in grazing pressure, leaving much of the primary production in the lake unutilized. Decay of this organic matter has depleted the water column of oxygen leading to anoxia in waters more than 40 m deep during periods of stratification.

In this paper, the food and feeding habits of the surviving haplochromines is examined to assess their role in the overall trophic ecology of the lake.

MATERIAL AND METHODS

Samples of haplochromine were obtained from the inshore areas of the Napoleon Gulf of L. Victoria by using multimesh gill nets. In the laboratory, the fishes were identified to genus and where possible, to species level using the key provided in Greenwood (1981). Food analysis was based on the point method as in Hynes (1950). Trophic groups of species were determined by the most dominant food item in thier diet.

RESULTS

Seventeen haplochromine species were examined for food analysis as detailed in Fig.1. The names that appear in quotes are cheironymns. The analysis included haplochromines of 6 cm to 19 cm standard length. The food of smaller fishes was not included in the results because it was very difficult to identify them.

Insects, especially larval and pupal chironomids, Ephemeroptera and Odonata nymphs were the most important food category. Out of the 17 species examined, 14 had insect remains as the dominant food item. Besides strict insectivores, many others previously not feeding on insects included insect material in their diet. Two species, *Astatoreochromis alluaudi* and *Ptyochromis xenognathus* had mollusc remains as the dominant food item. Two species, *Paralabidochromis* "rockcribensis" and *Paralabidochromis* "yellowbar" fed predominantly on the prawn *Caridina nilotica*. Ostracods, *C. nilotica,* phytoplankton and to a lesser extent, detritus contributed to the diet of several haplochromines which belonged to the insectivore and molluscivore trophic groups. Fish remains occurred in seven species which otherwise had insect remains as the most dominant food item in their guts. Four species included leeches in their predominantly insectivorous diet. The food of individual haplochromine species is shown in Fig.1. Eight food categories were recorded from the stomachs of the haplochromines examined in the study as shown in Fig.2. These were insects (69.2%), molluscs (8.9%), plant material (6.9%), prawns (6%), fish remains (5.2%), leeches (2.2%), detritus (1.4%), and zooplankton (0.4%).

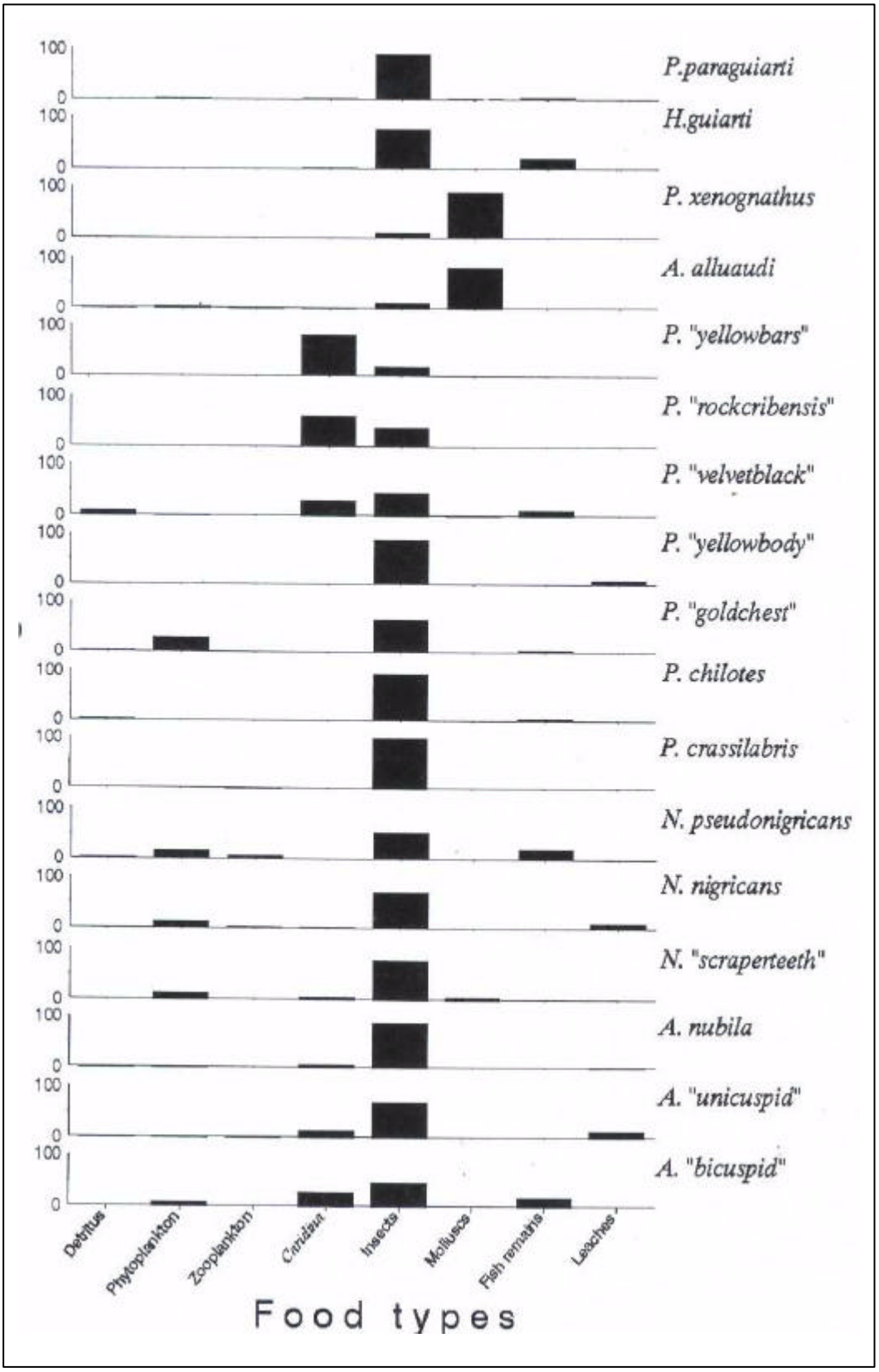

Fig. 1. Percentage contribution of items ingested by different haplochromines in Napoleone Gulf

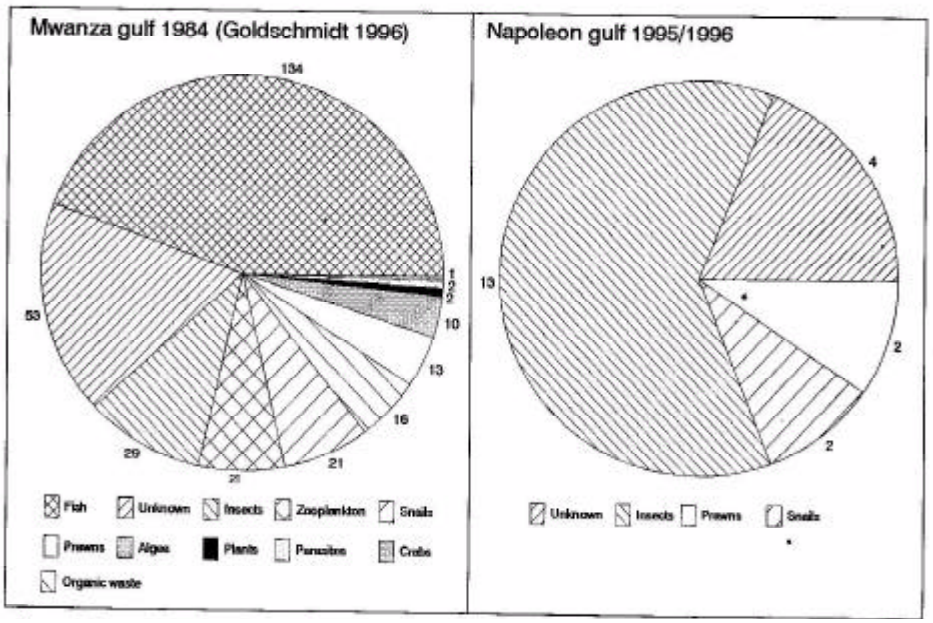

Fig. 2. Comparison of number of haplochromine trophic groups from Mwanza Gulf and Napoleone Gulf based on daa from the Mwanza Gulf 1996 and that collected dur ing this study.

DISCUSSION

Insects were found to be the most dominant food organisms ingested by the haplochromines in the littoral areas of Lake Victoria (Fig. 2). Besides the 13 species that had fed predominantly on insects, many others included some insect material in their diet. The haplochromines examined belonged to three trophic groups (Fig. 3) namely insectivores, molluscivores and prawn eaters. Greenwood (1974) working on the species in Napoleon Gulf recorded five trophic groups while in the sublittoral areas of the Mwanza Gulf (Goldschmidt, 1996), eleven trophic groups were recorded (Fig. 3.)

Comparison of the present data with the findings of research done before the upsurge of Nile perch shows that the number of trophic groups among the haplochromine cichlids has reduced and the species that are still surviving in the littoral inshore areas of L. Victoria tend to feed more on larval insects than other food items. The detritivores/phytoplanktivores, which once made up more than 50% of the haplochromine biomass were never recorded in the study. Thus most of the primary production in the system is not utilized.

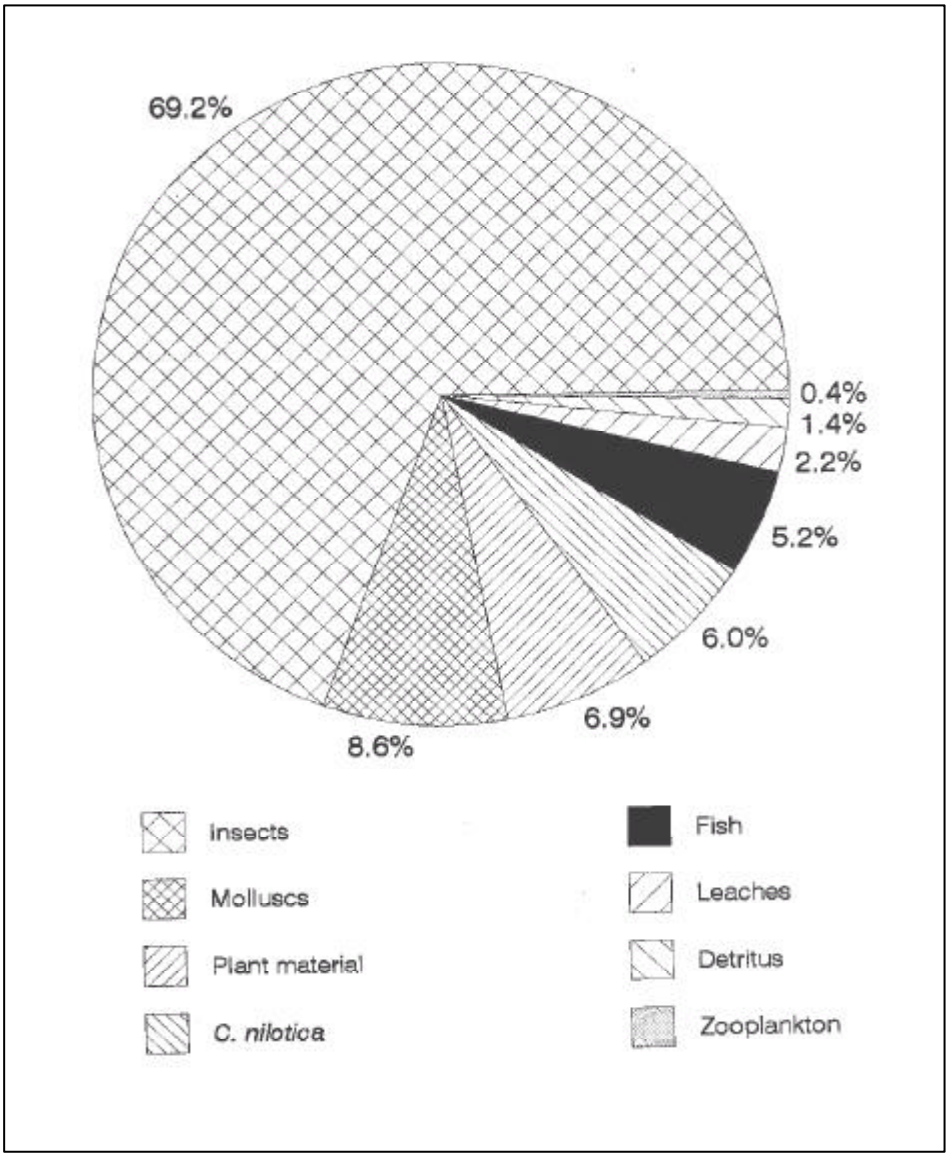

Fig. 3. Relative abundance of the various food items ingested by the haplochromine in the Napoleone Gulf.

CONCLUSION

The number of trophic groups among the haplochromines cichlids has reduced and probably those that were never encountered in the study have disappeared. This implies that the L. Victoria ecosystem is not efficient since most primary production remains unutilized. Steps should be taken to reduce on nutrient input in the lake so as to reduce on algal production.

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The role of *Caridina nilotica* (Roux 1833) in the Lake Victoria Fisheries with Reference to *Lates niloticus* (L.)

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SUMMARY

Caridina nilotica were sampled in three zones of the Tanzanian waters of Lake Victoria by vertical net and a frame trawl over a period of eight months. A total of 31 stations ranging from 6 m to 45.8 m depth were covered. C nilotica were widely distributed in both inshore and offshore waters. The importance of C. nilotica in the diet of the three commercial fish species was assessed between 1999 and 2000. C. nilotica is the primary food for L. niloticus, O. niloticus and R. argentea. High biomasses of C. nilotica were found in the fishing areas that probably support the fisheries.

INTRODUCTION

Caridina nilotica (Roux 1833) is an atyid shrimp typically found in benthic habitats and amongst aquatic weeds in tropical and subtropical zones of eastern and southern Africa. It grows to a total of about 25 mm length and feeds on bottom debris (Fryer 1960). In Lake Victoria, *C. nilotica* occurs throughout the Lake, and is extremely abundant in the littoral regions wherever there are weed beds. Fryer (1960) observed two species, *C. nilotica* and *C. africana*, and two forms of *C. nilotica* in Lake Victoria, one between the vegetation in the littoral waters and another with an epibenthic distribution in the sublittoral and deep waters.

Following the introduction of the Nile perch, *Lates niloticus* (L.) in the 1950s, marked changes in the Lake Victoria ecosystem have occurred. The disappearance of haplochromines in the late 1980s was coupled to a shift in the diet of Nile perch towards *C. nilotica*, *Rastrineobola argentea* (Pellegrin) and juvenile *L. niloticus* (Hughes 1986; Ogari & Dadzie, 1988; Ligtvoet & Mkumbo, 1990; Ogutu-Ohwayo, 1990). The rapid depletion of the main prey items (haplochromines) did not induce a corresponding decrease in the predator population because *L. niloticus* opportunistically switched to *R. argentea* and *C. nilotica*. Stocks of these two species appear to have contributed to the maintenance of the predator population and its high catch rates.

In the early 1980s, only a few shrimps were occasionally observed in bottom trawl catches in Mwanza Gulf after 1986 trawl catches for fish frequently contained thousands of shrimps. In February, 1992, a small trawl (cod end 5 mm) shot for 10 minutes recorded about 100 000 individuals of *C. nilotica* (Witte *et al*., 1992) and about 40 kg of *C. nilotica* was recorded in a 30 minutes frame trawl (Tweddle, personal communication). Othina and Osewe-Odera (unpublished data) reported that 3180 t of *C. nilotica* were landed in the Kenya waters of Lake

Victoria in 1995. This was 1.8% of the total landings. The reason for this increase is probably due to released predation pressure on juvenile shrimps by haplochromines. The formerly abundant haplochromines were potential predators of juvenile shrimps. *Caridina nilotica* consume the equivalent of 2.2% of annual lake primary production. Present net annual secondary production by the shrimp is estimated to be greater than the present fishery yield of the lake. However, the demographic status and absolute stock size of *C. nilotica*, and role in the food web of the lake is not known. Thus, it is important to determine the biomass available to *L. niloticus*, and the population biology (biomass, growth, mortality, recruitment, reproduction) and distribution of *C. nilotica*.

The feeding habits of the important commercial fish species (piscivorous *L. niloticus*, algivorous *Oreochromis niloticus* and zooplanktivorous *R. argentea*) are needed to understand the dynamics of the fishery and lake ecosystem as a whole. There is evidence that *L. niloticus* exhibits ontogenic shifts in diet (Mkumbo & Ezekiel, 1999) and there is spatial variation in foods eaten. All these aspects need further study if the role of *C. nilotica* is to be elucidated.

The objectives of the Lake Victoria Fisheries Research Project included multi-species modelling, assessment of the abundance and variability of the food sources of the major commercial species, in particular the role *C. nilotica* as a primary source for Nile perch. Fish production is strongly influenced by the quantity and quality of available food resources. This paper presents results on the distribution and abundance of *C. nilotica* and examines the role of *Caridina nilotica* in the fisheries of Lake Victoria based on trawl surveys conducted in the Tanzanian sector from June 1999 to January 2000.

MATERIALS AND METHODS

Sampling

Sampling for *Caridina nilotica* was carried out concurrently with the stock assessment programme. The Tanzanian part of Lake Victoria was divided into three (A, B and C) sampling areas and each area was fished on a quarterly basis over a 14 -day period. Area A stretched from Kome and Buhiru islands in the southwest, north eastwards to the south west of Ukerewe island, including Speke and Mwanza Gulfs. Area B started from the Tanzania-Kenya border southwards to the north west of Ukerewe Island. Area C covered the Kagera waters from Rubafu bay in the Tanzania-Uganda border southwards to Kome Island, including Emin Pasha Gulf.

The lake was divided into five nautical-mile-squares on the chart. In inshore waters each square was sampled if it was trawlable. In offshore water, one square in four was sampled. Stations within grid squares were selected to cover the different depth range.

The Research Vessel, RV Lake Victoria Explorer, (length 17 m; 250 Hp engine) was used for bottom trawling with a net of 22.6 m head rope and a cod end of 25 mm mesh. Towing speed was 3.5 knots and trawling duration was 30 minutes. *Caridina nilotica* was sampled daily with a specially designed vertical net with a metal frame of 1 m x 1 m mouth opening to examine its temporal and spatial distribution in three zones of the Tanzanian sector of Lake Victoria. The other sampling technique used was a frame (box) trawl net of 3.5 m x 3.5 m mouth opening in deep waters trawlable at the thermocline/oxycline layer.

The frame trawl was operated together with a NETSONDE net transmitting unit and a net receiving unit. The transmitting unit was attached to the net and the receiving unit was lowered in the water and connected to the monitor so that the position of the net in the water could be observed on the screen. The speed of the boat was adjusted to make sure that the net was set along the thermocline / oxycline. In most cases, the towing speed was 3.5 knots and the trawling duration was 30 minutes.

Data recording

The entire catch was sorted into species, counted and weighed. *Caridina nilotica* were weighed individually or as a total in grams. The carapace length was measured in mm from midpoint of the eyes to the margin of the cephalothorax and urosome with a vernier calliper. The total length was measured from the base of the eyestalk to the tip of the telson. The empirical relationships between individual *C. nilotica* total length (TL mm) and carapace length (CL in mm), and carapace length and weight were calculated. If the catch was too large, sub-sampling was carried out. The weights of the sub-sample and total catch from which the sub-sample was taken were used to obtain the raising factor. Abundance was expressed in numbers of *Caridina nilotica* per m^2 and biomass in wet weight (g m^{-2}).

Stomach samples from *L. niloticus*, and *O. niloticus* were collected from trawl catches carried out by the RV Lake Victoria Explorer in the three zones between March 1999 and January 2000. Total length was measured (cm) for each fish. The fish were dissected, the index of fullness assessed and volume of each food item present in the stomach determined. The contents were removed, examined and recorded. Prey organisms were identified and counted. These data provided quantitative information on the relative importance of *C. nilotica* as a food source for different sizes of *L. niloticus* at several localities. The fish were grouped in 10 cm size classes up to 100 cm plus (1-10 cm, 11-20 cm, 21-30 cm, 31-40 cm, 41-50cm, 51-60 cm, 61-70 cm, 71-80 cm, 81-90 cm, 91-100 cm and above 101 cm TL). The total weight and numbers of *C. nilotica* eaten by a given size of *L. niloticus* were recorded.

RESULTS

Species composition and distribution

A total of 31 stations were surveyed between June 1999 and January 2000, covering a depth range between 6 m and 45.8 m. The catch included *Caridina nilotica, Rastrineobola argentea*, molluscs, Chironomids, Oligochaete, and Odonata (Table 1.)

Table 1: Catch records for *C. nilotica* in the surveyed areas.

Location	Depth	*Caridina* (wt)	Molluscs	*R. argentea*	Haplo
Kibara		120	2140		
Ngoma		100	80		
Kambu		80	0		
Off Towa		0	0		
Mara bay		0	0		
Suguti bay		0.15	2000	7 pcs	
Burungu		0.23	700	4 pcs	7 pcs
Bawman's Gulf		0.23	2940		
Kirongwe		440			
Ruari pt		0			
Ikungu bay		253			
Irugwa		0	800		
Kweru		20			
Kisanji		20			
Kubanza		30			
Galinzira		23			
Ruiga		100			
Irumu channel		30			
Kaviga		140			
Nyarusenye		50			
Zigura isl.		30			
Kayenze		110			
Off Senga		100			
Shoka bay		120			
Vesi isl.		740		4200	
Bukimbwi		0	600	2000	
Kibara		0		12 pcs	
Off Kibara		0			

The abundance of *C. nilotica* varied from station to station as well as from month to month (Fig. 2).

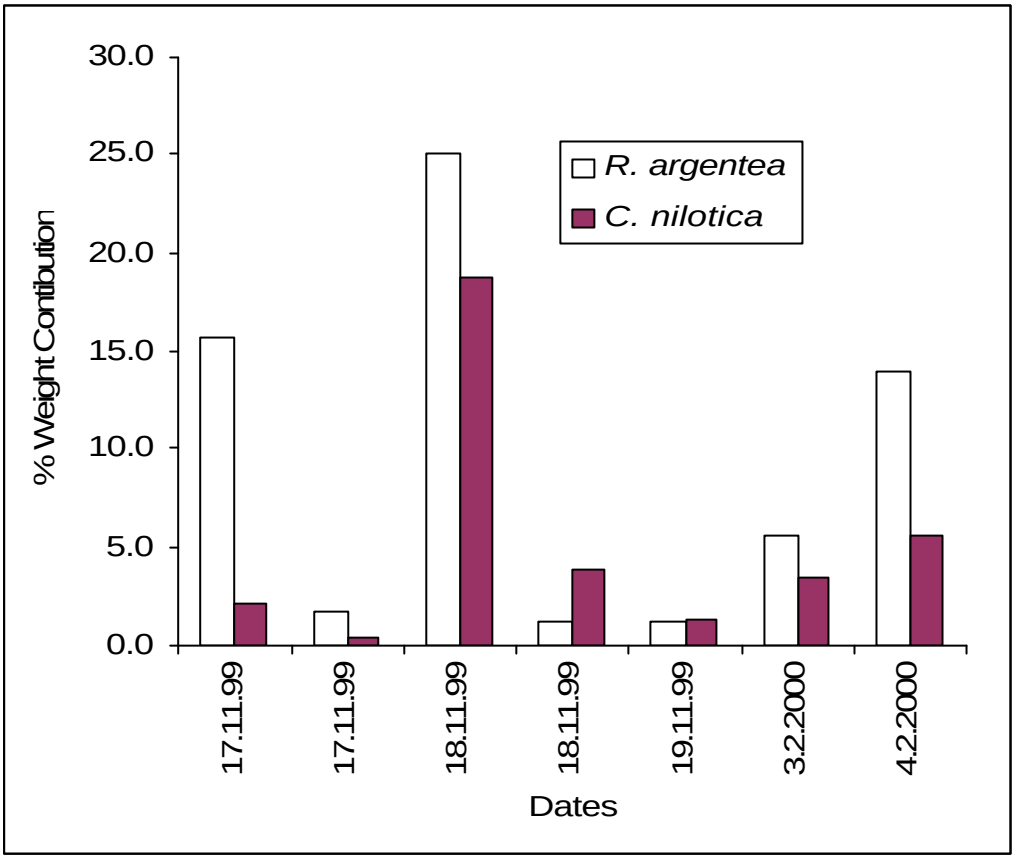

Fig. 2. Percentage weight contribution of *C. nilotica* in the *R. argentea* fishery from Sweya beach

The density of *C. nilotica* at three stations in area A for the month of June, 1999 was 2004 individuals m^{-2} at Kibara (6.75 m depth), 1295 ind. m^{-2} at Ngoma (19.85 m depth) and 714 ind. m^{-2} at Kambu point (9.4 m depth). In terms of wet weight, it was 120 g m^{-2}, 100 g m^{2} and 80 g m^{-2} respectively. The average catch rates fluctuated between 600 g hr^{-1} in June 1999, 0.732 g hr^{-1} in July 1999 (Table 2). The catch rates varied between stations and between areas. Area A had higher catch rates followed with Area B and finally Area C. (Table 3).

Table 2: Average monthly catch rates for *C. nilotica* from June 1999 to January 2000

Month	Average catch rate (g hr^{-1})
June 1999	600
July	0.732
August	-
September/October	23.43
November	285.2
December	114.3
January 2000	305.71

Table 3. Catch rates of *Caridina* per station from June 1999 to January 2000 for zones A, B and C

Zone	A	B	C
Catch rates	308.5 g hr^{-1} (n= 13)	143.0 g hr^{-1} (n=10)	93.25 g hr^{-1} (n=8)

The majority of *C. nilotica* were collected in the depth range between 6.75 m and 39.65 m. However, there was no direct relationship between the abundance of *C. nilotica* and depth. The presence of a thermocline / oxycline in deep waters was correlated with the amount of *C. nilotica* in the water column. On average, *C. nilotica* contributed between 11.76% and 75.34% to the *R. argentea* fishery at Sweya beach (Fig.2).

Population structure of *Caridina nilotica*

A Total of 18 069 *C nilotica* specimen were analysed for length frequency distribution in the three zones. The size class ranged from 1 mm CL to 8 mm CL. The carapace length distribution indicated one mode at 5 mm CL. The modal length of *C. nilotica* in the stomachs of *L. niloticus* was also at 5 mm CL.

Diets of *L. niloticus, O. niloticus* and *Rastrineobola argentea*

Caridina nilotica was the predominant food item in the stomachs of Nile perch, being found in approximately 50% of all fish in all sites. The number of *C. nilotica* in the stomachs of *L. niloticus* ranged from 4 individuals for a fish of 47.2 cm TL to 260 for a fish of 48 cm TL. The importance of *C. nilotica* to the diet of *L. niloticus* declined with increasing size of fish. Few fish > 50 cm

had *C. nilotica* in their stomachs whereas the stomachs contents of small fish < 10 cm was almost exclusively the shrimp.

DISCUSSION

Much of our current understanding of the autecology, production and ecological role of fish population is derived from studies of the diet based on analysis of stomach contents (Windell & Bowen, 1978). The results of this work show that *C. nilotica* is an important component of the diet of many fish species such as *Lates niloticus, Oreochromis niloticus, Schilbe* intermedius, *Synodontis* spp, *Brycinus* spp, *Bagrus docmak*, and haplochromine. *C. nilotica* being a primary consumer grazing on algae, also being a carnivore and detritivore, plays a vital role in the aquatic food web by transferring energy from the lower to the higher trophic levels. The *C. nilotica* is the primary food for fish in the size class 1-60 cm TL. As the predator becomes larger, the importance of *C. nilotica* as food declined *Lates niloticus* < 10 cm TL ate exclusively *Caridina nilotica*, but it only represented 17% of the food intake for the 71-80 cm size class. Hughes (1986) reported the same observations in the Kenyan waters of Lake Victoria. In his report the percentage contribution of *C. nilotica* declined from 60-85% for fishes between 5 and 40 cm TL, to less than 10% for fish larger than 80 cm in length. The same observation was reported by Gee, (1969); Okedi (1971); Hughes (1986, 1992); Ligtvoet & Mkumbo (1990); Ogutu-Ohwayo (1990a); Mkumbo & Ligtvoet (1992); Ogari & Dadzie (1988).

From this list, it is evident that *C. nilotica* is the important food source for the Nile perch stocks of Lake Victoria and its sustainability depends among other things on the abundance and availability of *C. nilotica* in the lake.

The study showed that *O. niloticus* feeds on *Rastrineobola argentea, C. nilotica,* algae, and some insects. Although *Rastrineobola argentea* has been reported to be a zooplanktivore, eating mainly planktonic crustaceans (Graham 1929; Corbet 1961; Hoogenboezem 1985), the present study did not record any *C. nilotica* in their stomachs.

For the period January to August 1997, *L. niloticus* with total length less than 40 cm, 20 cm and 30 cm from Speke Gulf, Mwanza Gulf and Ukerewe waters respectively contained *C. nilotica* in their stomachs constituting over 90% of the diet. These findings differ from those reported earlier (TAFIRI report 1996), where juvenile Nile perch was the major food item of this length group. They also differ from those reported by Mkumbo & Ligtvoet (1992) who found haplochromines were the major food items for Nile perch in the Mwanza Gulf. Further observations revealed that fish between 40-100 cm, 20-60 cm and 30-80 cm in total length from Speke Gulf, Mwanza Gulf and Ukerewe waters, respectively, consumed a variety of food items including *C. nilotica*, juvenile *L. niloticus*, haplochromines, *R. argentea*, fish remains, odonata, snails and *Barbus profondus*.

The food web structure of Lake Victoria presently includes two major pathways:

Trophic pathway based on algal production: This pathway flows from primary producers

(phytoplankton) directly to fish (*O. niloticus*) and also to zooplankton. Phytoplankton are also consumed by zooplankton which are preyed upon by juvenile *O. niloticus*, Chaoborus and *R. argentea*. Zooplankton, and perhaps Chaoborus, are consumed by the *R. argentea*.

Trophic pathway based on detritus: Non-utilized phytoplankton sink to deeper layers where it decomposes. *C. nilotica* and other invertebrates, which are consumed by juvenile and adult *L. niloticus*, consume these degraded products. Adult *L. niloticus* also prey on young *L. niloticus*. Nile perch is the harvestable top consumer of this pathway. In this food web *L. niloticus* is the top predator, feeding mainly on the shrimp *C. nilotica* (primary consumer) and on *R. argentea* and juvenile *L. niloticus* (both secondary consumers).

CONCLUSION

Recruitment is a key factor in determining the strength of cohorts. Since fish depend on *C. nilotica* for their food at early stages of their life, the quantity of *C. nilotica* is critical to survival. Thus *C. nilotica* availability is an important factor determining the relative survival of juvenile fishes. *C. nilotica* is potentially very important in the functioning of the aquatic environment.

These findings represent the preliminary output of a much wider study on the role of *C. nilotica* in the fish production of Lake Victoria. This work will be intensified and expanded to include information on production of *C. nilotica*, diel migration patterns and spatial and temporal shifts in the diet of the major commercial fish species of the lake.

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The Possible Evolution of Lake Victoria Fisheries as Assessed by Ecopath IV (with Eosim and Ecospace) Software.

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SUMMARY

The ECOPATH IV software is used to describe the trophic relationships within the exploited fish community of Lake Victoria as a whole. Further studies on system dynamics are made using the ECOSIM/ECOSPACE simulation programs included in the software that can define the effects on some possible fisheries management schemes for the future. The biomass of the key fish stocks are computed and the results are in agreement with recent field data. The possible evolution of the fish community under several fisheries management strategies is described, confirming the possibilities of recovery of the haplochromine stocks and current trends of overfishing of Nile perch. The importance of fishing sanctuaries for the further evolution of the ecosystem is particularly emphasized.

INTRODUCTION

Lake Victoria, East Africa has undergone dramatic changes in the structure of its ecosystem after the introduction of Nile perch, *Lates niloticus* (L.) more than thirty years ago (Wanink & Goudwaard 1994; Wandera & Wanik 1995). The population explosion of *Lates niloticus*, as well as the intensive riparian fishing pressures in combination with the increasing eutrophication due to agricultural and waste runoffs (Bundy & Pitcher 1995; Wilson, Medard, Harris & Wiley 1996) contributed to the decline of the multispecies stock of the lake into three commercially important species: two totally demersal exotics, the Nile perch and Nile tilapia, *Oreochromis niloticus* (L.), and the native sardinelike, zooplanktivorous, pelagic cyprinid " dagaa ", *Rastrineobola argentea* (Pellegrin) (Bundy & Pitcher 1995; Wilson *et al.*, 1996). The vast expansion of fish production in the lake has been due to the increased population of Nile perch at the end of the 1970s at the expense of the predation on endemic species, especially in the decimation of many haplochromine species (Wanink & Goudswaard 1994; Pitcher & Hart 1995 , Reynolds & Greboval 1995; Wilson *et al.*, 1996). The small cyprinid *R. argentea* remained the only indigenous species of commercial importance and became the major prey species of the Nile perch (Ogari & Dadzie 1988; Mkumbo & Ligvoet 1992).

The present paper is the follow-up of a previous contribution (Villanueva & Moreau 2000) in which the ECOPATH trophic model been used in order to describe the trophic relationships occurring in the well documented and intensively exploited Kenyan sector of the lake from the middle of the eighties (Moreau, Ligtvoet & Palomares, 1993) to the end of the nineties (Villanueva & Moreau, 2000).

Thus, it appears necessary to integrate the information so far accumulated by various research institutions of the three riparian countries, due to the several currently ongoing research projects reported in this volume. It is also hoped to show opportunities of cooperation towards an understanding of the lake as a whole.

MATERIAL AND METHODS

The ECOPATH IV Software

To construct the structure of trophic interactions occurring in the ecosystem, we used the steady-state simulation program, ECOPATH IV, as designed by Christensen & Pauly (1992 and 1993) and Walters, Christensen & Pauly (1997), based on the original ECOPATH model by Polovina (1984) and Polovina & Ow (1985). In structuring the model, the various organisms belonging to the ecosystem have to be grouped into " boxes " according to their common physical habitat, similar food preferences and life history characteristics. Then the model estimates parameters, on a per year basis, such as mean biomass, biomass production and biomass consumption or ecotrophic efficiency and flow to the detritus pool of every box considered in the ecosystem. It is assumed for the period considered that input to each group is equal to the output from it in order to deal with equilibrium conditions. It is also required to standardize the data input by applying the same units in each parameter considered. By establishing an equilibrium condition in the ecosystem, a system of biomass budget equation is determined for each considered group as:

Production - all predation on each grouped species - non-predatory mortality - all exports = 0.

ECOPATH expresses each term in the budget equation as a linear function of the mean biomass. The resulting budget equations become a system of simultaneous equations following the formula:

$$Bi\ (P/B)i\ EEi - Yi - Sigma\ (Bj\ Q/Bj\ DCji) = 0 \qquad (1)$$

where Bi biomass of the group i. (in tonnes/km^2)

P/Bi production/biomass ratio, usually assumed as equal to the total mortality (Z) as defined in fisheries science (Allen 1971; Lévêque, Durand & Ecoutin 1977)

EEi - ecotrophic efficiency: i.e. the proportion of the ecological production which is consumed by predators and/or exported (Ricker 1969)

Yi - yield (= catch), usually obtained through fisheries statistics (in tonnes/km^2/year)

Bj - biomass of the predators j on group i

Q/Bj the food consumption per unit biomass of j, food consumption of an age-structured fish-population (Pauly 1986, Palomares & Pauly 1998).

DCji fraction of i in the diet of j, (in percentage of weight or volume).

ECOPATH IV differs from previous versions as it has additional routines namely, ECOSIM and ECOSPACE (Walters et al. 1997). Aside from performing usual balancing of models by computing unknown parameters in every equation such as (1), these new routines provide descriptions of evolution occurring in the ecosystem considering various fishing management strategies and describe the trophic dynamics of the ecosystem as distributed over space.

Balancing the ECOPATH model for Lake Victoria

The actual catch for the whole lake has been adapted from Mkumbo *et al.*, (2000) and various contributions in this volume. The groups considered here are those already identified in the previous contributions by Moreau *et al.*, (1993) and Villanueva & Moreau.

The diet composition of the fish-eating birds now incorporates a significant proportion of small juvenile Nile perch keeping in mind that these birds are hunting at a maximum distance of 3 km from the shore. (Goudswaard & Wanink 1993 ; Wanink & Goudswaard 1994).

The demographical parameters of *Lates niloticus* are suitable for the whole lake, not only the heavily exploited Kenyan sector. The growth parameters (Loo = 185 cm and K = 0.18/yr) are from Witte & Van Densen (1995). Using length frequency distributions provided by these authors and personal data by C. Rabuor (personal communication), led to P/B = 2.5 for juveniles less than 40 cm TL and 0.7 for adults. Q/B has been recomputed accordingly (see below).

The contribution of the haplochromines to the diet composition of the various predatory fish has slightly increased due to the documented recovery of these populations. From information gathered from recent studies (for instance Tweddle & Cowx, 1999), it seemed appropriate to update the previously considered sub-categories of haplochromine species. Groups of predatory and phytoplanktophagous species were kept. The zoobenthophagous group inhabiting the littoral areas of the lake was amended, however, due to recent observations by Witte and his team (this volume) that showed the change in the diet consumption of this group from eating insects and mollusks in moderate amounts to an almost completely zooplanktophagous diet and since it appears that an important population of these particular haplochromines has been considered as food that may be exploited by adult *Lates niloticus*. Otherwise, small modifications in the feeding habits of some other groups such as juvenile *Lates niloticus* (Tweedle & Cowx, this volume), *O. niloticus* (Njiru 1999), *R. argentea* (Wandera 1999), native tilapia (P. Bwathondi, personal. communication.) and the lake prawn, *Caridina nilotica* (Lehman, Mbahinzireki & Ndawula 1996).

The P/B ratio of phytoplankton has been divided by 2 (180 instead of 365).

EE was assumed to be 0.98 for juvenile *Lates niloticus* since they are caught by fishermen or eaten by adults. For the other groups defined in this exercise, EE was set at 0.95 to indicate that every organisms in the ecosystem is being fully utilized by their respective predators aside from being heavily exploited in the fisheries, when appropriate.

Requirement for running the ECOSIM simulations

As already operated in Villanueva & Moreau (2000) , the Nile perch was divided into adults and juveniles, considering P/B, Q/B and feeding habits. The maximum size of a juvenile was assumed to be 40 cm total length (TL) because this is the minimum size caught by large mesh size gill nets and by long lines and they start to escape predation by adults (Ogari & Dadzie, 1988). Juvenile Nile perch are mostly observed on littoral areas of the lake (Hughes, 1986). For Q/B, two computations were performed separately for adult and juveniles using MAXIMS (Jarre, Palomares, Soriano, Sambilay, Christensen & Pauly, 1990) with the following parameters:

For both adults and juveniles Woo = 76 000 g. K = 0.18

Adults : beta = 0.10 P/B = 0.7 Wr = 1000 g Wmax = 72000 g. Q/B = 3.0
Juveniles : beta = 0.15 : P/B = 2.5 , Wr = 2g Wmax = 1000 gr Q/B = 7.4

Feeding and diet composition of these two groups have been established according to Ogari & Dadzie (1988) noting the differences in their spatial distribution. The age of transition from juvenile to adult is about three years. The average ratio of transition from juvenile to adult is 5. This value is achieved by dividing the maximum weight of the juvenile (1 kg) to the average weight of the adult (5 kg) as required for a proper use of ECOSIM (Walters *et al.,* 1997).

In addition to split the *Lates* group into juveniles and adults, it is necessary to split the fish yield according to the fishing gears used, as presently occurring and documented by Wanink *et al.*, (1999), Tweedle & Cowx (1999), and Njiru, Othina & Cowx (2000).

Large *Lates* are exposed to long lines and to large mesh size gill nets whereas juvenile *Lates* and *O. niloticus* can be caught by any gill nets (large and small mesh sizes). Various kinds of mosquito nets and scoop nets are used to catch specifically *R. argentea* and are referred to here as dagaa fishery. Littoral lines are utilized towards zoobenthophagous fish whereas haplochromines are considered in the present scenario to be exploited only by gill nets with small mesh sizes. Beach seines and trawls are not considered here as they have been banned in the three countries several years ago. This does not exclude that they are still used on a very small scale, mainly on the Kenyan sector of the lake. For the purpose of the present paper, it is assumed that their contribution to the fisheries is of marginal importance. In addition, the size distribution of their catch is similar to that obtained with small mesh sizes (Njiru *et al.*, 2000).

Requirements for the ECOSPACE simulation

The ECOSPACE simulation software requires the user to define the most likely habitats of the various groups considered in the model and also the spatial distribution of the fishing activity utilizing various gears.

Adult Lates can be found all over the lake but more particularly in open waters, and even in deep waters. Juvenile *Lates* are living in what has to be considered as littoral waters, possibly, less

than 15 m deep. *R.argentea* is found in littoral and open waters, in surface waters at night but in deeper waters during daytime.

Caridina nilotica is found in littoral as well as in deep open waters. At night they seem to move into surface waters feeding partly on zooplankton (Lehman *et al.*, 1996). Insects and larvae are found within 15 m depth.

Zoobenthophagous fish are not only found in the littoral zones but also in marshy areas regarded as fishing refuges along the shores. They share this distribution with tilapiine fishes (the native ones of which are very scarce and concentrated in such marshy waters). Among the haplochromine groups, zooplanktophagous populations colonize the whole lake while both predatory and phytoplantophagous ones seem to prefer the marginal marshy areas or 'refuges' waters.

The spatial distribution of the fishing operations towards every fish group are closely associated to the one of their main target fish. It is established according to the knowledge of local scientists, fisheries managers and fishermen.

RESULTS

Balancing the Model

The current estimates of biomass and other key features of the present ECOPATH IV model for the whole Lake Victoria and the diet composition of the groups considered was summarized.

For *Lates niloticus* as a whole, the actual biomass computed here (5.3 t/km^2) is the same as expected by Pitcher & Bundy (1995) when assuming the fishing effort to increase by 3% per year (scenario b, p 177) which actually happened (5.4 t/km^2). This is also in agreement with the findings of Tumwebaze & Getabu (1999) from trawl surveys at the end of the 1990s (5.6 t/km^2) and with biomasses estimates of 4.6 t/km^2 suggested for the Nyanza Gulf, Tanzania, by Witte & Van Densen (1995) or Witte, Goudswaard, Katunzi, Mkumbo, Seehausen & Wanink (1999).

During the eighties, the biomass of *R. argentea* might have been multiplied by 4, from 0.7 to 2.8 t/km^2 (Witte & Van Densen 1995). In the present exercise we obtained a biomass value for this group and the whole lake of around 4.2 which is in agreement with the trend of increase in the recent years.

The total biomass of all haplochromines at present is about 4.3 t/km^2 . Most of this biomass, about 3 t/km^2, is contributed by the zooplanktivorous group that has recently been observed to be recovering, concentrated in the pelagic areas. The rest of this biomass consists of the other groups dominating the littoral and marshy areas. Referring to acoustic abundance indices obtained in 1998 by Tumwebaze & Getabu (1999), the abundance of haplochromines was found to be approximately equal to that of the dagaa. This trend was most likely under progress in 1995-1996.

The biomass of Nile tilapia (4.5 t/km^2) is in agreement with that obtained by Getabu & Nyaundi (1999).

The biomass of Caridina nilotica estimated by Lehman *et al.*, (1996) was 4.8 t/km^2. We obtained a biomass of 1.9 t/km^2 assuming an ecotrophic efficiency of 0.95. The biomass of this group might be currently decreasing.

For zooplankton, the present biomass estimate is 4.3 t/km^2. By referring to Mavuti & Liiterick (1991), the densities recorded by Ndawula *et al.*, (this volume) correspond to biomasses of 0.9 to 35 t/km^2 from the shore to the open waters of the lake. A distinct heterogeneity of this group can be seen due to a possible overconsumption of zooplankton in the littoral waters when compared to those inhabiting the open waters.

Recent estimates by Hecky (this volume) showed that the biomass of phytoplankton in the open waters of the lake has increased to a value of 0.2 g/m^3 which means 4 g/m^2 (or t/km^2) over an average water column of 20 m. Our own findings are in agreement with these data.

Following the user's instructions of ECOSIM (Walters *et al.*, 1997), we analyzed the variations of biomass and catch of specific target group with time on a per gear basis and on a per group basis. However, the trends are the same for any group caught by a single specific gear. The evolution of the fishing effort was as follows: using gill nets and longlines, the fishery has been multiplied by 50% within ten years while the rest of the gears have been multiplied by 100% (Njiru *et al.*, 2000).

For the main zoobenthophagous species, *Bagrus docmak* (Forsskall), *Clarias gariepinus* (Burchell) , *Protopterus aethiopicus* (Haeckel) *Mormyrids* and *Synodontis* spp. , we would expect a progressive catch increase by 1.3 during the first years which could start to decrease afterwards. The biomass of these species would finally decrease by approximately 75% within the ten years of the scenario. We have no clear records regarding the increase in catch of these groups except that during the period 1994 - 1997 landings increased drastically (Mkumbo, Okaranon, Getabu, Muhoozi, Othina, Cowx & Tweedle 2000) probably due to the high commercial value of these groups when smoked. It was also reported by Kudhongania & Chitamwebwa (1995) and Njiru et al. (2000) that infestation of water hyacinths (Eichhornia crassipes) provided sufficient breeding shelter for these groups that may have permitted a temporary recovery.

The trend of evolution of haplochromines populations targeted by small mesh in the present scenario would be a maintenance of the biomass of the zoophagous fish and a decrease by 75% of the biomass of the two other groups. The catch of the three groups would be multiplied by a factor of 1.2 to 1.7 after ten years. Their biomass would increase when the fishing pressure increases on their main predators (Nile perch, catfish,) and competitors (dagaa), suggesting the sensitivity of this group to variations of the fishing activity with other gears and target fishes. The current increase in the abundance of haplochromines has been recently documented (see various contributions in this volume).

The biomass of dagaa (*R. argentea*), is expected to decrease by 75 % after ten years whereas the catch would be multiplied by 1.5 and stabilize after 8 years.

The catch of native tilapias is expected to increase by 25 % during the first three years and to decrease progressively afterwards. The biomass would permanently decrease until reaching only 50% of the original value.

Fish groups (*O. niloticus* and adults and juvenile *Lates*) that are caught with multiple gears were analyzed on a per species basis. The resulting trends can be summarized as follows.

For *O. niloticus*, the biomass would decrease by 25% whereas the catch would increase by 50 %

The evolution of biomass and catch of *Lates niloticus* has been the most difficult to identify. In any case, the observed evolution of the biomass shows alternating oscillations of the abundance of adults and juveniles in that the increase of the adult abundance occurs with a decrease of juveniles. This clearly reflects the predatory-prey relationship between the two. Similar could be derived from catch with different gears.

On average, the biomass of the whole Nile perch population would regularly decrease by 25 % during the ten years being considered whereas the catch would remain more or less constant or decrease slightly (by 10%). This holds true for adult or juvenile considered as target group although it seems that juvenile Nile perch are more susceptible to an increase of the fishing effort than adults.

In order to account for the possible interactions between the various scenarios related to specific fishing gears we ran a scenario in which the fishing activities irrespective of the gear in the entire lake would increase by 50 % during the ten years to come. The results confirmed most of the trends of variations observed here except that the biomass of zooplanktophagous haplochromines clearly increase by 50 to 100%.

ECOSPACE simulations for the whole lake

ECOSPACE requires first to establish a map, and then to run over ten years, in order to obtain figures which displays the possible evolution of the ecosystem with the current level of fishing activity while taking into account the spatial distribution of both the fishing effort with various gears and the groups of fish and food. As mentioned earlier, we assumed that no fishing would occur in the littoral 'refuge' areas as suggested by local scientists (M. van der Knaap, personal communication).

Fish-eating birds would concentrate along these "refuge" areas due to better accessibility of most of their preys (see below) . It is also to be considered that these birds would even cover a great distance from the shore as expected (Goudswaard & Wanink 1993; Wanink & Goudswaard, 1994)

We have further assumed that differences in the distribution of adult and juvenile Lates are characteristic of the whole lake. The adult would occupy more the open water areas with size increasing towards the deeper areas and the latter would concentrate on the littoral zones except the 'refuge areas'. This habitat partitioning leading to less cannibalism might explain the almost constant biomass of the two groups even if they are heavily fished.

Densities of *Bagrus*/*Clarias*, *Protopterus*, *Mormyrops*/*Synodontis* and even local tilapias would increase along the littoral areas and even more in the refuge areas which seem to highly promote the growth and recovery of these groups a documented elsewhere in this volume. The abundance of local tilapia in the refuges would increase since the growth of this group seems currently not to be constrained by fishery exploitation or heavy predation and competition food or space with the Nile tilapias.

Predatory haplochromines as well as the Nile tilapia would be most abundant in the littoral unprotected areas. Phytoplanktophagous haplochromine populations would stabilize in the littoral area away from the refuges in which their predators (*Bagrus, Clarias, Protopterus*) would develop but in the lake as a whole they would decrease.

Zooplanktivorous haplochromines, *R. argentea* and *C. nilotica* would maintain their biomass at a seemingly average level along the littoral zones except along the 'refuge areas' and increasing towards the open water areas. This may be due to the less resources competition, if there is any, among these groups and their ability to sustain the predation imposed by the Nile perch.

Zooplankton would be distributed homogenously all over the lake, not decreasing in the littoral zones, including the refuge areas. This is not in consistence with what has been pointed out by Ndawula *et al.,* (this volume) although gradation of phytoplankton density would be observed, especially elevated along the protected areas.

The overall trends obtained in show the possible elevation of the local tilapia biomass as compared to the rest of the fish community. This is the same, but in moderate levels, with most of the zoophagous fishes while Nile tilapia and Nile perch would slightly decrease in the long-term basis.

DISCUSSION

Fish-eating birds were included in order to show their increasing exploitation of the lake's fish resources (specifically haplochromines and, at present, dagaa) as observed by Wanink et al., (1999). There is a need to study the influence of this group due to possible competition with top predators, at least in the littoral zones. To some extent, it may also have contributed to the decline of the landings of dagaa currently observed in some parts of the lake (Mkumbo *et al.*, 2000 , Njiru *et al.*, 2000)

The simulations pointes out the possibility of recover of the haplochromine population, especially the zooplanktophagous ones. A possible reason apart from weak predation by other fish, is the recently increased density of zooplankton in the pelagic areas providing more food for these species. A recover of the previously dominating predatory fish such as the catfish, lungfish and others could be due to the protection of the littoral refuges against fishing operations.

The reasons for the different trends of biomass and catch between adult and juvenile *Lates* need to be investigated in detail. They might be due to a particular stock recruitment relationship and to the fact that, although cannibalism occurs, the adults also prey on competitors of the juvenile, leaving them more food resources to exploit and allowing them to grow quickly to the adult stage (Walters *et al.*, 1997).

Although ECOSIM allows simulations of catch and biomass evolutions which are in agreement with observations from 1995 to 2000, its predictive power has some limits. It is due to the fact that we cannot simulate simultaneously both the evolution of the fishing effort with several fishing gears and the resulting influence on the biomass of every fish species. In addition, it would be necessary to incorporate in the scenarios the possible evolution of the water quality mostly in terms of variations of the primary production.

The biomass of the economically important fishes are lower for the whole lake than those observed in the Kenyan sector by Villanueva & Moreau (2000). This confirms the non-homogenous distribution of the fish community in the lake already mentioned by several authors (Kudhongania & Cordone 1974; Witte & Van Densen, 1995).

The trophic dynamics pertaining to the distribution of the groups in the lake, as a whole, have been well simulated for most of the groups considered in the ECOSPACE scenario. The current scenario showed clearly the recover of the previously declining, and even disappearing, endemic fish population possibly due to the implementation of refuge areas. These areas characterized by poor oxygen supply which is insufficient for Nile perch survival (Moreau, 1982) could become sanctuaries that promote the biodiversity of the lake.

CONCLUSION

It is expected that a trophic model of the entire lake will be most useful as a basis for the elaboration of management strategies aiming at conserving, and possibly enhancing the biodiversity and productivity of this ecosystem. However, it will be necessary to develop some " local models " pertaining to limited parts of the lake for which the limnological characteristics and the fisheries are particularly well documented as in the Kenyan sector. In this respect, the present paper should be regarded as a call for improved cooperation and of information exchange among all interested scientists of the three riparian countries.

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Surplus Production Model for Lake Victoria (Kenya): Application of Auto-Regressive Integrated Moving Averages (ARIMA) for Fish Catch Prediction

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SUMMARY

Schaefer and Fox surplus production models could be used to determine MSY for the Kenya Sector of Lake Victoria from 1990 to 1996. Both models exhibit an equilibrium situation for the years considered but effort could only be determined from rate the function described by the present value (pv), future value (fv) and the number of periods being considered (nper). Effort increase showed a rate of 2.4% per annum in the number of boats fishing in the Kenya sector of Lake Victoria. Fox's model predicts stock decimation at an effort value of 10,929 canoes while the Schaefer model indicates 20,842 canoes.

Decomposition of catches of Lates niloticus and mixed tilapia species and total catches in Lake Victoria (Kenya) using Auto-Regressive Integrated Moving Averages (ARIMA) shows a periodicity of 4 or 5 years. A predictive trend for L. niloticus was best described by an S-shaped growth curve of the form:

$$Y_t = 1{,}000{,}000/(10.1606 + 1540.34 \cdot (0.488)^t),$$

Trend for tilapias was best fitted by a linear equation but with a shorter prediction period of only 6 years:

$$Y_t = 2{,}589.31 + 181.319 \cdot t.$$

Total catches could be predicted with an S-shaped growth curve which suggests that catches could stabilize in 10-15 years on assumption that the effort will not have changed appreciably:

$$Y_t = 1000000/(3.464 + 50.248 \cdot (0.782^t)).$$

The form and shape of trend analysis suggest that L. niloticus is likely to attain asymptotic catches in 10 to 15 years, whereas tilapias and Rastrineobola argentea may still realize increasing catches but future trends can only be predicted for very limited periods of time.

INTRODUCTION

Ecosystem models and multi-species models as well as traditional single-species models fall short of predicting power needed for practical management of fisheries resources due to the lack of sufficient data or information for the required parameters (Yoo & Zhang 1993). The questions asked about irregular data is whether there has been a change over the period under consideration or whether there is a trend in the data. According to Galpin & Basson (1990), the data is correlated over time, an aspect which must be taken into consideration in analysis, and time series methods are usually the most appropriate, either in the form of Box-Jenkins ARIMA (Auto-Regressive Integrated Moving Average) or intervention analysis.

Auto-Regressive Integrated Moving Average (ARIMA) has been used very sparingly in forecasting of fish catches (Yoo & Zhang 1993, Nikijuluw 1994, Stergiou 1989, 1990, 1991, Noble and Sathianandan 1991). In consideration of the multiple problems associated with methods based on catch, catch per unit effort and fishing effort, Molinet, Badaracco and Salaya (1991) have pointed out that ARIMA offers an alternative predictive power for future catches. Stergiou (1990) has indicated that accurate forecasting is difficult because of all sorts of uncertainty in production, socio-economic and socio-political problems. ARIMA nevertheless still offers several powerful options of data handling capabilities for smoothing and stabilizing time series before final extraction of parameters. Time series data exhibits basically four types of component movement: trend, cyclical, seasonal and irregular.

Several ARIMA models have been successfully tested for analyzing and forecasting the catches of demersal fish species exploited in the Canary Islands (Saila, *et al*., 1980), *Trachurus* sp. in the Mediterranean Greek waters (Sergiou 1991), *Penaeus* and *Lutjanus* species in Venezuela (Molinet *et al.*, 1991) and Korean catches of hairtail, *Trichiurus lepturus* (Yoo and Zhang, 1993).

The case of Lake Victoria (Kenya waters) offers a challenge to classical methods of estimating future catches due to inadequate effort data despite the availability of data on annual catches for several years. Secondly, Lake Victoria (Kenya waters) exhibits a non-equilibrium situation due to the multi-species nature of the fishery. Classical surplus production models can, therefore, not be used to estimate yields or Catch per Unit Effort (CPUE) for a given effort level. Analysis of univariate time series data of annual catches extracts the information on the stochastic variability from the time series itself and makes estimates of the future stochastic variability without any reference to the effort data.

MATERIALS AND METHODS

Data for this work was based on fisheries statistics for Lake Victoria from Kenya Marine and Fisheries Research Institute and the Fisheries Department of Kenya. The data for Kenya waters consisted of annual catches in tonnes from 1968 to 1996 for the major commercial fisheries in Lake Victoria.

Since data on effort is generally not available, the results from frame surveys of 1973 and 1991 of 4200 canoes and 6229 canoes were used to determine the annual rate of increment in boat registration, using the rate function:

Rate (nper, pv,fv)

Where:

nper is the total number of annual periods in an annuity (17 years from 1973 to 1991)

pv is the present value (4200 canoes for 1973) - the total amount that a series of future increments is worth now.

fv is the future value (6229 canoes for 1991), or the final value to be attained after the last increment is made. If fv is omitted, it is assumed to be 0 (the future value, for example, is 0).

With the calculated annual rate of increments, it was possible to interpolate the number of canoes from 1974 to 1990. By the same token it was also possible to extrapolate the number of canoes from 1972 to 1968 and also from 1992 to 1996 and use these values to estimate Catch Per Unit Effort (CPUE) using the Fox's and the Schaefer's models for the fisheries of lake Victoria.

Surplus production models

The Schaefer model (Schaefer 1954) was applied in the following forms:

$Y_i = a \cdot fi + b \cdot f_i^2$, if $f_I = -a/b$ and

$Yi = 0$ if $f_i = -a/b$

$f_{MSY} = -0.5 \cdot a/b$ and

$MSY = -0.25 \cdot a^2/b$

Fox's (1970)) model was used in its logarithmic form:

$\ln Y_i/f_i = c + d \cdot f_i$

$Y_i = f_i \cdot \exp[c + d \cdot f_i]$

MSY and fMSY were obtained by differentiating Y with respect to f and solving for dY/df = 0 for f.

$f_{MSY} = -1/d$

$MSY = -(1/d)\exp(c-1)$

Where:

Y_i Catch for yield for year i (i = 1, 2, ... , n)

f_I Effort for yield for year i (i = 1, 2, ... , n)

f_{MSY} Effort level at which MSY is obtained

MSY Maximum Sustainable Yield in terms of catch in weight

a,c Regression constants

b,d Slopes for the regression

ARIMA models

For different species, linear, S-curve or quadratic models were fitted to the data using a 4 year moving average. The models were then analysed according to the equation:

$$Y = T \cdot C \cdot S \cdot I$$

Where:

Y = The catch as a product of T, C, S and I
T = Trend component
C = Cyclical movement
S = Seasonal movement
I = Irregular movement.

The data was decomposed to fit a trend line to the data by least square regression, then detrended by dividing out the trend components (T). Smoothing of the detrended data was carried out by using a centred moving average of length equal to the seasonal cycle to remove the irregular movements (I). Once the moving averages were obtained, they were divided into the detrended data to obtain values of the raw seasonal. Within each seasonal period, the median value of the raw seasonal was found to make up the seasonal indices. The raw data was then were in turn used to seasonally adjust the data (S). The seasonally adjusted, detrended and smoothed data represented only the cyclical (C) components:

$$Y/(T \cdot S \cdot I) = C$$

Using stepwise omission of data for several years, forecasts were made and compared to actual data, which were not included in the parameter estimation.

RESULTS

Both Schaefer's and Fox's Surplus Production Models could be used to calculate MSY and fMSY from only 1990 to 1996. Data from 1968 to 1989 showed dis-equilibria and could not be used for any estimation. Schaefer's models indicates a Maximum Sustainable Yield (MSY) of 189,926.7 mt at an effort level of 5465 canoes while Fox's model indicate an MSY of 198,524.9 mt at an effort level of 4,292 canoes.

The Schaefer's and Fox's models could be, respectively, represented by the equations:

$$CPUE = 69.51 - 0.00636 \cdot \text{Effort}; \quad p=0.0204 \text{ (Schaefer's model)}$$
$$\ln CPUE = 4.85 - 0.000233 \cdot \text{Effort}; \quad p=0.0230 \text{ (Fox's model)}$$

The Catch Per Unit Effort (CPUE) is an index of relative abundance of fish stocks in the lake and lower values indicate that the stock levels are reducing and suggest that the fishing effort should be controlled.

Trend analysis for *L. niloticus* (Fig. 1) and total catches (Fig. 2) fitted an S-curve Pearl-Reed logistic trend model (Farnum and Stanton 1989)), with forecast ahead for 10 years respectively. The asymptote for *L. niloticus* was 98,419.4 mt while that of total catches was 288,657 mt. Trend analysis for *Lates niloticus*, mixed tilapia species and the total catch showed varying degrees of accuracy based on mean absolute percentage error (MAPE), mean absolute deviation (MAD) and mean squared deviation (MSD; Table 1).

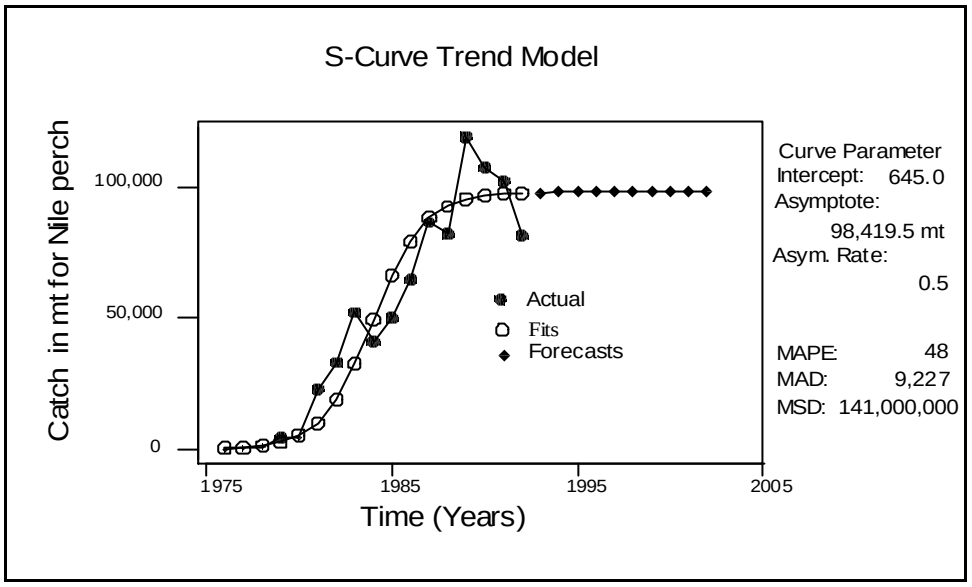

Fig. 1: Trend analysis for *Lates niloticus* with forecast ahead of 10 years with the relationship: Yt =106/(10.1606 + 1540.34 · (0.487827 t)). MAPE = Mean absolute percentage error, MAD = Mean absolute deviation and MSD = Mean squared deviation.

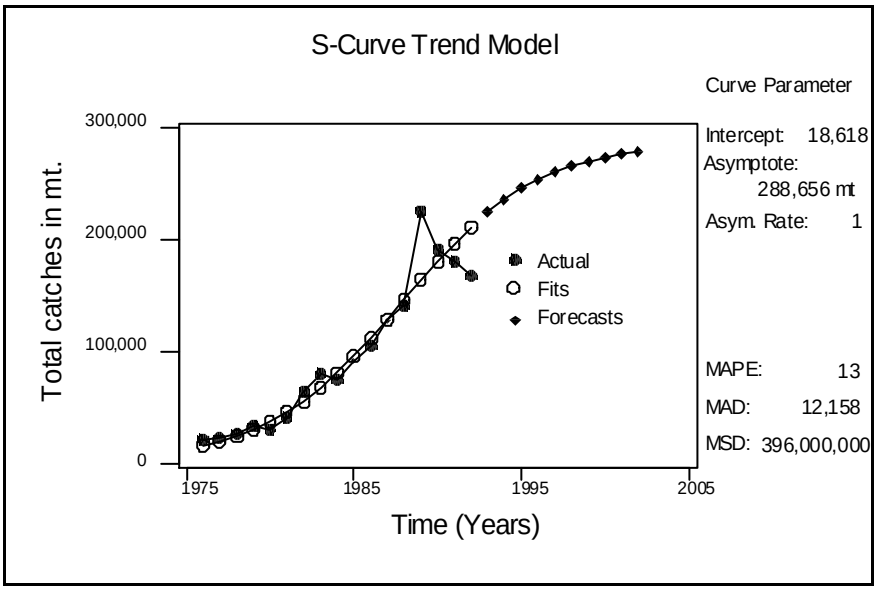

Fig. 2: Trend analysis for total catches with forecast ahead of 10 years with the relationship: $Y_t = 10^6/(3.46432 + 50.2482 \cdot (0.782012^{\,t}))$. MAPE = Mean absolute percentage error, MAD = Mean absolute deviation and MSD = Mean squared deviation.

A linear model (Fig. 3) described mixed tilapia species. The catch forecasts based on the different models for different catch categories did not compare well with the actual data. The t-statistic and p-values for forecast and actual data are shown in Table 2. Forecast for *Lates niloticus* was only comparable to the actual data for 3 years, for *Rastrineobola argentea* for 4 years, for total catches for 5 years and that of tilapia was not comparable well with the actual data. For example, forecast was done for catches from 1984 to 1991 using data from 1970 to 1983 to provide two sets of data; estimates for 1984 to 1991 (8 years forecast) and actual data (8 years) for the same period of time. These two sets of data were the ones compared by t-statistic.

Table 1: Three measures of accuracy for each of the time series data from Kenya waters of Lake Victoria for trend analysis and series decomposition.

Trend analysis	MAPE	MAD	MSD
L. niloticus	48	9,227	141,000,000
R. argentea	18	6,050	120,000,000
Tilapia species	41	1,362	3,250,223
Total catches	13	12,158	396,000,000
Series decomposition			
Lates niloticus	753	8,380	102,000,000
Rastrineobola argentea	67	10,168	143,000,000
Tilapia species	42	1,253	2,630,824
Total catches	25	14,484	446,000,000

Table 2. Comparison of forecast data with actual data not used in the ARIMA model estimation

	Forecasts	(Mean•10^4) ± SE	DF	t-statistic	p-value
Lates niloticus	3	1.0±27,983.5	2	1.26	0.3344
	4	3.44±6,925.0	3	4.35	0.0224
	5	3.90 ±6,342.3	4	5.29	0.0061
	6	4.55±7,383.0	5	7.18	0.0008
	7	3.54±7,905.3	6	5.11	0.0022
	8	3.80±8,055.4	7	4.76	0.0021
Tilapia species	3	-0.19±257.9	2	-7.20	0.0188
	4	-0.45±466.5	3	-3.19	0.0497
	5	-0.27±403.3	4	-6.71	0.0026
	6	-0.42±367.0	5	-11.3	0.0001
	7	-0.68±448.4	6	-15.2	<0.00001
	8	-0.44±1,035.4	7	-4.25	0.0038
Total catches	3	-0.38±12,500.0	2	-0.31	0.7879
	4	2.31±20,100.0	3	1.15	0.3335
	5	-3.84±24,000.0	4	-1.60	0.1851
	6	5.41±13,100.0	5	4.12	0.0092
	7	-	6	-	-
	8	15.1±16,400.0	7	9.22	<0.00001

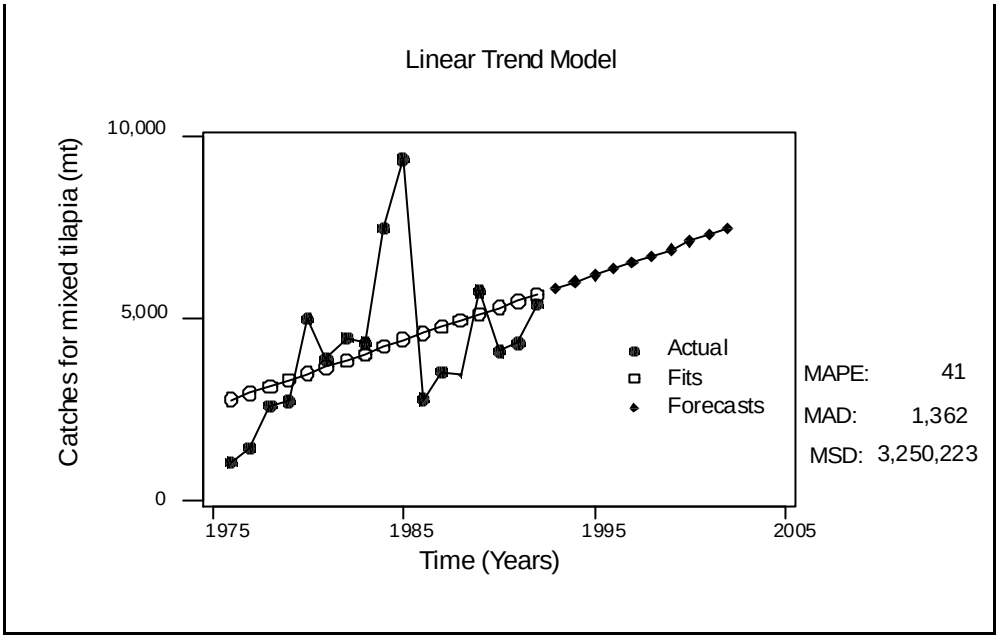

Fig. 3. Trend analysis for total catches with forecast ahead of 10 years with the relationship: $Y_t = 2589.31 + 181.319 \cdot t$)). MAPE = Mean absolute percentage error, MAD = Mean absolute deviation and MSD = Mean squared deviation.

DISCUSSION

The use of both Schaefer's and Fox's Surplus Production Models are highly dependent on reliable and accurate estimates of the effort, an issue which has never been resolved for the Kenya waters of Lake Victoria. However, if estimates of effort can be made based on percentage annual increments, then it is possible to use the surplus production models to predict future catches for several years. Both models were only applicable to data from 1990 to 1996 based on the assumption that an increase in effort results in a decrease in CPUE when the fishery has reached an equilibrium situation for a single species fishery (Sparre *et al*. 1989). For a multi-species fishery, the interpretation of results from the simple surplus production models is not straightforward according to Ursin (1984). There are too many interactions, which should be accounted for in the model like biological interactions, economic interactions and technological interactions.

The present estimated total number of canoes in the Kenyan sector of Lake Victoria (P. Rambiri, personal communication) is about 7000. This level of effort is already above and over the optimum effort of 5465 canoes (Schaefer's model) or 4292 canoes (Fox's model). Perhaps the analytical models, which take into, account the stock structures offer a better insight into the effect of prevailing fishing regimes.

Many fisheries management systems involve some level of control in fishing effort but data on this aspect of fisheries is still incomplete in Kenya. There has not been any intentional attempt to limit

the effort even though licensing of canoes and fishermen is done on an annual basis. If effort keeps on increasing at the present estimated annual rate of 2.35%, then the total number of canoes would rise to about 10,000 resulting in an estimated annual catch of 59,000 mt and a CPUE of 5.9 mt per annum, or an average of 23.6 kg per day and canoe for 250 fishing days a year in the next 7 years according to Schaefer's model. The same figures would give 49.1 kg per day and per canoe for 250 annual fishing days according to Fox's model.

The difficulties of using the surplus production models for Lake Victoria are amplified by the many estimates done for effort data. In most cases, there is inadequate data and therefore ARIMA methods offer an alternative, since the forecasts are based on the time series data itself without any reference to effort.

Though ARIMA models were applied to 17 years of time series data from Lake Victoria (Kenya), the data was not broken down into monthly catches which is a limitation for this preliminary analysis. ARIMA models also require that there is no autocorrelation in the time series data, a condition requiring more rigorous tests than are presented in this paper. Preliminary measures of the accuracy of the models were, however, carried out using the MAPE, MAD and MSD methods, which are adequate for only trend analysis. The method of forecasting remains subjective since it is a matter of choice for each individual but offers an avenue for stock forecasting in the absence of reliable and accurate effort data.

Schaefer's and Fox's models have their limitations for a multi-fleet multi-species fisheries. Both the models also assume an equilibrium situation, which may not be necessarily true for Lake Victoria. ARIMA models have been applied to time series data that exhibit the characteristic cyclical, seasonal and irregular movements in several cases, for example, the shrimp and snapper fisheries in Golfo Triste, Venezuela (Molinet *et al.*, 1991).

The need for Genetic Diversity Studies in Enhancing the Fishery Status of Native Tilapiines in Lake Victoria Region (East Africa).

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SUMMARY

Several non-indigenous tilapiine species were introduced into lakes Victoria and Kyoga basins following the collapse of the native tilapiine fishery to boost the commercial fishery in the region. Among the introduced tilapiines Nile tilapia, Oreochromis niloticus, which has become the most dominant, forms mainstay of the tilapiine commercial fishery. We discuss ways to enhance the native tilapiine species through hatchery production and indicate the role of genetics and aquaculture research in supporting the continued survival and the maintenance of the evolutionary potential of the remnant populations of the native tilapiine species of Lake Victoria Region (LVR Fig.1). The result of the establishment of non-indigenous tilapiines has been the relegation of the native tilapiine species of the two basins, O. esculentus and O. variabilis, from the main lakes to a few satellite lakes around them. The ecological status of the two species is highlighted and the resultant impact of the ecological changes on the genetic structure of the remnant populations discussed. Assessment of use aquaculture in boosting the remnant native tilapiine populations is made. The potential impacts of supportive breeding and aquacultural releases on the genetic structure of the remnant populations are highlighted. Suggestions are made on how to boost the ecological status of the two native tilapiine species without necessarily compromising their genetic diversity and evolutionary potential.

INTRODUCTION

Importance of tilapia species

In the Lake Victoria region (LVR), production from the tilapia fishery ranks second to Nile perch in economic importance and first as a source of animal protein for the people in the region; most of the Nile perch is currently exported. The basis of the tilapia fishery in the region is Nile tilapia, *Oreochromis niloticus*, an introduced non-indigenous species which, together with Nile perch and a small native minnow, *Rastreneobola argentea*, form the mainstay of the fisheries from lakes Kyoga and Victoria (Mwanja, 2000). Though basically African in natural range, the tilapiine species are currently found all over the world. Tilapiine species rank among the top choices in global aquaculture, especially in the tropics and subtropics, generating over 600,000 tonnes of

farmed fish annually (FAO, 1997). Tilapiine species, most particularly those of the genus *Oreochromis*, rank prominently among species that have been intentionally or unintentionally introduced into non-native waters. They have been transplanted all over the tropics and subtropics for uses in aquaculture, and to boost the wild fisheries (Mwanja, 1996, Kocher, *et al.*, 1997). They have increasingly become part of many menus worldwide, in both temperate and tropical regions. In Asia, carp culture has been steadily replaced by tilapia, and countries such as Taiwan, Singapore and the Philippines top the list of aquaculture producers of tilapia (Welcomme, 1988; Costa-Pierce and Doyle, 1997). In California and Arizona, and many other states in the southern U.S. such as Florida, Louisiana, Alabama, Arizona and Mississippi, tilapiine species have become established as a part of the natural aquatic fauna (Minkley, 1973; Knaggs, 1976; Legner & Pelsue, 1977; Legner & Fisher, 1980; ATA, 1996 & 1997).

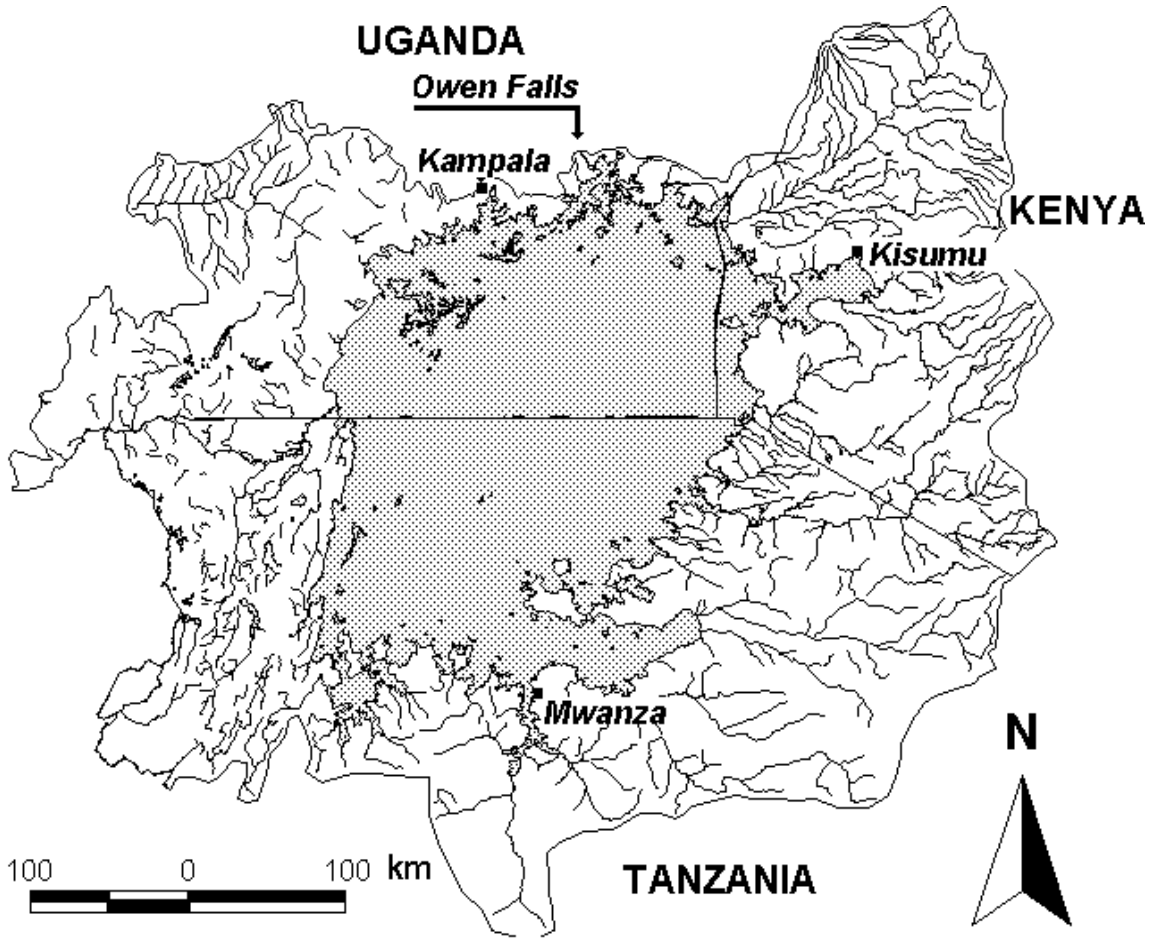

Fig. 1: Lake Victoria Basin Systems: 1. Yala Basin; 2. Nabugabo lakes; 3. Kooki lakes; 4. Eastern Rift Valley Lakes; and 5. Northern Tanzania lakes

Effects of marginalisation of the native tilapiine fishery of the LVR

With high demand for fish due to both increased local consumption and the higher economic returns resulting from the growing market in exported fish, the fishery of the LVR has come under increased pressure. The major question that faces the managers of the fishery and fisheries

scientists working in the region is 'how much fish can be taken out of the waters before once again destabilising the ecology of the whole system?' Lakes Kyoga and Victoria have already experienced one severe episode of overfishing, a factor that entailed the collapse of the native tilapiine fishery of the two lakes in the mid-twentieth century (Fryer, 1961; Fryer & Iles, 1972). The collapse of the native fishery led to the introduction of non-indigenous species including the Nile perch, which were intended to boost the ailing fishery and fill unoccupied ecological niches in the vast lakes. The introductions contributed to the ecological destabilisation of the LVR system, and to the loss of hundreds of haplochromine cichlid species in the region (Fryer, 1972; Barel, *et al*., 1985). Such a situation always comes about because of the narrow view of the fisheries, which, looks at what comes out (fisheries production) but not the actual ecological working and relationships among all the constituent species in a water body. The most severely impacted forms are frequently the economically "unimportant" species, especially populations that have become ecologically marginalized because of competition with the introduced non-indigenous forms and a consequent disruption of the ecosystem.

Genetic swamping

Genetic swamping occurs when a population of a species declines and disappears as a result of hybridisation with other species. In the LVR one tilapiine species, *Oreochromis spirulus nigra*, has already been lost through "genetic swamping" by the introduced sister species (congeners) *O. niloticus* and O. *leucostictus*. *O. spirulus nigra* has been lost both in its native range, Lake Naivasha (Leveque, 1997), and from three lakes into which it was introduced, Lake Bunyonyi (Lowe-McConnell, 1958, 1959) and the Kooki lakes, Lakes Kachera and Mburo, where it was introduced followed by *O. niloticus* and *O. leucostictus* (Fryer & Iles, 1972). *O. esculentus* has declined throughout the LVR, but from the molecular evidence adduced so far it appears that elimination from Lake Nabugabo was primarily due to hybridisation with *O. niloticus* (Mwanja, *et al.*, 1995; Mwanja, 1996).

It is postulated that the process of genetic swamping begins with an initial proliferation of the introduced congeners, followed by an increased frequency of hybrids in the locality, which become dominant behaviourally in interactions with native forms. This leads to marginalisation, but with the continued occurrence of hybridisation, of the less versatile species. Finally, the hybrids are eliminated through competition and repeated backcrossing to the dominant and ecologically more versatile species. Such a progression pattern favours *O. niloticus* and other introduced species over the native forms, especially where the latter are the minor component. Our evidence suggests that such a phenomenon is already happening in the case of *O. variabilis* (Mwanja, 2000). One way to possibly curb this pattern of genetic swamping is to keep the population of the native species higher than that of the exotic congeners, in such a way as not to compromise the effective population size and genetic diversity of the species. In Lake Kanyaboli, though *O. niloticus* was introduced, *O. esculentus* has remained the most abundant and dominant species. *O. niloticus* persists only as a minor component, and hybridisation was found not to be a major factor in the interaction of the two species in this lake (Mwanja, 1996; Agnese, *et al.*, 1999).

Enhancing the native tilapiine fishery of LVR

Why boost the remnant populations of the native tilapiines

In the LVR, the original commercial fishery was based on the two native tilapiine species *Oreochromis esculentus* and *Oreochromis variabilis*. Within only two decades of the establishment of a commercial fishery, overfishing was found to have severely impacted production from the native tilapiine fishery (Graham, 1929; Worthington, 1932). Instead of using native species to boost the fishery, the fisheries managers at the time sought to use ecologically more versatile species from outside the LVR. *Tilapia zillii and Oreochromis leucostictus* were the most prevalent of the introduced tilapiines, but were soon overtaken, and together with the native tilapiines became marginalized by the establishment of *O. niloticus* (Fryer, 1961; Welcomme, 1967). Currently the tilapiine fishery of the LVR is dominated by *O. niloticus*, while the total fishery is dominated by *O. niloticus* together with the Nile perch, and a native minnow, *Rastrineobola argentea* (Ogutu-Ohwayo, 1990; Kudhongania & Chitamwebwa, 1995).

After the severe reduction in population size following the inception of the commercial fishery in the early 20th century and subsequent overfishing, the recovery of the native species was thought to have been hindered by competition and hybridisation with the introduced non-indigenous congeners and predation by the Nile perch (Fryer, 1972). Currently the remnant populations of *O. esculentus* are only found in satellite lakes, while those of *O. variabilis* occur as both disjunct populations within Lake Victoria and as isolated populations in a few of the satellite lakes around Lake Kyoga (Table 1). *O. niloticus* has become established in most of the waters in the LVR, achieving the status of the most dominant tilapiine species in the region and occupying all kinds of waters. *O. niloticus* is trophically flexible, and has the ability to efficiently use and detoxify cyanobacteria (blue-green algae) (Balirwa, 1992). Use of cyanobacteria is important in Lakes Kyoga and Victoria, since the two lakes became limnologically altered from diatomous to predominantly cyanobacterial at the time of establishment of the non-indigenous species (Hecky & Bugenyi, 1993).

The stenotypic ecological character and hybridisation with the more versatile *O. niloticus* (Mwanja *et al*., 1995; Mwanja, 2000) has made the continued existence in the wild of the two native species precarious and there appears to be need of direct intervention. Direct intervention would require management of the fishery to boost the population numbers of the native species against those of the non-indigenous species through hatchery and aquaculture production. Intervention should be implemented now, when there are still viable pockets of the native species, rather than later. Working with a population that is approaching the point at which it is 'ecologically non-viable' would require the expenditure of much more resources for corrective measures, and these measures may still be insufficient if the population has passed the point of no evolutionary recovery.

Table 1. Coexistence of marginal tilapiine populations (*Oreochromis esculentus, O. variabilis* and introduced *Tilapia rendalli*) with congeners and the most dominant of the coexisting tilapiine taxa in the various water bodies.

Marginal sp.	Location/Lake	Congeners present	Most dominant species
	Nabugabo lakes:		
O. esculentus	Kayanja	-	O. *esculentus*
	Manywa	-	*O. esculentus*
	Kayugi	-	*O. esculentus*
	Koki Lakes:		
	Mburo	O. *niloticus and O. leucosticus*	*O. niloticus*
	Kachira	*O. niloticus and O. leucosticus*	*O. niloticus*
	Yala basin:		
	Kanyaboli	*O. niloticus*	*O. esculentus*
	Kyoga lakes:		
	Nawampasa	*O. niloticus, Variabilis* & *O. leucosticus*	All three species equally abundant
	Lemwa	*O. niloticus*	O. *niloticus*
	Kawi	O. *niloticus*	*O. esculentus*
	Nyaguo	*O. niloticus* and *Variabilis*	*O. niloticus*
	Bisina	*O. niloticus, Variabilis & leocostictus*	*O. niloticus*
	Lake Victoria:	*O. niloticus* and *O. leucosticus*	*O. niloticus*
	Kyoga Lakes:		
	Nawampasa	*O. niloticus and O. leucosticus*	All three species equally abundant
	Gigate	*O. niloticus and O. leucosticus*	*O. niloticus*
	Victoria Nile	*O. niloticus and O. leucosticus*	*O. niloticus*
	Bisina	*O. niloticus* and *O. leucosticus*	*O. niloticus*

The genetic structure of the LVR tilapiine species

In our studies (Mwanja *et al.*, 1995, Mwanja, 1996; 2000) we found that all tilapiine species, both native and non-indigenous, were highly subdivided into distinct evolutionary groups across the various water bodies in the LVR. Most of this genetic subdivision could be attributed to direct anthropogenic effects such as transplanting of fish strains/species and augmentation of wild stocks based on narrow broodstock. The broodstock is said to be narrow if the number of individuals used are non-representative of the entire natural breeding populations. Table 2 gives a summary of qualitative comparisons of the native tilapiine population genetic structure attributes to those of the most dominant species in the LVR, *O. niloticus*. All of the *O. variabilis* populations that were found in our studies were from waters where they coexisted with *O. niloticus*. A few of the sampled populations of *O. esculentus* did not share waters with *O. niloticus* and/or any other tilapiine species. Genetic analysis of *O. variabilis* and of populations of *O. esculentus* that coexisted with congeners showed that hybridisation has occurred and that populations were phyletically closer to the congeners than to putatively 'pure' populations of conspecifics. Given the ecological marginalisation and the evidence for hybridisation, *O. variabilis* must be considered as the most vulnerable of the two native species.

Table 2. Population genetic structure of two native tilapiine species relative to the dominant introduced species, *Oreochromis niloticus*, in the Lake Victoria Region. Modified from Mwanja *et al.*, (1995) and Mwanja (2000).

Attribute	Pure *O. esculentus* (congeners absent)	Mixed *O. esculentus* (congeners absent)	*O. variabilis*
Polymorphism	Lower	Higher	Higher
Allele diversity	Equivalent	Higher	Higher
Population subdivision	Higher	Higher	Higher
Migration	Lower	Lower	Lower
Heterozygosity levels	Equivalent	Higher	Higher

Table 3 shows the genetic distances among *O. esculentus* populations and between *O. niloticus* population and each of the *O. esculentus* based on RAPD markers (Mwanja, 2000). The *O. esculentus* populations that coexisted with *O. niloticus* in waters where *O. niloticus* was the most dominant (Lake Kachira and Lake Mburo) were found to be genetically closer to *O. niloticus*. These data, and th1ose from our previous studies (Mwanja *et al.*, 1995; Batjakas *et al*., 1997; Mwanja, 2000) indicate that the continued existence of the native forms has been compromised both ecologically and genetically through reduced relative abundance, interspecies competition and hybridisation with the introduced non-indigenous congeners.

Table 3. Genetic distances between *O. esculentus* populations within the Lake Victoria basin estimated from band sharing proportions of RAPD gels based on Nei (1973). Data from *O. niloticus* from Lake Victoria is included as the outgroup.

Lake	Kach	Mbr	Kany	Kayu	Kaya	Many	Kijan
Kachira	0.00	0.54	0.62	1.02	0.70	0.95	0.72
Mburo	0.00	0.77	0.95	0.58	0.92	1.11	
Kanyaboli			0.00	0.73	0.65	0.61	0.63
Kayugi			0.00	0.78	0.95	0.39	
Kayanja					0.00	1.07	0.77
Manywa						0.00	0.94
Kijanebolola							0.00
O. niloticus	0.85	0.78	1.19	1.02	1.03	1.63	1.02

(Kach= Kachira, Mbr = Mburo, Kany = Kanyaboli, Kayu = Kayugi, Kaya = Kayanja, Many = Manywa, Kijan = Kijanebalora).

Hatchery augmentation and ways of minimising negative impacts on the wild stocks

To enhance the ecological status of marginalized tilapiine species we would ideally need to use both supportive breeding of the native species and highly selective fishing pressure on the *O. niloticus* and other non-indigenous species. The latter is more difficult to achieve since there is no gear known to discriminate among tilapiine species based. The logic behind such a recommendation is that boosting the relative abundance of the native tilapiine species will protect them against being genetically swamped and may ultimately give them a competitive edge over the introduced congeners, at least in terms of numbers. Higher numbers also may ultimately translate into continued maintenance of genetic variation by reducing the loss due to chance or random effects (genetic drift) that are enhanced with reduction in population size. In Lake Kanyaboli of the Lake Victoria basin, and in a few of the Kyoga satellite lakes, *O. esculentus* has maintained its dominance over its congeners because of its high relative density within these lakes, and this has happened despite the presence of *O. niloticu*s likely due to the relatively less limnological changes (Mwanja, 2000).

There is a real danger of genetic diversity erosion when supportive breeding or hatchery production is not well planned. Studies by Ryman and Laikre (1990) showed that partial representation of the available genetic diversity in the hatchery broodstock and dominance of the hatchery stocks over the wild populations leads to decrease in the effective population size. They demonstrated that decrease in effective population size was more pronounced when supportive breeding was done repeatedly for successive generations using the same narrow broodstock. Tessier *et al*., (1997) found that estimates of variance and inbreeding in one population of land locked Atlantic salmon, Salmo salar increased by twice the original levels following hatchery augmentation. To minimise such negative impacts there has to be a balance between wild and hatchery stocks, and a ready and complete integration of the two in the wild environment. Care should be taken to keep the balance in favour of already co-adapted wild stocks, as imbalance can result in failure of recruitment and/or in subdivision of the natural populations.

The need for genetic studies in augmentation

For a successful restocking program, aquaculture or hatchery husbandry has to be combined with research on the structure of the genetic diversity and evolution of the targeted populations. It is especially important to obtain information about the population genetic structure before the restocking can be done. We need to be able to monitor the impact of the released cultured fish on the wild populations. The best way to do this would be to monitor changes in the genetic structure of the wild populations. It is important to remember that genetic variability is the foundation of a species' evolutionary and aquacultural future. Genetic variation provides flexibility and ability to respond to environmental change (Allendorf *et al.*, 1987). High genetic variability has been found to enhance fitness and survival values, and is related to the ability to rapidly select for favourable traits in any artificial selection and breeding system. Genetic studies allow us to

investigate the adaptability of the hatchery strains to the wild conditions, and give us the ability to assess the impact on the evolution of the wild stocks. Genetic studies using appropriate genetic markers can also allow us to follow the integration of the released cultured fish without need of physical tags.

An effective approach to the conservation and development of the native tilapiine species will require detailed knowledge of the amount and distribution of both phenotypic and genetic variation within each of the two native species, *O. esculentus* and *O. variabilis*. Our studies so far (Mwanja, 1996, 2000) have shown that there are still ecologically and genetically viable pockets of the two species in peripheral waters in the LVR. To once again enjoy the benefits of exploiting the biological assets of these species without driving them to extinction, emphasis has to be placed on understanding the genetically based variation of each form. Ability to measure genetic differences between populations of the native species would enable selection of broodstock that maximises representation of the whole range of variation of the remnant populations. Once the hatchery broods are released it is important to follow the changes in the genetic structure each generation following the release of the hatchery stocks, and to be able to adjust the broodstocks accordingly.

According to Kornfield (1991), successful propagation of wild fishes for preservation of germplasm and biological diversity over multiple lifetimes imposes at least three critical genetic demands: 1) the genetic identity of representatives of the taxa must be known with absolute certainty; 2) gene pools must remain uncontaminated during husbandry; and 3) the taxa must retain the genetic architectures of their progenitors. Such demands require tools that permit frequent and routine monitoring of the changes in population genetic structure. New molecular methods and their automation and computerisation of the collection and analysis of data, are of great benefit to such projects that require regular and continuous monitoring.

Use of molecular technology and genetic programs to foster the expansion of the LVR fisheries while conserving the biodiversity will only become feasible management tools in the region if there is concerted effort to train local personnel in fields such as molecular biology, genetics and modern methods of systematics. To accomplish these goals, it is our recommendation, (Mwanja & Fuerst, 1995), that a full fledged genetics program be instituted in Makerere University or any of the other East African Universities to educate local scientists in these increasingly important fields of biology. It is important to recognise that genetics and molecular biology are disciplines urgently needed not only in fisheries biology, but have indeed become an integral part of modern terrestrial agriculture. Plant and animal breeding are rapidly moving into a genetic and molecular revolution, and for the peoples of the LVR to exploit such advances we need to be at a level where the local experts can ably employ these tools in their work.

CONCLUSION

The importance of tilapia in the world and the LVR in particular will only continue to increase. Today tilapia has been appropriately dubbed as the aquatic chicken in reference to the worldwide distribution, ecological adaptability and acceptability. The managers of the tilapia region therefore need to devise ways that will protect this treasure and ensure that all strains and species continued existence is guaranteed, at least protected from excessive and destructive anthropogenic interference. First, we have to clearly identify what is left in the wild, and understand mechanisms driving the ecological and evolutionary changes among the extant strains and species. Efforts to boost or enhance populations of those marginalized units should be based on a good understanding of the evolutionary and ecological working of such forms, and should as much as possible allow for natural evolution of these marginalized units. We certainly will need to employ interventions such aquacultural and hatchery production to revive some of the populations, but this has to be based on genetics understanding so as not to compromise the evolutionary flexibility of the targeted and associated populations.

Opportunities and Challenges to Conserve the Genetic Diversity of the Fish Resources of the Lake Victoria Region, East Africa.

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SUMMARY

The threat to the biodiversity of the Lake Victoria Region continues to grow despite increasing knowledge about the system. Management of the region has for the last 50 years been largely focused on fish production, with little regard paid to maintenance of biodiversity. It is estimated that up to 200 species have become rare, endangered or extinct from the main lakes in the region since the environmental and human induced changes of the 1960s. Nevertheless, the studies reported here reveal the continued existence of an enormous biodiversity including genetic, species and habitat diversity in the 'satellite lakes' reminiscent of that originally recorded in the main lakes. In this paper, options are explored

for conservation of these newly discovered 'treasures', and a case is made for the conservation of these non-economical but ecologically significant fish species. In addition, our findings over the last ten years on the evolution and conservation genetics of the region's cichlid fishes are discussed. These studies have included consideration of both the haplochromine cichlids and the diversity of native and introduced tilapiine species. The remnant populations of the surviving species in the satellite lakes were found to be still genetically diverse and in evolutionary terms,viable. In this paper satellite lakes were found to be the most viable option for conservation of endangered or remnant surviving populations of cichlid species extinct in the main lakes. The paper also discusses the current paradigm in conservation of genetic biodiversity, and offers suggestions for effective management and conservation of biodiversity in the region.

INTRODUCTION

Lake Victoria Region

The Lake Victoria Region (LVR) has long been considered a unique zoogeographical area (Fryer & Iles 1972, Lowe-McConnell 1987). Among the characteristics that set it apart from other localities is the high concentration within the region of ecologically diverse freshwater lakes, each containing a similar range of aquatic fauna of the region, especially when comparisons are made

at the generic level (Kaufman & Ochumba 1993). Evolution appears to have repeated itself numerous times in the LVR. Some of these repetitive patterns are attributable to evolutionary parallelism, while others are probably the result of seemingly improbable but nonetheless real dispersal events among Lake Basins (Kaufman, *et al*, 1997). Examination of the distribution of the extant fish species suggests that a more expansive lake with adjoining east-west running rivers is thought to have historically occupied the region (Greenwood 1981). This historical system was fractured by the tectonic earth movements and the volcanic activity that characterised the early part of the history of the LVR, forming portions of the present lakes at various times from about 750,000 years ago to as recent as 4,000 before present (Greenwood 1981; Lowe-McConnell, 1996; Johnson *et al*., 1996). The LVR is now comprised of five large lakes: Victoria, Kyoga, Edward, George and Kivu, each containing similar but characteristic species groups that share a common origin (Greenwood 1981). The lakes, though zoogeographically similar, are geologically, hydrologically and limnologically distinct from each other.

Each of the large lakes in the region is associated with surrounding minor water bodies, from a few to several small lakes. We commonly refer to these surrounding minor water bodies within the basins of larger water bodies as "satellite lakes" of the larger systems. The examples of satellite lakes include: the crater lakes of western Uganda around Lakes Edward and George; the valley swamp lakes of the Kyoga basin; the rift valley lakes of Kenya and Tanzania; and the small lake systems such as those of Nabugabo, the Kooki lakes and the lakes of the Yala system in the Lake Victoria Basin.

Threats to biodiversity in the Lake Victoria Region

Factors that contributed to the demise of fish fauna in the Lake Victoria region have been well-documented (Fryer 1972, Barel, *et al.*, 1985, Kaufman 1992, Kudhongania & Chitamwebwa 1995, Stiassny 1996), and still impact the waters of the region. In fact, since the 1980s when the Lakes Victoria and Kyoga became dominated by non-indigenous species, Lake Victoria has become more anoxic (Hecky & Bugenyi 1993, Kaufman 1992), with increased infestation by water hyacinth, and has seen increased human settlement around the lake (Balirwa 1998). Swamps, the buffer (ecotone zone) to many water bodies in the region, have become increasingly vulnerable as a result of human settlement and crop and animal husbandry. Many riverine fishes are rare and increasingly at risk. The original major commercial fisheries species in the LVR out of the rivers, *Labeo victorianus* and *Barbus altianalis*, are reduced to non-commercial level and in fact these two species are rare in most rivers and within the lakes, and are currently considered endangered. Unfortunately, it is always very easy to ignore the status of species such as these when the fishery appears to be thriving by emphasising alternative species, such as the Nile perch and Nile tilapia in the LVR. Such complacency owing to a thriving commercial fishery may even have worse consequences on the less understood members of the fish assemblage, such as the various poorly studied and little known haplochromine species.

Anyone not intimately familiar with haplochromine fauna would likely fail to notice and perhaps deny the demise of many haplochromine species as a result of recent changes in the region. Though evidence exists suggesting that hundreds of species may recently have gone extinct (Fryer

1972, Barel *et al*., 1985, Ogutu-Ohwayo 1990, Balirwa 1992, Kaufman 1992, Witte, *et al*., 1992a, Witte, *et al*., 1992b, Kudhongania & Chitamwebwa 1995, Stiassny 1996) hundreds still remain and will be pulled ashore with the right fishing gear. Even to scientists familiar with haplochromine species, the loss of haplochromine species is not clearly discernible, since a large proportion of these species remains undescribed and unnamed (Kaufman 1992). For the sister group, the 'tilapiine assemblage, many in the general public around the LVR perhaps would not notice that the dominant *Oreochromis niloticus* is not the "*ngege*" of Lakes Victoria and Kyoga, even when *O. esculentus* and *O. variabilis* have become relegated to the minor water bodies and are no longer commercial species in the region. Several of the top predators, such as lungfish and catfishes, are no longer a commercial entity of Lake Victoria and Lake Kyoga fisheries, yet since the Nile perch has filled in so well on the market there is little out-cry from the general public for these original native highlights.

Dramatic limnological changes have continued to characterise especially Lakes Victoria and Kyoga in recent years. From increased nutrient loads and change in algal composition to proliferation of aquatic macrophytes and consequent changes in fish fauna, such alterations have increasingly become a normal trend of events in the large lakes of the LVR. Beside the voracious predatory way of Nile perch, limnological changes are thought to play a big role in loss of fish fauna in the LVR through bottom-up cascading effects (Hecky & Bugenyi 1993, Kaufman & Ochumba 1993). Human influence in the ecology of the LVR has sometimes been underrated. After the establishment of a large-scale commercial fishery on Lakes Victoria and Kyoga in the early part of the 20th century, emphasis has been largely on fish production (Graham, 1929; Worthington, 1932; Fryer, 1972; Cordone & Kudhongania ,1974; Ogutu-Ohwayo, 1990; Kaufman, 1992; Stiassny, 1996). This has been so despite the enormous effort by scientists to present the other side of the LVR fishery, the ecological and evolutionary importance of the non-economical biodiversity (Regan 1922a, 1922b; Greenwood 1966, 1974, 1981; Fryer 1972; Fryer & Iles 1972). Opposition to management policies by scientists has done little to sway managers even when a lot was at stake. For example the introduction of species and drift netting by river mouths, all of which have had dramatic impact on the diversity and ecological dynamics of the LVR, continued unabated in the 1960s despite the advocacy for a cautious and a more scientific approach to fishery management advocated by scientists. Lately scientists and managers seem to be working more closely, and revival of unified management bodies over shared waters such as Lake Victoria (Lake Victoria Fisheries Organisation - LVFO) is a big step forward in protection of biodiversity.

The challenges to management and conservation of aquatic genetic biodiversity

To adequately understand the role of genetic variability in functioning of an African inland fishery, we have first to understand the forces that shaped the evolution of these systems prior to the human influenced alterations of the 20th century. In addition, we also have to figure out the ways in which human induced alterations have influenced and will influence the genetic variation in future systems (Mwanja & Fuerst 1995). Before the largely human induced changes of the 20th century, natural selection and adaptation to local environmental conditions occurred over hundreds

or thousands of years without any significant human interference. However, with the surge in the exploitation of fish as a marketable commodity in the 20th century (Fryer 1972, Kaufman 1992), the human influence has become largely detrimental to the aquatic biodiversity, especially, through excessive fishing pressure, increased agricultural activities in the lake basins, and introduction of alien species (Trewavas *et al*., 1985, Barel *et al.*, 1985, Kudhongania & Chitamwebwa 1995). As the environmental change accelerates even further into the 21st century, natural and human induced factors will conspire to further influence the evolution of aquatic biodiversity. Among the elements that reduce genetic diversity are: inbreeding and genetic drift; introduction of alien species; alterations in the environment; biological and physical factors which can hinder genetic exchange between populations; and the consequences of monotypic (single species) augmentation of commercial species.

By recent estimates, Lake Victoria alone is thought to have over 500 species (Kaufman *et al*., 1997, Seehausen 1996), and over 70% of the species are undescribed, and their ecology is largely unknown (Kaufman 1992, Mwanja & Fuerst in press). Worse still, like in crop and animal husbandry, only a handful of commercially important species get the majority of the available resources for their management and development, while only a minor portion of the resources is put to protection of the species considered to be of non-economic importance. Yet traditional agriculture strain improvement practices usually result in loss of genetic diversity by selection for only a portion of traits in the breeding programmes aimed at ensuring maximum production, and through the resulting devaluation of the wild strains considered to be unproductive. The result is a water-based economy similar to the one that now prevails on land, with great emphasis upon a few high yielding species or even just strains, to the detriment of the majority of the rest of the species.

This variety of geological situations and histories presents a scientific challenge in understanding the relationships among the water bodies and among their associated flora and fauna. The challenge is increased by the apparent similarity in fish species composition among lakes of the LVR. The enormous adaptive radiation of cichlid species and the high endemism associated with each of the lakes (Fryer & Iles 1972; Greenwood 1981; Lowe-McConnell 1996) is another challenge. The current estimates for Lake Victoria alone are that over 500 species have evolved within the lake in the only 12,000 years since the lake's last major dry spell (Seehausen 1996; Kaufman 1997).

This paper represents a summary of our findings and discussions over the last ten years regarding the opportunities and challenges in conserving Lake Victoria Region fish genetic biodiversity. We present a case for need to divert resources to protection of fish species of non-economic importance but species we believe have significant ecological roles to play let alone the 'natural right' to propagate themselves without unwarranted anthropogenic interference.

METHODS

EXPEDITIONS TO LAKE VICTORIA REGION

Expeditions to the LVR usually involved various people at different times looking at different aspects of ecology and evolution of fishes in the region. Both passive and active gears were used in Lakes Victoria, Kyoga, George, Edward, Albert, and in several satellite lakes. Laboratory work involved different analyses from basic taxonomic work (Kaufman, 1992, Kaufman & Ochumba, 1993, Mwanja & Kaufman, 1995) to feeding experiments and use of isotope analyses for trophic relationships (Batjakas *et al.*, 1997) and molecular work for analysis of genetic and evolutionary relationships (Mwanja 1996; Fuerst *et al*., 1997; Mwanja, *et al*., 1997; Wu, *et al.*, 1996; Mwanja, 2000).

Survey for Fish Biodiversity in the LVR

A collection of fish species that was made during an initial study visit to Lake Nawampasa, one of the Lake Kyoga basin satellite lakes, revealed occurrence of species that were reported to be extinct or rare in the LVR (Greenwood, 1981, Kaufman, 1997, Mwanja, 2000). The study also revealed species that were equivalent or similar to some of the extinct cichlid taxa of the main lakes. As a consequence of these observations, a study was designed, that included fish species collections from the various representative satellite lakes in the region (Table 1). Effort was made to cover all types of habitats and seasons, taking into account both the diurnal and annual variations in weather and habitat types. The capture of fish specimens involved setting a fleet of 10 gill-net panels ranging in mesh size from 0.5 inches to 5.0 inches in three zones: by the shoreline, at 20 m from the shore and offshore. This mesh size range was found to be appropriate for both haplochromines and tilapiines. The fleets of gill nets were checked for the catch at 2 to 3 hourly intervals throughout the day. Fishing duration depended on the fauna content, variability of habitats within the lakes and size of the lakes. In locations where the catch was poor, the nets were left overnight, whereas in some cases where species were rare repeated sampling over several days was conducted covering all possible microhabitats of the targeted species.

Evolutionary relationships of the cichlid fishes of the LVR

Although studies during the 1980's and early 1990's revealed no marked genetic differences between various Lake Victoria haplochromine species (Sage, *et al.*, 1984, Meyer, *et al*., 1990), microsatellite markers designed for the LVR haplochromine cichlid species in our laboratory (Wu *et al.*, 1999) differentiated populations and species at a very fine scale (Wu 1999). These microsatellite markers were in addition useful in the phylogenetic analysis of cichlid species of the LVR (Wu 1999, Mwanja 2000).

RESULTS

Occurrence of Haplochromine Species in the Satellite lakes versus the Main lakes

Some of the satellite lakes, such as the Nabugabo lakes contained only a small number of species. Others, such as the satellite lakes around Lake Kyoga had a wider variety of taxa that included both known and several undescribed species. We found that these species were ecologically equivalent and relatively close in general morphology and dentition to species or genera reminiscent of the main lakes before the establishment of the Nile perch (Greenwood, 1981). A few groups, such as *Astatoreochromis allaudi, Pseudocrenilabrus victoriae,* and species of the genera *Astatotilapia and Paralabidochromis,* were widely distributed both in the main lakes and in the satellite lakes. Most of the piscivorous cichlids, such as species of the genera *Harpogochromis*, *Psammochromis* and *Prognathochromis*, were restricted to only a few satellite lakes, but also had a few of their species widely distributed among the satellite lakes.

Ecological genetics survey of tilapiine species: occurrence, distribution and genetic variation

Significant populations of the two native forms, *Oreochromis esculentus* and *Oreochromis variabilis*, were found in several of the satellite lakes and in Lake Victoria but as disjunct small pockets of individuals around enclosed bays or at the mouths of rivers flowing into Lake Victoria (Mwanja 1996, 2000). The most frequently encountered and currently forming the mainstay of the fishery in the region was *Oreochromis niloticus*, especially within the main lakes (Mwanja 1996, Fuerst & Mwanja, 1997). In all water bodies of the LVR and Lake Albert System surveyed, four species of the genus *Oreochromis* and two of Tilapia were found. One species of the genus Sarotherodon was only found in Lake Albert were it has been recorded to occur naturally in the Bugoigo lagoons (Greenwood 1966). These species were distributed among the minor satellite waters bodies with several having only one or two tilapiine species. *Oreochromis esculentus* was found exclusively in satellite water bodies while the other native species, *Oreochromis variabilis*, was found as small isolated populations in Lake Victoria and in the Victoria Nile, and also as the minor component of tilapiine populations in several of the satellite lakes in the Lake Kyoga Basin. The rest of the non indigenous tilapiine species, other than *O. niloticus*, were found in most cases at low frequency but sizeable populations in the main lakes and in several of the satellite lakes (Table 1).

Intermediate morphs between *O. niloticus* and *O. esculentus* were caught in many of the lakes in which the two coexisted. Similarly, intermediate morphs were found between *O. leucostictus* and *O. esculentus, O. niloticus and O. variablis*, and between the two introduced species of the genus Tilapia, *T. zillii* and *T. rendalli*. *O. niloticus* was the most abundant and most widely distributed in the LVR, and for most of the lakes it formed by far the largest part of the fishermen's catch on all lakes where commercial fishing was permitted. The native species *O. esculentus* and *O. variabilis* were found to be dominant only in a few of the satellite lakes. Molecular analysis using the RAPD technique generated molecular markers sufficient to describe the variation

among populations of the various species (Mwanja, 1996; Mwanja & Kaufman, 1997). Nearly all populations of the various species had over 50% polymorphism for the set of RAPD markers used (Table 2, 3 & 4). All populations carried substantial numbers of private alleles when compared to conspecifics. Band sharing within populations was also found to be high, especially for the populations from the satellite lakes.

Table 1. Number of species present in the LVR (haplochromines roughly estimated) and occurrence of the Nile perch (*Lates niloticus*) based on field survey 1990 - 1997)

Lake basin/system Lake	Haplo.	Tilapiines		Nile perch
	Species No.	Species No.		
		Native	Introduced	Rel. Abundance
Lake Victoria Basin				
Main lake	>200	1	4	Dominant
Lake Victoria				
Nabugabo lakes	<5	0	4	Dominant
Lake Nabugabo	<5	1	0	Absent
Lake Manywa	<5	1	2	Absent
Lake Kayanja				
Kooki lakes				
Lake Kachera	>20	1	4	Absent
Lake Kijanebalola	>20	1	4	Absent
Lake Mburo	>20	1	4	Absent
Lake Kyoga Basin				
Main lake				
Lake Kyoga	<50	0	4	Dominant
Satellite lakes				Absent
Lake Nawampasa	>60	2	3	Absent
Lake Lemwa	>50	2	2	Absent
Lake Bisina	>30	2	4	Rare
Lake Nyaguo	>50	2	2	Absent
Lake Nakuwa	<5	0	4	Dominant
Lake Nyasala	<30	1	4	Dominant
Lake Edward-George System				
Main lakes	~50	3	2	Absent
Lake Edward	>40	3	1	Absent
Lake George				
Satellite lakes	>30	0	1	Absent
Lake Saka	>40	3	1	Absent
Lake Kabaleka				

Table 2. Polymorphic loci detected by eight RAPD primers for tilapiine species of Lake Victoria basin. RAPD = Randomly amplified polymorphic DNA; T = total number of bands amplified using eight primers for any one population; P = number of polymorphic loci; % = percent of polymorphic loci; '-' refers to that particular species as being absent in that lake

Lake	*Oreochromis*												*Tilapia*					
	esculentus			*variabilis*			*niloticus*			*leucostictus*			*zillii*			*rendalli*		
	T	P	%	T	P	%	T	P	%	T	P	%	T	P	%	T	P	%
Victoria	-	-	-	66	48	73	40	24	60	50	35	70	44	24	55	-	-	-
Nabugabo	-	-	-	-	-	-	44	33	75	59	27	54	35	27	77	82	51	62
Kachera	55	37	67	-	-	-	53	43	81	55	43	78	-	-	-	-	-	-
Mburo	73	57	78	-	-	-	43	21	49	39	25	64	-	-	-	-	-	-
Kijanebalola	48	16	33	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Kayanja	44	19	43	-	-	-	-	-	-	-	-	-	-	-	-	46	8	17
Kayugi	62	37	60	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Manywa	37	22	60	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Kanyaboli	60	24	50	-	-	-	-	-										

Table 3. Proportion (%) of polymorphic loci detected by eight RAPD primers among populations of tilapiine species sampled at various points within the Victoria Nile as it flows from Lake Victoria into Lake Kyoga. RAPD = Randomly amplified polymorphic DNA; T = total number of bands amplified using eight primers for any one population; P = number of polymorphic loci; % = percent of polymorphic loci; '-' refers to that particular species as being absent in that lake

Lake	*Oreochromis*										Tilapia			
	esculentus			*variabilis*			*niloticus*			*leucostictus*			*zillii*			*rendalli*		
	T	P	%	T	P	%	T	P	%	T	P	%	T	P	%	T	P	%
Buwenda (Jinja), nearest to L.Victoria	-	-	-	86	67	78	73	43	59	49 (6)	7	14	+	+	+	-	-	-
Nababirje (Kisozi)	-	-	-	65 (6)	43	66	+	+	+	54 (6)	35	65	+	+	+	-	-	-
Bugondo (Mbulamuti)							58 (7)	26	45									
Namasagali (Kamuli), close to Kyoga							81	49	61									

Table 4. Polymorphic loci detected by eight RAPD primers for tilapiine species of the Lake Kyoga basin. RAPD = Randomly amplified polymorphic DNA; T = total number of bands amplified using eight primers for any one population; P = number of polymorphic loci; % = percent of polymorphic loci; '-' refers to that particular species as being absent in that lake; '+' indicates that the species is present in that lake but no RAPD analysis was conducted for that particular population; number in parentheses indicates number of individuals used in case were we had less than 10 individuals as a sample of that population

Lake	*Oreochromis*										*Tilapia*			
	esculentus			*variabilis*			*niloticus*			*leucostictus*			*zillii*			*rendalli*		
	T	P	%	T	P	%	T	P	%	T	P	%	T	P	%	T	P	%
Kyoga	-	-	-	-	-	-	80	67	84	98	94	96	116	116	100	-	-	-
Nawampasa	75	60	80	59	21	36	-	-	-	-	-	-	-	-	-	-	-	-
Muwuru	71	38	54	-	-	-	74	19	26	14	6	43	14	3	21	-	-	-
Nakuwa	-	-	-	-	-	-	92	58	63	20	11	55	-	-	-	-	-	-
Dalaja	+	+	+	-	-	-	59	44	75	-	-	-	-	-	-	-	-	-
Bisina	88	65	74	88	58	66	82	43	52	-	-	-	74	52	70	-	-	-
Nyaguo	78	70	90	+	+	+	39	19	49	-	-	-	-	-	-	-	-	-
Lemwa	66	41	62	-	-	-	+	+	+	-	-	-	-	-	-	-	-	-

DISCUSSION

Cichlid Species Losses

Despite its young age, Lake Victoria is estimated to have contained over 500 species of cichlids (Seehausen, 1996, Kaufman 1997) prior to changes caused by human activities starting at the turn of the 20th century. It is estimated that these changes resulted in the extinction of nearly two hundred species, with additional species being found at great risk of extinction during every new expedition made to the lakes (Witte *et al.*, 1992). Unfortunately, large portions of the extant cichlid fauna in the LVR remain undescribed, as was the largest portion of the extinct taxa. The continued changes in the lake ecosystem have put increased urgency on the need for studies to assess what is left in the wild. This urgency exists even if there is no reprieve for many of the most endangered species. We must at least try to tap the invaluable evolutionary information contained in the species that may be going extinct at a rate greater than we can currently study them. Some solace can be taken from the indications that some of the rarer forms may not yet be lost. The satellite lakes such as those of the Kyoga Basin in central Uganda harbour a wide variety of species which include both known and several undescribed ones that seem to be sister species others known to be extinct from the main lake. For example, we have discovered the scale-eating haplochromines of the genus Allochromis, thought to be endemic to Lake Victoria, though extremely uncommon, in the Kyoga lakes.

The opportunities for scientific exploration and conservation biology of the fish fauna of the LVR

The differences in geology, hydrology and limnology of different lakes of the LVR present contrasting conditions that offer different challenges and opportunities for scientific exploration and inquiries into fish faunal evolution and trends in the historical limnology of the region. Most of the lakes in the LVR are of recent origin and are characterised by a history of dramatic changes, brought about most importantly by volcanism and climatological changes (Fryer & Iles, 1972, Greenwood 1974, 1981, Johnson *et al.*, 1996, Leveque 1997). The largest of the lakes in the region, Lake Victoria, is known to have been formed about 750,000 years ago and geological evidence indicates that it has gone through at least one, and probably several long cycles of completely drying up and then refilling (Johnson, *et al.*, 1996). Johnson's group found that the last time of drying for Lake Victoria is thought to have occurred as recently as 14,000 years ago, and lasted for an estimated 2000 years. Based on the fish fauna similarities and distribution, Lake Edward is thought to have been more expansive than its present size, possibly stretching as Far East as to the shores of the current position of Lake Victoria. Lake Edward's history makes it a possible source of progenitor of fish species that reinvaded Lake Victoria after the last dry spell (Kaufman 1996, Kaufman *et al*., 1997). With the volcanism, Lake Edward is thought to have receded and finally broken up into Lake George, the current Lake Edward, and several satellite lakes such as Lakes Kabaleka and Bunyonyi. The history of Lake Kyoga is quite different. Lake Kyoga has a mean depth of only three meters and is a massive swampy area thought to have been turned into a lake when the outflow connecting Lake Victoria to the Nilotic water

system filled a shallow trough on the course of the River Nile to the north (Mwanja, Fuerst & Kaufman 1999).

Earlier studies characterised LVR haplochromine cichlid fishes as being depauperate in genetic diversity (Sage *et al.*, 1984, Meyer *et al.*, 1990). Also studies based on morphology have found that despite the enormous ecological and morphological radiation found among haplochromine species they still retain the similar basic body plan or, as technically referred to the same 'bauplan' (Fryer & Iles 1972, Greenwood 1981, Stiassny 1991, Kaufman 1997). The circumstances in the LVR present the possibility to correlate the limnological and geological history of the region with the history inferred from the relationships derived from the phylogeny among species of the different groups and water bodies.

Conservation Options for Fish Genetic Biodiversity

Previous and most of the current conservation efforts in Africa and elsewhere have focused on the salvaging of species on the brink of extinction, coming in most cases a little too late to protect the disappearing species. A better approach for protection of any species would involve intervention at the population level emphasising habitat heterogeneity and integrity of the involved population units based on genetic analysis. Such a route would be costly and in direct conflict with the kind of economic efforts of struggling economies such as those of Africa. However, this strategy is better, first, because emphasis is not put at ensuring species richness but rather at points where the species' chance for continued existence would be enhanced - habitat integrity and population level considerations in conservation planning. Second, because of the fact that evolution, which is the force behind the continued existence of any biological organism, occurs not at species level but at population level.

The high number of species in the LVR fisheries makes conservation of genetic diversity an enormous challenge and nearly impossible when the decision is to conserve the status quo of the extant diversity. The large species number, wide geographic distribution and, the limited resources for conservation requires that choices be made. Efforts to stem the loss of genetic diversity, can only work with extensive knowledge of populations within a species. The more genetically diverse a population is the better that population is in adjusting and adapting to the changing environment (Allendorf & Leary, 1987). The loss of genetic diversity has been a challenge to the conservation of the recent past and will be the main challenge of the future, especially where resources to take on such a challenge are limited. Disappearance of species from the wild is increasingly seen as a loss of genetic variation or reduced genetic variability (Avise 1994).

This entails affording the populations original natural habitats avoiding the impacts that previously led to their detriment. Ample habitat and other ecological requirements have to be met to sustain viable populations that allow for natural adjustment to environmental changes.

A number of management options to preserve the evolutionary process of the most vulnerable species are available but do require commitment from the managers and fishermen for such measures to succeed. One of the options is the reduction in fishing pressure on marginalized

populations. However, such an option would be in direct conflict with the survival and economic goals of fishing communities and has always failed in the LVR. Another option includes the use of selective cropping gears that would target the dominant species. A traditional option is the rule 'keep clear of the breeding grounds' during fishing and/or close seasons at the peak of the breeding activity for key ecological and fisheries species. This option could still be employed but requires work to map out the breeding and spawning grounds. An option considered to be more easily enforceable is totally closing out fishing on some lakes, especially the minor lakes that contain the remnant populations of the species at risk. Normally these tiny lakes are not that productive in economic terms, and their small size allows for effective monitoring. Creating such preserves would offer some natural safe havens to the endangered species.

In case of salvaging already dilapidated populations several options can be pursued with the aim of fostering genetic diversity. Creation of connection channels between water systems isolated by human activities, equivalent to corridors between habitat patches for game animals could ensure continued genetic exchange and interaction between originally uniform but currently subdivided units. Another option is selective augment the restricted native forms against the dominant forms through hatchery production. This option may be the only way out for several of the endangered species still extant in the wild. Selective augmentation has the effect of boosting the population of the restricted species, and if the genetic diversity is well monitored and managed, the genetic diversity of the endangered species will increase.

Restoration through reintroduction of species extinct in the wild but found in captivity and enhancement of marginalized populations is an option that could be tried in some of the minor lakes and perhaps later, after thorough genetic studies, in the large lakes too. Restoration is hard but if well planned and executed the option has the effect of revitalising the ecology and adding to the species diversity of the current systems. Efforts to do this have been suggested for LVR haplochromine fishes (Kaufman & Ochumba 1993; Mwanja 1996). For we cannot afford to leave the management of biodiversity to Nile perch and untameable limnological changes. With the knowledge so far available management should go in again and do its best to minimise the loss of the biodiversity.

Taxonomical problems within East African Nile Perch (*Genus Lates*): Molecular and Morphological Approaches.

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SUMMARY

The genus Lates currently comprises eight species. With the exception of L. calcarifer (a brackish species) all are confined to tropical rivers and lakes in Africa. Despite their great economic and ecological importance, the taxonomic status of several Lates populations still remains uncertain. This is particularly the case for the widespread L. niloticus and for its deepwater relatives L. macrophthalmus and L. longispinis from Lake Albert and Lake Turkana respectively. Although several studies have dealt with this problem during the last decades, the current taxonomy of the East African Lates is not conclusive. We recommend a reappraisal of the Nile perch taxonomy through modern approaches including Principle Component Analysis (PCA) and Analysis of Variance (ANOVA) single factor for both morphological and genetic analyses Genetic studies will be based on mtDNA, microsatellites and Direct Amplification of Length Polymorphisms (DALP).

INTRODUCTION

The *genus Lates* Cuvier in Cuvier & Valenciennes, 1928 currently comprises eight species, seven of which are found in various freshwater systems from tropical Africa. Another representative of the genus, *L. calcarifer* (Bloch, 1790), is a brackish species known from the Indo-West Pacific. Four endemic *Lates* are found in Lake Tanganyika. One species, *L. niloticus* Linnaeus 1758, is naturally widely distributed in various rivers and lakes of tropical Africa. Two other species, *L. macrophthalmus* Worthington 1929 and *L. longispinis* Worthington, 1932, are endemic in Lake Albert and Lake Turkana respectively where they are sympatric with *L. niloticus*. These two deepwater species are ecologically similar and are found offshore while *L. niloticus* seems to occur mainly in shallower inshore waters. Despite their great economic and ecological importance, the taxonomic status of several *Lates* species remains uncertain. Four major works have dealt with this problem during the last thirty years: Holden (1967), Greenwood (1976), Harrison (1991) and Hauser *et al.*, (1998). Since the results of those taxonomic works were not conclusive, we intend to tackle the problem with modern morphological and molecular approaches.

Morphological Characterisation of East African *Lates* Species

Worthington (1929) was the first to study *Lates* species from Lake Albert. He described two new species, *L. macrophthalmus*, an offshore deepwater form and *L. albertianus* Worthington, 1929, an inshore shallow water form. These two species besides *L. niloticus* from the lower

Nile, were distinguished based on differences in the relative depth of the caudal peduncle, the relative length of the maxilla, the ratio of snout length to eye diameter, and the relative lengths of the 3rd and 4th spines of the first dorsal fin (D1). It is important to note that the ranges of these characters overlapped for the three species.

In 1932, Worthington described two subspecies of *L. niloticus* from Lake Turkana, recognizing the close relationships between the Turkana and Nile fauna: *L. niloticus* rudolfianus Worthington, 1932, an inshore form and *L. niloticus* longispinis Worthington, 1932, a deep water offshore form. Again the ranges of the morphological characters taken into account overlapped. Although there were also strong similarities with *L. albertianus* and *L. macrophthalmus*, Worthington did not make a detailed comparison of the five taxa under consideration.

Holden (1967) analysed four morphological characters for the African Nile perch: number of spines in D1, Standard Length/Caudal Peduncle Depth, Caudal Peduncle Depth/Caudal Peduncle Length and Pelvic fin length/Pectoral fin length. Based on this study he considered *L. albertianus* as a junior synonym of *L. niloticus niloticus* and *L. macrophthalmus* as a valid species.

Greenwood (1976) examined the type material of *L. niloticus rudolfianus*. He noted that values of various morphological characters fell within the range of those of *L. niloticus* and considered *L. niloticus rudolfianus* as a junior synonym of *L. niloticus niloticus*. Comparison of *L. niloticus longispinis* and *L. niloticus niloticus* allowed differentiation between both groups based on a relatively larger eye, a longer third spine of D1 and a relatively shorter posterior extension of the maxilla in *L. niloticus longispinis*. Greenwood (1976) therefore considered *L. longispinis* as a valid species and not as a subspecies of *L. niloticus*.

Harisson (1991) carried out an analysis of the four lacustrine taxa and the riverine *L. niloticus niloticus* in order to reappraise the taxonomy of the East African forms. He recognized that two different species of *Lates* occur in Lake Albert, the inshore *L. albertianus* and the offshore *L. macrophthalmus*, both different from *L. niloticus* from the Nile. Harisson (1991) also noted that the two species from Lake Turkana (*L. rudolfianus* and *L. longispinis*) differ from *L. niloticus* found in the Nile but that *L. rudolfianus* is very similar to *L. albertianus*. The author stated that the current taxonomy of *Lates* from East Africa is not conclusive (see Fig. 1 for an overview of nomenclatural changes in freshwater *Lates*) and recommended a reappraisal of Nile perch taxonomy using more modern techniques.

Hauser *et al.*, (1998) also studied *Lates* populations from Lakes Albert and Turkana and from several other lakes where Nile perch was introduced by man. They used allozyme elctrophoresis techniques. Despite the adequate number of loci studied (50), they failed to find any diagnostic locus between *L. niloticus* and *L. macrophthalmus* from Lake Albert nor did they find a diagnostic locus between the Lake Albert *Lates* and *L. niloticus* from Lake Turkana. Hauser *et al*., (1998) also included *L. longispinis* in the study, but this taxon was represented by only one specimen and thus of very little statistical value.

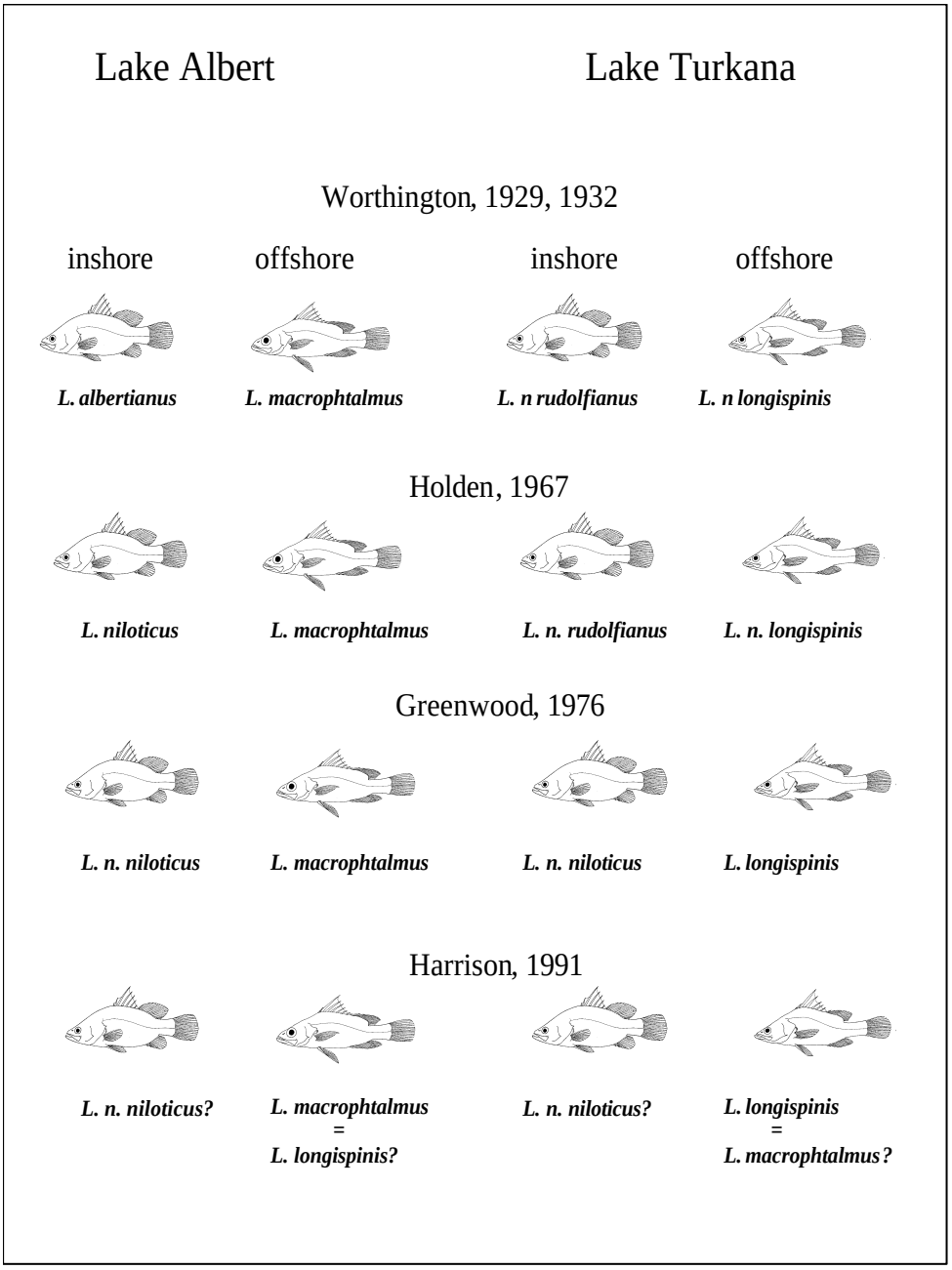

Fig 1. Taxonomic changes in *Lates* species from lakes Albert and Turkana since their original description.

DISCUSSION

The presence of diagnostic loci is not necessary to distinguish species. For example Agnèse *et al*., (1998) did not find any diagnostic locus between *Clarias gariepinus* (Burchell, 1822) and *C. anguillaris* (Linnaeus, 1758), two closely related catfishes, yet a factorial analysis of the genotypes clearly indicated the presence of two different groups without any overlap. These groups corresponded clearly with the two species. Hauser *et al*., (1998) applied such analysis to their genotype matrix but failed to obtain completely separated groups. Unfortunately, the specimens studied by Hauser *et al*., (1998) were not preserved or registered in any Museum collection, so it is not possible to verify their identity. Since the identification of *Lates* specimens is difficult, particularly for small specimens, misidentifications easily occur. Consequently failure in recognizing different groups can be due to such misidentifications and therefore the possibility that allozymes could distinguish between two or more species cannot be ignored.

CONCLUSION AND RECOMMENDATION

70 years after their descriptions, the taxonomic status of *Lates* populations from lakes Albert and Turkana still remains uncertain. Most of the morphological studies have been done using a very small number of specimens, sometimes based on less than 5 individuals per species and using inadequate statistical techniques (e.g. only based on comparison of mean values). Nevertheless it is very likely that two different species exist both in Lake Albert and Lake Turkana.

Whether or not these species are the same in both lakes or whether or not one of them corresponds to *L. niloticus niloticus* needs clarification. For such a study, large samples (50 or more specimens per population/locality) have to be examined using modern statistical approaches including Principle Component Analysis (PCA) and Analysis of Variance (ANOVA) single factor for morphological and genetic analyses. Techniques like Factorial analysis (FA) and PCA allow discriminating between populations even if there is no apparent diagnostic character (Vreven *et al*., 1998). Analyses of results from genetic studies based on allozymes, mtDNA, microsatellites and DALP (Desmarais *et al*., 1998) can also facilitate species identification. It is also obvious that all these techniques (morphological and genetical) will be more effective if applied simultaneously on the same specimens. Such type of studies already gave very good results to assess the taxonomical status of sympatric populations of other fishes, (Euzet *et al*., 1989; Paugy *et al*., 1990; Agnèse *et al*., 1998).

The Role of Conservation in Biodiversity and Fisheries Sustainability in the Lake Victoria Basin

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SUMMARY

Throughout the twentieth century Lake Victoria underwent massive and fundamental changes in its ecology that resulted in the fishery being converted from a multi-species system exploiting native fishes, to one in which three species make up most of the catch, two of which are introduced. With the new century, there are indications that this extremely dynamic situation has continued to develop. The invading Nile perch is showing signs of being overfished, and some of the native species that were in retreat are now re-emerging. In this paper we summarize management options that may favor both the maintenance of biodiversity and a sustainable fishery in Lake Victoria. These include: the development of an integrated lake plan, protection and restoration of water and general environmental quality, regulation of the fishery, protected area management and maintenance of faunal refugia, and biodiversity survey and long-term monitoring. The recommendations made here build upon existing plans for biodiversity conservation prepared as part of the Lake Victoria Environmental Management Programme (LVEMP). We urge that implementation of these recommendations be accelerated and that they draw fully upon the knowledge and experience established over the past two decades.

INTRODUCTION

Inland fisheries throughout the world are under increasing stresses from fishing and environmental pressures. These twin pressures have often led to considerable shifts in the balance of fish populations with the local loss of many species and the rise to dominance of a comparatively limited number of fish species that are often introduced. It is generally recognized that inland

water fishes and amphibians are the most endangered group of vertebrates. The International Convention on Biological Diversity seeks to rectify this situation by requiring that member countries take the necessary steps to protect biodiversity within their territories through a series of plans and actions aimed at conservation of natural resources.

In the tropics, most fisheries are exploited to levels that have produced substantial degradation in the assemblages; in the temperate zones, centuries of overfishing and regulation of river and lake basins have altered stocks. It is known that fish communities react to environmental and fishing pressures by a series of characteristic changes. These changes are termed the "fishing-down" process and involve the successive loss of the largest individuals and species in favor of smaller and shorter-lived fishes (Welcomme, 1999) as illustrated in Table 1. In this paper, we examine Lake Victoria as compared to this relative model and judge its status, with the major objective of exploring management options that reconcile sustainability of fisheries with conservation of biodiversity

History of Biodiversity loss and change in functional relationships in Lake Victoria

Throughtout the twentieth century, Lake Victoria underwent massive and fundamental changes in its ecology. At ehe beginning of the period, the lake was sparsely fished with a variety of simple traditional methods. Human occupancy was relatively low, much of its shoreline was covered in riparian forest, and there were extensive riparian wetlands. Towards the close of the century the lake supported an intensive fishery, human occupancy of the basin accelerated, the shoreline was denudd of trees, and many of the wetlands were reclaimed. The fish stock of the lake was subjected to three major series of events:

i) Fishing intensified over the century by the successive introduction of new technologies - commercially produced, artificial fiber nets, outboard motors, and improved fish processing and marketing systems.

ii) The introduction of five new species of fish influenced the faunal composition and balance.

iii) Increased human occupancy and associated agricultural activity, industrialization, and change in fish composition (i.e., shift from primary to secondary and tertiary consumers), and the denudation of the lakeshore increased the trophic level of the lake from meso- to eutrophic.

These three events influenced the structure of the fish stock and resulted in the fishery being converted from a multi-species system exploiting native endemics (an unknown number of cichlids, and a diverse assemblage of non-cichlids including the lungfish and several species of catfishes, mormyrids, and cyprinids) to one in which three species make up almost the whole of the catch, two of which are introduced. With the new century there are indications that this extremely dynamic situation has continued to develop. The invading Nile perch (*Lates niloticus* L.) itself is showing signs of being overfished, and some of the native species that were in retreat are now re-emerging.

Table 1. Indicators of change occurring in fish populations in response to fishing and environmental stress.

Indicator	Trend
Level of catch	Falling levels of total catch in single species fisheries, however catch levels can be maintained over a wide range of effort and can only be interpreted relative to the catch composition
Mean length	Disappearance of larger fish and falling mean size within species· Disappearance of larger species and falling mean size of catch as a whole
Number of species	In mesh selective fisheries an initial rise in number of species in catch from a few large ones to many small ones· Later falling numbers until the fishery is confined to few very small species· In multi-gear fisheries a steady loss of species throughout process.
Type of specie	·Decline and disappearance of anadromous and long distance riverine migrants· .Decline and disappearance of specialized and slowly reproducing species in favour of generalist species and species with high reproductive output, the latter often being exotics where introductions have occurred· .Decline and disappearance of higher trophic levels (predators) and their replacement by lower food chain species· .Decline and disappearance of species with high oxygen requirements and their replacement by species tolerant of low oxygen [eutrophication]· .Decline and disappearance of species with requirements for good visual conditions (e.g., pursuit and ambush hunters)
Response time	·In rivers and river-driven lakes and reservoirs shortened time between flood events and response by population
Other indicators	·P/B ratios rise· Mortality rates (z and f) increase· Higher incidence of diseased and deformed individuals (extreme eutrophication and pollution)

Fishing

The indigenous fish fauna of Lake Victoria was fished at an accelerating rate over the century, and by the 1950s and 1960s, there was evidence that most large species were overexploited (Graham 1929, Fryer and Iles 1972, Benda 1979, Muller and Benda 1981, Ogutu-Ohwayo 1990, Kudhongania and Chitamwebwa 1995).

In 1957, the fish catch at the Lake Victoria Fisheries Service (LVFS) recording stations was dominated by *Oreochromis esculentus* in Kenya and Uganda, representing 47% and 53% of the numerical catch, respectively (Table 2). *Oreochromis variabilis* was also abundant in Kenya (15%) and Uganda (20%). In Tanzania, Labeo victorianus was the dominant species representing 32% of the catch followed by *O.esculentus*, which represented 18% of the catch (Table 2). However, by the 1970's catches of *O. esculentus, O. variabilis, Labeo victorianus,* and *Mormyrus kannume* were severely reduced (Table 3). Catches of *Protopterus aethiopicus* were also locally compromised in the lake (Goudswaard et al. in press). Indeed by the late 1970s, small haplochromines were an important component of the fishery in Tanzania; and even here intensive trawl fishing rapidly eliminated local stocks (Kudhongania and Cordone 1974, Witte and Goudswaard 1985, Ogutu-Ohwayo 1990, Ligtvoet *et al*., 1995, Fig. 1). In Kenya, haplochromines were also an important component of the fishery in the mid to late 1970's, while in Uganda, *Bagrus docmak* was the most heavily harvested species during this period (Table 3, Fig. 1). In addition to the activities in the main lake, fisheries in the rivers for the commercially valuable species such as *L. victorianus* resulted in the near disappearance in the 1960s of these once abundant species (Cadwalladr, 1965, 1969).

In general, the changes in the Lake Victoria fish stock between 1950 and 1980 seem to conform to the general "fishing-down" model, as the fishery was characterized by a drift to the then smallest species - the haplochromine cichlids and Rastrineobola argentea, with the exception of Uganda, where some of the larger indigenous species (e.g., catfish, lungfish) still comprised a large proportion of the catch. Subsequent to 1980, the impact of the introduced Nile perch and Nile tilapia, which grow to a large size, temporarily reversed this trend.

Introduction of Non indigenous Species

The species flock of endemic haplochromine cichlids (600+ species) in the Lake Victoria basin is one of the most recent, diverse, and extensive radiations of vertebrate taxa (Greenwood 1980, Kaufman *et al.*, 1997). The predatory Nile perch was introduced into Lake Victoria from lakes Albert and Turkana during the late 1950's and 1960's to convert low value haplochromines into higher value and more easily captured and preserved fish flesh (Fryer, 1960; Hamblyn, 1961; Ligtvoet *et al.*, 1995). The dramatic increase in Nile perch in the 1980's in Lake Victoria (Table 3,4, Fig. 1) was followed by a drastic decline in populations of several indigenous species (Table 3,4, Fig. 1, Ogutu-Ohwayo, 1990; Witte *et al.*, 1992a,b; Kaufman, 1992; Kaufman *et al*., 1997). Most notable was the disappearance of over 50% of the non-littoral haplochromine

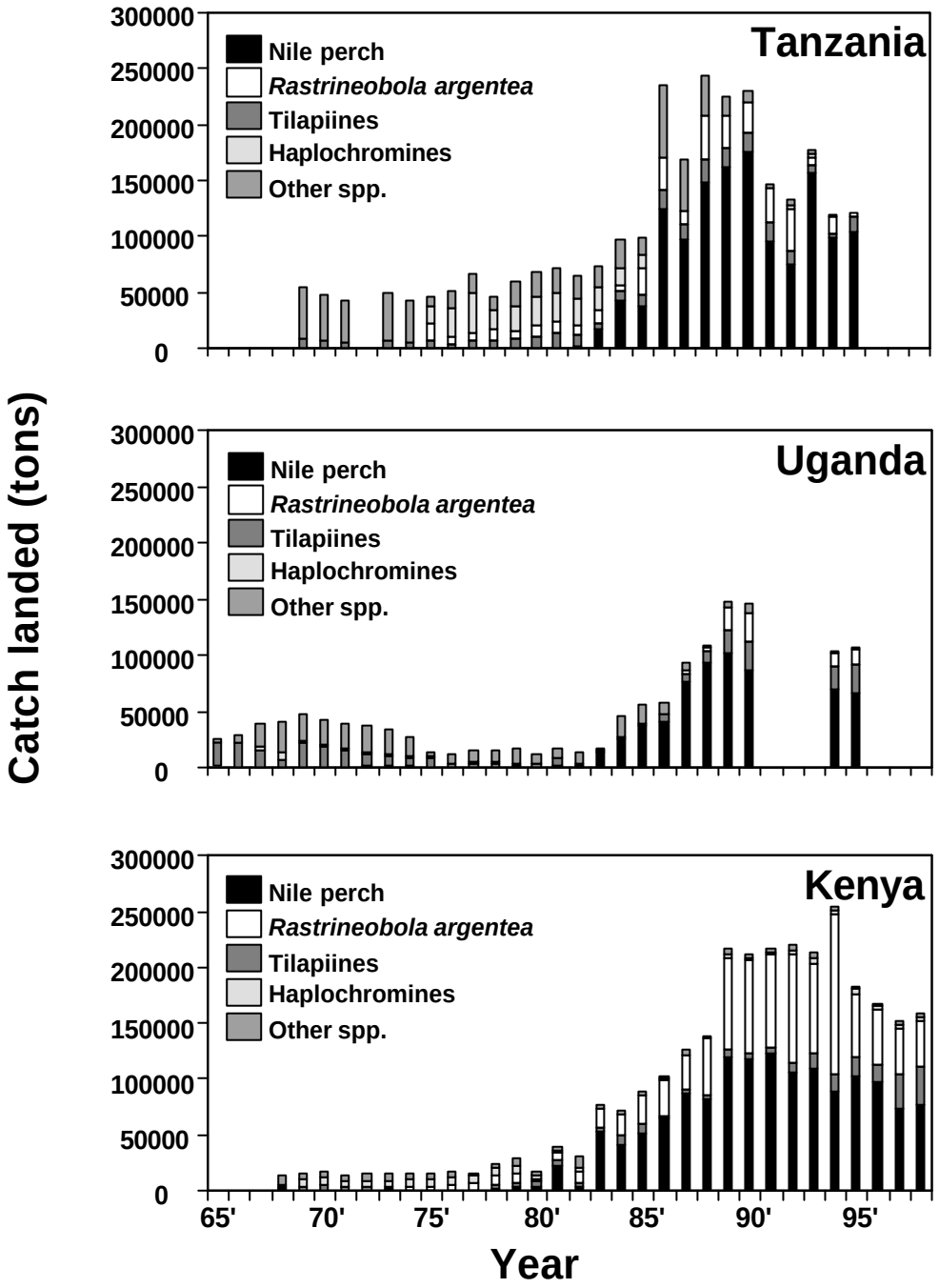

Fig. 1. Fish catch in tons for Tanzania, Uganda, and Kenya between 1965 and 1998. For years with no bars, there were no available data. The data for this figure was derived from a compilation provided by K. Geheb for EU-LVFRP based on the following references: Welcomme 1972, Oduor-Otieno *et al.*, 1978, Kongere, 1979; Republic of Kenya, 1979; Coche and Balarin, 1982; Zonneveld, 1983; Republic of Kenya 1988; Reynolds and Greboval, 1988; Maembe, 1990; Kudhongania and Coenen, 1991; Achieng, 1992; Ogutu, 1992; Greboval and Fryd, 1993, Othina and Osewe-Odera, 1995; Fisheries Division, 1998; unpublished Fisheries Division statistics (Dar es Salaam), and unpublished Fisheries Department Statistics (Nairobi).

Table 2. Annual summary of fish species composition of landings at recording stations in Kenya, Uganda, and Tanzania in 1957. These data were abridged from the Lake Victoria Fisheries Service Annual Report (1957/1958).

Fish Taxa	Kenya (7 stations)	Uganda (10 stations	Tanzania (16 stations)
	% total catch	% total catch	% total catch
Oreochromis esculentus	46.7	52.5	18.0
Oreochromis variabilis	14.9	20.2	3.9
Haplochromines	2.6	1.9	12.7
Labeo victorianus	14.7	2.4	31.9
Bagrus docmak	8.0	9.0	15.9
Barbus altianalis radcliffi	1.5	1.3	0.5
Mormyrus spp.	6.0	3.7	3.3
Clarias gariepinus	1.5	1.8	0.9
Schilbe intermedius	2.4	0.2	4.7
Brycinus jacksonii	1.1	5.8	2.6
Synodontis spp.	0.1	0.2	4.8
Protopterus aethiopicus	0.5	1.0	0.5
Other species	0.0	0.0	0.2

Table 3. Catch (tons) for the Uganda waters of L.Victoria for three time periods (1966/67, 1976/77, & 1986/87). For each period, the catch indicated represents the total for the 2 years combined. Tilapiines were mainly *Oreochromis esculentus* and *O. variabilis* in 1966/67, mainly *O. niloticus* in 1976/77, and exclusively the latter in 1986/87. Data were abridged from a compilation provided by K. Geheb for EU-LVFRP from the sources detailed in Fig. 2.

Taxa	1966/67	1976/77	1986/87
Lates	8	1000	117617
Tilapiines	35493	4960	11544
Bagrus	13291	9290	16346
Mormyrus	972	260	311
Clarias	4473	3240	1310
Protopterus	5253	4070	617
Barbus	1625	660	170
Synodontis	243	610	55
Haplochromines	3909	2560	5
Alestes	446	1000	0
Labeo	407	40	0
Rastrineobola	0	10	2001
Others	82	0	14

cichlids, or about 40% of the endemic haplochromine cichlid community in Lake Victoria (Kaufman, 1992; Witte *et al*., 1992a; Kaufman and Ochumba, 1993; Seehausen *et al.*, 1997a,b). Many indigenous non-cichlids (e.g. some catfishes, Goudswaard and Witte, 1997) some of that were, important in the pre-Nile perch fishery, also declined or disappeared (Table 3). The introduced Nile perch population is proposed to have been a major contributor to the mass extinction; the decline in endemic haplochromines was almost reciprocal with the increase in Nile perch (Ogutu-Ohwayo, 1990; Witte *et al.*, 1992a,b; Kudhongania and Chitamwebwa, 1995, Table 3, Fig. 1). However, other perturbations to the system may have also contributed to the decline such as increasing eutrophication (Seehausen *et al*., 1997a) advancing hypolimnetic anoxia (Hecky, 1993; Hecky *et al*., 1994), decrease in water transparency (Seehausen *et al*., 1997a), loss of migratory routes, etc. As recently as 1978, haplochromine cichlids contributed about 80% of the biomass and Nile perch less than 2%, with the remainder consisting of the introduced *Oreochromis niloticus*, native tilapiines still present at that time, and native non-cichlids (Table 4, Kudhongania and Cordone, 1974, Kaufman, 1992; Witte *et al*., 1999). By 1983 in Kenya and by 1987 in Tanzania, the Nile perch comprised greater than 80% of the catch (Kaufman, 1992; Witte *et al*., 1999). The standing stock of bottom dwelling fishes in the sublittoral waters of Mwanza Gulf dropped by a factor of five, and trophic diversity decreased dramatically (Witte, *et al*., 1999). Similar observations have been made in the northern part of the lake (Okaronon, 1994). The situation in Lake Victoria has been followed most closely, because of its economic importance and extremely high endemism. But similar changes have occurred with the introduction of Nile perch into other lakes in the region including Lake Kyoga (Ogutu-Ohwayo, 1994) and Lake Nabugabo (Ogutu-Ohwayo, 1993; Chapman *et al*., 1996a,b).

Changes in species richness in the system have created major changes in the food web and functional roles of certain species. For example, prior to the increase in Nile perch zooplanktivorous haplochromines represented more than 25% of the catch of commercial bottom trawlers in the sublittoral areas of the Mwanza Gulf (Goldschmidt *et al*., 1993), but by the late 1980's, *Rastrineobola argentea* was the only native zooplanktivore still abundant and showed a sixfold increase in biomass (Wanink, 1999). Other introduced species include *O. leucostictus, T. zillii*, and *T. rendalli*. These species have remained at low levels in specialized habitats and do not appear to have had a major impact on the lake.

Environmental Change

As a result of human occupation, deforestation, development of riparian agriculture, and urbanisation and industrialisation, Lake Victoria has changed its nature from a meso-trophic system dominated by diatoms to a eutrophic system dominated by blue green algae (Hecky, 1993; Crul, 1995). Primary productivity doubled, and algal biomass increased eight to ten-fold (Mugidde, 1993) accompanied by a shift in algal species composition (Hecky, 1993). One result of the increase in nutrient levels, and possibly also due to changes in the food web resulting from the elimination of many of the haplochromines, is that the deeper part of the lake (> 40m) is now stratified throughout much of the year (Hecky, 1993; Hecky *et al.*, 1994). In the shallower areas

Table 4. Mean catch size kg h^{-1} (and % of total catch) of bottom trawls (codend mesh 20 mm) in the northern part of the Mwanza Gulf (7-15 m deep) in 1978, 1987 and 1997. Head ropes were respectively 25, 18, and 22.6 m, catch durations 45, 30 and 45 minutes. All data were transformed to catch per hour with a 22.6 m head rope (Wiitte *et al.*, 2000).

Year	1978	1987	1997
Number of hauls	7	69	1
Lates niloticus	1 (0.1)	208 (97.0)	152 (76.2)
Haplochromines	1067 (92.3)	0 (0.2)	42 (21.3)
Other species	88 (7.6)	6 (2.8)	5 (2.4)

(10-40 m) duration and severeness of hypoxia increased (Wanink *et al*., 2001). What these changes would have meant for the haplochromine species flock even in the absence of Nile perch may never be known. It can however, be assumed that many of the benthic species would not have been able to adapt to total deoxygenation of the areas they previously inhabited. Certainly, the fish kills associated with upwellings of anoxic water in addition to the possible effects of phytotoxins suggest that use of this region may impose a high risk for some species (Ochumba, 1990; Kaufman and Ochumba, 1993; Kolding, 1993). Similarly, although some of the specialised phytoplankton feeders were known to feed predominantly on blue green algae (Goldschmidt *et al*., 1993), not all species that included phytoplankton in their diet may have been supported by the takeover of blue green algae.

With increasing hypolimnetic anoxia dramatic changes in the macroinvertebrate community can be anticipated as has been observed in some reservoirs. The increase in the detritivorous shrimp, *Caridina nilotica*, is one notable change (Witte *et al*., 1992a, Goldschmidt *et al*., 1993). Branstrator and Mwebaza-Ndawula (1998) suggest that use of low-oxygen habitats by *C. nilotica* may reduce their vulnerability to Nile perch predation, and the increased production of algal and detrital foods in Lake Victoria may contribute to continued growth of the *C. nilotica* population. Another apparent change in the macroinvertebrate community has been a shift from Chaoborus dominance in the insect fauna to chironomid dominance (Mbahinzireki, 1992). MacDonald (1956) reported an average density of 2000-2500 Chaoborus larvae per m^2 in Ekunu Bay of Lake Victoria (near Jinja) that represented about 70% of the total insect fauna. In contrast, Okedi (1990) reported a much lower density ranging from 12 to 38 Chaoborus per m^2 in Murchison Bay near Kampala (between November 1987 to April 1988), while chironomids comprised 61% of the insect fauna.

Further changes involve the riparian wetlands and the tributary rivers to the lake. Wetland reclamation and river pollution have contributed to the decline of migratory fish species in the basin that were once abundant.

Non-indigenous wetland plants are common in the Lake Victoria Region, and one of the most invasive species has been the water hyacinth, *Eichhornia crassipes*. It is native to Amazonia and has naturally spread to other areas in South America, but during the last century, it has colonized large parts of the tropics. Water hyacinth appeared in Lake Naivasha in Kenya in 1982 and in Lake Kyoga in Uganda in 1988. It was first reported in the Ugandan and Kenyan waters of Lake Victoria in 1989 and in Tanzanian waters in 1990 (Nyanjuna 1991, Twongo *et al*., 1995). The weed became firmly established in lakes Victoria, Naivasha, Kyoga, Albert, and along the River Nile. Water hyacinth is distributed into two distinct forms, as stationary fringes along shorelines and as mobile mats. In Lake Victoria, the weed established at an average fringe width of 10 to 15 m since 1995, but more recently has disappeared almost completely over most of its previous.

Water hyacinth invasion into Lake Victoria had significant socio-economic and environmental impacts including disruption of transport, reduction of water supply, negative impacts on water quality for humans and livestock, and spread of water-borne diseases (Twongo 1996). Water hyacinth may have turned out to be beneficial for a some species, especially for hypoxia-tolerant fishes, such as the lungfish (*Protopterus aethiopicus*) and *Clarias gariepinis* (Bugenyi and van der Knaap, 1998); however, in general it seems to reduce the diversity of plankton, floating and submerged macrophytes, macroinvertebrates, and abundance and diversity of fish (Twongo *et al*., 1995; Mbilinyi, 1998; Seehausen and Kangwe, 1998). The current state of remission of the water hyacinth infestation in response to the introduction of the weevils *Neochetina eichhorniae* and *N. bruchi* and ecological stress, is encouraging; however, the nutrient enrichment of Lake Victoria and related water bodies provides potential for the proliferation of water hyacinth if regionally coordinated control measures are not sustained (Twongo and Ondongkara, 2000, T. Twongo, pers. comm.). Recent observations suggest that water hyacinth has increased again in the Mwanza Gulf (Seehausen pers. obs.).

Biodiversity Banks - Faunal Refugia

Over the past decade, scientists have directed much effort to the identification of faunal refugia; habitats where prey might be protected from Nile perch predation. We currently recognize two major types of biodiversity banks: structural refugia within the lake (wetlands and rocky habitats) and refugia outside the lake (satellite water bodies).

Wetlands protect some prey from Nile perch predation because they serve as both structural and low-oxygen refugia for prey that can tolerate wetland conditions, and they serve as barriers to the dispersal of Nile perch (Chapman *et al*., 1996a,b; Kaufman *et al.*, 1997; Balirwa, 1998; Chapman and Chapman, 1998; Mbilinyi, 1998; Rosenberger and Chapman, 1999' Schofield and Chapman, 1999). We have found some haplochromines and some indigenous non-cichlids have been found to be relatively tolerant to low oxygen (Chapman *et al*., 1995; Chapman and Chapman, 1998; Rosenberger and Chapman, 2000), while Nile perch are not tolerant (Schofield and Chapman, 2000). This helps to explain why some indigenous species persist in wetland refugia, and why Nile perch are unable to exploit these habitats.

The ecotonal wetlands are particularly important refugia because Nile perch are rare in these habitats, and species diversity is higher than in the dense swamp interior (Chapman *et al.*, 1996a,b; Balirwa, 1998; Rosenberger and Chapman, 1999; Schofield and Chapman, 1999). Interaction with the main lake waters increases dissolved oxygen content and reduces carbon dioxide levels in the ecotonal wetlands, which makes these habitats more accessible than the interior swamps. These marginal wetlands still contain most functional elements of the indigenous fauna, and a much higher diversity than other areas currently lumped into the inshore zone, except for rocky shores and reefs. Areas deep in the fringing swamp are less rich because the dense fringing swamps act much as a biological filter, limiting colonization and survival to species that can tolerate the extreme conditions therein. However, even areas within the fringing swamp are important in the maintenance of a subset of the basin fauna (Chapman *et al*., 1996a; Balirwa, 1998; Chapman & Chapman, 1998).

Rocky shores and offshore rocky islands and reefs are the other major within-the-lake refugia. Their high structural complexity and relatively clear waters facilitate coexistence of many closely as well as distantly related species, permitting the highest fish species diversity of all lake habitats (Seehausen, 1999a; Seehausen *et al.*, 1997b). These habitats harbor a large number of rock-dwelling specialists (>150 species of diverse cichlid lineages and at least one native cyprinid) and serve as refugia for a large number of species that were not specialized rock-dwelling fish in the pre-Nile perch era but either survived only in these refugia or actively shifted to rocky habitats (Witte et al., 1992b; Seehausen, 1996; Seehausen *et al*., 1997b). The fish communities in rocky habitats are also currently the most trophically diverse fish communities in Lake Victoria (Seehausen *et al*., 1997b). However, it should be noted that several other high diversity within-lake-refugia have been identified but are less easily defined topographically (Kaufman and Ochumba, 1993; Seehausen *et al*., 1997b).

A decade of study has revealed that a small portion of the fauna considered lost from lakes Kyoga, Victoria, and Nabugabo is still extant in satellite water bodies around the main lakes (lakes, ponds, dams), and these systems provide a reflection of the pre-Nile perch fauna (Ogutu-Ohwayo, 1993; Kaufman *et al*., 1997; Aloo, 2000; Katunzi, 2000; Mbabazi, 2000; Kaufman). Evidence suggests that these small lakes have the ability to maintain stable population structures and community compositions of some cichlid fishes. In many cases dense hypoxic swamps separate these satellite lakes from the main lake and act as a biological filter preventing Nile perch colonization.

CONSERVATION OF BIODIVERSITY IN THE LAKE VICTORIA REGION

Conservation versus use: A Fundamental Dilemma

One of the major dilemmas of the age concerns the use of natural resources. On the one hand, there is the need to utilise natural resources to satisfy the nutritional requirements of a growing human population. On the other hand, there is the need to maintain existing genetic, specific, ecosystem biodiversity, and biodiversity generating processes for future generations. These two

imperatives are frequently in conflict because the maximisation of human societal needs for food, goods, and infrastructure involves the disruption of existing habitats and living communities. Efforts to resolve this conflict have been encouraged in a number of international fora including the Convention on Biological Diversity (CBD). Resolution of these conflicts is generally difficult because competing uses of inland waters are generally economically important and represent readily costed values, whereas the financial value of intact ecosystems and species survival is less readily established. At best, some value can be attached to the ecosystem services provided by a healthy environment, or values can be assumed on the basis of the opportunity cost of benefits forgone in the conservation process. One effect of this is that, while there is considerable external pressure to preserve the biodiversity of the lake, convincing local stakeholders of the desirability of limiting exploitation in the interest of such conservation is more difficult. Efforts to conserve biodiversity have, therefore, to be pursued despite this difficulty of providing short-term financial justifications. Because of the lack of immediate financial motivation, considerable efforts have to be devoted to education at all levels of society to arouse public awareness of the values and advantages of conservation-minded management.

RECOMMENDED AVENUES FOR BIODIVERSITY CONSERVATION

Any project to protect or restore the biodiversity of the Lake Victoria basin should form part of an integral lake plan. Such a plan is necessary so that national priorities can be developed at high political level on the basis of which funds can be located and legislation drafted. It should also be included in the national biodiversity planning which is part of the national obligation under the Convention on Biological Diversity. Additional support can also be sought through the major wetland conventions such as RAMSAR. The influence of upstream activities is particularly important in the case of rivers and riverine wetlands. Conservation reserves in such environments are only effective if they are formally included in general plans for the river basin as a whole. It is suggested that the development of an overall policy for biodiversity conservation is of high priority. The policy should be incorporated into more generalised planning for the conservation and management of the natural resources of the lake and its basin.

There is no doubt that, apart from other factors, fishing has exerted a major effect on the magnitude and composition of the fish stock. The best conservation strategy should, therefore, be linked to rational regulation of fishing effort to prevent the serial collapse of stocks that characterised the past history of the Lake Victoria fishery. Appropriate levels of fishing efforts on selected size classes and species may contribute to the maintenance and enhancement of biodiversity.

There have been recent proposals for reintroduction and restoration of cichlid species into satellite water bodies (Mwanja *et al.*, 2000). This need is driven by the current uncertainty about population trends and lack of protection in the main lake. However, much caution must be executed in considering this intervention because of potentially negative genetic effects. There is also a growing interest and support for enhancing the native Lake Victoria fishery using aquaculture (Mwanja *et al*., 2000). Aquaculture development can impact biodiversity in a number of ways. Cage and pen culture can accelerate sedimentation rates, the accrual of uneaten food increases

eutrophication, and antibiotics and antifouling compounds can lead to local toxic pollution especially in the smaller satellite lakes. These risks have to be taken into consideration in siting offshore installations and in allocating the numbers of installations permitted in the main lake. There are also risks of introductions of exotic species and genetic varieties into the lake. Such risks include increased competition for the refugial native stocks and loss of adaptations to the local environment by hybridisation. There is some evidence that the native *O. esculentus* genome has, at least in parts of the lake and its satellites, been absorbed into the genome of the introduced *O. niloticus* (Mwanja and Kaufman, 1995). Future introductions of species in support of the commercial fishery, the recreational fishery, aquaculture, or even conservation could impact the genetic make-up of species already present. Great care is therefore needed in following the existing protocols governing movements, introduction, and stocking of fish into the lake or its satellite waterbodies. In addition to regulation of the fishery and aquaculture, representative habitats in the lake should be reserved for conservation, with special emphasis on high diversity zones. These should include a selection among rocky shores, some offshore rocky islands, sandy shores, wetlands, and parts of mud-bottomed gulfs within the main lake. The small satellite water bodies outside the main lake are also suitable conservation/management units, because of their small size and the fact that dense, hypoxic swamps that will limit Nile perch penetration surround many of them. In addition, many of these small lakes have only a small number of stakeholders which facilitates integrated conservation and development actions.

The maintenance of wetlands in the Lake Victoria basin is critical to both ecosystem function and to the conservation of indigenous species. Wetlands provide many valuable functions (e.g., flood alleviation, ground water recharge, retention and regulation of pollutants and nutrients); products (e.g., fish, fuelwood, timber, crafts, herbal medicines, rich sediments for agriculture); refugia for fish and other fauna; and other attributes e.g. (biodiversity, aesthetic beauty for tourists). Permanent swamps, dominated by papyrus (*Cyperus papyrus*) and Miscanthidium violaceum are inhabited by unique assemblages of plants and animals with extraordinary adaptations to the extreme conditions (low dissolved oxygen, high levels of carbon dioxide, reducing conditions) imposed by the dense swamp environment. Ecotonal areas tend to be richer faunistically than the dense interior of permanent swamps with respect to several taxa including fishes, birds, and aquatic macroinvertebrates. However, the permanent swamps may still be very important in the maintenance of faunal structure and diversity; and their structural degradation (e.g., by conversions and drainage or by nutrients and pollutants) may precipitate declines in the diversity and richness of swamp and ecotonal taxa through loss of habitat, faunal mixing, and loss of refugia.

Numerous anthropogenic activities including primarily reclamation for agricultural production, but also irrigation systems, canalization, mining/extraction and industrial and municipal pollution currently threaten wetlands. Current strategies for the sustainable management of wetlands include co-management systems for shoreline wetland resources (multistakeholder strategies), protection mediated by such activities as economic valuation (e.g., Yala Swamp), Ramsar status (e.g., Lake George, Lake Nabugabo), and other efforts such as the River Nyando and Sondu-Miriu Conservation and Rehabilitation Project (LVFO 2000). LVEMP through its Wetland Management Component is also showing signs of success through the development of such strategies as the

Beach Management Units. The overall goal of setting policies by the East African governments is to promote the wise use and conservation of the East African wetlands so that their ecological and socio-economic functions are sustained for the present and future well being of the people.

Any attempt to conserve habitats and biodiversity in the lake can only be pursued successfully if the general environmental quality permits. Efforts to insure this should include the maintenance and restoration of water quality in the lake, its tributaries and associated wetlands. Toxic contamination should be kept within acceptable limits, and the nutrient (mainly phosphorus) level should be reduced to levels of before 1990 to halt and at least partly reverse eutrophication. To achieve this, we suggest that the lacustrine wetland fringe near densely populated, near-town and intensive agriculture areas be restored, and that there is an investment into modern sewage treatment plants. We suggest that a biological monitoring system be established, based on elements of the indigenous flora and fauna (e.g., Seehausen, 1999b). Such bio-monitoring systems are necessary complements to the conventional physical/chemical tests. The latter are snapshots in time, whereas bio-monitoring systems average environmental effects over longer time spans and thus have greater power as indicators of environmental change.

Adequate and timely water flow regimes are needed for the completion of the life cycle of many species of migratory fishes in the tributary rivers. Adequate water quantity is also needed for the protection of wetlands, and efforts to drain such areas for agricultural and urban use should be resisted. The impact of other users of the aquatic resources on fish assemblages reinforces the principle that any conservation policies must be integrated into the wider planning of all activities at the basin level.

Faunal Resurgence

The remnant populations of species that have persisted with Nile perch are extremely important because they are the seeds for recovery should predator pressure be reduced. In some lakes of the Victoria basin and some sections of Lake Victoria, overfishing has reduced numbers of large Nile perch and sparked a resurgence of indigenous species (Seehausen *et al*., 1997b; Witte *et al*., 2001). For example, in the Mwanza Gulf, Nile perch comprised 97% of bottom trawls in 1987 with a catch size of 208 kg h^{-1}; but by 1997, they comprised 76% of the bottom trawls with a catch size of 152 kg h^{1}, while haplochromines increased from 0.2% of the catch in 1987 to 21.3% of the catch in 1997 (Table 4). There is no doubt that this is a biologically filtered fauna, representing species that have persisted with Nile perch and species with the flexibility to respond quickly to reduced predator pressure.

In the sublittoral zone of the Mwanza Gulf, there has been a resurgence of some species of haplochromine cichlids, but only a few species in large quantities and only a few trophic groups, mainly zooplanktivores and detritivores (Seehausen *et al*., 1997, Witte *et al*., 2000). In Lake Nabugabo, overfishing of large Nile perch has also coincided with a resurgence of some endemic haplochromine species. In 1995, haplochromines were few in number and largely confined to the inshore areas of wetland ecotones. In 2000, haplochromines were abundant and had spread out

to occupy the inshore and offshore areas of wetland and exposed ecotones (Fig. 2). This overfishing-resurgence process represents a second "fishing-down" episode in Lake Victoria. The introduction of Nile perch and Nile tilapia temporarily reversed the fishing-down process that had occurred in the indigenous community. Overfishing of the large Nile perch is now leading to the exploitation of smaller Nile perch and smaller species.

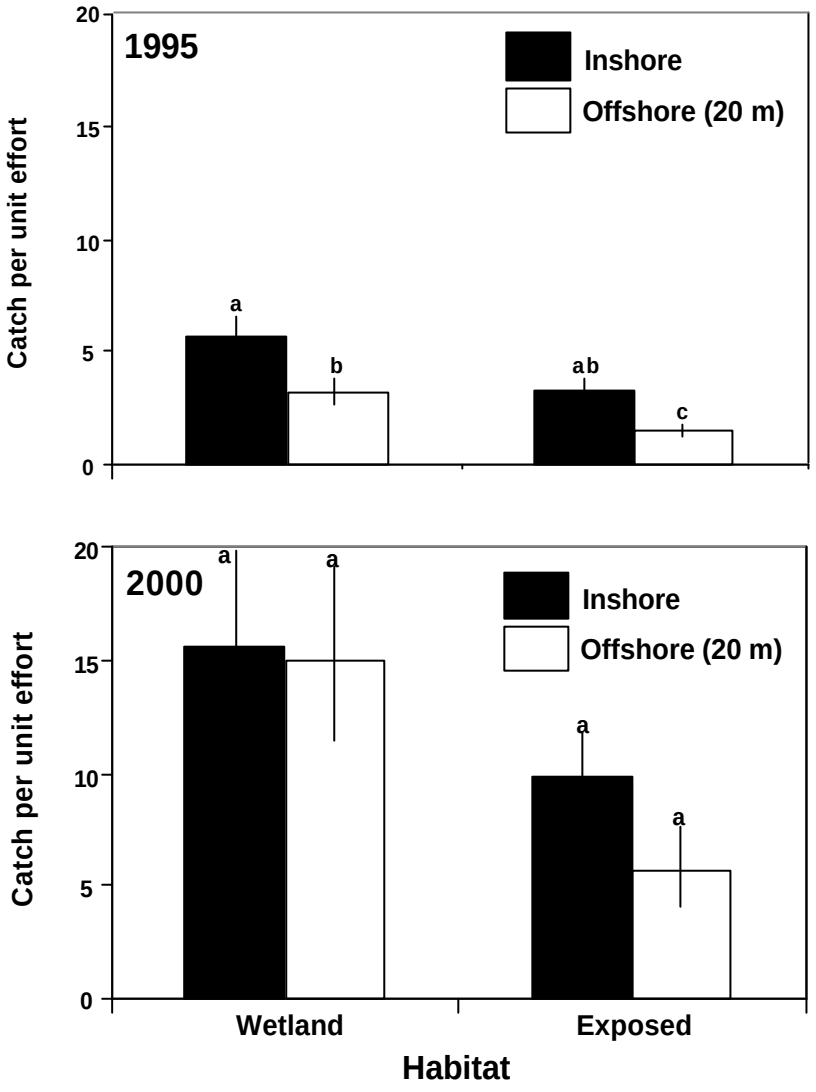

Fig. 2. The catch per unit effort of haplochromine cichlids (+SE) in the inshore and offshore (20 m offshore) areas of wetland and exposed ecotones in Lake Nabugabo, Uganda. Data were collected in 1995 (Schofield and Chapman 1999) and 2000 (Chapman *et al.*, unpublished data) using experimental gill nets. Bars that share the same letters are not significantly different at P<0.05.

Resurging populations in Lake Nagubabo, Mwanza Gulf, and other areas of the Lake Victoria Region will encounter an environmental milieu much changed from pre-Nile perch days, since only a subset of the basin fauna now exists. Thus, the post-Nile perch fauna will differ in composition and ecosystem function from the pre-Nile perch fauna (Seehausen, 1999a). The recovered food web may be very different from the pre-Nile perch food web. For example, resurging species may experience reduced competitive pressure for food resources, permitting either a higher level of specialization or, alternatively, a broader diet spectrum. In addition, some of the resurging species have survived in wetland refugia and offshore waters in the lake where they have experienced strong selection pressure for low-oxygen tolerance over several generations. For species that shifted to wetland refugia in response to Nile perch predation pressure, or which are recovering in the current hypoxic areas of Lake Victoria, we anticipate differences between the characteristics of pre- and post-Nile perch populations with respect to such characters as gill morphology, body size, and respiratory physiology. Preliminary observations revealed an increase in gill size in both *Rastrineobola argentea* (Wanink and Witte, 2000) and in the zooplanktivorous Haplochromis (Yssichromis) pyrrhocephalus (Witte *et al.*, 2000), but it is unknown whether this is due to heritable response to selection or due to environmentally induced phenotypic plasticity.

CONCLUSIONS AND RECOMMENDATIONS

The resurgence of some indigenous species that is increasingly evident in areas of Lake Victoria and Lake Nabugabo has given new hope for the maintenance of biodiversity in the system and a renewed interest in improved management options that promote sustainability of the fishery and biodiversity conservation. Resurgence data suggest that heavy fishing on the currently dominating species may enhance biodiversity. There is clearly a need to work out the fishing pressure that optimises both biodiversity and sustainability of catch.

A coherent plan for conservation and rehabilitation of the lake basin fish faunas should be developed without delay. The plan should include provisions for the setting up of reserves typifying the various habitats of the lake, its tributary rivers, associated wetlands and satellite lakes. It should also consider the human aspects of such reserves through consultation with local groups. The plan should be incorporated into more general policies for the management of the fishery and other water resources for the range of human activities in the lake basin. This will involve negotiation with all interested stakeholders. To aid in this process and in the formulation of strategies to reinforce conservation, efforts should be made to place financial and social value on the resources to be protected. The plan should be supported by education programs addressed to all levels of society aimed at clarifying the benefits of conservation and defining the processes needed to achieve it.

Macro-invertebrates Biodiversity in Satellite Lakes and Dams of Lake Victoria, Kenya

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SUMMARY

Preliminary survey was carried out in Lakes Sare, Kanyaboli and Simbi and in various dams viz: Mauna, Tinga (Migowa), Ugege, Uranga, Tinga (Kaleny juok) Mwer, Ulanda, Oyombe, Migowa, Kosiga, Kwambai (Ratanga), Gogo falls, Stella, Kokech and Kobodo dams. Both the benthos and macroinvertebrate associated with macrophytes were dominated by insects. In total, macrophytes had higher species richness than the benthic environment. Five Mollusca species that are potential vectors of various diseases of man, domestic animals and wildlife were among species collected. Low benthic species richness in the lakes and dams was observed. This was probably due to the homogenous substratum in the water bodies.

INTRODUCTION

Satellite lakes and dams of Lake Victoria harbour fish species which used to dominate the commercial fishery of the lake before 1980. The fishery of these satellite lakes has been proposed as possible source of stocking material for restocking L. Victoria with the native fishes which used form main stay of the fishery. Besides, there has been a suggestion to convert Lakes Kanyaboli, Sare and Simbi into national parks to preserve the lakes' rich biota (Muli, 1998). To ensure that restocking of Lake Victoria is successful and the parks are meet the objective for setting them, it necessary to plan carefully if success is to be realized. According to Cox (1998), environmental and ecological implications of stocking or introductions should be assessed first to avoid ecological catastophy. In view of fore mentioned reasons a study was initiated to establish the biodiversity of plankton, invertebrate and fish in the satellite and dams and the factors that influence their distribution. This information is necessary in understanding how the ecosystem of the satellite and dams works. Besides these data will be used to assess the implications of stocking or introductions fish to/from the satellite lakes and dams also to Lake Victoria. This paper presents preliminary results on the macroinvertebrates biodiversity in satellite lakes and dams of Lake Victoria, Kenya.

METHODS AND MATERIALS

Preliminary survey was carried out in Lakes Sare, Kanyaboli and Simbi and in various dams viz: Mauna, Tinga (Migowa), Ugege, Uranga, Tinga (Kaleny juok) Mwer, Ulanda, Oyombe, Migowa, Kosiga, Kwambai (Ratanga), Gogo falls, Stella, Kokech and Kobodo. Benthos were sampled using Ekman grab with a sampling area of 225 cm^2. Three grabs were taken per water body at

three sites. These sampling sites were located on line transect along widest length of each water body. That is, in middle and near edges on two sides of the water bodies. Organisms were separated from the collected sediment using sieves of mesh size 1 mm and 0.25 mm. **Macroinvertebrates associated with hyacinth** *Eichhornia crassipes* (Martius) Solms-Laubach were sampled by collecting the whole plant using handnet of mesh size 300µm. While macroinvertebrates associated with rooted floating plants were sampled by uprooting the whole plant by hand. Collected plants were carried to laboratory using in polythene bags. The organisms were separated from the plants by washing them using tap water under pressure over sieves 1 mm and 0.25 mm. In the field, specimens were fixed using formalin (10%). In the laboratory, all specimens were preserved in alcohol (70%) for identification later on. Organisms were identified to at least family/genus and abundance of each taxon was recorded. Identification keys of Pennak (1978), Mandahl-Barth (1973, 1988) and Brown (1994) were used. In parallel, water parameters, **dissolved O_2**, pH, temperature, conductivity, turbidity and transparency were measured at the same sites as the macroinvertebrates. The water parameters were measured at all sites at 1 meter intervals from the surface to bottom. Various meters were used to measure the water parameters. These were, for O_2 and temperature, model WTW Oxi 320, pH, model WTW 320/set^{-2}, conductivity, model WTW LF 96 and turbidity, model Hach 2100 P. The conductivity meter had automatic temperature compensation and the measurements were done at temperature 25 *C. Cell constant of the conductivity meter was 0.1 cm^{-1} * 2%. Transparency was measured using Secchi disk with black and white quadrants and a diameter of 20 cm. All the meters were calibrated before embarking on each sampling campaign. Sampling was carried out in January and March 1998 and again in March 2000.

To compare the macroinvertebrate diversity for the different water bodies, the species richness index, number of species (S) was used (Sheehan, 1984).

RESULTS

Species composition

All the water bodies sampled were characterized by black clay substratum with little plant detritus. The substratum was homogenous in all water bodies surface area.

Table1 lists the benthic macroinvertebrates collected in all the water bodies sampled. Overall twenty eighty taxa were collected during the sampling period. These fell within seven classes: Insecta, Crustacea, Oligochaeta, Hirudinea, Gastropoda and Bivalvia. Insecta dominated in species richness and abundance in all the water bodies sampled. Gastropoda, Bivalvia, Crustacea and Oligochaeta followed it in order of decreasing species richness. Species richness was very low all the water bodies. It ranged from 2 to 8. Most abundant species was brine shrimp Artemia salina Leach that was found only in the saline Lake Simbi. Other abundant organisms were the fresh water prawn, *Caridina nilotica* Roux and the dipteran, *Kiefferulus* spp. Common benthos were the dipteran, *Chironomus* spp. Meigen and the oligochaete, *Branchiura sowerbyi* Beddard. The other organisms were very rare. Of special interest in the list of fauna, are species that are potential vectors of various diseases of man, domestic animals and wildlife. Gastropods, *Bulinus globosus* Morelet and *Biomphalaria pfeifferi* Krauss that are vectors of various flukes which

Table 1. Occurance of Bethic macro-invertebrates in the different water bodies sampled

Taxa	S	Ka	Si	Ma	Ug	Ur	Kal	Mw	Ula	Oy	Ko	Mi	Kw	Kob	Kok	St	Go
Ephemeroptera (Nymph)																	
Callibaetis spp.								VR									
Odonata (Nymph)																	
Libellula spp.								VR									
Nehallenia spp.	VR							VR									
Enallagma spp.								VR									
Anax spp.																VR	
Coleoptera (Adult)																	
Agabus spp.			RR			VR											
Cybister spp.														VR			
Hemiptera (Nymph)																	
Micronecta spp.	VR			VR									VR	VR			
Cryphocricos spp.		VR															
Macrovelia horni				VR													
Trichoptera (Larvae)																	
Phylocentropus spp.	VR																
Tinodes spp.															VR		
Diptera (Nymph)																	
Kiefferulus spp.	CM	VR	AD			VR			VR	VR	VR	VR	VR		VR		
Chironomus spp.		VR	CM							VR	VR		VR		VR	VR	VR
Palmyia spp.	VR						VR					VR					
Gastropoda																	
Melanoides tuberculata					VR		VR								VR		
Pila ovata				VR													
Bellamya unicolor				VR													
Bulinus globosus				VR		VR											
Biomphalaria pfeifferi				VR													
Lentorbis junodi				RR													
Lymnaea natalensis				VR													
Bivalvia																	
Mutela spp.					VR												
Spathopsis wahlbergi																VR	VR
Hirudinea					VR												
Oligochaeta																	
Branchiura sowerbyi	CM	AD							VR								
Crustacea																	
Caridina nilotica				AD													
Artemia salina			AD														

S= Lake Sare, Ka = Lake Kanyaboli , Si =Lake Simbi, Ma = Mauna dam, Ug = Ugege dam, Ur = Uranga dam, Kal = Kaleny juok dam, Mw = Mwer dam, Ula = Ulanda dam, Oy = Oyombe dam, Ko = Kosiga dam, Mi = Migowa dam, Kw = Kwabwai dam, Kob = Kobodo dam, Kok = Kokech dam, St = Stella dam, Go = Gogo falls dam.

cause Schistosomiasias and Paramphistomiasis in man and his livestock were collected (Brown 1994). Another mollusc, *Lymnaea natalensis* Krauss which is vector of flukes which cause Fascioliasis, was also collected. *B. globosus* is vector of *S. mattheei* which infects sheep and man, though the infection in man are low.

Biomphalaria pfeifferi is vector of *Schistosoma mansoni* Sambon, *Schistosoma rodhaini* Brumpt and *Paramphistomum sukari*. While *Lymnaea natalensis* is vector of *Fasciola hepatica* Cobbold and *Fasciola nyanzae* Leiper. *F. hepatica* infects Cattle, Sheep, Buffalo, Wildbeetlees, Kob, Eland, Hartebeestes and Warthogs in the Lake Victoria catchment (Brown 1994). In Kenya prevalences of upto 20% in bovines have been reported by Preston and Castelino (1977). *F. nyanzae* infects Hippopotamus. In Lake Victoria prevalence reach almost 100% (Brown 1994).

Macroinvertebrates associated with water hyacinth are listed in Table 2. Twenty four taxa were collected during the sampling period The common taxa were ephemeropterans and dipterans. They contributed 38% and 38% respectively out of the total abundance of phytofauna on hyacinth collected. The common taxa were *Povilla adusta* Navás and *Chironomus* spp. The other taxa were either rare or very rare. Two gastropods, *Bulinus globosus* Morelet and *Lymnaea natalensis* Krauss that are vectors of Schistosomiasias and Fascioliasis respectively were also collected.

Out of all the water bodies sampled, only one taxa, *Parargyractis* spp (Lepidoptera) was found associated with the water lily (*Nymphaea violacea)* at L. Sare.

Physical and Chemical water characteristics of satellite lakes and dams

Mean (± S.E) values of various water physical and chemical water parameters measured for all the water bodies during the study are listed in Table 3. There was no stratification in all waterbodies except in L. Simbi. This is due to the shallowness of the water bodies such that there was mixing on a daily basis. Therefore mean values were determined for the depth profiles for all parameters for the water bodies were there was no stratification. Oxygen and temperature in Lake Simbi showed stratification. So, the mean values for surface and bottom water were determined separately for these two parameters. The values obtained were generally not substantially different from those of Lake Victoria except those of the saline Lake Simbi.

DISCUSSION

Most of the macroinvertebrates collected from satellite lakes and dams have been reported before as forming important food items of most fish species in the Lake Victoria (Corbet, 1961). However the species richness and abundance of the benthos in satellite lakes and dams is very low compared to that of Lake Victoria (Muli & Mavuti 1999). The water quality is not responsible for the low species richness and abundance of the benthos in satellite lakes and dams because it was not substantially different from those of Lake Victoria. Differences in the substratum could account for differences in species richness. Lake Victoria has heterogenous substratum (Muli, 1998) while that of satellite lakes and dams was homogenous.

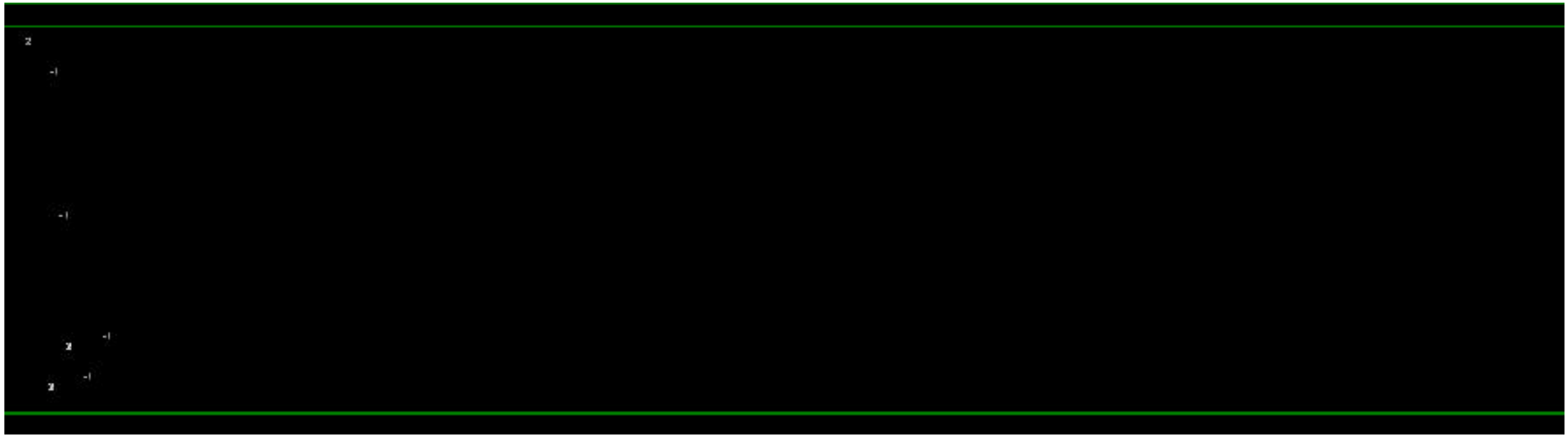
Table 2. Relative abundance of macroinvertebrates species associated with Water hyacinth collected from Lake Sare during the study period

Taxa	Relative Abundance
Ephemeroptera (Nymph **)**	
Povilla adusta	CM
Cloeon spp.	RR
Caenis spp.	VR
Odonata (Nymph **)**	
Libellula spp.	VR
Nehallenia spp.	VR
Coleoptera (Adults**)**	
Hydrochara spp.	VR
Gyrinus spp.	VR
Cybister spp.	VR
Bidesus spp.	VR
Laccodytes spp.	VR
Coleoptera (larvae**)**	
Gyrinus spp.	VR
Hemiptera (Nymph **)**	
Micronecta spp.	VR
Cryphocricos spp.	VR
Pelocoris spp.	VR
Macrovelia horni	VR
Trichoptera(Nymph **)**	
Cynerllus spp.	VR
Diptera (Larvae**)**	
Kiefferulus spp.	VR
Chironomus spp.	CM
Tipula spp.	VR
Gastropoda	
Bulinus globosus	VR
Lymnaea natalensis	VR
Hirudinea	VR
Oligochaeta	
Alma emini	VR
Acarina	
Araneae	VR
Crustacea	
Caridina nilotica	VR
Ostracoda	VR

Key for Abundance classification

AD - abundant > 60%
VC - very common 40-60%
CM - common 20-60%
RR - rare 10-20%
VR - very rare <10%

Table 3: Physical and chemical characteristics water (mean ± S.E) of the satellite lakes and dams



Key: ND - Not determined, 7.2(S), surface value, 2.2 (B) bottom value

S= Lake Sare, Ka = Lake Kanyaboli , Si =Lake Simbi, Ma = Mauna dam, Ug = Ugege dam, Ur = Uranga dam, Kal = Kaleny juok dam, Mw = Mwer dam, Ula = Ulanda dam, Oy = Oyombe dam, Ko = Kosiga dam, Mi = Migowa dam, Kw = Kwabwai dam, Kob = Kobodo dam, Kok = Kokech dam, St = Stella dam, Go = Gogo falls dam.

The low benthic species richness and abundance implies that amount of food available to the fish is low. Thus it is likely that fish production in the satellite lakes and dams is low (Manson & Leggat, 1982).

Lake Simbi of late has attracted attention due to the presence of flamingoes (*Phoenicopterus minor* and P. ruber), which migrate to this lake from Lake Nakuru. This is new phenomenon and has led to the suggestion to convert this lake into National Park. Besides this lake has unique bird species richness in that eleven of the birds are the European migrates (Boera 2000 pers. comm.). This further increases the value of lake. The birds' species richness and abundance can be improved by introducing fish species *Oreochromis alcalicus grahami* (Boulenger), as was done for Lake Nakuru (Trewavas 1983). *Oreochromis a. grahami is* voracious feeder of the brine shrimp *Artemia salina* Leach. Fairy shrimps can usually withstand predation from amphibians and carnivorous insects, but are soon eradicated in the presence of fish (Edmondson, 1959). Therefore, if the fish is introduced into this lake it would eradicate all shrimps. Absence of fish in this lake explains the high abundance of the shrimp. Lake Simbi has very narrow littoral zone and pelagic zone is very deep (depth 10-27 m). Thus the feeding ground of flamingoes is very small compared to that of Lake Nakuru which is shallow (Zm = 2.8 m). These physical characteristics perhaps have prohibited the flamingoes from establishing themselves to level of population found in Lakes Nakuru and Bogoria. This is in spite of presence dense crops of their food, the planktonic cynabacterium *Spirulina platensis* (Norst.) Geitl. in the lake. More and detailed studies are required to understand the Lake Simbi ecosystem. This lake is still unpolluted and therefore can serve as a control to the other lakes Magadi, Natron, Nakuru and Bogoria, were flamingoes migrate to and fro. This is important because the phenomena governing the migration of the flamingoes is still not understood and is understudy (Githaiga, 1999 pers. comm.). This information is crucial in deciding on whether to conserve lake as a national park or not.

Gastropods that are vectors of diseases have been reported before inhabiting macrophytes or the benthic environment in the Lake Victoria. Brown (1994) has summarized detailed information on the vectors and their epidemiology. Water hyacinth is likely to increase the abundance, diversity and distribution of these vectors. The hyacinth plant has several characteristics, which enable it to spread vectors. It is a well-known fact that higher density of invertebrate inhabits vegetated areas relative to unvegetated area. Brown & Lodge (1993) attributed this is phenomena to the fact that vegetation adds colonizable surface area to the bottom of a lake. Hyacinth has a mass of finely divided roots with luxurious growth of root hairs (Laal, 1989). These roots provide a large surface area and protection to the associated fauna from predation. Due to its migratory nature, hyacinth is likely to spread Mollusca vectors associated with it to areas hitherto uninfestated. Transmission of Fascioliasis in Uganda is limited by the rarity of *Lymnaea natalensis* in the dense stands of papyrus that commonly fringe the rivers and cover swamps (Ogambo-Ongoma 1972). In Sudan, Wright (1976) attributed the northern advance of *Bulinus ugandae, Bulinus truncatus* Andouin and *Biomphalaria sudanica* Martens to spread of *Eichhornia*. Likewise, hyacinth infestation in the Lake Sare is likely to increase the occurrence of Fascioliasis and Schistosomiasis in lake and its catchment.

Satellite Lakes, Rivers And Dams as Relics of Lake Victoria

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SUMMARY

Satellite lakes, rivers, ponds and dams provide the best reflection of the pre-Nile Perch Lake Victoria. Some fish species currently known to be rare in the main lake as a result of predation or environmental perturbation are represented in quite a number of satellite lakes and several other small water bodies in the lake basin. The small sizes and impenetrable thick vegetation cover around the satellite lakes, river systems and wetlands in general, render these ecosystems suitable and manageable microhabitats that act as refugia for a number of species. The diverse small water bodies and swamps which boarder them are potential sites for biodiversity conservation. Swamps are normally characterised by severe oxygen depletion, high structural heterogeneity of associations of Vossia cuspidate, Phragmites mauritanius and Typha domingensis that act as natural barriers to excessive exploitation and predation from the main lake predators. The paper is a result of exploratory surveys made in 25 habitats highlighting the species composition and the fishery of the satellite lakes. A conservation strategy for cost effective and sustainable utilisation is presented.

INTRODUCTION

The direct and indirect causes of decline in biodiversity in Lake Victoria has been a subject of study for sometime. The direct mechanisms involved include habitat loss due to human interventions that result in fragmentation, physical alterations of the habitats, over-exploitation of the resources with no scientific backing, pollution, introduction of alien species (Ogutu-Ohwayo, 1988) and global climatic changes. The proximate threats seem to originate from high rates of human population growth and lack of economic policy that value the environment and its resources. Satellite lakes, rivers, ponds, dams and floodplains have been singled out as important faunal reservoirs for Lake Victoria endangered species. Some fish species currently known to be rare in the main lake are represented in isolated groups of small water bodies in the Lake basin. They form microhabitats that act as temporary fish feeding habitats, for breeding and nurseries for a number of fish species. Predators like the Nile perch find it very difficult to penetrate the interwoven mats of macrophytes that boarder the majority of the small lakes. The wetland cover, which is normally associated with the satellite lakes, plays a very important role in regulating and controlling the activities in these water masses (Carter, 1995). Apart from acting as shelter, satellite lakes can be considered as natural conservation units that should be protected for scientific, cultural and recreational attractions. The paper gives a scope of the satellite lakes in the Tanzanian basin, analysing their potential for harbouring the endangered species in the main lake.

MATERIALS AND METHODS

Field trips to the satellite lakes were made by road transport. Samples were collected from the catches made by the fishermen and in places were it was possible experimental fishing was conducted using gillnets of meshes ranging from 1" to 3.5". Specimens were collected and identified to species level from all the localities in satellite lakes, rivers, ponds dams and floodpools.. Where commercial exploitation of the species existed weight composition by species was complied to give percentage composition of the catches per waterbody that was visited. Formal discussion with the riparian communities and the fishermen were conducted to raise awareness on the values of the small lakes and strategies to conserve them. Characterisation of the wetlands and the macrophytes that surround them was made and their role as hiding places for the juvenile fish and prey species was evaluated.

RESULTS

The scope of satellite lakes and their biodiversity potential

Table 1 gives a checklist of the satellite lakes, rivers, ponds and dams with the associated fish species. 25 small water bodies with more than 30 species of fish have been identified. These range from small water bodies such as minor temporary flood pools to big lakes like Burigi, Rwakajunju and Ngoma that support small-scale fisheries for the riparian population. Several temporary tributaries join either the main rivers or small lakes and connect to the main lake during the wet season. There are a number of lakes and freshwater marshes occur in the basins of the major rivers. For instance River Kagera forms several oxbow lakes with heavy cover of *Cyperus papyrus* around them. These include Lakes Ngoma, Rushwa, Katwe, and Kalenge. Similar lakes appear at Buswahili and Kirumi along River Mara.

The association of the lakes with river systems is important in that they have a permanent water supply and constant restocking of the species in case of over exploitation. The river systems in the lake basin is diverse and has a potential for biodiversity conservation. The surrounding vegetation cover comprising of *Cyperus, Phragmites, Typha,* and *Vossia* provides shelter and breeding refugia for a number of species. Floating macrophytes like *Lemna, Pistia, Nymphaea, Ceratophyllum* and *Potamogeton* occur invariably on the fringes of the wetlands that surround the satellite lakes. They form stable communities with floral characteristic features. In certain areas the swampy vegetation includes a mixture of higher plants like *Sesbania, Hibiscus, Mimosa, Miscanthidium* and *Ipomea* which have medicinal, economic and biological values.

The satellite lakes and wetland ecosystems are characterised by some features that are of economic value. The dense vegetation around the Satellite lakes changes the environmental conditions compared to open lake and hence preserve the gene pool by providing physical barriers to exotics. The habitats provide shelter and feeding opportunities for fish and nurseries for the young. The interwoven mats of vegetation cover retain a lot of nutrients that have agricultural value. They are also a source of water for both the domestic and livestock use Balirwa (1998).

Table 1. Check list of species collected from satellite lakes, rivers, ponds and dams.

SPECIES:	Kis.	Masi.	Bita	Rwak.	Rub.	Mar.	Kyr.	Kiag.	Bur.	Ikim.	Ka/Ru.	Ngon	Rus.	Kal.	Mal	Sim.	Lam.	San	Gan	Gil	Kir.	Nya	Mas.	Mag.
Lates niloticus (Linnaeus 1958)						x										x								
Brycinus jacksonii (Boulenger, 1912)		x		x							x							x						
Oreochromis esculentus (Graham 1928)	x				x							x		x	x			x		x	x		x	x
O leucostictus (Trewaras 1933)		x	x			x	x	x	x	x	x	x		x				x			x		x	
O. niloticus (Linnaeus 1757)	x	x		x		x	x	x	x	x	x	x		x		x	x	x	x	x	x	x	x	x
O. variabilis (Boulenger, 1896)	x								x	x								x			x			
Tilapia rendalii (Boulenger 1896)	x	x																x						
T irapia zilii (Gervais, 1848)					x	x	x																	
Haplochromine sp.	x		x		x			x							x		x	x			x		x	
Clarias gariepinus (Burchell, 1815)	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x
Clarias alluadi (Boulenger 1906)								x											x					
Labeo victorianus (Boulenger 1901)		x		x	x	x	x			x	x							x						
Barbus sp.				x							x	x										x	x	x
Protopterus aethiopicus (Heckel 1851)		x	x	x		x	x	x	x	x	x	x		x	x	x	x			x	x	x	x	x
Synodontis victoriae (Boulenger 1906)		x			x												x	x						
S. afrofischeri (Hilgendorf, 1888)											x						x	x	x				x	x
Petrocephalus catostoma (Gunther 1866)									x	x	x										x			
Mormyrus kanume (Forsskal 1775)	x								x		x	x				x					x			
Marcusenius victoriae (Worthington (1929)							x			x						x								
M. nigricans											x							x	x			x	x	x
Schilbe mystus (Linnaeus, 1758)		x		x			x				x						x							
Bagrus dokmac (Fors skal 1975)											x													
Afromastercembelus frenatus (Boulenger, 1901)									x	x	x	x						x						

Dam

Kyr:: Kyarano

Lakes

Bita.: Bitaraguru
Mil.: Mwilindi
Bur.: Burigi
Ikim. Ikimba
Rus.: Rushwa Sim.: Simiyu
Kal.: Kalenge
Mal.: Malimbe
Masi.:Masirori

Rivers

Rub.: Rubana
Mar.: Mara
Ka/Ru.Kagera/Ruvuvu
Ngon.:Ngono
Lam.:Lamadi
Gan.: Gangala
Mas.:Masuha
Mag.:Magogo

Pond

Kis.: Kisamba
Nya.: Nyambiti
San: Sangayeka
Gil.: Giligita

Flood pools

Kiag.: Kiagata
Kir.: Kirumi

There are also specific groups of algae, microphytes, zooplankton, macroinvertebrates, amphibians, reptiles, birds and higher vertebrates that are associated with the satellite lakes and rivers and have been found to provide recreational affinities.

It has been found that major threats facing the river these lakes include, increase in population and demand for food, whereby the fringe vegetation is being cleared for agricultural activities, industrial effluents like those from the coffee and fish processing plants, getting direct access to the rivers and later into the flood plains, deforestation and farming on the river banks leading to soil erosion that cause siltation on the riverbed and at the entrance to the main lake. Fishing with banned gears at the river mouths whereby riverine fishes are caught while moving up stream for breeding is a common practice that is observed on several places.

Dams, which are normally constructed with the purpose of irrigation and getting water for domestic purposes and power generation, are also known to harbour quite a number of species. Kyarano dam on the Tanzanian side has been found to comprise a number of species that have origin in the two inlet rivers.

The fishery potential

The shoreline regions of the Lake Victoria and basin lakes have for a long period been identified as suitable habitats for tilapiines species particularly *O.niloticus*. (Graham, 1929; Lowe-McConnell, 1958, 1975); Welcomme, (1965, 1966), Kudhongania and Cordone (1974). In almost all the places visited, tilapiines species were encountered (Table 1). The permanent big rivers like Kagera and Mara and the associated lakes, wetlands and floodplains, are found to have either high species diversity or large catches of individual species that support small scale subsistence fisheries practised by the surrounding population. These include Lakes Masirori, Kalenge, Rushwa, and Katwe from which *Oreochromis niloticus, O. leucostictus, Clarias alluadi, C, gariepinus, C. wernei, Protopterus aethiopicus, Labeo victorianus, Synodontis afrofischeri* and *S. victoriae* are exploited

River Simiyu and Rubana on the other hand have a very high fishery potential of the anadromous species. High quantities of *Schilbe intermedius, Synodontis victoriae, S.afrofischeri Brycinus jacksonii* and several representatives of mormyrids are caught during the rainy season while swimming upstream for breeding. The two rivers are however faced with the problem of high siltation. Land use practices and clearing of the fringing vegetation for agriculture along the riverbeds have been found to distort the habitats for fishes through dissipation of alluvial soils as a result of drainage. This destroys the breeding nets of the tilapiines along the river shorelines and the entrances to the main lake.

Burigi which is the largest lake on the Tanzanian side, supports a very big fishery based on *O.leucostictus, O.niloticus, O.variabilis, O.microchir, Clarias gariepinus, Protopterus aethiopicus, Petrocephalus catastoma, Mormyrus kannume* and *Afromastercembelus frenatus*. The high diversity is however a result of the conservation programs in the game reserve where much the lake area falls. Fishing activities are restricted and this gives relief to the exploitable population. On the otherhand, Ikimba, which is the second largest Satellite Lake, has very low fish diversity. An average of 2-3 kg of fish per boat is landed. Quite a number of fishermen have switched to farming for their livelihood.

Lake Malimbe is very close to Lake Victoria and is unique in the sense that with only a few meters from the main lake has over 70% of its catch comprised of Oreochromis esculentus, which is completely lacking from Lake Victoria. Other species caught include *Protopterus aethiopicus, Clarias gariepinus* and some haplochromines. However the fishery is poorly developed making use of floating rafts with 3 inch gill nets. The oxbow lake at Buswahili along river Mara has been noted for high catches of *O.leucostictus*. The six species normally caught in the area are represented with their relative quantities in per average catch in percentages. These comprise of *Schilbe intermedius*, (0.03%) *Marcusenius victoriae* (1.1%), *Clarias gariepinus* (22.5%), *O.niloticus* (17.4%), *P.aethiopicus* (19.1%), and *O.leucostictus* (39.7%). In almost all the lakes visited species that had the universal occurrence included the tilapiines, *Clarias*, and *Protopterus*. In general the fishing technologies on the satellite lakes is very primitive. The mesh sizes in use vary from 2-3 inches and longlines with hooks of sizes 9,10,11 and 12 are variably used for catching *Clarias* and *Protopterus*.

The fishing crafts in use range from simple rafts to dugout canoes, which are not very, secure. There are no regulatory measures on the gear sizes and the fishermen take full control of the mesh sizes depending on the available exploitable sizes. The prevailing water splashing method (Katuli) still puts the situation in the lakes worse due to the distracting nature of the method. Further to this the blocking of the river mouths with weirs to catch the breeding population of the anadromous species that climb upstream for breeding adds more pressure to the stocks. However the influx of fishermen to most satellite lakes is hampered by the impenetrable nature of the wetlands that surround them. Accessibility to the lakes is very difficult and this allows few people to the exploitable areas.

The Conservation Strategy

The loss of genetic, species and ecosystem diversity in Lake Victoria is compounded by growing exploitation of the fisheries resources increase in the human population activities to meet socio-economic needs the natural resources. Habitat and niche changes as result of introduction of alien species have also contributed to the decline of biodiversity in Lake Victoria. Balirwa (1998) the biological diversity in the satellite lakes is still very high and for a great part virgin due to the buffering capacity of the dense macrophytic cover of the swampy surroundings. The swamps are characterised by severe oxygen depletion high structural heterogeneity in which association of *Vossia cuspidate, Typha domingensis* and *Phragmites mauritanius* intermingle at various localities. There is a dense intermingling from the interior to the open water Carter (1955), Chapman & Lien (1955). The wetland seem to play an important role as shelter against *Lates* predation for a number of fishes in the satellite lakes since the Nile perch seems to be relatively intolerant of extreme hypoxia. Despite the natural conservation barriers the satellite lakes and wetlands in general are faced with threats that include clearing of the wetlands for agriculture and harvesting wetland forestry resources, exploitation of the fisheries, discharge of the waste waters from the industries to the rivers and land use practices that result into siltation.

CONCLUSIONS

Efforts should be made that will act as incentives for conservation and sustainable use of biodiversity components of the wetlands and satellite lakes. While devising the conservation plan, the following issues need to be addressed:

a) There should be full participation of the local people in the whole process of conservation, including decision-making.

b) The beneficiaries should be educated so that they appreciate the benefits and comprehend the techniques of conservation and sustainable use.

c) The economic advantages gained from the conservation should be shared equally among the members implementing the conservation programme.

d) The local people should be assisted in the provision of alternative means of survival where strict or special measures are to be applied to conserve biodiversity.

e) Provision has to be made to establish community-based committees that will serve as forums for identifying problems and dealing with them at their own level.

Investigation into the effect of salt treatments in reduction of post-harvest losses of Nile perch (*Lates niloticus* [Linn]) during smoking and storage.

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SUMMARY

Nile perch (Lates niloticus) constitute 50% of total landings in Kenya. The bulk of Nile perch is harvested from Lake Victoria whose landings contribute 92% of total fish production. Fishermen, processors and traders experience post-harvest losses of Nile perch. The heaviest losses occur during the rainy season, which corresponds, to the period of optimum productions. The major causes of post-harvest losses of Nile perch were found to be bacterial deterioration, blowfly larvae infestation, moulds and fragmentation. Salting of fish in brine concentration of 20% (w/v) before smoking, resulted in smoked product having salt content of at least 10% wwb. This concentration was found to reduce fragmentation during smoking; inhibit blowfly larvae infestation, delay and reduce beetle larvae infestation during storage. The salting process reduced moisture content, water activity of flesh and appeared to retard microbial spoilage. There was a slight reduction in protein and lipid contents on dwb after the smoking process.

INTRODUCTION

Nile perch in Kenya is found in lakes Victoria and Turkana. Since 1981, the production of Nile perch from Lake Victoria has been steadily and presently contributes approximately 50% of the total fish landings in Kenya. Lake Turkana contributes only 3% of the total Nile perch produced in the country.

On average, 55% of total Nile perch landed in Lake Victoria is processed for export. Substantial amount of Nile perch landed are cured using traditional processing methods, which include smoking, frying in own oil and sundrying. Brining is not commonly practised especially in the Lake Victoria region.

Post harvest losses of cured fish occur during processing and most significantly during storage. The major causes of post harvest losses include blowfly infestation, moulds, bacterial, fragmentation and beetle infestation.

It is against this background that the present work was undertaken with the aim of using salt to reduce post harvest losses of smoked fish.

MATERIALS AND METHODS

The following materials were used:

Fish: Fresh Nile perch weighing approximately 3 kg purchased from landing sites.
Salt: common cooking salt
Firewood: for smoking was from Acacia species.
Equipment: - Traditional smoking kiln.
- Novasina humidity and temperature.
- Measuring instruments for water activity.

The methods used included:

Fish preparation

All fish used in this study were weighed individually and standard lengths recorded. They were then split open along the backbone, gutted, cleaned, cut into two i.e. head and tail (**Plate 1**) and re-weighed.

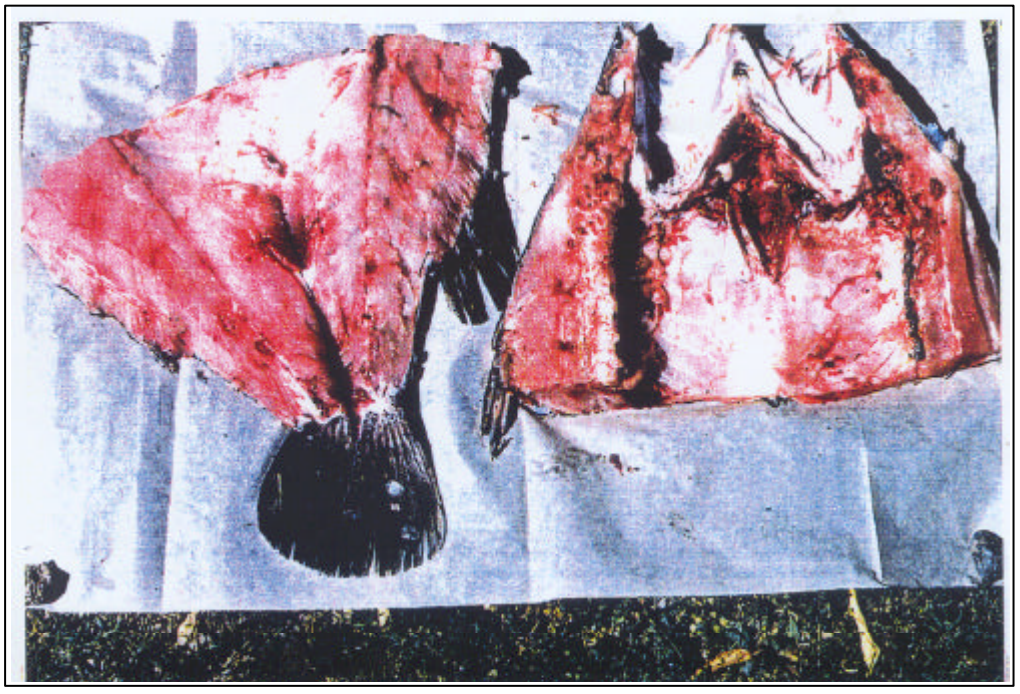

Plate 1: Dressed Nile Perch ready for smoking

Brining

Gutted and split open fish were immersed in their respective brine solutions ranging in concentration from 0% to 25% w/v and left overnight (approximately 19 hours). After brining, the fish were drained and one fish from each salt treatment was used for water activity, moisture and fat analysis. Samples from 0 (unsalted) and 15% (salted) brined fish were also analysed for protein. The rest of the fish were left to dry in the sun for 2 hours before the smoking process.

Smoking

The brined fish were loaded into a traditional smoking kiln (**Plate 2**) and smoked for about l0 hours. After smoking, the fish were individually re-weighed. Samples from all the treatments were analysed for water activity, moisture and salt. Samples brined in 0% to l5% salt concentration were also analysed for protein.



Plate 2: Traditional smoking kiln "Lunyo" found in Kenya

Storage

All fish were stored in a well-ventilated room, with average temperature of l9 °C and 38% humidity for 3 months.

Quality Assessment

At daily intervals, the quality of the fish was assessed visually with particular attention paid to presence or absence of beetles, blowflies and their larvae.

Analytical Procedures

Moisture

Oven drying method was used for determination of moisture content.

Water Activity

Water activity was determined by using Novisina Aw meter, whose readings were taken at 25 °C every l5 minutes until 2 consecutive readings were constant.

Lipid Content

Bligh and Dyer (l959) method as modified by Hanson and Olley (l963) was used.

Protein Content

Total nitrogen was determined by micro kjeldahl method from which % crude protein was calculated.

Salt Content

This was determined by titrating against Silver nitrate using potassium chromate as indicator (FAO, 1981)

RESULTS AND DISCUSSION

Moisture and water activity

Overnight salting with 15% brine significantly reduced the moisture content and water activities of fresh fish from 77.5% and 0.99 to 74.5% and 0.95 respectively ($p<0.001$ and $p<0.005$, respectively, student t-test), as shown in Table 1.

Table 1: Effect of brine concentration on moisture, salt content and water activity of Nile perch flesh.

Brine conc. %	Before smoking				After smoking			
	Salt content %		Moisture cont %	Aw	Salt cont %		Moisture content %	Aw
	Wwb	dwb			wwb	dwb		
0	0.45	1.6	78.7	0.99	1.2	2.0	39.9	0.95
10	5.4	22.2	75.7	0.95	6.1	10.8	43.4	0.9
15	7.5	26.1	71.3	0.95	9.9	13.5	26.9	0.8
20	8.4	28.8	68.7	0.95	12.5	16.2	22.8	0.73
25	11.2	35.3	68.3	0.93	12.4	17.4	29.1	0.83

Figures are means of 5 determinations (duplicate estimates on two fish)

The salted fish showed no signs of spoilage after overnight brining, compared with unsalted fish which had deteriorated as a result of microbial spoilage. Although some osmotolerant bacteria can cause spoilage below water activity of 0.95, those responsible for spoilage of fresh fish require a higher water activity of about 0.98 for rapid growth (FAO, 1981). The water activity in the case of salted fish in these trials was reduced to 0.95 (Table 1) and this appears to have inhibited bacterial growth in the overnight brined fish.

Salting and smoking further reduced water activity to 0.76, whereas smoking without salting reduced it to 0.91. The difference was statistically significant ($p<0.005$, student t-test). Additional salt lowers the water activity, and this explains why salted fresh and smoked fish had lower water activity compared with unsalted fish. However, the water activity did not decrease significantly with increase in salt concentrations from 15% to 25% (Table 2).

Table 2. Proximate composition and water activity of flesh of Nile perch before and after hot smoking.

Sample	Moisture cont %	Protein cont. %		Lipid cont %		Salt cont. %		Aw
		wwb	dwb	wwb	dwb	wwb	dwb	
Unsalted before smoking	77.5	17.2	77.3	4.7	21.1	0.3	1.3	0.99
Salted before smoking	74.5	17.3	69.5	5.3	11.6	4.3	17	0.95
Unsalted hot smoked	31.1	48.8	70.8	13.6	19.7	1.2	1.7	0.91
Salted hot smoked	29.8	45.9	65.5	8.9	12.7	7.1	10.1	0.76

1. *The figures shown are means of 12 determinations (duplicate on each of 6 fish).*
2. *The salted and unsalted Nile perch had been immersed in 15 and 0% brine concentrations, respectively overnight, before smoking.*

The salt content in the fish flesh after brining, but before smoking increased with increase of brine concentration used, and the higher the salt content the lower the moisture content (Table 1).

Protein content

Table 2 shows that salted fish have lower protein and lipid contents when expressed on a dwb compared with unsalted fish. This is as expected due to additional salt content in the flesh. Salt denature protein and Mackerel protein is denatured completely at 15% salt concentration (Akande, Knowles and Taylor, 1988).

Yield

After the smoking process, the yield of salted fish was higher 35.9% wwb than that of unsalted fish (29.6% wwb) (Table 3). The difference was statistically significant (student t-test, $p<0.025$).

The higher yield of salted fish compared with unsalted fish, may be partly attributed to the fact that salted smoked fish tended to fragment less than unsalted and also partly due to salt content, associated with greater retention of water. The yield of unsalted fish may not bring any financial benefits to the processor since smoked fish in Kenya is sold per piece rather than by weight.

Fragmentation

Immediately after smoking the Nile perch and also during storage, it was noted that the unsalted fish appeared more prone to fragmentation than the salted. The smoked salted fish flesh appeared very firm and much more appealing than the salted (Plate 3)



Plate 3: Unsalted smoked (US) and salted (SS) Nile Perch immediately after processing

The textural damage of unsalted fish flesh was probably due to microbial spoilage during overnight immersion in water, which may have increased the tendency for the final product to fragment (FAO, 1981). Salting denatures protein giving it firmer texture.

The firm, less fragmented texture of salted, smoked fish, may fetch the processor more money since unfragmented pieces of fish tend to be higher priced than fragmented pieces in Nigeria (Moes, 1980). However, consumer acceptability of salted fish would also have to be taken into consideration.

Table 3: Yields of unsalted and salted Nile perch after smoking.

	Unsalted	Salted
Weight of fresh fish (Kg)	3.5	3.6
Weight after processing (Kg)	1.0	1.3
Moisture in flesh after processing %	31.1	29.8
Processed yield % wwb	29.6	35.9

Blowfly infestation

Before smoking

When the fish were left to dry in the sun after brining, it was noted that blowflies crowded on unsalted fish, but a few settled on the salted fish. After 2 hours of sundrying, before smoking blowfly egg batches were noticed on the head sections of unsalted fish, but none on salted fish.

During Storage

Between 5 and l0 days of storage, some larvae were observed in smoked fish that had salt content 5.2% wwb or less and moisture content above 42.4% . The larvae were reared to adult stage and identified as those of Lucilia cuprina (wied). The same species was found infesting cured fish in Indonesia (Esser, Hanson and Taylor, 1985). These results imply that the eggs were laid on smoked fish after processing and more likely during storage. It is apparent from these results that moisture content is critical to survival and growth of fly maggots in unsalted and lightly salted fish products. Moisture content below 40% appears detrimental to larval survival. However, this moisture content concept may not apply to heavily salted fish products. McLellan (1963), Green (1967) and Mills (1979) noted that blowflies were not attracted to salted fish, regardless of moisture content. However in South East Asia, blowflies will feed and reproduce in fish whose salt concentration is as high as 40% dwb (Esser, 1988a; UNIFEM, 1988).

Beetle infestation

Dermestid beetle adults began to appear on all the unsalted fish after 32 days of storage. Larvae were noticed after 46 days of storage (Table 4). The beetles were identified as *Dermetes maculatus*. Beetles attacked salted smoked fish, which had salt contents 5.2 wwb or less within 8 weeks of storage. No beetles or their larvae were noticed in fish that had salt content in excess of 10% wwb until after 20 weeks of storage (Table 4). After 12 weeks, of storage the unsalted fish flesh had been reduced to dust like particles, which according to Osuji (1973) consists mainly of insect excrement (Plate 5). There was little damage to the flesh of fish with salt content > 6.1 % wwb after 12 weeks of storage, probably due to the late onset of beetles (Table 4). This agrees with observation FAO (1981) where it was reported that although salted fish may be attacked by *Dermestes* spp during storage, the losses are usually much lower than those of unsalted fish. In Thailand, however, where salting precedes curing, salted, dried and smoked fish are attacked by dermestid beetles during storage causing heavy losses to processors (Hanson and Esser, 1982; Rattagool, Metathip & Esser, 1988). The density of both beetles and larvae varied inversely to the salt content with the fish having the highest salt content, showing the least infestation (Table 4). It was observed that fish brined in 15, 20 and 25% salt had few or no beetle infestation after 12 weeks of storage. Mushi and Chiang (1974) and Osuji (1975 a) found that larval development in *D.maculatus* was impossible on fishmeal with salt concentration of 10%. Okumu (1989) demonstrated that a salt content of 7% dwb significantly reduced the rate of oviposition and larval growth; and also increased larval mortality of *D. maculatus*. This is in agreement with observation in the present study, that larvae were not noticed in stored fish with salt contents above 10%, up to 12 weeks of storage. However, after 20 weeks of storage, shrivelled larvae were noticed in fish with salt concentrations above 10% wwb, although no flesh damage was notable.

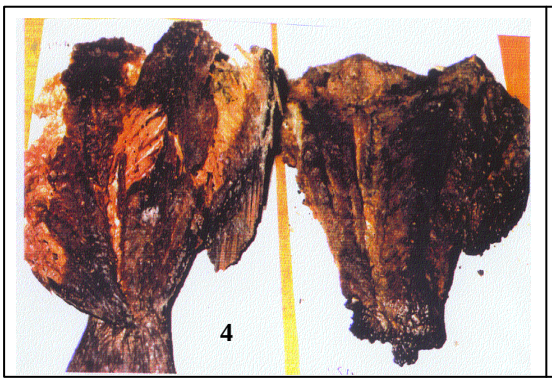

Plate 4: Unsalted smoked and salted Nile perch after 12 weeks of storage.

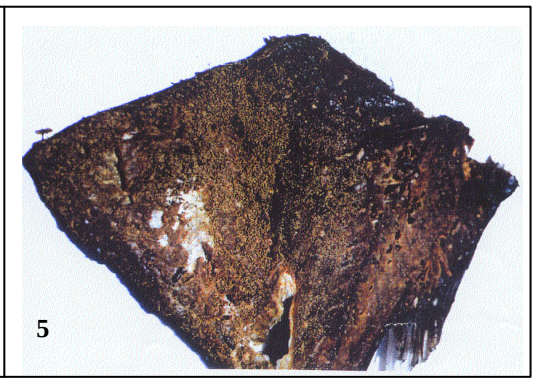

Plate 5: Smoked Nile Perch showing heavy beetle infestation and flesh damage

Table 4: Spoilage agents affecting stored smoked fish and the time of onset as observed during field trials on storage.

Spoilage Agent	No. of fish affected	Part of fish affected	Salt content range % wwb	Moisture content range %	Time of onset (days/wks)	Insect density
Moulds	17	Heads	0.3 - 8.0	27.9 - 66.2	4 - 7 days	-
	6	Tails	0.3 - 8.0	15.8 - 25.6	10 - 43 days	-
Fly larvae (maggots)	6	Heads	1.0 - 5.2	42.4 - 66.2	5 - 10 days	Moderate
Putrification	6	Heads	1.0 - 5.2	42.4 - 66.2	9 -12 days	-
Beetles	20	Heads & Tails	0.3 - 1.4 (unsalted)	19.6 - 27.3	32 days	Heavy
Beetles	9	Heads & Tails	2.0 - 5.2	14.2 - 34.4	8 weeks	Moderate
Beetles & larvae	20	Heads & Tails	0.3 - 1.4 (unsalted)	17.5 - 28.3	46 days	Heavy
Beetles & larvae	10	Heads & Tails	6.1 - 8.0	21.6 - 26.5	12 wks	Moderate
Beetles & larvae	6	Heads & Tails	10.0 - 11.2	22.0 - 28.2	20 wks	Low

Note:

Fragmentation occurred on all stored fish (observed), but the degree varied; with the salted fish and those with moisture contents above 38% showing least fragmentation. Plate 4 shows fragmentation of salted and unsalted fish after 12 weeks storage.

1. *Results are drawn from observations of 46 individual fish.*
2. *Heavy density: Heavy insect infestation that resulted in fish flesh damage subjectively estimated to be more than 25% (plate 5)*
3. *Moderate density: Few adult insects and larvae on the flesh. Little flesh damage.*
4. *Low density: only a few insects and larvae present. Hardly any flesh damaged caused (less than 1%)*

CONCLUSION

Brining Nile perch with 20% salt concentration (w/v) (i.e. salt concentration above 10% wwb) before smoking reduced losses of the smoked product through blowfly infestation and fragmentation. It also delayed the onset of beetle infestation and reduced the fish damage by beetle larvae.

Shelf-Life of Warm and Cold Water Fish in View of Market Demands

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SUMMARY

Fillets from warm and cold water fish were purchased from processing plants and stored at 0°C and 5°C in styrofoam boxes. During storage, sensory, microbiological and chemical tests were carried out. The warm water Nile perch Lates niloticus and the cold water Ocean perch Sebastes marinus stored at 0°C remained acceptable for 2-3 weeks and 1 week respectively. However, fillets stored at 5°C were rejected within a week. At limit of acceptability for both fish stored at both temperatures, Total Plate Count (TPC) was 10^6-10^7/g in plates incubated at 22°C and 10^4 in plates incubated at 37°C. The H_2S- forming bacteria were slightly more in fillets stored at 5°C than fillets stored at 0°C. Plates incubated at 37°C had fewer H_2S- forming bacteria than plates incubated at 22°C. The TVB-N was ³ 20 mg/100 g and ³ 25 mg/100 g for Nile perch and Ocean Perch respectively and the TMA was five times more in the former than latter fish.

INTRODUCTION

Technological advances of the last century have enlightened consumers about safety, quality, nutritive value and 'greenness' of the food available on the market. This enlightenment has resulted in market demands being drafted into institutional regulations or standards albeit without proven scientific basis. Compliance to some of these regulations has been quite expensive to the trading parties. For instance, the EEC Council Directive 91/493, has had a profound effect on the economies of non-compliant third world countries from the tropics dependent on the European Union (EU) market, although information used for its chemical and microbiological specification was derived from studies conducted on temperate water fish.

In the international fish trade, the inscription of fish and fishery products shelf life on packages and its attestation have gained prominence in the recent past. However, in some fish exporting countries, information on shelf life has been unreliable and controversial. For instance, Uganda´s chilled Nile perch *Lates niloticus* fillets have experimental shelf-life of at least 21 days (Gram, *et al.*, 1989; Shewan and Murray 1979) but 5-7 days according to the market vendors in Europe. This controversy has caused financial losses to some fish exporters and importers.

Information on tropical fish storage under commercial conditions has been conspicuously lacking, although some work under laboratory conditions has been done Gram *et al*, (1989) and Gram, *et al*., (1990). On the contrary, studies on temperate water fish and their spoilage patterns have been well documented, (Shewan, 1961; Banwart, 1981; Hobbs, 1985; Howgate, 1982; Connell, 1990; Huss, *et al.*, 1997).

Most comparative studies conducted, have entailed acclimatisation of fish to the required temperature for a specific period of time (Sumner and Magno 1985, Devaraju and Setty 1985) or were separately conducted in areas of origin (Shewan, 1961; Hobbs, 1985; Connell, 1990). Thus, the experimental conditions were heterogeneous. Consequently shelf life ascribed to some fishery products involved in international fish trade, has been variable. However, the heterogeneity in the present study was greatly reduced as both, Lake Victoria Nile perch, a tropical fresh water fish and north Atlantic Ocean perch (*Sebastes marinus*) had naturally acclimatised to an average temperature 26°C and 8°C respectively.

A comparison of the spoilage trends under commercial processing and storage conditions of these two fish species was deemed ideal to illustrate the unfairness of some market demands. Essentially, the study sought to establish the shelf life for commercially handled chilled Uganda Nile perch fillets on the EU market based on sensory, chemical and microbiological parameters.

MATERIALS AND METHODS

Sample Collection

A number of Styrofoam boxes containing chilled (< 1°C) 132 fillets of Nile perch with an average weight of 280gms were airfreighted to Iceland from Uganda (Greenfields) over a 70hr shipment period. Accompanying records indicated that fillets were 9-11 days old on arrival. Four-day old 147 Ocean perch fillets with an average weight of 123.5 g and a temperature of 4.7°C were bought locally from a Reykjavik plant.

Sample Treatment

Styrofoam boxes containing 47 and 42 fillets of Ocean perch (OP) and Nile perch (NP) respectively, were stacked and stored at 5°C. The remaining fillets for both species were similarly packed and kept at 0°C. Subsequently, sensory evaluation, microbiological and chemical parameters were carried out regularly.

Sampling Plan

Two fillets of NP and four fillets of OP per storage temperature were aseptically and randomly picked from the styrofoam boxes for the three tests twice per week.

Sensory Evaluation Method

Fish quality was assessed by Icelandic Fisheries Laboratories (IFL) trained panel consisting of 10-12 persons. Samples were cut into 20g pieces, boiled in aluminium boxes at 98°C for 5 minutes and served to each panellist. Samples were served in duplicates. An EEC hedonic scale from 0-10 was used (Howgate 1982). The duration between the time of capture and limit of acceptability represented shelf life of the fillet.

Microbiological Methods

Iron Agar (IA) was used for Total plate count (TPC) and H_2S-forming bacteria counts according to Gram *et al*. (1989). A primary dilution was prepared by homogenising 25g of fillet with 225g of Butterfield´s phosphate buffer using a Seward stomacher 400 laboratory system. Serial dilutions were prepared in buffer and 1ml of appropriate dilution pour plated with Iron Agar and an overlay. Duplicate plates from samples kept at 0°C and 5°C were incubated for 72 and 48 hrs at 22°C and 37°C respectively. The number of black colonies i.e. H_2S-forming organisms and white colonies constituted the total plate count (TPC).

Chemical Methods

TVB-N and TMA determination by steam distillation

200 ml of 7.5% aqueous trichloroacetic acid solution was added to 100g of fish muscle and homogenized in a Waring blender. The mixture was filtered through a Whatman no 3 paper. 25ml of filtrate were transferred into a distillation flask and 6ml of 10% NaOH were added. Steam was produced by a Kjeldahl-type of distillator (Vapodest Gerhardt). A beaker containing 10ml of 4% boric acid and 0.04 ml of methyl red and bromocresol green indicator was placed under the condenser for the titration of ammonia. Distillation was started and steam distillation continued until a final volume of 50 ml was obtained in the beaker (40 ml distillate). The boric acid solution turned green when alkalinised by the distilled Total Volatile Bases (TVB-N), which was titrated with aqueous 0.25N sulphuric acid solution using a 0.01 ml, graduated microburette. Complete neutralisation was obtained when the colour turned pink on the addition of a further drop of sulphuric acid.

Determination of Trimethalamine TMA followed the same initial procedural steps as TVB-N except that instead of NaOH addition, formaldehyde (20 ml) was added to the distillation flask to block the primary and secondary amines. An aliquot of the TCA extract was reacted with 45% KOH, formaldehyde and toluene, thoroughly shaken, and allowed to stand for 10 min, after which the toluene layer was removed. An aliquot of the water-free toluene extract is reacted with a picric acid solution and the resulting colour is quantitatively measured using a spectrophotometer.

RESULTS AND DISCUSSIONS

Initially, all spoilage indicators showed similar minimal values although Nile perch (NP) was 9-13 days post-mortem and Ocean perch (OP) was 4 days post-mortem. The values were within the EU acceptable quality and safety limits i.e. sensory score 8-7, TPC ≤ 10^3, TMA ≤ 10-15 and TVB-N of < 35-40 mg/100g. After 3 days, however, sensorial and microbiological indices in both fish increased dramatically while chemical indices barely increased. However, by the 16-19th day post-mortem, the NP fillets stored at 0°C were barely edible and the OP was on the borderline of acceptability, i.e. 7 days post-mortem (Table 1). The warm water fish had therefore kept longer than cold-water fish at chilled temperatures. The result was in agreement with previous studies (Shewan, 1961; Bramsnaes, 1965; Shewan and Murray, 1979; Liston, 1980; Gram, 1992; ICMSF, 1998). However, the actual storage time of Nile perch differed slightly with Shewan and Murray (1979) and Gram, *et al*., (1989). The former reported 29 days and the latter 23 days compared to < 19 days NP in this study. The differences were attributed to the sampling procedures. Whereas Gram et al. (1989) thoroughly washed fish with methanol prior to aseptic filleting, the fillets for the present study were purchased from the open market where the likelihood of contamination was high. Besides the EU Council Directive 91/493, applicable to most Ugandan plants, forbids disinfectant use on fishery products. Unlike the previous study, the fillets in the present study were not placed into sterile plastic bags prior to storage. The shelf-life reduction was also attributed to commercial handling, logistical and management constraints at source (Uganda) and en-route (Europe).

Table 1. Sensory description of Nile perch and Ocean perch fillets during storage at 0°C and 5°C.

Keeping time & Temp °C		Sensory description of each fish using Torry scheme	
(Days*)	T°C	Ocean perch (OP)	Nile perch (NP)
0	0	Lack of characteristic flavours of species.[8]	Muddy, metallic, burnt and bland or no sweet taste or no liver taste. [7&6]
	5	Same as above.[8]	Same as above [7&6]
3	0	Condensed milk, caramel or toffee-like odours.	Meaty, rancid sour and TMA[5&4]
	5	Absolutely no flavours.[6]	Inedible ∴ not presented to the panellists. [3,2&1]
6	0	Trace of off flavours, some sourness but no bitterness.[5]	Inedible ∴ not presented to the panellists. [3,2&1]
	5	Some off flavours and some bitterness.[4]	

As the sensory scores decreased with storage time (Table 1), the microbiological indices, total plate counts (TPC) and H2S forming bacteria increased appreciably (Figs.1a, b, c, d).

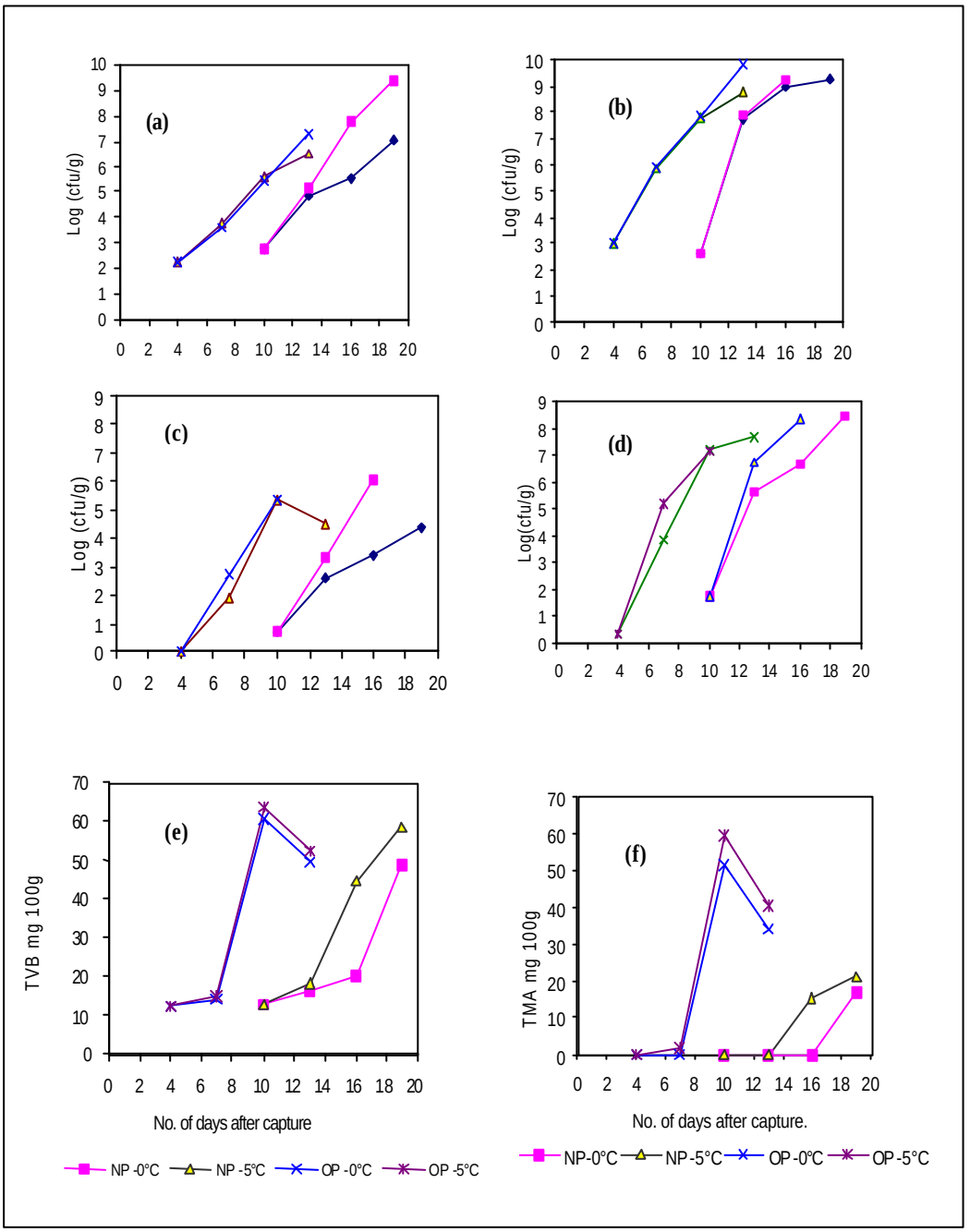

Fig. 1. Bacteria growth (TPC) on plate agar incubated at: (a) 22°C and (b) 37°C, during storage of NP and OP fillets kept at 0°C and 5°C. Growth of H_2S-forming bacteria on IA agar incubated at (c) 37°C and (d) 22°C during storage of NP and OP fillets kept at 0°C and 5°C. Development of (e) TVB-N and (f) TMA during storage of Nile perch and Ocean perch fillets kept at 0°C a

Although the TPC plates incubated at 22°C did not show clearly the differences between fillets stored at 0°C and 5°C up to the third day of storage (Fig. 1a.), the panellists differentiated and rejected them accordingly. This observation augmented the indispensability of sensory evaluation in fish quality assessment (Howgate, 1982; Botta, 1995). Although TPC did not correlate with the level of freshness, it indicated the risk of spoilage. Bacterial loads in fish rarely indicate the sensorial quality of fish (Gram et al. 1992), but fish with a microbial load of >106 is regarded as spoilt (Shewan, 1961; Liston, 1980; Howgate 1982 and Connell, 1990). Based on this limit therefore, OP and NP samples stored at 0°C and 5°C, reached the upper limit of acceptability on 7th and 12th day respectively (Fig.1a). However, in Fig.1b, the upper limit of acceptability was reached long after the fillets had been rejected (Fig. 1b). Fillets stored at 5°C were rejected on day 11th and 14th for OP and NP respectively and similar samples kept at 0°C rejected on 11th and 17th day respectively. The shelf life difference between OP fillets stored at 0°C or 5°C was negligible whereas NP stored at 0°C and 5°C showed a difference of 3 days. The differences in NP shelf life as a function of storage temperature was attributed to the dominance of psychrotrophic spoilage at 0°C and mesophilic spoilage bacteria at 5°C, which were selectively targeted by incubation at 22°C and 37°C respectively. The results of the present study were in agreement with Liston (1980) who noted that the counts were ten times lower, when incubation temperature was ≤ 35-37°C than when it was at 20-25°C. Incubating plates at 37°C only seemed to target the few surviving mesophiles as shown in Fig.1b. In most Ugandan laboratories 35-37°C is the standard incubation temperatures for TPC analysis in chilled fillets while most European laboratories maintain 20-25°C. The use of different incubation temperatures for the same product gives different results as it was shown in this study and the practice inevitably infringes on the credibility of the laboratory that uses inappropriate incubation temperatures. Citation of incubation temperature on result sheet is therefore unavoidable.

As Hobbs (1985) observed not all bacteria present on fish are spoilers but as cited by Gram *et al*., (1989), only certain active spoilers were responsible for spoilage in fish. These spoilers or H_2S-forming bacteria, have the ability to reduce trimethylamine oxide (TMAO) to TMA, produce hydrogen sulphide from sodium thiosulphate and / or cysteine incorporated in the growth culture medium and form black colonies as a result of FeS precipitation. The number of H_2S-forming bacteria on plates incubated at 22°C (Fig 1c) was higher at any storage time than on plates incubated at 37°C (Fig 4) probably due the psychotrophic nature of H_2S-forming bacteria. Gram *et al*. (1989) identified H2S-forming bacteria in the study, as Alteromonas putrefaciens currently known as Shewanella putrefaciens and a few of them as Vibrionaceae.

The correlation between sensory and H_2S-forming bacteria on plates incubated at 37°C was not as evident as on plates incubated at 22°C (Fig. 1d), which further demonstrated that incubation at 22°C was better procedural step for assessing microbial load in chilled fish products than 37°C.

Regarding total volatile bases (TVB-N) and trimethyalamine (TMA) analysis, it was noted (Connell 1990 and Howgate 1982), which TVB-N occurred even in fresh fish as presently indicated (Fig.1e) for both species albeit below 20mg/100g. Its presence has been attributed to ammonia, one of the major components of nitrogenous volatiles. The "lag phase" of 3 days in OP at both

storage temperature and 3 - 6 days for NP stored at 5°C and 0°C respectively during which, TVB-N was below 20 mg /100g (Fig. 1e), corresponded with the exponential growth period of spoilage bacteria in Fig. 4, though TVB-N did not similarly show a sudden increase. The Icelandic and Ugandan quality regulations specify TVB-N limit as 25 mg /100 g for the respective fish species. Based on these regulations which bear the hallmark of the EU Directive 91/493, the shelf life for OP fillets kept at both temperatures, was around 8 days compared to 15 and 18 days for NP fillets kept at 5°C and 0°C respectively. These storage times correlate with the results of sensory evaluation (Table 1). Since TVB-N measures volatile bases in their totality, it does not relate directly to bacterial spoilage. Hence, Connell (1990) and Connell and Shewan (1980) suggested the use of TMA as a more specific chemical index for microbiological spoilage. Similar trends observed in Figures 5 and 6 confirmed Howgate's (1982) observation that most changes in TVB-N were due to TMA component. The TMA in OP detected in both treatments during the early days of storage though in small quantities < 2 mg/100 g, increased almost vertically to > 50 mg/100 g at the end of its storage time i.e. day 7. The trend corresponded more accurately with H_2S - forming bacteria (Fig.1c) than TPC (Fig. 1a). On the contrary, the presence of TMA in Nile perch only became apparent ≤ 20 mg/100 g at the end of storage time i.e. on days 16 and 19 at storage temperature 5°C and 0°C respectively. Even at rejection time on day 19, the TMA content was still within the acceptable EU limits of 10-15mg/100g (Connell, 1990) though H_2S-forming bacteria counts were quite high (Fig.1c). The extremely low quantities of TMAO compared to >25 mg /100 g Gram *et al*., (1989) found, implied that H_2S-forming bacteria in NP probably relied on another compound as an electron acceptor other than TMAO, therefore TMA was a poor indicator of spoilage in Nile perch.

CONCLUSION

Fish stored at 0°C kept longer than fish kept at 5°C irrespective of species. Nile perch (tropical fish) and Ocean perch (temperate fish) fillets stored at 0°C in Styrofoam boxes (simulated commercial conditions) had a shelf life of 16-19 days and 7 days respectively. Storage of fillets at 5°C in display cabinets during marketing lessens their shelf life. High storage temperature (5°C) did not favour proliferation of psychrotrophic spoilage bacteria, which probably accounted for the different spoilage rates between fillets stored at 0°C and 5°C. At the end of storage time, TMAO in NP was less than in OP by at least a factor of five. The TVB-N was a better indicator of spoilage than TMA. Finally, complementarity of sensory, microbiological and chemical spoilage indicators was unavoidable in assessment of fish freshness.

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The Gender Role in Fish Processing and Trading Practices in Lake Victoria (Kenya)

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SUMMARY

This paper examines the role of gender in fish processing and trade along the Kenyan part of Lake Victoria. The study was carried out with aid of a structured questionnaire administered through personal interviews. Two surveys were conducted sequentially, in which samples of fish traders and processors were interviewed. Results show that at the artisanal level women dominate fish trading and processing. Most female traders and processors were introduced into the fish business by their parents or spouses while male traders have joined the fish trade because the business requires little initial capital. The most frequently traded fish is Nile perch, with a slightly greater proportion of men trading in adult of this species than females who mainly trade in juveniles. Male traders prefer to deal in fresh fish, while the largest proportion of women deal in sun-dried fish products. The three main sources of financing the fish business are: income obtained from selling farm produce or livestock, money lent by relatives and from respondents' personal savings. The paper concludes that there is gender disparity in many aspects of the fish trading and processing. It recommends improved infrastructure, increased access of women to credit facilities, improved techniques of fish processing and preservation to avoid spoilage, and to enhance incomes from fish trading and processing.

INTRODUCTION

Lake Victoria is inhabited by over 177 fish species, 127 of which are cichlids mostly of the Haplochromis species. Unregulated fishing activities, coupled with the introduction of exotic Nile perch and Tilapine species in the 1960s, are among the factors that have led to a drastic change in the species composition of the lake. Currently, three species dominate the fishery: the Nile perch, (*Lates niloticus*), "Dagaa" (*Rastrineobola argentea*), and Tilapia (*Oreochromis* spp.). These constitute 50%, 37% and 6% respectively of the tonnage of the fish caught from the fishery (Othina, 1994).

The groups that work within Kenya's Lake Victoria fishing industry are diverse and may be defined along the lines of age, ownership and target species. Perhaps the most prominent labour divisions within the fishery defined by gender. Although fishing in the Kenyan part of Lake Victoria has always been a predominantly male domain, women have historically practiced fishing using certain techniques. The most important technique was called *'teng'o'* (herding) which mainly caught the catfish (*Clarias* spp.) and the lungfish (*Protopterus* spp.) species. (Geheb, 1997).

Haplochromis were also caught using woven traps and processed using simple techniques like sundrying, smoking and salting. These fish were always available as a source of protein. According to Abila (1995), men initially performed the production and marketing activities. Gradually men have become more committed to fish harvesting and thus their marketing role has diminished. Currently over 80% traders from the fishery are women (SEDAWOG, 1999). In the past, thousands of women were engaged in fish processing. Most of the processing was carried out at the landing sites or places close to it. The fish, which was not sold fresh, was smoked or sundried. It was usually poor women who alone, or in small groups, processed fish. Many of the fish processors were fishermen's wives.

Most of the Nile perch landed from Lake Victoria is sold to fish processing plants. The artisanal fishmongers are left with only the juvenile and the damaged Nile perch, which the factory agents reject. The artisanal fish traders have a chance of selling the large and undamaged Nile perch during the rainy seasons when the agents do not come to buy fish due to impassable roads. An increasing amount of dagaa is also being sold to fishmeal industries. Traditionally, fish traders developed relationships with particular fishermen from whom they purchase most of their fish. With the factories taking an increasingly larger share of the catch, the relationships between fish traders and fishermen have been severed. The fishermen are under contract to deliver to the purchasing agents who can also afford to pay them a higher price than the fishmongers (Abila, 1997). Processing plants therefore have a considerable effect on fish traders who are mainly women. Men benefit more than women in the Nile perch fishery in that, as fishers they sell mature fish direct to the fish industry agents and fetch better prices. Thus women are left to trade in juvenile fish and factory rejects which are less profitable.

Though there exists a body of data on fish marketing (Abila, 1995), fish utilization and marketing (Yongo, 1991) and on women, social organization and production (Gerrard, 1992) for Lake Victoria, there is little information on gender issues, especially with respect to trading practices and preferences that display disparity between the sexes. This study examines the participation of gender in fish trade and processing in the Kenyan part of Lake Victoria.

The overall objective of the study was to examine gender divisions in fish processing and trading. This was achieved through a number of specific activities: first, to determine the main characteristics, by gender, of fish processors and traders. Secondly to examine the reasons why male and female fish processors and traders choose fish businesses over alternative trades. A third objective was to ascertain the species and forms of fish traded, and reasons for dealing in them, with respect to gender. Fourth was to explore why traders substitute trading of one type of fish with another. Lastly was to investigate the sources of capital for initiating fish processing and trade

METHODOLOGY

A survey of fish traders and local fish processors in Kenya was carried out at eighteen sites, consisting of six fish landing beaches and six each of small and large inland fish markets. The sample sites were selected along the shores of Lake Victoria, equally spread out in the northern,

southern and gulf zones in the Kenyan part of the lake. In each of these sites a structured questionnaire was administered through personal interviews. The targeted respondents were local fish traders and processors who normally lived at the survey sites or who lived elsewhere but usually come to the beach or market to process, buy or sell fish. In practice only those traders and processors who were present on the beach or market at the time of survey were involved in the study. A total of 319 respondents (50 males and 269 female) were interviewed. The collected data were analysed with the assistance of SPSS package.

RESULTS AND DISCUSSION

Characteristics of fish traders and processors

The study showed that the majority of fish traders and processors were women. Of the female traders interviewed, 80% were married, 9% were single while 9% were widowers. In comparison, nearly the same proportion of male respondents, 81%, were married while 14% were widowed. The average number of children per female trader or processor in the sample was six.

It was also evident that most males and females in the target group were engaged in fish trading alone. Of the sample, 74% of male and 57% of females were specifically fish traders. Comparatively more females (43%) combined fish trading and processing than did males (24%).

According to Croll (1981), fish trading is an opportunity for divorced or deserted women in a region where they have limited property rights. The number of widowed individuals in Kenya's Lake Victoria fishery has increased significantly due to the AIDS epidemic, leaving many women in charge of households, and obliging them to turn to fish trading and processing so as to earn money to make up for the short falls that farming alone creates. It is also suggested that fisher related activities have been more attractive in certain types of marriages. Gerrard (1992) observed that fish traders in Tarime Tanzania, tended to be women from polygamous households or those who have older husbands or migrant husbands. However the results in this study indicated that most traders came from monogamous rather than polygamous families. Of 211 interviewees responding to the question, 158 were from monogamous families while only 53 came from a polygamous marriage. Data was not collected to ascertain how many of the female respondents were actually living with their spouses.

Reasons for joining fish trading and processing

Results displayed in Table 1 show that the majority of female and male traders have been involved in processing or trading the principal commercial species - Nile perch, 'dagaa' and tilapia - for over five years. In the last two years proportionately, more women than men have joined the fish processing and trading sector.

Table 1. Number of years respondents have processed or traded the principal species

Gender		No. of years			
		<2 yr.	2-5 yrs	> 5yrs	Total
Male	Count	11	5	34	50
	% within Gender	22	10	68	100
Female	Count	85	34	150	269
	% within Gender	31.6	12.6	55.8	100
Total	Count	96	39	184	319
	%	30	12.3	57.7	100

Source: SEDAWOG 1999

Several reasons have been advanced as to why people, particularly women, join the fish trade. Francis (1995) argues that the migration of men to other parts of the lake and to urban centres has left women to take up duties traditionally performed by men. This has caused them to take up fish trading and processing as a source of income. Labour mobility was at first stimulated by a legal requirement during the colonial period and also by new needs for cash for taxes, clothing and cash to purchase bride wealth (Clayton and Savage, 1974). Geheb (1997) advances a similar line of reasoning in explaining that people joined fish trading and processing because of their desire for a cash income. Their entry into these sectors is favoured by the very low initial capital and financial input required. According to Francis (1995), there has been a net decline in agricultural production in Western Kenya since the Second World War. This has increased the need for cash to buy food accompanied by a dramatic rise in the number of essential household goods and items that can only be bought with cash. According to Francis (1995), women in fishing communities have traditionally been involved in farming. Thus, as farm yields decline, many women have turned to trading fish.

However, the studies cited above do not explain why fish businesses would be the ultimate choice in an environment of competing trading opportunities. This study investigated why male and females choose to deal in fish rather than other trades. The respondents gave various reasons, which have been grouped into nine categories in Table 2. According to the results, most females do fish processing and trading because it is a business that has run down their family lineage. Such women were introduced into the business either by their parents or by the husband on marriage. The second most important reason why females choose fish processing and trading over other occupations is that in the area where they come from, particularly those living around fish landing beaches, fish is the most readily available commodity that can be traded. This group of females consider fish to be 'their product', which they can sell to the outside world. Thirdly, some females take up the fish trading business because it requires little capital to start and, once started can begin earning profits immediately. In comparison, the low capital requirement is the most important reason for men who join fish business followed by those who believe that it can rapidly generate profits.

Table 2. Why Men and Women deal in fish

Reason for Trading/ Processing Fish	Women (N=45)	Men (N=19)
Fish is highly marketable; there is high demand for fish; many people here eat fish.	4.3%	21.1%
Requires little capital to start; you start earning money immediately; fish business is easy to start.	19.6%	31.6%
Fish is lighter and easy to transport on head or bicycle than other commodities.	4.3%	5.3%
Fish business is very profitable; fish business has reliable returns.	8.7%	21.1%
I come from the lake area; fish is the most readily available commodity on my beach/ market; there is nothing else to trade here.	23.9%	5.3%
Fish provides me with both cash income and food at the same time.	6.6%	5.3%
I was introduced to fish business by parents/ spouse; I inherited fish business skills; I have long- term experience in fish trade.	28.3%	5.3%
I can easily buy fish from fishermen or wholesalers on credit; It is easy to relate to fish suppliers since we meet daily.	2.2%	0%
It is easy to plan fish business alongside farming activities and household duties; I can do fish trading throughout the year.	22%	5.3%

Source: Survey results

Species of fish traded

Male and female fish processors and traders deal in various fish species, which include Nile perch, tilapia, 'dagaa', '*fulu*' (Haplochromines) and other species. The fish traded by most men and women is Nile perch. Fig. 1 shows that a higher percentage of women are engaged in 'dagaa' trading compared to men. In contrast, a greater percentage of men trade in tilapia than women. The reason for Nile perch being the most traded fish could be because it is one of the dominant fish in the lake and it is available and profitable. However respondent's reasons for trading in a particular fish species over the others are; Nile perch traders are attracted to that species because it brings in high profits, juvenile fish is easily available, and there is high demand for the species. The reasons why traders prefer dealing in tilapia is that it has a high demand, it is readily available and it brings in good profits. '*Dagaa*' seems to have many advantages, which makes traders to choose to trade it. According to 'dagaa' traders, the fish business requires very little capital to start. Some traders interviewed had begun the business with as little as Ksh. 200 (US $ 3). 'Dagaa' also has a ready market since many people consume it and it is easily divisible into small

units hence, many people can afford it in different quantities. The fish is easy to handle, process and store. In contrast to the smoking and deep-frying used to process other fish species, sundrying '*dagaa*' does not incur any additional processing expenses. Some '*dagaa*' traders are also able to buy it frequently on credit.

Why traders stop trading a species of fish

Irrespective of the advantages in trading any one of the fish species, some traders often stop trading a particular fish species and shift to another one. Each respondent was asked if he or she had attempted trading on any fish species but failed, and to give a reason for why this had happened. Several reasons were advanced. Some traders of (adult size) Nile perch had stopped because it was no longer easily available since most of it is going to fish processing factories. Other Nile perch traders left it because, they said, not many consumers like the fish. Yet others claimed that the Nile perch trade was not very profitable. Some traders who had left trading tilapia and '*dagaa*' also cited low profitability as the reason for doing so. Some '*dagaa*' traders had stopped the trade because sun drying the fish took too much time and too much space, which was often not available. Others left because too many people had joined the '*dagaa*' trade, flooding the market with the fish. One '*dagaa*' wholesaler had stopped trading in the fish because he had given out too much fish to retailers on credit, until he ran out of working capital. A common reason given for ending tilapia trading was that the fish had become very scarce.

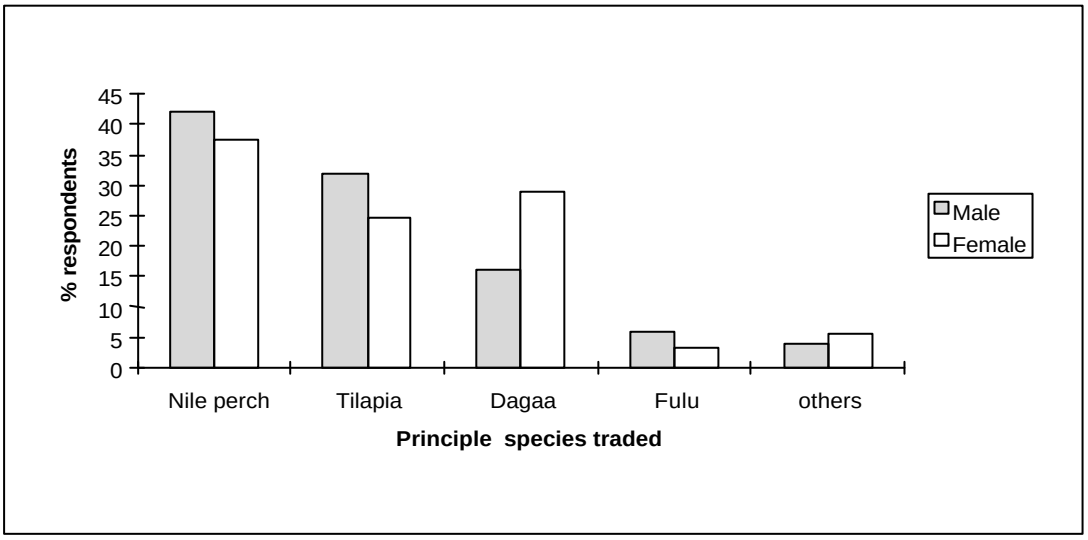

Fig. 1. Principle species traded (Source: LVFRP, 1999)

Sizes of Nile Perch Traded

There are two contrasting markets for Nile perch. The export market, which uses high quality fish, and the local market which deals in juveniles and that fish which has been rejected by the factory agents due to poor quality. Demand for Nile perch in both markets has increased causing pressure to catch even Nile perch of less than a kilogram.

An attempt was made to verify how much of the Nile perch processed and traded was indeed juvenile fish. Results in Table 3 show that out of 21 male and female traders of that fish, 17 dealt in juvenile fish. The researchers recorded the weights of a randomly picked sample of fish traded by respondents and other traders at each survey site (See Table 1). Juvenile fish, in this study, was taken as Nile perch weighing less than 500 grams. Therefore, although the survey involved a relatively small sample, the findings would indicate that most local processors and traders of Nile perch trade on juvenile fish much of the time.

Table 3. Products traded by female traders

Size of Nile perch traded	Number of women traders (N=17)	Number of men traders (N=4)	Aggregate (percentage)(N=21)
Juvenile Nile perch (< 500gms)	13	4	81%
Nile perch size above 500gms	4	-	19%

Fish products traded

Traders may sell their fish fresh or processed. Fish is mainly processed to preserve it and to improve its flavour. If not sold fresh, fish is generally sold smoked, sundried or fried. These products are displayed either on manila sacks, wooden stalls, or cement slabs. The diversity of processed products at inland markets is often higher than at beach markets. This could be because of the distance from the source of supply, coupled with poor infrastructure, making it difficult for fish to reach these markets in a fresh state. Thus the fish is semi-processed in various ways to preserve it. Additionally, for Nile perch some products come from urban-based fish processing factories. Table 4 shows the forms of fish found at inland and beach markets during the study.

Table 4. Fish product forms traded

Species	Product forms in inland markets	Product forms in beach markets
Nile perch	Fried fillet, juveniles, and frames; split and smoked, split and fried, fresh adults and juveniles, smoked juveniles	Fresh, smoked and fried juvenile
Tilapia	Fried, fresh, smoked, split sundried, split smoked	Fresh and smoked
Dagaa	Sundried and fresh	Sundried and fresh

Amongst the traders who sell 'dagaa', most sell a sun-dried product. After fishermen land 'dagaa' they sell it to mainly female buyers who wash, sundry, and later sell it. This process involves patience, which the respondents claim females have, and which males do not have. Smoked 'dagaa' is a recent product form which, in some markets, is sold by men (SEDAWOG, 1999). In the case of processed tilapia, men prefer to trade in smoked tilapia, while females prefer sun-dried tilapia. Female processors and traders normally fry tilapia at the beach or market place. Fresh tilapia that is not sold by evening is processed to preserve it for sale later.

Men mostly trade in fresh Nile perch because they own boats and sell directly their fish to factory agents who pay them immediately. Women are disadvantaged financially as they cannot compete with the factory agents who are well equipped with finance and preservation technology. Women prefer to deal in a diversity of fish formats. This is a coping strategy aimed to maximize trade. Results of the study show a nearly equal proportion of fresh, smoked and fried Nile perch traded by women.

Reasons for trading in various products

Results of the survey presented in Figures 2 and 3 indicate that men generally trade in fresh fish while women prefer to trade in sun-dried fish. This is probably due to the fact that men own bicycles, which ease transportation of fresh fish to inland markets before spoilage. Women prefer to deal in sun-dried fish possibly because they lack means to rapidly transport fresh fish to the market. Most women either walk to the market place or use public transport to get to distant markets. In the latter case, they often have to walk long distances to get to places were they can board such transport. Some women also prefer dealing in processed fish since in this form fish can be preserved longer. Although processing preserves fish longer, it means additional costs, and hence a loss to the trader. Processing of fish also increases the time before the fish can be sold on.

There are traders who buy and sell fish at the same beach market because there is less damage due to fish spoilage since it is bought and sold within just a few hours after landing. These traders sell mainly fresh fish. This means that the traders do not incur additional costs nor spend extra time on fish processing.

Thus, by selling fresh fish, traders cut down on processing costs which they can pass on down as lower prices to consumers. Traders of fresh fish stated that unprocessed fish, especially tilapia, has high demand, is readily available and is very profitable.

In comparison, processed fish has the advantage that it has a longer shelf life, hence, allows fish to reach distant markets in good condition. Frying is also a fast method of preserving previously unprocessed fish that remains unsold at the end of the day. In some inland markets, most Nile perch and tilapia comes already fried. Traders at such markets therefore have little chance of buying fresh fish. On the other hand, traders of smoked fish argued that smoking is less costly than frying fish. In addition, they think that smoked fish has a longer shelf life than either fried or sun-dried fish.

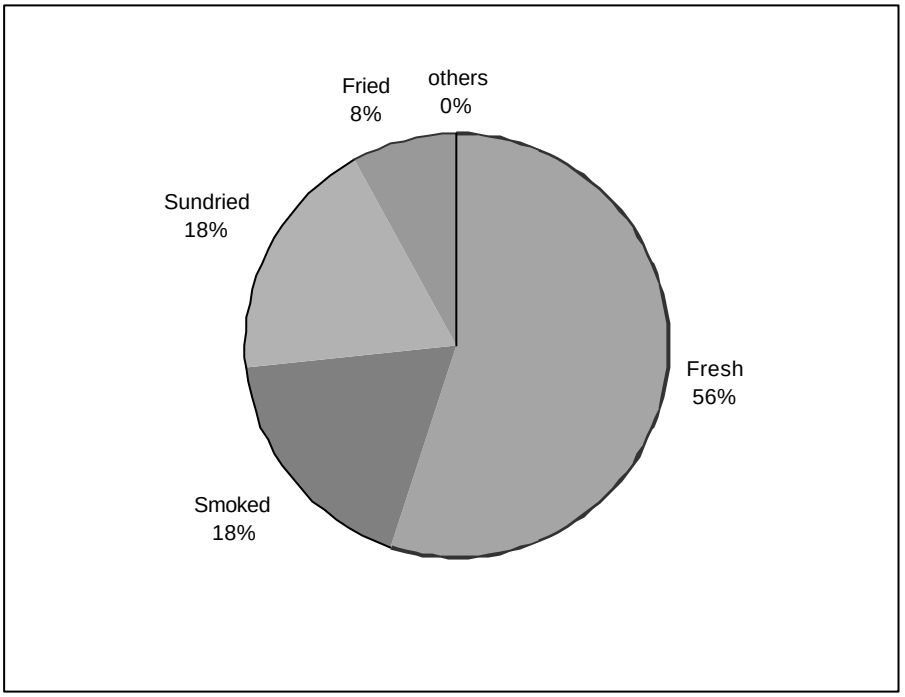

Fig. 2. Products traded by male traders (Source: LVFRP, 1999)

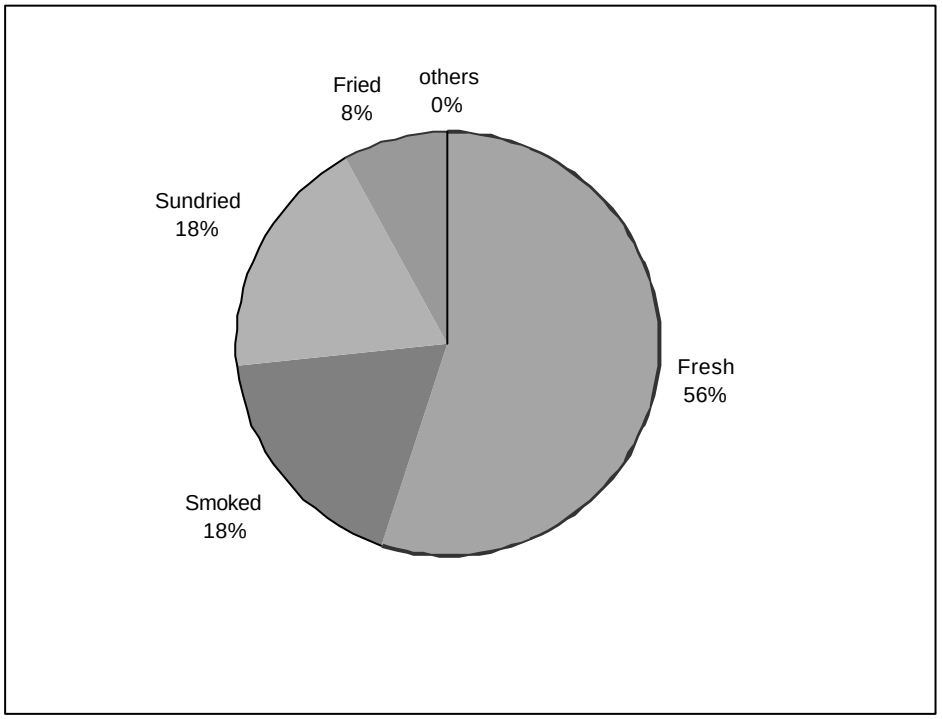

Fig. 3. Products traded by female traders (Source: LVFRP, 1999)

Traders of sun-dried fish point out that it is the easiest and cheapest method of preserving fish. Sun drying does not require expenditure on fuel wood or frying oil. In the case of '*dagaa*' it is the main way of preserving the fish. Sellers of '*dagaa*' explained that the market for fresh 'dagaa' is limited to the areas around fish landing beaches. Consumers in inland markets only like '*dagaa*' in the sun-dried state. Similarly, traders of sun-dried tilapia can also keep their processing costs down, and hence, many consumers prefer to buy it.

Sources of Capital for fish processing and trade

Fish processors and traders were asked to state the source of funds used to finance their initial fish business. Table 5 gives the different sources of capital mentioned and their frequency. Thus, the three main sources for the initial financing of fish businesses are incomes obtained from selling farm produce or livestock, money lent (often interest free) by relatives or friends of respondents and respondents' own personal savings over long period of time. It is also noteworthy that, in a sample of 64 processors and traders, none had used a loan from a financial or credit institution to start the business.

Another important observation is that traders' or fishers' groups are not an important source of funds for initiating the fish business. Traders may form small groups (locally known as 'nyaluoro') in order to benefit from a revolving fund contributed to by its members. Women are only slightly more likely to be members of such a group than men. 48% of women belonged to traders' or fishers' group compared to 45% of male respondents.

Table 5. Sources of capital for fish business

Source of finance	Number of respondents obtaining funds from sources	Percentage
Own savings	19	29.6
Loan from relative or friend	20	31.2
From selling farm produce or livestock	21	32.8
"Nyaluoro" traders' group	1	1.6
From another business	1	1.6
Other sources	2	3.1
Total	64	100

Gender involvement in Nile perch frames processing

This study did not cover the artisanal processing of Nile perch frames. However, other previous studies have indicated that the Nile perch frames processing sector is dominated by women. A survey carried out in 1994 revealed that 75% of frame processors and traders in Obunga in Kisumu town were women (Abila, 1994). Similar numbers of women are employed in frames processing in Homa-bay and Migori. Abila and Jansen (1997) have outlined the problems facing women engaged in this sector. This could be because of small amount of capital involved, which women can afford.

The main problems experienced in fish processing and trade

Fish spoils and becomes inedible faster than most foods, thus becoming unacceptable and may be lost as an item of nutritional value. Preservation and processing techniques involving heat treatment (frying and smoking) and reduction of available water (sun drying and smoking) can reduce the rate at which spoilage happens, thus allowing fish to be distributed to distance markets. However when the infrastructure and mechanisms designed to preserve fish are poor, then fish is lost because it is spoilt before it reaches the consumer. For example, most of the road infrastructure along the Kenyan part of Lake Victoria is poor. During the rainy season transportation of fish to the market becomes very difficult. Processing also becomes difficult as fish cannot dry and firewood is scarce and, if available, damp. This causes fish to spoil. This has repercussions on the fish prices, as during the rainy season the harvest from the lake is good but the prices are low. Many dagaa fish traders experience product spoilage in these conditions because their "dagaa" does not dry sufficiently.

The fishmonger pays a fee each time to the local authority to be able to sell fish in the market. which is charged as per the quantity of fish to which the women complain it is too high. The fish processors and traders lack credit facilities to expand their business. Female traders have no access to the credit facilities but unlike the males, females do not own assets that they can dispose of nor do they own property that they can use as collateral to obtain credit from the banks.

CONCLUSIONS

Women are the majority in the fish trade and processing sectors where they play a vital role. Despite their importance and contribution to this artisanal industry women have received little attention, either from the government or non-governmental organisations. The negligence of this sector is probably a matter of priority. With limited funds priority is always given to activities that will bring greatest immediate gains.

Technology development in this sector is still very crude. Much development has occurred in the actual artisanal fishing activities, which is a male domain as compared to the artisanal trading and processing sectors, which ensure that fish reaches the consumers before it is spoilt. Processors incur loses when the fish deteriorates in quality and extra costs have to be incurred to preserve the fish. The increase in fish landed during the rainy period is wasted, as the roads are very poor

and impassable. This brings loses to the national economy and a waste to the resource. Technology must be improved to solve this problem of post harvest loses.

Credit should be available to the women so that they can invest and improve their fish trade and processing. Women need money so that they can buy the large and the good quality fish that is profitable. They also need to invest in cheap and easily maintained transportation such as bicycles so as to reach the market quickly.

It is important ecologically, socially, and economically to ensure that, once caught, fish is marketed in the most efficient means and that the final sale is transacted to the satisfaction of both the consumer and the seller. From the study, there is need to improve infrastructure that will enhance quick and efficient transport of fish to markets.

There is need to empower women traders economically, so that they can also be able to trade in the sustainable fish species. From the study it is evident that quite a number of traders trade in juvenile fish because it can be acquired cheaply. The fish traders need access to credit facility to improve their business.

There is need to develop more efficient preservation and processing techniques to avoid spoilage. This will increase the amount of fish reaching the market place. Other benefits will be reduced pressure on fish resource, increase in income to the traders, greater food security and improved health.

Commercial Tilapia Production Recommendations and Enterprise Budgets for East Africa in the Absence of Formulated Feeds

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SUMMARY

A series of experiments and trials was conducted at Sagana Fish Farm (elevation 1230 meters) which is located in Central Province Kenya but is very similar in climate to the Lake Basin area. Various combinations of chemical fertiliser and bran were evaluated in terms of resulting water quality, fish growth and pond carrying capacity, and cost of inputs to produce one kg of fish. Enterprise budgets were made based on prices of inputs in Central province. The objective of the research was to develop a system that can achieve standing crops of at least 5 tons ha^{-1} of market size fish for a feed/fertiliser cost of less than KSh 25 per kg of live fish produced.

In a tilapia/clarias polyculture, standing crops of 2.5 to 3 tons per hectare can be obtained with chemical fertilizers alone. A combination of bran and chemical fertiliser can result in fish production of 5 to 7 tons per hectare in about 6 or 7 months. The bran exerts a mitigating effect on some of the water quality problems resulting from the use of chemical fertilisers. A sample enterprise budget is presented in which feeds and fertilisers account for 33% of variable costs, labour (field workers plus security) accounts for 33%, fingerlings account for 21% and interest 14%. In this budget, feeds and fertilisers cost less than KSh18 per kg of fish produced. However, break-even price is KSh 67 per kg when pond amortisation and cost of capital is considered. Producers who are in the Lake Victoria areas would have a difficult time turning a profit unless they find a niche market that capitalises on the freshness and food safety of the fish. If the farm size (area under water) is increased to 5 hectares, break-even cost of fish production will drop to about KSh 56 per kg. Producers with larger farms would be able to lower their prices and possibly turn a profit even near the lakes. They could supply an export market if the exchange rates were favourable. As a few fish farmers begin to make some money through the semi-intensive management scheme presented here, more intensive strategies may become feasible. However, it is clear that farmers who start small without borrowing money have an advantage because even subsidised interest rates are high.

INTRODUCTION

Use of organic matter such as compost and manure work well for small scale family ponds and, in a few other special cases, such as with chicken houses over ponds, for commercial scale production. But as the size of a production operation increases to a point where a middle-class living can be made solely from fish farming, a more intensive feed-based system is usually preferred. Extension agents who have been trained on small-scale fish farming often cannot advise on commercial-level investments. In Kenya for example, one interested investor who intended to construct at least 30 one-acre ponds was advised by the extension service to hang a bag of manure in the corner of each pond to fertilise. In East Africa there is a lack of business planning advice for fish farming and this makes it difficult for investors to plan a farm. Sample enterprise budgets for commercial-scale fish farms allow banks to make decisions on lending. Numbers can be taken from the literature and a fairly good set of management options described from books, but there is no substitute for real production statistics, real prices and real fish that have been produced and sold in the country under prevailing economic conditions.

The major suppliers of tilapia to the world market rely almost exclusively on a high quality feed; usually a steam-extruded floating pellet containing 30-32% crude protein with balanced amino acids and the full requirement of vitamins and minerals as described in the National Research Council's Nutrient Requirements of Fish (1993). This goes for pond cultured tilapia as well as cage culture and certainly intensive raceway or recirculating systems. Although this option may be open to commercial farmers in East Africa sometime in the future, it would take several key developments for such systems to become common in East Africa. For one, a steam extruder, even of the smallest production capacity, is very expensive; costing about $US 100,000, not including shipping and import duties. A manufacturer of floating pellets would have to have many clients lined up who will pay top price for a high quality feed before investing in such equipment. Extruded, air-dried pellets, using an extruder similar to a meat mincer would be easier to make than steam-extruded. After several discussions with feed producers, we estimated that extruded, air-dried pellets containing 30% crude protein and full vitamin pack plus antioxidants will cost about $US 500 per ton. Even at the acceptable Feed Conversion Ratio (FCR) of 2, this would mean the feed alone would cost $US 1 (KSh 74 at today's rates) per kg of live fish produced. Tilapia sells for about KSh 80-120 per kg in Central Province, Kenya, and for about KSh80 per kg inland from Lake Victoria. At Lake Victoria landing beaches, prices fluctuate but KSh40 is a usual price (Wafula, pers. comm). It is easy to produce fish at a cost of less than KSh50 per kg when few inputs and large water areas are used but land costs and alternative uses make this ultimately an expensive proposition in a private commercial setting. At Sagana Fish Farm, we are looking for a system that can achieve standing crops of at least 5 tons ha^{-1} for a feed/fertiliser cost of less than KSh 25 per kg of live fish produced. Combined cost of feed and fertiliser needed to produce a given net weight of fish has been termed the "monetary FCR" by Hepher (1988).

Hepher (1988) has observed that natural food such as phytoplankton contains about 55% protein on a dry matter basis. This is well above the 30% protein requirement of Nile tilapia. However, the energy content of phytoplankton is lacking. He therefore proposed an energy-rich

supplementary diet to complement the high protein natural diet and thereby increase tilapia production. Rice bran has been used as a supplemental feed for tilapia for decades all around the world. It is usually cheap and in adequate supply. In many cases it has been the sole input to a pond, and, if applied in high quantities could act as an organic fertiliser as well as a feed. Rice bran, maize bran and wheat bran are often used in combination with manure. However, manure is carbon-rich like bran and does not provide nitrogen and phosphorus in optimum quantities. Consequently, the use of chemical fertilisers such as urea and DAP or TSP can provide N and P for protein-rich primary production, and, combined with bran as a carbon source and as a relatively energy-rich feed, seem to be a viable combination for semi-intensive, commercial-level tilapia culture.

At Rwasave Fish Station, Rwanda, an experiment was conducted in which fish were fed rice bran at 5 g per fish per day in ponds stocked at a density of 2 male tilapia per square meter. A mean net yield of 2620 kg ha^{-1} and an apparent feed conversion of 7.6 were obtained after 192 days. No chemical fertilisers were applied, but small additions of chicken manure and grass were used as fertiliser (Verheust *et al.*, 1991). Perschbacher combined inorganic fertilization and feeding rice bran to tilapia, reaching a maximum rice bran application of 46 kg $ha^{-1}d^{-1}$, and obtained a mean net yield of 1160 kg ha after 159 days (Perschbacher and Lochmann 1994). This is somewhat less than the mean net yield of 1582 kg ha^{-1} in an experiment conducted at Sagana in which urea and DAP were applied at 8 kg N plus 2 kg $Pha^{-1}wk^{-1}$ and a daily rice bran application of 60 kg ha^{-1} (Veverica *et al.*, 1999).

At a rice bran cost of KSh 6, 000 per ton, use of chemical fertiliser alone was more economical than a bran/fertiliser combination and much less expensive than bran alone, up to a standing crop of 1660-kg ha^{-1}. If bran cost reduces to KSh 3, 000 per ton, the high bran rate plus half fertilizer rate resulted in greatest net returns, followed by the half bran/half fertiliser treatment. Non-volatile suspended solids was inversely related to bran input rate. Soluble phosphorus levels were very low during the whole experiment. A half bran plus full fertiliser (60 kg ha^{-1} rice bran daily and 16 kg Nha^{-1} and 4 kg Pha^{-1} weekly) treatment was not tested at this time but the water chemistry and fish growth results indicated this may have been a better option than either of the two combinations tested.

Diana and Lin (1996) found that adding supplemental feed (floating pellets, 30% crude protein) after fish reached 150 g resulted in greater annual profit than either fertilisation only or feeding right from the start. The feed used in these trials was fairly costly. Fertiliser in Thailand is less expensive than in Kenya. After those experiments, Diana *et al*., (1996) tested a combination of chemical fertiliser and home feed ration (although complete diet) at three different stocking densities. Ration was decided by determining full satiation once a week and then feeding half that amount. Their diet was a nutritionally balanced, 30% protein-floating pellet. Fertiliser input was reduced as feed input increased but the average chemical fertiliser input was 13 kg N $ha^{-1}wk^{-1}$ and 6.3 kg $Pha^{-1}wk^{-1}$. It was estimated that the wastes from the feed added another 15 kg N $ha^{-1}wk^{-1}$ resulting in a total input of 28 kg $Nha^{-1}wk^{-1}$. Feeding rate averaged 1.65% of body weight per day. Feed conversion averaged 1.4. All male *Oreochromis niloticus* at the intermediate stocking density (6 m^{-2}) reached a standing crop of 22.4 tons per hectare after 194 days. Average weight

was above 300 g.

STUDY AREA

Previous experiments conducted at Sagana Fish Farm in Kenya revolved around bran and fertilisers as inputs. The first experiment conducted at the station, named "R*elative contribution of supplemental feed and inorganic fertilisers in semi-intensive tilapia production*" ran from October 1997-March 1998. Four treatments were tested: Chemical fertiliser as urea and DAP at weekly application rate of 16kg Nha^{-1} and 4 kg P ha^{-1} ; weekly urea and DAP application of 8kg N ha^{-1} and 2 kg P ha^{-1} plus 60 kg ha^{-1} rice bran daily; 120 kg ha^{-1} rice bran daily; and 120 kg ha^{-1} rice bran daily plus weekly application of 8kgNha^{-1} and 2 kg P ha^{-1}. Ponds were limed at 5 tons agricultural lime ha^{-1} prior to filling. All ponds were stocked with *O. niloticus* averaging 32 g at 20,000 ha^{-1} and *C. gariepinus* at 2,000 ha^{-1}. Ponds were drained after 140 days but fish growth had not slowed except for the first treatment in which chemical fertiliser only was applied.

At Sagana, optimum N input rate seems to be between 16 and 20 kg N $ha^{-1}wk^{-1}$. Carrying capacity is somewhere between 2 and 3 tons ha^{-1} (Veverica *et al.*, in press). At the highest N application rate in both trials, some deaths of tilapia occurred probably due to high total ammonia coupled with rather high pH, which resulted in high-unionised ammonia levels. It appeared that the nesting of the larger fish resulted in greater turbidity due to suspended clay and this may explain the much lower standing crop attained in the second trial when compared to the first. It was very difficult to maintain TA at our target of 75 mgl^{-1} as $CaCO_3$. Total hardness was reduced by high applications of soda ash.

We had no idea of carrying capacity of the bran fertiliser mix but needed to know this in order to generate recommendations for stocking rates. Therefore two newly renovated ponds that had not been in any CRSP experiment were stocked at about the same time as the warm season trial of the optimum N experiment. The objective was to compare water quality with the ponds in the optimum N experiment and to see how high standing crop could be attained before fish growth stopped. This trial was done at about the same time the warm season experiment for optimum N was being performed. Only two relatively new ponds were used; fish left over from the previous optimum N experiment were used. The objective was to find carrying capacity for ponds receiving bran at about home the usual feeding rate and chemical fertiliser at the optimum rate for Sagana, determined to be 20 kg $Nha^{-1}week^{-1}$ (Veverica *et al.*, in press). Although optimum P was not known, P input was kept at 8 kg P $ha^{-1}wk^{-1}$ because the ponds were new and in order to duplicate the fertilizer input of one of the treatments in the optimum N experiment.

SITE DESCRIPTION

Sagana is located in a relatively low-lying plain in Central Province, Kenya. A rice project is located in the same plain, about 30 km from the farm. Several small-scale rice farmers have recently started operating near the fish farm. However, maize is the main staple crop grown throughout Central Province.

The Sagana Fish Farm, belonging to the Kenya Department of Fisheries, is situated at 1200 meters above sea level, and receives its water from the Ruthagathi river which originates on Mt. Kenya. This river runs cool year around; its temperatures at Sagana are usually 19 to 21C. Total alkalinity ranges from 16 to 28mgl^{-1} as $CaCO_3$, and total hardness is 13 to 28 mgl^{-1} as $CaCO_3$, with higher values in dry months. A cool season extends from June through August. There is not much difference in average air temperature in the so-called cool season. Minimum air temperatures tend to be the same but maximum temperatures are lower in cool season due to increased cloud cover. Weather at Sagana is similar to weather around the Lake Victoria basin, only a bit drier and with somewhat lower maximum air temperatures. Sagana climate is not indicative of most of Central Province, which tends to be at 1600 to 2200 meters elevation and with cooler climate.

All ponds at the station are constructed of black cotton soil (2:1 montmorillonite), of high clay content (about 80 to 90%) with high cation exchange capacity. Ponds D09 and E10 used in the carrying capacity test were extensively renovated the year prior and had newly excavated bottoms. They have the same surface area as ponds in other CRSP experiments (800 m^2) and the same maximum water depth (100cm) and minimum water depth (60 cm). A lime requirement was calculated at 8 tons per ha for these ponds and a high P retention capacity has been noted. More information on this site is found in the site description booklet published by the PD/A CRSP (McElwee 1999).

MATERIALS AND METHODS

Prior to filling, both ponds received 50 kg TSP spread out on the pond bottom (125 kg P ha^{-1}) and no lime. The ponds were stocked before the first application of urea and DAP as the fish needed to be moved out of the holding tanks without delay.

Ponds were stocked with all male tilapia produced by sex reversal (Popma and Green 1990) resulting from the previous experiment on optimum N, averaging about 90 g (Table 1). A stocking rate of 3 fish per m^2 was intended, with 90% *O. niloticus* and 10% *C. gariepinus*, but losses of tilapia prevented this. The standing crop at stocking was at or above the estimated carrying capacity when only chemical fertilisers are used. Fish were sampled at about 14-day intervals. All fish caught in the seine were counted and a total weight measured. If less than 50 tilapia were caught, a second seine haul was be made.

Water quality measurements were made on the same schedule as for the optimum N experiment that was being conducted concurrently. Temperature and dissolved oxygen (DO) were measured weekly at four depths (5, 25, 50, and 75 cm below surface) at the pier near the drain in the morning and the afternoon. Total alkalinity (TA) and pH were measured weekly using column samples collected at three places in each pond. Chlorophyll a (corrected and uncorrected), TAN, nitrite, nitrate, and soluble reactive-P were measured. Total N, total P, and total hardness (TH) were measured every four weeks. Methods used were as indicated in the CRSP Handbook of Analytical Methods (PD/A CRSP 1992), with the exception of nitrate analysis, which was performed using the NAS method (Skekely 1975). Water sampling and analysis were done on Mondays (all were usually finished the same day or by Tuesday), and fertilisers and soda ash

were applied on Tuesdays. Fish sampling was done on Wednesdays. Ponds were topped off to replace evaporation and seepage losses weekly (Mondays or Tuesdays). During the experiment it became apparent that P was in low supply, so on two occasions, 10 kg TSP was added to each pond.

Wheat bran was added as feed beginning at 2% body weight per day and reducing to about 1.5% body weight per day at the end of the trial. After the first week of May, we switched to rice bran because the wheat bran source could no longer supply.

Pond D09 was drained first because fish average weight had remained about the same for two previous samplings. Pond E10 was drained a couple weeks later. Some fish were sold at KSh 120 per kg to a customer who wanted his fish live and others were sold at KSh100 per kg gutted weight. About a thousand of the fish were used to stock pond C-3 for a longer grow-out period to see if the bran/fertiliser treatment could get fish to filleting size (over 400 g). Feeding rate was kept at 2% body weight for pond C-3.

Table 1. Pond stocking data and fish production results for ponds D09 and E10 (800 m^2 each) in bran-fertiliser carrying capacity test.

Pond	D09	E10
Duration (days)	206	211
STOCKING DATA		
Number tilapia	2160	1914
Weight (kg) tilapia	174.90	202.40
Average weight tilapia (g)	81	106
Number *Clarias*	240	240
Weight *Clarias* (kg)	34.80	43.94
Average weight (g) C*larias*	145	183
Stocking rate (kg ha^{-1})	2621	3079
Stocking rate (fish m^2)	3.0	2.7
HARVESTING DATA		
Number tilapia	1895	1507
Weight (kg) tilapia	491.60	482.90
Average weight (g) tilapia	260	320
Daily weight gain tilapia (g d^{-1})	0.88	1.02
Survival tilapia (%)	87.8	78.7
Number *Clarias*	240	247[1]
Weight *Clarias* (kg)	68.66	81.51
Average weight *Clarias* (g)	286	330
Survival *Clarias* (%)	100	>100
Gross fish yield (kg ha^{-1})	7002	7052
Net fish yield (kg ha^{-1})	4381	3976

RESULTS

Some fish in E10 died after stocking because they were in poor condition, having been held in the holding tanks and cool water for a long time. It was assumed that most fish losses were either from poor stocking conditions or cormorant depredation and occurred within the first month of stocking and therefore did not have an impact on gross fish yield (GFY). Early fish mortality was assumed when constructing the graph showing standing crop over time (Fig. 1).

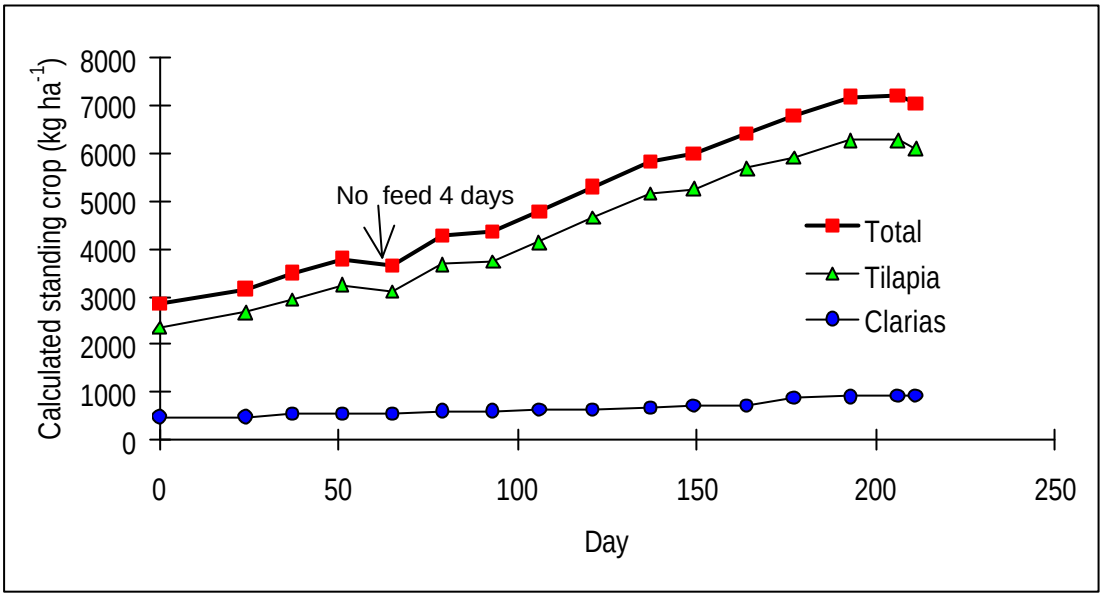

Fig. 1. Calculated average standing crop for ponds D09 and E10 during the carrying capacity test. First and last points are based on total weights. Other points assume a total number based on observations of fish mortality and multiply by measured average weights of a sample.

Gross fish yield was about 7 tons per hectare for both ponds (Table 1); 6 tons as tilapia and about 1 ton as *Clarias*. Clarias did not grow well at all and only reached 300 g, which is under market size of 400-600 g. Tilapia reached market size.

Even though the total N input was higher than the highest treatment in the optimum N experiment for most of the production cycle, TAN and nitrite levels remained relatively low (Table 2). The lower pH in ponds receiving bran meant that unionised ammonia levels were much lower (by a factor of 3) than for the 20 kg N and the 30 kg N treatments in the optimum N experiment. Despite the high level of P addition and the initial application of TSP soluble P levels were much lower for these ponds than for the ponds in the optimum N experiment (Table 2).

The pond water in D09 and E10 became very turbid due to nesting and feeding activity of the fish. The fine particles of the black cotton soil remain in suspension for a long time. Levee erosion was not quantified but it was extremely high and much greater than in any other ponds kept in production for the same duration. Nesting and fish activity in the search of food were both responsible. Fat tends to build up in fish fed bran but these fish had very little fat deposition

(visual observation during gutting of fish). It is quite probable that the suspended clay had a detrimental effect on primary production and is the main reason for the carrying capacity remaining at 7 t ha^{-1}. This is much lower than the 20 t ha^{-1} standing crops achieved in Thailand using a high quality feed and fertiliser (Diana and Lin 1996). It is however, very cost-effective and is our best result to date.

Table 2. Water quality parameters (average ± SE) for ponds D09 and E10 receiving the bran plus chemical fertiliser compared to those for ponds (3 reps per treatment) receiving chemical fertiliser only at either 20 or 30 kg N ha^{-1} wk^{-1} in the warm season repetition of the optimum nitrogen experiment conducted at the same time as the carrying capacity test. Other parameters of the optimum nitrogen test are reported in Veverica *et al.*, b (in press).

	Bran plus chemical (Avg N in =28 kg)	Chemical only at 20 kgN	Chemical only at 30 kg N
Morning dissolved oxygen (mg l^{-1}) at 25cm from top	0.8 ± 0.08	1.9 ±0.16	1.8 ±0.05
Afternoon dissolved oxygen (mg l^{-1}) at 25cm from top	11.7 ± 1.65	10.5 ±0.25	12.7 ±0.45
Morning water temperature (°C) at 25 cm from top	23.8 ± 0.05	23.6 ±0.04	23.3 ±0.10
Afternoon water temperature (°C) at 25 cm from top	27.7 ± 0.30	27.5 ±0.10	27.9 ±0.25
Morning column pH	8.1 ± 0.05	8.8 ± 0.3	8.8 ± 0.2
Total alkalinity (mg l^{-1} $CaCO_3$)	89.5 ± 4.5	64.0 ± 1.6	55.3 ± 0.8
Total hardness (mg l^{-1} $CaCO_3$)	73.5 ± 5.5	47.5 ± 4.3	30.8 ± 3.6
Total nitrogen (mg l^{-1})	4.8 ± 0.2	5.0 ± 0.7	6.1 ± 0.5
Total ammonia nitrogen (mg l^{-1})	0.9 ± 0.21	0.6 ± 0.09	0.8 ± 0.08
Nitrite- nitrogen (mg l^{-1})	0.03 ± 0.00	0.1 ± 0.05	0.3 ± 0.11
Nitrate-nitrogen (mg l^{-1})	0.08 ± 0.01	0.2 ± 08	0.3 ± 0.01
Total phosphorus (mg l^{-1})	0.9 ± 0.7	2.6 ± 0.5	3.7 ± 0.2
Soluble reactive phosphorus (mg l^{-1})	0.14 ± 0.05	1.3 ± 0.08	1.5 ± 0.23
Chlorophyll a corrected for phaeophytin (mg M^{-3})	254.5 ± 42.5	182.2 ± 78.4	198.5 ± 16.9
Chlorophyll a uncorrected (mg M^{-3})	278.0 ± 42.0	252.3 ± 97.8	271.0 ± 25.7

Pond C^{-3}, that received a higher feed rate (Table 3) was drained after two successive sampling showing little increase in growth but GFY was only slightly higher than 7 t ha^{-1}. The only difference was that FCR was higher and fish viscera had more fat when compared to the results from D09 and E10.

Table 3. Results of fertiliser and bran combinations used in various experiments at Sagana Fish Farm, Kenya. Some experiments were terminated before carrying capacity was reached. Gross fish yield numbers are written in boldface in trails where ponds were drained when carrying capacity was attained.

Weekly chemical fertiliser input		Daily bran input (kg ha^{-1})	Number of ponds	Length of cycle (Grams)	Mean wt. tilapia at harvest (kg ha^{-1})	Gross Fish Yield (Days)	Net Fish Yield (NFY) (kg ha^{-1})	Cost [1] per kg NFY (KSh)	AFCR[2]	Reference
(kgN ha^{-1})	(kgP ha^{-1})									
16	4	0	3	144	81	1663	1127	26.5		Veverica et al. (a), 1999. Gichuri (1999)
20	8	0	3	147	60	**3229**	2191	30.9		Veverica et al. (b), in press- cool season
20	8	0	3	133	181	**1901**	957	39.8		Veverica et al. (b), in press-warm season
20	8	72[3]	2	210	290	**7027**	4179	27.4	3.6	Ponds D09 and E10, this report
8	4	60	3	144	106	2231	1582	27.2	6.0	Veverica et al. (a), 1999. Gichuri (1999)
8	4	120	3	144	131	2730	2098	32.8	8.7	Veverica et al. (a), 1999. Gichuri (1999)
0	0	120	3	144	106	2234	1607	39.4	12.4	Veverica et al. (a), 1999. Gichuri (1999)
16[4]	6	120[5]	1	126	410	**7175**	2081	33.6	7.2	Pond C03; this report

1. Cost of feeds and fertiliser only, bran always at KSh3 kg^{-1}.
2. AFCR: apparent feed conversion ratio = total amount feed added/net fish yield
3. Wheat bran and rice bran. Input rate varied from 52 to 100 kg ha^{-1}d^{-1}
4. Average over the cycle; began at 20N plus 8P.
5. Rice bran. Input varied from 90 to 140 kgha^{-1}d^{-1}.

DISCUSSION

It appears that a stocking rate of 27,000 tilapia and 3,000 catfish per hectare is a bit too high for this input regime if market size of tilapia is 300g and that for catfish is over 400g. If we assume that the carrying capacity is 7 tons per hectare, 6 of them as tilapia and 1 as catfish, then a stocking rate of 20,000 tilapia per hectare is realistic to obtain a projected harvest size of 300g. Catfish are more problematic as their growth tends to level off at 400 g at Sagana no matter what the stocking density. If market size for catfish is estimated to be 500 grams, then a stocking rate of 2,000 ha^{-1} would be recommended. These results indicate that as estimated standing crop approaches 7T ha^{-1} it is a good idea to begin harvesting. At least 3 weeks of feeding and fertilising were undertaken during which time fish grow was almost nil, just to make sure carrying capacity was reached. Had the ponds been harvested sooner, feed conversion and cost of inputs could have been lower.

Fertiliser cost varies according to the exchange rate and is therefore somewhat predictable. There is no fertiliser manufacturing plant in Kenya so all fertiliser is imported. Bran cost varies according to local grain harvests and according to government policy. Rice bran cost us KSh 6,000 per ton, (equivalent to $100 per ton at the exchange rate of KSh 60/$US), in 1997-98 but is now purchased for under KSh 1,660 per ton (equivalent to $23 per ton at an exchange rate of KSh 72 /$US). One reason for the big change is that the rice mills in Central Province are no longer under the complete control of the government. The latter price is considered unnaturally low and it will probably adjust up as the animal feed buyers and bran producers strike a balance. Including delivery costs to Sagana our price is still well under KSh 3,000 per ton but we prefer to be conservative and use this price for our enterprise budgets.

A summary of CRSP experiments is presented in Table 3. Treatments were either purely chemical fertilisers or some combination of bran and fertiliser. Stocking rates were variable but were never below 2 fish per m^2 except in the last pond noted in the table. Price of bran was kept at a uniform 3KSh per kg so as to compare the various treatments. We used actual prices of the fertiliser because those did not vary much. *Clarias* made up about 10% or less of the fish stocked. From rows 2 and 3 of the table, a carrying capacity of 2 to 3 tons ha^{-1} can be expected from chemical fertiliser alone. Other fertilisation rates have been tested but those presented here are for the treatment that resulted in best production and greatest marginal returns. Adding bran to the fertiliser treatment more than doubled the gross fish yield.

Enterprise budget

Based on the results from the first experiment in which fish were grown to 90 grams on chemical fertiliser and on the results presented here in the carrying capacity test, a rudimentary enterprise budget is presented in table 4 for one hectare of fishponds. The two phases described use similar stocking rates and can be conducted in the same pond, hence there is no need to split the fish nor drain between phases. The only change is the input regime. The budget is conservative in that it uses the full number of days that was used in the carrying capacity test, even though the last three weeks or so exhibited little or no growth and continued bran and fertiliser inputs.

Table 4. Enterprise budget for a one-hectare production farm

Variable costs	Unit	Price (KSh)	Price ($US)	Quantity	Value (KSh)	Value ($US)
First phase: no feed						
Urea	kg	19	$0.32	540	10,260	$171
D.A.P.	kg	23	$0.38	400	9,200	$153
T.S.P. to satisfy soil P demand	kg	25	$0.42	625	15,625	$260
Tilapia fingerlings	Piece	3	$0.05	22500	67,500	$1,125
Clarias fingerlings	Piece	5	$0.08	2500	12,500	$208
Field labor: stock, feed, fertilize, harvest	Man-day	120	$2.00	160	19,200	$320
Security personnel	Night	150	$2.50	208	31,200	$520
Second phase: bran plus fertilizer						
Bran, including transport	kg	3	$0.05	15000	45,000	$750
Urea	kg	19	$0.32	779	14,803	$247
D.A.P.	kg	25	$0.42	1183	29,575	$493
Field labor: stock, feed, fertilize, harvest	Man-day	120	$2.00	210	25,200	$420
Labor, levee renovations, after draining	Man-day	120	$2.00	150	18,000	$300
Security personnel	Night	150	$2.50	208	31,200	$520
Sub total variable costs					329,263	$5,488
Interest on operating capital:16% p.a.					52,682	$878
TOTAL VARIABLE COSTS					**381,946**	**$6,366**
Fixed costs						
Amortization of ponds, equipment, 15yrs	Ponds	400000	$6,667	0.067	26,667	$444
Interest on investment, ponds only	16% p.a.	400000		0.16	64,000	$1,067
TOTAL FIXED COSTS FOR 1 YEAR					**90,667**	**$1,511**
Gross revenues						
Tilapia	kg	100	$1.67	6091	609,063	$10,151
Clarias	kg	100	$1.67	939	93,856	$1,564
TOTAL REVENUE					**702,919**	**$11,715**
RETURNS TO LAND, WATER AND MANAGEMENT:					**230,307**	**$3,838**
Breakeven price per kg fish:					67.23	$1.12

Stock fingerlings avg. weight 15g at 25,000 per hectare;
Fingerlings purchased off-station
First phase is 140 days; second phase is 200 days
Exchange rate was 60KSh=$1US when trials carried out

Monosex fingerlings are sold at the same price as mixed sex at Sagana so it does not matter if the farmer chooses mixed sex tilapia production or monosex when the ponds are stocked the first time. However, if fingerling cost is considered, a farmer can use fingerlings harvested from production ponds to restock and save almost KSh 90,000 thereby increasing profits. Purchase of catfish fingerlings would still be necessary but this would only cost about KSh12, 000. The deciding factor when deciding if monosex tilapia should be stocked would be size of fish to market and any price difference for tilapia of less than 250 g. Another choice is to produce all-male fingerlings on the farm. This is not difficult and would require 3 small ponds totalling less than 0.1 hectares for stocking 1 hectare worth of ponds. For that matter, on-farm production of catfish is also highly feasible. A third choice is to stock mixed sex tilapia at high density for the first phase (about 5 per m^2) and hand sex or simply grade by size to stock the second phase ponds.

A set of 9 or 10 ponds, about 1000 m^2 each would be ideal for the one-hectare farm that wishes to supply fish to a market on a weekly basis. A pond could be seined weekly beginning at month 9 of the production cycle as it reaches about 6.5 tons ha^{-1} and drained on the fourth week. The full production cycle should take less time than the sum of the two experimental cycles used to make the enterprise budget.

Land costs have not been included, as they are extremely variable in Kenya, nor has cost of water (we assume gravity flow). If land and/or water costs were high, a more intensive production scheme would usually be preferred. The interest rates in this enterprise budget are based on the rate used by the Agricultural Finance Corporation of Kenya in April 1999, when the carrying capacity test was being run. The Government of Kenya subsidises the credit scheme. Payments on these loans are made annually. The AFC requires a 3-year cash flow plan as well as an enterprise budget and farm plan (Mr. Kairu, pers. comm.)

In this enterprise budget, feeds and fertilisers account for 30.7% of variable costs, labour (field workers plus security) accounts for 23.1% and fingerlings account for 25%. Usually, the factor that accounts for the majority of the variable costs is the one to work on lowering. However, thirty percent is already very low for the contribution of inputs to the overall production costs. In this budget, feeds and fertilisers cost less than KSh18 per kg of fish produced. However, break-even price is KSh 71 per kg. Producers who are in the Lake Victoria areas would have a difficult time turning a profit unless they find a niche market that capitalises on the freshness and food safety of the fish. If the farm size (area under water) is increased to 5 hectares (Table 5), feed and fertiliser cost would increase by a factor of 5 but labour would only have to increase by a factor of 2 or 3. Break-even cost of fish production will drop to about KSh 52 per kg. Producers with larger farms would be able to lower their prices and possibly turn a profit even near the lakes. They could supply an export market if the exchange rates were favourable. As a few fish farmers begin to make some money through the semi-intensive management scheme presented here, more intensive strategies may become feasible. However, it is clear that farmers who start small without borrowing money have an advantage because even subsidised interest rates are high.

Table 5. Enterprise budget for a five-hectare production farm

Variable costs	Unit	Price (KSh)	Price ($US)	Quantity	Value (KSh)	Value ($US)
First phase: no feed						
Urea	kg	19	$0.32	2700	51,300	$855
D.A.P.	kg	23	$0.38	2000	46,000	$767
T.S.P. to satisfy soil P demand	kg	25	$0.42	3125	78,125	$1,302
Tilapia fingerlings	Piece	3	$0.05	112500	337,500	$5,625
Clarias fingerlings	Piece	5	$0.08	12500	62,500	$1,042
Field labor: stock, feed, fertilize, harvest	Man-day	120	$2.00	400	48,000	$800
Security personnel	Night	150	$2.50	416	62,400	$1,040
Second phase: bran plus fertilizer						
Bran, including transport	kg	3	$0.05	75000	225,000	$3,750
Urea	kg	19	$0.32	3896	74,017	$1,234
D.A.P.	kg	25	$0.42	5915	147,875	$2,465
Field labor: stock, feed, fertilize, harvest	Man-day	120	$2.00	525	63,000	$1,050
Labor, levee renovations, after draining	Man-day	120	$2.00	375	45,000	$750
Security personnel	Night	150	$2.50	416	62,400	$1,040
Sub total variable costs					1,303,117	$21,719
Interest on operating capital:16% p.a.					208,499	$3,475
TOTAL VARIABLE COSTS					**1,511,616**	**$25,194**
Fixed costs						
Amortization of ponds, equipment, 15yrs	Ponds	200000	$3,333	0.067	133,333	$2,222
Interest on investment, ponds only	16% p.a.	200000		0.16	320,000	$5,333
TOTAL FIXED COSTS FOR 1 YEAR					**453,333**	**$7,556**
Gross revenues						
Tilapia	kg	100	$1.67	30453	3,045,313	$50,755
Clarias	kg	100	$1.67	4693	469,281	$7,821
TOTAL REVENUE					**3,514,594**	**$58,577**
RETURNS TO LAND, WATER AND MANAGEMENT:					**21,549,645**	**$25,827**
Breakeven price per kg fish:					55.9	$0.93

Stock fingerlings avg. weight 15g at 25,000 per hectare;
Fingerlings purchased off-station
First phase is 140 days; second phase is 200 days

As market price approaches the break-even production price, it is important to figure on how individual farmers can optimise their management based on the inputs available so their production prices can be competitive. A single recipe or "management package" will not provide farmers with the opportunity to use the inputs that may be available to them. Some may be able to get rice, maize or wheat bran but chemical fertiliser may be expensive or hard to find. Others may have access to manure for "free". Some may have access to much input at varying prices and will need to calculate which combination of inputs results in least-cost production. These experiments and trials should provide some guidance for farmers and extension agents. They can be used as a basis of a business plan but they do not cover all of the options. Farmers must first of all decide on desired market size as this will indicate whether or not mixed sex or monosex tilapia fingerlings should be sought.

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Comparative Study of Soya Meal and Dagaa Protein in Dietary Source for the Rearing of *Clarias gariepinus* fry at Songoro - Kenya

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SUMMARY

A mature female of Clarias gariepinus weighing 350g from fish ponds at Sangoro Aquaculture Research Centre was induced by pituitary gland homogenate of the male fish of the same species under hypophysation technique. After 36 - 48hrs at an incubation temperature of 19oC in an asbestos tank, over 5,000 hatchlings were realized. 3,900 fry were taken exactly after attaining five days of age and were transferred into plastic troughs, sustained on wild zooplankton harvested from fishponds. The fry were fed on zooplankton for 14 days while in the troughs and then weaned before they were put on artificial diet.

The fry then were fed on three trial diets of dagaa - D1, Soya meal - D2, dagaa + Soya blend - D3 twice daily. A fixed feed regime of 6% of the body weight per day of the protein supplement was adopted except for the control. A cohort of 25 fry, 14 days old of initial average total length (TL) 1.12mm and average weight 7.69mg were taken. Their average total length TL mm and body weight were determined when the fry attained the ages of 32 and 45 days for all the troughs.

Proximate analysis done on the ingredients revealed that dagaa had crude protein CP 58% (w/w)%, whole Soya meal - 34.48%; full sprouted - 44.88%; alkaline soaked, 30.48%; boiled, 14.72%; rice bran 6.98%; cassava (total carbohydrate), 88.37%; crude fat, 0.48% and energy Kcal/g 3.85.

The experiment was concluded after 45 days with specific growth rate (SGR)%/day 5.18, D1; 4.79, control; 4.08, D3 and 2.97, D2 respectively.

With reference to average TL (mm) specific growth rate was 1.16, D1; 0.92, control; 0.85, D3 and 0.75, D2 respectively. Mortality was least with the control, which had 22.8%; D3, 63%; D1, 72.2% and D2, 77.2% in an ascending order. Whereas survival rate was highest with the control, 77.3; D3, 37; D1, 27.8 and 22.8% D2 Soya meal respectively.

Both dagaa and Soya meal showed a perfect relationship (Time Vs Average Wet weight - mg). D1 (r = 0.902), r2 = 0.814; D2 (r = 0.933, r2 = 0.875; D3 (r = 0.999), r2 = 0.998 and control (r = 0.921), r2 = 0.848. The experiment proved that zooplankton offered the

best nutritional value followed closely by diets D3, D2 and D1 for the first 32 days. But after that, it was parallel to the wild zooplankton. There was a decline in the body weight for D2, D3 and the control but not D1.

All statistical analyses were carried out by the multiple range method of Duncan (1955).

INTRODUCTION

Clarias gariepinus is a good candidate for aquaculture because of its high fecundity in the range of 5,000 - 192,000 eggs (Rinne and Wanjala, 1983). It can survive in low dissolved oxygen conditions, can be marketed live, it has a rapid growth rate, can withstand high diurnal temperature fluctuations, prefers warm water and is able to feed on many trophic levels in a pond (Douglas Clay, 1979), it being omnivorous.

Fish farmers in the tropical countries generally harvest their fish at 3 to 6 months of age, or in the case of catfish, at less than 300g-body weight or 30cm total length. Production of sufficient and high quality fingering is a major constraint to aquaculture production in the tropics. Our preliminary observations on the production of *C. gariepinus* fingerings have indicated that high mortalities are due to smothering by silt when raw river water is used, microbial (bacterial, fungal and viral) infections, nutritional deficiencies and low dissolved oxygen concentrations. Upto 100% mortality of fry is common within the first 10 days of rearing from larvae. Fish fry were highly sensitive to a diet of Vitamin C. Deficiencies have been known to cause reduced growth rates, deformation of skeletal tissues, increased rate of mortality (Kitamula *et. al.*; 1965, Halver *et al.*; 1969, Lovell, 1973; Wilson, 1973, Lim and Lovell, 1982).

Aflotoxin and rancid fats from major dietary ingredients have been documented to cause mortality in fish (Balarin.J.D.,1982).

Growth is always better when Clarias fry is fed on live feed such as artemia and zooplankton. Use of balanced diet containing high ratio of protein (55%, UYS) and heart (Herchet, 1985) got better growth as opposed to that of zooplankton feeding. The formulated diet in this study is meant to address deficiencies of vitamin c and minerals by feeding the fry on zooplankton for 14 days after egg yoc absorption. The feeds should be processed before formulation, remove free fats, moisture and aflotoxin development during storage.

Over 5,000 fry were obtained by induced spawning of a ripe female *Clarias gariepinus*. Of these, 3,900 were used for diet trials in 13 plastic troughs. Feeding of the hatchlings was started at an age of five days after absorption of the yolk sac. The fry were then divided into four dietary groups of 300 each.

An artificial indoor static micro-environment system of 13 troughs of 15 litres each was used with raw Sondu-Miriu water rearing the fry. The water was channeled into the laboratory through a

header tank. Each trough was filled up to a mark of 12cm with conditioned river water. Rearing of fry was carried out at water temperatures of 20 ± 2?C and pH 6 ± 2. The purpose of conditioning the water was to render it safe from pathogenic and parasitic infections of fry. The water once left to settle in a container for upto four days is free from contamination by coliform bacteria and silt which could result into high larval mortalities.

Three diets were formulated using dagaa, Soya meal and a blend of dagaa and Soya-meal. These were administered on three groups each with 300 experimental fish larvae for 18 days. A control constituting of 300 fry was sustained on zooplankton harvested from a fishpond throughout the experimental period.

Kjeldhal analysis was used to determine crude protein content of the dagaa, Soya meal and a blend of the two. The Pearson square method to standardize the protein supplements to 45% protein level in the prepared diets.

OBJECTIVES

(i) To evaluate the suitability of plant and dagaa (*R. argentea*) based protein feeds for rearing catfish, *C. gariepinus* fry.

(ii) To formulate a supplementary feed from locally available materials; Soya-meal, and dagaa as protein dietary sources.

METHODS AND MATERIALS

A three-diet study was conducted with *Clarias* garepinus for fry at Sangoro Research Centre. A statistic indoor rearing system was used for an experiment of diet trials in thirteen plastic troughs of capicity 15L containing 11L raw Sondu-Miriu river water. The depth of water in the troughs was maintained at 12cm. A mature female *Clarias gariepinus* weighing 350g was induced by pituitary gland homogeneate processed from a male fish of the same species under hypophysation technique. After 36-48 hours at an incubation temperature of 19°C in an asbestos tank. Over 5,000 fry were obtained. Stripping and fertization of the eggs were done according to Scoonbee and Prinsloo (1986)

After 5 days, 3,900 fry were transferred from the incubation tank to the rearing plastic troughs kept at temperatures of 20+ 1°C and pH 6+ 2. Each trough was stocked with 300 fry reared under the same conditions.

Prior to rearing the troughs were set in the laboratory room 4 days before transfer of fry from the incubation tank. Conditioned water was used to replace the one in the troughs twice every day. The fry were not until after a day in their new micro-environment. The fry were fed twice daily at 8.00am and 4.30pm to satiation on wild zooplankton harvested from the fishponds using an improvised plankton net of mesh 25 bongo nets.

The feeding was done after changing 1/3 of the original water volume in the morning and syphoning bottom of the trough. After a period of 14 days the fry were weaned and gradually introduced to a formulated diet. At that age, 25 fry were taken from control tank and their average total length and body weights were determined in milimeters and miligrammes respectively.

Preparation of feed Ingredient

Drying, cooking, boiling, roasting, germination and fermenting processed soya meal. The beans were then milled using a ball hammer to provide whole soya meal flour. Cassava was peeled, dried, sun-dried and milled to obtain flour. Rice bran was also grounded to obtain fine particle sizes for compounding. From the fishmongers, *Rastrineobola argentea* was obtained, snails, *Caridina nilotica*, and pressed to remove water and oil and then sun-dried.

The dagaa was further dried in the oven-night at 80°C to remove free moisture then milled by a ball hammer to obtain whole dagaa flour. Proximate analysis was done on all the ingredients before the diets were formulated. Plankton net material was improvised as a screen to get particle sizes of 0<125 m of the diet material, (Girim, 1979).

Diet and feeding regime

The protein supplement ration was calculated using the formula given below: -

$$\frac{300 \times 6 \times \tilde{n}}{100}$$

Where: ñ = mean wet weight of the fry
300 = stocking density
6% = body wet weight per day.

Experimental Design

Batches of 1200 fry were recruited in groups of 300 for the following feeding regimes: -

Troughs 3,4,9 & 10 were sustained on diet a dagaa diet.
Troughs 1,2,11 & 12 were sustained on a Soya- meal blend.
Troughs 5,6,7 & 8 were sustained on a blend of Soya and dagaa.

Growth performance, condition factor, mortality and survival rates of the fish were monitored after periods of 18,32 and 45 days.

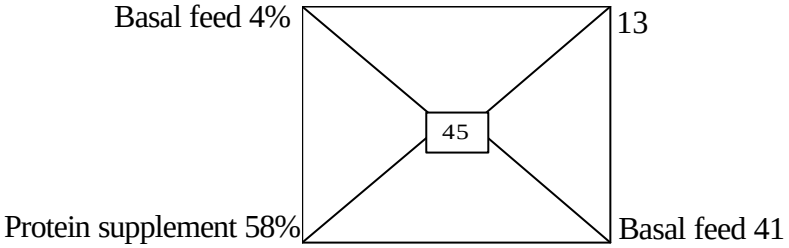
Feed formulation

Basal of feed formulation

Basal feed and protein supplement were combined and standardized using Pearson's' method. Protein average of a basal feed made from rice bran and cassava with protein content of 7 and 1 respectively was determined as 4. Rice bran proportion was 87.5% whereas that one of cassava was 12.5%. 100g of the basal feed were made out of these feeds by mixing 87.5 g of rice bran and 12.5g of cassava. The feed was packaged in a moisture proof atmosphere in the dark until use.

Diet 1 formulation:

Basal feed and protein supplements were combined using the Pearson's' square method.

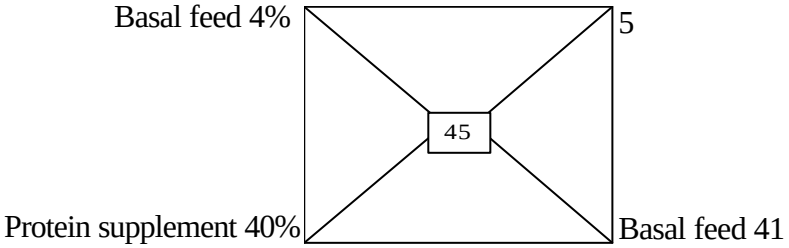


The ratios of the above feed were calculated as below:

Basal feed 13/54x100=24.1%
Protein supplement 41/54x100= 75.9%

100g of these feed was made by mixing 24.1g of basal feed with 75.9 g of the protein supplement and stored in the dark in a water proof package.

Diet 2 formulation:



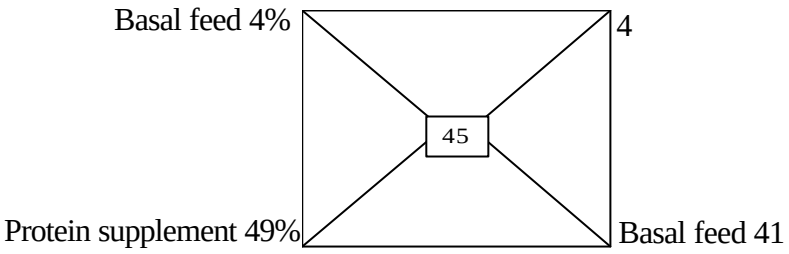
The above feed was prepared as follows: -

Protein content of roasted Soya + protein content of sprouted Soya were mixed as follows: -

Basal feed 5/46x100= 10.9%
Protein supplements (Soya meal blend): Roasted Soya flour +Sprouted Soya - flour = 41/46 x 100 = 89.1%

100 g of the above feed were made by mixing 10.9g of basal feed with 89.1g of the protein supplement and stored in a moisture proof package in the dark.

Diet 3 Formulation



(Dagaa + Soya blend)

The above feed was made as follows: -

Basal feed 4/45 x 100 = 8.9%
Protein supplement 41/45 x 100 = 91.1

100g of the above feed were made by mixing 91.1g of the protein supplement with 8.9g of the basal feed and stored in a waterproof container.

RESULTS

Proximate analysis done on ingredients showed dagaa had protein contents 58%, Soya meal 40%, a blend of Soya meal 49%,{cassava (Total carbohydrate 88.37%) protein content 1. 23%, Crude fat 0.48% moisture contents 8.76, crude fiber 1.17% }, Soya meal 34.48% , Rice Bran crude fiber ,19.38% , Crude protein 6.98% and dagaa crude fat 13.35%.

Crude protein of Soya beans treated in six various ways indicated that full sprouted had 44.88%, Mild sprouted 44.45%, Boiled 41.57%, Roasted 35.1% Whole and untreated 34.48% and Alkaline soaked 30.8% w/w% respectively

Dagaa gave the highest specific growth rate SGR (%/DAY), 5.18%; followed by control 4.79%, (Soya meal + Dagaa) blend, 4.08% and Soya meal at the least 2.97% .

Showed that the control had the best performance in the first two days followed closely by (Soya + Dagaa) blend and then Soya meal. Dagaa was relatively poor in the same period but picked very well thereafter until after 45 days. After 32 days Soya meal declined sharply as compared to (Soya + Dagaa) blend whereas the control decline was gradual.

Table 1. *C.gariepinus* growth progress for 45 days

Diet	Tank	Age (days)	N	Average TL (cm)	Average Wet Weight (mg)
Control	13	14	22	1.12	7.26
1	3,4,9,10	18	40	1.05	-
2	1,2,11,12	18	40	1.1	-
3	5,6,7,8	18	40	1.13	-
Control	13	32	100	1.56	34.2
1	3,4,9,10	32	100	1.11	17.4
2	1,2,11,12	32	100	1.16	28
3	5,6,7,8	32	100	1.28	31
Control	13	45	25	1.5	35.16
1	3,4,9,10	45	25	1.6	39.59
2	1,2,11,12	45	30	1.41	20
3	5,6,7,8	45	96	1.42	28.2

Table 2. Mortality and Survival over the experimental period - 45 days

Diet	1	2	3	Control
Average Mortality %	72.2	77.2	63.0	22.8
Average Survival %	27.8	22.8	37.0	77.3

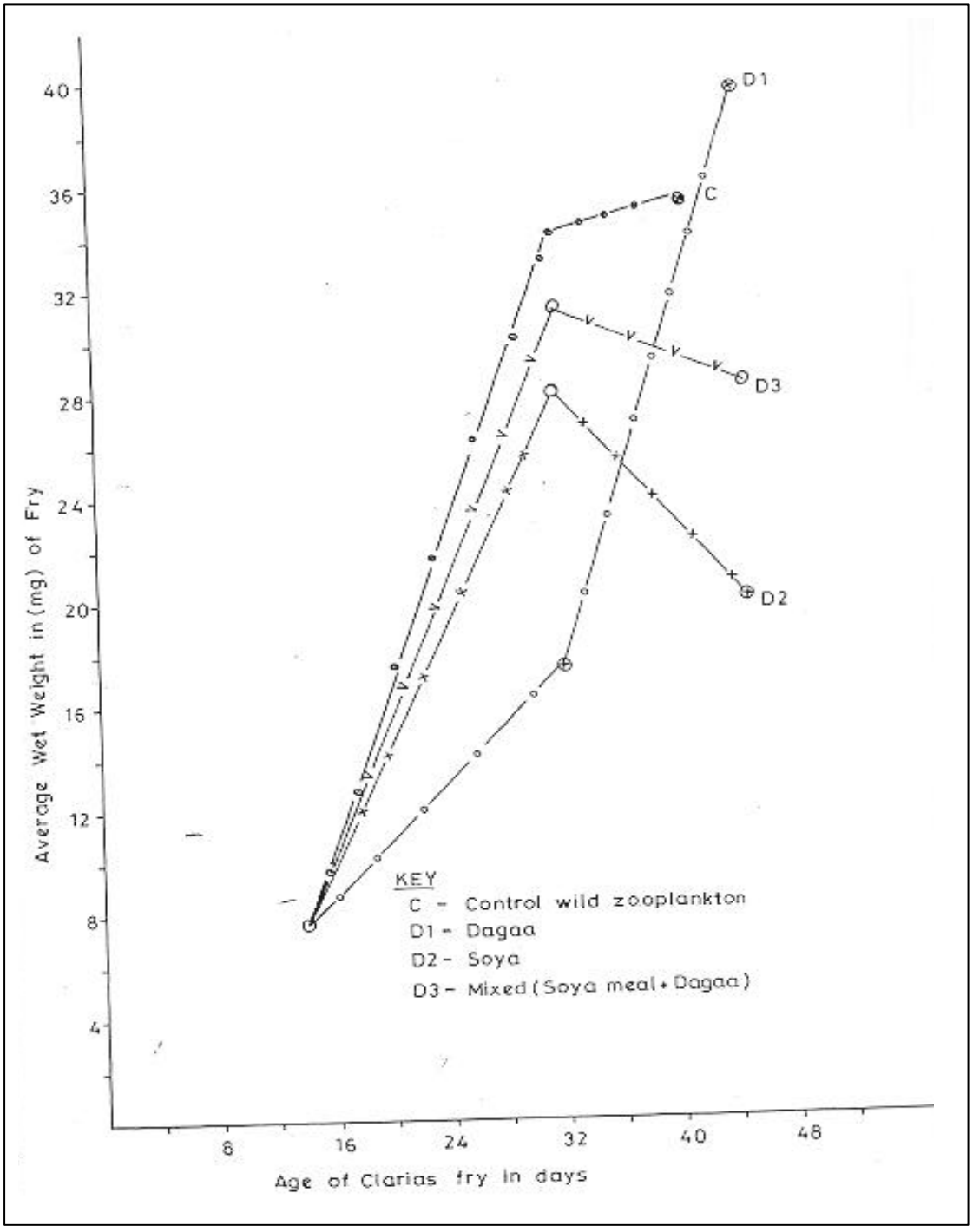


Fig. 1. The relationship between average fish wet weight and time for each protein source.

Table. 3. Crude protein of Soya beans treated in six different ways

Sample treatment	Roasted	Whole untreated	Full sprout	Alkaline soaking	Boiled	Mild sprout
Average C/Protein w/w%	35.1	34.48	44.88	30.8	41.57	44.45

Table 4: Chemical Composition of protein supplement and basal feeds

Sample treatment	Cassava	Soya meal	Dagaa	Rice bran
Energy Kca/g	3.85	6.18	5.16	-
M.C. (d.b)	8.76	9.035	-	-
Crude Fibre (w/w)%	1.17	-	-	19.38
Crude protein (w/w)%	1.23	34.48	58	6.98
Carbonhydrates (w/w)%	88.37	-	-	-
Crude Fat (w/w)%	0.48	17.51	13.35	-

Table 5: Diet average, average wet weight (mg) and SGR (%/day)

Diet	Average initial wet wt (mg)	Average final wet wt (mg)	SGR (%/Day
Control zooplankton	7.955	35.164	4.79
1 (58%)	7.955	39.59	5.18
2 (40%)	7.955	20.0	2.97
3 (49%)	7.955	28.20	4.08

Table 6: Diet average TL(cm) and SGR (%/day)

Diet	Initial Average TL (cm)	Final average TL (cm)	SGR (%/Day)
Control zooplankton	1.12	1.496	0.92
1 (58%)	1.12	1.6	1.16
2 (40%)	1.12	1.4	0.75
3 (49%)	1.12	1.45	0.85

DISCUSSION

With the rapid rise of world population, worldwide or regional protein shortage, there is great need to identify a good cultivable fish of high fecundity, which can raise fry in mass for aquaculture. *Clarias gariepinus* is this Candidate.

Clarias gariepinus fry responds positively to Soya meal as a protein dietary source and also to a fortified diet. This is true possibly because of amino acid fortification.

Zooplankton is a good starter feed for *Clarias gariepinus* followed by (Soya meal + Dagaa) blend, Soya Meal and dagaa meal respectively until the fry are 32 days old. The scenario, however, changes thereafter until the fry were 45 days when they showed a parallel relationship with the fry feed on Zooplankton. This is probably due to protein deamination.

Dagaa picks up gradually than the other three; this is because the protein is not hydrolyzed fast in the stomach of the fry and/or digestion is slow due to inadequate secretion of pepsin from the developing gut.

After the fry attaining 32 days of age there is conspicuous decline in the body weight for diet; Soya meal, Soya meal blend and the control respectively. This is so because dagaa protein supplement does not deaminate fast so as to create a deficiency. This suggests that the protein level should have been stepped up for the other diets after 32 days.

Excessive erosion of nitrogen solution during extraction and deamination led to sharp decline with Soya meal . Soya meal has a digestibility of 84.3% whereas that of animal protein is 97% (Atwate R, A.P. Bryant, 1899).

Very high average mortalities were recorded as Soya meal, 77.2%; dagaa, 72.2%; (Soya meal + Dagaa) blend; 63% and the control, 22.8% see (Table 2) respectively. Fortifying Soya meal with dagaa decreases mortality by 22.2%. This means that certain essential amino acids are incorporated during the fortification. The high mortalities are attributed to vitamin deficiency and free fat acid in the artificial diet. (Dabrwski, 1988) has documented that fry of size (6.5-8.8mg) fed on dry diets display high mortality (7.8 - 56.2%) than those fed on live Artemia nauplii (33.2mg). A Vitamin-mineral premix is a prerequisite when fish are kept in captivity (raceway, aquaria, even earthen ponds) for very intensive culture with a limited natural food supply (Clay,1981).

CONCLUSION

Where high-grade fishmeal such as dagaa is not readily available or not competitive in price, Soya meal can offer a valuable alternate source of protein as a dietary source in fry production of Clarias gariepinnus. Dagaa, however remains a superior protein supplement and where readily available should be used.

RECOMMENDATIONS

Diets can only be formulated after proximate analysis is done on the potential ingredients meant to supply protein supplement.

Nutritionist should work hand in hand with aquaculturalist and feed compounders and vise versa for maximum nutritional and economic benefit from artificial diets.

Further research to be conducted on amino acid spectrum of Soya meal and dagaa as protein supplements for effective utilization.

Further studies on proximate analyses diet trials are needed to formulate fish feeds using locally available raw materials, for example, from agricultural and industrial byproducts. Ingredients used in feed formulation should be well selected, processed and stored in proper package materials to avoid contamination and mass mortalities in fry production.

Early fry should be raised and reared on live natural feed before putting them on artificial diets at least after they attain the age of 14 days on the minimum.

To make aquaculture feasible ingredients should be area specific, locally available and cheap. This means that protein levels should be stepped up with time as the fry physiological requirement demand. The protein level of the protein supplement should be increased after the fry attain the age 32 days.

There is need to incorporate Soya beans in the development of fish diets and save on foreign exchange used to import fish feeds.

ACKNOWLEDGEMENTS

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An Assessment of Co-Management Potentials in the Lake Victoria Fisheries in Kenya

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SUMMARY

Co-management is a system or a process by which responsibility and authority for management of common resources is shared between the state, local users of the resource as well as other stakeholders, and where they have the legal authority to administer the resource jointly. Co-management has received increasing attention in recent years as a potential strategy for managing fisheries. This paper presents and discusses results of a survey undertaken on the Kenyan part of Lake Victoria fisheries to assess the conditions - behaviour, attitude and characteristics of resource users, as well as community institutions - that can support co-management.

The survey was implemented through a two-stage stratified random sampling technique based on district and beach size strata. A total of 405 fishers, drawn from 25 fish landing beaches, were interviewed using a structured questionnaire. Data was entered and analysed in EXCEL and SPSS programs. This paper is based on the first stage analysis of the survey results, mainly involving cross tabulation of variables.

The study reveals that Kenya's Lake Victoria fisheries qualify in a number of the identified criteria for successful co-management. However, there are some critical conditions that still lack, such as definition of boundaries in the fishing ground, community members' rights to the resource, delegation and legislation of local responsibility and authority. On the basis of this study alone, it is, therefore, not possible to make authoritative conclusions on the potentials for co-management in Kenya's Lake Victoria fisheries. Further studies, especially using participatory methods, may produce more conclusive information on the subject.

INTRODUCTION

Fisheries in many parts of the world are under pressure or in crisis, raising doubts about the effectiveness of current management regimes. The problems facing global fisheries are myriad, but can be summarised in three categories: first is biological - the threat of depletion of fish stocks. The second is economic: the over-accumulation of labour and fishing capital, described by Pearse (1994) as 'the waste of labour and capital in redundant catching capacity, excessive costs and declining incomes'. The third problem is that of governance, which arises because many fisheries are managed by the state.

Governments commonly manage fisheries through legal and administrative measures - the so called 'command and control regime', which regulate when, where and how fishing activities should take place (Dubbink & Vliet, 1995; Johnston, 1992; Pearse, 1994). Advocates of the command and control regime argue that administrative means such as laws and licences, especially if backed by law enforcement, can constrain and guide individual and group strategies towards responsible use of resources. The command and control regime is, however, often criticised as being outdated, inadequate and ineffective. It is blamed for the increasing problems of implementation, compliance and control of fisheries regulations (Kooiman 1993; Stone, 1975). Dubbink & Vliet (1995) explain that the command and control regime faces problems at the instrument level (the choice of appropriate regulatory instruments) as well as at the organisational level. The latter arises because governance is mainly organised at the macro-level of state bureaucracy, making irrelevant the potential contribution of the meso-level (the level of civic and private contribution) and the micro-level of the individual appropriator or firm. Government systems are often distant, impersonal, insensitive, understaffed, under-funded and too bureaucratic. Hence, they have a limited capacity to regulate and monitor what goes on in widely scattered fishing grounds (Jentoft *et al*., 1998; Pomeroy *et al.*, 1997).

The failure of state organs to regulate fisheries has prompted re-thinking into new strategies for fisheries management. First is the market-based regime, whose central theme is that the government should create market mechanisms and use instruments such as quotas, taxes and subsidies to regulate fisheries. The main disadvantage of market-based mechanisms is that they often do not achieve the desired objectives due to market failure (Gordon, 1954; Neher, 1988). Market failure is said to occur when the price mechanism or the market system fails to bring about a 'social optimum'. As Tidsell (1993) explains, 'the market system induces individuals to maximise their private gains, and provides them with little incentive to work for society's best interests'.

Another drawback of the market-based regime is the lack of clear property rights in fisheries. Clearly defined property rights, among other conditions, are essential for the proper functioning of a market mechanism, hence that of the market-based regime. In some systems, individual transferable quotas (ITQ) are applied as a way of allocating property rights. However, even ITQs fall short of restoring full property rights. Pearse (1994) explains that full property rights can only be attained if the rights are 'exclusive, perpetual, divisible and transferable, and convey all the economic benefits to its holder'. Thus, even the person to whom a fishing quota has been allocated does not have exclusive rights to a stock of fish, since the stock is shared with other quota holders. Without full property rights on the resource, user groups have less incentives to conserve it than would be if the use and ownership rights are clearly bestowed on them. On the other hand, full privatisation of natural resources, if it can be achieved, could raise concerns of inequity in resource utilisation. The equity problem is especially important for developing countries, where access to a natural resource is crucial for the subsistence of impoverished population groups (Baland and Platteau, 1996).

Co-management is one approach in fisheries management that has received much attention in recent years as a potential answer to the problems of governance. The principle behind co-management is that some responsibility for collective problems should be transferred to user groups and other civilians at the community level. Sen & Nielsen (1996) define co-management as 'an arrangement where responsibility for resource management is shared between the government and user groups'. Jentoft *et al*., (1998) define it as 'the collaborative and participatory process of regulatory decision-making among representatives of user groups, government agencies and research institutions'. These are similar in content to Geheb & Crean's (1999) definition of co-management: 'resource management that draws on the input of at least two distinct groups of people which have legal authority to administer a resource jointly'. They explain that in co-management, fishing communities can play an active, even dominant, role in conjunction with Fisheries Departments, and that additional stakeholders such as fish processing factories and fishermen's co-operative societies can also have a role. Co-management is, therefore, some form of collaboration between the government and user groups, in which both parties share authority for resource management to varying degrees. The basis of co-management is that neither local communities nor central governments can, on their own, successfully manage common resources. Jentoft *et al*., (1998) argue that resource users must be allowed to participate in regulatory decision-making, implementation and enforcement, because they have wide knowledge and experience. Furthermore, their participation in management gives the process legitimacy (Dubbink & Vliet, 1995; Jentoft *et al.*, 1998).

Co-management is not a fixed idea. Sceptics have this as its major undoing - that it lacks a strong theoretical foundation. Others see co-management practices as remnants of the past, ideal situations, requiring particular cultural foundation or communal values that have become increasingly rare in modern settings. Jentoft *et al*., (1998) attribute such pessimism to an overly narrow understanding of the social theory about the role and nature of institutions. However, the negative criticisms of co-management should not overshadow its potential benefits.

For successful co-management to be effected, certain conditions are essential. First, it requires an appropriate institutional and organisational framework for common property resource governance. Second is the requirement that resource user groups are adequately organised to act collectively for their common good. According to Balland & Platteau (1997), co-management may have very little success if user groups are totally incapable of collective action to manage resources. Olson (1965) explain why communities may not act collectively to solve common or public problems, and by extension, why co-management may be difficult to establish.

Ostrom and Pinkerton Criteria for Co-management

Many cases of co-management and community-based management of natural resources have been studied in different locations around the world (Balland & Plateau, 1996; Berkes, 1989; Jentoft & McCay 1995; Hannesson, 1998; Ostrom, 1986; 1990; 1997; Wade, 1988). From the results, certain conditions are emerging which appear to be central to the possibility of developing and sustaining institutions that can support successful co-managerial arrangements. Ostrom (1990) and Pinkerton (1989) have summarised and documented some of those key conditions necessary

for successful co-management institutions. From their work, co-management is likely to succeed in resource systems where: boundaries are clearly defined; membership is clearly defined; the user group is cohesive; the user group has prior experience with organisation and the benefits of management exceed costs.

Additional criteria are that: there be participation in management by those affected; management rules are enforced; the user group has legal rights to organise; there is co-operation and leadership at the community level; there is decentralisation and delegation of authority, and there is co-ordination between the government and the community.

These key conditions are explained, analysed and discussed in this study, in as far as they exist in the fishing communities of Lake Victoria in Kenya. Lake Victoria, the world's second largest fresh-water lake, faces a number of problems, which consequently affect the efficient, equitable and sustainable utilisation of its resources. There are reports of declining fish stocks, uncontrolled and increasing fishing effort, use of destructive fishing methods and decreasing opportunities for local communities to benefit from the fisheries, among other issues (Abila & Jansen, 1997; Crean, 2000; World Bank/ GEF, 1996). Lake Victoria fisheries, thus, depict a typical example of a common property where the applied management regime seems to have failed in achieving compliance. Of the three East African countries sharing Lake Victoria, the problem of management failure is most observable in Kenya, which owns only 6% of the lake, but has the highest and fastest growing fishing intensity and, evidently, the largest proportion of overfished waters.

The history of fisheries management in Kenya shows that in the pre-colonial era the main regulatory mechanisms were the formal and informal mechanisms embedded in traditional practices of fishing communities (Geheb, 1997; Owino, 1999). The colonial authorities introduced state-based formal regulations, which effectively shifted responsibility for the fishery away from the lake side communities into the hands of the state, thus changing it from a community-managed property into a state-managed property. This command and control regime has persisted into post-independence, progressively eroding community-based resource management structures. This has been facilitated by failure of the legal framework to recognise community-based institutions as well as by the increasingly integrated economy of the lake. By involving them in co-management, it is hoped that user groups will find incentives to comply more with the fishery regulations.

OBJECTIVES

The goal of this paper is to present and discuss results of a survey undertaken on the Kenyan part of Lake Victoria to assess the conditions - behaviour, attitude and characteristics of resource users, as well as community institutions - that can support co-management. The study is part of the socio-economics research activities of the Lake Victoria Fisheries Research Project (LVFRP), whose overall goal is to design a management plan for the fisheries of Lake Victoria.

METHODOLOGY

A two stage stratified random sampling strategy was employed. Beach landings were selected for sampling on the basis of districts and beach size. Within each district the selection of beaches was based on the proportional number of small and large beaches on Kenya's portion of Lake Victoria, based on a 1994 boat count (Asila & Othina, 1995). A total of 25 landing beaches were sampled (Table 1) 17 of them categorised as small with less than 29 and 8 as big with more than 29 boats. Three beaches that had been selected were replaced either because of the poor state of access roads or they had been blocked by the water hyacinth.

The respondents in the co-management survey were fishers of all categories - boat owners, gear owners, crew and retired fishers. Once at the landing site, the selection of respondents did not follow a pre-determined random selection procedure. Initially, the register of boats at beaches was consulted in order to identify a sample. Some beaches, however, did not maintain a register. On other beaches, boats on the register had already departed and the method was no longer used. Subsequently, at small beaches, anyone who was available to be interviewed was selected. At the larger beaches, the first four respondents, corresponding with the number of interviewers, were selected randomly from the fishers present on the beach, after which the beach leader would recommend additional interviewees. A total of 405 respondents from 25 beaches were interviewed. Of the respondents, 43% had fished for more than 11 years, 20% for 6-10 years, while 37% had fished for 5 years or less.

A team of 4 researchers using a structured questionnaire collected data. All questions in the questionnaire were pre-coded. Once collected, data was first entered in EXCEL and subsequently transferred into SPSS for analysis. This paper is based on the first stage analysis of the survey results, mainly involving cross tabulation of variables. The results are evaluated and discussed on basis of the 11 key conditions identified by Ostrom (1990) and Pinkerton (1989) as essential for successful co-management. In each section the key criteria is first outlined, followed by the presentation and discussion of the survey results relevant to that condition.

Table 1. List of beaches selected for the survey

District	Beach (No. of boats in brackets)
Busia	Budumbusi (50); Nalera (50); Bulwani (26);
Bondo	Sirongo (19); Sifu Island (48); Kamariga (37); Madundu (28); Kunya (18); Kokach (14)
Kisumu	Kagwel (12)
Nyando	Nyandho/ Chuowe (21)
Rachuonyo	Kamwala/ Alara (11); Miti Mbili (25)
Suba	Kamwai/ Alii (14); Sukru Island (70); Luanda Nyamasare (37); Litare Kandiege (21); Kongata Takawiri (16); Kibuogi 'B' Island (15); Konyango (18);Nyagwethe (10)
Migori	Okiro (20); Aloma (18); Luanda Konyango (31); Gethegunga (18)

RESULTS AND DISCUSSION

Clearly defined boundaries: *The physical boundaries of the area to be managed should be distinct so that fisher groups can have accurate knowledge of them. The boundaries should be based on an ecosystem that fishers can easily observe and understand. It should be of a size that allows for management with available technology e.g. transport and communication.*

Physical boundaries of the area to be managed

There are international political boundaries that fishers clearly know about. Certain water-based geographical features and landmarks demarcate such boundaries. For example, in the Port Victoria area, Kenya-Uganda border is known by fishers to be just behind Sumba Island. In the Sio Port area, the outlet of Sio River into the lake marks the same boundary. In the Karungu area, the Migingo Islands located on the Kenya-Uganda-Tanzania tripoint demarcates the boundary separating the three countries. Thus, there is sufficient clarity as to the demarcation of international boundaries. In many cases fishers are reminded of the border line by being repeatedly arrested, fined or their gear confiscated for trespassing international boundaries.

The administrative district boundaries on land are known by fishers but are not clearly identified in the water. This is because each beach falls in a location, district and province which are clearly known to the fishers. District Fisheries Officers normally regard the water adjacent to beaches in their district, and within the international boundary, to be within their jurisdiction. On this basis, fishers may be expected to take water around their beaches to belong to their district. However, where two beaches share a district boundary, for example Osieko in Busia District and Nambo in Bondo District, it is not easy to place the water around the beaches in either district.

Another concept of physical boundary may be in terms of where fishers land their fish. Fishers are generally sure of where they will land their fish. Each fisherman has a beach to which he or she belongs, and which each of them refers to as 'my' beach. Any fisherman who does not belong to a particular beach and wishes to land fish there must seek permission. This may be in form of verbal permission from beach authority (38%), a letter of introduction from the previous beach leader (37%) or paying a landing-rights fee (locally called a 'kanyaga': (22%). Only 3% of fishers thought they could land on a beach to which they do not belong, without seeking permission.

Respondents further indicated that permission, if granted, would entitle a fisher from another beach to fish in their water. Of the fishers interviewed, 92% stated that anyone with permission would be allowed to fish in the waters adjacent to their community. Thus, fishers recognize the beach as a boundary that excludes non-members. The beach can, therefore, be used as basis for defining a boundary since the demarcation is clearly understood and accepted by most fishers. Any boundary formed on the basis of a beach is likely to be effective.

Ecosystem boundaries

An ecosystem defines the complex interaction between an organism, in this case fish, with its environment. Features of an ecosystem would, in this case, be breeding areas for fish or fish nurseries and river mouths. In the survey, 40.8% of Kenyan fishers indicated that they would not fish in fish nurseries and in other closed areas. About 79% of them would not fish in those closed areas because they understood them to be breeding areas. This indicates that most fishers have a good concept of boundaries based on the ecosystem of the lake. Thus, the breeding and closed areas provide an ecosystem-based boundary, of which fishers have good knowledge of.

Technological and communication boundaries

Managing the open waters of the lake raises the additional problem of communication. Fishers have to travel some distance to their fishing ground, with Nile perch and 'dagaa' fishers travelling longer distances than their tilapia counterparts. Most Kenyan fishers agree that the distances to their fishing grounds have been increasing. Of the Kenyan fishers, 89% indicated that they now go on longer fishing trips than they did 5 years previously. Some of these fishers have to use outboard engines to reach their fishing grounds. For some fishers, for example those targeting tilapia, it may be that they are fishing in the same fishing grounds, but they spend more time to catch the same quantity of fish they caught 5 years ago.

To be able to monitor activities on the open waters of Lake Victoria, it may be necessary that those patrolling or monitoring have similar communication facilities as those possessed privately by fishers. Thus, outboard engines are necessary for regular monitoring use. However, the use of such facilities has the negative effect of raising the cost of managing the fishery.

In summary, the boundaries recognized and understood by fishers are the international boundaries, administrative boundaries on land, boundaries based on landing beaches, and ecosystem boundaries demarcating breeding and closed areas. For co-management, boundaries can be based along the lines described above. In most cases, the transport and communication means on either land or water can enable the monitoring of such boundaries. However, there is need for improved transport facilities, such as outboard engines to raise the monitoring capacity. One non-recognizable boundary is that which divided fishing grounds between different communities.

Membership clearly defined: *Individual fishers or households with rights to fish in a bounded fishing area, and participate in area management, are clearly defined. In addition, the number of fishers or households should not be too large so as to restrict effective communication and decision making.*

In the Kenyan part of Lake Victoria, this second criterion fails in a number of ways. First, The Fisheries Act allows anyone to fish as long as he or she has obtained a fishing license from the Department of Fisheries (Kenya Government, 1991). This license is granted on payment of a fee and, in practice, is rarely subject to any other condition. Anyone from any part of Kenya can obtain a fishing license to fish on Lake Victoria.

In the survey, 58% of fishers did not agree that one community should claim parts of the lake and exclude others. This suggests that fishing communities themselves do not want to define membership, and exclude non-members from fishing. Similarly, 61% of fishers did not agree that fishing communities themselves should say who could fish in their waters. In addition, 95% agreed that anyone could fish in the waters adjacent to their community or beach. In fact, most fishers, 93%, indicated that they often meet with fishers from other communities when they go out fishing. This shows that many fishers do not recognize any membership restriction that may keep off non-community members from fishing near their beach. Furthermore, a majority of fishers, 70%, believe that the waters next to their beach belong to the government. This negates any attempt to exclude non-community members and define membership in terms of which individuals or households have the right to fish in the waters near the community. Thus, it seems that there is no clear membership definition, as described by Ostrom (1990) and Pinkerton (1989), in the Lake Victoria fisheries.

Group cohesion: *The fishers group or organization should permanently reside near the area to be managed. There should be high degree of homogeneity, in terms of kinship, ethnicity, religion or fishing gear type, among the group. Local ideology, customs and belief systems should create a willingness to deal with collective problems. Finally, there should be a common understanding of the problem and of alternative strategies and outcomes.*

In terms of ethnicity, the survey revealed that three ethnic groups - Luo (73%), Abasuba (14%) and Luhya (12%), dominate Kenya's Lake Victoria fisheries. These ethnic groups largely occupy specific ethno-political boundaries. The Luhya group is mainly found in Busia District at the northern end of Kenya's Lake Victoria shoreline. The Suba ethnic group is largely in the Suba District, which was carved out from Homa-bay and Migori districts. The Luo, who are the majority, are mainly in Bondo, Kisumu, Nyando, Rachuonyo, Homa-bay and Migori districts. In recent years, though, fishers from different communities have migrated into new fishing areas, which has slightly reduced the degree of ethnic homogeneity in most areas around the lake. It is, therefore, common to find Luo fishers fishing in Busia district, or Luhya fishers in traditionally Luo-dominated districts.

Interestingly, 99% of respondents in the survey thought that their own communities were historically fishers. Each ethnic group has its customs and taboos, which indicate cohesion of members. However, the survey revealed that customs and taboos no longer play significant roles in the management of the fishery. Only 1.5% of respondents indicated that taboos have a role in regulating fishing activity in their village. Possibly as a result of regular interaction between fishers of different ethnicity as well as the impact of modern religion and education, the importance of local ideology, customs and beliefs have diminished in regulating the fishery. Within each ethnic group, fishing communities have traditionally grouped along clan lines. Some beaches, in fact, bear the name of a particular clan. For example, of the beaches sampled in this study, Kokach, Kagwel and Konyango reflect the names of the local clans bearing the same names, who traditionally have occupied the area of the respective beaches. Thus, many beaches have in the past developed on basis of clan structures. Members of one clan are of the same family lineage or kinship.

An indicator of cohesion is that most fishers, 86%, agreed that they are able to recognize almost all members of their own communities. In addition, 68% of fishers indicated that they always go out fishing with the same group of fishers. This would suggest that, within each of the communities, there is the possibility of effective communication. However, 93% of respondents stated that they fish in the same places with fishers from other communities. The survey, though, did not reveal to what extent fishers interact with the members of these other communities whom they fish together with, hence, the possibilities for communication across different communities. As a further indicator of cohesion, over 41% of fishers said they would tell their fellow fishers if they knew of a good fishing spot. Some said they would do this because it is difficult to keep secret such information.

With a few exceptions, generally there is specificity of gear types according to beaches. Fishers on one beach, with few exceptions, tend to use one type of fishing gear. Thus, certain beaches are specifically for 'dagaa' fishing, while others are Nile perch or tilapia beaches. Some beaches such as Bukoma, in Busia district, specialize on beach seining. Other beaches will only use gillnets, longlines or mosquito seines.

According to Ostrom (1990) and Pinkerton (1989), group cohesion requires *a common understanding of the problem and of alternative strategies and outcomes*. Results in this survey do indicate that most fishers perceive a decline in the fishery. In the survey, 343 respondents were asked to compare various conditions of the fisheries at the time of the survey, compared to what it was 5 years previously. Their responses are displayed in Figure 1. The fishers also perceive fishery management problems, the most important being lack of regulation to govern the fishery (24%), followed by the problem of gear theft (16%). The third most important problem is the use of illegal fishing techniques (14%).

In summary, there is high degree of homogeneity in terms of ethnicity and kinship as well as gear types among groups to be managed. At the same time, fishers commonly perceive problems facing the fishery, and do recommend alternative management strategies.

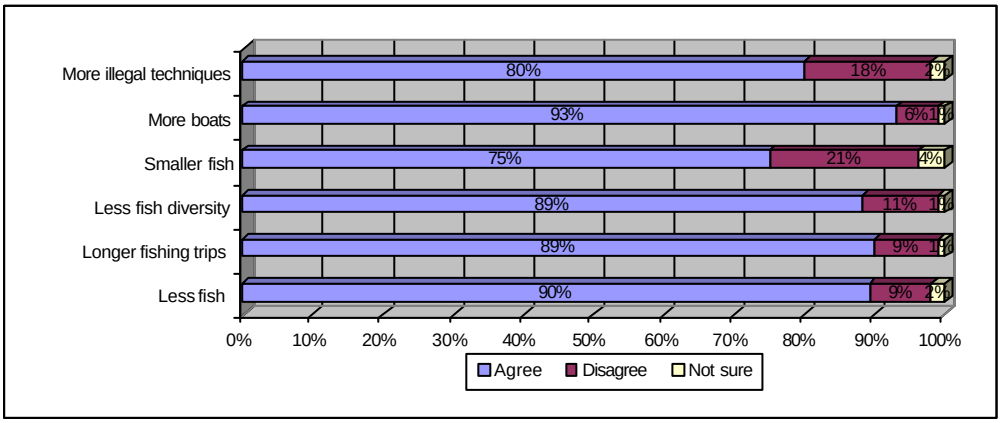

Fig. 1. Fishers' Perception of Current Resource Condition, Compared to 5 Years Previously

Existing organization: *The fishers have some prior experience with traditional community-based systems and with organization, where they are representative of all resource users and stakeholders interested in fisheries management.*

In most fishing villages the traditional management systems, where a community was headed by a clan elder, no longer exist. This has been largely replaced by a government administrative system, where a chief appointed by the state heads a location, whose boundaries have been drawn along areas traditionally occupied by particular clans. However, at community level there is a beach leader who is elected by fishers. There are also a number of organizations that have come up in most beaches, although some have little relation with the traditional organizations.

Most respondents in the survey have past or current experience with one or more types of community-based organizations. Of 405 total respondents in the survey, 294 have been a member of a community-based organization. These may be a cooperative society, a marketing group or a savings and credit group based on the beach. Virtually all beaches have a beach committee charged with the responsibility of organizing fishers and handling disputes among fishers on the beach. The Beach Leader, sometimes called 'Chairman', heads the beach committee. The authority of the Beach Leader, and by extension, the mandate of the beach committee, is fully recognized by most fishers. Of all fishers interviewed, 84% stated that they would first complain to the beach leader whenever they had problems in the fishery. In contrast, less than 10% of fishers would, in the first place, report their fishery-related problems to the Fisheries Department. Another 4% indicated that they would report fishery-related problems to the community elders or fellow fishers.

Furthermore, most fishers (67%) stated they would obey the instructions of the Beach Leader in fisheries related matter. Thirty percent of fishers would take instructions from the Fisheries Department representative on the beach while another 2% would obey other government officials based in the community.

In summary, most fishers have experience with community-based organizations, which, however, are not traditional. The system of beach committee, headed by a Beach Leader, as an organ for organizing fishers and solving community disputes and fisheries-related matters, is well understood and accepted by nearly all fishers.

Benefits exceed cost: *Most likely where individuals have the expectation that the benefits to be derived from participation in, and compliance with, community -based management will exceed the costs of investments in such activities.*

Co-management essentially means that some of the costs of managing the fishery will be transferred from the state, or the society, to the particular community using that resource. Whatever role is found as suitable for local fishing communities to play in the co-management process, it is a new cost to that community which, otherwise, they would not be paying. The benefits to be derived from co-management, (such as better fish yields and community's exclusive use rights over the resource within a defined boundary), must be balanced against the costs of managing the fishery.

These costs may include the allocation of the community's time, effort and resources to surveillance, defense and retaliation.

Fishers will participate in management if they expect the management outcome to solve their resource problems. As Figure 2 shows, most fishers perceive a decline in the resource status in the last 5 years. Two factors contribute to the worsening resource status: an increase in the number of fishing boats (93%) and in the number of illegal fishing techniques now being used to catch fish (80%). As a result of this situation, fishing pays less now than 5 years previously. As such, the benefits of management could be the reversal of declining yields and an increase in fishers' income. A community highly dependent on a particular resource could be expected to attach high value to that resource. In this case, the benefits of achieving a healthy fishery, by reversing the trends of resource scarcity, must rank very highly in the priorities of local fishing communities. However, this survey did not collect data to ascertain this.

In summary, this study lacks sufficient information as to whether benefits of co-management in the Lake Victoria fisheries would exceed the costs.

Participation by those affected: *Most individuals affected by management arrangements are included in the group that makes and can change the arrangements. The same people that collect information on fisheries make decisions about the management arrangements*

Although fishers, fish traders, and fish processors are the most affected by management arrangements, these groups are not involved in making decisions concerning the fishery's management. The Fisheries Act (Kenya Government, 1991) does not define any role for involving fishing communities in managing the fishery. The Fisheries Act itself has been made without the participation of fishing communities.

Despite this omission, most fishers would prefer to directly participate in decision-making concerning management of the fishery. In the survey, 84% of the fishers stated that fishers should be allowed to participate in rule making. In contrast 14% would not wish to see fishing communities participate in fishery management, while 2% made no preferences. One of the areas in which fishers would like to be involved is in applying sanctions to offenders. The survey results revealed that 76% of fisher would like fishing communities to be allowed to punish offenders. However, most fishers, 71%, did not agree to the suggestion that that no more fishers, boats and nets should be allowed on the lake. Similarly most fishers, 61%, disagree that fishing communities should be the ones to determine who can or cannot fish.

One of the reasons why fishers strongly feel they should participate in management is because they are dissatisfied with the current management system of the lake. The majority (54%) stated that the Fisheries Department does not do well protecting the fish stocks. As evidence of their lack of participation and little contact with the Fisheries Department personnel, most fishers are not aware of some of the basic fishery regulations contained in the Fisheries Act. Asked to state the minimum mesh size of gillnet allowed in the lake (which correctly is 5 inches), 52% specified a wrong mesh size, while only 41 % got it correctly. The rest, 7%, did not provide any response

or were not sure.

Research and data collection on Lake Victoria fisheries is principally carried out by The Kenya Marine and Fisheries Research Institute and, to a lesser extent, the Fisheries Department. Other national research institutions, including universities, as well as NGOs also have a role in collecting data. Of these institutions, only the Fisheries Department has the mandate of making management decisions. Fishers are neither involved in collection information nor in making decisions on the management of the fisheries.

In summary, fishers are willing to participate in making decisions affecting them, and in implementing some of them. However, at the moment there is little opportunity for them to do so. The institutions that collect fisheries information are not directly related in making management decisions.

Management rules enforced: *The management rules are simple. Monitoring and enforcement can be effected and shared by all fishers.*

Most fishers, 85%, did not agree to the suggestion that fishery regulations are 'no good'. Most respondents, 77%, thought that their fellow fishers obeyed fisheries regulations, while 22% thought otherwise. Despite this, a large proportion of fishers, 44%, indicated that they saw fishers breaking fisheries regulations 'all the time', while 41%, of respondents saw fishery regulations broken 'sometimes'. The remaining 16% indicated that they never saw fishery regulations being broken on their beaches. The Fisheries Department is responsible for taking action against rule-breakers in the fishery. The kinds of action taken by the Fisheries Department against the breach of regulations are listed in Table 2. It is not clear as to whether or not the Fisheries Department personnel destroy fish caught with illegal gears and techniques. In the survey, 48% of the fishers stated that they had seen fish catches being destroyed while almost a similar percentage, 49%, had not seen the Fisheries Department take such an action on their beaches. The remaining 3% were not sure.

Table 2. Action taken by the Fisheries Department

Action	All the time	Sometimes	Never
How often Fisheries Department personnel are seen arresting fishers on the beach	9.6%	59.3%	31.3%
How often Fisheries Department personnel are seen destroying illegal gear on the beach	5.4%	44%	50.6%

The success of the enforcement of fishing rules differs depending on the type of rule and how easy it is to effect and be understood. Fishers gave various opinions, shown in Table 3, concerning the efficacy of enforcement of various regulations. From the table it seems that most rules are simple and easy to understand, hence are, according to fishermen, effective.

Table 3. Fishers' perception of eficacy of Fisheries Regulations

Efficacy	Effective	Unaware of regulation	Useless
Mesh size control	63.9%	2.2%	33.8%
Closed fishing areas	57.7%	2.5%	39.8%
Closed fishing season	47.8%	2%	50.2%
Poison ban	79.1%	1%	20%
Trawling ban	66.9%	8.7%	24.4%
Minimum fish-size regulations	65.4%	2%	32.6%
Licensing	78.8%	0.7%	20.4%
Boat registration	92.3%	0.5%	7.4%

In summary, there are a number of management rules applied in the fisheries. Fishers commonly break many of these regulations. However, most fishers think that nearly all the mentioned regulations can be effective. This would suggest that they are simple to understand and effect. However, monitoring and enforcement is done by the Fisheries Department alone, and there is little role for fishers. Fishers are largely dissatisfied with the current management system of the lake.

Local rights to organize: *The fisher group has the right to organize and make arrangements related to its needs. There is enabling legislation from the government defining and clarifying local responsibility and authority.*

A major weakness of initiatives aimed at involving local communities in fisheries management is the lack of legal recognition of such an approach. The Fisheries Department has encouraged the formation of beach committees, lead by a beach leader, on each beach. The beach committee has many roles and responsibilities, some of them defined, while others are just assumed. The following are some of the roles:

a) Presenting fisher community's problems to the Fisheries Department

b) Solving conflicts between fishers, or any other persons residing on their beach.

c) Is the link between the government and the community, through which any inward or outward communication for the community is channelled;

d) Convenes and chairs community meetings

e) Receives visitors on the beach

The responsibilities of the beach leader and committee listed above, however, are not legislated. They are sectoral arrangements by the Fisheries Department, aimed at letting communities do

those tasks that the Fisheries Department finds hard to perform. The lack of legislation is a major weakness of the system, since the beach leader assumes powers and authority, for which he/she has no legal rights to exercise. The Fisheries Act itself does not mention or specify any roles for local communities. It does not mention or recognise the institution of the Beach Committee. The Act entrusts almost all the functions of fisheries management to the Fisheries Department through the Director or Commissioner of fisheries. Despite this, the legitimacy of the beach committee and the beach leader seems to be widely accepted by fishers, and their roles are clearly understood. As table 4 shows, most fishers prefer to report their fishery-related problem to the beach leader. In summary, Kenya's Lake Victoria fisheries lacks an enabling legislation from the government defining and clarifying local responsibility and authority. The Fisheries Department has encouraged the formation of beach committees, headed by a beach leader, but this authority is not legislated. Despite this, fishing communities recognise the legitimacy and authority of the beach leader and the beach committee.

Table 4. The relevant authority to complain to in fishery related problems

Authority	% of responses
Beach leader	83.7
FD representative	9.7
Elders	2.2
Fellow fishers	1.7
The police	0.7
Don't know	0.7
Other	1.2

Co-operation and leadership at community level: *There is an incentive and willingness on the part of fishers to actively participate, with time and effort and money, in fisheries management. There is an individual or core group who takes leadership responsibility for the management process.*

Fishers themselves recognize their potential role in ensuring that regulations are followed. In the survey, 94% of fishers agreed that there was a need for the government and fishing communities to take regulations more seriously. As previously discussed, most of the fishers (76%), agree that fishing communities should be allowed to punish offenders. At the same time, 84% of all fishers agree that fishing communities should be allowed to participate in rule making.

Asked what they would do if they knew that a fellow fisher was using illegal fishing technique, 84% fishers said they would report it. Fig. 2 shows to whom they would report regulatory infringements of this kind.

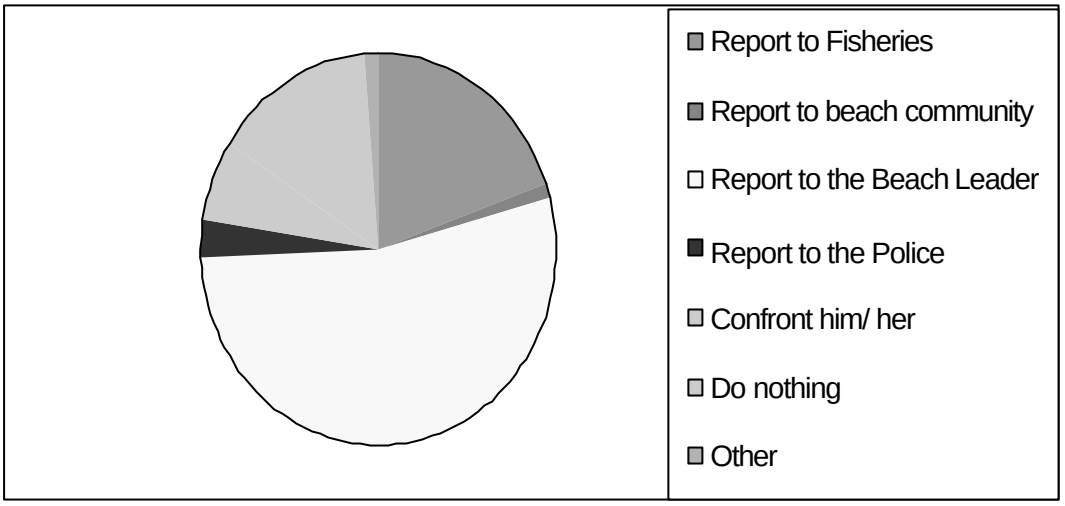

Fig. 2. Fishers' perception of current resource condition, compared to 5 years previously

As previously indicated, there are regulations in place already which respondents said have been made by the fishing communities. In the survey, only 11% of fishers said that no such regulations existed. The rest either confirmed that there were community-made rules in their beaches, or they (8%) did not know that such rules existed. Apart from this, members of the community often spend time attending village meetings discussing problems facing the community and the lake. Fishers also informally discuss amongst themselves problems facing the fisheries.

In almost all the fishing communities, there is a core group who will take leadership responsibility for the management process. The survey revealed that all beaches (100%) have a beach committee, headed by a beach leader. The survey results also indicate that various other community organisations were present on most of the beaches. They included fishermen co-operatives, marketing groups, savings and credit groups and other more informal fisher groups. These groups can potentially take responsibility for some aspects of managing the fishery or improving the welfare of fishers. Most fishers (77%) belong to one or more of these community organisations.

In summary, there is willingness on the part of the fishers to participate with time and effort in fisheries management. The survey did not reveal whether or not fishers would also contribute money towards management activities. On nearly all beaches, there is also an individual or core group, in form of a beach leader and beach committee, who can take leadership responsibilities for the management process. Other community organisations such as co-operatives, fishers' groups, marketing groups and savings and credit organisations can also play a part in certain aspects of fisheries management.

Decentralisation and delegation of authority: *The government has established formal policy and/or laws for the decentralisation of administrative functions and the delegation of management responsibility and/or authority to local government and local government organisation levels.*

The Government of Kenya has established a policy of decentralised management and development prioritisation, through the District Focus for Rural Development policy. At the District level there is a District Development Committee (DDC), chaired by the District commissioner. Members of this committee include heads of various government departments at the district level, representatives of the local government and members of parliament, amongst others. There are various tasks and responsibilities of the DDC but overall, it allocates development resources within the district.

In the same spirit of decentralisation and delegation, the Fisheries Department has informally let some tasks of management to be carried out by the fishing community alone or jointly with the Fisheries Department. Often these are tasks that the Fisheries Department finds hard to perform, or it lacks the means to do so. For example, the local communities can patrol the lake if they have the means to do so. The beach leader can also look out for those breaking fisheries regulations around the beach report them to the Fisheries Department. The beach leader may even apply sanctions on some fisheries-related offences. For very minor offences, the beach leader and his committee can punish offenders by fining them or suspending them from operating on the beach. For serious offences, such as fish poisoning, the community leaders may take the offender to the Fisheries Department for prosecution. However, the actions taken by the beach leader are limited in that their legality can, and in fact is often, disputed by some community members, and even government authorities.

In summary, the Fisheries Department has informally decentralised and delegated some little authority to fishers' communities, especially those tasks that the Fisheries Department is not in a position to do. However, this is limited by the lack of clear legal backing for communities to perform these roles.

Co-ordination between government and community: *A co-ordination body is established, external to the local group or organisation and with representation from the fishers' group to or organisation and government to monitor the local management arrangements for resolving conflicts, and reinforce local rule enforcement.*

In Kenya's Lake Victoria fisheries there is no body that qualifies for the above description. In effect, fishing communities largely operate on their own, with little reference to, or support from, any external body. The Government, through the Fisheries Department, legally performs the supervisory role, but the relation is so top-down, that little co-ordination is affected. The Government organ has no representation from fishers' communities to ensure a co-ordinated response to management problems. At the same time, Fisheries Department is not represented in the beach committee.

SUMMARY AND CONCLUSION

In summary, fishers recognize and understand international boundaries, local administrative boundaries on the land, boundaries based on landing beaches, and ecosystem boundaries demarcating breeding and closed areas. However, there is no clear boundary demarcating fishing grounds to separate different communities. Also there is no clear membership description, defining

households and individuals with rights to fisheries resources.

Fishing groups are, to a large extent, homogeneous in terms of ethnicity and kinship as well as gear types. At the same time, fishers commonly perceive problems facing the fishery. These factors indicate that fishers have some degree of cohesiveness, which is important for establishing local institutions for co-management. Most fishers have experience with community-based organizations. The system of beach committee, headed by a Beach Leader, as an organ for organizing fishers and solving community disputes and fisheries-related matters, is well understood and accepted by nearly all fishers. Fishing communities recognise the legitimacy and authority of the beach leader and the beach committee.

Fishers are willing to participate, with their time and effort, in making decisions affecting them and the fisheries, and in implementing some of these decisions. But at the moment there are few opportunities for them to do so. There are a number of management rules applied fisheries, although fishers commonly break many of them. Despite this, fishers think that most of the applied regulations can be effective. This would suggest that the rules are simple enough to understand and implement. However, monitoring and enforcement is done by the Fisheries Department alone, and there is little scope for fishers to be involved. There is lack of an enabling legislation from the government defining and clarifying local responsibility and authority. On nearly all beaches, there is an individual or core group that does, or can, take leadership responsibilities for the management process. These include the Beach Leader, beach committee and other community organisations such as co-operatives, fishers' groups, marketing groups and savings and credit organisations. These can have roles in fisheries management.

In conclusion, the study has revealed that Kenya's Lake Victoria fisheries qualify in a number of the conditions identified by Ostrom (1990) and Pinkerton (1989), for establishment of local level-institutions that can support successful co-management. However, there are some critical conditions that are still lacking, such as definition of boundaries in the fishing ground and community members' rights to the resource, delegation and legislation of local responsibility and authority. On the basis of this study alone, it is, therefore, not possible to make firm conclusions on the potential of co-management in Kenya's Lake Victoria fisheries. Further studies, especially using participatory methods, may produce more conclusive information on the subject.

The Case for Community-lead management of the Lake Victoria basin's environment

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SUMMARY

Integrated management systems recognise that the well being of specified resources may well hinge upon the well being of other resources. This paper sets out to examine the management of just a few of the multitude of resources that occupy the Lake Victoria basin of East Africa, including fisheries, forests and coastal areas within the basin. It will examine these resources from the perspective of their status vis-à-vis other resources and how they affect one another. The paper finally considers the suggestion that community-based management strategies are potentially the best management strategies for the achievement of integrated management within the Lake Victoria basin.

INTRODUCTION

Lake Victoria's basin contains a rich diversity of resources that include minerals, wild life, agriculture, industrial, forest resources, fisheries and, possibly most important, human resources. Resources within the basin are centrally managed giving rise to two main shortcomings. Firstly, the well being of one resource group very often impinges upon the well being of other resources groups. For example, it has been argued that the widespread burning of forest resources aimed at clearing land for agriculture has contributed to the eutrophication of Lake Victoria (Hecky, 1993). Another example is that the rise of an artisanally based processing capacity for Lake Victoria's Nile perch fishery has contributed to widespread deforestation close to the lake's shore (Kamweti, 1992). Under these two examples, forestry managers may be in no position to anticipate, let alone act upon, the down stream damage that occurs as a direct result of the exploitation of the resources under their jurisdiction.

The second shortcoming concerns the multiple uses of a resource. Under conventional analysis, it may seem most productive to understand resource use in terms of the maximisation of a single output, such as fish from a water regime or trees from a forestry regime. However, management may well obtain greater resource use efficiency if it values the multiple uses of resources. For example, a private forest monocropped for timber may not be as productive as a common property forest that is exploited for timber, fuel wood, fodder, fruit, nuts and medicinal plants (Meizen-Dick & Swallow, 1997). By seeking to maximise the productive output of a resource by concentrating on a single resource component within a spectrum of resource use patterns, managers may actually erode the food security and coping strategies of its users.

In this way, the activities of resource managers in the Lake Victoria basin can potentially affect not only how a resource is used, but also the well being of other resources. There are additional difficulties with centralised management strategies within the basin. They are set within the confines of a hierarchical structure of administration, in which power diminishes the further one travels from the region's capital cities and provincial towns. In this way management at isolated, rural locations is more of an abstraction than a guiding concern in the daily lives of resource users. This condition is exacerbated by the resource constraints of managerial structures within the basin: they are typically under-funded, under-staffed and often lack necessary expertise. In other words management exists more in name than it does in any other guise, and yet the managerial apparition is legitimised by government, by its stated objectives and by its very formality. This degree of administrative abstraction, this paper shall argue, does not lend itself to the effective nor equitable management of the basin's resources.

As a result of this degree of abstraction we are faced with a management system that may well yield wholly unanticipated results. In this paper, we set out to develop some of these ideas and show in what ways the management of the Lake Victoria basin's resources is a lop-sided and only moderately successful affair. It is the intention of this paper to be provocative, because it is the feeling of its authors that allusions to co-management within the basin are more lip-service than a whole hearted grasp of the necessary shifts in power that co-management implies. We intend to delineate what this shift implies by suggesting that management systems that use the community as their main, operative, component, may be a way of either supporting centralised management initiatives, or an independent management system in itself.

PRESENT MANAGEMENT STRATEGIES: SUCCESS OR STRUGGLE?

Outside of privately owned resources, the onus for the management of most natural resources in Lake Victoria's basin lies with the state. Management initiatives of these varieties are often typified by a number of characteristics:

(a) control is heavily centralised: management of the resource is vested in the state and the further from the capital city the resource lies, the less tangible is the control. Irrespective, the importance of the characteristic is that it precludes the addition of other actors within the regulatory regime at a local level.

(b) Control is 'scientific': as with fisheries and forestry resources, the assumption is that an optimal rate of exploitation is possible to identify. This information is derived from studies of reproduction rates amongst the resource populations, which supposedly enables Maximum Sustainable Yields (MSYs) to be determined.

(c) Regulation is assumed to be possible: under a state management regime, the assumption is made that the various inputs required for these styles of regulation are available. Hence, the funds and expertise to carry out stock assessment exercises are available. Crucially, it also assumes that once optimal rates of exploitation have been identified, then the state has the means, the ability, the expertise, the staff, the funds and the will to enforce the regulations necessary to obtain optimal exploitation.

(d) Infringements are detectable: centralised systems of regulation and monitoring assume that it is possible to efficiently detect those who disobey the law. "In many cases the state lacks the local information and ability to penalise…", particularly when resources are diffuse and where the number of points that need to be monitored are many (Meinzen-Dick & Jackson 1997).

(e) Regulation is exclusive: although many resources will fall under the jurisdiction of ministries of natural resources, individual departments are exclusive - hence, those involved in forestry departments are in no way responsible for down stream events in fisheries sectors, irrespective of whether or not these events have arisen as a result of, say, deforestation.

(f) Regulation is justifiable: the above styles of regulation are on the 'right' side of the law. Because they are the products of the Government, they are perceived as being a *priori* correct and legitimate. By implication, groups of exploiters have not the right to regulation, and it follows that they cannot be trusted to regulate, that they are unable to regulate, or that they are unwilling to regulate.

The difficulties noted above with these centralised management styles are exacerbated by the often typical national backdrop of cash-strapped government, severe social and welfare problems, fluctuating economies, competing political interests and the problems associated with poor administration and graft. Management of Lake Victoria's resources, therefore, may often be only partially effective, or definitely ineffective. Broadly speaking, the problems associated with these centralised styles of management may be summarised as follows:

(a) They are expensive: the costs of monitoring a resource for its population dynamics and/ or whether or not exploiters are breaking rules are prohibitive if such regulation is to be carried out by a single, central regulatory institution alone (Geheb 1999).

(b) They assume that the state is the sole source of regulation. This degree of centralization is inefficient if the state is under-staffed, lacking in technology, under-funded and under-motivated (Geheb 1999).

(c) The rules assume homogenous communities of exploiters and homogenous applicability. The rules assume that all resource users will equally be able to obey the rules, and that the outcome of these regulations will be uniform irrespective of culture, location, history nor political systems. They cannot, in other words, capture human diversity and are too inflexible to cope with dynamic systems of resource use (Geheb 1999).

(d) They are too focussed and exclusive and unable to cope with events that occur within their mandate for which the exploitation of outside resources are responsible. They cannot, in other words, cope with the down stream effects of exploitation. Nor, in addition, can they cope with the multiple uses to which resources may be put (Swallow *et al.*, 1997).

(e) With the state largely unable to regulate resources effectively, many have assumed open-access characteristics. The failure by the state to identify that there may be links between resource conservation and the degree of ownership of those resources by local communities has contributed to their demise.

In this sense, government involvement in the administration of resources may not only be seen as problematical, but as actually comprising a part of the problem. This assertion needs some qualification. The difficulties of government involvement in the management of resources are two pronged.

One the one hand, the problem of how exploiters are perceived creates difficulties. Although Hardin (1968) was not alone in his thinking, he was certainly the most articulate exponent of the view that resource exploiters were "anarchic villains in a 'tragedy of the commons' that leads inexorably to resource depletion and economic waste (McCay, 1978). Although Hardin never specifically states it, he certainly implies that the best alternative management strategy be lead by a centralised authority drawing upon so-called 'mutual coercion' strategies to obtain optimal outputs and regulation. Certainly, a review of the Fisheries Acts of the riparian states of the Lake Victoria basin indicates a full expectation that the disincentives associated with the breaking of fishing regulations are coercive ones - fines and imprisonment. So too straying across a National Park boundary might get one shot. The rhetoric of government too is palpable here, and resource users forever viewed as 'ignorant' and in need of 'education' and 'sensitisation', as if by somehow knowing about the resource problem in which they are a component, they might remedy it.

And yet there is plenty of evidence that rural resource exploiters within Africa are not only fully cognisant of the dynamics of the resources that they exploit, but also aware of changes within it, seasonal variations and fully capable of adapting to these and even experimenting with alternative exploitation strategies (see Binns, 1995; Swift 1979; Richards 1985; Brokensha *et al.*, 1980).

Equally, there is much literature to suggest that small-scale, rural resource exploiters are both willing and capable of managing the resources upon which they rely (Geheb, 1997, 1999; Johannes, 1978, 1981; Kada, 1984; McCay & Acheson, 1987; Thomas, 1996).

On the other hand, the perceived wisdom of the state is all to often unquestioned. Resource exploiters are led to believe that the state has some kind of monopoly on the wise exploitation of the resource. Certainly government believes that it has the right to monitor resource use and to enforce regulations upon resource exploitation. The belief that this is the case in East Africa is so entrenched that it supersedes the questionable *ability* of the state to carry out these tasks. The 'wisdom' that underlies these perceptions is received, more often than not from colonial predecessors (Leach & Mearns, 1996). If one is to wholeheartedly accept this arrangement of government-dominated managerial strategies, then one must also, of necessity, assume the exclusion of communities of resource users from management.

This view of the state as a monopoly of wisdom, justice and management, which is taught in virtually every primary and secondary school in the Lake Victoria basin, has even more insidious affects. It serves to rob communities of any sense of being able to insert them into the management vacuum and removes from them any sense of responsibility over their resources. Perhaps most troubling, by proclaiming these monopoly rights of resources and how they are exploited, governments contribute to resource insecurity by ensuring the complacency of communities in

the face of increasingly more heavily exploited resources. In other words, rather than act positively to counteract a negative resource trend, communities will await the action of a disinterested government.

Above, we mentioned that communities might very well be able to manage the resources upon which they rely. In the next section, we take a brief look at the specific benefits to be derived from including communities within management strategies.

THE COMMUNITIES, STATE AND THE BASIN: PRESENT MANAGERIAL ROLES AND FUTURE STRATEGIES

Many resource managers see resources as largely physical manifestations - such as ore deposits, forests, fisheries etc. - that often generated by 'nature'. It is very rare for them to view resources as social constructions. In this sense, there often exists a two-way relationship between resources and the communities that rely upon them. Social structures amongst pastoral people, for example, have everything to do with trying to maximise the benefits from the rangelands upon which they rely. The spirits upon which traditional healers in Luo fishing communities rely are to be found in the lake, while those of inland Luo farming communities reside in the ground. Hence, the way in which a resource is exploited may even affect the fabric that binds a community together, that determines its social structure, bonds and rituals. This community knowledge about a resource, and the relationship the community shares with the resources on which it relies, is often referred to as 'social capital' (Ostrom, 1995), and the way that a resource is exploited very often has to do with the manner in which it is 'embedded' within the folds of social capital. The place of resources within community life, and their relative position to centralised resource management systems, give community-level resource management systems several advantages (adapted from Geheb, 1999):

(a) The costs of implementation, monitoring and enforcement are transferred from any outside institution to the community itself. Given that many external enforcement agencies in 'developing' nations are often unable to afford these costs, this factor is quite possibly the most important of the benefits to be derived from such a transfer of responsibilities.

(b) Because resource-using communities have a greater vested interest in the sustainability of their resources, the implementation of such regulatory systems can lead to the more effective monitoring of the resource and the more efficient punishment of offenders.

(c) Because resource-using communities have typically had considerable historical experience regulating the resources on which they rely, they are likely to not only perceive the benefits of creating them, but will, in all likelihood, choose such institutions that they are already familiar with, and which they can draw from their history. This means that the regulations that arise are more likely to capture the diversity within and between communities than any type of externally imposed regulation. Regulations of community origin may be better placed to capture the diversity of uses that resources have for communities.

(d) The reasons why people obey or disobey regulations always has something to do with

the benefits they perceive to gain. In other words, if disobeying a regulation is likely to yield greater benefits that obeying it, it is unlikely that people will obey the regulation. How benefits are viewed will vary from community to community and from culture to culture. Internally generated community regulations are more likely to capture these benefits than those regulations imposed from the outside.

(e) Common property resources are often fraught with problems of uncertainty. Management cannot account for such uncertainties, particularly because of difficulties in monitoring resource variations. However, because of their intimacy with the resource base, communities are better able to assess variations within the resource as they occur, and able to react to these more rapidly than any external institution overly-reliant on scientific assessment of resource change. In this way, communities will also be able to react to resource changes generated from beyond the resource.

We argue, therefore, that communities must have central roles in the following important areas:

(a) monitoring the resource.
(b) developing regulations for the management of the resource.
(c) developing sanctions to impose upon offenders.
(d) determining how the resource may be exploited and by whom.
(e) defining the kinds of assistance they receive from the state.
(f) implementing the rules for which they are responsible.

What is implicit in these suggestions is that communities receive some sort of 'ownership' or 'guardianship' over the resources that they exploit. While this would appear to be a pre-requisite for the successful management of the resource, so too is lack of interference and legitimising, in the eyes of the state, those institutions that communities are able to create. In the examples that follow, we attempt to show that the centralised management authorities are not a necessary ingredient for obtaining satisfactory management outcomes.

In their controversial study of farming in Machakos, Kenya *et al*., (1994) argue that during the colonial period, a high degree of government involvement in on-farm development resulted directly in the productivity declines and high rates of erosion. The recent turn around has occurred despite high population pressure, and has very little to do with any centralised intervention.

On Mihama Beach in Mwanza District in Tanzania, landing officials established their own 'Committee for Environmental Protection'' to clear the beach of obstructive water hyacinth. Soon, however, the Committee's activities widened to cleaning fish filleting slabs at the receiving pontoon, cleaning the beach of any mess and patrolling to ensure that no fisher broke fishing regulations. They claim to regularly seize illegal nets and also to have arrested several people using poisons to fish with. In return, the Committee took a fish per boat that landed, and, at the end of the day, sold off the accumulated fish for salaries to their members. When, in September 1999, Mwanza Municipality started collecting taxes on the beach, however, fishers refused to pay a fee to the Beach Committee, arguing not only that they were unwilling to pay taxes twice over, but also that the Municipality was the stronger of the two revenue collecting groups. At present, the Mihama

Beach Committee continues to operate without funding (*Own data collected by M. Medard and K. Geheb, 19/1/2000)* .

In a case study from Shinyanga District in Tanzania, Leach & Mearns (1988) argue that efforts made in conservation and the curbing of over-grazing within the district have been successful because "…the decisions were taken by the villagers themselves, fully confident that the reserve is *mali yetu* (our property)". Government attempts to reforest areas within the district from centralised nurseries failed.

In his study of fuelwood use in Kisii District in Kenya, Mearns (1995) argues that forestation has occurred largely on owned plots of land, while concomitant deforestation has occurred in nearby (government controlled) forests. He argues that the forestation movement had, in large measure, to do with recognisable benefits to be derived from cultivating trees to meet the demand for building poles.

In Geheb's (1997) study of Kenya's Lake Victoria fishery, he examines a case from Kaloka Beach in Kisumu District where the fishing community set about attempting to prevent the use of illegal gear in their waters. The operative unit around which they formed these arrangements was an identified area of water that they considered as their own and which they were prepared to defend against outside intrusion. The initiative failed, however, when the District Commissioner vetoed support for the scheme, explaining that the villagers could not 'take the law in their own hands' the scheme succeeded.

In the 1980's, population densities in Kenya's Kakamega District were as high as 1,500 people per square kilometre. What intrigued researchers was that the higher the population density in the district, the higher the degree of forestation. In many cases (over 75 % of 528) forests were deliberately planted by inhabitants. In virtually every case, the highest degree of forestation occurred on private land, and there was thought to be little scope for pursuing communal forestation strategies (Chavangi, 1992; Leach & Mearns, 1988).

As a result of corruption and low staffing levels in the 1970's, police in Shinyanga District in Tanzania were increasingly unable to curb cattle rustling amongst Sukuma herds, nor able to ensure the recovery of stolen stock. As a result, locally initiated '*sungusungu*' vigilante groups formed, whose "…main objective was to protect the lives and property of rural inhabitants. They patrolled their villages, and arrested and punished those who they suspected to be involved in criminal activities. Their main targets were cattle rustlers and other rural bandits" (Bukurara 1996). The activities of the sungusungu groups, and the manner, in which they were organised, was embedded in Sukuma social structure and tradition. According to Bukurara (1996), the groups have been very successful - so successful, in fact, that they have been legalised. The groups are not without their opponents, however. The police and Judiciary, Bukurura explains, object to the Sukuma taking the law into their own hands, and argue "…that *Sungusungu* members are attempting to turn the clock back to primitive punitive measures…The competition between the two suggest that Tanzanian state institutions are more concerned with the protection of legality of monopoly of their powers than with the actual problem of crime" (Bukurura, 1996).

This latter example is very important. If terms like 'community participation' are to develop any further than political rhetoric, centralised government institutions must be willing to devolve a large measure of the responsibility they have over resources, and possibly accept radically different roles in the future. If the successful management of resources within the Lake Victoria basin is to occur, it must firstly incorporate communities into its structure and it must be sufficiently dynamic to respond to the down-stream effects of resource exploitation elsewhere.

This is not to say that there are no roles for the state in the management of the Lake Victoria basin's resources. In much of the co-managerial literature, it is understood that many of the local-level difficulties we associate with monitoring and regulatory enforcement, may become community responsibilities. Larger scale, administrative responsibilities, however, can only really remain the preserve of the state. "For example, some of the environmental externalities associated with water and soil management in the Nile River system can be accommodated at the level of the micro-watershed; others can only be accommodated through the co-ordinated efforts of nation states" (Swallow, 1997). This is particularly the case for the Lake Victoria basin and its environment. At the micro-administrative level, resource users become, as it were, too close to the problem to be able to observe changes and trends in other geographical areas, and amongst other resources. It is in these information gaps that the government should turn to focusing its energies, in the monitoring of regional and national trends for the purposes of advising and guiding small-scale groups of resource users, and in the definition of extension services.

CONCLUSIONS

This paper has argued that state management of the Lake Victoria basin's resources has failed on two principal counts: their failure to include communities in decision making and their failure to be able to cope with the down-stream affects of resource exploitation elsewhere. It argues that in many cases, the state makes a less than positive contribution to the management of the basin's resources, and may even be part of the resource management problem. In addition, the paper argues that this arrangement is based upon two main perspectives: firstly, that resource users are perceived as unable to manage their resources, and secondly that the state is both able and has the right to carry out these functions. In these ways, the state can, in actual fact, be a part of the problem rather than a solution. The paper has argued, on the basis of empirical evidence obtained from within the lake basin, that control by communities of exploiters may be one possible way of achieving desirable managerial outcomes.

Ownership: The Management Foundation of Sustainable Fisheries of Lake Victoria.

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SUMMARY

This paper explores the ownership status of the Lake Victoria based on data generated in Tanzania. The data indicates that despite management efforts by the Fisheries Division, total fish catch has continued to decline, this has generated debate on finding a better management regime. Top on the discussion is co-management. This has been considered as a solution to the declining fish catch and an institutional set up in the form of Beach Management Units has been established a long the Tanzanian side of the lake. Where as this management regime promises better results, the way it is implemented is very vital, in addition, the way it is formulated should inculcate a sense of responsibility in the resource. In order to create this, ownership of the resource is very crucial, thus this paper recommends ways how ownership can contribute to a better management of the lake.

INTRODUCTION

The fisheries of Lake Victoria are as timeless and important as the lake itself. The riparian communities have always depended on this fishery for their subsistence activities generating food for consumption and for employment. Thus, the Lake has been part and parcel of the local communities. Some communities (Sukuma) claim that they lived in that area before the lake existed (SEDAWOG 2000b)[1] . Since the formation of the lake until 1940s the local riparian communities who were the primary users of the Lake must have managed this fishery. It was not until 1947 that Lake Victoria Fisheries Service was founded. At the same time a central authority was established to manage this fishery for the three riparian states which were almost getting their independence. The responsibility was later taken over by the national fisheries departments (Witte & Densen 1994). The major goal of fisheries policy in Tanzania has since that time, "to promote conservation, development and sustainable management of the Fisheries Resources for the present and future generations".

In 1997 this Policy goal was redefined[2] to include outlined community participation as a strategy in achieving this goal. In 1972 the centrally implemented fisheries policies were unable to take care of grassroots problems. Thus it was decided to decentralize the system to move decision

[1]*This is an acronym used to refer to the Socio-economic Data Working Group of the Lake Victoria Fisheries Research Project. This group comprises socio-economic researchers working in the Fisheries Research Institutes of Kenya, Uganda and Tanzania parts of Lake Victoria.*

making closer to the people. This resulted in power being transferred to the District Fisheries Officers who regulate their district fisheries, but are answerable to the District Development Committees (DDC) and Regional Development Committees (RDC). In turn the RDC is answerable to the Prime Minister. This did not however relocate power to the local people but only enabled decisions to be made at much lower level (Districts) than previously. Thus, it has remained a top-down regime. This management system has contributed to decline in landings as indicated in Fig. 1.

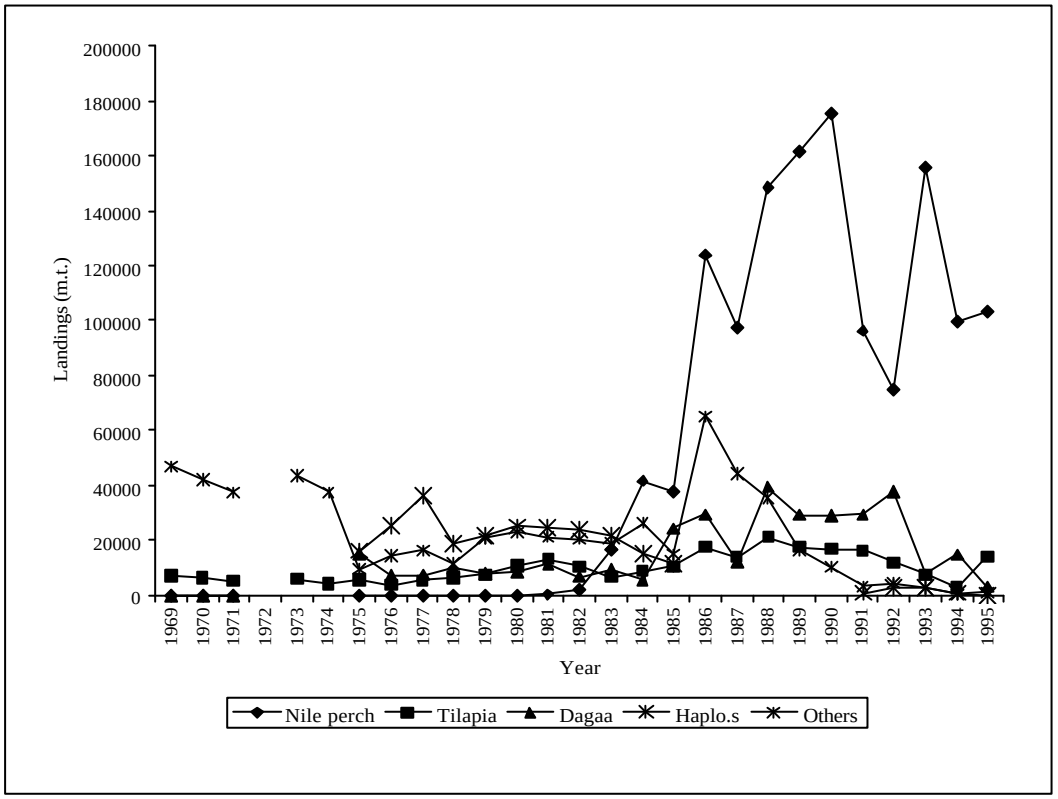

Fig. 1. Lake Victoria (Tanzania) landings from 1969 to 1995 (source: Greboval and Fryrl 1994; Unpublished, Department of Fisheries figures. *Source: Fisheries statistics*

The failure of top-down management regimes, and the desire for participation management has reoriented the thinking of fisheries managers in the three riparian states of Lake Victoria to seek involvement of local communities in decision-making process. In Tanzania, this desire has given birth to over 500 Beach Management Units (BMU) formed across the entire lakeshore Tanzanian side. These BMUs have been formed in over 500 beaches in the lake through one-day consultative meetings between the Fisheries Division and the local communities (Hoza & Mahatane

[2] *The policy statement has 18 statements the 12th one states that 'to improve the involvement of the fisher communities in the planning, development and management of fishery resources'*

1998). The BMU's have been formed on government instructions not based on community consent or opinion. This perception is especially shared by BMU members belonging to the local communities. The communities themselves see the BMUs as an extension of the Fisheries Division and not as a community management regime (SEDAWOG 2000b). In fact, the BMUs, according to their organizational structure, are directly answerable to the Fisheries Division.

The introduction of these BMUs is expected to reverse the decline in catches as indicated in figure one above. The important question is; will these BMUs give the desired results? The argument in this paper is that the decline in catches has been due to the open access status of the lake. Individual fishermen have no rights to exclude others from fishing, fisherman seem to believe that, leaving fish to grow and reproduce, means leaving the fish for other fishermen. The result is therefore a "race-to-fish" and subsequently decline in catches. It is therefore argued here that, so long as the lake is open to all, any management regime will not yield the desired goals (sustainable fisheries). The open access nature of fisheries is a fundamental cause of poor economic performance and biological overexploitation. A solution is proposed that, local communities should be allowed to own the lake. This will generate use value as well as use rights, which will lead to sustainable fishery. Some few examples are given towards the end of this paper as evidence of how ownership of fishing areas has produced sustainable fishery. This can be understood clearly from Hardins model of Tragedy of the commons (ToC).

THEORETICAL FRAMEWORK

Hardin's (1968) theory of Tragedy of the Commons clearly illustrates the concept of ownership. In this theory Hardin envisions a pastureland open to all. Thus, Hardin's statement has always been challenged because he refers to open access rather than common property. Whether he talks of open access or common property, one thing should be clear from his argument. Everybody either owns a common property in the village or nobody owns it, however use rights are attached to a specified user group. In many cases such common properties have use rights attached to a specified group but such groups have no legal possession rights.

The Hardin example based on pastureland may be equated with access rights to Lake Victoria fisheries. It has a finite capacity to support fishing. The implication is that if there are more fishermen than the lake can handle, each fisherman will catch less and the lake's productivity will decrease. Hardin was particularly interested in the economic decision-making process of a rational herdsman who is interested in maximizing his benefits. He argues that as a rational being, each herdsman will seek to maximise his gain. More or less continuously asks himself what the utility of adding one more animal to his herd. Hardin believed that a rational herdsman will conclude that he should add an animal to his herd, and then another and another.

In the fishery of Lake Victoria, the rational fisherman will maximise his catch by devising ways and means of increasing his catch which may imply using illegal gear. Hardin explained, "Since the herdsman receives all the proceeds from the sale of the additional animal, the benefit of adding an animal (or more boats and or illegal gear) is nearly +1. This is a function of the overgrazing created by one animal. "Since the effects of overgrazing are shared by all the herdsmen,

the negative utility for any particular decision-making herdsman is only a fraction of -1". This fraction is subtracted from his positive benefit giving 1-1/x. Hardin then concludes that the end result is the ruin of the pasture resource.

In this theory the underlying issue is that this pasture is 'open to all'. This condition implies that nobody owns the pastureland or nobody can be held responsible if the pastureland is degraded, destroyed or misused. Everybody however potentially enjoys the benefits of it when it is productive. Steins (1999) defines Open access (open to all) as a state in which the common-pool resource has no use rights attached to a specific group, resulting in a general 'free for all'.

CONCEPT OF OWNERSHIP

"It is important to create an appropriate, functional framework for community conservation, one primarily based on ownership" "Ownership of land and resources is the basis for the three broad forms of community conservation. (Barrow & Murphree 1998)

Definition

Possession of or holding of a resource with the associated full rights to use. Ownership is a critical factor in management since it determines the linkage between responsibility and authority over the resource, it also determines the incentive structures for sustainable use.

Ownership of a resource basically implies possession and use rights. A right is a claim to a benefit stream that is consciously protected, in most cases, by the state. Rights define the uses that are legitimately viewed as exclusive and the penalties for violating those rights. Rights are exercised following a clearly defined set of rules. For example, a right provides the authority for a fisher to operate in a specific fishing ground. How the fisher exercises that right through the fishing activity is specified by rules which may dictate the type of fishing gear used or the time of year when the fishing gear can be used (Pomeroy & Harkes 1999). Schlager and Ostrom (1993) distinguish between different types of rights:

a) Access rights: the rights to enter a physical property e.g. participate in the fishery.

b) Withdrawal rights: the right to obtain the products of a resource e.g. catches a certain amount of fish.

c) Management rights: the right to devise operational-level rights of withdrawal.

d) Exclusion rights: the right to devise operational-level rights of access

e) Transfer rights: the right to sell or lease all or part of the above collective-choice rights.

When possession and use rights are exercised together, sustainability of the resource use can more easily be achieved than otherwise. But when use rights are exercised without possession, the result may or may not be sustainable. For Lake Victoria it has been unsustainable. Why should this happen?

When there are use rights in a Common Property Resource (CPR), then users will be compelled to exploit it, always being controlled by the following characteristics of CPR's; (i) Subtractability: that is any other fisherman will not catch the fish that you catch from the lake. This means that fishers will want to catch as much fish as possible regardless of their fishing practices. Fishers' interests will be to catch as much as possible. In Lake Victoria, for instance, this is compounded by the problem that access rights are not defined in terms of who can fish but in terms of what gear are permitted. Nor are there rights on the limits of catch per fisherman (quotas). (ii) Excludability - because fishermen cannot exclude others from the fishery, as many fishermen as possible will join the fishery. This will lead to overexploitation, degradation and eventual ruin of the resource. This is attributed to user incentives to maximise their own utility (Steins 1999). This is one of the major causes of degradation of Lake Victoria.

This whole scenario is converted when you add possession. Possession has a tendency to create a feeling of use value, besides this, possession also includes costs to be incurred by the owner. In other words the owner incurs costs as well as enjoys benefits from using the resource. The combination of these two issues should lead to responsible use of a resource or an item. In economics, responsible use of a resource is equivalent to efficiency. In fact Swanson and Göschl, (1999) argue that ownership (property rights) has implications for efficiency. From their viewpoint one can argue that property rights (ownership) are an incentive in themselves. Given that within the world of intellectual property, there are trademarks, copyrights, patents and plant variety rights, it would seem possible that similar rights be established for the exploitation of living aquatic (i.e. freshwater and marine) resources if we want to achieve sustainability of the resource use. When an item or resource is owned, there will be a tendency to develop a responsible use for it. This is so because ownership does not only result in benefits but it also introduces costs on maintaining a resource. Thus in order to achieve a sustainable exploitation of a CPR, ownership (possession and use rights) must be guaranteed.

Ownership status of Lake Victoria

The complexities associated with managing Lake Victoria are directly related to its status as a common-pool resource. One may consider the lake zone as having no clearly defined boundaries. At best it can be described as a band of land and water on either side of the shoreline, which is defined in a different way in different localities and national contexts according to physical, biological and cultural criteria (Jones 1998, Sorenson, *et al*., 1984). Secondly, perceptions of the lake present a frustrating atmosphere for the development and implementation of management strategies. The lake is perceived as a 'free for all resource'. This is evidenced in the attitudes of the local fishermen who believe that nobody or everybody owns the lake (SEDAWOG 2000a). When asked who owns the waters, 43% of the fishermen answered nobody/everybody. From the survey, however, it could also be deduced that government ownership is perceived as open access by the local fishermen (SEDAWOG, 2000a). Moreover, the fishermen believe that they can fish from anywhere in the lake. These fishermen also believe that everybody should be allowed to fish and that nobody should be prevented from fishing in the lake. On the government side, the lake is perceived as a revenue generating resource. The Local District Councils in Tanzania and Uganda, and The Fisheries Department in Kenya, generate incomes from licenses

charged on fishermen and fishing boats. Thus the more fishermen and boats which can be registered, the more income will be generated. Anybody with the recommended equipment is not refused entry into the fishery.

The open access state of the lake is one of the reasons why local fishermen perceive an increase in the number of fishermen and boats in 1999 compared to 1994. In fact over 80% of the fishermen interviewed agree that there has been an increase in the number of fishermen and boats (SEDAWOG 2000a). Disobedience of regulations is yet another response of fishermen to open access. It is also possible that the impact of water hyacinth would not have reached its level if some form of property rights were attached to the lake. Transformation of the lake fishery from traditional to commercial form is another result of open access.

Efforts to co-manage the lake have already been initiated; the approach, however, raises a lot of questions. It places the community external to the lake and nevertheless expects the community to enforce government regulations formulated without community inputs. Any such management approach that is not addressing possession and use-rights jointly by the two parties will not achieve a sustainability of the fishery because such a regime does not recognize that Lake users are the best-suited custodians of the lake. A sense of responsibility will not be achieved as long as the community is viewed as external to the lake. To render the fisheries of Lake Victoria sustainable, a sense of responsibility must be generated through a transfer of ownership, or proprietorship, from the state to the community and thus to the resource-user level (Barrow & Murphree, 1998).

Some cases where ownership of resource has led to better-managed common-pool resources.

1. Tagba Lagoon (Ivory Coast) (Hviding & Jul-Larsen 1995). The ownership regime here is territorial rights. These are clearly defined and allocated according to family groups. This lagoon is divided into three family territories. These families manage their territories on the basis of three different principles: Control over access by foreigners through establishment of quotas and fees, Limitation of fishing effort through regulating seine setting and through prohibition of fishing certain days and areas, Organizing collective production and marketing types, which effectively controls the effort of participants. It is reported that this tenure system has created a range of conflicts however it has prevented the exhaustion of the resources and the impoverishment of the villagers. Territorial rights is a possible regime in Lake Victoria but should be based on village level.

2. Lake Chiuta Malawi. (Donda, 1998). The management of the fishery of this lake had been initially under customary tenure, whereby the Chief and fishers committees controlled the regulations and managed the fishery. The traditional management system that existed was an informal Territorial Use Rights in Fisheries (TURF). Thus the responsibilities of the chief and fishers committees were majorly to limit entry and monitor stocks of the

lake. These responsibilities were effectively implemented because the community viewed the lake as theirs. The result of this management system led to Increase in catch and kept fish stocks at productive level. Average production in 1970s was 1,400 tonnes and in 1980s it went up to 1,600 tonnes while in 1990s it still went up to 2,700tonnes.

3. Viti Levu Fiji Island (South Pacific) (Cooke, *et al.*, 1996, Jennings and Polunin 1996). In this Island there is a well-established system of traditional fishing grounds known as qoliqoli. This is officially known as customary fishing rights areas (CFRA) owned by local community members. These people manage their own fishing areas through committees. Management issues differ from one place to another but are basically on restrictions on access, closed seasons in certain areas in order to alleviate bait fishing pressure, protect corals, protect fragile vegetation of the small island, and stop uncontrolled béche-de-mere fishing among others.

RESULTS

There are two common issues, which can be deduced from these case studies, these are; one, there is some form of ownership vested on the resource users. This is evidenced in the forms of territorial right areas, customary tenure designated plots and customary fishing rights areas. The second is the result of these management arrangements on the stocks and economic performance. In all these case studies community ownership of these common-pool resources have led to either increase in stock, better incomes for the communities and or a high management index. Lake Victoria cannot be an exception if some form of ownership can be introduced. This lake is surrounded by local communities who are organised in form of villages recognised by the riparian governments, each village has some form of leadership which handles the most prevalent problems such as conflicts, security and administration. Just as in Viti Levu as well as Lake Chiuta, these villages can be vested with powers to control access into the lake and exclude others especially law-breakers from fishing. These villages, through patrolling their beaches can implement this management strategy. Further more these villages can also participate in monitoring of stocks through taking daily catch data. As already discussed above what is fundamental is to introduce ownership (not only use rights but also possession rights) of the lake to the local communities. The formation of co-management units, which we are witnessing especially in Tanzania, is a way, which attempts to make local fishermen own the management process, this can be built upon to allow them own the lake. What is required to reorganize these BMU's so that they may have local support and backing.

CONCLUSION

In order to sustainably manage Lake Victoria, its ownership status has to be addressed. There is a tendency of wanting to involve local communities in a top-down approach, especially in cases where the government forms community beach committees without the agreements of communities. This, in essence, only improves vertical communication; and does not create any horizontal communication. Managing the lake requires real partnership and alliances principally between the government and the communities. Moreover communities should play a pivotal role

in this partnership. In order to achieve this it should not be simplified to the provision of benefits but has to relate to wider issues of land use and tenure together with local and national economic needs and aspirations.

RECOMMENDATIONS

a) Efforts should be made to reverse the still prevailing perception held by the local communities, that the natural resources are owned by the government and that the communities are not partners of the government but its subjects.

b) Government authorities should transfer ownership of the lake from themselves to the local fishing communities allocating them territories where they can fish.

c) A law should be enacted to create an atmosphere in which the fishers of Lake Victoria become legitimate only by belonging to a fisher (producer) organization thus facilitating the transfer of lake ownership as well as of the control of entry to the lake fishery.

d) Fishers should be given exclusive use rights and control of exclusion from and transfer of rights.

Assessing the Impact of Increasing Settlement of Various Communities on Social Amenities along Lake Victoria (Kenya)

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INTRODUCTION

Lake Victoria is the second largest freshwater lake in the world. Uganda, Tanzania and Kenya also share it. It covers an area of 63,000 Sq. Km with Kenya having 3755 km^2.

The lake has been the major source of food for a highly populated area where the seven districts bordering the lake, namely Busia, Bondo, Rachuonyo, Homa Bay, Suba and Migori. According to the 1979 census, a total population of 2,035,648 people lived in an area of 11,908 km^2 giving a density of 120 people/km^2.

There has been a rapid increase in the number of fishermen and fishing vessels along with their gears in the Kenyan part of Lake Victoria. Unfortunately, statistical information has only been collected for few years on fisherfolk and canoes, and this information does not reveal the development that has taken place. Latest surveys to measure the size of the fishing industry in the |Kenyan part of Lake Victoria was carried out by the Sociology Team of the Lake Victoria Fisheries Research Project between 1971 and 1972. According to the survey, 4,100 canoes were operating on the Kenyan part of the lake. These canoes employed some 10,700 fishermen, either as owners of the canoes, gear-owners or laborers. It was estimated that 10,700 belonged to household totaling to 80,000 members (Jansen, 1993).

Therefore, this paper tends to show the changes in settlements of various communities scattered along the lake. It took into consideration all social amenities in the beaches and their associated problems.

OBJECTIVES

The broad objective of the study was to generate data that is to be used to formulate policies governing the management and utilization of the lake Victoria resources with greater community participation.

Specific objectives

a) To investigate why beaches grow or collapse and what are the major factors encouraging growth of the beaches.

b) To assess the impact of the increasing population along the beaches on social amenities

available, sanitary conditions of the beaches and associated problems

c) To investigate the nature of migration between landings.

METHODOLOGY

This study was conducted in the three zones northern, gulf, and southern zones between 15th may 1998 to 4th January 1999. Data was obtained through survey questionnaires, which were administered through personal interview by interviewing various fishing groups of people living in various fishing villages and beaches around the lake.

Beach observation and key informant questionnaires were used to collect data. Fishermen, traders, processors, hoteliers were selected randomly with 20 people being interviewed per beach. A total number of 262 respondents were successfully interviewed. A stratified random sampling method was used to select beaches which were categorized into small, medium and large according to the number of boats registered there, that is within the southern, northern and the gulf zones.

RESULTS AND DISCUSSIONS

Most of the beaches where interviews took place were established between 1961 and 1981. Five of the beaches were established way before the 1960's, while the other 14 were established after the 1960's though none was established after 1991.Among all the tribes interviewed in the sampled beaches 74% were Luos 15% Subas, 10% Luyhas and 1% others.

Out of 262 respondents interviewed about 51% of the interviewees were full time fishermen, 27% full-time traders, 7% full-time processors and 5% seasonal fishermen, 5 seasonal traders, and five others.

Economic Activities

From observations made during the study, small markets being established during fish landing and trading have characterized beaches. Various groups of people living in these landing beaches are involved in various economic activities that earn them a living. A part from these two groups of fishermen and fish mongers who get their income from the fish, a large number of different service institutions have developed around the fishing industry where many hundreds of women and men along the kenyan shoreline have established small hotels, shops where they sell refreshments to the fishermen and fishmongers. Also some people are occupied in the production and repair sector of capital equipment used in fishing operations. Other groups earn money on transporting the fishmongers from the landing places for fish to the market place.

Data from this study reveals that about 49% of the people living at the landing beaches were involved in Fishing activities while 15% dealt in Fish trading, 8% in shop keeping Table 3.

Beaches around the lake may be categorized according to the kind of fishery that is dominant on that beach. In most of the beaches, multi-fishery practices are done whereby 16 practiced Nile perch fishery, 15 dagaa fishery, 10 tilapia, 1 haplochromis and 4 were other fisheries. Almost all beaches sampled had some kind of organization with a beach leader or chairman.

Table 1. Economic activities respondents are involved in

Economic activities	% number of respondent interviewed
Fishing	49%
Fish Trading	15%
Shop Keeping	8%
Fish Processing	6.5%
Hotel Business	6.5%
Farming	4%
Selling Petrol Lubricants/Paraffin	1%
Net/boat making/ mending	2%
Selling Agro Produce	1%
Others	7%

Growth of beaches

Out of 19 beach leaders interviewed, about 74% perceived that their beaches are growing while 26%indicated that their beaches were collapsing. Also 40% of them revealed that their beaches were growing due to high landings and availability of market, 17% indicated marketing role by strong cooperative and women groups, booming of other businesses10%. High beach landings have attracted more economic activities, which attract more people to the beach leading to growth of beaches.

The following are some of the factors mentioned by beach leaders as important for growth of beaches;

Table 2. Major factors for beach growth.

Factors	% No. of Beach leaders
Marketing roles by strong cooperatives/women groups.	17%
High landings/ available markets	40%
Beach locations (Near urban town)	10%
Booming of other business	10%
Good Infrastructures (Good roads, transport boats, hospitals	10%
More land for expansion	7%
More housing units/ increasing of population	3%
Good management of the beach and cooperation	3%

Several responses were given by respondents as to why they preferred to go fishing and trading in these particular beaches. About 28%of them preferred to Fish or trade so as to earn a living or get employment, 22% indicated that there were better prices and ready market for their products, 16% indicated high supply of fish at those beaches, 23% its near their home area Table 3.

Table 3. Reasons for Fishing and trading in these beaches

Reasons	% No. of respondent
To get employment/ Earn a living	28%
Near my home/ home beach	23%
Better prices and ready market	22%
High Supply of fish/ high catches	16%
My family stays here/married here	5%
Near to town/near my place of work	3%
Near to the main Road/easy transport	2%
Others	1%

Number of housing units at the beaches

All sampled beaches had a total of 505 permanent housing units and 3,196 temporary houses. From the figure below, Sori Karungu has the highest number of both permanent and temporary housing units, followed by Kibro beach. However the number of housing units present in that beach also determines growth of beaches.

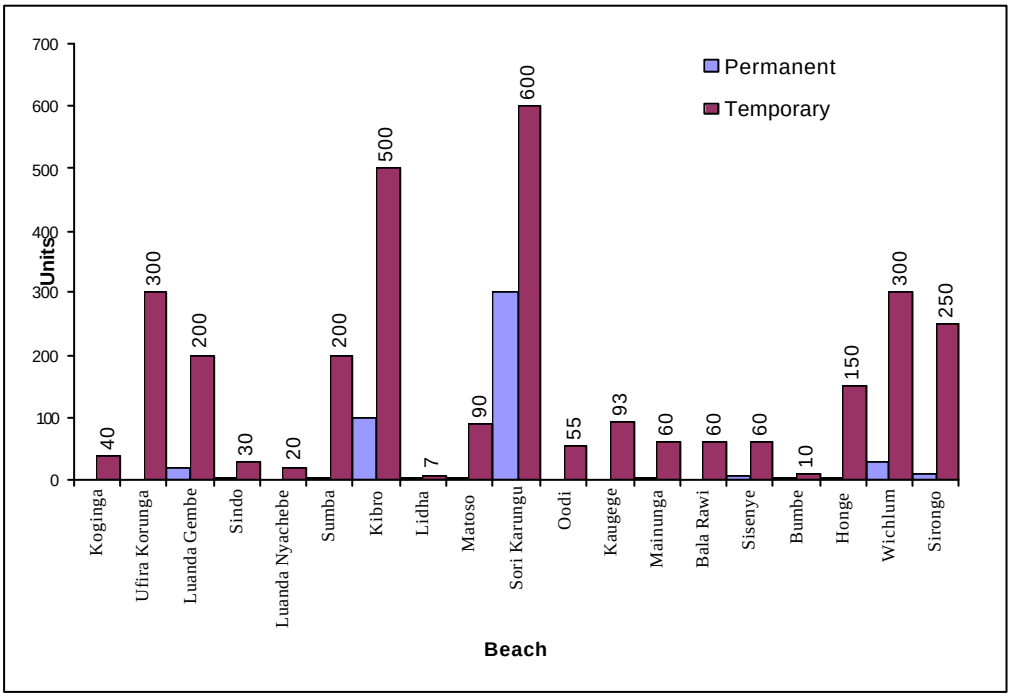

Fig. 1. The number of housing units at beaches

Collapsing of Beaches

Table 4. Reasons for collapse of beaches

Reasons	% No. of beach leaders
Inactive cooperative societies/poor management	20%
Low landings/lack of market/scarcity of fish	40%
Poor infrastructures (bad roads, lack of amenities	10%
Rampant theft of gears, boats, Engine (piracy)	20%
Others	10%

Some respondents perceive that beaches collapsed due to low landings and lack of market for fish (40%), inactive Cooperative societies (20%) and piracy in the Lake (10%). (Table 4). About 56% of the beach leaders interviewed perceived that their beaches had been deserted before while 44% had never been deserted.

Table 5. Reasons why some beaches were deserted

Reasons	% No. of beach leaders
Cholera / dysentery outbreak	40%
Scarcity of fish (Low landings)	30%
Because of water hyacinth blockage	20%
Heavy rains (inaccessibility)	10%

About 40% beach leaders acknowledge that their beaches were deserted due to outbreak of cholera, 30% due to scarcity of fish and 20% due to blockage by water hyacinth. Out of 19 beaches sampled 12% were completely deserted, 25% more than half, 38% less than half and 25% half way.

The impact of increasing population on the beaches (change in population)

The great increase of fishermen and equipment in the lake has resulted to rapid growing population along the landing beaches as mean for earning money. This growth of population is a result of easy entry to the fishing occupation because of lack of employment elsewhere. Data from this study also revealed that an estimated population of 30,650 people lived or operated in the sampled beaches at the time of interview while 23,000 people lived in these beaches two years ago (1996). This shows that the population had increased by 25 % in those beaches in two years period.

Table 6 shows that sori karungu had highest population, followed by sumba and koginga beach respectively.

Table 6. Total population at the landing beaches

Beaches	1998	1996
Koginga Beach	3000	2000
Ufira Kolunga	600	300
Luanda Gembe	1000	700
Sindo	500	300
Lwanda Nyachebe	500	800
Sumba	3000	2000
Kibro	900	600
Lidha	250	150
Matoso	300	200
Sori Karungu	11500	7000
Oodi	800	400
Kaugege	500	300
Mainuga	500	350
Bala-rawi	600	500
Sisenye	500	300
Bumbe	200	150
Honge	2000	2500
Witchlum	2000	1500
Sirongo	2000	3000
TOTALS	30,650	23,000

Data collected during the survey indicated that about 78% of the beach leaders interviewed perceived that their beach population was increasing while 11% perceived that it was decreasing and 11% just the same.

Table 7. Causes for increasing in population at the beaches

Causes	% No. of Beach leaders
Easy employment/High landings/more boats coming	44%
Booming of other business	25%
Availability of houses	13%
Near to urban center/ Locational factors	9%
Better prices attract more people	6%
Better infrastructures (tarmac roads)	3%

Table 7 above shows that 44% of the beach leaders interviewed had perceived that their population was increasing due to high landings and availability of employment while 25% due to booming of other business and 13% availability of houses. However the major factors that contributes to the increasing of the population was the migration between the landings and natural birth.

Impact of increasing population in social facilities

The study also revealed that the changes in settlement along the beaches had a lot of impact on the following.

Impacts of population change on nutrition

The changes in settlements have affected the nutrition status of the fishing communities by affecting the supply of fruits, cereals and vegetables as in Table 10.

Table 8. Impact of increasing population on nutrition

Impact on nutrition	% No. of respondents
Shortage of cereals	49%
Shortage of vegetables and fruits	31%
Shortage of meat and milk	8%
High demand for preferred species (tilapia)	1%
High prices of food	1%
Low catches	9%
Unbalanced diet (depending on fish only)	1%
Others	1%

Sanitation:

In sanitation the fishing communities have experienced a lot of hardship whereby 52% of the respondents indicated shortage of latrines at the landing beaches, 20% perceived lack of clear water for drinking while 10 % indicated enough latrines at their beaches Table 9.

Table 9. Effects on sanitation

Impact on sanitation	% no of respondents
Insufficient latrines	52%
Poor handling of fish (storage)	4%
Lack of clean water	20%
No latrines at all	9%
Poor housing structures	4%
Enough latrine are build	10%
Others	1%

Environmental Effects

Increasing population have impacted negatively on the environment. Cutting down of trees for house building, settlement and firewood have led to deforestation of the beach areas which has led to erosion thus degrading the environment.

Beach and water pollution is very much evident at the landing beaches. Washing of clothes, household utensil and fish cleaning is often done in these areas leading to pollution.Also many of the immigrants have brought with them illegal fishing methods and gears which end in depleting the fish resource thus degrading the environment.

Social Effects

In almost all-landing beaches and villages cases of theft, in decent behavior, prostitution and drunkard ness have been the order of the day. Negative social problem like prostitution have become rampant as a result of low income of fishermen and scarcity of fish in the lake causing single mothers carrying out business of fish trade to indulge in prostitution so as to get enough supply of fish from the fishermen.

Various Amenities Available in Beaches and associated problems.

Table 10 shows all the social facilities available between 1996 and 1998. All beaches had no electricity, piped water, salting mat, petrol station, and Refrigeration room.

There were only twelve fish bandas as in the sampled beaches of estimated population of 30,650 people at least 2554 people sharing a fish banda.

About 1,350 private toilets were found in sampled beaches and 504 traditional processing units. Actually the trend in this table is that since 1996 there has been an increase in almost all facilities but the rapid increase in population cannot cope with the increase in this facilities.

Table 10. Changes in social facilities for the last two years

Facilities	1998	1996
Passable road	10	10
Schools	36	33
Hospitals	34	29
Churches	72	57
Post offices	7	6
Public toilets	37	32
Private toilets	1350	1069
Co-operative offices	39	8
Fish banda	12	10
Dry storage room	4	1
Concrete cleaning slab	3	3
Bathrooms	85	21
Off loading tables	4	3
Traditional processing units	504	482
Electricity	0	0
Piped water	0	0
Salting mat	0	0
Recreational facilities	8	8
Vegetable market	15	15
Fish market	18	43
Shops	215	106
Hotel	126	87
Boat /net making	15	14
Ice plant	0	1
Bars	8	6
Refrigeration	0	0
Petrol station	0	0
Banks	2	1

Problems experienced on Beaches.

Fish folks around Lake Victoria have several problems they experience at the fishing villages and landing beaches. The following are what they consider as their main problems.

Table 11.Problems encountered by beach population

Problems	% No. of respondents
Poor roads/high transport costs	14%
Lack of capital/loan facilities	19%
Lack of market/low prices/ price fluctuations	19%
Theft of gears/ Engine/boats(piracy)	9%
Low sales /Few customers/ Low income	7%
Lack of infrastructure/ latrines /clean water	6%
Lack of cold storage	3%
Lack of hospitals and inadequate facilities	5%
Lack of banking facilities	2%
Shortage of fishing gears/equipment /high prices	3%
Attack by Hippos	2%
Scarcity of fish/ fish decline	2%
Inaccurate weighing machine	2%
Others	8%

Lack of market/low prices and price fluctuations 26% is one of the main problems affecting the fishing community, 19% respondents perceived lack of capital and loan facilities while 13% perceived poor roads and high transport costs at the landings to be their main problems (Table 11).

Diseases affecting the fishing communities.

About 31% of the respondent interviewed indicated malaria as number one disease affecting the beach population. 16% indicated dysentery/ diarrhea, 15% typhoid and 13% cholera. Table 12. Indicates that most of these serious diseases affecting the fishing community are either got by eating or drinking foods or water that is contaminated with human body wastes such as urine, vomit and feaces. These landing beaches around the lake are also areas invested by mosquitoes, which causes malaria that has killed millions of people throughout the world.

Table 12. Diseases affecting the beach population

Type of diseases	% No. of respondents
Malaria	31%
Dysentery/Diarrhea	16%
Cholera	!3%
Typhoid	!5%
Amoebae	8%
Coughing	9%
Skin diseases	3%
Birlharzia	2%
Others	3%

Recommendations for prevention of diseases around the beaches.

1. Improve beach or urban sanitation and clean water supply.
2. Intensify public education/ information dissemination on typhoid, malaria, cholera etc.
3. Vigorous enforcement of public health laws governing food handling and general cleanliness around the beaches.

Out of 227 respondents interviewed about 49% got their treatment at the hospitals while 36% got at the dispensary and 15% were attended to by a traditional healer.

Migration between landings

Due to migratory tendencies of fish in the lake many fishermen follow the fish and migrate between the landings. This migration may be seasonal, monthly or even daily depending on the environment. These settlements along the beaches due to migration is either on temporary basis or permanent, permanent in the sense that one can spend many years before returning to their homes. Data from this survey reveals that out of the total respondents interviewed, 74% came from around the Lake, 23% came from the inland, 2% from the islands and 1% from a neighboring country. Same data collected indicated that the longest period the respondents had stayed in the beach was 49 years and shortest period was 2 months.

In the last one month a total number of 2,162 people migrated to these beaches, while 929 people migrated out of their beaches. About 68% of these people migrated on monthly basis while 32% on seasonal basis.

Of the 259 interviewees 36% had migrated to any beach before and 64% had not. The longest period one has stayed on migrating trip was 20 years and shortest period of 1 week.

Table 13. Reasons for migrating to other beaches. (Out-migration)

Reasons	% No. of respondents
In search of good catches/Better prices/Better market	65%
Because of closure of beach by water hyacinth	22%
To look for employment /to do business	4%
"I accompanied my spouse"	2%
"Tembea" type of fish destroys our fishnets/trawling	0.5%
No access road to the beach (beach had collapsed)	4%
Rampant theft of gears there	2%
Others	0.5%

About 65% of the respondents interviewed indicated that they migrated to other beaches to look for good catches or better market while 22% due to closure of beach by water hyacinth (Table 13).

Table 14. Why people migrate to their beaches (in-migration)

Reasons	% No. of Beach leaders responding
High catches	61%
Good prices	18%
Easy accommodation	7%
Better transportation	7%
To look for employment	7%

Table 14 shows that 61% of respondents migrated into other beaches because of high catches while 18% were to look for better prices.

Sanitary conditions of the beaches

The sanitary conditions of the beaches around the lake are very poor. Basic facilities like clean water for drinking, latrines, houses are inadequate for the growing population at the beaches.

There were about 1,387 toilets for the population of 30,650 people, which gives an average of

22 people sharing a toilet. Most beaches have no clinic or dispensary to take care of the health of their people. The few hospitals available are far away from the beaches. The beaches have no clean water for drinking; they depend on the lake water. Although this study indicated availability of toilets and bathrooms at some landing beaches, a large population excreate in the open grounds, they even wash fish, utensils and bathe in the lake, polluting it. To improve the sanitary conditions of the beaches basic sanitary and hygiene measures have to be observed. Either by cleanliness in food preparation and handling especially when handling fish and in the cases of malaria the cleaning of all the bushes around the beach, cleaning the compound by collecting empty containers where mosquitoes can breed.

About 57.14% of the beach leaders interviewed indicated that most houses in their beaches are built between 1- 30 meters away from the lake shore, 14% said between 31-90 meters away, 7% indicated 91 meters and above. This indicates that the houses are built within danger zones and are vulnerable to rising water levels.

The general over view of major impacts of the settlements was lack of infrastructure for water supply, sanitation, transportation, communication, poor housing units, poor public health and education.

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Developing a Local "Custodianship" over Lake Victoria's Shoreline Wetlands: the Example of Jinja, Uganda

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INTRODUCTION

The use and management of wetlands and generally of shoreline ecosystems has traditionally been the premise of local communities, indigenous people and of rural and urban poor, which use "open access" resources from these zones of transition between adjacent ecosystems to provide multiple resources for their livelihood. The sustainable management of wetlands and the inland water biodiversity has, however, also become a concern of international environmental and water law. Can environmental law entitle and empower the local water shoreline resource users?

By analysing the procedure how administrative and legal development to implement international environmental law takes place in a local context the paper discusses with a cases study of an urban wetland women's groups procedural issues related to community participation in environmental law. According to Ebbesson (1998:70) "public participation in environmental decision making is a form of political participation, implying a more expansive notion of democracy than the standard liberal approach". The case study describes the establishment of a local regime of a sustainable wetland management as a bottom up empowerment process. The case study is situated on the shoreline of lake Victoria, in the swamps of Loco, Walukuba and Budumbuli in the second largest town of Uganda, Jinja. After analysing the legal situation of the swamps bordering Lake Victoria, the paper describes the local process of establishing a management regime on the use of the lake shore resources which resulted in a "custodianship". The participatory bottom up process of legal codification described in this paper consists in legalising a regime which "encloses" an open access resource by making it accessible to the poor under certain environmental conditionalities. Law is "...like a power grid or transportation network..." for change (Trubeck 1972:6). The case study of Jinja town demonstrates that in a democratic context, willing to realise reforms the process how law is generated and can foster environmental rights of marginalised population segments.

Lake Victoria's Inland Water Shoreline Wetland Ecosystems and the Law

Situated at the equator between Uganda, Tanzania and Kenya, Lake Victoria has a surface of 68'000 km^2 (Howell and Allan 1994), the largest lake of Africa and a main water reservoir of the White Nile, used in the desert countries of Sudan and Ethiopia for irrigated agriculture. Among the world wide 245 international river basins the Nile (6'699 km length) is shared by the largest number of states (Hirji and Grey 1998:79). At the equator, Lake Victoria forms a natural storage basin. Lake Victoria is a shallow lake which includes along its 3'500 km shoreline numerous swamps. Before and after the lake, sections of the Nile river basin also include numerous swamps,

out of which the Sudd in Sudan is the largest.

Swamps are important habitats in Africa for a rich plant and animal biodiversity which has been used by humanity since the Neolithic (Balek, 1977; Howard-Williams and Thompson, 1985). The Nile swamps also exercise a considerable regulatory effect on the regime of the river (Collins 1994, Hulme 1994). The ecosystem of Lake Victoria has a unique biological diversity which plays an important role in research on the evolutions of species and their adaptation to different ecosystem habitats. The lake however suffers from rapid deterioration of the shoreline ecosystems, mainly the wetlands, which are breeding and hiding grounds for fish and providers of multiple plant and animal diversity and resources to the communities and to the maintenance of the ecosystem balance. The swamps also act as filter for runoffs from adjacent catchments and thus protect the open water from silt and nutrient rich drain. Since the 1960s the intensification of agriculture, mining, industrialisation and urban growth have contributed to the deterioration of the water quality of the lake through the discharge of sewage and waste water which pollutes the lake. Heavy loads of agricultural and industrial effluents threaten the integrity of the lake shore ecosystem and degrade this resource base used by the indigenous and local communities for plant collection, fishing and small scale gardening.

An understanding of water shorelines as ecosystem providing multiple resources such as water, fish, plants which populate, use and clean water, is expressed in many myths all over the world. Shorelines of inland waters have also been discovered to be the ecosystem in which humanity achieved the Neolithic revolution (plant domestication). However, despite its old age value for humanity, a sustainable and integrated legal regime for this habitat has yet to be developed. As zone of transition between the open water and the land, shorelines including swamps are subject to multiple local and national law related to various planning sectors as well as international water and environmental law which might be conflictive or lack adequate translation into sustainable local management system. Recently, however, international concerns and subsequent research about the loss of plant and animal species biodiversity and human vulnerability related to deteriorated water quality and loss of livelihood resources have isolated shorelines of inland water ecosystems as zones of special concern of international water and environmental law.

Wetland Shoreline Ecosystems of Lake Victoria in International Law

In international water law inland water ecosystems have only recently been addressed and they are not (yet) a subject of law. The 1997 Convention on the Law of the Non-Navigational Uses of International Watercourses recalls the principles and recommendations adopted at the United Nations Conference on Environment and Development of 1992 in the Rio Declaration and Agenda 21. The Convention maintains that "watercourse states shall, individually and, where appropriate, jointly, protect and preserve the ecosystem of international watercourses" (article 20). In International Environmental Law, the protection of inland water ecosystems and local community participation and entitlement in sustainable use and management of these resources have been addressed by the Convention on Biological Diversity and by the Wetland Convention. The 1992 Convention on Biological Diversity (CBD) promulgated an ecosystem approach and a holistic approach of environmental protection and advocated, in 1998 to protect transboundary inland

water ecosystems through the implementation of a joint work plan with the Convention on Wetlands . The 1971 Convention on Wetlands of International Importance especially as Waterfowl Habitat (Ramsar Convention) has focused in 1999 with several resolutions on inland water biodiversity management to establish guidelines to carry out a legal review and to strengthen local communities' and indigenous people's participation in a wise management of wetlands. The three riparian countries of Lake Victoria, Kenya, Tanzania and Uganda are all members of the Ramsar Convention and of the Convention on Biological Diversity. The protection of wetlands as biodiversity habitats in inland waters currently discussed in the framework of the Convention on Biodiversity is of specific importance in the on-going effort to harmonise and develop appropriate rules, substances and procedures to manage this second largest lake of the world.

Legal regimes governing existing shared water course have developed within specific historical contexts before the recent efforts to harmonise international water law and environmental law at international level. Whether the shoreline wetland ecosystems of lake Victoria are protected by international law must be analysed in the context of the River Nile and of East African treaties and conventions related to the use of shared water systems. What is the legal status of wetland ecosystems around lake Victoria in international law? While being either neglected or endangered by the provisions in the treaties concluded in the first half of this century, the status of the shoreline water ecosystem including wetlands is recognised in the recent regional treaties encompassing a part on the riparian states of the River Nile. The Kagera River Basin Authority and the Lake Victoria Fishery Organization agreements include both provisions to harmonise different and conflicting water interests and co-operate in managing quantitative and qualitative aspects of the water ecosystem.

In our review of the regional treaties related to Lake Victoria and the river Nile we limit ourselves to the aspect of the legal status of the aquatic shoreline ecosystem including wetlands. More than ten international agreements and treaties exists between two or several riparian states of the river Nile. Not all treaties are recognised by all concerned states (The 1929 Treaty between Egypt and UK) on behalf of Sudan and the 1949 Treaty concluded between Egypt and the UK on behalf of Uganda, and the 1959 Treay between Egypt and Sudan. The treaties concluded in the colonial period are characterised by the consideration of water use for irrigation only and don't protect aquatic resources such as swamps and codify water rights only quantitatively for its use in irrigation. The post-colonial treaties contrast positively with the colonial treaties in their emphasis on institutional aspects of co-operation in river basin management. Procedural law is a main asset to enforce environmental concerns in the management of international watercourses and their aquatic ecosystems. The 1967 Hydromet agreement, renamed TECCONILE (Technical Cooperation Committee for the Promotion of the Development and Environmental Protection of the Nile Basin) in 1992, includes almost all countries of the Nile basin and encompasses a wide objective for a holistic management of the basin water resources including Lake Victoria's shoreline ecosystem. In 1977 the Kagera Basin Organisation was established by the Governments of Burundi, Rwanda, Tanzania and Uganda which share the basin of the river Kagera, a major tributary toLake Victoria. It constitutes the first encompassing and modern international treaty along a part of the Nile basin which provides for co-operation and joint management. In 1993 the Tripartite Agreement of East African Co-operation between Kenya, Tanzania and Uganda

established a permanent, independent intergovernmental organisation dealing with the ecosystem of lake Victoria, the Lake Victoria Fisheries Organisation (LVFO). Compared to other African institutions of collaboration in the joint management of a river of lake system, such as the Southern African and the Volta Basin, where water allocation is a dominant issue, the LVFO member states endorse the common mission of maintaining the health of the lake ecosystem. LVFO has among other tasks the mandate to harmonise the existing legislation and to develop suggestions for national rules related to the lake and its resources. The procedural elements of law developed so far in this regional organisation are valuable assets in view of protecting the wetlands of this international water system. The treaties concluded in the post-colonial period by a part of the river Nile riparian states focus on procedural rights and co-operation among neighbours in research and monitoring of water uses by including the notion of multiple and conflicting water uses and an ecosystem approach to the common watercourse.

What is the status of the rights of local communities to use and manage the lake shore water resources in a sustainable way and to participate in decision making? The LVFO convention and organisation endorse the Brundtland Commission (1987 Our Common Future) approach to sustainable resource management which acknowledges a correlation between poverty and environmental degradation and the necessity of the full participation of local communities in resource management and its related decision making structures. So far, however, the organisation has not significantly included Non Governmental Organisations and Community Based Organisations in its decision making process and have not developed any concrete policy and legal provision to ensure the right of local communities, many of which consisting of people living in extreme poverty directly from the resource use of the lake ecosystem in its codification. The communication and evaluation of a local bottom up lake resource management project, as suggested in this paper, can bring some impetus into the organisation to contribute to participatory structures of lake resource use and management which include also women, the poor and the marginalised, as advocated by the Brundtland Commission and the UNCED Agenda 21, which forms the base of the approach endorsed by the riparian states of Lake Victoria.

To implement participatory structures and procedures in environmental law is dependent on the existence of permissive and adequate laws and policies at national level, of "good governance" contexts. The following case study of community participation in lake shoreline resource management is situated in Jinja, Uganda. Before describing and assessing in some details the local process of developing environmental law as participative process, we thus summarise our analysis of the legal, administrative and policy context of Uganda related to environmental law and policy.

Among the three riparian countries of Lake Victoria, Kenya, Tanzania and Uganda only Uganda has established a coherent environmental and water legislation which provides for a sustainable use and protection of swamps as part of the lake ecosystem and allows local authorities as well as local communities to assume an active role in enforcing protections of wetlands as part of the local environment. Kenya's legislation at national and local level does not provide for the protection of wetlands at the shore of Lake Victoria Also, the right of local communities in participating in sustainable use of wetlands is not foreseen in the water or environmental legislation in Kenya

(Kenya is currently (1998) in process of reviewing it's water present Water Act (Cap 372) and has developed a "Draft Water Act (CAP.372) Amendment Bill, 1998" which would replace the amendment bill of 1992). Tanzania has similarly to Kenya multiple pieces of legislation which deal with water use and protection without being harmonised in a unified water act (The Water Utilization (Control and Regulation) Act 1974, no 42 of 1974 as amended by Act No. 10 of 1981. The Fisheries (General) Regulations 1973 as amended by the Fisheries (Explosives, Poisons and Water Pollution) Regulations, 1982 GN). And similarly to Kenya there is no law which empowers local communities to control and protect their environment including the shoreline wetlands. Contrary to these two country situations, Uganda has a comprehensive environmental, water and wetland legislation. While in Uganda the period before 1986 was marked by civil war, encroachment into natural resources and mismanagement, Uganda enacted new environmental legislation and policy with the Constitution, 1995, the National Environmental Statute, 1996, the establishment of the National Environmental Management Policy, the new Water Law and Water Policy in 1995 and the Wetland Statute in 1997. Thus today, together with the new Land Bill 1998 and the Local Government Act 1997, Uganda'a environmental law is comprehensive, intersectorial and relevant from national to local level. The environmental law and policy is currently in the process of being implemented and the case study of Jinja town, elaborated in the next chapter, is a result and piece of the ongoing process of forging and implementing the law and thus of "mainstreaming environment in development".

Wetland Shoreline Ecosystems of Lake Victoria in the national Law of Uganda

It was President Muzeveni who has endorsed in 1986 a new paradigm of environmental law. If shifted from "command and control" processes to a proactive role by integrating environmental procedures in planning and by providing for environmental impact assessment. The law as well as the policy context established in Uganda do allow active citizen participation in the elaboration as well as in the implementation of environmental law as the following brief review of the main laws and policies intends to show.

The constitution of Uganda, 1995, acknowledges people's rights to a healthy environment, and the principle of equity between present and future generations. It defines the protection of the environment as a national objective, vests the authority over natural resources in central and local government (article 237 (2) (b)). It states the right and duty of the parliament to provides measures to protect the environment and to promote environmental awareness (Article 245) and thus empowers parliament to provide through law for measures to promote sustainable development. Concerning our specific interest: the inland water ecosytems of an urban shoreline of Lake Victoria, the constitution includes two passages stating that the wetlands and water bodies are among the natural resources to be protected though environmental law and policy. The constitution has thus placed the environment among the fundamental rights and freedoms of people. It provides for peoples involvement in the formulation and implementation of development plans and programs that affect them, the conservation of biological diversity and wetlands, and an enactment of laws to preserve the environment from abuse. The constitution is an important,

highly legitimised document in the country which provides the fundament of Uganda's environmental law. How the environment shall be managed in a sustainable way is defined through general principles of environmental law and policy in the National Environmental Statute.

The National Environmental Statute 1995 and the National Environmental Action Plan 1995 are both also the legal and political outcome of a large participatory exercise which resulted in the amendment of the previous multiple and conflicting pieces of sectorial law related to the use and management of natural resources in Uganda and to the formulation of a comprehensive co-ordinated environmental policy and legislation based on the principles of the UNCED Agenda 21 and the Earth Summit of 1992. Current water and environmental law in Uganda provides for an integrated use, protection and management of the water ecosystem and for community participation at the different levels of action and decision making through the establishment of decentralised administrative and policy making structures.
Additionally to these achievements in water and environmental law, wetlands have a specially protected status:

a) The National Environment Management Policy adopted the NEAP objectives related to wetland conservation and management as strategy encourages the integration of socio-economic and environmental concerns at District level by enabling them to make bye-laws on the sustainable use and management of wetlands.

b) The policy 1994 added "guiding principles" of wetland management which provide for community participation, the legitimation of the continuation of traditional wetland resource uses and a ban on using wetlands which are utilises as sewerage treatment plants.

c) The National Environment Statute 1995 has also a focus on wetlands. It provides for the management of wetlands (section 38), for restrictions on the use of wetlands (section 37) and prescribes penalties for defaulters (section 103). It empowers NEMA to set standards for the management of wetlands and provides for the issuing of guidelines and prescribing measures for the conservation of biological resources both in situ and ex situ. The precise formulation of the restrictions on the use of wetlands were instrumental in developing a local wetland management regime, as will be describes in the next chapter on Jinja's Bye-Law development.

d) The National Policy for the Conservation and Management of Wetland Resources, 1995 and the Wetland Resource Regulations, 1997, support the objectives defined in the environmental law with technical guidelines. Of specific importance for the case study in Jinja is the fact that a traditional wetland resource uses by the people are enumerated as listed and explicitly allowed.

These laws and regulations provided the necessary background to allow to realise a co-management system with the local communities using the wetlands of the shoreline of lake Victoria

in Jinja. The institutional set up of environmental law and policy in Uganda allows thus to link international law with national law and with local management systems. This is a major pre-condition to implement community participation in environmental law and sustainable resource management as the following example of Jinja intends to demonstrate.

Developing a "home tailored" Bye-Law to manage Lake Victoria's shoreline in Jinja, Uganda

Jinja Municipality and its Environmental Policy

Situated at the source of the Nile and the shore of Lake Victoria, Jinja town, the second largest city of Uganda and among the seven major riparian towns of the lake among the most industrialised and also among the polluters of the lake. Jinja has developed, however, a very active environmental policy which includes stakeholder participation and community participation and empowerment. Within this setting a proactive bottom up law-making process could take place. The process started 1995 and is coming to consolidation for the new millenium.

Jinja was built at the end of last century as administrative centre and trading station for East African trade in the Basoga county, in which towns were historically unknown. With the construction of an electric power station (the Owen Falls dam) 1947 - 1952 and the economic boom of the post war period the town became the chief industrial town of Uganda. Colonial urban growth was based on racially and socially segregated units planned to assure the benefit of European and Asian industrial and administrative upper class (Jinja Structure Plan 1993:5). Since the deportation and expatriation of the Asian population in 1972, the industrial development virtually stopped and recovers only slowly since peace has been restored by the current Muzeveni government. Thus currently more than 70% of the 65'000 inhabitants of Jinja town make a living in the informal sector and urban agriculture is widespread. The town has inherited from the industrial boom a set of old factories, a copper smelter, match, steel, leather tannins and other factories, and their deposits of industrial waste which consists of a danger to people's health and to the water quality of the lake.

In 1993 the government of Uganda has launched a decentralisation programme which aims as enhancing decision-making and at improving the revenues of local authorities to provide social services. Jinja was one of the first local authorities which was decentralised in 1993/1994. The town started decentralisation by creating first committees around the problems health and environment and a post for an environmental officer. Jinja then decided to embark in an innovative process advocated at the Rio UNCED Conference on Environment and Development, called the Local Agenda 21 Community Model Program and joined 1995 a world wide initiative by networking with other towns around the globe which followed the same policy approach, consisting of a three year participatory urban environmental planning process. Through a partnership creation and consultation process consisting of public hearings and participatory evaluations and ranking exercises the citizens were called to formulate a vision of "the Jinja we want," then to prioritise

the activities to be tackled. The improvement of Jinja's natural environment including wetlands was ranked as first priority by the participants, to tackle the health hazards faced by the Jinja people: domestic sanitary conditions and waste disposal as second priority. The town thereafter made an Environmental Impact Assessment related to the priorities set, set up an action plan and started activities to improve the urban environment by including community participation.

The concept of the Local Agenda 21 procedure is to provide environmental services through a process of strategic service planning done with participation of all stakeholder groups and the public, while the implementation is backed up with expert services and partly delegated to the private sector. A key aspect of this mode of planning is to include people's perception and knowledge of their environment and to develop cost sharing mechanisms through participatory solutions to environmental problems. The participatory planing process in Jinja town encouraged the formation of self help groups and entitled them to participate as partners of the Local Government in planning and managing the urban environment.

Economic, Institutional and Legal Status of Jinja's Shoreline Wetlands

Towards Lake Victoria three extensive bays on the shoreline are covered with wetlands: Masese-Bdumbuli, Kirinya East (Walukuba) and Kirinya west (Loco). One of them is used for secondary sewage treatment. All swamps of the town are intensively used by the communities to gather plants for crafts, construction, medicinal herbs etc. Most people living near the swamps draw resources from this habitat. A survey on the economic and institutional aspects including formal and traditional user rights of swamp resource use (Wacker 1997) had shown, that most people living near the lake shore wetlands of Jinja town use some resources from this habitat, that women and poorer population segments are the main swamp resource users, that poverty and more sustainable wetland resource use correlates positively but that the user rights protecting the more sustainable uses of swamp resources are overruled in praxis by informal regimes and their enforcement mechanisms around the economically more viable and ecologically more destructive swamp resource uses carried out in majority by better off population segments.

The analysis of the existing user rights on swamp resources generated a complex pattern of overlapping traditional and new user rights over swamp resources which can be summarised as follows: According to the traditional land rights which continue to assume authority in more remote, rural, less money economy oriented and low density settlements and villages swamps are managed as "common property". The access to the swamp resource uses is determined by clan and lineage membership. User rights are functional, they relate to a certain use and not a specified area. Thus in the same surface several user rights can overlap if the swamp area under consideration is used for hunting, for plant collection too, for fetching clean water, for reed and firewood collection, as seasonal garden plot and for grazing the fallow patch. Thus property rights reside in kinship while user rights are related to different type of uses. In the peri-urban area the traditional land rights have lost authority and individual selling or renting out of land bordering the common swamp to

foreigners has eroded the "common property regime". In the more urban, more market oriented and modern settlements bordering swamps, overuse of swamp resources (e.g. for grazing) and environmental degradation has taken place sporadically.

According to the formal land rights swamps are public land. Between 1975 and today (currently in change with the implementation of the new Land Act 1998) the state had the legal entitlement over all land in Uganda. De facto land use and land markets were governed by ad hoc arrangements between the willing buyer and willing seller, willing tenant and willing patron and controlled informally by custom and local Chiefs and Elders. Within the Municipality the swamps were shared by the different users through individual arrangements which ranged between "first come first served" systems, "sharecropping" and "labour tenancy" systems. The arrangements were determined by the agricultural use of swamps while fishing, hunting and gathering were marginalised. Besides providing resources mainly to the urban poor the urban swamps are also used as waste dumping ground, public toilet and as sewerage treatment plant of factories which release heavy metals and toxic effluents into the swamps.

In view of developing a wetland user regime in Jinja Municipality, which corresponds to the national policy and law related to wetlands, protects sustainable wetland resource use and bans destructive and polluting practices, we learnt from our survey on the prevailing legal regime in the swamps that elements of customary and modern law coexist, while modern law is territorial, customary law is centred on the person (kinship) and on the specific use concerned (Wacker, 1997). While territorial rights allow to exclude and include users, user rights differentiate between modes of resource use. Both elements are important in environmental law: the identification and limitation of entitled users and the differentiation between sustainable and non sustainable modes of resource use. Furthermore, the enforcement of rights and duties are located at horizontal level in the case of customary rules and at hierarchically higher level for conflicts related to formal land rights. For the development of an environmentally sound user regime in the swamps both system of social control have an important value. We thus envisaged to develop a legal regime of the wetlands in Jinja, which includes the acknowledgement and participation of wetland resource users and the Municipal authorities.

Empowerment of Wetland Resource Users

The Jinja Urban Wetland Women's Project (JUWWP)

In the follow up of the 4th UN-World Conference on Women in Beijing 1995, at which Uganda's Vice President had held a splendid key note speech on "Positive action" and a women's group chairlady from Jinja had been invited to participate at the parallel NGO Forum, expectations were high in the town, that women's world might become a better place if women join together and participate in decision making. A local team wrote a proposal to form a "Jinja Urban Wetland Women's Project" and received a donation of 20'000 USD to realise the project. One of the team members, a town planner, later became the women director of the project, the other one,

an experienced women's group leader a vice-leader in the project. After initial preparations among the women, the inaugural meeting of Jinja Urban Women's Wetland Project took place. The project was submitted for acceptance to the local authorities and leaders who were then invited to form an "advisory board" to guide the women's project in carrying out environmentally sound development activities in the swamp and to protect women's interests and commitment in environmental management of this public space. The minutes of the meeting state about the event: "the above mentioned attendees of the meeting decide to create the Jinja Urban Wetland Women project. The aims of this project are:

1) to promote women's groups in generating income and enhance the value from wetland resources
2) to encourage the diversification of wetland resource uses and to define alternatives for disruptive wetland activities
3) to enhance the organisation of wetland resource users in managing in partnership with the town the wetlands sustainably and be involved in the monitoring of the environmental condition of the wetlands. They will be assisted through credits and training.
4) to encourage long-term user rights of women's groups in wetlands to endorse and implement the Ugandan wetland policy".

The aim, structure and activities of the "Jinja Urban Women's Wetland Project" have provided for a twofold participatory process, one among the swamp resource using women interested to form a group to use and manage the swamp in a sustainable way, a second participatory process which included the urban and environmental authorities, other stakeholders in the wetlands and local leaders. The planning process was open to all stakeholders interested in swamp management, environment and women's promotion. After launching the Jinja Urban Women's Wetland Project (JUWWP) its structure includes 500 members, three leadership structure for each urban swamp, one overall leadership and an advisory board with a representative from the town, the Local Agenda 21, research, NEMA and the donor who co-decide together with the women on annual work plans of the project in wetland resource use and management. The JUWWP project proposal includes activities in gardening, gathering (plants, reeds, clay...), fishing , a revolving fund credit system and a training program in environmental awareness, leadership and income generating promotion.

Empowerment through Participatory Planning and Action

The JUWWP aims at setting up long term user rights of women on swamp resources to invest in their maintenance and generate better returns through optimisation of the swamp resources uses and to become partners of government in sustainable wetland management. In a participatory process "Jinja Urban Women's Wetland Project" (JUWWP) has drawn user maps of the three swamps in Jinja by including the members in the drawing process, negotiation and agreeing on a

coherent pattern of swamp resource use and by consulting the researchers and the urban and environmental authorities from the Local Government. The user plan is adopted by the women's group members in consensus consisted in a demarcation of the shoreline swamp as single ecosystem. The swamp user plan included large zones foreseen to remain virgin and to be used for gathering reeds and medicinal plants only as well as for fishing near the open water; this ecological reserve is then surrounded by a "buffer zone" consisting of small scale gardens and some fish ponds for more intensive use and income generating. The plan was accompanied by an action plan made by each of the 25 women's groups which are members of JUWWP in a participatory with project aims, activities, a work plan and a budget for which a credit was withdrawn from the revolving fund of the JUWWP project. For approval the user map and the work plan were submitted to the advisory board and approved on condition of additional approval by the National Environmental Management Authority (NEMA), the Central Government authority on environmental issues.

Having identified in several participatory meetings adequate structures, the members of the "Jinja Urban Wetland Women's Project (JUWWP) started researching and monitoring the wetlands of Jinja: investigating about user rights and about resource values, identifying ways on how to enhance their income and expertise with swamp resources and they replanted tree seedlings from vanished species in the swamp. They collect herbs, manufacture improved crafts after their training, generate income and decide to plant tree in the swamp to improve the environment. In 1998, the regional Lake Victoria Fisheries Organisation (LVFO) organises a fist regional meeting for all NGO's having a stake in Lake Victoria and its shoreline and the JUWWP leader participates in the event, where she is found to be the only women leader and was elected to represent the Ugandan NGO's on the regional NGO-structure set up. During the whole two years 1997 and 1998 JUWWP tried to receive user rights of one swamp by inviting many national and local authorities to view their project, by including NEMA in decision making and monitoring their activities. However, their demands were always turned down. In 1988 JUWWP participated in an international workshop on urban environmental management in Jinja by realising a very successful museum exhibition on the "cultural values of wetlands" in the Town Hall. JUWWP members cooked wetland food, played theatre and a youth group sung. At this occasion, JMC donated a market plot to the women's group on which they build a kiosk to sell their handicrafts. It boosted the group's morale.

With its success in its activities JUWWP experienced a leadership and structure crisis . Leadership of the project was competed, membership criteria contested, two men swamp NGO's formed themselves in the town and claimed rights in the swamps and donor assistance. Some women members drop out of the group and some leaders were criticised for dishonesty which offended them as they invested unpaid time and energy into the group. The demand of JUWWP to receive long term user rights in the swamp in order to manage and monitor the habitat for people's needs in a sustainable way was locally contested: is a women's group exclusive (leaving men out of the leadership and member criteria) or inclusive (as they pretend to manage the swamp for all users (men and women). The crisis provoked a new development step in the women's organisation. JUWWP analyseed the points of leadership critique as participatory evaluation and learned relevant elements in managing common property (e.g. the kiosk).

Did the group objective to get user-rights on swamps for women fail? Two years passed since the JUWWP project started and so far the idea to delegate responsibility and user rights on swamps to a woman's group had not yet materialised. A legal complication existed in trying to identify an appropriate term for a structure which would be inclusive - leaving access to everybody to use swamp resources - and exclusive enough to be entitled to prevent destructive practices and allowing only wetland resources uses which are compatible with environmental law which implies that the uses are limited in their number and intensity or quantity of user rights. Another difficulty with maintaining a structure of rights and duties in swamp resource use resides in the nature of the habitat and the necessity of extensive and collective monitoring efforts, efforts, however, which should bring an adequate reward to be sustained by the actors. This space is used by several hundred different users most of which don't know each other and who have different types of uses which are partly conflicting with each other. How should such a structure be which provides control and generates enough rewards to maintain the control once set up? The main problems of institutions building were the identification of users and definition of membership (member and non member), identification of rights and regulations, generation of economic means to maintain the structure, leadership structure, election, control, rotation etc. and the definitions of rewards and penalties and identification of a line of command to enforce the rules. Once the critical issues of developing an adequate management system could be singled out, a solution could be developed.

Why a new wetlands management law was locally developed in Jinja

Two main reasons led the local pacticipatory process in wetland management to embark into legal drafting:

a) the economic rationality of market forces or free resources exploitation in the wetlands leads to deplete this environment;

b) the environmental law of Uganda demands that wetlands should remain a free access zone for all users but on the same time the law states that the use should be sustainable and thus regulated by accepted user rights among the wetland resource users.

The concretisation of the environmental law at local level implied to develop a "common property resource management system" which allows access rights to all interested users and on the same time provides for adequate rules to protect the resources and to enforce the regulations. In Jinja the by-law was developed out of these two considerations based on a set of research steps and regulatory or legal conclusions.

An evaluation of the actual resource use in the lake shore wetlands revealed that unsustainable wetland resource uses correlate with more income, a finding which implies, that economic forces work towards the destruction of the habitat. A regime allowing a sustainable use and management of the swamp would therefore have to include institutional and legal barriers against free economic effects. After establishment of the group structure and election of leaders and definition of objectives and group rules, the group embarked in a participatory planning process with the main wetland

users and identified different needs and priorities in the swamps. Together with an environmental assessment carried out, the women have drawn user maps of the wetlands depicting zones for the different uses, thus a land use plan. This plan was submitted to the National Environmental Management Authority (NEMA). The local environmental officer could provide a positive EIA result for the traditional activities that women wanted to carry out in the swamps for their project. This positive feed-back allowed the women's group to start investing in more long term oriented activities in the swamps, e.g. by planting valuable traditional tree species, whose materials the women use for making handicraft. However, tenure insecurity and wetlands degradation e.g. from dumping of solid waste etc. continued to disturb them. They lacked the necessary authority to enforce a sustainable use of wetlands despite their own knowledge acquired at seminars and their own commitment to care for the swamp. As the women were stopped by neighbouring men to plant trees, they applied to the Local Government authorities and to research to assist them in getting some form of tenure security on their investments in the swamp.

Drafting a Lake Shoreline Wetland Bye- Law as Participatory Process

A process of draft bye-law formulation thus started with internal consultative meetings among the members of the women's group, an independent investigation in the legal aspects of the prevailing swamp resource uses and an other independent assessment on the relationship between the different prevailing institutional arrangement governing the swamp resource use in Jinja and its economic returns.

The wishes concerning a sustainable swamp regime as expressed by the wetland women's group had thereafter to be "translated" into a language for which an equivalent in law might be found, the proposals were analysed and discussed with lawyers to develop options for a local bye-law providing some "tenure security" for sustainable swamp resource uses and provisions to monitor and enforce sustainable swamp use practices in partnership with the local women's group.

Thereafter an external consultation of the intention to establish a swamp user regime for and with a women's group in Jinja took place. A series of meetings with various segments of civil society and representatives of diverse sector interests took place to discuss the proposed new swamp regime and law. At one of these meetings the will to co-operate with the women's group regime on sustainable swamp management expressed by the parastatal providing water and sanitation services in Jinja town was a major highlight. Belonging to the interest group using the public swamps as sewerage treatment plant and on the same time in its role as "lead agency" of Uganda in charge of monitoring water quality and health aspects of water provision, the willingness expressed by the local director of this parastatal to become a contributing partner to a local swamp regime to maintain the shore line ecosystem of Jinja Municipality was an important result.

It gave rise to a new calculation on the costs and benefits of the women's project: besides generating income by making handicrafts sold at favourable "eco-label" prices to locals and foreigners: Could the service the women's group was providing to everybody, to manage and

monitor the swamps ecosystem not be also a source of income? Could JUWWP become a service provider to the general public? What legal form would be most appropriate to express the rights and duties of the women's group to maintain a sustainable lake shore swamp managing regime in the town?

In a next participatory planning sequence the group worked on setting up an appropriate legal regime which positions the women's group vis-à-vis the resource base of the swamp and other stakeholders in this habitat. This process was accompanied by an evaluation of existing legal provisions related to the urban swamps in Uganda. This participatory planning sequence led to the formulation of a first draft of a "constitution of JUWWP". The sixty page document complied lists of different person centred interests around which rights and duties towards other users of the same resource base were enumerated. The document did not contain the expression of a direct relation of the group towards the environment (the space) but a structure of rights and duties of different actors and stakeholders towards each other. A second participatory map making exercise around the user regime as foreseen by the group in the actual swamp habitat of Jinja allowed in two steps to "translate" the people centred categories into spatial and resource related categories.

Once the critical issues were identified which matter for the wetland resource user to be codified, the actual Bye-Law making process could start. A draft bye-law was written and then debated with the assistance of two lawyers at a public meeting which included representatives from different interest groups in the town.

The minutes of the Bye-Law making workshop of 23.12.1998 allowed to catch the atmosphere in which Jinja Municipal Council encouraged the participants to generate "good laws" as democratic procedure:

"The wetland has to be there for us to be there also; therefore, the wetland belongs to all of us and each is entitled to use it as an individual. If not used wisely, the wetland might perish. This is why we have to organise individuals and put in place rules so that the wetland will be able to serve us for ever and ever. What do these rules have to achieve? They must be able to control activities taking place in the wetland... The council will charge the women's group to look after the wetland just as they look at their children.... According to the 1995 constitution all land belongs to everybody and wetlands are cared for by the government and wetlands within the Municipality belong to the Council. We are again delegating the power to the persons who are always in the wetlands. They are known to be the best custodian to the Council. In this case it is you the women to be the wetland guards. You can harvest from the wetland to improve your wellbeing but not destroy it... It is a requirement for a legal entity not to deal with any on the non-entities. The women's group up to now does not belong to them but with the by-law they can achieve to gain this status, if, however, the bye-law does not conflict with the bigger laws of the country. Once acquired, the Council can deal directly with the women's group. There are good laws and there are bad ones. Bad laws are laws that can not be enforced and don't appreciate the conditions they are supposed to cover, or which are dictatorial laws and primitive to the

members. I would like to end by saying avoid making bad laws, your law is a junior one, make sure yours doesn't conflict with the senior laws. I wish you a good journey as you move from a non-entity to an entity group":

The Bye-Law (see full text in Annex) elaborated by the swamp user women's group and its consultants was discussed at several public meetings. Suggested amendments to the draft bye-law were made by representatives of the civil sector e.g. industry managers, men swamp gardeners etc., by politicians e.g. councillors and by officers in charge of environmental, health. land use, social and gender portofolios within the Local Government Structure. The consultation process ended with a general public meeting, on which the draft bye-laws were approved by the large public before they were handed over to the Local Government for consideration. The draft was introduced by the Assistant Town Clerk to the concerned committees such as the Public Health and Environment Committee and then to the full Council for approval. With some amendments and improvements (see table in the annex) the draft bye laws were approved by the Council under Minute PH 9/99: Draft Bye-Laws. By following the rules as set up in the 1997 Local Government Act, the proposed draft bye law was thus discussed and adopted by the relevant working committees of the issue, amended, published, then presented, debated and finally accepted clause after clause at a full Council meeting. It corresponds to the legal provisions paragraph 43 (Part 3, part 4, part5 and part 6) of the Local Government Act, 1997.

Discussion of Jinja's Bye-law, the Concept of a "Custodianship"

The bye-Law corresponds to the provisions set by the national water, wetland and environmental. Concerning what type and extent of wetland resource use is allowed, the local bye-law repeats the exact wording of the existing national law. New is the provision for a partnership between the local authority and a representative of a local wetland user community. It includes the allocation of user rights - including long-term user rights - under environmental conditionalities. It also includes the provision of authority to a locally appointed collective and rules for endorsement by the existing governmental authorities to allow local community leaders to enforce environmental law and standards among the community. It provides thirdly for a procedure of co-operation between government and local communities. The local bye-law translates the notion of "community participation" into an institutionalised structure of partnership between government and local wetland resource users.

The key concept of the bye-law is the delegation of a Municipal Council functions to an appointed "custodian" who is entitled to generate a fee for his services and is in charge of providing the services by implementing the national environmental law at local level. The concept of "custodianship" avoids to interfere with the land law related to wetlands because if does not intend to change the public property status of this water ecosystem. But the concept of "custodianship" intends to transform a de jure state property and de facto "free-for-all" (res nullius) resource regime into a form of user-right controlled by a identifiable group which is not privately owned nor managed by government but in which an identified community of resource users have rules concerning the inclusion and exclusion of resource users, rules on how the

resource should be used and how the costs and benefits should be shared resulting from it. The thus created community based user regime exists in a hierarchical relationship with the government, who has the duty to protect the community based management system and to assist the custodians with training and technical guidance to use the swamp resources in a sustainable way.

The "custodianship" model set up in Jinja is not a common property regime controlled autonomously by a local community (Bromley 1991, Berkes 1989:10, Gibbs and Bromley 1989:25), as it doesn't change the codified land rights, but it intends to re-develop some common property management qualities including community based decision making and equitable sharing of benefits. As summarised by Bac (1998), much of the literature on commons suggests a "bucket brigade" metaphor to characterise common property regimes. "Given a resource management problem, a group of people will organise themselves and allocate property rights in a way that is similar to the formation of a bucket brigade to put out fire in a rural community. The tragedy of the commons arises only if the link between the management regime and the resource users is destabilised, by a shock, such as technological innovations, governmental intervention or sharp fluctuations in the commercial yield of the resource". This metaphor is useful for the lake shore wetland management system and its fate in Jinja town. While the majority of the lake shore dwellers do use lake ecosystem resources such as reeds and fish from the swamps, etc. the wetland resource use and management is secondary to the main income source of the wetland resource users. Swamps provide a low economic revenues and fluctuating and hardly predictable yield, economic activities are exposed to ecological risks related to sudden rises of the lake level as well as theft risks by wildlife. Among others this is an explanation why private property right systems tend not to develop in swamps. Urban swamps such as the ones in Jinja town are used by a large number of partly anonymous, and fluctuating people having lacking in their majority institutional arrangements among each other which would generate common rules and regulations among the swamp users, a "fire brigade" effect can thus hardly develop. Among the swamp resource users, women are the majority.

In Uganda and Jinja customary law excluded women from having or inheriting land property, but women are responsible to provide food for their families. Within a context of high urban unemployment, many women lack formal sources of revenue as well as access to cultivable land to grow subsistence crops. As illegal encroachers on the wetlands the swamp resource users experience however neighbourhood and a common fate which forms ties of mutual consent. The above described Jinja Urban Wetland Women's Projects promised and set in motion a process of transformation which allowed women swamp users to change their status from an illegal resource user to a women's group member status in a group which has a potential of achieving a legal entitlement to use the swamps and furthermore also the potential to gain prestige (workshop invitations etc.) and access to new resources (income generating activities). The "custodianship" implemented in the Bye-law in Jinja has also the potential to re-establish eventually a "bucket brigade to put out fire in the community" which cares for the sustainable use and maintenance of the lake shore wetland ecosystem.

Conclusion: Implementing Environmental Law through Local Participation

1. Several international convention endorse participation as strategy or means to realise their objectives.

The Rio Declaration in 1992 maintains in principle 22 the right of indigenous people and local communities to participate in environmental decision making and the UNCED "Agenda 21" contains numerous places where public participation is highlighted as prerequisite, approach or instrument to achieve sustainable development and equity among the present and future generations. In International Law some treaties on environmental protection require the introduction of an "open ended" framework legislation and the application of precautionary principles. The implementation of these two instruments depends substantially on the type of political participation existing in the countries.

2. Participation enhances the implementation and legimitacy of law

There are several theories (Kelsen 1992) of law and sociology related to the question whether public participation really is a legitimacy factor in environmental law and governance. For legal positivits legitimacy is not really a concept. They are concerned with the question of legality and take for granted the legitimacy of law and the internal validity in the sense of a norm's compatibility with a superior norm that is in turn compatible with a yet superior norm. The positivists paradigm assumes that law is valid, as is a decision made in accordance with the relevant rules. Participatory elements in decision making processes can however be considered as relevant with the application of a sociological, "external" perspective on law which looks at procedural elements of law. Jürgen Habermas (1996) argues that the claim for validity and legitimacy of legal norms must rest on the participation of citizens in the making as well as the application of these norms. Such participation requires in turn formal as well as informal forums for discourse and communication. To be legitimate, however, the procedure must not only provide for public participation and transparency but must also "regulate (the) bargaining from the standpoint of fairness" so as to give equal opportunity for the parties to influence one another. With the case study in Jinja we have intended to show that a process of local empowerment can complement positively a process of defining adequate local laws.

3. Co-management systems of natural resources require a long term process of partnership building between local communities and government to protect local entitlements, enhance local capacity and maintain enabling partnership structures.

The case study of Jinja town is situated in an enabling political context which allowed a local negotiation and partnership building process between the urban authorities and a group of local women wetland resource users. The interests of the local users coincided well with the recent environmental law reforms carried out by the Ugandan government for the sustainable management of wetlands. A process of local institution building and empowerment preceded the use of a legal reform, the creation of a local by-law by the actors concerned. But it is only the legal consolidation of the once established partnership between different actors which can provide for long term user rights and stable environmental management regimes.

Concerning the recent discussions related to participation in among the parties to the Convention on Biological Diversity (1992) and the Ramsar Convention (1971) the case study of Jinja intends to show that participation is a long term process consisting mainly of partnership building and the institutionalisation of extended roles of decision making by local communities over the use and management of natural resources. The ecosystems of shared inland water provide in Africa since the Neolithic multiple resources for local communities of vital importance to them. Case studies on successful partnerships with local communities in sustainable water ecosystem management at local level could contribute to re-discuss and eventually to extend the notion of participation and the commitment to this human right in the current development of water and environmental law related to inland water ecosytems.

ACKNOWLEDGEMENT

The case study on the development of a local regime for the sustainable use and management of a lake shore ecosystem is a result of a five years research partnership between Jinja Municipality, Uganda, the Jinja Urban Wetland Women's Project, the Fisheries Research Institute in Jinja, Uganda and the University of Zurich, Switzerland in the project "Use and protection of water resources in Lake Victoria through sustainable management of wetland ecotones" . The participatory, bottom up development of a local regime to manage the lake shore ecosystem has been supported, facilitated and encouraged by Jinja Municipal Council and many shoreline resource users involved in the process.

ANNEX: JINJA'S WETLAND RESOURCES BYE-LAW, 1999

Jinja Municipal Council

1. These Bye-Laws may be cited as the Wetland Resources Bye-Laws, 1999
Interpretation
2. In this Bye-Law, unless the context otherwise requires:

"Drainage of wetlands" means removal or exclusion of water from a wetland by pumping, excavation of channels growing within a wetland fast growing trees excessive abstraction of water from a river entering a wetland and drainage use;

"Person" means any natural or legal person;
"Sustainable use of wetlands" means human wetland utilisation which ensures the greatest benefit to present generations while maintaining its potential to meet the needs and aspirations of future generations.

"User-permission" means a license issued by Wetland Custodian which permits sustainable use of the wetlands, the manner of which may by specified by the Wetland Custodian in consultation with the Jinja Municipal Council Environmental Committee.

"Wetland Custodian" means an association of person committed to the realisation of the objectives laid out in Section 3 of this Bye-Law; and who having met the criterion laid out in Section 7, have been appointed as Wetland Custodian under the same section.

"Wetlands" means areas of Jinja Municipal Council permanently or seasonally flooded by water where plants and animals have become adapted.

Objectives

3. The objectives of the Bye-Law are:

(a) to facilitate the sustainable use of wetland resources by and for the benefit of the people and communities using the wetlands of Jinja Municipal Council;
(b) to permit the sustainable use of the natural resources of the wetlands in a manner which is compatible with the continued presence of these wetlands.
c) to end the unsustainable uses of wetlands so that the functions and values derived from the wetlands are maintained for present and future generations.

Sustainable Use Obligations

4. Sustainable use obligations
(a) The following uses of and/or activities in the wetlands are prohibited:
(i) reclaim or drain a wetland;
(ii) erect, construct, place, alter, extend, remove or demolish any structure that is fixed in, on, under or over any wetland;

(iii) disturb any wetland by drilling or tunnelling in a manner that has or is likely to have an adverse effect on a wetland;
(iv) pollute or deposit in, on, under any wetland any substance;
(v) cultivate a wetland or an area within a wetland other than in the manner specified in the applicable environmental law and policy;
(vi) destroy, damage or disturb any wetland in a manner that has or is likely to have an adverse effect on any plant or animal or its habitat;
(vii) remove soil from a wetland for purpose of making bricks;
(viii) introduce or plant any exotic or introduced plant or animal in a wetland.

(b) Any departure from the prohibitions listed in sub sections (a) (i) (viii) of this section shall be subject to:

(i) An Environmental Impact Assessment, if so required by any applicable law of policy, and/or by the Jinja Municipal Council Environment Committee and the Wetland Custodian;
(ii) Express permission of the Jinja Municipal Council and the Wetland Custodian;
(iii) Conditions, if any, contained in the user-permission.

5. Subject to the conditions contained in Section 6 and the provisions of any applicable law and/or policy, the following uses of and/or activities in the wetlands are permitted:

(a) harvesting of papyrus, trees, reeds and medical plants;
(b) cultivation where the cultivated area is 0.25 hectares or less;
(c) fishing using nets, traps, spears, hooks and baskets;
(d) collection of water for domestic use;
(e) grazing of livestock;
(f) hunting,
(g) any other activity which has been expressly permitted and sanctioned by the Wetland Custodian and the Jinja Municipal Council Environment Committee.

6. Any of the activities listed in the Section 5 can only be carried out under the conditions that the user:

(a) obtains a user-permission from the Wetland Custodian in consultation with the Jinja Municipal Council Environment Committee;
(b) follows the guidelines and the instructions on the sustainable use of wetlands as contained in Section 3;
(c) carries out the permitted activity in the manner and within the limits prescribed by the Wetland Custodian and the Jinja Municipal Council Environment Committee.

Custodianship of the Wetlands

7 The Jinja Municipal Council shall appoint a Wetland Custodian from among the existing users of the wetland.

(a) In the appointment of the Wetland Custodian, the Jinja Municipal Council shall take into consideration the following:
  (i) the contribution of the prospective Wetland Custodian to the sustainable use of the wetlands;
  (ii) the ability of the prospective Wetland Custodian to carry out the duties listed in

Section 9 of this Bye-Law.

(b) The custodianship so granted to the Wetland Custodian by the Jinja Municipal Council shall be subject to such reasonable conditions as the Jinja Municipal Council shall deem necessary.

8. The Wetland Custodian shall have the right to use and/or carry out the activities listed in Section 5(a) to (g) of this Bye-Law in consultation with other wetland users, PROVIDE that:

(a) The Wetland Custodian shall not be required to obtain a user permission.
(b) Shall otherwise comply with all the conditions in Section 6 of this Bye-Law.

9. It shall be the duty of the Wetland Custodian to ensure that the objectives contained in Section 3 are realised and/or maintained by:

(a) Planning, monitoring and/or regulating the permitted activities listed in Section 5 in consultation with the other wetland users;
(b) Participating in research, disseminating information and sensitising the public on the sustainable use of the wetlands;
(c) developing and promoting new sustainable uses of the wetlands, such as eco-tourism;
(d) Issuing use-permissions to other wetland users in accordance with the procedure laid down in Section 10 to 13;
(e) Following, applying and implementing any instructions and/or guidelines issued by the Jinja Municipal Council Environment Committee;
(f) Notifying the Environment Office of any violations of this Bye-Law;
(g) Submitting quarterly activity reports to the Jinja Municipal Council Environment Committee, with a copy to the national wetland management lead agency.
(h) The Wetland Custodian shall be entitled to a share of the fees realised by the Jinja Municipal Council through the issuance of user-permissions, so as to enable the Wetland Custodian to carry out and fulfil the duties listed in sub-section (a) (i) to (vii) of this Section.

Miscellaneous

Issuance of User-Permission

10. An application for a user-permission shall be made through the Wetland Custodian to the Jinja Municipal Council and shall be accompanied by a fee to be set by the Jinja Municipal Council.

11 The Wetland Custodian shall have the right to refuse to grant a user-permission, and shall record the reasons for doing so;

12 On refusal by the Wetland Custodian to issue a user-permission, the applicant shall have the right to appeal against such refusal to the Jinja Municipal Council Environment Committee.

13 A user-permission issued under this Bye-Law shall not be lent, transferred, sold or assigned to any other person.

14 Upon issuance, a user-permission shall remain in force for two years.

15 any person who carries out any activity in the wetlands in contravention of this Bye-Law commits an offence and may:

(a) have the user-permission revoked;

(b) be ordered by the Jinja Municipal Council Environment Committee to restore the wetland to its former condition and/or to make good the damage done or compensate the injured party.

Penalties

16 Penalty for breach of this Bye-Law shall be given in accordance with Section 40(7) (b), (d) and (e) of the Local Government Act, 1997.

17 (a) Upon notification by a member of the public, a holder of a use-permission and/or the Wetland Custodian, of a violation of this Bye-Law, the Jinja Municipal Council Environment Committee shall take appropriate action within their powers so to do so within seven days of the notification.

(b) In the event of Jinja Municipal Council Environment Committee failing to take such action as referred to in the sub-section (a) of this section, a member of the public, a holder of a use-permission and/or the Wetland Custodian shall have a right to initiate legal proceedings under this Bye-Law against the offender in his/ her or their name(s).

Regional Human Resource Development in the Fisheries of Lake Victoria (Based on Recent Tanzanian Experience)

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SUMMARY

A six-month period was spent in utilising participatory methods to identify the main constraints to community development within the fisheries sector. These principally fall into the categories of lack of external support by the public sector, and inherent problems within the communities themselves. Of the latter, on which this paper mainly concentrates, 54 individual areas of address were identified. Some of these are of minimal importance, being identified by only a small minority: others are of major importance. Using 30% of respondents identifying a constraint, this 54 was narrowed to 14 key areas. Furthermore, by analysing the base reasons for the existence of these 14 individual areas, a conclusion was reached that a serious commitment to community development, throughout the riparian area, is required. Since Tanzania cannot operate in isolation, it is recommended that the Human Resource Development programme be expanded into Uganda and Kenya.

INTRODUCTION

Lake Victoria displays an impressive array of developmental projects. Virtually all address the issues of biology, ecology, technology and production. Development of the people, both in the public and private sector, has been largely overlooked. Acknowledging this gap, an extensive programme was initiated in 1999 in Tanzania to provide a detailed profile of the key actors, to identify their training needs, and to evaluate the effectiveness of present systems. Based on this information, a five year Human Resource Development programme was designed. Detailed training plans drafted, and priorities established.

With changes in the economic relationship between the three countries, and recognition of the importance of the resource, it rapidly became clear that this programme would (and could) be expanded to encompass the entire system and its people. Within Tanzania it has been recognised that previous investment in facilitating participatory involvement at community level, or identifying the real training needs of professionals, has been minimal. Previous training had always been externally driven, ad hoc, and almost never addressed the real training requirements.

The strategic objective of this HRD programme was to present the assessment of needs, and resultant Training Plans based on the maximum input of participants and key players themselves, whether private or public sector. The outcome therefore would reflect totally how people assessed

their own, and colleagues, or fellow group members, training needs. Additionally it would allow a platform for group identification of problems within any particular system.

The specific objectives were therefore established as:

1. Following a thorough assessment of the training needs of participants, a Dual Focus assessment of each individual's role within the system, and an analysis of probable future directions of the fishery and therefore future needs, to draft a Human Resource Development Programme
2. To design suitable training plans to access the proper training at the proper time over a five-year period.

Such a Programme can be justified since positive outcomes would be:

a) Efficient management and skilled administrative personnel. Those charged with the responsible management of the ecosystem, its production and its sustainable exploitation must be equipped with the best possible tools for the job. These tools are not necessarily what was required 10 or 15 years ago. Frequently staff are required to be multi-skilled and often lack the specifics. These shortfalls must be addressed

b) Community understanding of how best to utilise their resource in the long term. The concept of co-management, whereby functional offloading from government to communities is used to develop a joint management approach, is accepted by all three governments. Clearly, if co-management is to be achieved, a degree of functional offloading from Government to communities, is essential. If however these communities are not sensitised, empowered, educated and trained, the possibility of achieving this degree of participation will remain remote.

c) Support service personnel who can respond to the particular and dynamic needs of these communities. Fisheries cannot exist in a vacuum. The involvement of planners, community development staffs, and co-operative development staff is crucial. Integrated approaches, with public sector constituents fully cognisant of the roles and services of each other, will be necessary.

d) Educational and research Institutions which target the specifics of Lake Victoria. With the dynamics of development clearly visible in the LV system, it will be necessary to equip and support these Institutions allowing them to keep pace with the changes, to respond to specific needs and to prioritise local issues, in participation with the communities.

e) Relationships, linkages and management systems, which are, clear, practical and effective. New initiatives will require new methods of management. These must be carefully planned, roles clarified, authority and responsibility understood. Ever increasingly, senior managers are required to incorporate outside assistance and function in a liaison capacity. These links and collaborative approaches also require new skills.

METHODOLOGY

Within a limited time frame, it was necessary to conduct a bimodal schedule of visiting and gathering information and comments. In short, each office / area / community was visited (as far as was possible) twice, with a six to seven week gap between visits. This allowed a logical development of ideas amongst the fishery participants themselves.

i) An introductory visit, no formal interviews, no need to identify solutions or detail experiences. An explanation of what is trying to be achieved, stressing the importance of the participants initiating the ultimate comments and recommendations, credibility building, answering questions, informally discussing topics of mutual interest. The impressions were then recorded for later use.

ii) A period in which participants could initiate discussion amongst themselves, at a time and setting of their choice. With no checklist of points to cover, since none were issued at the first meeting, people were free to let the flow of their discussions take any direction which they considered appropriate. Sufficient time was available for all members of the "group" to put forward their ideas, and for the group as a whole to prioritise their ideas and formulate comments representative of the entire participatory number.

iii) A second visit in which a more formal approach was adopted. The reason for this structured format is simple. Since the objective was to clearly define zonal needs in addition to individual and specific group needs, a similar format for all similar situations would have to be adopted. Otherwise information could not be compared, and aggregated data impossible to quantitatively identify. Since different approaches were undoubtedly required for different participant groups (viz. District Fisheries Office staff and a Part Time Rural Women's Fish Marketing Group), various tools were used and these are introduced in detail in section 2.4. This visit, using the appropriate tools, built on the original impressions, incorporated the refinements resulting from the intervening period, and focussed attention of the participants on:

- Reasons for problems
- Training and institutional reforms required to overcome problems

The team concur that this is the correct approach, given the constraints, objectives and the fundamental requirement for participation at the earliest possible stage of plan development rather than purely at the implementing stage.

Communication and assessment tools

The most obvious tool to use in any situation is an interview. This however is not as simple as would first appear. It is essential to prepare, and to strike a balance between keeping the interview on line, and not intimidating the interviewee. Interviews in this case were limited to officers in the public sector, or private sector individuals who were not part of a group. Additionally,

non-formal interface is a continuous part of any evaluation, and would come under the umbrella of interview. Apart from quantifying responses to very specific questions, this technique does little to assist in deciding if responses are truthful, biased or representative of the community / group / cadre as a whole.

The structured plural interview leading to group assessment (particularly group self-assessment) was successfully employed as a basis for identifying consensus on problems, solutions and future directions. Two distinct formats were utilised. The first refers to homogenous groups, that is those with a commonality of purpose, aspiration, social profile etc., and who have in some way attempted to mobilise.

The second group oriented semi structured approach is much more relevant to non-homogeneous groups, that is, those who represent a wide spectrum of social / economic profiles, but who display one common denominator linking them as a group (e.g. location or gender). They are generally not as "organised" as the former and have yet to identify the commonality of purpose, which could encourage this. Additionally, this format is used for individuals.

The different approach is justified in the sense that in the first approach attempts to identify the prevailing conditions and subsequent activities leading to success or failure: the second attempts to identify the pressures and responses (successful or not), which would influence a group decision to mobilise.

With both the above sets of groups a third tool was employed to analyse the strengths, weaknesses and development needs (as a functioning group of people) by identifying how they have influenced performance in the past, how they may do so in the future, and the lessons learned. This process is known as Critical Incident Analysis.

It is important to note that the above three approaches, more often than not, stimulated far more questions than they provided answers. This is one of the pitfalls of any type of Participatory Rural Appraisal. However, the information generated was sufficient for our purpose, the information is still available, and will form a basis, a benchmark, for future Fishery Community Mobilisation. Such an integrated approach to community development will be able to refine and focus these findings.

With public sector officers, a completely differing approach was required. Existing in a structured environment, they respond to more formal assessment, and have a well-defined sense of functions and responsibilities…missing at community level. Often therefore with this structured environment simple Task Analyses can be employed to identify weaknesses in performance (requiring training or otherwise). What is missing from this structured environment however, is a defined set of goals, programmes and services, against which to measure performance. Many alternatives exist, but consensus was reached that no one single approach would offer the assessment data or identify weaknesses to a sufficient degree of accuracy to allow justified conclusions to be drawn. Hence a number of tools, as with the private sector, were used and the results compared. These tools are illustrated in Appendix 1.

RESULTS

The results fall into two categories. The first was a fully comprehensive and detailed Training Plan for the public sector. Secondly was the identification, across the entire Tanzanian Lake Victoria fisheries sector, of the constraints to social development amongst fishing communities. A total of 54 problems were identified and to assess which of these 54 were the most important, an arbitrary decision was taken to " *accept a particular problem as being universally important if 30% or more of the respondents indicated it as being so*"

This exercise generated the following 14 key problems, and these are presented in Table 1.

Table 1: Identified constraints to Community Development (where identification number refers to a list of 54 from which actual problems were identified).

Category of Problem	Actual Problem	Identification Number
Group development	Lack of group mobilisation / empowerment	20
	Lack of working capital / credit due to status	12
	Lack of inward investment due to status	01
Gender recognition	Lack of gender awareness	15
	Lack of gender education	02
Technical processing and handling	Lack of fish handling skills	09
	Lack of processing equipment	14
Marketing	Lack of business / entrepreneur skills	07
	Lack of marketing skills	03
	Lack of consistent markets	16
	Lack of transport to district markets	30
Education	Lack of environmental education	04
Legal protection	Lack of knowledge of fishery regulations	29
	Theft	10

A closer examination of these defined categories shows a degree of overlap indicating that not only is "Group Development" a category in its own right, but is also the common denominator at the root of all other problems. This is illustrated below, in Fig. 1.

DISCUSSION

Utilising various approaches, each geared to a specific target group, facilitated the identification of problems facing that group. The negative side, of course, is that it makes it very difficult to compare between the differing groups. The overall objective however, was to identify the key problem areas facing the fishing community as a whole based on aggregated data which allowed the best perception of the entirety without necessarily being specific to any one group.

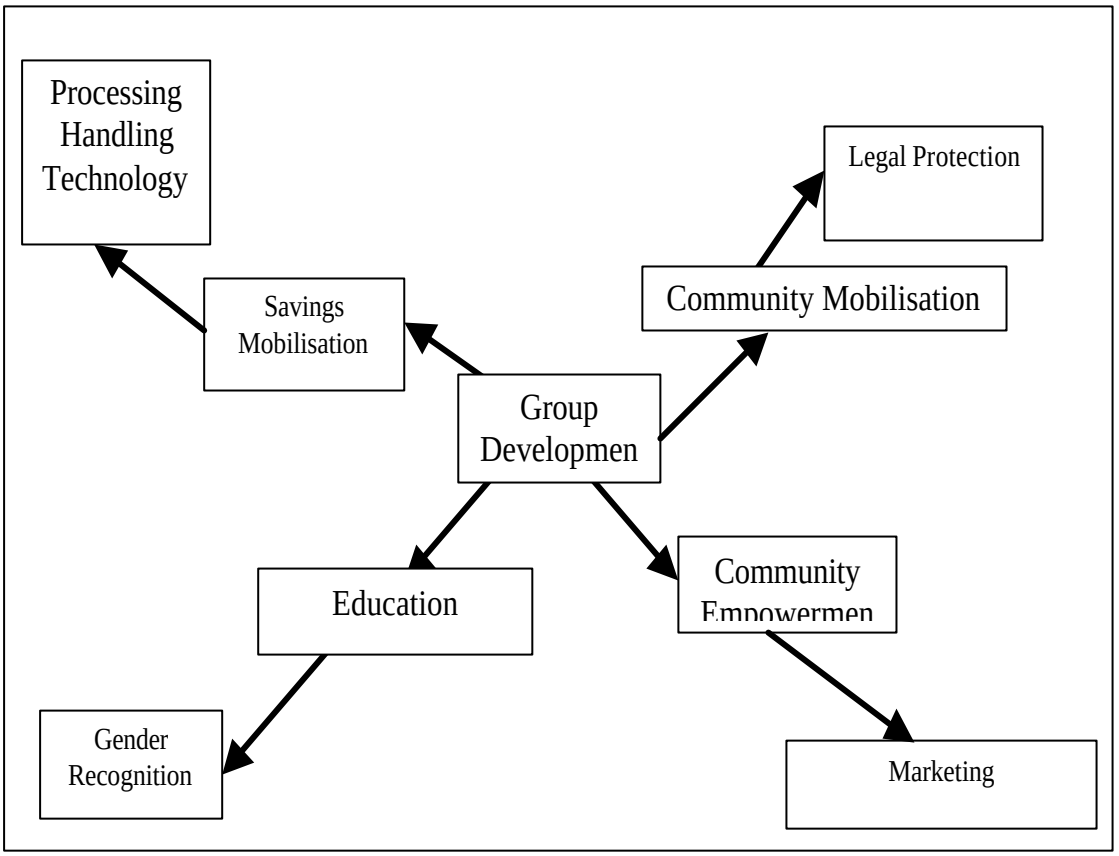

Fig. 1. Problems relating to each other

In summary therefore, the approach of statistically examining the overall situation, generated very strong evidence that most of the problems faced within the private sector Fishing Communities could be addressed through Community / Group Development. This finding justified the inclusion of Planning Officers, Community Development Officers and Co-operative Officers into the HRD programme. To facilitate this Group development, and to co-ordinate the inputs of planners, fisheries staff, community developers and co-operatives developers, it is clear that a change of procedure and approach is required.

The resulting structure would facilitate functional offloading reducing the strain on District Council resources, and community participation in

a) Policing as a surveillance strategy. Only by achieving the collective confidence and commonality of purpose will these communities be able to defend their own resource.

b) Statistics collection.

c) Two-way extension methodologies. Again collective confidence and accurate representation of the extension needs of the community as a whole will be achieved by developing community identity.

d) Revenue collection.

Tanzania however cannot operate or implement such a programme in isolation and expect success. The resources of the Lake are communally owned and must be communally managed if sustainability is to be achieved. Responsibilities must be communally shared, and there is no doubt that this realisation is now being translated into specific regional initiatives. With Lake Victoria Fisheries Organization (LVFO) as the regional institution coordinating fisheries activities on Lake Victoria, the opportunity to implement HRD within the three riparian states and to harmonise planning, training and management, is clearly identifiable. Coordination, management, evaluation and monitoring of the national implementation within the three Contracting Parties should lie with LVFO, and indeed, they themselves should be incorporated into the HRD process. However the need to establish individual national coordination units cannot be overlooked.

In conclusion, the need for expanding the Tanzanian initiative is there. Expansion of the HRD programme to include Kenya, Uganda and LVFO Secretariat itself can be justified on various levels.

a) The recent Commonwealth Heads of Government Meeting in South Africa endorsed the concept of more "people oriented development".

b) Investment in people reduces the need to invest in technological innovations, since the capacity of people to develop their own responses is enhanced

c) Regionalisation will result in savings through economies of scale and having a centralised coordinating authority.

d) The sustainability of the resource will ultimately depend on tri - state cooperation. Parity in capacity to function effectively in all three is a cornerstone of this philosophy.

e) Communities in Kenya and Uganda also demonstrate a need to develop the confidence and abilities to manage their own futures

f) Management of the resource will depend entirely upon the skills and abilities of individual managers, and the effectiveness of management systems in all three countries.

g) Open discussions with the LVFO Secretariat clearly demonstrate that the current capacity to implement and manage such regionalisation is insufficient, and that the ultimate efficacy of an enhanced, expanded programme will only be assured if the needs of the LVFO Secretariat are simultaneously addressed.

h) There is little doubt that accessing international assistance to implement an HRD programme would be eased by presenting a regional consensus on the need, and displaying regional cooperation on initiatives and management.

i) The expansion of HRD processes into a Regional initiative is clearly in line with the agreed philosophy of the East African Community (EAC), the Contracting Partners and the LVFO Secretariat.

RECOMMENDATIONS

The principle of regionalising the programme has been proposed and plans are now developed to implement similar HRD Needs Assessments and draft Training Plans in Kenya and Uganda. It is also observed that the LVFO Secretariat will take up the responsibility for management and implementation of the actual programme(s). It is imperative therefore that the identified needs of the Secretariat, especially in the initial phases, be addressed.

The recommendations for individual HRD are clear and unequivocal. In order to ensure that development of the fishery as a whole, and specifically to facilitate the inclusion of participants [other than fisheries] in a collaborative and integrated approach, the following are strongly recommended

Formation of:

a) A community nominated "Beach Facilitator", at every beach.

b) A District Fisheries Mobilisation Team [comprising the District Fisheries Officer and the above mentioned District staff] in each District.

c) A DFMT co-ordinator within each District Council.

Additionally;

a) The Tanzanian initiative should be expanded and repeated in the Republic of Uganda and the Republic of Kenya. The approaches which have proved effective should be adopted to ensure harmony in implementation of the proposed Regional HRD Programme

b) The present capacity of the LVFO Secretariat to co-ordinate, implement, manage, monitor and evaluate the benefits of the programme should be addressed by assessing present internal needs and addressing any deficiencies.

Appendix 1: Formal Technical Needs Assessment tools

The main tools utilised in Technical Needs Assessment in the public sector were:

a) Self and Peer Analysis (or Assessment to some authors) is an approach to improving performance through individuals assessing their own strengths and weaknesses with the help of colleagues doing the same work and reaching a consensus on remedial actions. It is a process, which can provide a structure for identifying key performance areas (within any job) and receiving feedback from peers on actual performance. This involved inviting, in both group and individual sessions, staff to firstly identify the functions of their jobs (including potential future functions). With a simplified criteria of performance being Strong / Weak (time frames allowed no more detailed analysis), illuminating and parallel perceptions were generally resulting. This is no surprise when one examines the number of years these officers have shared a work environment. The outcome is a very well accepted image of an individuals strengths and weaknesses. One spin off advantage of this result is that, contrary to expectations perhaps; a sense of team spirit is engendered.

b) Upward Appraisal was not always possible to conduct, mainly due to its potential to create conflict amongst working groups who already have an unstable relationship. Being assessed by peers and subordinates can be a daunting process. It is also remarkably accurate. Within this exercise, staff are invited, confidentially to assess their senior's performance, in terms of professional strengths and weaknesses. When aggregated, these comments will give a strong indication of where address is required.

c) Function Analysis and (to a much lesser extent) Task Analysis were employed to identify crucial steps in a given responsibility. Obviously, when a particular function is not being fulfilled, this adversely affects the overall performance of the individual, self-esteem, confidence and morale. Often it is not purely an individual's capacity to perform, but also the conditions in which that performance is expected. This type of "bottleneck" identification allows serious weak links in any particular chain to come to light and be addressed. The negative side of this type of analysis is that it can be subjective. To overcome this it was necessary to have the views of numerous people, with differing perspectives, to reach consensus on the real need rather than the perceived need of any one commentator

d) Performance Deficiency analysis allows the comparison between what skills are required to do a particular job, and what are available to do the job. Again objectivity is crucial, and is ensured only through a team approach. Similar to a functional analysis, it is more applicable to professional levels of staff who have multi-functions within their remit. Whereas functional analysis examines the requirements to fulfil a designated function, performance deficiency examines the skills and knowledge required to operate as a post holder with many assigned functions.

e) Given that the strategy of this programme is to maximise efficiency without requiring large staff recruitment levels (since these are extremely unlikely to be accepted), it is necessary to carry out a Performance Budgeting exercise. This, by examining who, and what are required, and for how long, to complete a particular aspect of a job satisfactorily, generates a budget of requirements which cannot be undercut, if objectives are to be met. By comparing this bare minimum to what is available, the required personnel in terms of numbers, skills, and time allocations can be uncovered. The really useful part of this technique is that it allows a framework around which calculations can be made to re-allocate staff, maximising efficiency. Different models can be drafted until the best compromise between efficiency outputs, and the inputs of training and re-allocation of duties, is identified.

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