Lake Victoria Environmental Management Program (LVEMP)

# Regional Synthesis Report on Fisheries Research and Management

States, trends and processes

By:

**Jeppe Kolding, Paul van Zwieten, Julius Manyala, John Okedi, Yunus D. Mgaya, Faustino Orach-Meza**

Final Report, Maun, Wageningen, Dar Es Salaam. December 2005

Cover pictures:
Trawler catch of *Lates niloticus* in Nyanza Gulf (Winam Gulf) near Kisumu in experimental trawl with 5mm codend mesh. Photo: Frans Witte.
Algal bloom in Winam Gulf near Kisumu. Photo: Paul van Zwieten

## Table of contents

# Acronyms

| | |
|---|---|
| B | Biomass |
| BMU | Beach Management Units |
| C | Catch or yield from the fishery (usually by year) |
| CAS | Catch Assessment Surveys |
| CEDRS | Catch and Effort Data Recording System |
| CPUE | Catch Per Unit of Effort |
| DoF | Department of Fisheries |
| DWD | Directorate of Water Development (in Uganda) |
| E | Exploitation rate (= F/Z or Y/P) |
| EAF | Ecosystem Approach to Fisheries management |
| EAFFRO | East African Freshwater Fisheries Research Organisation |
| F | Fishing mortality (usually annual instantaneous rate) |
| f | Fishing effort, the nominal fishing intensity |
| FAO | United nations Food and Agricultural Organization |
| FIRRI | Fisheries Resources Research Institute (at Jinja) |
| HEST | Haplochromis Ecological Survey Team |
| K | Curvature parameter, parameter of the von Bertananffy growth equation |
| KMFRI | Kenya Marine Fisheries Research Institute (at Kisumu) |
| $L_\infty$ | Length infinity, parameter of the von Bertananffy growth equation |
| LVEMP | Lake Victoria Environmental Management project |
| LVFO | Lake Victoria Fisheries Organization |
| M | Natural mortality (annual instantaneous rate) |
| MCS | Monitoring, Control and Surveillance |
| MSY | Maximum Sustainable Yield |
| P | Total gross production |
| q | Catchability coefficient |
| TAFIRI | Tanzania Fisheries Research Institute (at Mwanza) |
| TF | Total phosphorous |
| TL | Total length |
| TN | Total nitrogen |
| Z | Total mortality (annual instantaneous rate) |

## Acknowledgement

This report has been a stepwise exercise from the national levels to the regional level. We greatly acknowledge the various contributions in the national reports and during the workshops from all participants from TAFIRI, KMFRI and FIRRI as well as from the Departments of Fisheries from Kenya, Tanzania and Uganda.

It has been a major work to reformat and reconstruct the trawl data series of Tanzania and Uganda back in time and we are grateful for the help and assistance from Bwathondi, Kees Goudsward, John Okaronon and Oliva Mkumbo. Not least our gratitude goes to Jean Collins at FAO for going through the archives in a failed search for the earliest FAO data.

We appreciate and acknowledge the various useful comments and assistance from the LVFRP team: Ian Cowx, Denis Tweddle and Martin van der Knaap.

Lastly we would like to express our sincere gratitude to Robert Hecky, Greg Silsbe, Stephanie Guildford and Rose Mugidde for kindly sharing their recent work on the primary productivity in Lake Victoria. It gave us so much great inspiration - and was a crucial link to understand (we hope) the fish and fishery processes.

The views presented in this report are those of the Consultants and these do not necessarily correspond to the views of LVEMP or the riparian Governments of Lake Victoria.

## Executive summary

During the past eight years of the LVEMP project (Phase I) the various components have been able to collect considerable amounts of data and information. The outputs, however, in the form of the analyses, results, reports and papers, are to a large extent isolated to just cover the activity of the individual component, and much of the findings are of a descriptive nature (e.g. LVEMP 2005). Results therefore become fragmented and analytical output is rarely integrated across disciplinary boundaries. Lack of prioritisation in research has lead to a large output of activities and papers that in some cases duplicates already known work. The research activities have not as yet lead to strategic conclusions on the future focus of research, monitoring, investments and preventive measures, nor has it been translated into a holistic understanding of the ongoing processes or integrated management actions.

This report is a first attempt to systematically compile and consolidate available data - over as long a time frame as possible - into 56 selected indicators. The indicators cover the physical environment, the primary and secondary biological levels, the fish faunal composition, life-histories and abundance, the fishery in terms of yields, effort and catch rates, economics, management. Aquaculture and Database indicators are included as well. Together they represent and illustrate the most comprehensive picture of the present status and the past trends and changes of the Lake Victoria ecosystem and fisheries based on the best available data. Not all indicators are complete, and it is hoped that gaps and missing information can be added in the future. Some indicators are covering the history of the lake over the past 4 decades, while others are based on relatively new research work and only show the latest development. **Only when viewed in combination has it been possible to derive an evidence based understanding of the processes that drive the Lake Victoria ecosystem.**

The most important trends are:

- Lake Victoria is undergoing accelerating eutrophication. The nutrient inputs have doubled, algal biomass has increased 6-8 times, which lead to an increased deterioration of the water quality and an increase in anoxic areas.
- Overall water level has been decreasing since 1961 and average rainfall has decreased since 1978.
- A sudden and abrupt change in fish community structure occurred 25-30 years after the introduction of Nile perch. This complete change in ecosystem structure is such that the pre and post Nile perch boom represent two "different lakes". The sudden community changes occurred simultaneously with a period of decreased wind speeds and lowered temperatures creating longer than usual stratifications.
- In the past decade there has been no change in the Nile perch abundance, while an increase in Haplochromines, Nile tilapia, Dagaa and other species is observed.
- There are no changes in any of the important life history indicators (mean size, max size, growth etc.) of nile perch since 1984.
- There are no significant changes in the experimental trawl catch rates of Nile perch over the past decade, while overall catch rates in the fishery decreased from 7 kg/fisher to 3 kg/fisher since 1990 and are now back to the average catch rate of any African freshwater fishery.
- Effort in terms of numbers of fishermen has increased from 35000 to 165000 since 1970 and boats have increased from 9000 to 52000 since 1970, while total catch has remained stable between 400 000 and 500 000 ton over the past decade.
- The value, export and contribution of the fishery to the GDP have increased, while the contribution of the catches to food supply has declined from 80% to 20% since 1980.

- There are increased investments in the fishery as indicated by the relative increase in number of boats (from 4 fishermen/boat – to 3 fishermen/boat), and the number of processing plants.
- The number of researchers and research activities has increased, but the storage of data and historic information at all levels (from individual researcher to LVFO) is in a complete mess, and very few data are in an easily accessible format.

The overall conclusion is that Lake Victoria is undergoing rapid and profound changes in nearly all important indicators from both bottom-up and top-down processes. It will be a major challenge not only to continue the monitoring of these changes, but far more so in trying to manage them. So far most of the various activities in terms of research and management on the lake have operated in disciplinary isolation, and many researchers work only regarding their 'own' speciality. Fisheries management for example seems to have been based purely on fisheries indicators (with effort as the main driver), while little or no attention has been paid to the implications from the parallel work of the limnologists and ecologists on the lake.

While the general consensus seems to be that the lake is overexploited and needs fisheries management, this synthesis shows that the present status of the exploited stocks in Lake Victoria is that they are in good health with no signs of overfishing. Furthermore the dynamics of these stocks appear to be almost exclusively bottom up driven in which case the present fisheries management concentrated on limiting fishery activities could have little or no effect.

The overall fishery production is simplified and is limited to a few major species since the abrupt change in the early 1980s. In addition the fish production has increased in line with the increase in nutrients and primary productivity, which explains why the fishery has been able to absorb the increased effort. There are, however, emerging signs that this growth in biological production has now reached a limit, and that further eutrophication will bring a decline. Limnologists have concluded that the ideal nutrient concentrations of the lake have been exceeded, and the flattening trajectories for the production estimates for Nile perch appear to support this conclusion. **Further nutrient enrichment will most likely seriously affect the Nile perch fishery** and the fish biodiversity, while other, hardier species, like Nile tilapia, Dagaa, Clarias, and Protepterus are likely to continue to grow. Under increased eutrophication, both the economic backbone (the Nile perch) and the ecological and aesthetical value of Lake Victoria will suffer, exemplified by the 'pea soup' environment in the closed bays and gulfs as a result of algal blooms.

So far the dynamics of the fish production in Lake Victoria appears to be entirely environmentally driven, as there are few or no signs of fishing impact on the observed changes. However, if catch rates and particularly production estimates in the future will begin to fall, while effort continues to grow, it will be a big open question whether the decrease is due to environmental degradation or due to overfishing or both. Unfortunately such a debate will only exacerbate the already ongoing controversies on the status of the Lake Victoria fisheries. It is high time that the environmental and fisheries research and management activities are integrated, and that a holistic ecosystem approach to fisheries (EAF) management is adopted. The present disciplinary segregation and approach, as well as continued implementation of traditional single species management regulations, albeit disguised as co-management, will not solve the present fisheries related problems in Lake Victoria.

Management needs to reset its priorities. As eutrophication appears to be the single most important driver of the productivity, environmental as well as fisheries management priorities should focus on this issue. With the at present limited influence of the fishery activities on the stocks, the present fisheries biological management emphasis on size and effort regulations can be questioned, though an evidence/data based precautionary approach based may be taken. Continued, systematic and mandated monitoring of catch and fishing effort and through fishery independent surveys based on regionally agreed on protocols should therefore get the highest priority. Meanwhile as eutrophication is also the most important threat to the ecosystem, the fishery could intensify and diversify to lower trophic levels with a higher productivity in order to remove as much organic matter as possible.

# 1. Introduction

The Fisheries Research and Fisheries Management components of the Lake Victoria Environmental Management Project (LVEMP phase 1) in the three collaborating East African countries Kenya, Tanzania and Uganda have over the past eight years made substantial progress towards gaining information to understand the Lake Victoria ecosystem and fisheries to assist the decision making process in the resource use management of the lake. However, whilst the components have been able to collect considerable amounts of data and information during the LVEMP and from other sources, analyses are often isolated and simple, the data are difficult to access and therefore cannot be used to their full potential. Results from different components are seldom integrated and analytical output is also rarely translated into proposed management actions. Lack of prioritisation in research has lead to a large output of activities and papers that in some cases duplicates already known work. However, it has not as yet pointed to overall strategic conclusions about where the focus should be in the future with regard to research, monitoring, investments and preventive measures. What seems lacking was a clearly identified output of a state of the lake baseline (Regional Stocktaking Report, July 2003). To address this concern, it was decided to consolidate, analyse and synthesize the data and knowledge generated over time, not only by the LVEMP but also from other sources in order to get a complete overview of past trends and the current status of the fisheries and biodiversity of Lake Victoria.

To achieve the LVEMP phase 1 and the Fisheries Research and Management objectives, a well-coordinated analysis, synthesis and interpretation of all relevant available data, information and knowledge is required. This combined report will document changes in Biodiversity, Fisheries, Industry and Management that have taken place over the recent decades. It will provide an overview of the present knowledge and status of the fish and fisheries of the lake as well as identify past changes and continuing trends that may require closer monitoring or remedial action. The report will provide as detailed information and spatial resolution as possible at the regional scale to support fisheries decision making on Lake Victoria's fisheries resources.

To achieve the desired synthesis, an international consultant, Dr Jeppe Kolding of the University of Bergen, Norway in co-operation with Paul van Zwieten of Wageningen University, the Netherlands, was requested to guide and assist the process of preparation of individual National Reports as well as integration of these national reports and other studies into a Regional Synthesis report on the Fisheries and Management of Lake Victoria. With the signing of the consultancy contract in Entebbe on 23 May 2005 the consultants proceeded to guide a series of working sessions with researchers and managers from the Fisheries Research and Fisheries Management components of the three countries as called for in the consultancy contract. This final report gives the results of the working sessions, a summarised account of the National Synthesis reports, and an analysis of the current state, trends and processes.

### *Objectives of LVEMP*

It was expected that the outcomes of the LVEMP activities would "be species distribution and habitat maps, information on the genetic make-up and diversity of different populations, understanding of the causes of decline of fish species, understanding of the impact of environmental changes on the biology, behaviour and survival of declining species, guidelines for species conservation and restoration, an updated bibliography of Lake Victoria and its fisheries. Substantial progress on data acquisition has since been made through LVEMP and from other sources but there is need to:

a) Analyze them, in a quantitative manner using appropriate methods

b) Summarize the information gained and place it in the context of information existing before the LVEMP and also the information that may have been generated by other entities.
c) Consolidate, analyze and synthesize the data and knowledge generated by the LVEMP and from other sources in order to get a complete picture of past trends and the current status of the fisheries and biodiversity of Lake Victoria and its catchments in line with the expectation of the LVEMP.
d) Use the available data, information and knowledge to arrive at the expected outcomes of the Fisheries Research and Management Components of the LVEMP.

*Scope of this report*

The compilation of this report involves the consolidation, analysis, synthesis and the development of trends; the interpretation of data, spatial and temporal variability, inter-species relationships, behaviour of species as well as impact of environmental changes on biodiversity and the causes of species decline. The main activities undertaken to compile the report included:

- Data consolidation and formatting;
- Sourcing of relevant data from other sources are used where relevant to amplify or validate LVEMP generated data (e.g. base maps and related information)
- Data analysis which meets the requirements of the LVEMP while adhering to international standards of scientific data analysis and interpretation.
- Techniques for the harmonization of outputs.
- Write-up and techniques to refine the understanding of bio-energetic relationships between different components of the food web that often raises concerns about modifying any element of the food web, e.g. algal productivity, the trophic interactions of even the major fish species and the efficiency of trophic transfers that are still poorly known as a basis for discussing the potential for recovery of many of the threatened species.
- Write-up for additional studies on the genetic diversity and population structure of most organisms in the lake basin.
- Dependence of the currently acceptable contaminant levels for pesticides and mercury on food web structure, system productivity and environmental conditions.

The report writing process involved access and use of the data produced through the activities of the Fisheries Research and Management Components of the LVEMP which includes:

- All fisheries frame survey data;
- Laboratory analyses;
- Fisheries research and management databases;
- Socio-economic information and database;
- Relevant databases from other Components of the LVEMP;
- Literature sources from libraries;
- Reports from the Secretariats of the LVEMP;
- Data and information from other entities operating on Lake Victoria.

The report is written in a manner and format that helps to address specific concerns under the various sub topics within the Fisheries Research and Fisheries Management Components of the LVEMP. In addition, the synthesis reporting process and activities helps to:

- Identify data gaps and make recommendations on additional equipment where necessary to be used for sampling after the harmonization of the use.
- Provides a report that can be used in the development of the regionally integrated study plan for phase two and

- Identify new techniques for handling, processing and analyzing specific datasets (Terms of Reference, see Appendix 1).

**Note**

At the time of writing of this report the National Reports of Tanzania and Uganda and the draft National Report of Kenya were available. However, only a limited number of data sets as presented in these national reports. Therefore the synthesis report has in many instances more the character of an exploration of available information, as it was presented to the International Consultants in the National Reports, than a full analysis of trends aggregated over the whole lake based on which the type of conclusions can be made that were required from the ToR.

## 2. Approach

### *The process to reach a regional synthesis*

#### Goals of the regional synthesis

The intended end result of the national reports and the regional synthesis is to be viewed as the start of an **atlas of time-series and spatio-temporal patterns of well-referenced indicators** to guide the management of Lake Victoria fisheries resources. The short-term goal is to describe the present status of the Lake Victoria ecosystem to provide information for the process of formulating the LVEMP2 objectives. The medium-term goal of such an 'indicators atlas' is to aid in:

1. the set up of a series of necessary and consistent monitoring activities,
2. the contextualisation of specific research,
3. the consolidation of the knowledge base for future research and management.

The long-term goal is to give a comprehensive ecological basis for a multidisciplinary effort in defining ecosystem based management. It was envisaged during the planning of the consultation that, if the current process of synthesizing information is successful, Lake Victoria could be a leading example in the development of an information system that would aid an ecosystem based approach to management in a tropical freshwater fisheries context.

#### Structure of the process: indicator selection

The international consultants have guided the Fisheries Research and Management components of the LVEMP in the consolidation, analysis, synthesis and the development of **trends**, based on available data taking into account **spatial and temporal variability**, inter-species **relationships** and behaviour of species. This resulted in national syntheses reports from the three countries. During the inception workshops in each of the three countries Uganda, Kenya and Tanzania a long list of potential indicators to describe the states was proposed. As far as possible these indicators were to be constructed as time series in order to produce trends showing spatial and temporal variability. During the regional workshop this list was consolidated into a smaller list that formed the basis of the regional synthesis.

The basic layout for all the indicators proposed is in the form of timelines (graphs, tables) as well as series of maps showing spatial changes over time (see next section). It was agreed during the three inception workshops in Uganda, Kenya and Tanzania to extend the timelines as far back as possible, to enable the establishment of long term trends, in order to distinguish between natural variations and short and long term trends, and to assess the state of Lake Victoria in 2005 in a historical context. This required that the collection and reporting of data in temporal and spatial dimensions extends to long before the period of the LVEMP horizon of data and information collection.

Assessing the **impact of environmental changes** on biodiversity and the **causes of species decline** required information from the Water Quality components. Dr. Hecky, the international consultant leading the Water Quality report agreed on the need for this cross-linkage of the research results of the different components, and has provided the consultants with the necessary information. The intention for the regional synthesis was to establish relations between the fisheries, biodiversity and environmental indicators using correlative and multiple regression analyses and other relevant statistical methods. This was of course subject to the availability, accessibility and quality of the data sets. Unfortunately the time series of data provided to the international consultants in formats that could be used for such an in depth analysis were very limited and therefore precluded a statistical correlative approach. The synthesis therefore is written in a more exploratory fashion.

As the report is a synthesis, the various methods of data collection used will not be described unless in exceptional cases where special clarifications are needed to understand the time series or spatial patterns presented. To enable tracing of the data and information used, all data points in the time series were to be extensively referenced.

(see Appendix 2 for detailed description of the process)

### Formats for presentation of (semi-) quantitative and qualitative indicators

Time series and spatial distributions were to be quantified as much as possible with an indication of the variation around mean values in order to establish the significance of trends. While reporting on variation around the mean, or sometimes even the mean itself, is not always possible, both because of lost data or because not all indicators lend themselves to quantification, it is still necessary to report on known and reported changes. There are different ways of doing this. In Appendix 3, we give some suggestions. In principle all time series and temporal changes in spatial patterns will be reported on an annual basis, unless seasonality is an important element of explaining variation, in which case the reporting will be on a monthly basis. Spatial patterns including depth distributions of species are to be presented in 10m intervals.

### Limitations of the synthesis report

With the exception of most of the available trawl data from Uganda and Tanzania, no raw data related to the selected indicators for the regional synthesis report were received by the international consultants. The National Consultant indicated that the international consultants should use the data as presented in word processed format. Wherever no data are available in a format that could aid in aggregation and statistical analysis on a regional level time series are presented as they appear in the national reports. Also the statistical trend analysis of the indicators will be limited to where data were available to the consultancy. In all other cases an interpretation of the reporting in the national reports will be made and checked against available literature.

### Data base management

During the course of the consultancy it appeared that the items in the ToR related to:
(1) data consolidation and formatting;
(2) sourcing of relevant data from other sources that are used (...) (e.g. base maps and related information)
(3) data analysis which meets the requirements of the LVEMP while adhering to international standards of scientific data analysis and interpretation and
(4) techniques for the harmonization of outputs"
were in fact more important than the initial emphasis on describing and analysing states and trends suggested. The required in depth analysis of states and trends was greatly hampered by the limited availability of long term datasets. It was realized that how data are presently collected, handled and stored – both recently collected data as well as historical data – greatly impedes the possibility of establishing historic time series and statistically reliable

trends. Consequently the foundation for an evidence based evaluation of ecosystem based fisheries management objectives and measures will be greatly impeded. This is a matter of great concern! Therefore a separate section is devoted on the database issues arising based on our experiences with the data presented to us.

### *Analysis and synthesis*

#### Steps taken in the synthesizing process

The steps taken in the preparation of the regional synthesis reports were:

- During the inception workshops in the three countries Uganda, Kenya and Tanzania, the chapters of the National Reports were devised and a list of indicators to be reported on was established. The procedures were described in an Inception Report distributed in June 2005. National synthesis reports were expected to be organised in such a way that they could be used as detailed reference works – as compendia of trends. It was also envisaged that they could be used for the beginning of producing (bi)-annual national reports on the state of Lake Victoria.
- A regional workshop held in September 2005 in Kisumu focussed on reaching consensus on the indicator list and the status and trends of these indicators. The regional synthesis report will be organised around the indicators selected. The results will be linked with the water quality synthesis report.
- If possible the regional synthesis will explore and interpret trends as multiple regressions and/or hypothesis formulations on possible relationships and processes. A discussion on Consequences of the analysis of the information and knowledge presented for fisheries management will be discussed.
- No stock-assessment or food-web modelling has been carried out. Modelling exercises were limited – given data availability - to statistical regressions and correlations of time-trends.

### *Methods of analysis and synthesis: states, trends and processes*

#### Background of the 'indicator' approach

Indicators are understood as "pieces of evidence or clues, that tell us something about the condition of something of interest" (Bertram and Stadler Salt, 2000) or more formally: "parameters that describes (quantitatively) a current condition in relation to predetermined reference or sets of references that, when observed over time, demonstrate trends; that usually has a significance extending beyond the measurement or value itself; and that provide the means to assess progress towards an objective" (NRC, 2000). Another definition is given by Garcia & Staples (2000) "An indicator is a variable whose fluctuations reveal the variations in *key attributes* of sustainability in the ecosystem, the fishery resource or the social well-being. The position and trend of the indicator in relation to *reference points* indicate the present state and dynamics of he system". According to these authors the purpose of indicators is "... to provide a *simple tool* for any interested party or stakeholder to be able to *track progress* toward achieving sustainable development within a sector or across sectors[1]". Predetermined reference points are then to be defined in relation to management objectives.

From these definitions it is clear that management objectives are the primary consideration for the choice of (sets) of indicators. Indicators relate to objectives by providing information on the present state in relation to the objective, and, over time, the direction of change. This

[1] In the present case two important links across sectors are immediately evident: Caridina and Rastrineobola used as fishmeal for livestock feed production; the link between the impacts of eutrophication of the Lake Victoria on its stocks and the causes of eutrophication (sewage and city planning, agriculture, forestry)

means that the choice of indicators is dependent on the management objectives. A recent FAO Technical Guideline for Responsible fisheries on the ecosystem approach to management (FAO, 2003) stresses this point: broad **policy goals** are to be translated into **issues**, at levels that management can address, based on which **operational objectives** can be defined. These are related to measures and are to be monitored, reviewed and evaluated through **indicators** and **performance measures**. In a list of examples of indicators (in the appendix in the FAO Technical Guideline) an objective is first stated, then follows an example indicator and the data requirements for that specific indicator.

As the choice of indicators is intimately related to issues or concerns, while specific ecosystems are as diverse in their behaviour as the people that are using them, no global set of indicators can be devised that are useful for all practical management situations. The technical options for indicators are almost limitless. Many ecosystem properties are of interest and what the "key attributes" are will depend to a large extent to the use of its resources. A high diversity of uses and interests – within fisheries and outside – are to be assessed and this diversity of uses means that a large variety of decisions require dependable information that is relatively easily understood and accepted as relevant by decision makers, whoever they may be. Conversely, many indicators will be irrelevant for the specific management situation. Management objectives, acceptance of information, and cost of information will determine what set of indicators will be most relevant for any particular situation, next to biological, technical (sampling, eliciting information) and statistical considerations. ***Indicators are meant to improve communication on complex issues between stakeholders in management.*** This means that an approach to the choice of sets of indicators should be directed at devising a useful toolkit to achieve this.

The first consideration on the choice of indicators is the objectives of management. Indicators relate to concerns about the various aspects of the use as well as the present or resulting state of a resource that will be expressed or interpreted differently by fishermen, authorities, researchers and other interest groups. Whether the indicators can work to establish consensus on what the state of a resource actually is, and sometimes the possible causes of that state, strongly depends on whether consensus exists on the management objectives that are to be evaluated. But it also depends on how management is perceived to be done by the different groups of people. As an example: categorical detailed information used to evaluate **state changes** is of particular importance in the multi-species fisheries of Lake Victoria.

In the biological and fisheries literature on Lake Victoria much concern is expressed on the impact of fishing and eutrophication on the remains of the endemic biodiversity of haplochromine species. Any management objective dealing with biodiversity concerns has to address the issue of categorical detail of information[2]. However, objectives of fisheries management in Lake Victoria that would include biodiversity concerns expressed at a species level, are presently difficult to address, given the current incomplete and scattered fisheries research and information system of Lake Victoria. At the same time, no clear consensus in the research community exists on what constitutes the functional integrity of an ecosystem and hence the categorical level at which biodiversity should be maintained: species, communities, trophic guilds etc. More generalised approaches, without categorical detail on a species by species basis, therefore could be interesting to address biodiversity concerns. Our current understanding of the energy flows and genetic flows in fish communities, leads to proposals of indicators of ecosystem functioning that largely discard the taxonomic categorisations on which fisheries assessments are now done: trophic-levels and other categorisations based on general life-history parameters (e.g. reproductive strategies, resilience to fishing, size) are considered better descriptors of ecosystem state than categorisations based on taxonomic species.

---

[2] In particular when expressed in terms of the resource base for the fisheries - on a species-by-species or on a species-community level -, but also when expressed on the basis of protecting the resource system itself e.g. through an area approach (closed areas, MPA's).

However, this immediately raises issues about the communicability of such indicators and the relation to stakeholder concerns. Trophic level- and life-history indicators are far removed from the social and economic significance that species (categories) have – except maybe for size indicators. At present it is difficult to see how this information, which is not regarded as a prime concern in the daily livelihoods of fishermen nor of the thriving industries based on Nile perch, could be linked to the concerns of the users. Species diversity is, for fishermen, seen at most as an asset in as far as it increases the potential for diversifying the utilisation of the productivity of the lake with its different environments, but not as an end in itself. In fact a strong utilitarian attitude towards nature conservation is the norm for most stakeholders in the riparian countries around Lake Victoria. Livelihood needs are too pressing to warrant an investment in conservation for purely moral, ethical or aesthetic reasons. This attitude strongly determines the feasibility of implementing nature conservation goals. Nature conservation with the only purpose to maintain biodiversity may have limited appeal to the societies around Lake Victoria. In stead, nature conservation measures that also provide social and economic benefits, may receive stronger support. Nevertheless, a pure focus on the benefits only, may not be sufficient to trigger the support of local communities who have to undergo.the consequences of the implemented measures. A more strategic approach is to also assess what costs are involved to maintain or preserve the benefits provided by nature. Devising indicators that show the costs and benefits of maintenance of biodiversity is then more appropriate.

A second set of considerations deals with how decisions on resource utilisation are made or should be:

1. Who participates in the decision making process, and what roles are assigned to the different partners;

2. How are objectives formulated, what indicators are considered to be valid measures to evaluate objectives, and what are acceptable levels of resource utilisation (reference points);

3. How is the effectiveness of resource protective measures evaluated and what role does biological information plays in the decision making process?

These considerations deal with the quality of the management process, in which the transparency of decision making and the information on which decisions are based is paramount. Positions in the decision making process in the triangle of fishers, authorities and researcher are derived from each of their activities. To put it simple: a fisherman fishes, the authorities manage and the biologist produces facts about impacts on states of nature. The biologist role is to provide information on the pressures on and state of a resource that can be understood and is accepted as valid by all participating in the management process. Too often the biologist has taken up the role of defining objectives of management based on the results of analysis of biological and fisheries information collected. In our view, the biologist's role in management is to have a more impartial role. In short his role is to:

- Generate information on the environment, <u>fishery and the stocks</u>
- Prepare the <u>evaluation procedure</u>
- Be aware of <u>information needs</u> of all stakeholders in management
- Relate <u>information to experiences</u> of fishermen
- Assist in collective <u>sense-making</u> of disparate data and information
- Facilitate <u>learning</u>

Devising communicative indicators are an important and useful step in fulfilling this role.

Next, financial considerations are important. The potential to observe states, changes of states and trends over time in a resource, and with that the choice of indicators, is related to the costs of observation. Resources to obtain fisheries information are not unlimited. The costs of obtaining the data needed are high, given the state and priorities of the economies of the riparian countries of Lake Victoria. However, the fish export industry is now contributing extensively and visibly to the three economies. At the same time much of the contribution to the economy of the fisheries in terms of food supply and supply to other industries (livestock and aquaculture) remains hidden. Indicators can be an extremely useful tool to bring out this importance. The request to produce more precise assessments in a multi-species and ecosystem context - also expressed at various stages during the course of the synthesizing exercise - has lead to the recognition that there are limits to the management relevant information that can be produced; both in relation to what can be known and predicted as well as to the value of the fishing industry. In a developing-country context both limits are reached much faster. The complicated multi-species multi-gear fisheries, the diversity in ecosystems, relative paucity of knowledge on the functioning of these ecosystems, and the limited financial resources all require approaches to maximize utilization of available information in a fishery, including those of the resource users. Devising monitoring programs, deriving indicators from these, and establishing a mandated evaluation procedure are then important approaches.

Lastly, integrated assessment of ecosystems is a great challenge and the development of an ecosystem based management of a huge system like Lake Victoria requires a basic comprehension of the main processes taking place in the Lake and its catchments area. Description of states and processes alone is not sufficient to allow comprehension, but will rather lead to "information overload" barring the emergence of meaningful insights and strategies for management. Comprehension may be attained through reductionistic[3] analyses of key processes and feedbacks mechanisms of an ecosystem, but in fact this approach has lead to the information overload currently experienced by stakeholders in any assessment of ecosystems around the world. Instead of leading to a pragmatic basic understanding of ecosystems these approaches have lead to an ever increasing need for more data and detailed research into processes in an endless cycle of historical "just-so" stories (Peters 1991). Lake Victoria appears to be no exception to this rule, as the account of the LVEMP synthesis will show. The problem is that knowledge about variations in (isolated) processes cannot give directives on whether systems states are "good" or "bad": the reductionistic perspective does not give directionality in time and therefore bars value assessments (Steele 1998). A holistic approach (see footnote 4: addressing the "why" questions) that combines an analysis of key processes operational in Lake Victoria, with methods where directionality in time is made explicit, will aid in real comprehension of the system. An assessment along these lines will give guidance to the choice of a comprehensive set of indicators and the development of monitoring systems that will aid in ecosystem based management (Choi et al. 2005).

### Indicator frameworks and selection of candidate indicators

Gathering and use of data and information is one of the activities within an organisational setting that determines in part the accountability of its decisions. Indicators, as a tool to summarise data in order to monitor states, communicate information, support management and/or evaluate management action, are to be chosen to increase the accountability of the decision making process within the organisational setting. To arrive at a robust framework of

[3] The reductionistic approach entails splitting processes up into smaller and smaller entities. Reductionism is defined as an attempt to seek explanation by invoking smaller scales and holism as the resort to larger scales, than those at which the observations were made (Wiegert 1988). The table shows the relationship between the spatial-temporal scale of observation (e.g. cell, organ, individual, population, community or landscape), the type of questions that can be posed, and the conceptual model of 'understanding' or seeking explanations for the observations. From Kolding (1994).

| Scale | Question | Explanation |
|---|---|---|
| Large | Why? | Holistic |
| Observation | What? | (none) |
| Smaller | How? | Reductionistic |

information transfer, considerations such as timelines of information, responsiveness to action and handling of uncertainty are important criteria for the choice of particular indicators, but other criteria may be important as well (see Appendix 4). In the course of the LVEMP synthesizing effort we have not gone through a complete process of indicator selection in which all stakeholders were involved. Nevertheless, the presentation of the information in time trends based on what fisheries researchers and managers perceive as workable is an important first step to arrive at a comprehensive set of indicators that can be used for management decisions.

### States, pressures and processes

Our presentation of the indicators selected is based on established known or – preferably, proved links between the states and the pressures or drivers of the states. The basic assumption in fisheries theory is that catch (C) and stock abundance, or standing biomass (B) are related by

$$C = F \times B = f \times q \times B \qquad (1)$$

where $F$ is the fishing mortality defined as $f \cdot q$, and $f$ is a measurement of the nominal fishing effort or intensity, and $q$ is the so-called catchability coefficient. Standing biomass, or stock abundance is a state expressed for instance as the average amount of fish (tonnes) in Lake Victoria in a given year. The stock abundance is related to biological production, which is a rate expressed for instance as the amount of fish produced per year (tonnes/year). More precisely biological production ($P$) is the total amount of tissue generated in a population (or community) in a particular space during a given period of time, regardless of its fate. It is of central interest in the exploitation of renewable resources, since the yield (Catch) is a fraction $F$ (Fishing mortality) of the mean biomass, and is a fraction ($x$) of biological production $P$.

$$P = Z \times B \rightarrow C = F \times B = x \times P \qquad (2)$$

Where Z is the total mortality (= fishing mortality + natural mortality).

What is not well expressed in these formulas is the increasing recognition that the level of biomass and the amount of biological production are always and often pre-dominantly driven by the environment. Hence,

$$C = F \times B(E) = f \times q \times B(E) \qquad (3)$$

Biomass is here shown as a function of the environment (E). This equation can be rewritten as:

$$C/f = q \times B(E) \qquad (4)$$

Where C/f is the catch rate or catch per unit effort (CpUE). Catchability (q) is defined as the relationship between the catch rate (CpUE) and the true population size (B). So the unit of catchability is *fish caught per fish available per effort unit and per time unit*. For scientific research surveys, or experimental fishing, effort is standardised and fishing gears kept constant in order to keep a simple (constant) relationship between catch rates and population abundance (B), i.e. to minimise the inherent measurement errors and/or variations in f and q. Another main – often the only - supply of information on fishing effort, catch and catch rate is through monitoring of fisheries input (fishing effort) and output (catch), i.e. through fishery-dependent monitoring. Long-term monitoring of fish stocks is almost by necessity dependent on information obtained through the fisheries exploiting them as experimental research surveys are often expensive and cannot be maintained. With that long-term monitoring, and subsequent trends, is highly dependent on the official fisheries statistical system in use. Fishery-dependent monitoring entails at least the collection of two essential parameters in fisheries statistics: catch (C) and fishing effort (f) and from these the derivation of catch-rate (C/f) (FAO, 1999). Catch and Effort Data Collection (or Recording) Systems (CEDRS) maintained to address information needs for fishery management vary in their degree of administrative and statistical sophistication, but all share the collection and maintenance of these basic parameters.

Equations (3 and 4) express that changes in biomass in the above equations reflects both the changes in fishing mortality (F=C/B=q·f) and changes in the standing stock through environmental factors (E). The relative contribution of environment and fishing is extremely important for relevant management activities, and can be estimated if long-time series of catch, effort and environmental indicators are present. In many smaller lakes that are highly influenced by allochthonous inputs (river discharge, rainfall, run-off from land), lake water levels appears to be a highly useful indicator for the environmental impact on stocks (see Jul-Larsen et al. 2003b and 2003a for a general account). In Lake Victoria water level may be an important indicator for annual recruitment success as well, in particular for more riparian stocks, or stocks that depend on shallow areas in the lake as spawning or nursery areas. Over the longer term an important environmental driver will be the reported eutrophication of the lake (Hecky, 1993; Mugidde, 1993; Silsbe et al. 2005). Indicators for eutrophication could be various, and will have to be assessed in particular on their ease of obtaining long-term data through continuous monitoring (see also the Water Quality synthesis). This synthesis is intended to give some propositions to that effect.

In traditional fishery stock assessment the environment is normally not included as a driver of the system. The methods used are all so called steady state models, where the only driver is the fishing mortality (F=q·f). If, however, the ambient environment is not in a steady state, then these methods will fail and produce false results (see e.g. Jul-Larsen et al. 2003a for the results and value of classical stock-assessments in African lakes). In many tropical fresh waters, the observed changes in productivity of fish resources may be largely due to environmentally driven processes, in particular where large changes of nutrient input occur (Kolding and van Zwieten 2005). Given the known environmental changes in Lake Victoria, it is therefore extremely important to establish the relative importance of the environmental drivers vs. the traditional effort drivers.

**Hierarchy in presentation of indicators (reflecting processes)**

Based on this analytical framework a hierarchy of indicator sets can be derived, that distinguishes between causes of states and states themselves. I.e. ecosystem drivers – water levels, wind stress related to up-welling (Lake Tanganyika, Lake Malawi!) and eutrophication - are state indicators on the ecosystem level but have a large impact on productivity of stocks and on fishing pressure, and can therefore be considered drivers in this context. To make such a hierarchy implies some causal relation that may or may not be known to exist for the particular system for which the indicators are devised. If more drivers have an impact on the chosen indicator, then the effects on the indicator should be partitioned by choosing more indicators. An example can immediately be derived from the above equations: the combined effect of effort and ecosystem drivers (environment) on the catch rates of a stock. These scale problems should be addressed when devising a toolkit of indicators. A hierarchical set of indicators where fishing is contextualized by species life-histories and system variability is a grouping of information along three main axes (Jul-Larsen et al. 2003):

- System variability: indicators on ecosystem drivers and habitats – indicators of ecosystem **drivers**
- Species: state indicators based on generalized life-history patterns of fish species and communities; biomass indicators (e.g. catch-rates) – indicators of ecosystem **states**

- Fishing effort: selectivity and scale of operations of fishing patterns expressed in indicators on fishing effort, investment in the fishery and spatial allocation of effort; export indicators and catch indicators can be included in this set; as well as monitoring control and surveillance indicators and other social and management indicators – indicators of **pressures** through human activities in ecosystems.

**Other indicators**

The LVEMP included work on aquaculture and the development of database management systems. These areas will be assessed based on indicators as well. The purpose of these indicators is to aid in an assessment of the achievements and eliciting the problems in these areas. Lastly quite some work has gone into biodiversity and other assessments of the small waterbodies (satellite lakes) in the Lake Victoria basin. At the current limited time frame of the research done in these lakes, no trends can be derived from this work that warrants an inclusion in the overall synthesis of the state of Lake Victoria, given the time limitations of the synthesizing process. We refer to the national syntheses reports for and assessment of the achievements of the research work done.

**Indicators selected during the regional workshop in September 2005 (Kisumu)**

| Level | Type of indicators | Indicator |
|---|---|---|
| **Fishery indicators** | | |
| System | Productivity | 1. Lake depth |
| | | 2. Windstress |
| | | 3. Rainfall |
| | | 4. Water level/water balance |
| | | 5. Secchi depth |
| | | 6. Temperature |
| | | 7. Nutrients |
| | | 8 Oxygen |
| | | 9 Primary production (Chl-a) |
| | | 10 Species composition of micro algae |
| | | 11 Water hyacinth |
| | Secondary productivity | 12 Lake flies (abundance) |
| | | 13 Caridina (abundance) |
| | | 14 Zooplankton (abundance) |
| Species | Biodiversity, community, foodweb | 15 Species composition (experimental trawls) |
| | | 16. Feeding habits of main commercial species |
| | | 17 Mean size, maximum size, length frequency |
| | Life history | 18 Slope of the biomass size spectrum |
| | | 19 Growth parameter estimates |
| | | 20Length at 50% maturity |
| | Stock | 21 Experimental catch rates (trawls, gillnets) by species |
| | | 22 Fishery catch rates (by species) |
| Effort scale of operation, selectivity and drivers. | Catch and effort | 23 Catch |
| | | 24 Effort (nr. fishermen, boats, types of gear) |
| | | 25 Spatial distribution of fishermen |
| | | 26 MSY estimates |
| | Social and economic | 27 Contribution of the fisheries to GDP |
| | | 28 Contribution Nile perch to domestic food supply |
| | | 29 Boat owners, crew |
| | | 30.Export volumes and values |
| | | 31. % level of education by age group |
| | | 32. Total earnings in the fishery |
| | | 33. Fish prices |
| | | 34. Per capita fish consumption |
| | | 35. Landing sites and factories |
| | | 36. Feed production (fishmeal reduction of Rastrineobola and Caridina) |
| | | 37. Number of processing plants |
| | Control and surveillance, co- management, fish quality assurance | 38. Nr. BMU's |
| | | 39. Enforcement statistics |
| | | 40. # Inspectors at landing sites |
| | | 41. Number of certified landing beaches |
| **Other indicators** | | |
| | Aquaculture | 42. # technologies generated (feeding regimes, pond siting, cultures developed, cultured species) |
| | | 43. # small water bodies stocked |
| | | 44. # farmers adopting generated technologies |
| | | 45. # fish species added to domesticated species |
| | | 46. # fry produced and distributed per annum |
| | | 47. Fish yield per unit area and per annum |
| | | 48. Total number/area of ponds |
| | Database | 49 Publications (books, papers etc.) |
| | | 50. # scientific journals subscribed to |
| | | 51. # number and type of software for data analysis |
| | | 52. # digitized old and new literature data sets |
| | | 53. # visitors visiting the institutes |
| | | 54. #number scientists with basic scientific database knowledge |
| | | 55. # datasets available in digital by type and category |
| | | 56. # of databases available |

To the indicators selected at the Kisumu workshop were added the indicators 1. Lake Depth; 2. Windstress and 16: Feeding habits of main commercial species

The indicators selected will be reported on as follows:

1. Time series as much as possible in graphical form. Sometimes the time series are presented in a table.
2. A short description of the indicator
3. If the time series allows a trend analysis will be done. This can only be done if the original data were available to the (inter)national consultants allowing a regression analysis and an analysis of the variability around the trend to assess its direction and significance. If no such data are present only developments in mean values can be shown, without further assessment of the significance of these developments.
4. If no aggregations can be made over the three countries, the development in time series for the three countries will be shown. No further trend analysis will be made and no comments on the significance of the developments will be given. Also if data have been received only in graphical form from the national reports, only the graphs from the national report will be shown with no additional analysis to what already was made in these reports.
5. The word "trend" will be used wherever an actual statistical analysis has been carried out that enable an assessment of the confidence limits around the means or the regression. In all other cases the "development" will be used.

Overall conclusions on the indicator will be limited to the series where actual trend analysis has been done.

***Organization of the report***

The remainder of the report is divided into two sections. The first section reports the "states and trends" of the indicators chosen. This section can be viewed as a first attempt at an **atlas of time-series and spatio-temporal patterns of well-referenced indicators** to guide the management of Lake Victoria fisheries resources. If carried out in a more comprehensive manner in a second stage of the LVEMP, such an atlas may lead to a true aid in management. The second part of this chapter is devoted to an outline of the main processes taking place in the lake based on the analytical framework outlined earlier. These two sections can in a later stage iteratively lead to a more comprehensive set of key indicators. Both sections are needed to aid in a better comprehension of the states and processes of the Lake Victoria ecosystem.

The next chapter will be devoted to the current state of the availability, accessibility and quality of the data that are needed to assess states and trends according to the approach taken in this synthesis. Conclusions are given both on the current assessment of the processes and states based on the information available, on the necessity to arrive at a better monitoring systems and the need for better scientific co-operation and exchange of data, information and knowledge. Lake Victoria will then be a leading example in the development of an ecosystem based approach to management in a tropical fisheries context if this can be achieved.

# 3. ANALYSIS AND SYNTHESIS SELECTED INDICATORS

## *STATES AND TRENDS*

### Primary productivity indicators

1) Depth profiles of Lake Victoria

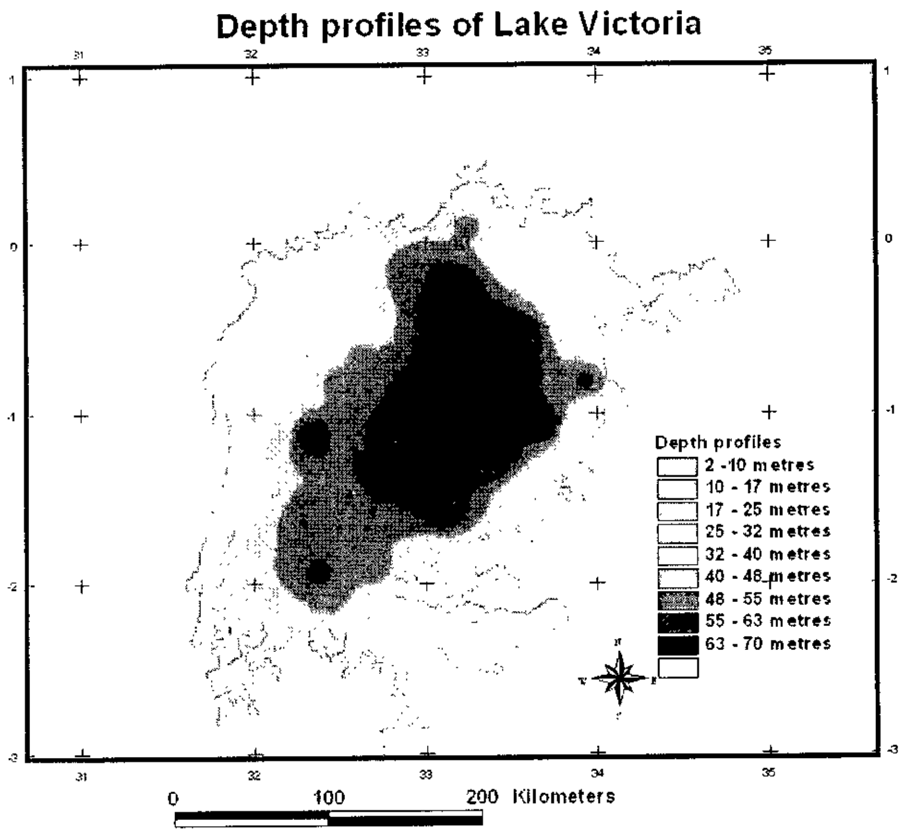



Figure 1: Depth profile of Lake Victoria (Source: Hecky et.al.?)

The western part of Lake Victoria is shallower than the eastern part and much influenced by the wind forces (Indicator 2: windstress). Consequently, it experiences more mixing and cooling patterns. The deeper eastern part of the Lake is much more influenced by thermal stratification patterns and therefore mixing is mainly by density currents dependent on seasonal temperature changes in surface water. Hence the south-eastern part is more productive due to upwelling conditions (while downwelling = less productivity) occurs in the north-eastern part. Furthermore, nutrients from River Kagera and the western shores can be well mixed into the upper mixed layer of the lake rather than being transferred directly into the deeper hypolimnion.

2) Wind stress

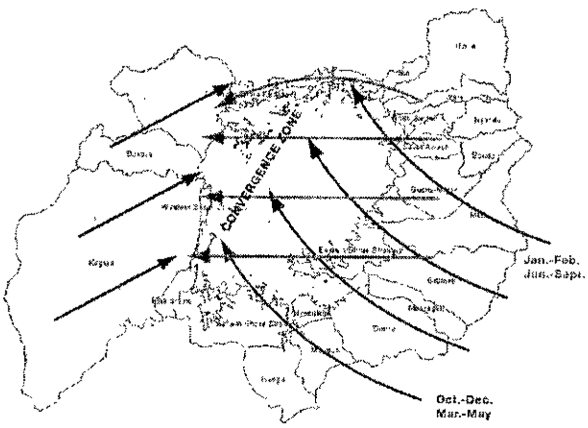



Figure 2: Global wind patterns over Lake Victoria (Source: taken from presentation at the Arusha stakeholder workshop November 2005 by Ssebuggwawo V, Kitamirike J. M, Khisa P, Njuguna H, Myanza O, Hecky R & Mwanuzi F.)

Meteorology is dominated by ITCZ –two dry and two wet seasons accompanied by wind shifts that affect the lake. During wet season there is a convergence of two humid air masses over the western part of the lake. Waves and turbulence are always higher on the western side of the lake because of the dominance easterly winds and long fetch across the lake.

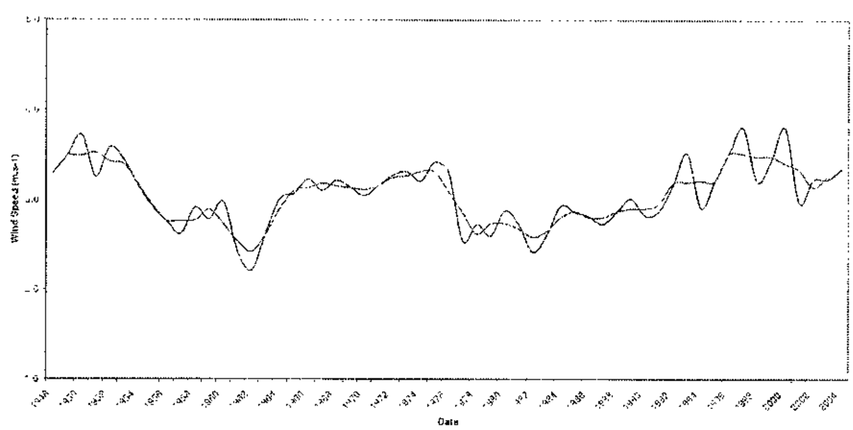



Figure 3: Time series in wind stress over Lake Victoria based on a NOAA NCEP reanalysis of data that use regional meteorological models to generate weather records based on nearest available weather stations. The purple line is a three year running average also plotted. Though these are virtual – i.e. modeled - data, they are based on real weather data for the region (courtesy: Silsbe, 2005).

**Indicator use**: Lake stratification is influenced both by wind speed and temperature

**Data availability:** the data presented in figure 3 are modelled data. As they were not part of the list of indicators prepared in Kisumu no data were presented. We refer to the Water Quality Synthesis report for basic data and further analysis.

3) Rainfall

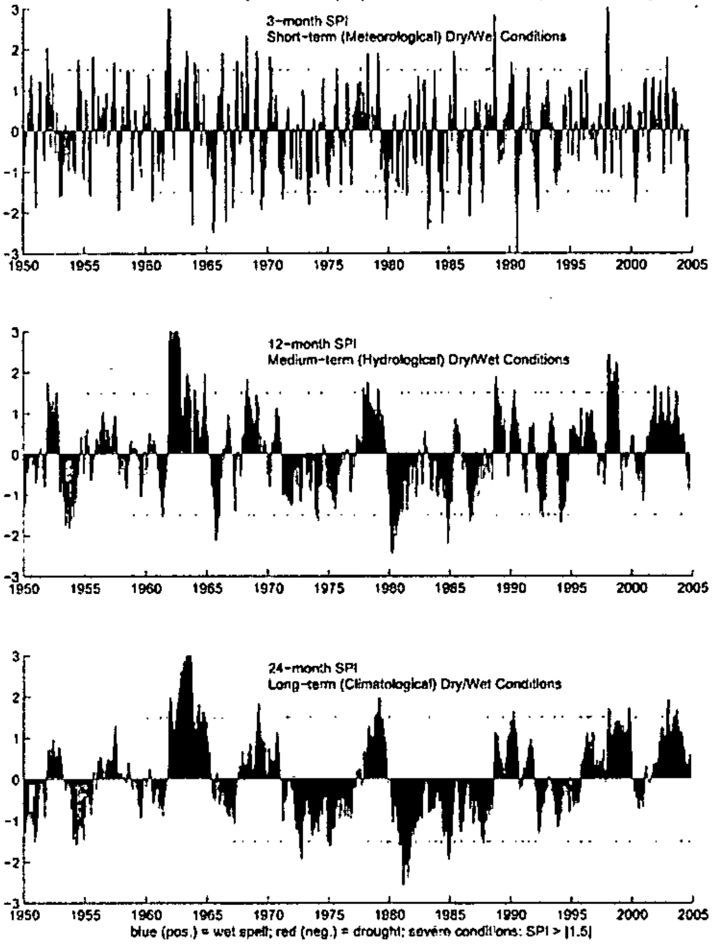



Figure 4. Standardized Precipitation Index (SPI) – Lake Victoria Watershed 28E-36E/2N4S. (Source: Analysis by A. Lotsch – alotsch@worldbank.org).

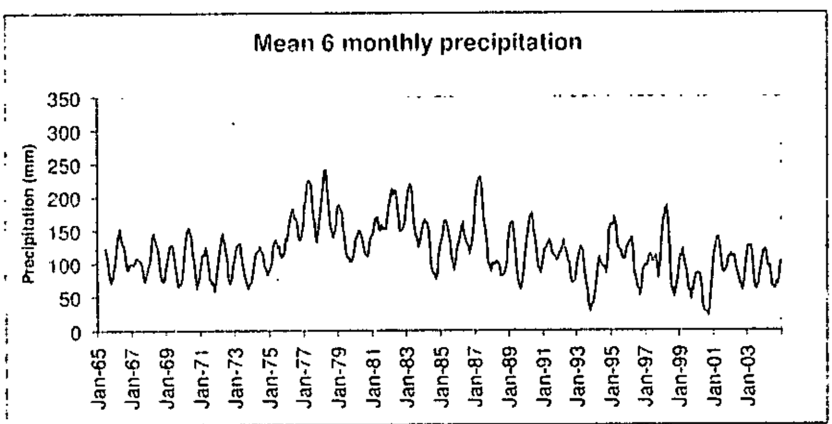



Figure 5 Time series of 6 monthly running average of rainfall over Lake Victoria based on a NOAA NCEP reanalysis (see Fig 3)

**Indicator use**: Monthly rainfall patterns could be a very useful indicator to predict local recruitment success and annual catches.

**Data availability:** the data presented in figure 5 were not available for further analysis. The time series presented in the National Reports were not useable for further analysis.

4) Waterlevel/waterbalance

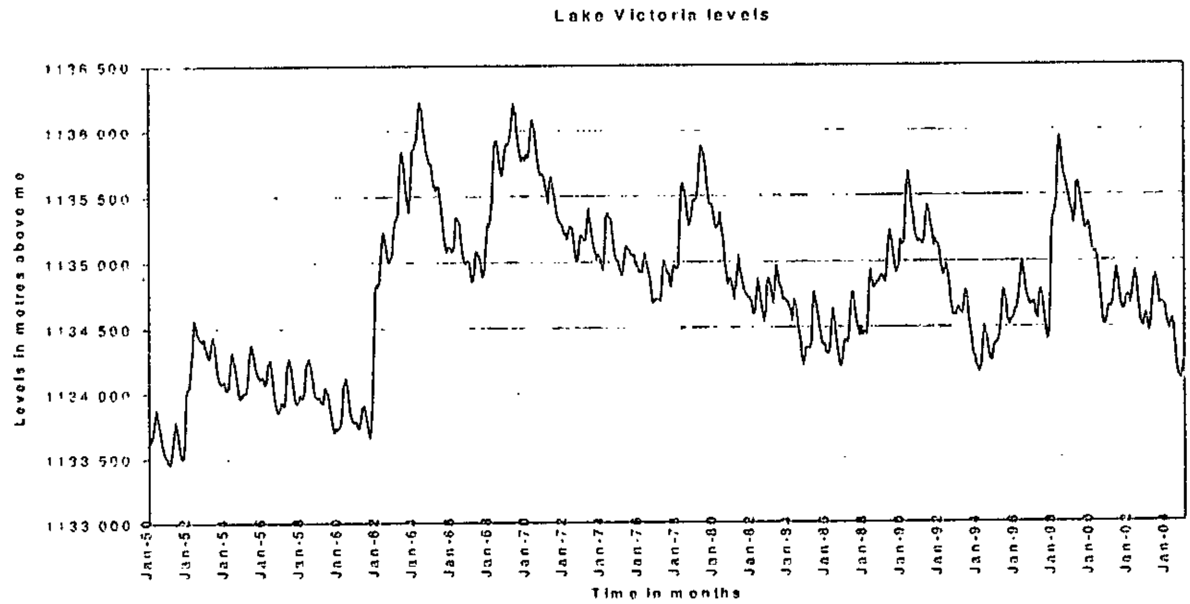



Figure 6 Monthly average water levels measured (daily) at Jinja Pier. DWD Entebbe. Data provided by R. Hecky. Should be updated and extended (Joel Okanga, Water Synthesis Report, 2005)

Since 1963 there is a general decreasing trend in water levels, with occasional peaks.

**Indicator use:** Monthly average water levels are potentially a good indicator for recruitment success of in particular Tilapiines species that depend on shallow areas as nursery areas; potentially it could be useful as an indicator of recruitment success for other species as well, including Nile perch. The expectation is that after a peak in water level catch rates will increase between 2-4 years later when the species enters into the fishery. Welcomme (1970; pers. com.) for instance reported a boom in fish production after the sudden increase in water levels in the early 1960s. Fluctuations in Nile perch stocks in terms of Catch Per Unit Effort (CPUE) indicator could be related to peaks in water levels. As the Jinja pier series is a point observation this indicator is perhaps only useful for the northern part of the lake. A better indicator may be total water balance of Lake Victoria.

**Data availability:** the data presented in figure 5 were not available in a format that allowed further analysis.

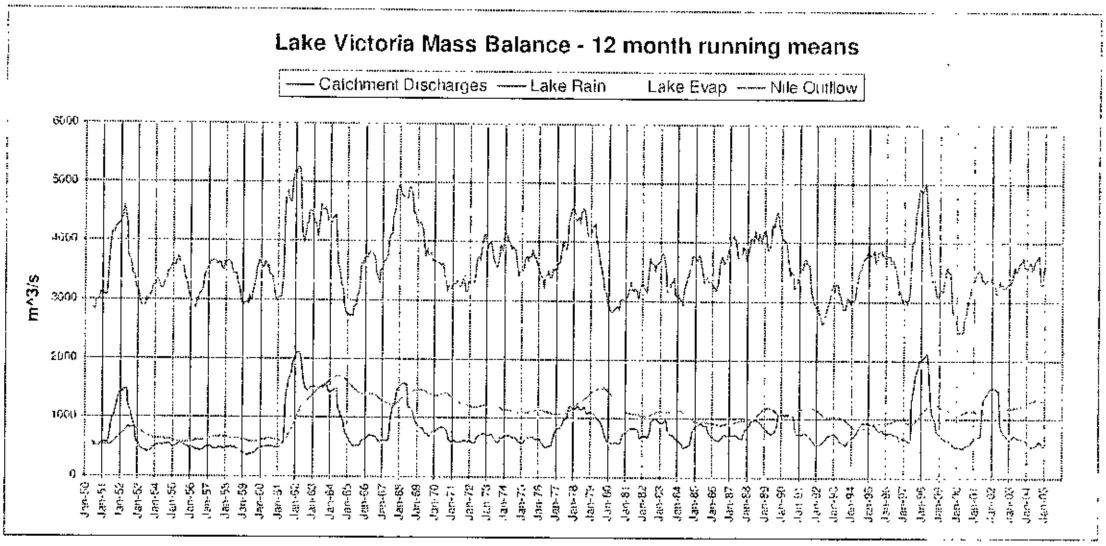



Figure 7: Modelled long term series generated by a water balance model. Source: Presentation at the Arusha Stakeholder Workshop By R. J. Mngodo, J. R. Okonga, F. D. Sangale, S. M. Sewagudde, F. L. Mwanuzi and R. E. Hecky LVEMP Regional Water Quality Report (2005))

Decrease of any of the components of the system, specifically, rainfall, river inflows or Nile outflows either raises or lowers the lake level. The presently observed fall in lake level is a result of a combination of two factors (a) reduced input in terms of rain and inflows into the lake and (b) Increased outflows caused by excess releases at Jinja. General absence/ limited rains on the lake in recent years resulted in falling of lake levels by 1.64m from 1998 to November 2004 with the year 2004 having been severely hit by this shortage of input. An increased outflow for power generation exacerbates this situation: eexcess releases accounted for 45% of the total fall in the period 2001-2004. Years 2003 & 2004 accounted for 77% of the extra lake drop with over 50% occurring in 2004 alone.

**Indicator use:** see Indicator 5) Water level.

**Data availability:** data were not available to allow correlation with catch rates (experimental and fishery).

5) Secchi disc

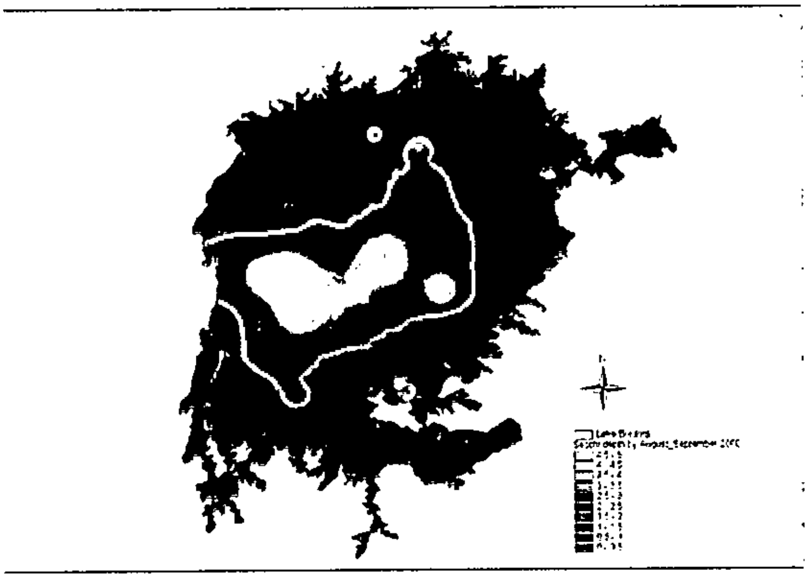


Figure 8: Map of Secchi depths derived from August –September 2000 (Source: taken from presentation at the Arusha stakeholder workshop November 2005 by Ssebuggwawo V. Kitamirike J. M, Khisa P, Njuguna H, Myanza O, Hecky R & Mwanuzi F.)

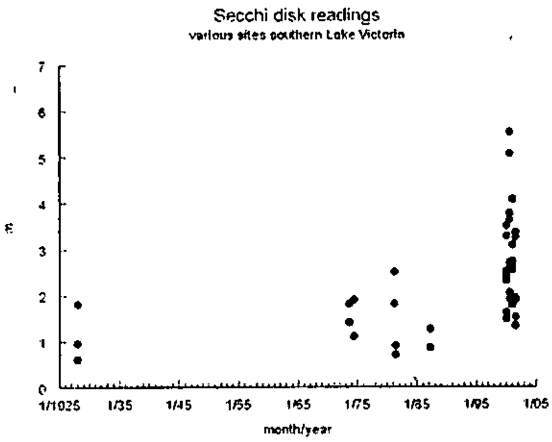



Figure 9: Various Secchi Depth readings from the southern part of Lake Victoria. Sources: Worthington (1930): Speke Gulf, January 1928, depth of 5-7 m; Emin Pasha Gulf, February 1928, depth: 10 m; Akiyama et al. (1977) Mwanza Gulf, April-December 1973, depth: 8 m January-December 1974 depth: 8 m; Van Oijen et al. (1981) Mwanza Gulf, February to April 1981; depth 7-14; HEST Report (1986) Mwanza gulf. 1986, depth of 7-14 m. de Beer, (1990) Mwanza, March to May 1987,depth of 7-14 m; Mkumbo (2002) Depth categories 5-10, m, 20m with steps of 10m up till 60+ meters, February 2000 and 2001 and august-September 2000 and 2001. No sites specified.

The reported decrease in euphotic depth (not visible in the reported Secchi readings!!!) through eutrophication has affected (benthic) primary production and has been correlated with the loss of endemic cichlid species that rely on visual cues for mating (Seehausèn *et al.*, 1997). Furthermore, the decrease in euphotic depth is linked to primary productivity of the lake and fish productivity (Silsbe, 2005).

**Indicator use:** Secchi disk readings are a particularly simple way of obtaining information on the visibility of the lake. Changes in visibility are an indication of changes in sediment load and micro-algal suspension.

**Data availability:** Data available from the national syntheses reports were in a form precluding further spatial aggregation.

6) Nutrients

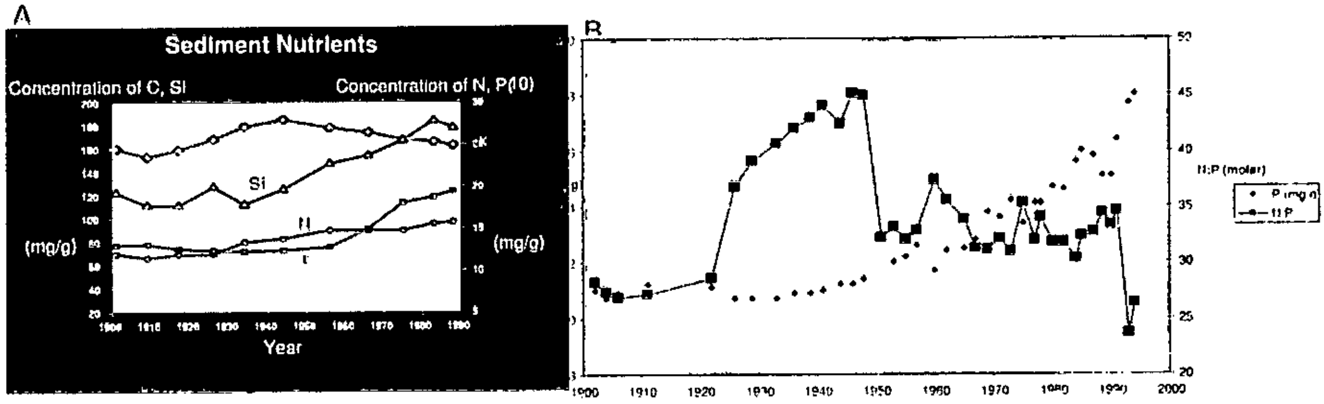



Figure 10A: Concentrations of sediments in cores. B. Sediment nutrients in the Itome core (Source: taken from presentation at the Arusha stakeholder workshop November 2005 by Gikuma-Njuru, P., D. Rutagemwa, R. Mugidde, R.E. Hecky, L. Mwebaza-Ndawula, P.M. Mwirigi, J.O.Z. Abuodha, R. Waya, A. Matovu, J. Kinobe)

Lake Victoria has clearly shown signs of eutrophication since the late 1980s (see also Water Quality Synthesis Report, 2005). Nutrient enrichment in the water column and in the sediment accelerated after the 1960s. Phosphorus concentrations have risen by a factor of 2 to 3. Total phosphorus concentrations with a range from 1.0 μM to 12.0 μM, and an average of 2.7 μM. The total nitrogen concentrations vary from 20 μM to 250 μ M, with average values increasing from 37.0μm in offshore to 110 μm in inshore. The amount of nitrogen in the lake has not increased to match the increase in phosphorus as indicated by the total nitrogen (TN) to total phosphorus (TP) ratios in the range 8.0 to 42.0, with an average of 15.7. Average TN: TP ratios were almost double in inshore than offshore indicating that P is excess relative to N in offshore than inshore. The higher phosphorus relative to nitrogen concentrations have stimulated growth of nitrogen fixing algae that fix and bring in approximately 480 tonnes a year of atmospheric nitrogen. The average Silica concentrations (17.3 ± 13.6 μm) have decreased by a factor of 10 since the 1960s, as result of increased phosphorus loading. The high nutrient concentrations support elevated algal primary production by a factor of 2 and algal biomass by a factor of 6 to 8. Algae, macrophytes and invertebrates species composition have responded to changes in nutrient enrichment. Average algal primary production has increased 2 fold and supports a 4 to 5 fold increase in fish yield compared to 1950s (Mugidde, Water Quality Synthesis Report, 2005). However, adverse eutrophication effects include excessive algal biomass, harmful algal blooms associated with fish kills, reduction in lake transparency, changes in algal and invertebrate communities, loss of desirable fish species and seasonal bottom water oxygen depletion.

**Indicator use:** The annual point estimates of nutrient levels as presented in the National Fisheries Syntheses reports are useful to assess the local status off the lake over long time periods. In combination of other indicators (oxygen, secchi disk, phytoplankton) they will provide warning signals of local excess in eutrophication resulting in local fish kills or disappearance of species from local catches. This in particular will be apparent first in the relatively shallow bays with high population densities as around Kisumu, Mwansa and Entebbe. They are, however, not sufficiently detailed as a monitoring tool in relation to fish stocks. There is no sufficient long time series data to establish the correlation between primary production and fish production.

**Data availability:** The data presented in Figure 9 were not available for further analysis. Data presented in the National Fisheries Synthesis report were not available for further analysis. We refer to the water quality synthesis report for a more in-depth analysis.

7) Oxygen

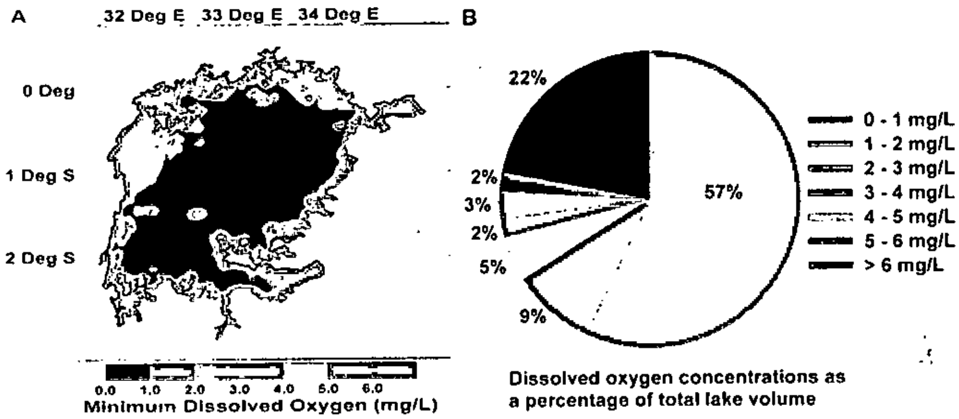



Figure 11: Planimetric distribution of minimum dissolved oxygen concentrations in the water column with (A). corresponding concentrations expressed as a % of lake volume as measured at 50 stations in February 2000 (B). (Silsbe, 2004)

**Indicator use:** oxygen concentrations are an indicator of organic loading. As in the figure below, it will allow an assessment of the habitat of benthic invertebrates and fish. Local continuous measurements may serve as a warning on local organic load conditions and potential fish kills. It is an important indicator that requires monitoring on vertical and horizontal profile as well as on temporal scale in order to explain fish distributions and abundance.

**Data availability**: Dissolved oxygen concentration in the surface and bottom waters as presented in the National Synthesis reports of Kenya were not available for further analysis. We refer to this report for an analysis of the local nutrient levels. No data were available for further aggregation over the lake and hence for further analysis. We refer to the water quality synthesis report for a more in depth analysis of this indicator.

8) Temperature

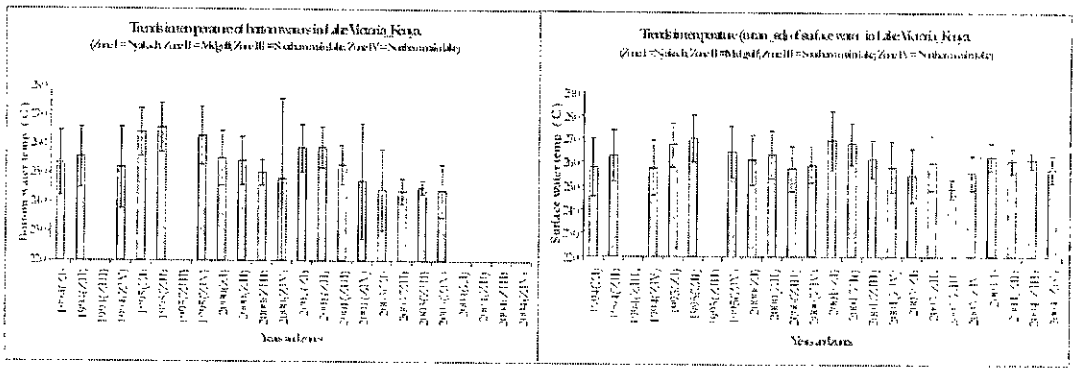


Figure 12: Developments in surface (left) and bottom (right) temperature at several stations in the Kenyan section of the lake. Though it is not indicated what the error bars around the means represent, it seems that there are no significant difference in bottom temperatures and only a few in surface water temperature (Source: Kenya National Synthesis Report on Fisheries Research and Management).

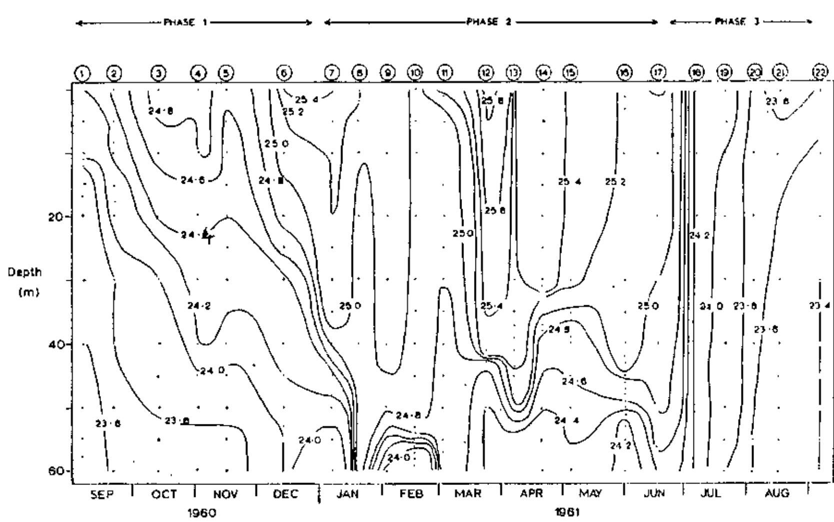



Figure 13: Time series of temperature profiles at Bugaia Island (UP2) 1960-61, adopted from Talling (1966)

**Indicator use:** as temperature is relatively invariant over larger scales it is only a good indicator for long term processes as global warming. In this for there is limited use for fish and fisheries assessments. Figure 12 is added to how local temperature profiles over time have been represented by Talling (1966). Such representations are useful to indicate stratification profiles. Temperatures taken at relevant depths to show stratification patterns over the scale of the whole Lake can be useful as indicators of the size and timing of stratification processes that, in combination with oxygen levels as represented in indicator 7 are highly relevant to assess spatial patterns in fish stocks, and potential incidences of fish kills in relation to eutrophication.

**Data availability:** The data presented do not allow further analysis. We refer to the water quality synthesis for a more in depth analysis.

9) Primary production (Chl-a)

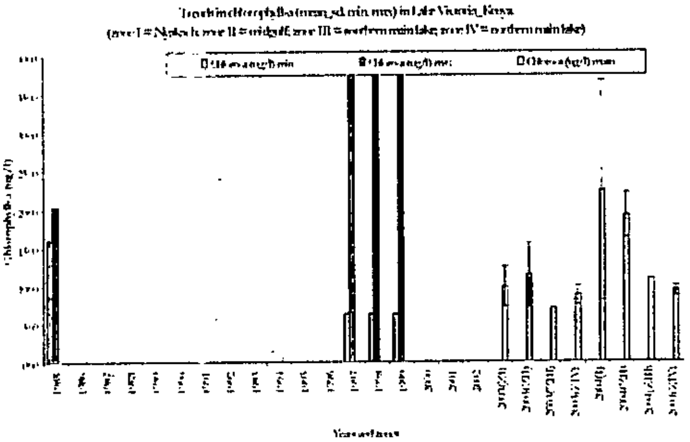


Figure 14: Developments in Chl-a concentration over time (coloured bars) and in various portions of the Kenyan part of the lake (grey bars). Source: Kenya National Synthesis Report on Fisheries Research and Management

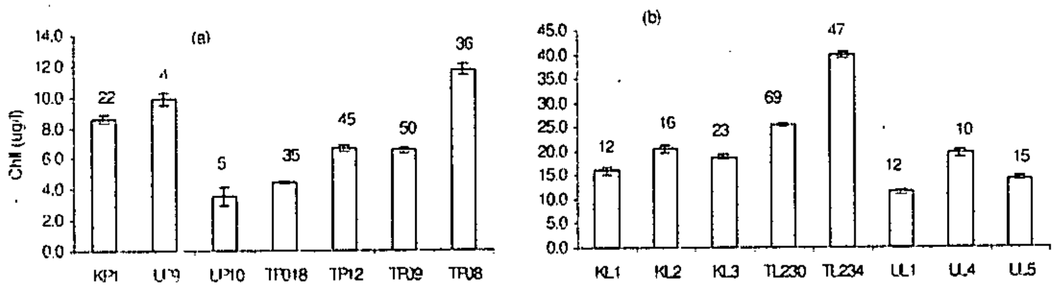



Figure 15: Mean Chlorophyll a concentrations in the (a) open pelagic lake zone and (b) Mwanza, Napoleon and Nyanza Gulfs. n values are shown above the bars (note scale change between the figures –gulfs and littoral areas have higher chlorophyll concentrations). Source: Gikuma-Njuru. P., D. Rutagemwa, R. Mugidde, R.E. Hecky. L. Mwebaza-Ndawula, P.M. Mwirigi, J.O.Z. Abuodha. R. Waya, A. Matovu, J. Kinobe, Arusha Stakeholder Presentation).

Chlorophyll-a is highly correlated to gross phytoplankton production. Euphotic depths are also highly correlated to phytoplankton biomass. Studies on nutrient status have shown that due to the advanced state of eutrophication, phytoplankton production is more limited by light than nitrogen or phosphorous. Self shading appears to limit the depth of phytoplankton production and continued enrichment of the lake will not increase gross phytoplankton production as it is already light limited over most of the lake's surface area (Silsbe *et al.*, 2005). Silsbe *et al.*, (2005) conclude that the ideal nutrient concentrations to support a productive fishery while maintaining an acceptable water quality level have been exceeded.

**Indicator use:** Chlorophyll-a levels can be used as a local and lake wide indicator for fish productivity status. A presentation of changes over time should show chl- a concentrations in a spatial context integrated over the Lake.

**Data availability:** data presented here only refer to the Kenyan side of the lake and allow no further analysis. We refer to the water quality synthesis report and Silsbe *at al.* (2005) for an in depth analysis of chlorophyll-a in relation to eutrophication.

10) Species composition of micro-algae

Table 1: Number of algal species from each algal phyla encountered and unidentified individuals (others) in the five surveyed zones of Lake Victoria - Tanzania, January - February 2002 and the corresponding Shannon-Wiener Diversity indices.

| Phyla | | Zones / Rainy season | | | | |
|---|---|---|---|---|---|---|
| | | Mwanza Gulf | Speke Gulf | Mara zone | Kagera zone | Emin Pasha Gulf |
| Cyanophyta | | 15 | 24 | 40 | 15 | 18 |
| Bacillariophyta | | 7 | 10 | 16 | 12 | 5 |
| Chlorophyta | | 15 | 12 | 26 | 11 | 11 |
| Dinophyta | | 0 | 0 | 4 | 0 | 0 |
| Euglenophyta | | 4 | 0 | 0 | 1 | 0 |
| Others (unidentified) | | 9 | 13 | 22 | 15 | 10 |
| **TOTAL** | | **50** | **59** | **108** | **54** | **44** |
| | ***H'*** | **0.1802** | **0.149** | **0.1** | **0.134** | **0.18** |
| July - August 2002 | | | | **Dry season** | | |
| Cyanophyta | | 6 | 11 | 10 | 5 | - |
| Bacillariophyta | | 4 | 8 | 6 | 4 | - |
| Chlorophyta | | 4 | 4 | 10 | 5 | - |
| **TOTAL** | | **14** | **23** | **26** | **14** | - |
| | ***H'*** | **0.252** | **0.154** | **0.209** | **0.223** | - |

Source: Uganda National Synthesis Report on Fisheries Research and Management

**Indicator use:** Shifts in algal composition towards blue green algae (Cyanophycaea) indicate changes in the trophic status of the lake which could lead to eutrophication and deterioration in the fisheries.

**Data:** There.are no adequate time series data available to show the shift towards blue green algae. We refer to the Water Quality Synthesis report for more in depth information

11) Water hyacinth

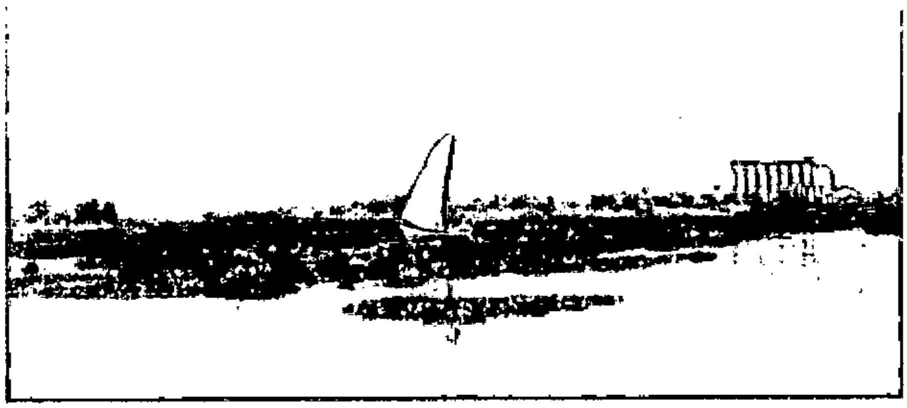


Plate 1: Kisumu bay under water hyacinth (Eichornia crassipes) cover in the 1990's (Source: Job Mwamburi (KMFRI) – presentation Environmental Quality (August 2005))

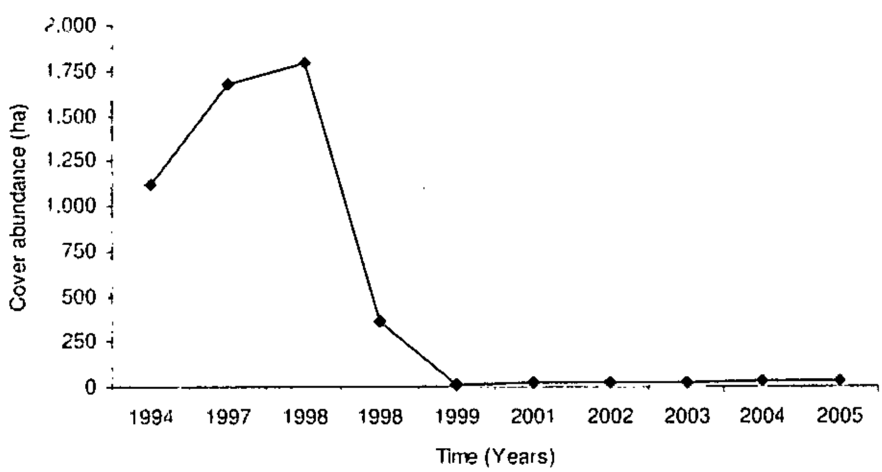



Figure 16: Trends in water hyacinth cover abundance on Lake Victoria, Uganda, between 1994 and 2005. (Source: Uganda National Synthesis Report on Fisheries Research and Management)

Water hyacinth entered the lake in 1989 through Kagera river (Njuguna 1991). Peak cover abundance of water hyacinth in Lake Victoria was attained in 1998 and was followed by an unprecedented collapse when massive mats sunk to the lake bottom. A number of factors could be attributed to the rapid collapse of the weed. Factors such as biological control by the introduced weevil, mechanical control measures succession by other aquatic weed (*Vossia cuspidata* and *Najjas horrida*) and chemical control all contributed to this rapid collapse. In addition to the above, the *El Niño* rains together with the winds contributed so much to the control efforts in that the weeds were crashed and weakened. See Kenya and Uganda national synthesis reports on fisheries research and management for further analysis of this indicator.

**Secondary production indicators**

12) Lake flies abundance

**Indicator use:** Abundance of lake flies, zooplankton and *Caridina* are all important for assessing secondary production of the lake. All are important as food for various stages in the life-history of *Rastrineobola*, Nile perch and other fish species. To assess changes in food-web structure estimates of abundance of these secondary producers over time are needed.

**Potential indicator:** size and occurrence of swarms of lake flies over the Lake assessed through satellite imagery.

**Data availability:** no data available.

13) Caridina

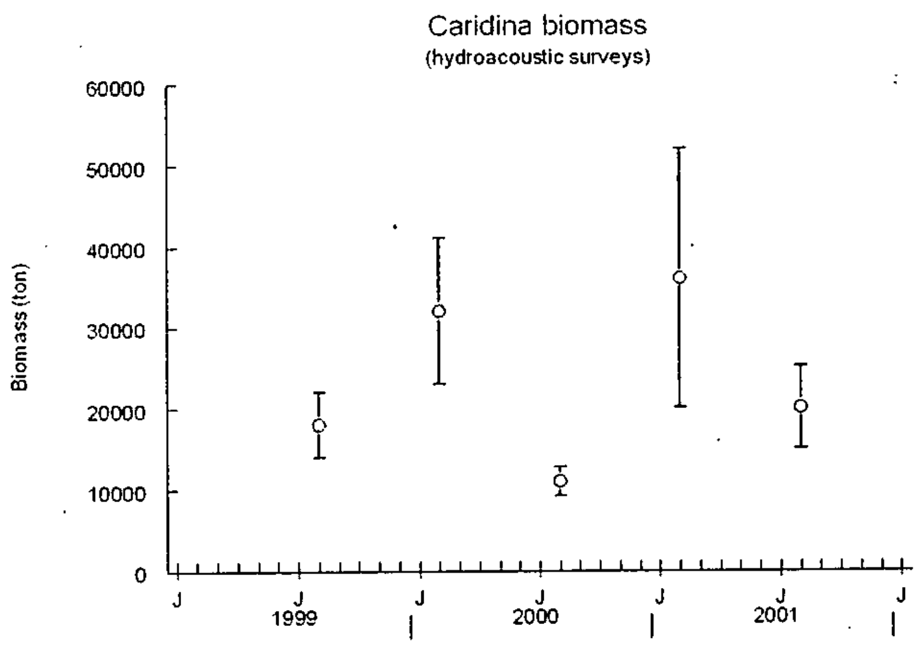



Figure 17: Development in *Caridina* abundance (Source: Hydro acoustic surveys over Lake Victoria: Uganda National Synthesis Report on Fisheries Research and Management)

Abundance of lake flies, zooplankton and *Caridina* are all important for assessing secondary production of the lake. All are important as food for various stages in the life-history of *Rastrineobola*, Nile perch and other fish species. Since the start of its fishery, *Caridina* abundance is in itself a good indicator of the status of this fishery. On the basis of three years data with five data points, no trend analysis With the exception of the July 2000 point no mean biomass estimate is significantly different from the others. The July 2000 point is significantly different from the August points. The abundance estimates seem to point out some seasonality in abundance.

**Indicator use:** Biomass estimates are useful in food web studies. To assess changes in food-web structure estimates of abundance of these secondary producers over time are needed.

**Data availability:** Data were not available in a format that allowed further analysis of changes in food webs. Hydroacoustic survey data should continue to estimate biomasses in a consistent and comparable manner over surveys to allow analysis of trends and spatial patterns.

14) Zooplankton.

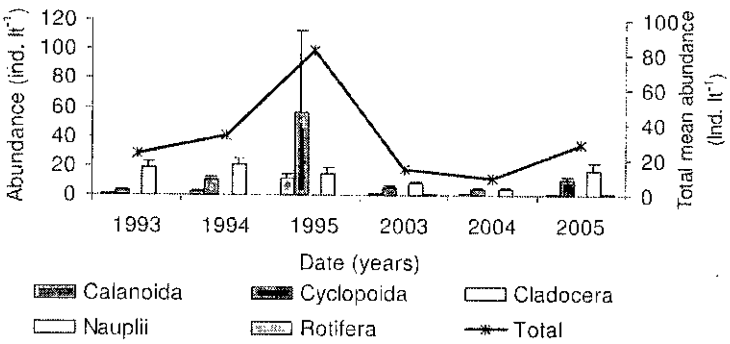



Figure 18: Developments in mean abundance estimates of zooplankton in Ugandan waters of Lake Victoria, 1993 – 2005 Error bars are ????. From the (Source: Uganda National Synthesis Report on Fisheries Research and Management).

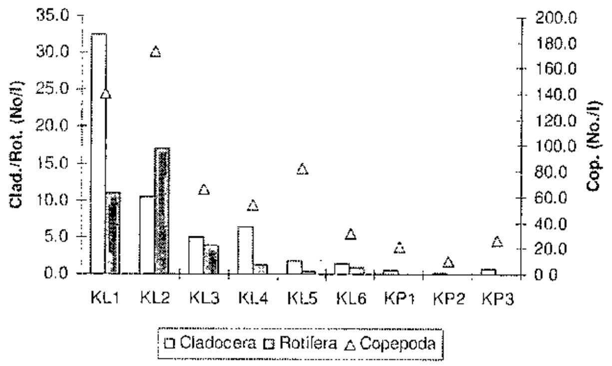



Figure 19: Mean abundance estimates of zooplankton broad taxonomic groups at littoral ( KL) and pelagic ( KP) stations, Lake Victoria 2000-2005. Key: Cop.= Copepoda, Clad.= Cladocera, Rot.= Rotifera Source: Gikuma-Njuru, P., D. Rutagemwa, R. Mugidde, R.E. Hecky, L. Mwebaza-Ndawula, P.M. Mwirigi, J.O.Z. Abuodha, R. Waya, A. Matovu, J. Kinobe – Arusha Stakeholder presentation.

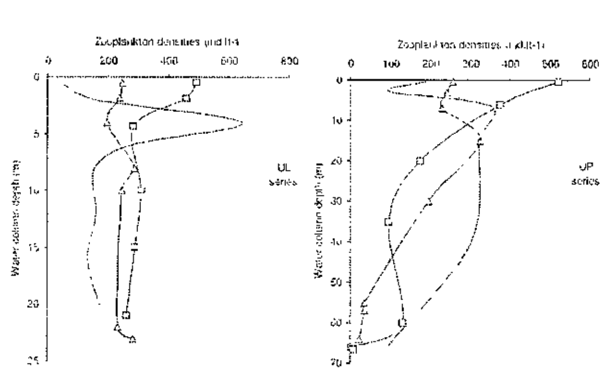



Figure 20: Vertical distribution patterns of zoo-plankton in Ugandan littoral (UL) and pelagic (UP waters) in 2001.

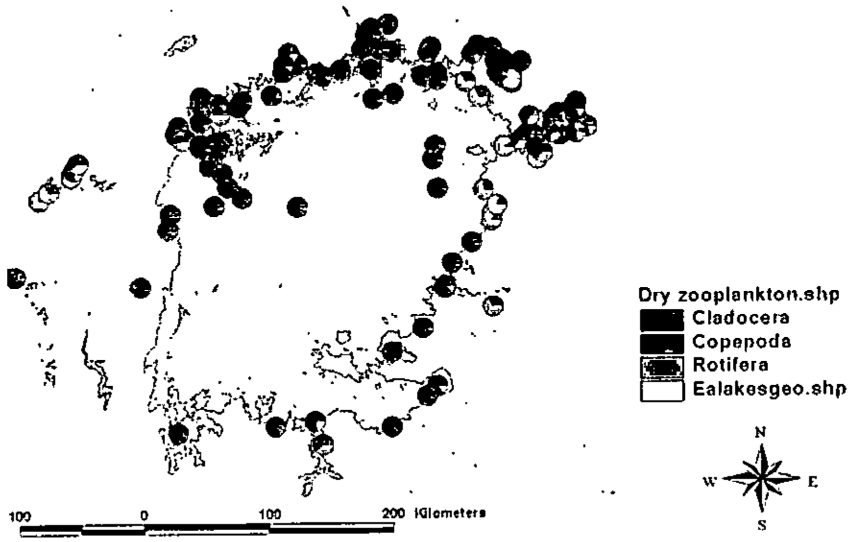



Figure 21: Distribution and proportions of major zooplankton taxa in Lake Victoria (Source: Kenya National Synthesis Report on Fisheries Research and Management)

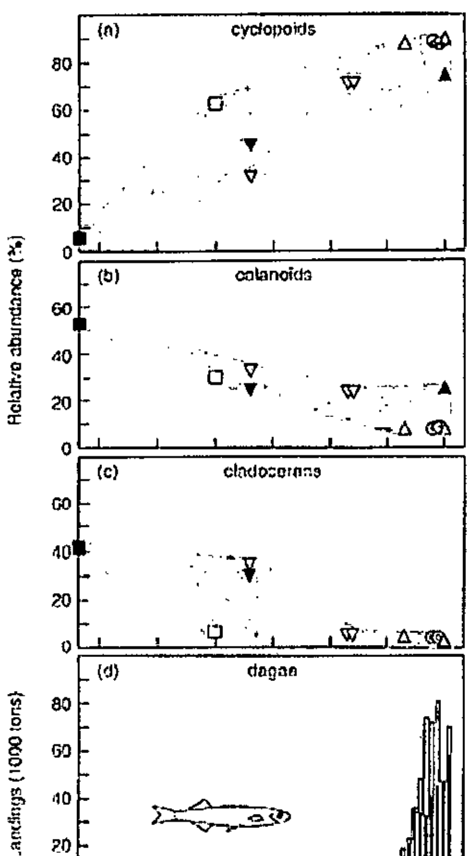



Figure 22:
Changes in zooplankton and Rastrineobola argentea (dagaa) in Lake Victoria between 1927 and 1991. (a-c) The relative abundances of cyclopoids, calanoids and cladocerans were calculated from the following sources (sampling and station details in Table 1): filled squares (Worthington, 1931), unfilled squares and filled downward triangles (Rzóska, 1957), unfilled downward triangles (Akiyama et al., 1977), unfilled upward triangles (Hoogenboezem, 1985), unfilled small and large circles (Katunzi et al., in prep.; this study), filled upward triangles (Mwebaza-Ndawula, 1994). The filled symbols (black = offshore station; grey = Pilkington Bay) represent the data from the northern waters used by Gophen et al. (1995). Unfilled symbols represent the stations in the Mwanza Gulf (small circles = shallow station Luanso Bay). (d) Annual landing data for dagaa are given for the Kenyan waters (black bars) and the whole lake (black plus stacked open bars). No data for the Tanzanian waters were available for 1990 and 1991 (From Wanink, 1998).

The role of zooplankton in secondary productivity is directly related to production of zooplanktivorous fish species like haplochromine zooplanktivores, dagaa, immature stages of Nile perch and other species. It is not clear from the original presentation of the data whether the error bars in Figure 14 represent Standard Deviations or Standard Errors. No further information was obtained after commenting on the draft National report to that effect. As no sample size is indicated as well no further conclusions can be drawn on the basis of this information. It is also not know if the samples are taken consistently from the same sites. If the error bars are standard errors then there is no significant difference in the mean estimates over the years of the various zooplankton families. Density variations then suggest more or less stable standing crops over the period. Figure 17 shows clear spatial distributions over the Lake. Vertical distribution patterns of zooplankton in the first quarter of the year 2001 are presented in figure 19. The distribution of major taxa over the lake is presented in figure 20. Spatial integration of the three last figures (18, 19, and 20) should yield maps of lake wide distributions. Annual series of such maps can indicate temporal changes.

**Indicator use:** Shifts in relative abundance can be directly related to availability of food for fish, food webs and production.

**Data availability:** data were not presented in a format that allowed further analysis. No reports form the Tanzania or Kenya national reports were obtained. We refer to the Water Quality Synthesis report for a more in depth analysis. Appendix 5 gives a taxonomic list of zooplankton species encountered. No data were available to allow trend analysis of major taxa.

## Biodiversity, community and food web indicators

15) Species composition in experimental trawl catches

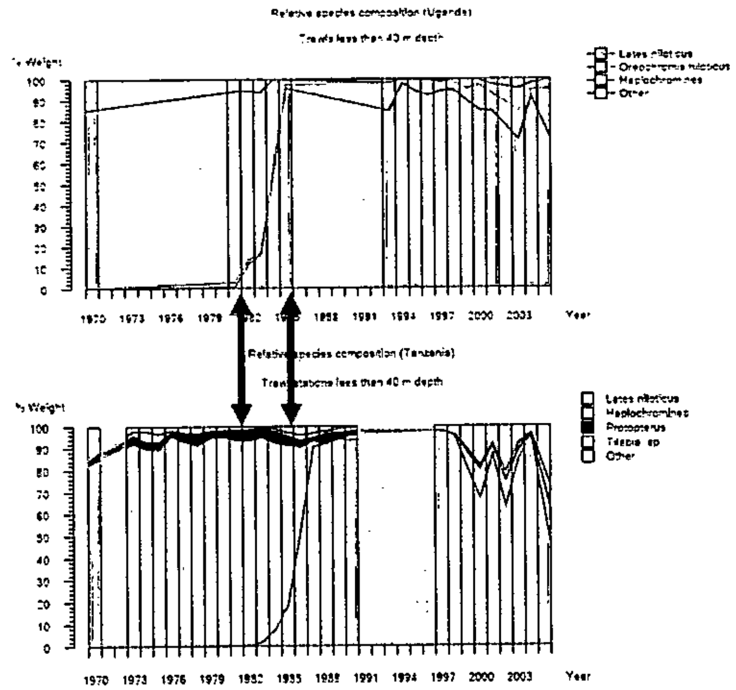



Figure 23: A. Relative fish species composition based on trawl survey data (Source: trawl surveys in Uganda). B. Relative fish species composition based on trawl survey data (Source: trawl surveys in Tanzania with RV Mdiria, RV Kiboko and RV Explorer). Red arrows indicate start and end of the nile perch upsurge in Uganda.

The indicator shows the abrupt change in fish community structure 25-30 years after the introduction of Nile perch in the lake, the two year shift in timing between the northern and southern part of the lake. the present relative increase in haplochromines (in particular Uganda). tilapiine and other fish species (in particular Tanzania) of the Lake.

**Indicator use:** Relative species composition in the trawl surveys is an important indicator to assess long term changes in the fish community of Lake Victoria. Spatial desegregation of this indicator linked to spatial distribution of indicators of eutrophication (oxygen concentration) may serve as an early warning to more comprehensive changes in fish community structure as a result of these processes.

**Data:** Data from Ugandan trawl surveys are available for the years presented by weight only. Species composition indicators can be easily calculated based on regular experimental trawl monitoring programme. More categorical detail can be obtained if the categorical resolution of the data collection would be made consistent between years (within countries) and between countries. At present the data can only be analysed based on the 4-5 broad species-categories as presented. Survey data from Kenya were not available for analysis.

16) Feeding habits of main commercial species

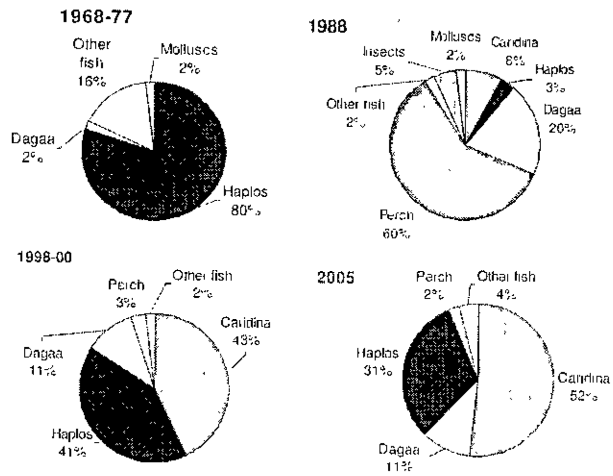



Figure 24: Changes in the food and feeding habits of Nile perch from 1968 to 2005. (Source: Tanzania National Synthesis Report on Fisheries Management and Research)

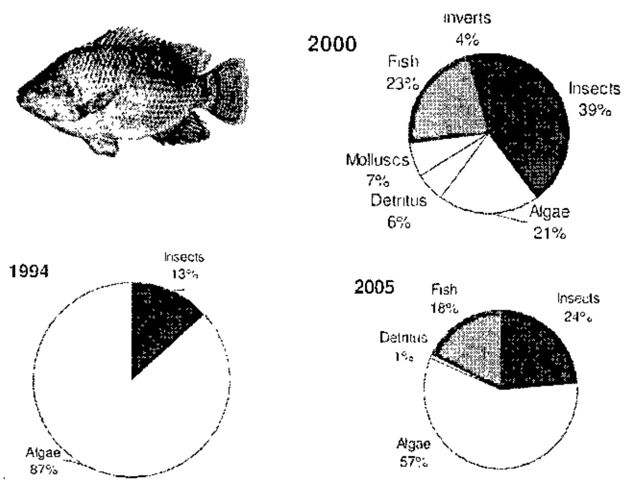



Figure 25: Changes in the food and feeding habits of Nile tilapia from 1994 to 2005. (Source: Tanzania National Synthesis Report on Fisheries Management and Research)

Feeding habits of Nile perch/tilapia have changed concomitant with faunal and floral changes

**Indicator use:** Changes in feeding habits of common species indicate changes in the food web.

**Data availability:** No new information was presented to the consultants on the basis of which new foodwebs could be constructed. However, some changes in feeding behaviour base don gut-length contents was presented at the meeting in Arusha in November 2004 that is presented here. No validity check could be made as data were not available.

## Life-history indicators

17) Mean, maximum size and size frequency distribution

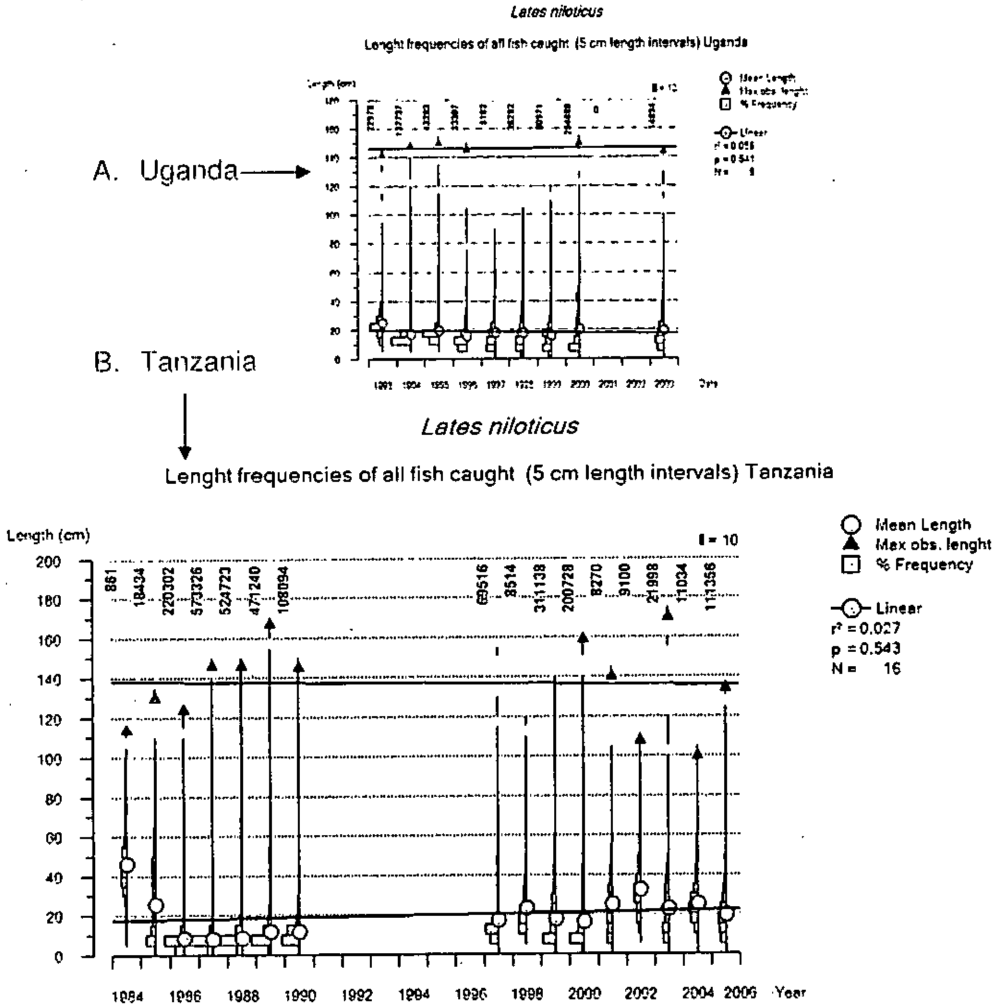



Figure 26: A. Nile perch length frequencies (5 cm intervals) all specimen caught in experimental trawl surveys. Source: Trawl survey Uganda B. source Trawl surveys Tanzania (see indicator 15). Green marks are mean length of all specimen, blue marks maximum length observed in the experimental trawl catches. Black and blue lines are regressions over the mean and maximum length respectively. Only the blue marks are used in the regression of the maximum length: in the remaining years nile perch >100 cm was recorded as 100+ nile perch.

Preliminary indicator analysis shows no changes in mean and maximum length in the experimental trawl catch of Nile perch for the period 1993 to 2003 in Uganda (Figure 26A) and over the period 1984 – 2006 in Tanzania (Figure 26 B). As Nile perch > 50 cm are fast swimmers and therefore can escape trawls it is possible that no change in mean length is simply an artifact of the survey design. It can be argued that the specimen >50 cm are caught randomly in the trawl. If this is the case than a change in mean length of Lates >50cm would be observed in this size group over time. However, mean length of Nile perch >50 cm also shows no change (Figure 27). No changes were observed in maximum length over the same periods in both countries as well.

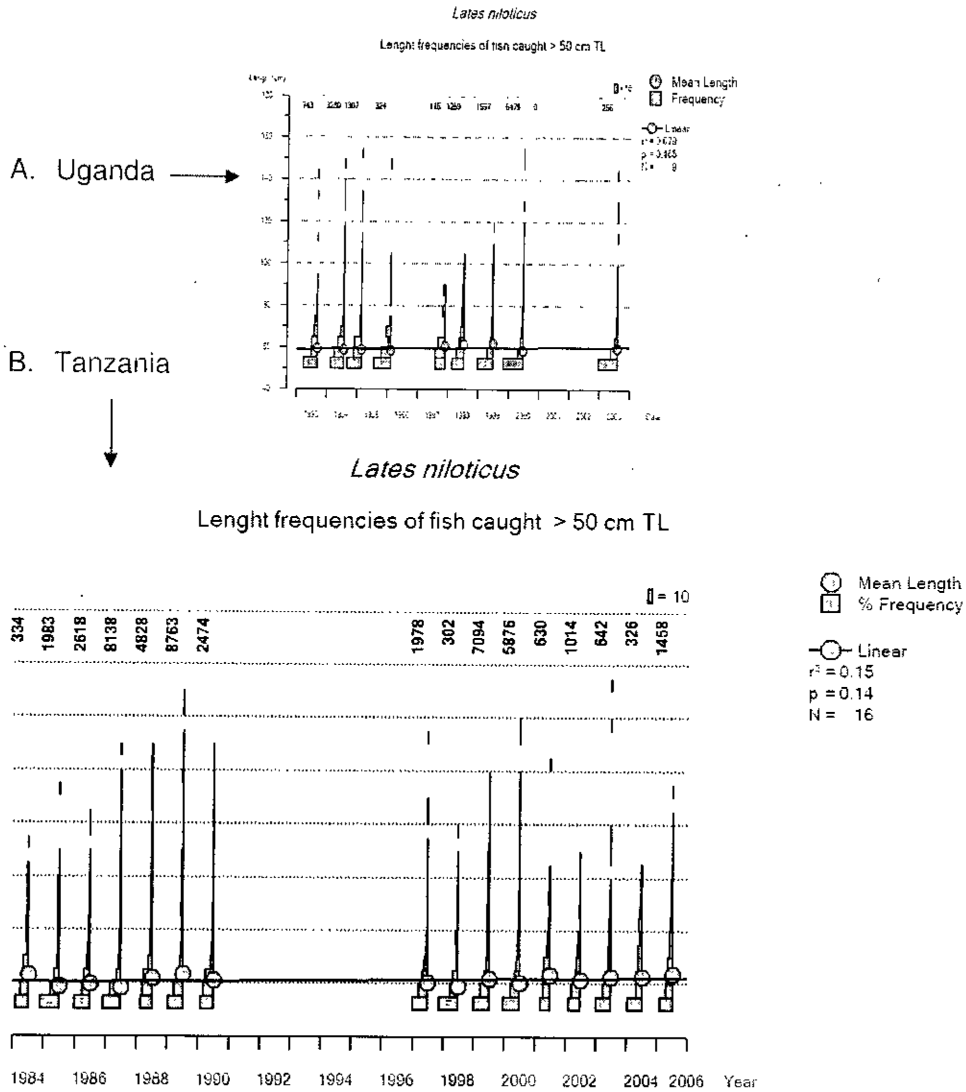



Figure 27: A. Nile perch length frequencies (5 cm intervals) specimen >50 cm caught in Experimental trawl surveys. Source: Trawl survey Uganda. B. source Trawl surveys Tanzania (see indicator 15). Green marks are mean length of all specimens. Black lines are regressions over the mean.

**Indicator use:** the mean and maximum size of fish caught are important indicators for fishing pressure, in particular when the target of a fishery is on the larger sized fish, as is the case for Lates niloticus in Lake Victoria.

**Data:** Data from Ugandan and Tanzanian trawl surveys are available for the years presented under indicator 14 and annual change and variability can be measured. No data are available for other species. Survey data from Kenya were not available for analysis.

18) Slope of the biomass size spectrum.

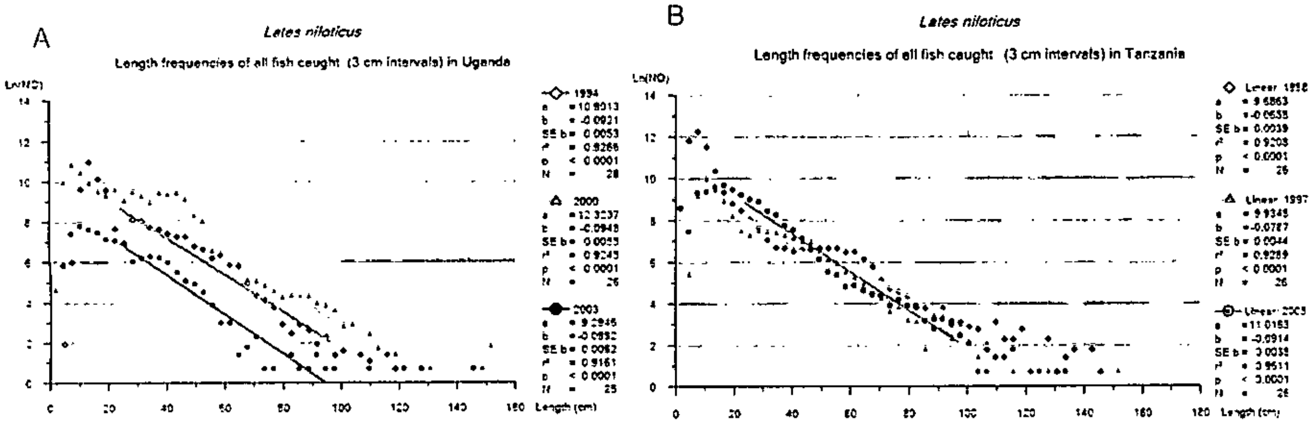



Figure 28: A. Ln-transformed size distributions of Nile perch in Uganda. No significant changes in slopes between 1994 and 2003. Regressions between 20 and 100 cm. (Source: Trawl surveys Uganda.) It should be noted that not all the collected length data were made available (several years are missing). B. Ln-transformed size distributions of Nile perch in Tanzania. Changes in slopes between 1988 and 2005 only; significance of these changes are to be tested still. Regressions between 20 and 100 cm. (Source: Trawl surveys Tanzania including HEST data)

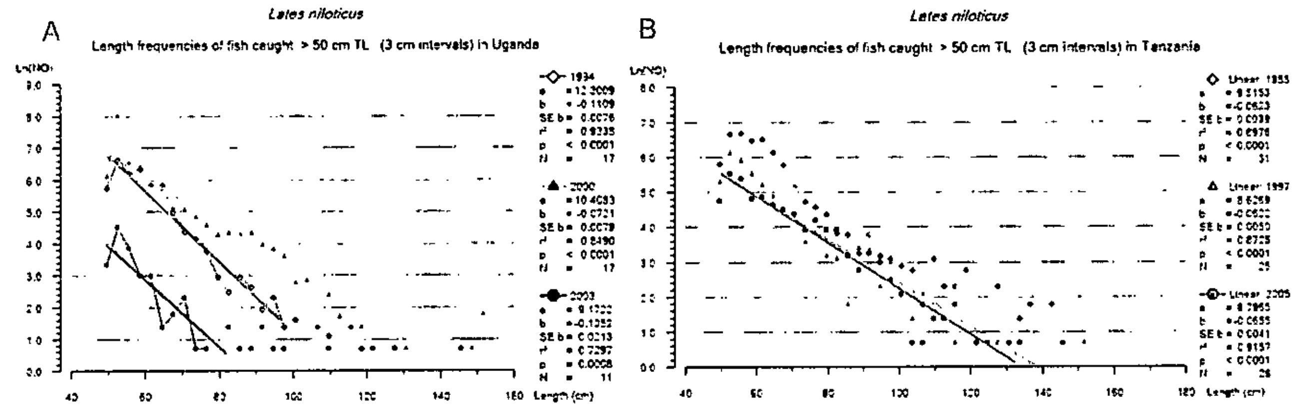



Figure 29: A. Ln-transformed size distributions of Nile perch in Uganda of fish > 50 cm TL (minimum slot size). No significant pattern in slopes Source: Trawl surveys Uganda B. Ln-transformed size distributions of Nile perch in Tanzania of fish > 50 cm TL (minimum slot size). No significant pattern in slopes Source: Trawl surveys Tanzania including HEST data.

Changes in the slope of the regression over the log-transformed biomass size spectrum (of individual species or of the total fish community) indicate changes in the size structure of the fish stock or fish community: an increasing slope reflects a decrease in mean size. Changes in the intercept (with y-axis) of the regression over the biomass size spectrum indicate changes in productivity. As intercept and slope are highly correlated a separate slope analysis needs to be carried out (van Zwieten *et al.* 2003), the differences in slopes between 1988 and 2005 for all lengths in Tanzania may therefore be spurious. Preliminary analysis of the indicator on the biomass-size distribution of Nile perch in the trawl survey catches shows no significant change in size structure and varying levels of productivity. A separate analysis of Nile perch of >50 cm (Fig 28) also indicates no change in size structure.

**Indicator use:** The indicator gives information on long term structural changes in stocks and communities. The statistical power of the trends in slopes or intercepts are generally low indicating that long time series are needed to asses changes in this indicator. It is therefore not a useful indicator for short term management decisions.

**Data:** Data from Ugandan and Tanzania trawl surveys are available for the years presented under indicator 17 (mean and maximum size) and annual change and variability can be measured. No data available for other species. Trawl survey data from Kenya are not yet available.

Table 2: Different estimates in growth parameters ($L_\infty$, K), mortality estimates (Z and F) exploitation rate (E) and size at 50% maturity of Nile perch. Source: Uganda National Synthesis Report on Fisheries Research and Management.

| *Period/Area* | *Population Mean length* | *$L_\infty$* | *K* | *Z* | *F* | *E* | *Size at maturity* | *Source* |
|---|---|---|---|---|---|---|---|---|
| **Nile perch** | | | | | | | | |
| 1964-1967 | - | - | - | - | - | - | 40-59 cm TL (F)<br>30-34 cm TL (M) | Okedi (1971) |
| 1984 | | 256 cm TL | 0.09 | - | - | - | 67.5 cm TL (F)<br>53.3 cm TL (M) | Acere (1985) |
| 1988-1992 | - | - | - | - | - | - | 90-99 cm TL (F)<br>50-54 cm TL (M) | |
| | | 256 cm TL | 0.29 | - | - | - | 64 cm TL (F)<br>50 cm TL (M) | Okaronon (2003) |
| 1982-1984 | | 251 | 0.09 | 2.2 | - | - | | Acere. (1985) |
| 1987 | | 205 | 0.19 | 1.6 | - | - | | Asila & Ogari. (1988) |
| 1999 – 2002 | | 221 | 0.17 | 2.2 | 1.88 | 0.86 | | Muhoozi, 2002 |
| 2003 | | 169 & 230 | 0.18 & 0.20 | 1.5 | 0.98 | 0.66 | | Rabour et al. (2003) |
| 2003 -2004 | | - | 0.18 | 2.2 | 1.87 | 0.85 | | Taabu *et al.* (2005) |
| **Period/Area** | **Population Mean length** | **$L_\infty$** | **K** | **Z** | **F** | **E** | **Size at maturity** | **Source** |
| **Nile tilapia** | | | | | | | | |
| | 51 cm TL | - | - | - | - | - | 27-35 cm TL | Welcomme (1967) |
| Early 1990s | | | | | | | 18 cm TL (F)<br>24 cm TL (M) | Balirwa (1998) |
| 1999-2000 | | 75 cm TL | 0.4 | - | - | - | 22.5 cm TL (F)<br>21.5 cm TL (M) | Okaronon (2003) |
| ? | | 60 cm TL | - | - | - | - | 24-27 cm TL (F)<br>22-25 cm TL (M) | ? |
| 2002 | | 75 cm TL | 0.4 | - | - | - | 21.5 cm TL (F)<br>22.5 cm TL (M) | Okaronon (2003) |

Table 4: (Contd.) Different estimates in growth parameters of Nile perch. Source: Uganda National Synthesis Report on Fisheries Research and Management.

| *Period/Area* | *Population Mean length* | $L_\infty$ | *K* | *Z* | *F* | *E* | *Size at maturity* | *Source* |
|---|---|---|---|---|---|---|---|---|
| **Dagaa** | | | | | | | | |
| Winam Gulf | | 67.80 | 0.58 | 2.86 | 1.98 | 0.69 | | Manyala (1991) |
| Uganda waters | | 64.50 | 0.92 | 3.59 | 1.22 | 0.34 | | Wandera (1992) |
| Winam Gulf | | 63.40 | 0.94 | 3.23 | - | - | | Manyala (1992) |
| Mwanza Gulf | | 52.00 | 1.14 | - | - | - | | Wanink (1989) |
| Inner Winam Gulf | | 59.00 | 0.74 | 3.47 | 1.89 | 0.54 | | Manyala (1995) |
| Mid Winam Gulf | | 62.00 | 0.74 | 2.97 | 1.39 | 0.47 | | Manyala (1995) |
| Outer Winam Gulf | | 58.00 | 0.68 | 3.38 | 1.8 | 0.53 | | Manyala (1995) |
| Mbita Area | | 62.00 | 0.66 | 3.03 | 1.45 | 0.48 | | Manyala (1995) |
| Open lake | | 58.00 | 0.63 | 3.35 | 1.77 | 0.53 | | Manyala (1995) |
| Kikondo | | 54.00 | 1.75 | 4.13 | 0.12 | 0.03 | | Ogutu-Ohwayo and Wandera (2000) |
| Lingira | | 54.00 | 1.76 | 4.42 | 0.39 | 0.09 | | Ogutu-Ohwayo and Wandera (2000) |
| Bugaia | | 57.90 | 1.14 | - | - | - | | Ogutu-Ohwayo and Wandera (2000) |
| Pre-perch | 60 mm SL | 95.6 mm SL | NA | - | - | - | 44 mm SL (F)<br>52 mm SL (M) | Okedi (1981) |
| Transition | 49 mm SL | 64.5 mm SL | 0.92 | - | - | - | 41 mm SL (F)<br>44 mm SL (M) | Wandera & Wanink (1992) |
| Intensification of exploitation 1992 | 45 mm SL | 54.0 mm SL | 1.76 | - | - | - | 41 mm SL (F)<br>42 mm SL (M) | Wandera (2000) |
| Intensification of exploitation 2002 | 41 mm SL | - | - | - | - | - | 41mm SL | Wandera & Taabu (2002) |

19) Growth parameter estimates (k, $L_\infty$)

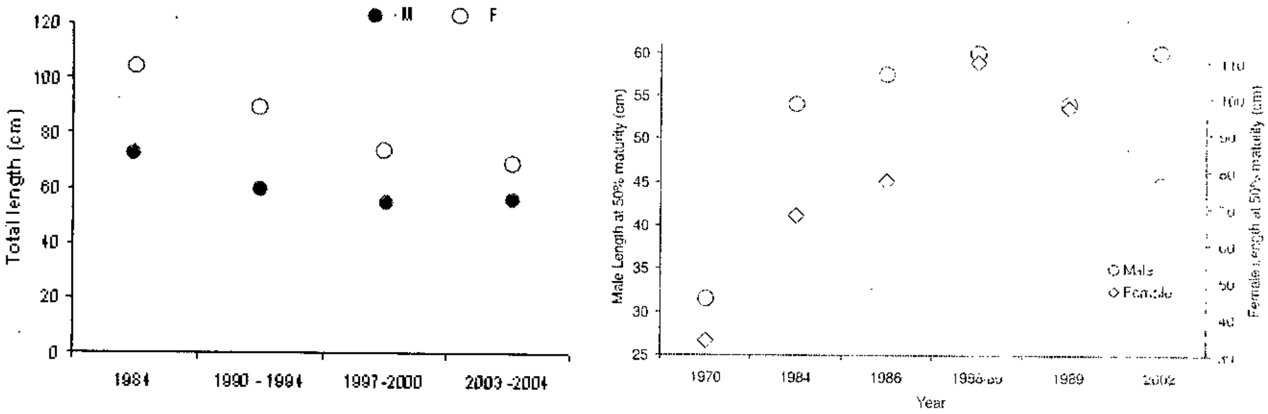
See table 2.

**Indicator use:** Different calculated growth parameters could indicate differences or changes in pressures on the stocks over time. However, as k and $L_\infty$ are inversely correlated (Sparre and Venema 1989), and the methodologies of estimating these parameters involves expert judgement that may differ between researchers, no comparison between the different estimates over time can be made if no common method in choice of parameter estmates has been made. Therefore the estimates shown represent a range of possible parameter values for the three species.

**Data:** The estimates shown were taken from literature. We refer to the original texts for a discussion on the estimate

**Data:** The estimates shown were taken from literature. We refer to the original texts for a discussion on the estimates.

20) Length at 50% maturity




A B

Figure 30: A. Developments in mean size at 50% maturity of Nile perch from Lake Victoria Uganda. (Source: Uganda National Synthesis Report on Fisheries Research and Management). B. Variation in mean size at 50% maturity of Nile perch from Lake Victoria, Tanzania. (Source: Tanzania National Synthesis Report on Fisheries Research and Management). M=male, F=Female. Note that in both graphs the x-axes does not represent a continuous time series!

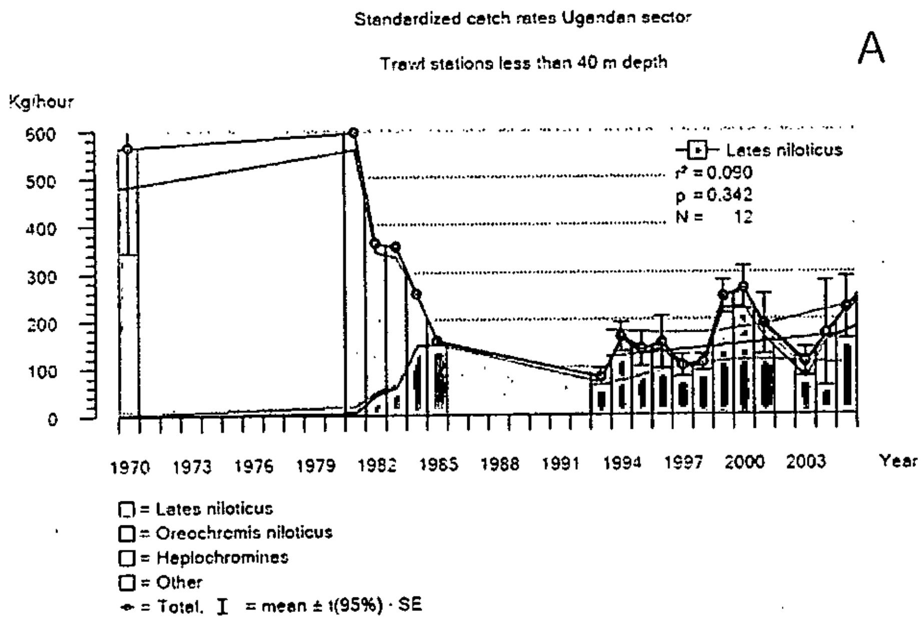
The various measurements in Uganda and Tanzania show the variation in calculated length at maturity form male and female nile perch. As the definition of maturity stages is very subjective, and the stages used are not indicates, as well as no confidence limits of the estimates are provided, no conclusions on developments can be drawn.

**Indicator use:** Changes in length at maturity are often used as an indicator in relation to the changes in mean length of the population fished. It is also often used

**Data:** No data were available for further analysis.

## Stock indicators from experimental and fishery catch rates

21) Experimental trawl catch rates



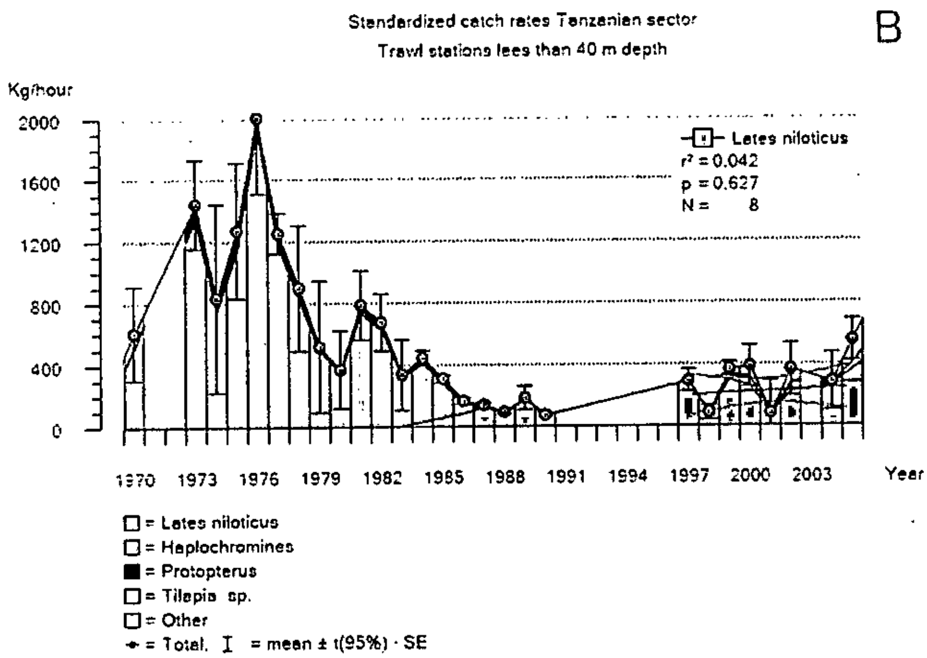




Figure 31: A: Trends and developments in experimental trawl catch rates in Uganda. (Source: trawl survey Uganda). B: Trends and developments in experimental trawl catch rates in Tanzania. (Source: trawl surveys in Tanzania with RV Mdiria, RV Kiboko and RV Explorer). Note the difference in the units of the Y-axis. Also note that experimental trawlers do not catch Rastrineobola (dagaa) or Caridina hence the apparent lowered productivity of the overall stocks.

**Indicator use:** Catch-rates are the single most important indicator to assess the status of a fishery. Catch-rates from experimental trawling can give an unbiased estimate of the relative changes in the fish stocks if the survey design is consistent over time. The fishery can be divided into three phases; pre-Nile perch (1970-1980), exponential growth (1981-1993) and the stabilization phase (from 1994 to present). No significant change in average catches rates of Nile perch (biomass) have been observed from 1994 to 2005).

**Data:** Data from Ugandan trawl surveys are available for the years presented for this indicator where annual change and variability can be measured.

22) Fishery catch rates (by species)

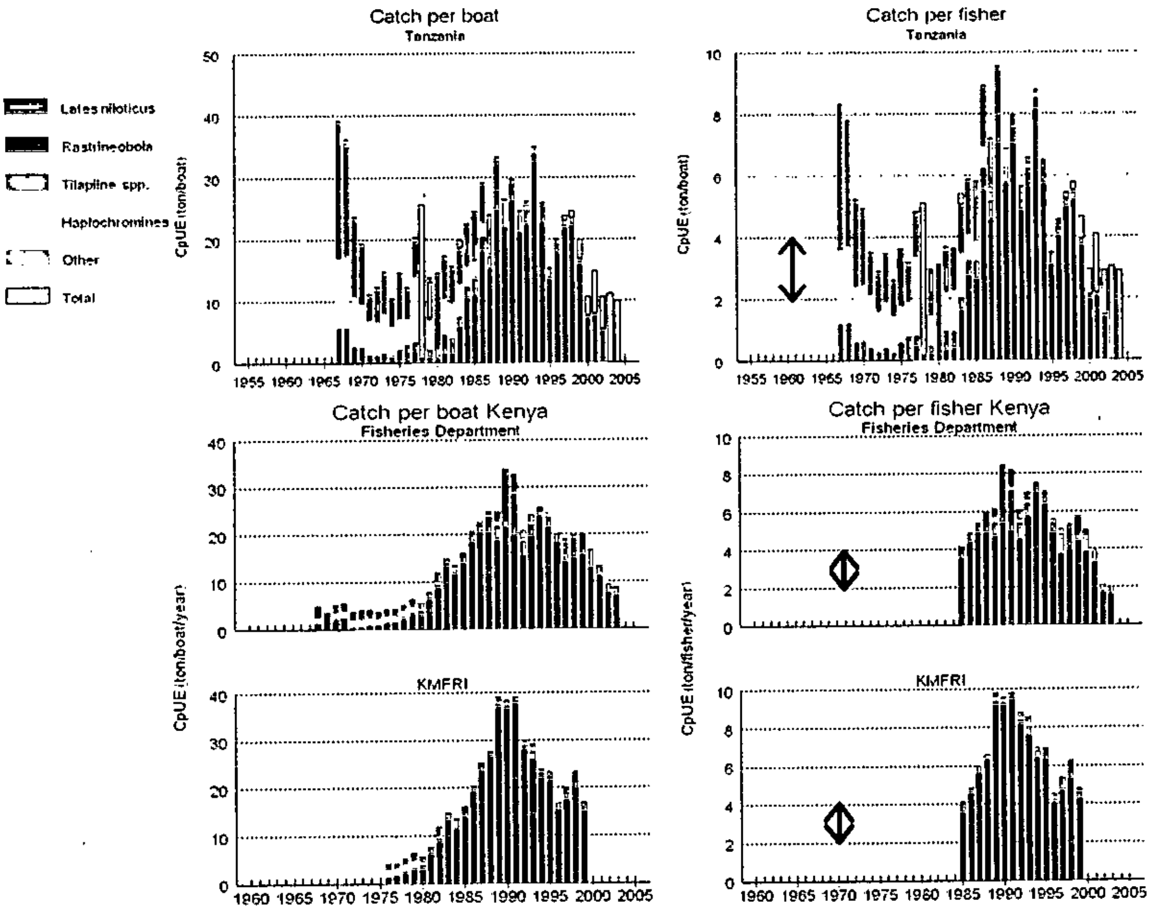



Figure 32: Developments in catch rates (ton/year/boat or ton/year/fisher) in Tanzania, Kenya. The arrows indicate the range of catch rates that is found in most fully exploited African lakes (see figure 69) Note that the catch rates of all species categories including Lates niloticus (Nile perch) are severely underestimated in years where a category "All species" is indicated (Source: CEDRS Tanzania, Kenya).

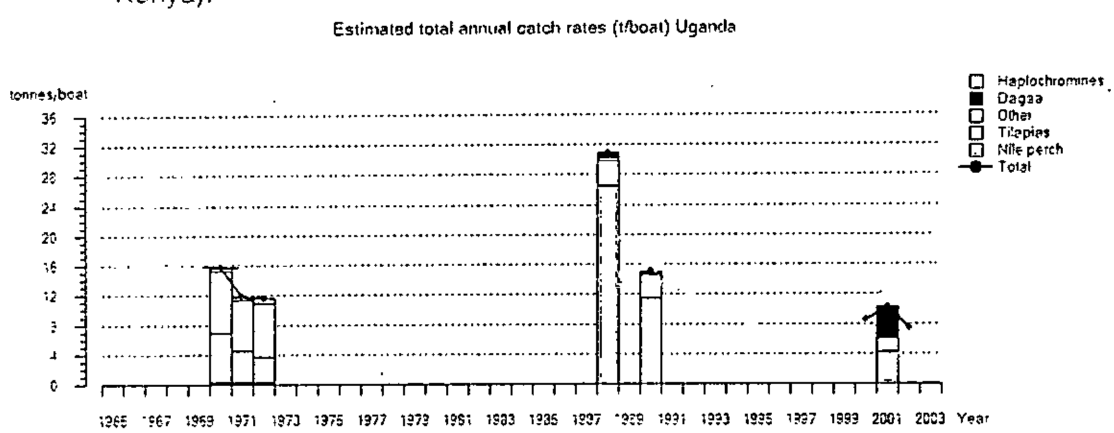



Figure 33: Developments in catch rates (ton/year/boat or ton/year/fisher) in Uganda (Source: CEDRS Uganda)

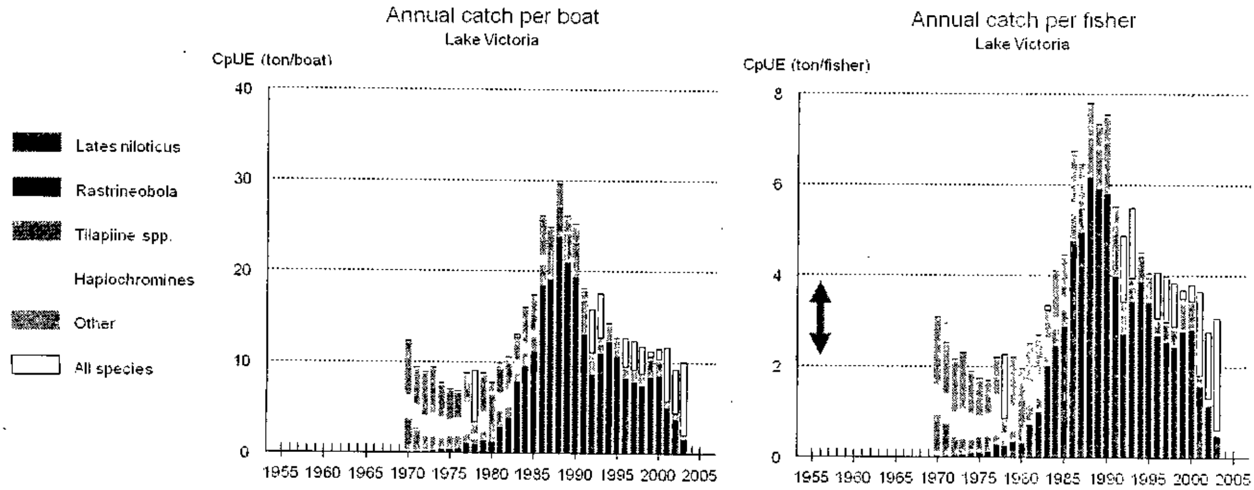



Figure 34: Trends in overall catch rates (ton/year/boat or ton/year/fisher) in Lake Victoria. Total effort on the lake was estimated by linearly extrapolating the numbers of fishermen and boats between years for which data were available. Catch rates were subsequently estimated by dividing the total catch (Figure 37) with the total effort (Figure 38). The arrows indicate the range of catch rates that is found in most fully exploited African lakes (see figure 69). Note that the catch rates of all species categories including Lates niloticus (Nile perch) are severely underestimated in years where a category "All species" is indicated (Source: CEDRS Tanzania, Uganda, Kenya).

The indicator shows changes in CPUE over time which reflects the average return on effort by individual fishermen or by single boat. Under certain conditions it also reflects the available stock for the fishery depending to a large extent on their spatial effort allocation. Overall recorded catch rates over all species of the lake have declined from between 6-7 ton/fishermen/year in the late eighties to about 3 ton per fishermen per year since 2000. The average CPUE for many African lakes is 3 tonnes per fisherman per year (Fig' 69).

**Indicator use:** Catch rates are the single most important indicator to assess the status of a fishery. It is central to any assessment of states, trends and causes of states and trends through relations with top down and bottom up processes. Time series of catch rates can be correlated to time series of indicators of these processes to assess the likely mechanisms of change.

**Data availability:** Data on catch and effort are presently only available in aggregated format, which means that the presented catch-rates can only be based on these aggregated data. Original data from Catch Assessment surveys or catch and effort data aggregated on the level of the surveys could give a much more detailed view on the developments in overall catch rates including an assessment of the variability in the data, and the uncertainty of the estimates. At present no such analysis can be done: this causes that the data presented are prone to contention. As it is well known that the present CEDRS in all countries involved is not well organized this cannot be resolved at present. It is therefore of utmost importance that a well organized CEDRS is developed and implemented.

## Catch and effort indicators

23) Annual catch

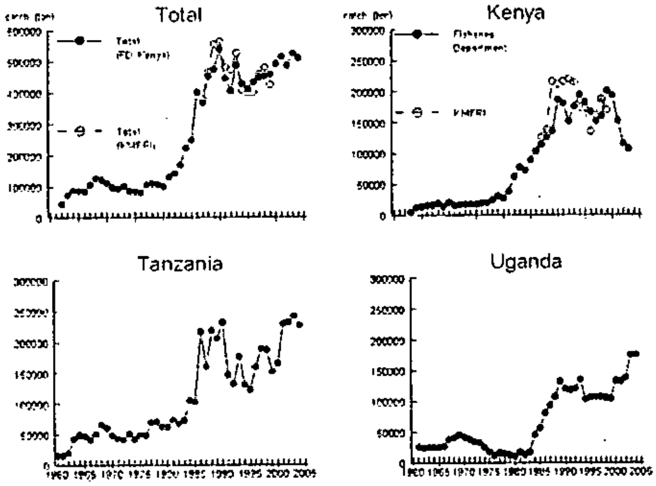



Figure 35: Total catch by country. In Kenya the Fisheries Department and KMFRI have separate CEDRS with diverging overall estimates of the total catch. No information was obtained on the procedures to arrive at the two estimates (Source: CEDRS Tanzania, Uganda, and Kenya).

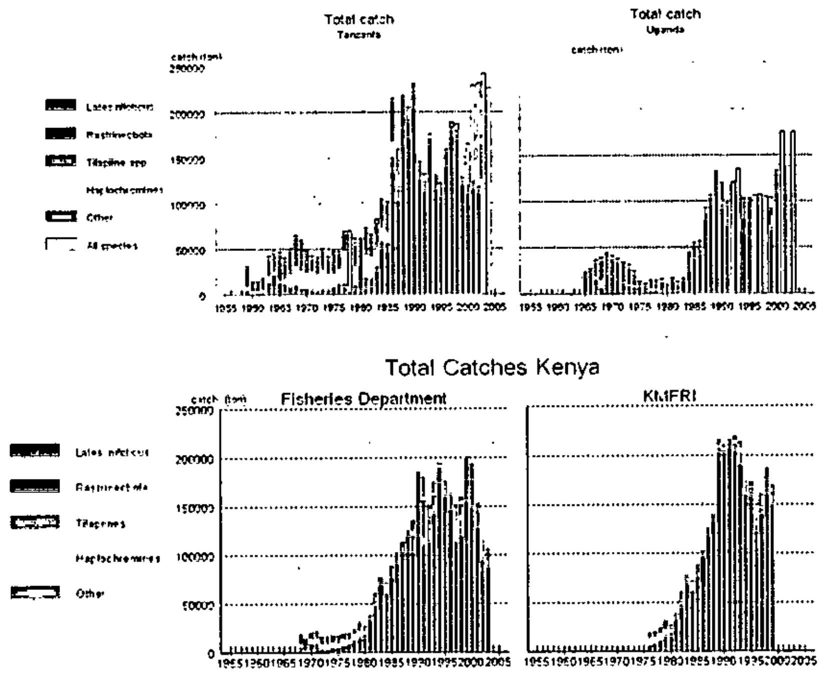



Figure 36: Total catch by species country. In Kenya the Fisheries Department and KMFRI have separate CEDRS with diverging overall estimates of the total catch. No information was obtained on the procedures to arrive at the two estimates (Source: CEDRS Tanzania, Uganda, and Kenya). Note that the catch estimates of all species categories including Lates niloticus (Nile perch) are severely underestimated in years where a category "All species" is indicated (Source: CEDRS Tanzania, Uganda, Kenya).

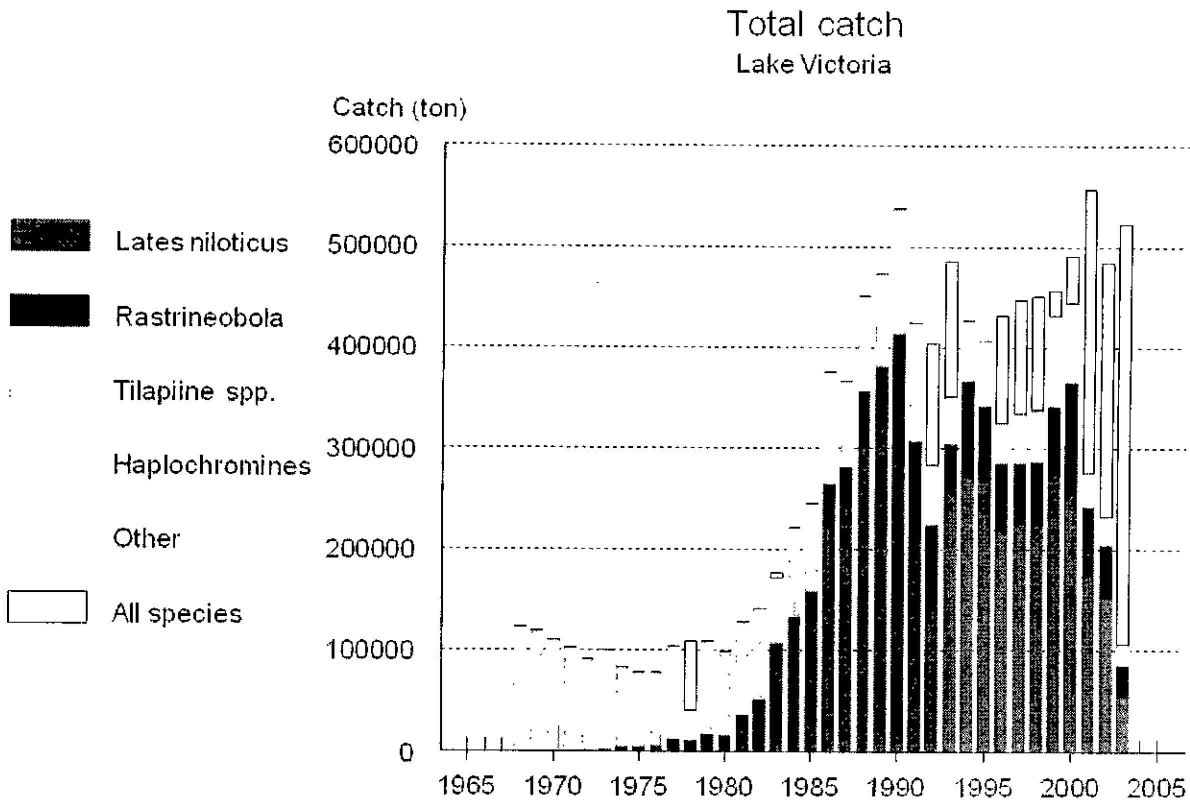



Figure 37: Total catch of Lake Victoria by species. For Kenya the data of the DoF are used as these represent the longest time series. Note that the catch estimates of all species categories including Lates niloticus (Nile perch) are severely underestimated in years where a category "All species" is indicated (Source: CEDRS Tanzania, Uganda, Kenya).

The fishery can be divided into three phases; pre-Nile perch (1970-1980), exponential growth (1981-1993) and the stabilization phase (from 1994 to present). The total catch of Lake Victoria increased dramatically during and after the nile perch boom and has since remained stable between 400 000 and 500 000 ton.

According to KMFRI's catch records Dagaa constituted about 77,000 metric tones, or 44% of fresh fish landed on the Kenyan sector of the lake in 1995 (Abila and Jansen 1997). It has constituted between 37- 45% of the total annual catch in the past (Othina and Osewe Odera, 1996). It is expected that the contribution of dagaa to the catches in both Tanzania and Uganda will not differ much from Kenya. Thus the total catch of Rastrineobola is severely underestimated in the total catch estimates of Lake Victoria.

**Indicator use:** Catch data are the single most important indicator to assess the overall production of the lake both from a biological as well as from a national economic point of view.

**Data availability:** Data on catch and effort are presently only available in aggregated format, which means that the presented catch data can only be assessed based on these aggregated data. Original data from Catch Assessment surveys or catch and effort data aggregated on the level of the surveys could give a much more detailed view on the developments in overall catches including an assessment of the variability in the data, and the uncertainty. At present no such analysis can be done: this causes that the data presented are prone to contention. As it is well known that the present Catch and Effort Data Recording System in all countries involved is not well organized this cannot be resolved. It is therefore of utmost importance that a well organized CEDRS is set-up in Tanzania, Uganda and Kenya.

24) Effort: numbers of boats and fishers; numbers of fishing gears

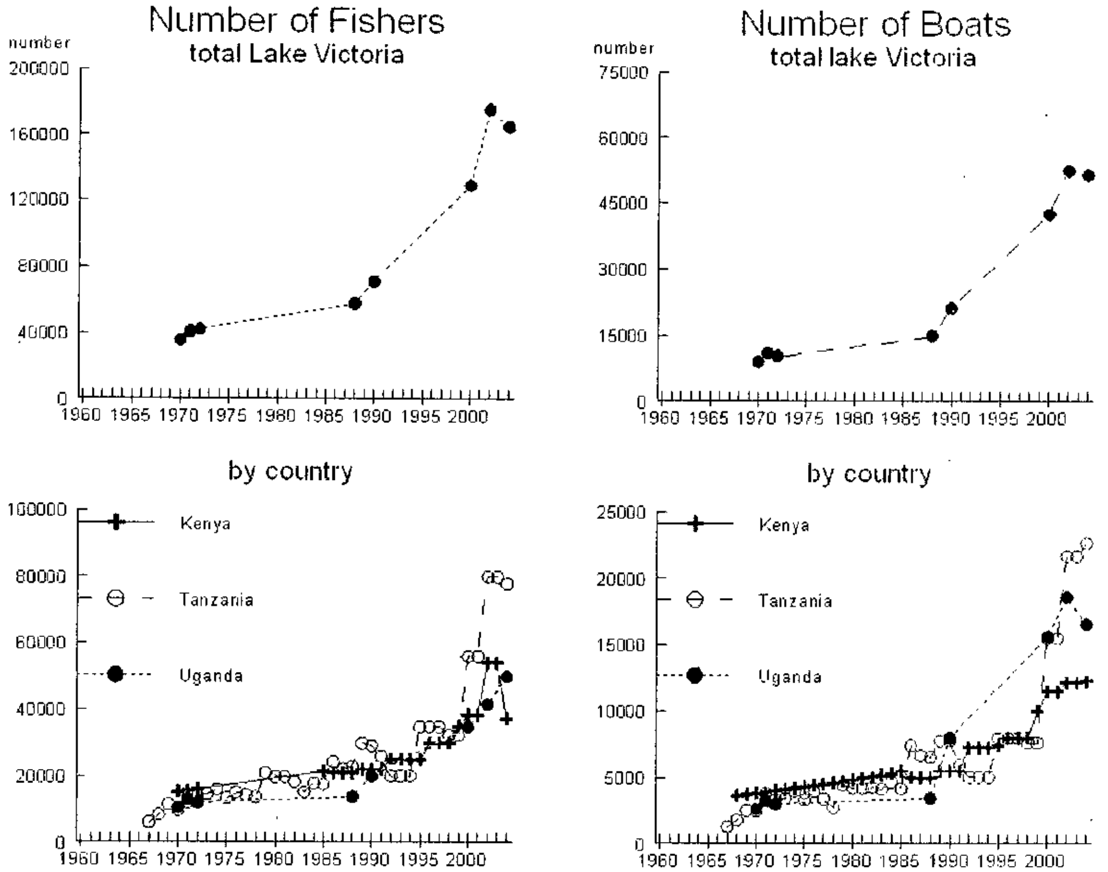



Figure 38: Fishing effort by country by total number of fishers and boats. The data points in the upper graphs represent the years in which all countries have reported effort data. (Source: CEDRS of Tanzania, Uganda and Kenya).

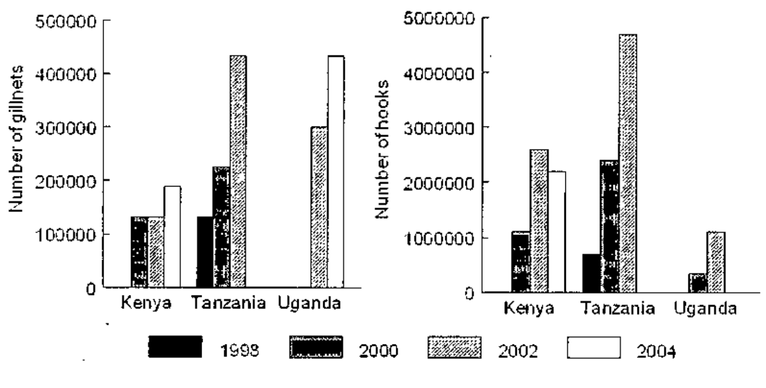



Figure 39: Fishing effort by country by total number of gillnets and hooks (for longlines) by framesurvey (year). (Source: CEDRS of Tanzania, Uganda and Kenya).

The fishery in terms of catches can be divided into three phases; pre-Nile perch (1970-1980), exponential growth (1981-1993) and the stabilization phase (from 1994 to present). Fishing effort appears to follow the developments in the stocks closely, with a rapid increase in overall effort - expressed here in numbers of fishermen and boat – between 1980 and 2003. At present numbers appear to stabilize (Figure 38). Measures of fishing effort expressed in numbers of gears show a rapid increase in numbers of gillnets and longlines between 1998 and 2004 (Figure 39). We refer to the reports on the frame surveys conducted between 1998 and 2004 for a more detailed analysis of recent shifts in the fishery. The stabilization in numbers of boats and fishermen, the recent increase in numbers of gears, the recent diversification of gears and a possible divergence of the fishery offshore point to an increased competition on resources between fishermen to stabilize their daily outcome. In this respect Lake Victoria is now comparable to other African Lakes again (Figure 69).

**Indicator use:** Overall fishing effort by numbers of fishermen, boats and gears is the single most important measure of fishing pressure on stocks. They are obtained through frame-survey's that need to be held regularly. Total catches from the fishery are calculated by raising catch rates obtained through Catch Assessment Surveys with effort data. The Effort indicators are also highly useful as economic indicators both to assess movements of labour into and out of the fishery (van Zwieten et al. 2003a) and as assessment of the level of investments into the fishery (van Zwieten et al. 2003b; figure 43).

**Data availability:** Data availability is shown in the figures 38 and 39. As measures of fishing effort are essential to assess total input and calculate the total output of the fishery it is therefore of utmost importance that a well organized CEDRS is set-up in Tanzania, Uganda and Kenya.

25) Spatial distribution of fishermen

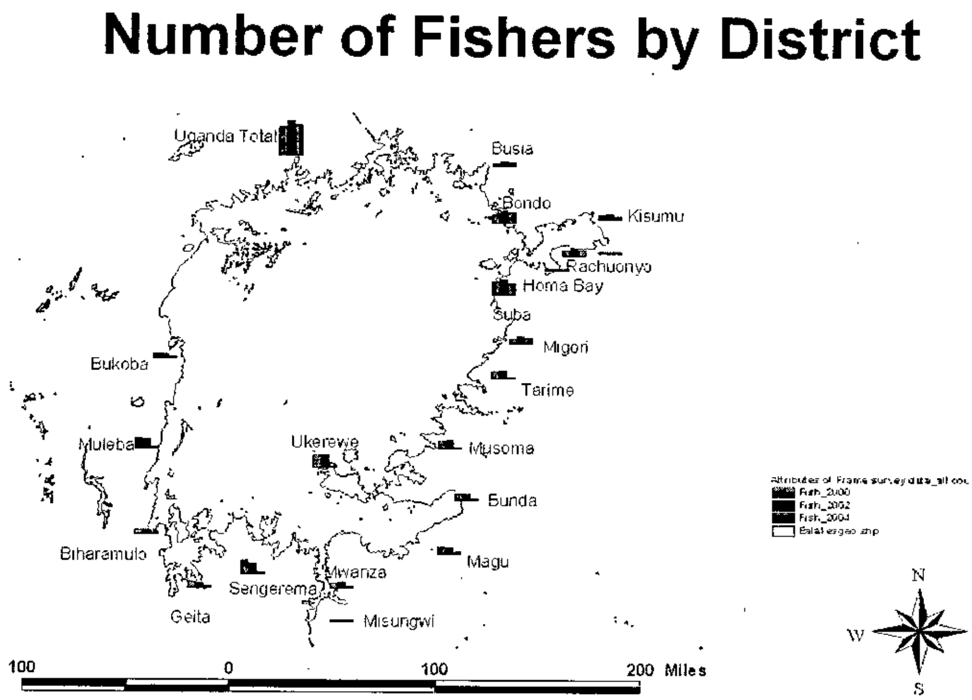



Figure 40: Effort distribution of fishermen over the Lake (Source: Frame surveys 2000 2002 and 2004 in Tanzania, Uganda and Kenya).

The indicator provides an overview of the spatial allocation of fishing effort. Particularly interesting in figure 40 is the lowered number of fishermen in most districts in 2004 compared to the previous frame-survey year, indicating a possible movement of fishermen out of the fishery. In Kenya, fishing effort is concentrated in the districts outside the Winam gulf. Because of time constraints and non-availability of long term data on distribution of fishermen over the lake it was not possible to assess whether this concentration of fishermen was a recent phenomenon indicating a movement of fishermen out of the Winam gulf or a historically normal state of affairs. As the Winam gulf is a potential area in which the effects of eutrophication of fish stocks would be felt at an early stage, which also would mean that fishermen would move out of the area if stocks declined as a result if this, this indicator will be particularly important to monitor (van Zwieten et al. 2005).

Cowx et al. (2005), assert that there is a distinct regional variation in gears. They say (not show!) that for example, in areas close to processing factories gill-nets and longlines, targeting nile perch, are the most commonly used gears. These are the areas outside the more isolated western coast of the Lake. Diversification of gears was greatest in the western part of the lake. Also other measures of effort show a clear distinction in the distribution of fishing patterns over the lake. This is particularly useful information when assessing the need and effect of lake wide effort measures in a co-management context.

**Indicator use:** Effort data obtained through frame-survey's are generally underutilized, as they often are only used as raising factor to establish total catch. However, much more information can be gleaned from them (see Indicator 24). A particularly useful way of assessing changes in the fishery is a spatial distribution of fishing effort as a measure of local overfishing.

26) **Data availability:** Frame survey data, also historically, can be aggregated by district. No data were available to make such an assessment. Figure 40 was taken directly from the Kenya National Synthesis Report. As measures of fishing effort are essential to assess total input and calculate the total output of the fishery it is therefore of utmost importance that a well organized CEDRS is set-up in Tanzania, Uganda and Kenya.

27) Different estimates of MSY over the years

**Indicator use:** The classical approach to a rational exploitation of fish stocks involves the control of fishing mortality (effort and fishing methods) in such a way that annual catches of specific stocks can be continued indefinitely according to pre-determined objectives related to the productivity at different stock levels. The catch-effort curve of sustainable yields (Schaefer 1954) exemplifies this approach: at any level of fishing effort up to the level where the 'surplus yield' is maximised, a yield can be found that is theoretically sustainable and stable. Which level of fishing effort is chosen depends on a number of strategic objectives (Salz 1986) such as securing a minimum biomass, maximise food production (MSY), maximise the resource rent (maximum economic yield, MEY) or employment. Of these objectives, the concept of Maximum Sustainable Yield (MSY) at which effort levels should be set in order to maximise food production has gained most prominence. Various models estimating MSY, or maximum yield per recruit, have been used extensively in African fresh water fisheries, and the concept of MSY has formed part of the research goals in many fisheries development projects as well (Kolding 1994). The biological assumptions of the surplus-production models most often used in the African context, the Schaefer model, are described in the next section (page 90). Predicted MSY from these models, when fitting with only data points on the ascending side of the yield-effort curve, are always very close to the actual current mean catch and consequently the usual conclusions are that the effort level is, at the time of the investigation, at its limit. Actually, Hilborn and Walters (1992) concluded that it is simply not possible to find the top of a yield curve without going beyond the top, or in their words: "*You cannot determine the potential yield from a fish stock without overexploiting it*". A critical assessment of whether this was indeed the case also in the Lake Victoria situation and the consequences for management advice would be highly informative.

**Data availability:**
No MSY estimates were obtained; no assessment of the different estimates over time could be made.

## Social and economic indicators

28) Contribution of fisheries to GDP

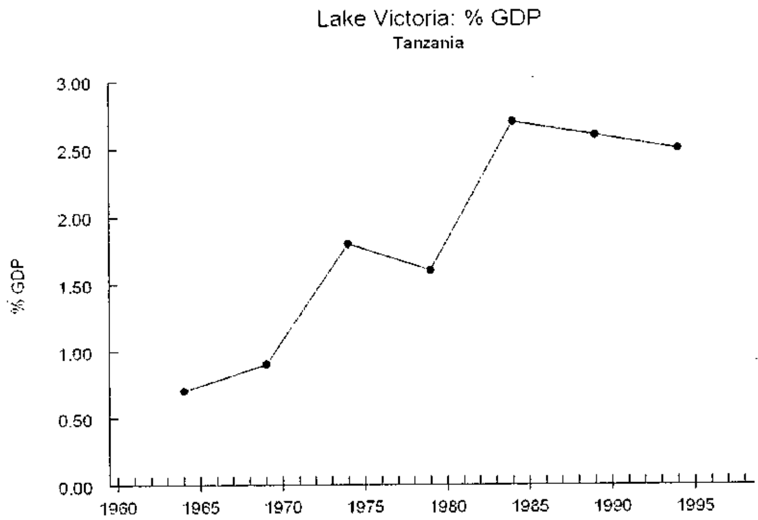



Figure 41: Contribution of fisheries to GDP (Source: Tanzania National Synthesis Report on Fisheries Research and Management)

The fisheries contribution to the GDP in Tanzania has grown since 1964, but appears to stabiles in recent years at around 2.6%.

**Indicator use:** The indicator is one measure of the economic importance of the Lake Victoria contribution to the national economy. We do not know what is included in the measure and if it reflects all economic activities derived from fishing.

**Data availability:** No data are available from Kenya and Uganda.

29) Contribution of Nile perch to domestic food supply

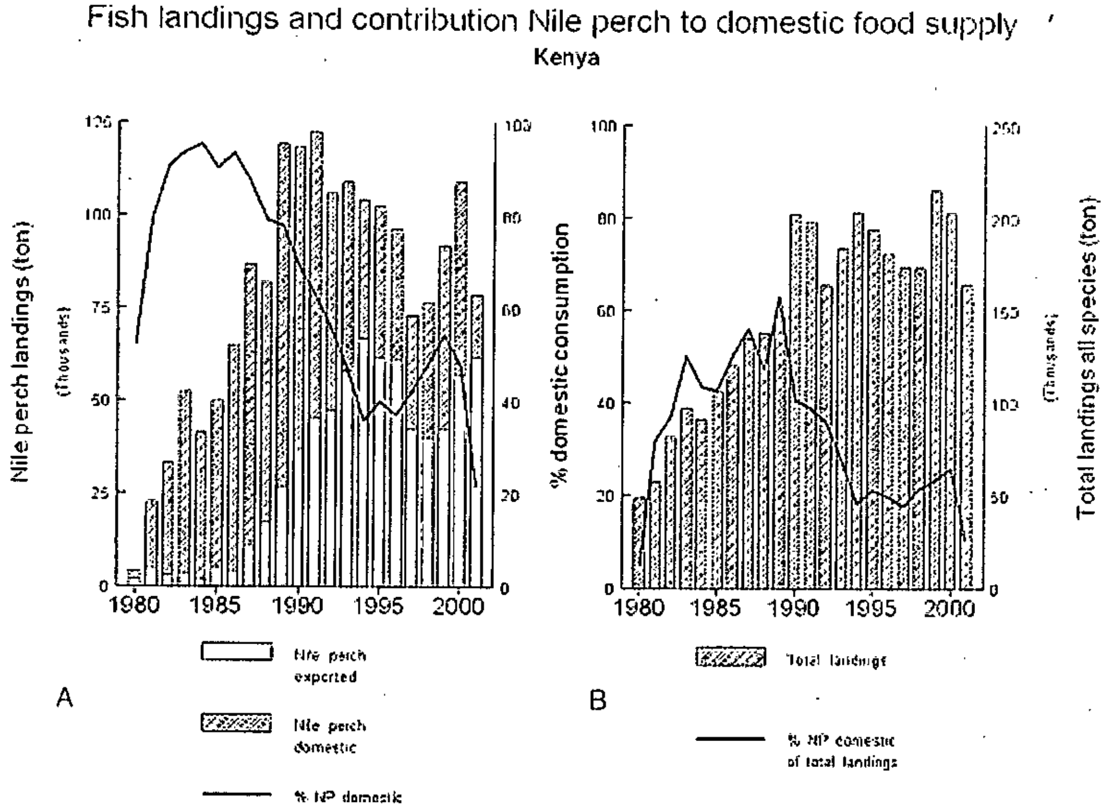



Figure 42: A. Contribution of Nile perch to domestic food supply compared to the total landings of Nile perch. B. The contribution of Nile perch to domestic food supply compared to the total fish landings. (Source: Kenya National Synthesis Report on Fisheries Research and Management)

Prior to 1985, there was an increasing contribution of Nile perch to domestic food supply (90%) declining to less than 25%of total Nile perch landings in 2001 due to increased export (A). Figure B shows that after 1989 Nile perch became increasingly less important as a source of domestic food, stabilising in the late nineties at around 20% of the total landings, dropping since 2000 to around 10%.

**Indicator use:** The contribution of Nile perch to domestic food supply is an indicator of availability of protein food to the populations of the three countries.

**Data availability:** No data were available for Tanzania and Uganda

30) Boat owners, fishermen crew

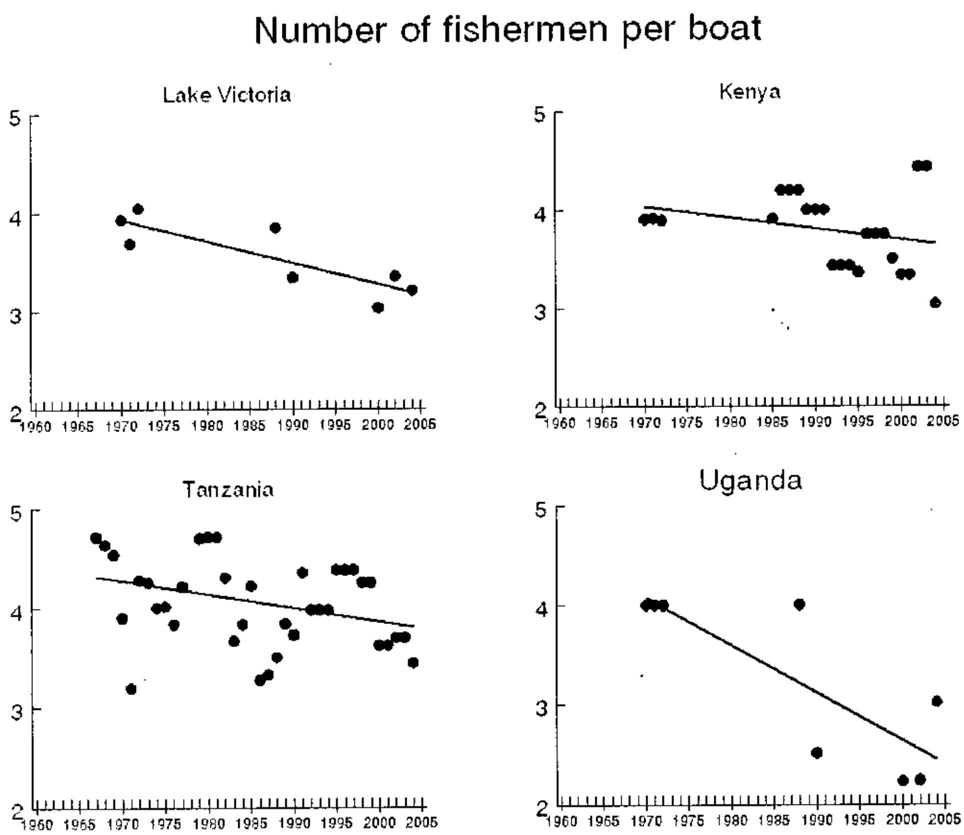



Figure 43: Changes in number of fishermen per boat in Lake Victoria.

The number of fishermen per boat is decreasing in all countries. As the number of boats has been increasing rapidly (indicator 24) it appears that the level of investment per fisherman increased over the period examined.

**Indicator use:** The number of boat owners relative to the number crew would be an indicator of the level of investment into the lake as boats are often the most expensive piece of equipment used by a fisherman (van Zwieten 2003b). As no separate information is available on boats, owners and crew, we have assessed the total number of fishermen relative to the number of boats.

**Data availability:** Data from frame-survey's are available

31) Export volumes and values

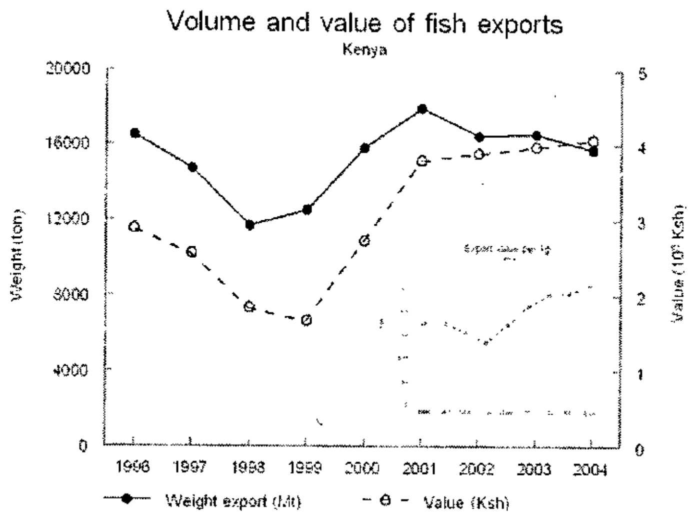



Figure 44: Fish export and value of Nile perch from Kenya (Source: Kenya National Synthesis Report on Fisheries Research and Management)

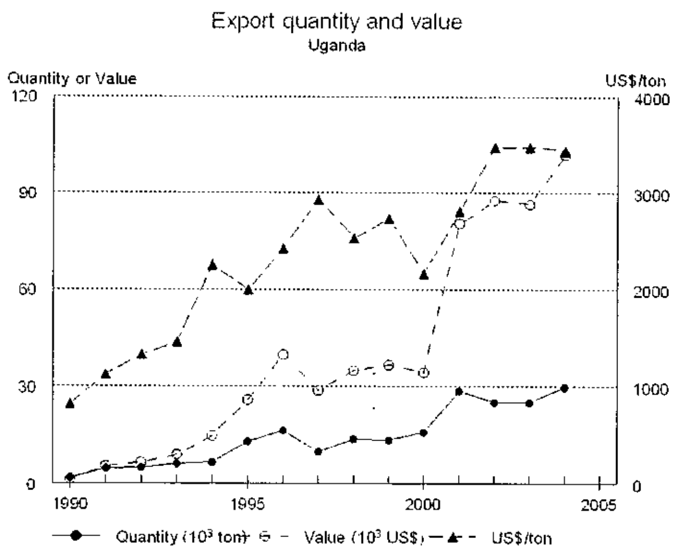



Figure 45: Fish export and value of Nile perch from Uganda (Source: Uganda National Synthesis Report on Fisheries Research and Management)

Fish exports from the three countries have continued to rise from the 1990s to the present.

**Indicator use:** The fish export and value is an indicator of contribution of the sector to foreign exchange earnings, employment, revenue and earnings to fishers. It is a measure of the health of the fishing industry but can also be an indication of food insecurity when no fish is reserved for local consumption.

**Data:** The data are available in the three countries on a monthly basis.

32) Level of education (by age group)

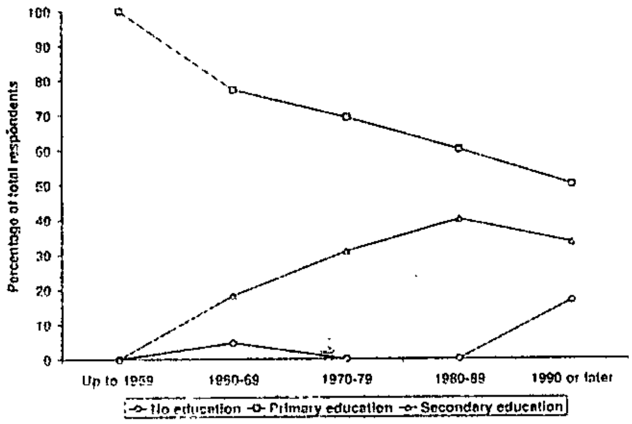



Figure 46: The level of education of fishermen in Lake Victoria-Kenya (Source: Kenya's National Fisheries Research and Management Report)

Table 3 Changes of educational level of the fishers from 1960 to 1990s and beyond. Source: Wegoye et.al 2003, FIRRI 2002

| | 2002 (n=21) | 2003 |
|---|---|---|
| No schooling | 11.2% | 17% (n= ) |
| Primary education | 66% | 63% (n= ) |
| Secondary education | 28% | 19% (n= ) |
| Tertiary education | 4.8% | 1% (n= ) |

Table 4: Level of education among fishers (Source: Tanzania National Synthesis Report on Fisheries Research and Management)

| | *Reference* | | | | |
|---|---|---|---|---|---|
| | Leendertse 1993 Kagera | Kulindwa 2001 | Kisusu and Onyango 2001 | Muro et al 2005 | Kilosa et al 2004 |
| **Various levels** | *Percent* | | | | |
| Primary | 66 | 82.4 | 82.1 | 70.8 | 88 |
| Secondary | 12 | 12.3 | 11.2 | 7.1 | 12 |
| College | 1 | 0.5 | 0.4 | 1.6 | 0 |
| No Schooling | 11 | 4.6 | 6.3 | 20.5 | 0 |
| Informal | 0 | 0.2 | 0 | 0 | 0 |

Source: Tanzania National Synthesis Report on Fisheries Research and Management

**Indicator use:** This indicator shows the variations in the level of education and hence knowledge level among the fishermen. It is an indicator of the ability to implement co-management through the BMUs and better opportunities to adopt new technologies. This is a good indicator of where emphasis should be put in capacity building.

**Data availability:** Data are available but should be harmonised between countries to enable both aggregation over the region and comparison by relevant spatial unit (village, district, country etc.)

33) Total earnings in fishery

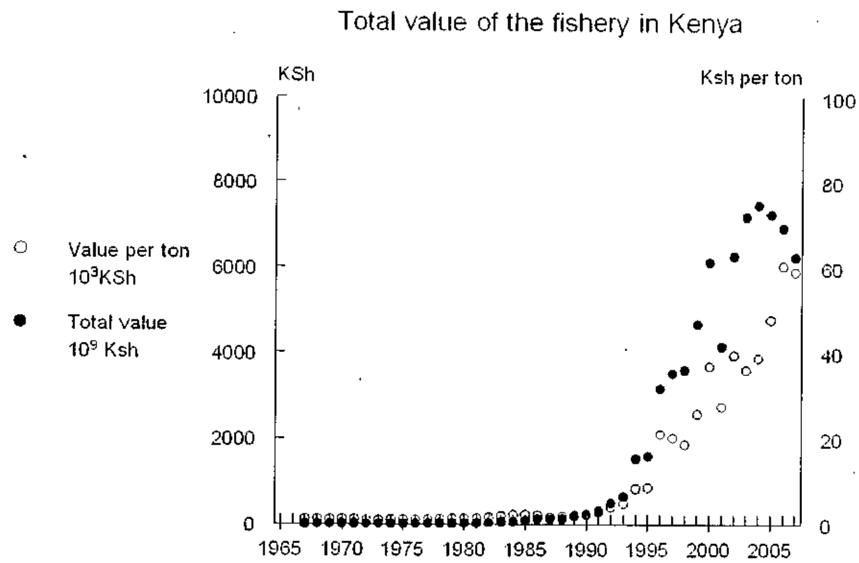



Figure 47: Total earnings from fishery of Lake Victoria – Kenya (Source: Fisheries statistics Kenya)

The sharp increase in total earnings in the 1990s is associated with increase in the number of fish processing factories. It could not be assessed what economic activities directly related to fishing are included in this indicator.

**Indicator use:** The total value of fish is an indicator of the economic importance of fish export.

**Data availability:** No data were available for Tanzania and Uganda. The indicator requires a more thorough investigation into what is and what is not included in the value. Data should be harmonised between countries to enable both aggregation over the region and comparison by relevant spatial unit (village, district, country etc.)

34) Fish prices

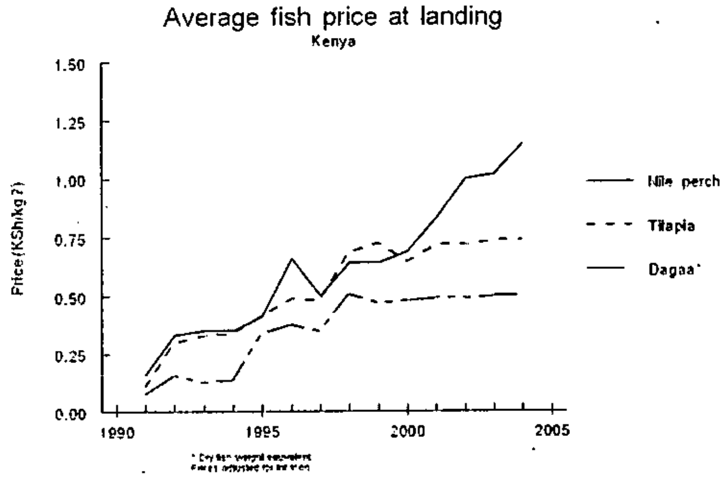



Figure 48: Average fish price at landing site in Kenya (Source: Kenya National Synthesis Report on Fisheries Research and Management)

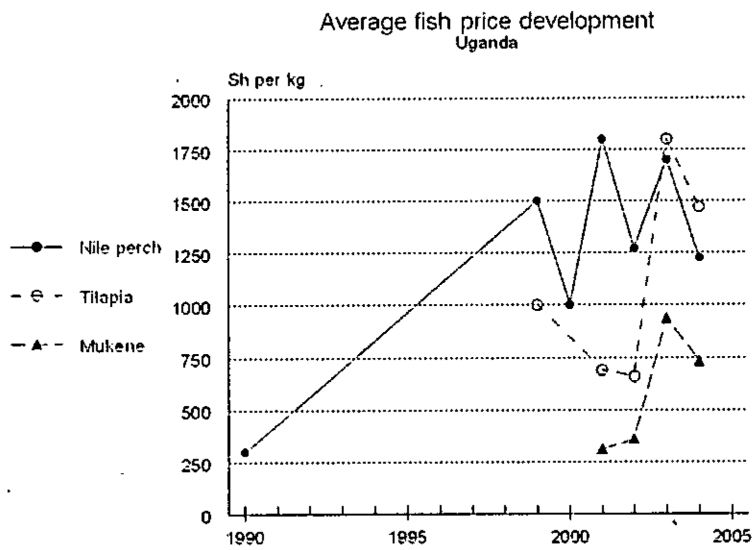



Figure 49: Average fish price at landing site in Uganda (Source: Uganda National Synthesis Report on Fisheries Research and Management)

Prices remained stable and inelastic for a long period of time (Reynolds and Greboval, 1998) until the advent of fish processing plants. When Nile perch started dominating the catches, prices increased. Towards the end of the 1990s and early 2000s, prices in Tanzania moved to a landmark of about Tshs 1000 (1 USD).

**Indicator use:** Fish prices are indicators of both demand and supply factors as well as the propensity to spend. The buyers are willing to pay for the market value of the fish commodity. The fish price change is responsible for influencing the general fish prices. The increase in prices and higher income may have led to improved capacity of the fishermen to invest in boats (indicator 30).

**Data availability:** No data were available for Tanzania. Data should be harmonised between countries to enable both aggregation over the region and comparison by relevant spatial unit (village, district, country etc.)

35) Per capita fish consumption

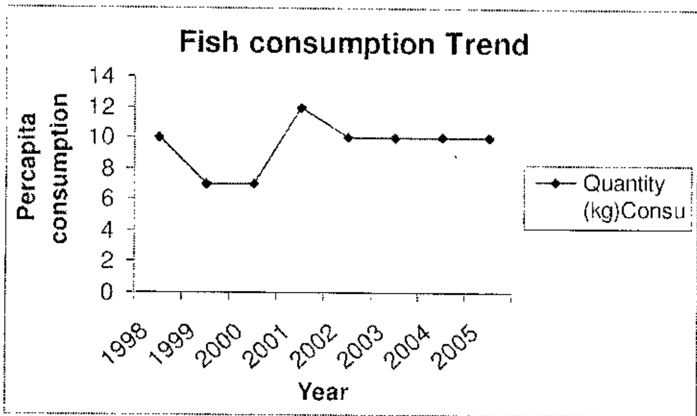



Figure 50: Variations in per capita fish consumption in Uganda (Source: Uganda National Synthesis Report on Fisheries Research and Management)

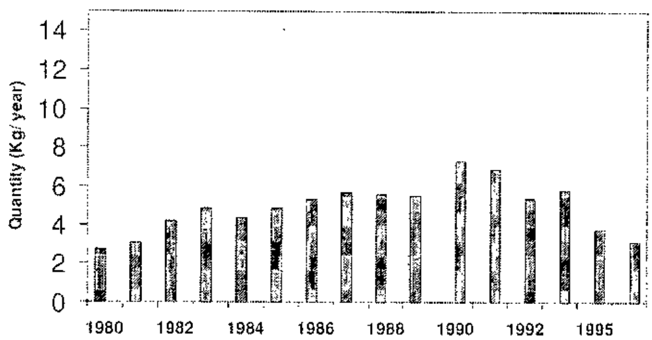



Figure 51: Variations in per capita fish consumption in Kenya (Source: Kenya National Synthesis Report on Fisheries Research and Management)

Per capita fish consumption fluctuates around 10 kg/person per year while that in Kenya increased from around 3 kg/year to 7 in the early nineties dropping to betwene3-4 kg in the late 1990s. It is not known what the contribution of Lake Victoria is to the per capita fish consumption in both countries. No data are available for the protein intake by the riparian communities based on Lake Victoria fish. For Tanzania FAO has calculated that the contribution of fish as animal protein fluctuates between 30 and 35% over the period from 1976 to 2001 (Tanzania National Synthesis Report).

**Indicator use:** This indicator shows the availability of fish for local consumption and the ability to purchase fish. This is an indicator of disposable income but is influenced by supply and demand.

**Data availability:** No data were available for Tanzania. Data should be harmonised between countries to enable both aggregation over the region and comparison by relevant spatial unit (village, district, country etc.)

36) Landing sites and factories

Table 5: Number of landing sites (Uganda)

| Year | Number of Landing Sites |
|---|---|
| 1970 | 620 |
| 1971 | 197 |
| 1972 | 244 |
| 1988 | 291 |
| 1990 | 715 |
| 2000 | 597 |
| 2002 | 552 |
| 2004 | 554 |

Source MAAIF. DFR 2004

A landing site is a place along the lakeshore where boats anchor or land to discharge fish catches. There are fish landing beaches that are not recognized by the Government but could be well known to the communities for social activities. Gazetting of a beach follows a procedure where inspection for the minimum requirements of social amenities is carried out. There are approximately 307 gazetted fish landing beaches in the Kenyan section of lake Victoria. Those that qualify to be gazetted are listed in the official government newsletter "The Kenya Gazette" and become recognized places for landing and subject to all requirements as contained in the legal provisions. In Uganda, there were 554 landing sites in 2004 while in Tanzania, there were 575 landing sites. Those beaches that do not meet the minimum requirements may remain social beaches but the government operations will not recognize them and any infrastructure developments cannot take place.

**Indicator use:** Uncontrolled establishment of landing sites is an indicator of abundance and demand for fish and a measure of dispersion of the fishery. Reduction in the number of landing sites is a result of response to the establishment of Beach Management Units (BMUs) around the Lake.

**Data availability:** No data were available for Kenya and Tanzania. Data should be harmonised between countries to enable both aggregation over the region and comparison by relevant spatial unit (village, district, country etc.)

37) Animal feed production from "dagaa"

Table 6: The table below shows the quantities of dagaa used by the milling companies in 1996 (FISHING IS DONE ONLY TWO WEEKS DURING DARK PHASES OF THE MOON – 15 WEEKS PER YEAR OF PRODUCTION ON AVERAGE)

| *Milling Company* | *Quantity of* **Dagaa** *Utilized (Tons per week Wet Weight)* | *Animal Feeds output (Tons / year)* | % |
|---|---|---|---|
| O | 30,000 | 150,000 | 56 |
| P | 10,000 | 50,000 | 19 |
| Others | 13,000 | 65,000 | 25 |
| Total | 53,000 | 2650,000 | |

*Source: Abila and Jansen 1997*

The consumption of fish species that should otherwise be used for fishmeal implies the limited availability and/or high prices for large table fish for human consumption (e.g. Nile tilapia and Nile perch) that are currently targeting export market. Previously Dagaa has been mainly used as food for humans and has often been referred to as the "poor man's food". The animal feeds industry started using Dagaa as the main source of crude protein in the industry in the early 1990s. The present limitation and competition is not caused by limited availability of stocks in the lake that can withstand high fishing pressures, but is probably caused by limitations in fishing effort and hence market availability. The "dagaa" that is destined for fishmeal production is often mixed with haplochromines and *Caridina.*

In Uganda, the main animal feed processor (Novita in Jinja) uses "dagaa" as one of the main sources to manufacture animal feeds and fish feeds. Other minor factories include Ugachic and Bugeree in Kampala. In Kenya, the main millers are Unga Feeds and United Millers. Main fishmeal factories in Tanzania are based in Dar-es-salaam.

The fish meal industry in Kenya has continued to expand, stimulated by export to the neighbouring countries, who in return export dried Rastrineobola to Kenya. Even as the amount of Nile perch offal from factories for fish meal reduction increased, the industry soon turned to 'dagaa'. Dagaa proved to be an even richer source of crude protein for animal feeds. In 1995, the fishmeal industry in Kenya was using about 69% of 'dagaa' that was landed on the Kenyan part of Lake Victoria (Abila and Jansen, 1997). In 1999 another fishmeal factory with an additional capacity of 40 tonnes per day was constructed near Kisumu (Abila, 2000). The advantage of using 'dagaa' in fishmeal vis-à-vis for human consumption has generated some controversy.

**Indicator use:** An indication for the demand for fish for this industry, and with that an indication of the pressure on small size fish (including haplochromines) and stocks low in the foodweb (*Rastrineobola, Caridina*).

**Data availability:** no data are available from Tanzania and Uganda

38) Number of processing plants

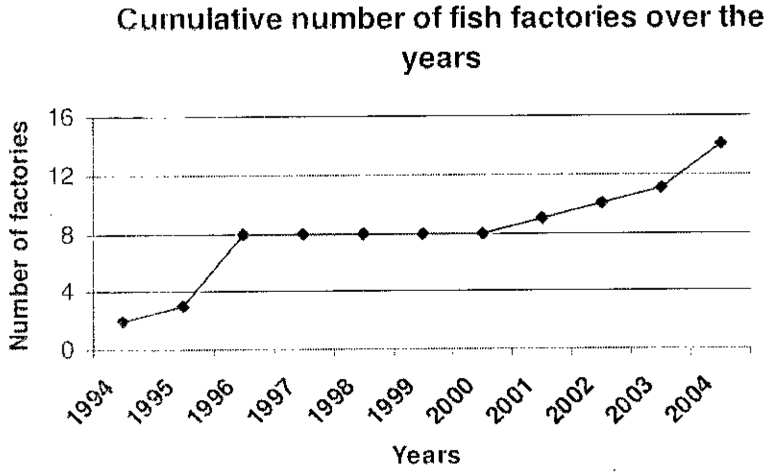



Figure 52: Cumulative number of fish factories over the years in Uganda (Source: Uganda National Synthesis Report on Fisheries Research and Management)

Although the number of factories has gone up in all three countries, they are not operating at their established capacities indicating an overcapacity.

**Indicator use:** The establishment of fish processing factories is an indicator of investment in the fisheries sector and with that a measure of pressures on stocks.

**Data availability:** No data available for Tanzania and Kenya.

**Monitoring, Control and Surveillance, Co-management, Fish Quality Assurance, Fish levy trust**

39) Beach Management Units (BMU's)

Table 7: Development of functional Beach Management Units (BMUs) in Lake Victoria

| **Key output indicator:** No. of functional BMUs each year | **1997** | **1998** | **1999** | **2000** | **2001** | **2002** | **2003** | **2004** | **2005** | **Target** |
|---|---|---|---|---|---|---|---|---|---|---|
| **Kenya** | - | | | 200 | 200 | 200 | 245 | 306 | 306 | 306 |
| **Uganda** | | | | | | | | | 330 | 554 |
| **Tanzania** | | | | | | | | | 511 | 572 |

The concept of BMUs is an innovative attempt at ensuring community participation in fisheries Management. Although the concept was initiated in 2000, the establishment of BMU's took time. At present, more than 75% of all landing beaches in Lake Victoria have functional BMUs. The concept of BMU is an indication of the ability of communities to manage their own resources and accent to ownership. The development of BMU is also expected to enable the communities to participate in fisheries statistical data collection.

**Indicator use:** The development in number of functioning BMU's is an indicator of the level of community participation in the management of the fishery.

**Data availability:** See figure 39.

40) Enforcement statistics

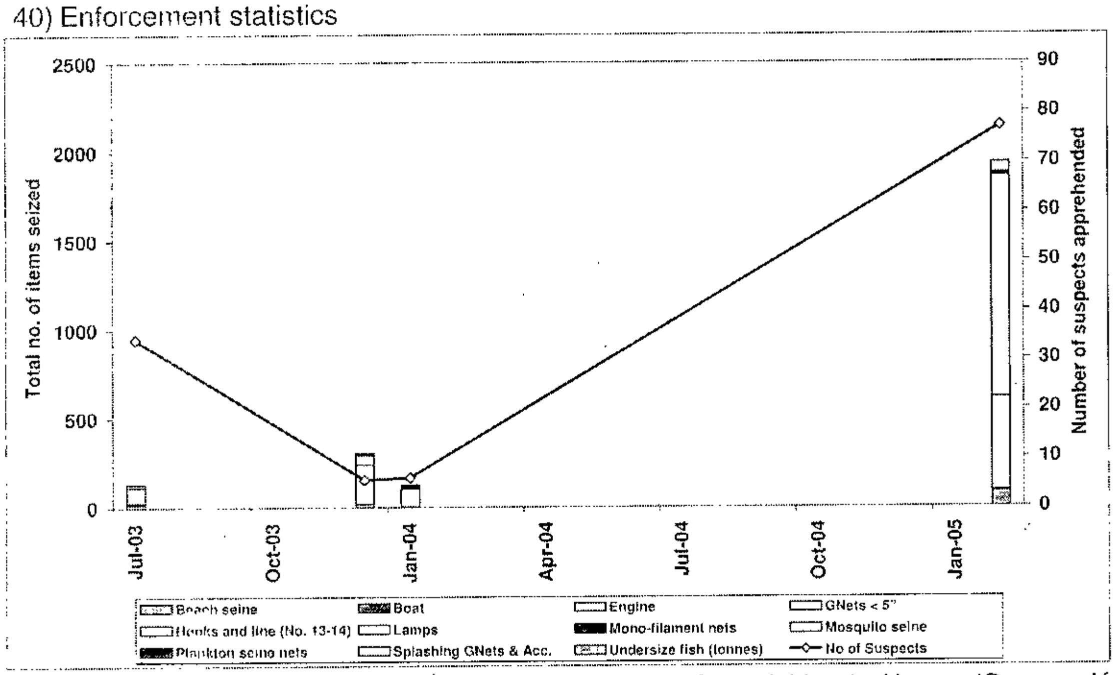



Figure 53: Monitoring, Control and Surveillance (MCS) activities in Kenya (Source: Kenya National Synthesis Report on Fisheries Research and Management)

Table 8: Illegal fishing gears recorded in Frame Survey in Lake Victoria (Tanzania side, 1998 – 2004). (Source: Tanzania National Synthesis Report on Fisheries Research and Management)

| *Year* | *Beach Seine* | *Gillnets <5"* | *Mosquito nets <10 mm* | *Katuli* | *Mono-filaments* |
|---|---|---|---|---|---|
| 1998 | 826 | 11771 | 8 | - | - |
| 2000 | 999 | 18128 | 3267 | - | - |
| 2002 | 1454 | 96832 | 4830 | - | - |
| 2004 | 1532 | 57376 | 0 | - | 5041 |

Enforcement statistics should show a declining trend to reflect compliance and effectiveness of MCS. This indicator is useful when used together with BMU should enhance the compliance. Trends in the MCS activities in all the riparian states are similar in terms of quantities of items seized and prosecutions.

**Indicator use:** Number of illegal fishing gear confiscated and number of fishers apprehended for using illegal fishing gears indicates both the level of enforcement of measures as well as the level of compliance. The indicator should be used in conjunction with measures of exerted enforcement activities to assess level of compliance.

**Data availability:** We refer to the national synthesis reports for further elaboration on these indicators. At present the reporting of data and differences in approaches between countries do not allow further aggregation of information into a regional indication of enforcement activities.

41) Number of inspectors at fish landing sites

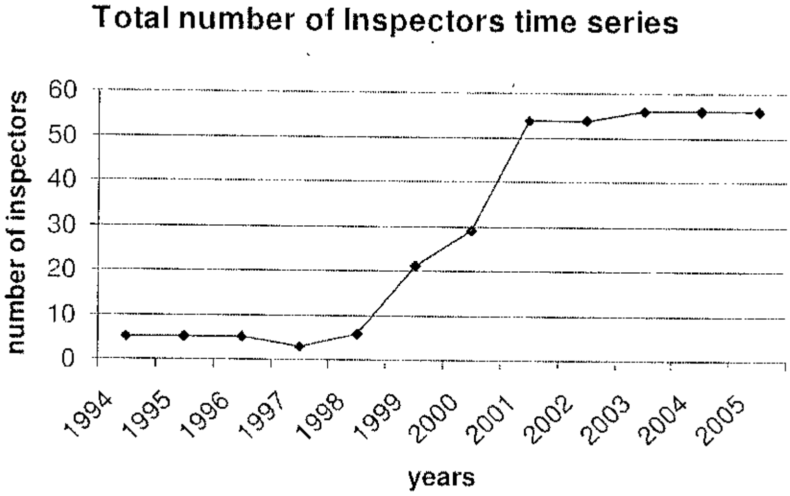



Figure 54: Numbers of Inspectors from 1994 to 2005 (Uganda). (Source: Uganda National Synthesis Report on Fisheries Research and Management).

The number of inspectors at landing sites will improve fish quality and public health. In Uganda the number of fish inspectors has increased from less than 5 in 1994 to over 55 in 2005.

**Indicator use:** Indication of the level of input in ensuring fish quality.

**Data availability:** no data available from Tanzania and Kenya.

42) Number of certified landing beaches

A landing site is a place along the lakeshore where boats anchor or land to discharge fish catches. There are fish landing beaches that are not recognized by the Government but could be well known to the communities for social activities. Gazetting of a beach follows a procedure where inspection for the minimum requirements of social amenities is carried out. There are approximately 307 gazetted fish landing beaches in the Kenyan section of lake Victoria. Those that qualify to be gazetted are listed in the official government newsletter "The Kenya Gazette" and become recognized places for landing and subject to all requirements as contained in the legal provisions. In Uganda, there were 554 landing sites in 2004 while in Tanzania, there were 575 landing sites. Those beaches that do not meet the minimum requirements may remain social beaches but the government operations will not recognize them and any infrastructure developments cannot take place.

**Indicator use:** Uncontrolled establishment of landing sites is an indicator of abundance and demand for fish and a measure of dispersion of the fishery. Reduction in the number of landing sites is a result of response to the establishment of Beach Management Units (BMUs) around the Lake.

**Data availability:** No data were available for Uganda, Kenya and Tanzania. Data should be harmonised between countries to enable both aggregation over the region and comparison by relevant spatial unit (village, district, country etc.)

### Aquaculture indicators

43) Number of new technologies generated (feeding regimes, pond siting, number of culture systems developed, number of cultured species)

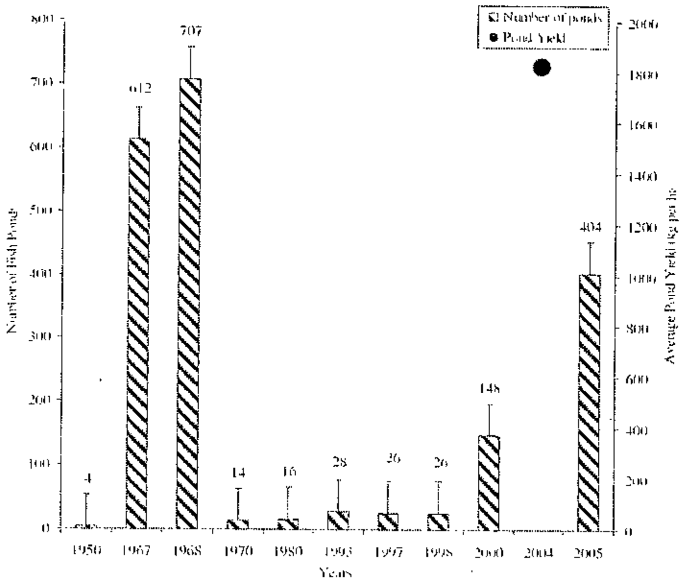



Figure 55: Total number and average yields of fish ponds in the Lake Victoria basin Tanzania. Note the significant drop in number of ponds after earlier attempts at establishing aquaculture activities (Source: Tanzania National Synthesis Report on Fisheries Research and Management)

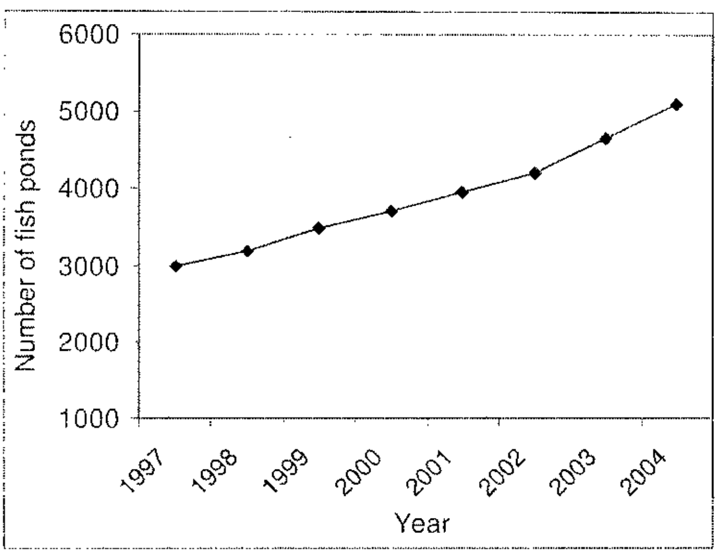



Figure 56: Developments in the establishment of fish ponds since 1997 in the Lake Victoria Basin. (Source: Kenya National Synthesis Report on Fisheries Research and Management).

Table 9: Number of new technologies generated in aquaculture in Uganda (Source: Uganda National Synthesis Report on Fisheries Research and Management)

| Output Indicator | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 |
|---|---|---|---|---|---|---|---|---|---|
| Number of fish species being cultured | 2 | 2 | 2 | 2 | 3 | 3 | 4 | 6 | 6 |
| Avg. Number of Nile tilapia fry produced and supplied to farmers( '000s) | 60 | 100 | 180 | 240 | 360 | 600 | 740 | 720 | 600+ |
| Avg. Number of fingerlings of catfish produced and supplied to farmers ('000s) | 0 | 0 | 0 | 0 | 24 | 36 | 48 | 72 | 30+ |
| Number of brochures produced | 0 | 0 | 0 | 2 | 0 | 2 | 0 | 3 | 4+ |
| Number of booklets produced | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 2 | 2+ |
| Number of technologies developed at the Research Station | 0 | 1 | 2 | 2 | 2 | 3 | 2 | 4 | ? |
| Number of fish farmers trained in aquaculture skills at Kajjansi | 0 | 10 | 20 | 24 | 28 | 24 | 15 | 48 | 22 |
| Number of service providers trained in aquaculture at Kajjansi | 0 | 4 | 6 | 7 | 6 | 6 | 5 | 4 | 6 |
| Number of ponds established in L. Victoria basin (estimate) | 3000 | 200 | 300 | 200 | 200 | 300 | 400 | 600 | 800 |
| Number of Active Fish Farmers in the Lake Basin | | | | | | | | | |
| Average size of fish ponds constructed in the Basin | <500m$^2$ | | | | | | | | 0.5ha? |
| Number of contact fish farmers involved in participatory research | 10 | 15 | 20 | 30 | 42 | 50 | 30 | 48 | 60 |

There has been a significant development of aquaculture in the Lake Victoria basin during the life of LVEMP. A number of new technologies have been developed, number of fish ponds has increased in the riparian states, and number of fry and fingerlings distributed to farmers has grown exponentially as shown in the following tables 11, figure 45 and 46 for the three countries.

44) Number of small water bodies stocked
45) Number of fish species added to domestic species
46) Number of fry distributed per annum
47) Fish yield per unit area and per annum
48) Total number/area of ponds

**Indicator use:** The indicators as provided in table 9 for Uganda provide information on "project progress" and are important to assess internal project goals. However they provide limited information on the actual success of the activity in terms of adoption outside project activities.

**Data availability:** Data from Tanzania and Kenya as provided in the national syntheses reports did not allow further regional aggregation.

49) Number of farmers adopting new technologies

**Indicator use:** This is an important indicator for the measurement of success of aquaculture develoOment efforts: it would provide information on the actual adoption of new technologies outside project activities. In general it would be advisable when devising projects to select indicators that can aid in such assessments. Another indicator could be the request for information on new technologies received by aquaculture research and extension institutions. Further thought on the development on indicators with which project activities could be critically assessed is needed.

**Data availability:** No data are available for this indicator.

Database

50) Publications (books, papers etc.)
51) Number of scientific journals subscribed to
52) Number and type of software for data analysis
53) Number of digitised old and new literature data sets
54) Number of visitors visiting the institutes
55) Number of scientists with basic scientific database knowledge
56) Number of datasets available in digitised format by type and category
57) Number of databases available

For a description, presentation and analysis of the indicators under this section we refer to the national syntheses reports and the tables below. The data presented do not allow for further aggregation due to differences in presentation and meaning.

Table 10: Uganda

| | *- 1980* | *1981-1985* | *1986-1990* | *1991-1995* | *1996-2000* | *2001-2005* |
|---|---|---|---|---|---|---|
| **Capacity** | | | | | | |
| Sitting capacity (FIRRI Jinja) | 8 | 8 | 16 | 16 | 24 | 40 |
| Sitting capacity (FIRRI Kajansi) | | | | | 6 | 6 |
| No. of book shelves (FIRRI Jinja) | 6 | 6 | 15 | 15 | 30 | 50 |
| No. of book shelves (Kajansi) | | | | | 5 | 5 |
| Office space | | | | 2 | 2 | 7 |
| Jinja Conf. facilities (Sitting capacity) | | | | | 40 | 100 |
| Kajansi Conf. facilities (Sitting capacity) | | | | | 30 | 30 |
| Toilet facilities | | | | | 2 | 2 |
| **Personnel** | | | | | | |
| System Administration | | | | | | 1 |
| Training and outreach | | | | | | 1 |
| Information management | 2 | 3 | 2 | 2 | 2 | 4 |
| **Database facilities** | | | | | | |
| Computer | | 1 | 6 | 8 | 19 | 46 |
| Heavy duty multi-colour printers | | | | | | 2 |
| Multi-colour plotter | | | | | | 1 |
| Scanner | | | | | 1 | 5 |
| CD burners | | | | | 1 | 6 |
| Photocopier | 1 | | | 1 | 3 | 7 |
| **Bibliographies** | | | | | | |
| -Annotated | | | 2 | 1 | 2 | 5 |
| -Descriptive | | | | | | 2 |
| Books | 8 | 9 | 12 | 29 | 90 | 289 |
| Ph.D. theses | 3 | 3 | 3 | 4 | 6 | 26 |
| MSc theses | 1 | 3 | 3 | 3 | 17 | 24 |
| Reprints | 30 | 37 | 45 | 54 | 63 | 182 |
| Abstracts digitized | | | | | | 49 |
| Digitized books | | | | | | 4 |
| Annual reports digitized | | | | | | 4 |

Table 11: Kenya

| | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Bibliographies** | | | | | | | | | | | |
| Bibliographies | | | | | | | 4 | 8 | 14 | 20 | 26 |
| Journals, Papers, Reprints Collection | 133 | 194 | 302 | 546 | 834 | 1938 | 2082 | 2326 | 2492 | 3538 | 3684 |
| Books Received | 54 | 56 | 56 | 58 | 58 | 85 | 193 | 195 | 201 | 201 | 201 |
| Digitized information | 1695 | 1695 | 1695 | 1695 | 1695 | 1695 | 1695 | 1695 | 1695 | 1695 | 1695 |
| Visitors to KMFRI Website | | | | | | | | | | 853 | 1347 |
| Scientists (Basic Database) | | | | | | | | | 29 | 31 | 31 |
| Print Journals/Periodicals Subscription | None | | | | | | | | | | |
| Online Journal Subscription | | | | | | | | | | | |
| **Databases** | | | | | | | | | | | |
| | CDS/ISIS | | | | | | | | | | |
| | Reference Manager | | | | | | | | | | |
| | | | | | | SAMAKI | | | | | |
| **Software for data analysis** | | | | | | | | | | | |
| | SPSS | | | | | | | | | | |
| | FISAT | | | | | | | | | | |
| | ACCESS | | | | | | | | | | |
| | | ECOPATH | | | | | | | | | |
| | | | | | | | ECOSIM | | | | |
| | | | | | | MINITAB | | | | | |
| | | | | | | SAMAKI | | | | | |
| | | | | | | | | | | | BIPLOT |
| **Internet, Email, Telephone** | | | | | | | | | | | |
| | | | | Dial-Up | | | | | | | |
| | | | | | | | | | | Visat 64 KBPS | |
| **Desktop Publishing** | | | | | | | | | | | |
| | | | | | | | Plotter + Software | | | | |
| | | | | | | | Laser Printer C | | | | |
| | | | | | | | Deskjet (2) | | | | |
| | | | | | | | Digitizer | | | | |

| | | | |
|---|---|---|---|
| | | | Laser 2100 (EU)<br>Laser 1300 (EU)<br>Scanners (3) + Software<br>Publisher<br>Adobe Pagemaker<br>Coreldraw<br>Digital Cameras (3) |
| **Communication** | | | |
| E-mail/Internet | | Yes | |
| Teleconferencing | None | | |
| Telephone | Yes | | |

Table 12: Tanzania

| Tanzania | 1998 | Before 2000 | 2000 | 2001 | 2002 | 2003 |
|---|---|---|---|---|---|---|
| **Software** | | TANFIS<br>Lotus 123<br>FISAT<br>VP planner<br>ARTFISH | Excel<br>SPSS<br>FISAT | Excel<br>SPSS | Excel<br>SPSS | Excel |
| **Databases** | | | FishBase | FishBase<br>Reference Manager<br>Library Management Information System | SAMAKI Database<br>FishBase<br>Reference Manager<br>Library Management Information System<br>Directory of scientists | SAMAKI Database<br>FishBase<br>Reference Manager<br>Library Management Information Syst<br>Directory of scientists |
| **Back-up systems** | | Ditto tape drive | HP CD-writer and zip drive | Sony CD-writer | | |
| **Computers (cumulative)** | 1 | 6 | 24 | 46 | 48 | 60 |
| | **1977-1992** | **1988-1992** | **1995-1997** | **1997-2002** | **1997-2005** | **2001-2005** |
| **Projects** | HEST | IDRC | LVFRP I | LVFRP II | LVEMP | IUCN |

In order to implement ecosystem approach to fisheries management, a proper acquisition, storage, retrieval and dissemination of research information is vital to as aid in informing the management of Lake Victoria fisheries. Though the indicators mentioned are very important to take stock of what is available, it is in the end the quality of the data and data storage and retrieval that will enable establishing time series and trends of relevant indicators.

*PROCESSES*

This section aims at trying an improved understanding of the nature and force of the various drivers that affect the Lake Victoria ecosystem. As seen from the state indicators described in the previous section, the lake has undergone drastic changes over the past 4-5 decades in terms of productivity, species diversity, fisheries, and socio-economic development. The question is what these changes mean in terms of necessary management. There is an ongoing controversy on what the status of the present fishery, with emphasis on the Nile perch, actually is. Several authors (e.g. Cowx 2005, Mkumbo et al. 2002, Katurole and Wadanya 2005) have concluded that the fishery is close to, or has already exceeded, the potential sustainable productivity, and that there is an immediate need for concerted management actions. Other stakeholders are of the opinion that the fishery is still healthy and thriving, and can possibly be expanded. It is therefore of high priority to establish the actual state and trends of the resources, and what factors are the most important drivers for future development in fishery stocks.

## Major changes in the Lake Victoria ecosystem

### 1. Demographic changes

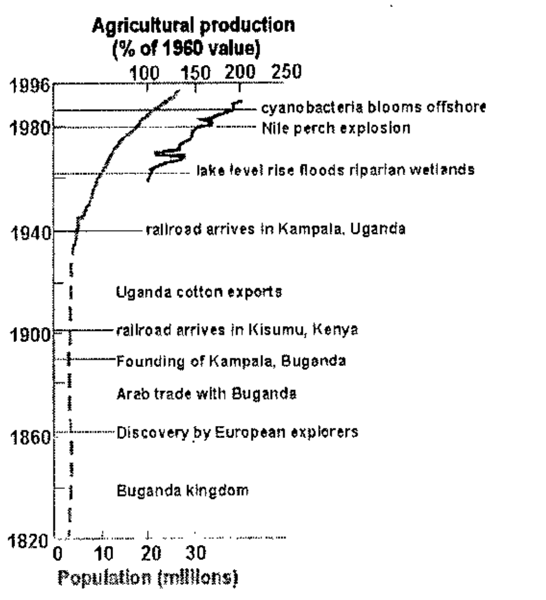



Figure 57: Development in total population and agricultural production around Lake Victoria (Adapted from Verschuren et al. 2002)

The Lake Victoria basin has undergone a rapid increase in population and agricultural production in the past century, especially post Second World War. Today approximately 30 million people in five countries share the basin. This regional growth has had consequences for the Lake Victoria catchment's area (Verschuren et al. 2002, LVEMP Water Quality report 2005): increased population, increased deforestation and increased agricultural production and associated utilization of fertilizers have lead to an increase in eutrophication of the Lake environment.

## 2. Eutrophication

Eutrophication in Lake Victoria has contributed to loss of fish species due to reduced light penetration (Seehausen et al. 1997, 2003 – Indicator 4), causing loss of chromatic volume and reduced benthic algal depth distribution altering food webs and causing deep water hypoxia (Indicator 5). Fitness of many species has likely been altered (Verschuren et al. 2002; Table 13).

Nutrient loadings to the lake from the surrounding catchments area has risen by a factor of 2, and the primary productivity in the lake has increased by a factor of 2 with 6-10 fold changes in algal biomass in both near shore and offshore environments between 1969 (chlorophyll: 1.3 – 4.9 $mgl^{-1}$) and 1993 (chlorophyll: 17 – 21 $mgl^{-1}$). The increased eutrophication has resulted in a lake environment with favourable conditions for Water-hyacinth (*Eichhornia crassipes*) along the shores, much reduced $O_2$ concentrations in the deeper parts, and increased densities of atyid prawns (*Caridina nilotica*) and lakeflies (*Chaoborus* and *Chironomids*).

Table 13: Evidence supporting recent eutrophication of Lake Victoria (adapted from Verschuren et al. 2002)

| Parameter | Units | Historic (1960) | Modern (1990) |
|---|---|---|---|
| Secchi Disc | m | 6.4-8.2 | 1.3 – 3.0 |
| Surface Oxygen | %saturation | 90-98 | 107-146 |
| Oxygen (40-60m) | mg/l | 2.9-4.3 | 0.5-2.2 |
| Dissolved Si | µmol/l | 71.4-82.4 | 0.6-35.7 |
| Total phosphorus | µmol/l | 0.7-2.3 | 1.7-2.7 |
| Chlorophyll | µg/l | 1.2-5.5 | 8.4-40 |
| Algal biomass | µg/l | 16-1210 | 200-6030 |
| Algal species (at max. biomass) | | *Aulacoseira* | *Cylindrospermopsis* |
| Algal productivity (O2) | $mg/m^2/d$ | 4.9-11.4 | 8.2-20.4 |
| Fish yield | ton/year (kg/ha) | 100000 (14) | 450000 (65) |
| Catch composition | Dominant species | *Oreochromis* | *Lates* |
| Number of fishers | Total ($\#/km^2$) | 26000 (0.4) | 125000 (1.8) |

## 3. Phytoplankton production

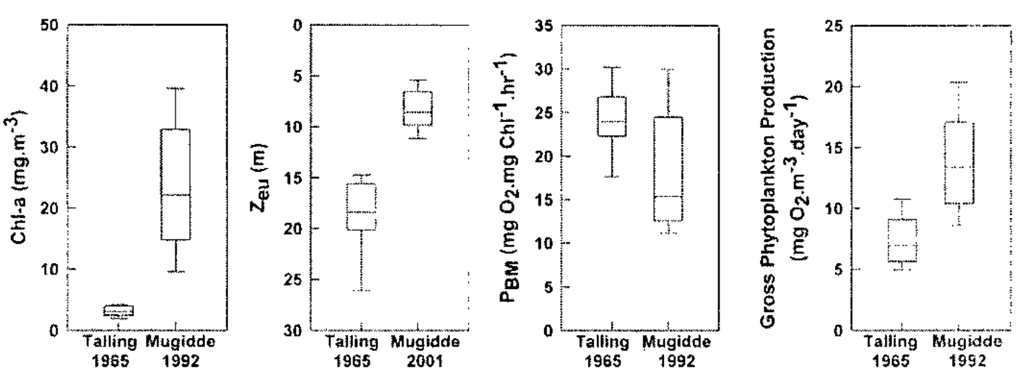



Figure 58: Gross phytoplankton production (PPG; right panel) is a product of the phytoplankton biomass (chl; left panel), the euphotic depth (Zeu; middle left panel) and the photosynthetic irradiance parameters (PBM and aB). Overall, gross phytoplankton production has increased through eutrophication (from Silsbe et al., 2005)

## 4. Relation phytoplankton production and fish yields

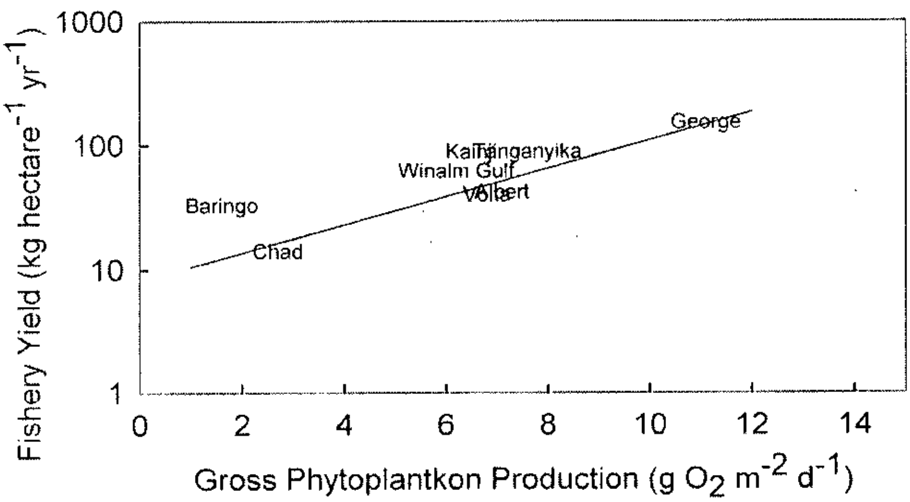



Figure 59: Melack (1976), Oglesby (1977) and Downing et al. (1990) showed that there is a relatively strong relation between fishery yields and phytoplankton production. The graph indicates the state of different tropical lakes on the productivity-phytoplankton production axis.

## 5. General relation fish productivity and nutrient concentrations

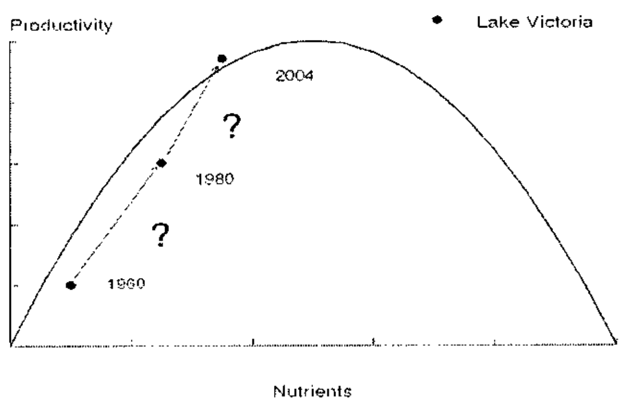



Figure 60: Theoretical relationship between primary production and nutrient concentration. In general fish productivity per unit area will tend to be a domed-shaped function of nutrient concentrations, with the descending part being a result of increased eutrophication, which leads to bacterial decomposition and ensuing oxygen deficiencies. (Ryder et al., 1974). The question is where on the curve is the current state of Lake Victoria.

## 6. Waterlevels, waterbalance and nutrient recycling

(Changes in) Lake waterlevels (indicator 2) appears to be indicative for fluctuations in fish productivity in floodplains and lakes (Welcomme and Halls 2001; Jul Larsen et al. 2003a,b; Kolding and van Zwieten 2005). Welcomme (1970 and pers. com.) reported that after the sudden increase in lake water levels of in Lake Victoria levels in the early 1960-ies (Fig. 5) fisheries production increased dramatically. The increased lake levels must have contributed to a significant rise in nutrients both from run-off and inundation. For example a great loss of the fringing papyrus (*Cyperus papyrus*) swamps was observed in this period due to rain and lake level rises which disintegrated them or washed them ashore (Kudhongania and Chitamwebwa 1995). Hecky (pers. com.) proposed that the observed increases in recruitment are caused by an increase in inflowing allochtonous silicates leading to a higher availability of diatoms, the main food of larvae and juvenile fish, leading to a higher survival rate and with that to increased recruitment. Similarly, changes in wind stress (indicator 3) and temperature (indicator 7) control the stratification, miction, and upwelling patterns, which again have profound effect on nutrient recycling and periods of oxygen deficiencies in the hypolimnion. These bottoms up effects have strong influence on the fish productivity and biodiversity.

## 7. Fishing Effort

A sevenfold increase in numbers of fishermen and boats in Lake Victoria since the 1970-ies (Indicator 24) indicates that fishing pressure has increased tremendously, almost exponentially. Increased population sizes and in particular increased economic possibilities (fish trade: indicator 30; domestic demand: indicator 28, indicator 33; indicator 36) after the Nile perch boom and the new markets for food and fishmeal from *Rastrineobola* (Dagaa) and fishmeal from *Caridina* from the lake has lead to this fast increase in exerted effort.

## 8. Summary of major changes and important issues

In summary the ecosystem of Lake Victoria is constantly changing, and some of the changes such as demographic growth, nutrient influx (eutrophication), and fishing effort are showing ever accelerating trends. While increased nutrients initially will tend to also increase the biological fish production, the relationship is dome shaped (Fig. 56) and fish production will stagnate or decrease with hyper eutrophication. Likewise, increased fishing effort will also initially increase fish yields, but also this relationship is dome shaped and yields will stagnate or decrease with too high fishing effort.

Two important issues arise from these changes:

1. The Lake Victoria ecosystem is not in a biological steady state, and
2. How can one discriminate and attribute observed changes in the fish stocks to be driven by either the environment and/or the fishery when the trajectories are of the same shape?

The answer to the latter question is of fundamental importance for the focus, priority and emphasis of fisheries as well as environmental management actions and points to an urgent need for the integration of the environmental and the fishery related research and monitoring.

### Steady state? – Limitations of classical stock assessments

The first issue arising from the changes is that the described non-existence of a biological steady state of Lake Victoria is of vital importance for fish stock assessment. Various attempts for evaluating the state of the exploited stocks have been done using classical stock assessment methods, such as Yield per recruit, VPA, and Surplus production models that use time series under the assumption of a biological steady state. The results of these assessments (e.g. Cowx *et al.*, 2005) show that:

- Standing stock of Nile perch has decreased and that 95% of the biomass comprises immature fish.
- There is a large scale use of non-selective and environmentally damaging (illegal) gears, especially beach seines (indicator 35; indicators of gear development not mentioned in the list).
- The total estimated catch of Nile perch has declined in recent years from the peaks in the 1990s.
- Yield is close to or has exceeded MSY
- Catch per unit effort has declined from about 80 to around 45 kg per boat day

- Fishing mortality of Nile perch in Lake Victoria is high (F = 1.42-1.64 yr-1) and the exploitation rates (E = 0.78-0.85) are estimated to be approximately 40% above the optimum.
- Predictive modelling (ECOSIM) of the future of the Nile perch fisheries under a scenario of increased fishing effort suggests that the fisheries are unsustainable and will decline in the long term.

All this leads to the conclusion that the lake – in particular the Nile perch fishery – appears to be overfished. Cowx *et al.*. 2005 assert that "*unless concerted action is taken, the potential for degradation of the resources is prevalent*".

However classical stock assessment based on steady state models has a poor history in African Lakes, which all seem to be mainly environmentally driven (Jul-Larsen *et al.*. 2003). In the management of the African freshwater fisheries, the traditional focus has been on fishing pressure with only limited considerations for environmental causes of changes in stocks. A long history of regulations against the allegedly detrimental effects on stocks of various fishing methods used exists. Alerts to the effects of the ever-increasing fishing pressure are of a more recent date, and attempts to set sustainable levels of effort have been the goal of much research done. Although the various attempts to regulate fishing effort have often proved to be fairly ineffective (Malasha, 2003) many African freshwater fisheries continue to thrive.

The classical approach to a rational exploitation of fish stocks involves the control of fishing mortality (effort and fishing methods) in such a way that annual catches of specific stocks can be continued indefinitely according to pre-determined objectives related to the productivity at different stock levels. The catch-effort curve of sustainable yields (Schaefer 1954) exemplifies this approach: at any level of fishing effort up to the level where the 'surplus yield' is maximised, a yield can be found that is theoretically sustainable and stable. Which level of fishing effort is chosen depends on a number of strategic objectives (Salz 1986) such as securing a minimum biomass, maximise food production (MSY), maximise the resource rent (maximum economic yield, MEY) or employment. Of these objectives, the concept of Maximum Sustainable Yield (MSY) at which effort levels should be set in order to maximise food production has gained most prominence. Various models estimating MSY, or maximum yield per recruit, have been used extensively in African fresh water fisheries, and the concept of MSY has formed part of the research goals in many fisheries development projects as well (Kolding 1994).

It is important to reiterate the biological assumptions of the surplus-production models most often used in the African context, the Schaefer model, because of the many policy implications that rose from them:

- Density dependent logistic growth under **environmentally stable conditions**, which means **constant carrying capacity**
- It is a **single species** model, with man the only predator
- In the traditional application (e.g. Cowx *et al.*, 2005) it supposes a **continuous steady-state** which means instantaneous equilibrium between catches and surplus regeneration

These biological assumptions have been questioned for a long time in an extensive literature (e.g. Larkin 1977, Sissenwine 1978, Kolding 1994). For now we will just note that natural variability in fish stock levels due to environmental changes or variation results in changing values of the underlying biological parameters of the model: the intrinsic growth rate ($r$) and the carrying capacity ($K$). This will ensue in considerable uncertainty around the estimated sustainable yield curve, as constant conditions are not present and surplus production is not regulated by effort alone. However, in systems with a large environmental variability, attempts to relate trends in fish stock levels to fishing alone may be more difficult. Such trends will be hidden in environmental variation or, in statistical terms, noise or error, resulting in what is often called 'process error' (Caddy and Mahon 1995) that is variability caused by the unknown states of nature. **For the successful application of standard models it is therefore important that environmental forcing is small and systematic compared to the effects of fishing.** Moreover, the multi-species and multi gear situations encountered in most tropical small-scale fisheries, in particular in freshwaters, make the application of standard models even more problematic.

In addition, and very unfortunately, the predicted MSY from these models, when fitting with only data points on the ascending side of the yield-effort curve, are always very close to the actual current mean catch and consequently the usual conclusions are that the effort level is, at the time of the investigation, at its limit. Actually, Hilborn and Walters (1992) concluded that it is simply not possible to find the top of a yield curve without going beyond the top, or in their words: "*You cannot determine the potential yield from a fish stock without overexploiting it*".

Still, the MSY concept remains deeply rooted in planners, administrators and research personnel, but so far it has mainly created misunderstandings or false expectations. Attempts to determine MSY in environments with a large, but to some extent predictable variability in productivity levels have generally failed (Jul-Larsen *et al.*, 2003). In general the yield (or Yield Per Recruit), models have not been of much use in any of the freshwater fisheries in Africa (George Coulter, pers. com.).

#### Expectations arising from the major changes in the Lake Victoria ecosystem

A series of logical inferences can be derived from the above described major changes in the state of the Lake Victoria ecosystem, as well as from the general ecological expectations that is known from similar situations (Jul-Larsen *et al.*, 2003, Kolding and van Zwieten 2005). In particular, there is a need for explaining **why there is no apparent visible impact on the exploited stocks** (Indicators 17, 18, 21) from the ever increasing fishing pressure on the lake, and in contradiction with the results derived from classical stock assessment methods:

1. The introduction of the Nile Perch, together with a general increase in eutrophication, has lead to a loss of biodiversity (Haplochromines) and the whole lake changed abruptly in the early 1980s with a dramatic simplification of the ecosystem (Indicator 16, Figs 21 and 22). Subsequently this has lead to a higher turnover from primary productivity into fish flesh at the top-predator (Nile perch) level. This has driven the Nile Perch boom, i.e. the greatly increased production of this species.
2. Developments in the fishing industry and export markets have lead to an increased attraction of labour and investments into the fisheries and therefore an increased effort since the Nile perch boom.
3. The demographic changes around the lake (urbanization, industry, deforestation, agricultural runoff) have resulted in a eutrophication of the lake environment. This eutrophication represents an increase in productivity of the various trophic levels in the food web, cascading up and including Nile perch.
4. This increase in Nile perch biomass and production has, due to the increased biological productivity of the lake - up until present, been sufficient to absorb the concurrent increase in fishing pressure. The individual return from the fishery (i.e. the catch rates or catch per unit of effort), averaged over the whole lake, therefore remains overall stable. (*This does not mean that there could be no local overfishing in heavily exploited areas of the lake!*). This also implies that, with no changes in catch methods/efficiency, overall fishing mortality has remained overall stable.
5. An important indicator of changes/impact from the fishery on the exploited stocks, due to the use of highly selective gear such as gillnets, is the decrease in average length in the

catch. Increased effort generally results in decreases in average length of a species –e.g. Nile perch in the fishery. If this does not occur, this will be another sign that – at the level of the whole lake – fishing pressure is (as yet) not sufficient to induce changes in overall stock structure.

6. Fluctuations in standing stocks and hence overall catch rates are caused by fluctuations in recruitment success of the various stocks involved (*Caridina*, *Rastrineobola*, Tilapias, Nile perch). Increased run-off from the land, rivers during periods of high rainfall that result in increased water levels causing a temporary increase in allochthonous nutrient inputs result in increased larval and juvenile survival and hence improved recruitment success, which will be visible in the catches of Nile perch and tilapia after a time lag of 2-4 years when the species recruits into the fishery. Climate change resulting in either prolonged periods of drought or rainfall will affect the fluctuations in standing stock and cause short term trends in catch success.
7. Increases fishing effort will continue until the increased fish productivity is fully absorbed by the fishery which will be (judged from comparison with other small scale African fisheries, see Jul-Larsen et al. 2003, FAO 2004) when the average return to the individual small-scale fishermen has reached around 3000 kg/year (Fig. 69). Increases in numbers of fishermen will then occur if (1) the average income from the fishery is maintained due to increase in prices, or (2) other targets are chosen. The latter will be indicated by a decrease in average trophic level of the whole fishery: that is fishermen will target more and more the high productive species lower in the food web, like *Rastrineobola* or *Caridina*.
8. With increased eutrophication, the overall biological fish productivity will level off and eventually decrease, as the relationship is dome shaped (Fig. 60). The overall shape of the relationship is also dependent on the individual species' capacity to endure deteriorating water quality and changes in the phytoplankton community. Species susceptible to anoxic conditions, such as Nile perch (Fish 1956) will be affected first, while more hardy species such as Nile tilapia or *Protopterus* will initially flourish (e.g. Njiru et al. 2002). Early warning signs of the effects on fish stocks and the fishery of deteriorating water quality will be first observed in the relatively closed bays and heavily populated/urbanised bays as Mwanza gulf and Nyanza (Winam) gulf. Indications for this will be reduced catch rates starting with Nile perch, species changes, and movements of fishermen out of these regions into still productive offshore areas. *Without good spatially explicit monitoring systems these developments may therefore initially not be observed in overall catches and catch rates of fishermen.*

**The evidence**

i) Ad1. <u>Introduction Nile perch</u>: Indicator 15: Species composition: sudden switch from haplochromis dominated to Nile perch dominated ecosystem. Evidence in steady state Ecopath models before and after the Nile perch boom. Indicators 21 (experimental catch rates), 22 (fishery catch rates) and 23 (catch).
ii) Ad 2. <u>Development in fishing industry</u>: demographics (Fig. 57), and indicators 24 (effort), 28 (contribution of Nile perch to food supply), 30 (export volumes and values) 32 (total earnings in the fishery), 33 (fish prices), 34 (per capita fish consumption, 35 (landing sites and factories), 36 (feed production - Rastrineobola, Caridina).
iii) Ad 3. <u>Eutrophication and fish productivity:</u> table 13 (Verschuren et al. 2002) and figure 58 (Silsbe et al. 2005). Indicator 7 (nutrients). 9 (primary productivity), 12 (lake flies abundance). 13 (*caridina* abundance), 14 (zooplankton abundance), 21 (experimental catch rates). 22 (fishery catch rates) and 23 (catch). Results from hydro acoustic surveys. We refer to the Water Quality Synthesis Report for an extensive discussion.
iv) Ad 4. <u>Fish biomass and fishing pressure</u> (Nile perch!). Indicator 21 (experimental catch rates), 22 (fishery catch rates) and 23 (catch).

The following figures (Fig. 61 – Fig. 66) show that there has been no significant changes in the fishery catch rates of Nile perch over the past two decades:

CPUE (ton/boat)

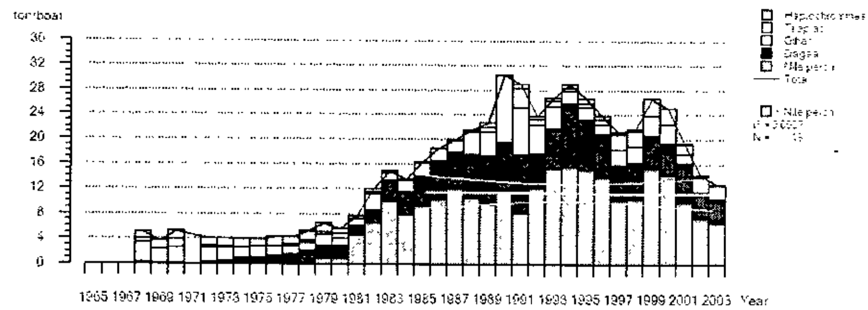



Figure 61: Kenya: no significant changes in catch rates in the fishery on nile perch between 1985 and 2003.

CPUE (ton/boat)

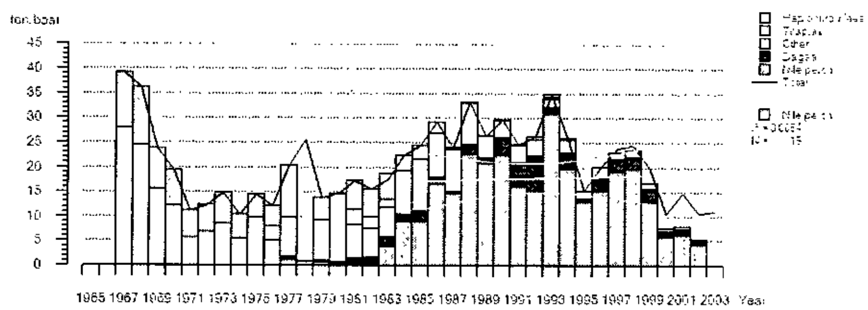



Figure 62: Tanzania: no significant changes in catch rates in the fishery on Nile perch between 1985 and 2003. Note that after around 2000 there has been a general underreporting of catches by species compared to estimated total catch, while the estimate of total catch is based on frame surveys only (i.e. no catch assessments have been done since 1999!!)

CPUE (ton/boat)

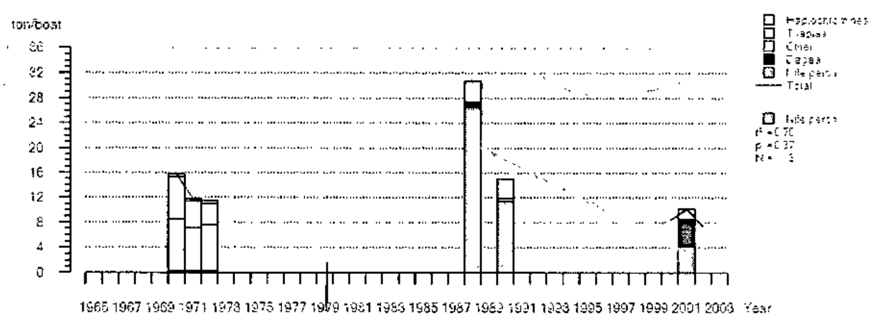



Figure 63: Uganda: no significant changes in catch rates in the fishery between 1985 and 2000, but data points too few to establish any meaningful trend

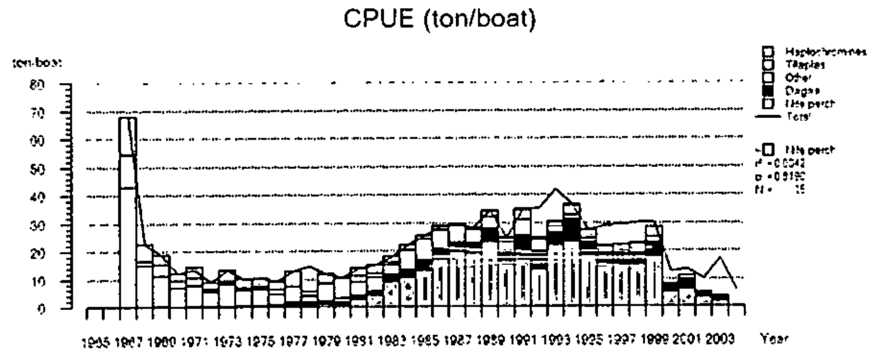



Figure 64: Whole Lake Victoria: no significant changes in Nile perch catch rates in the fishery between 1985 and 2000. Recent year's statistics are uncertain due to collapse of the CEDRS system after 1999.

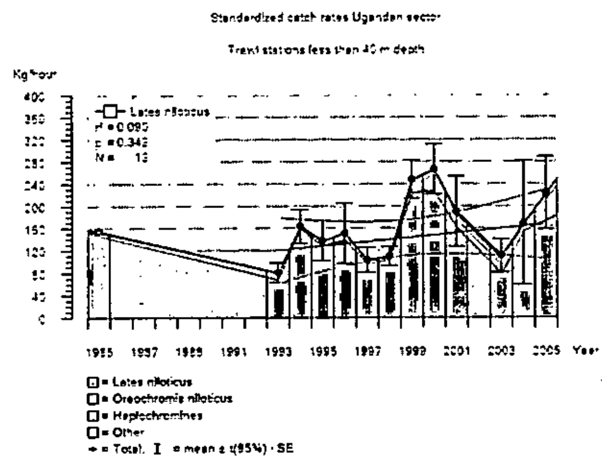


Figure 65: Trawl surveys (Uganda) 1985-2005: no significant changes in Nile perch biomass between 1993 and 2005, but with large inter-annual variation.

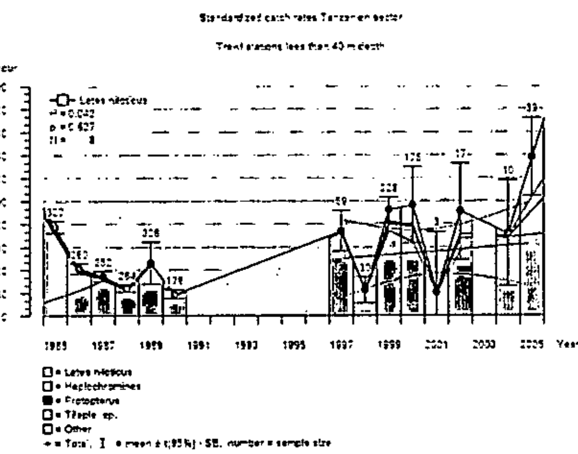


Figure 66: Trawl surveys (Tanzania) 1985-2005: no significant changes in Nile perch biomass between 1997 and 2005, but with large inter-annual variation.

Given the substantial increase in effort (Fig. 38), while both the experimental (trawl surveys) and the fishery dependent catch rates (CEDRS data) has not changed significantly, the only reasonable explanation is that the fish production[4] has increased with the phytoplankton production as a result of increased eutrophication.

**Estimates of total production and fishing mortality of Nile perch**

An attempt has therefore been made at estimating the production and exploitation rates of Nile perch from Uganda and Tanzania (Kenya is omitted due to lack of available trawl data from this country). The estimation procedure, based on estimated *q*, and observed $CpUE_{trawls}$ and Yield, are as follows:

The catch rate (*C/f*) or Catch per Unit of Effort (*CpUE*) is the catch per unit of effort over a time interval and defined as

$$CpUE = \frac{C}{f} = q \cdot B$$

Thus the catchability coefficient (*q*) is defined as the relationship between the catch rate (*CpUE*) and the true population size (*B*). So the unit of catchability is *fish caught per fish available per effort unit and per time unit.* Catchability is also called gear efficiency (Hillborn and Walters 1992) or sometimes fishing power, and is strongly related to gear selectivity because it is species and size dependent.

An estimate of the catchability coefficient (*q*), can be obtained from two independent observations of *CpUE* and Biomass (*B*) (Table 14). As *q* can be assumed constant for experimental fishing, a series of annual biomass estimates can then be calculated from *CpUE* and *q*.

Next, the fishing mortality (*F*) can be calculated as it is simply defined as the fraction of the average population taken by fishing in a year. In other words, *F* can be considered as an invariant measure of effort (Rothchild 1977). *F* is also called the instantaneous rate of fishing mortality, i.e. the rate at which fish are dying due to fishing, and therefore expressed per time unit, usually per year. *F* can be measured without reference to the nominal effort, the configuration of the fishing gear, or the manner in which the gear is employed (Jul-Larsen et al. 2003). *F* can be defined as

$$F = \frac{C}{B} = q \cdot f$$

Thus in summary:

- *q* (Catchability coefficient) = CPUE/*B* = constant
- $B_y$ (Biomass) = $q \cdot CPUE_y$
- *Fy* (Fishing mortality) = $Yield_y/B_y\ y^{-1}$
- *M* (Natural mortality) = $0.35\ y^{-1}$ = constant
- $P_y$ (Total production) = $Z \cdot B_y = (Fy+M) \cdot B_y$

Table 14: Estimates of *q* based on Nile perch mean density figures (t/km²) in year 2000 from Cowx et al. (2005), and mean experimental trawl catch rates for year 2000 (Indicator 21, Fig.66 and 67). (No data from Kenya)

| Country | Density (t/km²) | Area (km²) | Biomass (t) | CpUE (Kg/hour) | q |
|---|---|---|---|---|---|
| Uganda | 9.44 | 29240 | 276026 | 228 | 0.00083 |
| Tanzania | 10.18 | 34680 | 353042 | 253 | 0.00072 |

[4] Biological production (*P*) is the total amount of tissue generated in a population (or community) in a particular space during a given period of time, regardless of its fate. It is of central interest in the exploitation of renewable resources, since the yield (Catch) is a fraction *F* (Fishing mortality) of the mean biomass, and is a fraction (*x*) of biological production *P*. *P=Z.B, Catch=F.B= x.P*

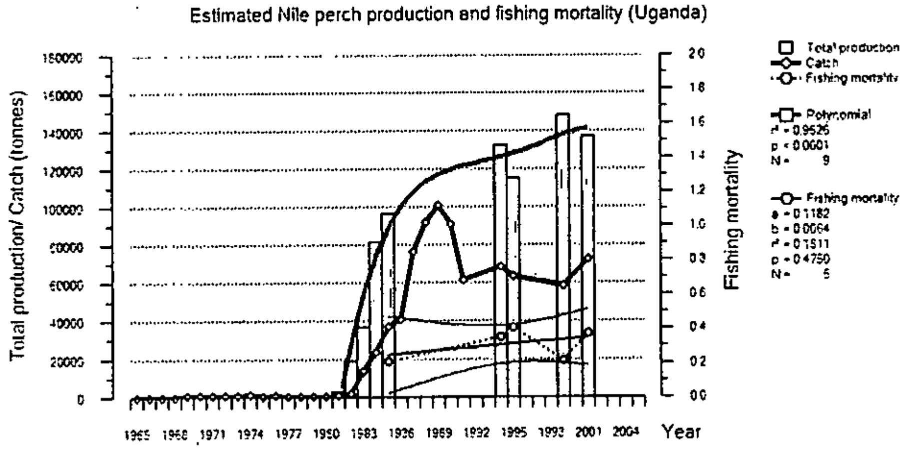



Figure 67: Uganda Nile perch: Total reported catch (green diamonds + black line), estimated total annual production (orange bars) and estimated annual fishing mortality (blue circles + dotted line). The total production has increased logistically (red line). There is no significant change in fishing mortality (F) (Blue line). Mean F = 0.34 y-1 → E =F/Z ≈ 0.5. The total production seems to follow the initial upward curve of the dome shaped pattern as predicted (Figure 60).

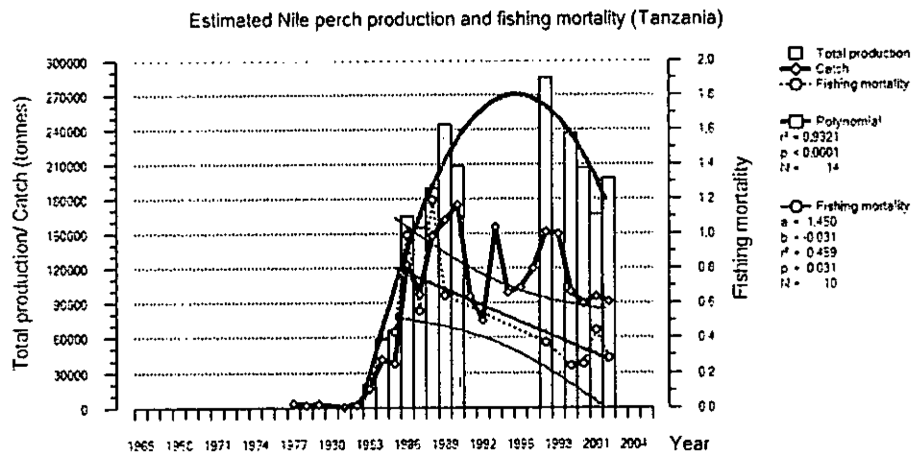



Figure 68: Tanzania Nile perch: Total reported catch (green diamonds + black line), estimated total annual production (orange bars) and estimated annual fishing mortality (blue circles + dotted line). There is a significant decline (!) in fishing mortality (F) and the total production seems to follow a dome shaped pattern as predicted. If reported catches would be correct then the descending trend after 1996 is indicating that the dome has reached a maximum and is now declining due to adverse environmental conditions (eutrophication). However, it is highly likely that catches of Nile perch from 1999 (as indicated in Fig. 36 and 37) have been severely underreported. If that is the case then F would be higher, and the regression probably non-significant, and descending limb less conspicuous, or flat as in the Ugandan case. In that case, mean F = 0.32 y-1 → E =F/Z ≈ 0.5.The Ugandan picture (Fig 59 above), the decreasing Fs, and the stable CpUE's (Fig 60) are indirect indications of the supposed underreporting in Tanzania,. However, that the productivity has reached a maximum cannot be excluded.

v) Ad 5. Average length (of Nile perch) in the catch. Indicator 18 (Slope and intercept of the biomass size spectrum) and indicator 17 (mean size, maximum size, length frequency). There are no significant changes in either the mean lengths or the slopes of the biomass-size spectrum, which indicates that there is no visible impact on the size structure of the stock from the fishery.

*vi)* Ad 6. Causes of fluctuations in standing stock through bottom up recruitment effects can be inferred from Indicator 4 (water level, water balance), indicators 3 (rainfall) combined with 21 (experimental catch rates), 22 (fishery catch rates) and 23 (catch). The evidence of the causes of the fluctuations in relative standing stocks as expressed by the trawler catch rates and in the fishery is yet circumstantial. The relation of catch (rates) with productivity and effort is as follows: CpUE=f(lake levels, effort) and/or CpUE=f(productivity, effort) and Catch = f(lake levels, effort). The approach is stepwise multiple regression with CpUE as dependent parameter and various indices for productivity and effort as dependent parameters[5].

vii) Ad 7. Productivity changes and increased effort.

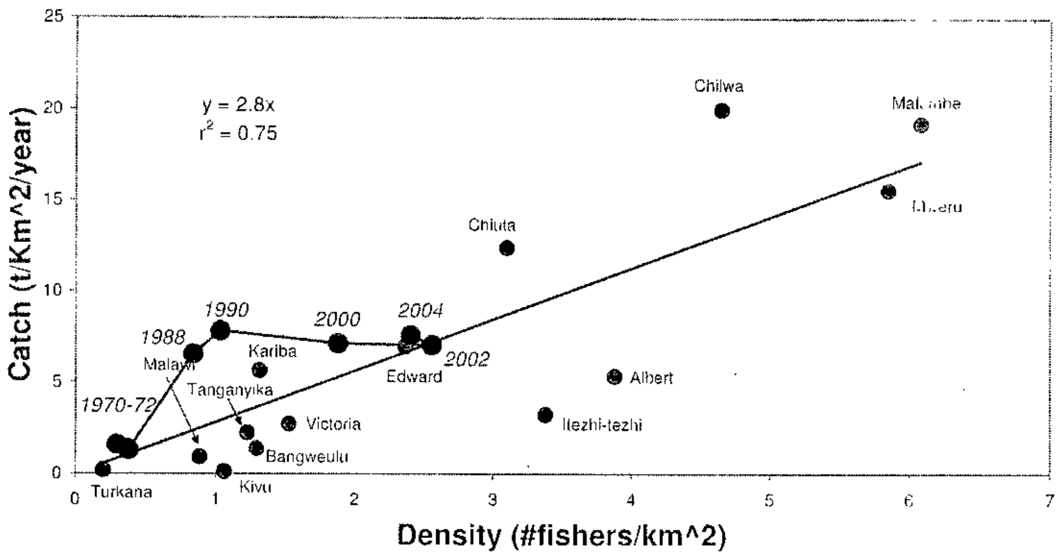



Figure 69: Catch rates plotted versus effort density in 15 African lakes (data from the period 1989-92). The trend line indicates an average yield of about 3 tons per fisher per year irrespective of water body and country. Superimposed (in blue) is the development in Lake Victoria between 1970 and 2004, which shows how productivity has increased over time concurrently with the increase in effort. After an initial boom production in the late 1980's and early 1990s, the individual catch rates are now approaching the overall mean again. Adapted from Jul-Larsen et al. 2003a.

---

[5] The analysis is still to be carried out on the longer time series of trawl surveys in Uganda and Tanzania that only have become available for analysis beginning of December 2005. At this stage no actual data have been received on the indicators 2, 5, and 21: the figures as presented in the report are copied from existing reports.

Ad.8. Increased eutrophication and fish productivity. Early warning signs

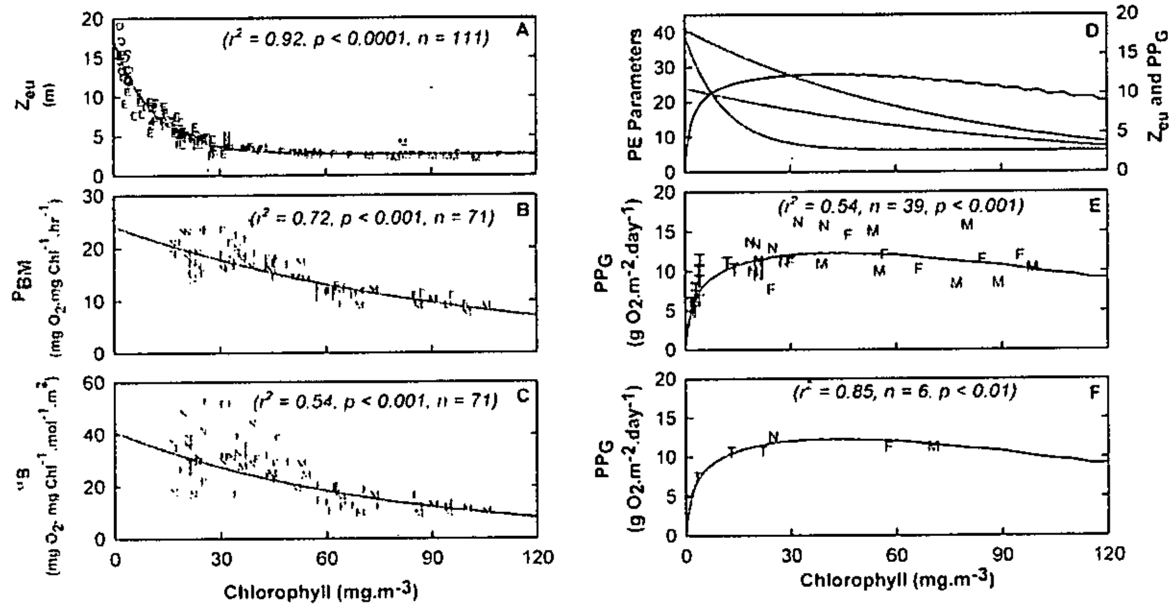



Figure 70: The upper limit of gross phytoplankton production in Lake Victoria: Implications for the lake's fishery. Gross phytoplankton production can be modelled as a function of chlorophyll (using A, B and C). As shown in Figures D-F, gross phytoplankton production increases with chlorophyll, but then levels off when chlorophyll exceeds ~ 25 mg.m-3. Model validation showing predicted gross phytoplankton production (PPG) versus chl-a solid line) with A) calculated PPG from M – Inner Murchison Bay, F – Fielding Bay, N- Napoleon Gulf and T–B Bugaia Island, T-P Pilkington Bay, T-G Grant Bay and T-K Kavirondo Gulf where T denotes source of data (Talling 1965), B) spatial averages of calculated PPG from A and C) spatial averages along with data from Lake Malawi (closed triangle 1992, open triangle 1993; Patterson et al. 2000), Lake Tanganyika (open circle; Hecky and Fee 1981) and Lake George (closed square; Ganf 1974).(From Silsbe et al., 2005).

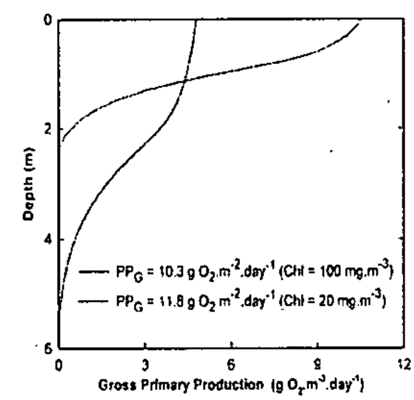



Figure 71: PPG is lower at site with high biomass (Chl = 100 mg m-3) than at a site with low biomass (Chl = 20 mg m-3) because photosynthetic parameters are lower and constrained due to a diminished euphotic zone (From Silsbe et al. 2005).

Figures 70 and 71 from Silsbe et al. (2005) indicate that the continuing nutrient enrichment of Lake Victoria will not increase gross phytoplankton production as it is already light limited over most of the lake's surface area. Gross phytoplankton production levels off when chlorophyll exceeds ~ 25 $mg.m^{-3}$. Further nutrient inputs will most likely only cause a higher propensity of algal blooms in response to shallow diurnal stratification, thus increasingly deteriorating the water quality with no added benefit to the lake's fishery. The estimated trajectories of the total production of Nile perch from Uganda and Tanzania (Figs 67 and 68) seem to follow the same dome shaped pattern as the gross primary productivity, and that Nile perch production has now reached a maximum and will level off or decrease with increased eutrophication. Silsbe et al. (2005) concluded that reducing nutrient fluxes into the lake will decrease phytoplankton biomass in inshore areas without necessarily significantly decreasing gross phytoplankton production.

**Conclusions on processes**

There seems to be ample evidence that the biological fish productivity, represented by the top predator Nile perch, has increased in Lake Victoria since the faunal changes in the early 1980s, concomitantly with the increased primary productivity. The increase in productivity, albeit fluctuating, has supported the simultaneous large increase in fishing effort, explaining the apparent resilience of the Nile perch, and the contradictions between the observed fishery indicators and the results from stock assessment modelling. At present there are no signs of overfishing on the Nile perch stock: in fact there appears to be even no significant signs of fishing. The mean exploitation rates (E) of Nile perch are around 0.5 which in theory should be optimal for a top predator (Jul-Larsen et al. 2003a). However, the increased fish productivity as a function of increased nutrient levels in the lake is theoretically a dome shaped curve, and there are signs that the top of the dome may have been reached, at least for Nile perch. The estimated total production figures for Nile perch (Figs 67 and 68) are levelling off and the overall catch rates plotted versus effort density (Fig 69) is again approaching the average trend in 15 other African lakes. Silsbe et al. (2005) concluded that "*Although more research needs to be carried out to determine the ideal nutrient concentrations in Lake Victoria to support a productive fishery while maintaining an acceptable level of water quality, we conclude that these ideal nutrient concentrations have been exceeded*". The trajectories for the production estimates for Nile perch appear to support this conclusion. **Further nutrient enrichment will most likely seriously affect the Nile perch fishery** as well as fish biodiversity. While other – more hardy – species like Nile tilapia, Dagaa, Clarias, and Protepterus are likely to continue to grow under increased eutrophication, both the economic backbone (the Nile perch) and the ecological and aesthetical value of Lake Victoria will suffer: the 'pea soup' environment in the closed bays and gulfs are poignant examples of these changes (see e.g. front cover photograph of Winam Gulf, Kisumu, taken in September 2005).

**So far the dynamics of the fish production in Lake Victoria appears to be entirely environmentally driven, as there are few or no signs of fishing impact on the observed changes. However, if catch rates and particularly production estimates in the future will begin to fall, while effort continues to grow, it will be a big open question whether the decrease is due to environmental degradation or due to overfishing or both. Unfortunately such a debate will only exacerbate the already ongoing controversies on the status of the Lake Victoria fisheries. It is high time that the environmental and fisheries research and management activities are integrated, and that a holistic ecosystem approach to fisheries (EAF) management is adopted. The present disciplinary segregation and approach, as well as continued implementation of traditional single species management regulations, albeit disguised as co-management, will not solve the present problems in Lake Victoria (Anon. 1989, Misund et al. 2002, Conover and Munch 2002, Jul-Larsen et al. 2003).**

- more smaller Nile perch being caught is not because there are less large Nile perch but because the fishery target smaller Nile perch through smaller mesh sizes. From an evolutionary point of view this is a good development (Conover and Munch 2002)
- no change in growth parameters: but different ways of estimating makes it difficult to conclude on this

*Foodwebs*

- feeding habits of Nile perch/tilapia has changed concomitant with faunal and floral changes

*Trawl catches*

- No change in experimental catch rates over the last decade for both Tanzania and Uganda trawl series
- Overall catch rates in the fishery decreased from 7 kg/fisher to 3 kg/fisher since 1990. Average catch rates are now back in the range of any African fishery

*Catch and Effort*

- Effort in terms of numbers of fishermen has increased from 35000 to 165000 since 1970 and boats has increased from 9000 to 52000 since 1970
- Catch has remained stable between 300 000 and 400 000 ton
- There is limited information yet on fishermen movements. It is expected that fishermen will move away from shallow bays under increased eutrophication as this will decrease fish productivity and hence catches

*Socio economic indicators*

- contribution to GDP increased
- contribution to food supply has declined form 80% to 20% since 1980
- more investments in the fishery as indicated by the relative increase in number of boats (4 fishermen/boat – 3 fishermen/boat)
- exports are increasing
- CpUE is stable (for nile perch) or decreasing (overall) but the value/ton of fish is increasing (also in absolute terms)
- more educated fishermen in the fishery: by now 40% are at secondary level of education
- despite that price of fish has increased the fish per capita consumption has remained at the same level
- regional variations in per capita fish consumption
- fish landing sites: more landing sites, higher dispersion of the fishery
- not enough data on fishmeal production (*Rastrineobola*). Observation that medium sized fishmeal processing plants use up to 30 tons/week fishmeal production but only for a limited period of time over the year (one or two weeks per month when fishing takes place).

*Enforcement , co-management*

- BMU's have been established almost to target
- Compliance with fishery regulations is still very low
- Fish quality inspectors have risen from around 5 to 55 (in Uganda) the expectation is that this will be reflected in the quality of fish landings and the general health situation of the beaches. Fish inspectors were established after the export ban to Europe and the present increase in exports may indicate the effectiveness of the inspection activities with regard to fish quality.
- Indication of the expectation of the availability of fish for export: increase in factories

## CONCLUSIONS

### *Summary and conclusions on status and trends*

56 indicators ranging from the physical environment, the primary, secondary, and tertiary biological levels, the fishery, the economics, management, aquaculture to research activities have been selected and compiled over as long time frames as possible. Together they represent and illustrate the best available picture of the present status and the past trends and changes of the Lake Victoria ecosystem and fisheries. Not all are complete, and it is hoped that gaps and missing information will be added in the future. Some indicators are covering the history of the lake over the past 4 decades, while others are relatively young and only show the latest development.

Below follows a brief summary of the indicators, what they show, and their general development over the past 4 decades:

*Primary productivity:*

- Long term changes that affect the ecosystem, biodiversity and fishery
  - Nutrient input, algal biomass and stratification
  - Nutrient inputs doubled, algal biomass increased 6-8 times, stratification → increased anoxic area

- Medium term fluctuations that affect the fishery (recruitment success)
  - Water level
  - Relation to wetlands
  - Nutrient fluctuations from run-off and drivers
- Overall water level has decreased since 1961 and average rainfall has decreased since 1978.

*Secondary production*

- Shifts in zooplankton composition over the long term (Wanink, 1998)
- No change in Caridina
- Changes in zooplankton may be due to changes in phytoplankton (from increased eutrophication) and feeding habits of fish
- Little can be said at present about expected correlations as only limited data are available

*Biodiversity, community and foodweb indicators*

- Changes in fish biodiversity is reflected in both sides of the lake (Tanzania + Uganda)
- Abrupt change in fish community structure 25-30 years after the introduction of Nile perch. This complete change in structure is such that the pre and post Nile perch boom represent two "different lakes". The sudden community changes occurred simultaneously with a period of decreased windspeeds and lowered temperatures creating longer than usual stratifications.
- In the past decade an increase in haplochromines, *Oreochromis niloticus* and other species is observed. It is at present not known what has triggered the reappearance of haplochromines (fluctuations in relation to water levels? – predator-prey relations?)

*Life history indicators*

- no change in mean and maximum length of Nile perch (both overall and for specimen > 50 cm)

*Aquaculture*

- Aquaculture revived, new technologies adopted, farmers participating in research to revive disappeared species of fish
- No indications presented for adoption of technologies outside programs questioning the long term sustainability of this project activity
- Interesting relations between fisheries and aquaculture (fingerlings, fishmeal)

*Database*

- Centres have been established but very few data are yet in an easily accessible format.

The overall conclusion is that Lake Victoria is undergoing rapid and profound changes in nearly all indicators from both bottom up and top down. It will be a major challenge not least to continue the monitoring of these changes, but far more so in trying to manage them. Effective management requires consensus on the cause and effect of the observed changes and political willingness to do something about it. Our impression is that so far most of the various activities in terms of research and management on the lake have operated in isolation with only regard to their 'own' set of indicators. The fisheries management for example seem to have been based purely on fisheries indicators (with effort as the main driver), or preconceived truisms inherited from elsewhere, while little or no attention has been paid to the implications from the parallel work of the limnologists and ecologists on the lake. As is shown in this synthesis the present status of the Lake Victoria exploited stocks appears to a very large extent and maybe even almost exclusively bottom-up driven in which case the present fisheries management concentrating on limiting fishery activities has little or no effect. The implications of the increased eutrophication in terms of biodiversity and fishery productivity have been largely ignored among the fishery researchers – at least in terms of management information – while discussions instead have concentrated on various *ad hoc* hypotheses on what the causes of observed changes are. These discussions usually ended with the reiterated dogma that any observed change can and should be traced to the fishing activities. It is a paradox that, while the observed resilience of the stocks has caused controversy about the actual status, the unified consensus on the management solutions appears to be traditional gear and effort regulations. The main difference is that the largely failed enforcement of fishing regulations will now be attempted through BMU's and of implementation of existing fishing regulations and measures through co-management.

### *Conclusions regarding processes*

There are, at present, no significant visible effects of the fishery on the main exploited stock. Overall abundance and demographic structure has remained relatively stable. Likewise the fishing mortality has not changed significantly, despite an ever increasing fishing effort, which indicates that biological production[6] has increased concurrently with effort. There are strong indications that the increased tertiary productivity results from increased primary productivity, which again is a function of the increased eutrophication.

There are signs of a slow recovery of the abundance of haplochromines. The abundance of *Rastrineobola* and Nile tilapia seems to be increasing as well, though very limited information is available on this due to the breakdown of the catch and effort data recording system.

The present status of the Lake Victoria fisheries is that there are no signs of overfishing on the main commercial stocks, although locally this may be the case. Fisheries catch rates fluctuate but still without a clear trend, although there may be signs of a decrease. This, however, may also be due to poor (or lacking) monitoring of the catches through catch

[6] It is important to stress here that biological production is a rate, i.e. is a function of time (expressed e.g. as tons per year). This should be clearly distinguished from biomass which is a state (expressed e.g. as tonnes).

assessment surveys, while effort has been intensely monitored by three consecutive biannual frame surveys.

Lake Victoria is not in a steady state, which explains why classical stock assessments have failed, as the underlying assumptions have been violated.

The production-nutrient relationship is dome shaped (Ryder et al. 1974, Fig. 60) which means that production eventually will taper off and subsequently decline. The important question is then: where we are at present on this curve with respect to the fishery? The primary productivity seems now to have reached a maximum (Silsbe et al. 2005), and there are indications that this is also reflected in the fish productivity, at least on the top predator level. The continuing nutrient enrichment of Lake Victoria will not increase gross phytoplankton production as it is already light limited over most of the lake's surface area. According to Silsbe et al. (2005) further nutrient inputs will only cause a higher propensity of algal blooms in response to shallow diurnal stratification, thus further deteriorating water quality Conversely, reducing nutrient fluxes into the lake will decrease eutrophication in inshore areas without necessarily significantly decreasing gross phytoplankton production. Further nutrient enrichment and ensuing deterioration of the water quality will therefore most likely seriously affect the fish biodiversity, and the Nile perch fishery, while other – more hardy – species like Nile tilapia, Dagaa, Clarias, and Protepterus are likely to continue to grow under increased eutrophication.

No relationship has been established between experimental catch rates and water levels – at this stage with limied time series information. But there is visual indication that the 1999 and 2004 increase in catch rates came after a sudden increase in the water levels (Fig. 6).

As eutrophication appears to be the single most important driver of the productivity, management priorities should focus on this issue in addition to the management of fishing effort. Since eutrophication is the most important threat to the ecosystem, the fishery could intensify and diversify to lower trophic levels in order to remove as much organic matter as possible. The use of *Rastrineobola* and recently also *Caridina* shows the beginning of a 'fishing down'[7] process. The lake therefore appears not only to be important as a direct way of feeding the population with fish but also in an indirect way as source of fish meal for aquaculture or animal husbandry for the production of cultured fish, poultry or cattle. .

Management needs to reset its priorities. With little or no influence on the stocks from the fishery activities, the present emphasis on fisheries regulation can be questioned. **The potentially very strong impact of the increased eutrophication on the fishery, and the emergent signs that a maximum in the gross primary production may have been reached, would warrant a much higher management commitment on the eutrophication issue from both environmental and fisheries management perspectives.**

As the development so far has been mainly environmentally driven in terms of nutrient drivers, and as changes in these drivers most likely will continue in the foreseeable future, it

---

[7] Fishing down the food web sometimes has a negative connotation (e.g. Pauly et al. 1998). On the ecosystem level, however, such an exploitation pattern may be considered unselective across the species diversity range and therefore ecosystem conserving (Jul-Larsen et al. 2003). Many small-scale artisanal freshwater fisheries, particularly in freshwater environments, use a multitude of fishing techniques (some of which often are illegal such as small mesh sizes, barriers, weirs, and seines) in order to take advantage of all productive parts of the system they exploit (Turner 1996, Welcomme 1999, Misund et al. 2002). As a result of the multi-gear, multi-mesh situation they generate an overall fishing pattern which has a relatively uniform selectivity over a large range of the organisms and sizes. While such a fishing pattern generally is condemned and persecuted for being 'harmful', 'unselective' or 'indiscriminate', the actual result on the community could very well be a fishing pattern close to the theoretical optimal (Caddy and Sharp 1986, Kolding and van Zwieten 2005).

is of utmost importance that a continued comprehensive monitoring of the most important indicators shall continue. How many indicators to monitor, and what level of monitoring frequency should be applied is basically a question of available economic and manpower resources.

*Conclusions on databases*

One of the most important issues to be addressed in the LVEMP phase II is the availability, accessibility and format of data and databases pertaining to experimental research as well as monitoring surveys. The experience from this synthesising exercise is that:

1. A disproportionate amount of time has been used by the consultants to simply get access to data (which in many cases failed(!!)) and reformat these into formats that made comprehensive analysis and plotting of trends possible.
2. Historical data are not readily available and accessible as original observations. Most data are stored in some non-indexable, inconsistent and inconvenient format, if indeed they are kept at all. Often the primary data are allegedly lost and only available in aggregated formats. If they are available in their original formats, then the format precludes quick accessibility: e.g. the historical trawl data of Tanzania consisted of a few hundred lotus (.wk1) files, that needed to be turned into a flat file format before comprehensive analysis could be done. In this case it took one week to achieve this before the analysis of these data could even start and figures as presented in this report could be produced.
3. Data are stored haphazardly - in various formats - in various places – and with various levels of quality - with various levels of meta-information (collated by whom, where, when and how) and in ways that often preclude proper statistical evaluation or even any evaluation at all where no meta-information is provided. Quite a number of excel files we received from our Kenyan and Tanzanian colleagues could not be used without extensive consultations with the researcher from whom the files originated. In many cases this was not possible given the time limits of the synthesising exercise.
4. Data often appear to be the personal property of the individual scientists, even when collected under a concerted effort such as LVEMP or LVFRP/LVFO. For research data this may sometimes be reasonable if the data are not yet published and are part of thesis research. However, in that case a time limit should be set (e.g. three years and if after that, if they have not been published, they should by then be "common" property or at least handed over to the institution responsible for their storage). Mandated monitoring information, however, such as trawl surveys, CAS and frame surveys, should be public property, of course with clear guidelines on who gets access on what and how. But when to make these data accessible should be clear: immediately after digitising. The process to obtain the information from trawl surveys for this report appeared to be long and tedious precluding thorough analysis of the data. *To this date trawl data that are known to exist – e.g. from Kenya - have not been made available for analysis in this synthesis. These data are tremendously important as the Winam gulf is expected to be one of the first areas in which the fisheries will be affected by increased eutrophication! The trawl survey data from this area may serve as a warning sign for the remaining lake.*
5. Data access seems to depend more on personal goodwill than part of a collaborative institutional effort to analyse, understand and advise on the states and pressures of very important economic activities in the region.

If these issues are not well addressed in future projects with a large research component as the LVEMP1 and LVFRP/LVFO - also in relation to earlier surveys ad data collections done – then funding of in particular fisheries experimental surveys and data collections are largely wasted.

*Conclusions regarding the synthesizing exercise:*

Integrated assessment of the Lake Victoria ecosystem is a great challenge and the development of an ecosystem based approach (EAF) to management of a large and changing system like Lake Victoria requires a basic comprehension of the main processes taking place in the Lake and its catchment area. There appears to have been a tendency to isolate and compartmentalize the research into disciplines (or components), with very limited cross disciplinary flow of information, or acknowledgement of how the results of other disciplines can help in a more comprehensive understanding. Description (and isolated analyses) alone is not sufficient to allow comprehension, but will lead to "information overload" barring the emergence of meaningful insights and strategies for management. It is as if "one cannot see the forest because of all the trees". As illustrated in the present synthesis, a pragmatic and holistic understanding of the Lake Victoria ecosystems is needed to give guidance to the choice of a comprehensive set of indicators and the development of monitoring systems that will aid in ecosystem based management. In this report we have presented a basic analytical framework and a basic analysis of the main processes taking place in the lake environment. This has resulted in a hierarchy of indicators in indicator sets. Only when seen in combination it was possible to derive an understanding of the processes taking place in the Lake Victoria environment affecting fish stocks and the fishery, and also an explanation for why classical stock assessment (building on steady state assumptions) has largely failed.

1. This report is a first effort to synthesize states and trends based on a comprehensive set of indicators selected during a series of workshops with researchers involved on a range of scientific and managerial specialists.
2. A comprehensive analysis at this stage has been limited due to the vast differences in presentation and availability of data between countries, and the limited insight from the various components on how their activities contributes to the larger picture. A further comprehensive analysis is still required.
3. The set of indicators presented here needs to be reviewed in depth in a consultation between scientists, managers and other stakeholders. Key indicators should be selected for continuing monitoring above and independent of individual research projects. This will result in a more thoroughly guided approach to data collection and information processing than is currently possible.
4. A regional annual or biannual report, alias "The state of Lake Victoria 20xx", based on a selected set of indicators will be a powerful tool in guiding co-operation between scientists and managers of the different countries involved, and a powerful aid in fisheries and environmental decision making.

Besides good catch statistics, which have deteriorated since the late 1990s, there is adequate biological information for fisheries resource management and conservation. More emphasis should be put on synthesizing this information and making it available to management. Large amounts of research data and information have been collected from different sources but are rarely integrated. Analytical output is only to a limited degree translated into proposed management actions. Lack of prioritization in research has lead to a large output of activities and papers that in some cases duplicates already known work, while not leading to overall strategic conclusions about where the focus should be in the future in regard to research, monitoring, investments and preventive measures.

The shift in management to embrace co-management has caused stakeholders in the fishery to have a sense of ownership of the resource and therefore can aim at responsible fishing. For this arrangement to work there is therefore a need for a high level of information sharing. There is a need to disseminate accurate, timely and readily understood information on the status and trends of the fisheries to better inform stakeholders. Only if the important stakeholders in the fishery understand and accept the information presented through indicators will they support the efforts to manage the fisheries.

## Recommendations

Status and trends

1. An inventory of key indicators should be established and maintained while new ones should be added as appropriate.
2. An inventory of key parameters for each indicator should be established and maintained while new ones should be added as appropriate.
3. Methods of data collection, analysis and synthesis should be standardized both nationally and regionally e.g. trawl stations and sampling stations for water quality monitoring.
4. Rehabilitation of the catch and effort data recording system (CAS or CEDRS). Frame surveys give a good understanding of the fishing pattern and intensity, but without good contemporary data on the catches only one side of the equation is provided.

Processes

1. Focus on managing eutrophication in view of consequences for:
    a. biodiversity
    b. fisheries
    c. food web

   Further studies are required on lower trophic levels especially the contribution of blue green algae, zooplankton, macroinvertebrates to the biological productivity of the lake.
2. There is need to develop methods to segregate the impact of eutrophication vs. the impact of fishing as they theoretically have the same trajectory. Without a clear picture of causes and effects the ongoing controversy will only exacerbate.

Fish stocks

1. There is need for research and monitoring on the development of sources of fishmeal like *Rastrineobola*, *Caridina* and lake flies.
2. Development of offshore exploitation of dagaa is desirable in view of very little effort in the deep open waters of Lake Victoria.
3. Continued monitoring of fish stocks and the fishery is needed: continuous monitoring of total catch and CPUE is still necessary as indicators of the status of the fishery of the lake. Time series of fishery independent and fishery dependent catch and effort data are the backbone of any management information system and monitoring systems that provide this information should get the utmost attention and priority.
4. A precautionary approach in managing the fishery is needed based on a thorough analysis of existing data and continued monitoring.

Fisheries management

1. There is need to reassess and test the gazetted management regulations, particularly on gears and size selectivity, as there is growing evidence that many regulations are not ecologically or evolutionary optimal.

Socio-economics

1. Monitoring of effort dynamics and movement patterns of fishermen in and out of the fishery. as well as within the lake and research on the reasons for migratory behaviour is needed in particular to establish a relation of this behaviour to the fishery productivity.
2. The fish levy trust fund should be operationalised to ensure a sustainable source of funding for research and management of Lake Victoria fisheries.
3. "Research Bays" could be established in which no fishing takes place to study and determine the effect of eutrophication on fish breeding and production.

Database

1. We suggest that a very strong component in a follow-up phase of the LVEMP will be to facilitate and create a common database and database management system, as well as a regional protocol for scientists to handle and store data in ways that make them accessible and understandable for future generations!
2. Further development of a regional database is necessary at the LVFO headquarters.
3. Better integration of various subcomponent activities during the implementation of a possible Phase II of LVEMP should be reached already when formulating the program (e.g. the water quality, primary productivity, and fisheries). A synthesizing effort such as is attempted in the current report should be the central goal of such a program and not a retrospective activity. The production of a regularly appearing state of the lake report based on a limited set of clear multidisciplinary indicators could assist in reaching such a goal.
4. Research based data should be deposited as a rule at the information and database centres that have been established in the riparian states. An exception is when data are intended for specific research undertakings like MSc and PhD thesis work. These, however, should also be turned in after three years from the time of submission.
5. All researchers should be legally bound to surrender all data generated under any project or programme to their employers and clients.
6. Concerted efforts should be made to retrieve, digitize and archive in a format that is compatible with other datasets nationally and regionally.

## REFERENCES


Abila and Jansen (1997) .......

Abila, R. (2000). The Development of Lake Victoria Fishery: A Boon or Bane for Food Security. IUCN Report No. 7. 28 pp.

Acere, T.O. 1985. Observations on the biology of the Nile perch L. niloticus (Linne) and growth of its fishery in the northern waters of lake Victoria. FAO Fish. Rep. 335: 42-61)

Akiyama, T., A.A. Kajumulo and S. Olsen. 1977. Seasonal variations of plankton and physico-chemical condition in Mwanza Gulf, lake Victoria. Bull. Freshwat. Fish. Res. Lab. 27: 49-61

Anonymous 1989. Report of the multispecies assessment working group. Int. Counc. Explor. Sea., C.M. 1989/Asess: 20, Copenhagen.

Asila, A. A. &J. Ogari. 1988.The growth parameters and mortality of Nile perch (Lates niloticus L.)estimated from length-frequency in the Nyaiiza Gulf (LakeVictoria). FA0 Fisheries Report, 389:272-287.

Balirwa J.S. (1998): Lake Victoria wetlands and the ecology of the Nile tilapia, Oreochromis niloticus Linne. Ph.D Thesis of the University of Wageningen, The Netherlands. 247p.

de Beer. (1989). Light measurements in Lake Victoria, Tanzania. Ann. Mus. Roy. Afr. Centr. Sc. Zool. 257:57-60.

Bertram and Stadler Salt, 2000. Selection of Indicators for Great Lakes Basin Ecosystem Health. Version 4. State of the Lakes Ecosystem Conference. http://www.binational.net/solec2002/doc/Selection%20of%20Indicators%20v4/English/Selection%20Indicators%20Whole%20doc%20access.pdf

Caddy. J.F. and Mahon R. 1995. Reference points for fisheries management, FAO Fish. Tech. Pap. 347, Rome, FAO.

Caddy, J.F. and Sharp, G.D. 1986. An ecological framework for marine fishery investigations. FAO Fish. Tech. Pap. No 283. FAO, Rome. 151 p.

Choi. J.S. K.T. Frank, B.D. Petrie, W.C. Leggett 2005. Integrated assessment of a large marine ecosystem: a case study of the devolution of the eastern scotian shelf, Canada. Oceanography and Marine Biology: an annual review 43: 47-67.

Conover, D.O. and Munch, S.B. 2002. Sustaining Fisheries Yields over Evolutionary Time Scales. Science 297: 94-96.

Cowx, I. (ed.) et al. 2005. Review of the exploitation pressures on the fisheries resources of Lake Victoria. Unpublished LVEMP report. 125 pp.

Degnbol P., A. Jarre 2004 Review of indicators in fisheries management - A development perspective South African Journal of Marine Science/Suid-Afrikaanse Tydskrif vir Seewetenskap [S. Afr. J. Mar. Sci./S.-Afr. Tydskr. Seewet.]. Vol. 26, pp. 303-326.

Downing, J.A., C. Plante and S. Lalonde. 1990. Fish production correlated with primary productivity, not the morphometric index. Canadian Journal of Fisheries and Aquatic Sciences 47, 1929 – 1936.

FAO, 1999. Indicators for sustainable development of marine capture fisheries. FAO Technical Guidelines for Responsible Fisheries No. 8, FAO, Rome 68p.

FAO, 2003, Fisheries Management - 2. The Ecosystem Approach to Fisheries FAO TECHNICAL GUIDELINES FOR RESPONSIBLE FISHERIES 4 Suppl. 2 FAO Rome http://www.fao.org/DOCREP/005/Y4470E/Y4470E00.HTM

Fish, G.R. 1956. Some aspects of the respiration of six species of fish from Uganda. J. Exp. Biol. 33:186-195.

Ganf 1974

Garcia, S.M. and D.J. Staples 2000. Sustainability reference systems and indicators for responsible marine capture fisheries: a review of concepts and elements for a set of guidelines. Marine and Freshwater Research 51: 527-556

Gophen, M., P.B.O. Ochumba, and L.S. Kaufman 1995. Some aspects of perturbation in the structure and biodiversity. Of the ecosystem of Lake Victoria(East Africa). Aquat. Living Resources 8:27-41

Hecky, R.E. 1993. The eutrophication of Lake Victoria. Verh. int. Ver. Limnol. 25:39-48

Hecky and Fee 1981

HEST Report (1987). Research program of HEST and TAFIRI during 1987 and 1988 HEST/TAFIRI Report 37, Rijksuniversiteit Leiden, The Netherlands

Hilborn, R. and Walters C.J. 1992. Quantitative Fisheries Stock Assessment - Choice, Dynamics and Uncertainty, New York, Chapman and Hall.

Hoogenboezem, W. 1985. The zooplankton in the Mwanza Gulf (Lake Victoria) and the food of a zooplanktivorous cyprinid (Rastrineobola argentea) HEST Report, Rijksuniversiteit Leiden, The Netherlands.

Jansen, E. G. (1997). Rich fisheries - poor fisherfolk, Some preliminary observations about the effects of trade and aid in the Lake Victoria fisheries., IUCN The world conservation union: 16.

Jul-Larsen, E., Kolding, J., Nielsen, J.R., Overa, R. and van Zwieten, P.A.M. 2003a. Management, co-management or no management? Major dilemmas in southern African freshwater fisheries. Part 1: Synthesis Report. FAO Fisheries Technical Paper 426/1. FAO, Rome.

Jul-Larsen, E., Kolding, J., Nielsen, J.R., Overa, R. and van Zwieten, P.A.M. (eds.) 2003b. Management, co-management or no management? Major dilemmas in southern African freshwater fisheries. Part 2: Case Studies. FAO Fisheries Technical Paper 426/2. FAO, Rome.

Katurole, G. and Wadanya, J. 2005. A study of impacts of fishing pressure on Nile perch fishery on Lake Victoria, Uganda, using fisher folk community data. Pp. 495-504 In LVEMP 2005 Knowledge and Experience Gained from managing Lake Victoria Ecosystem. A publication of the Lake Victoria Environmental Management Project (LVEMP), Dar-es-Salaam, Tanzania. 725 pp.

Kolding, J. 1994. Plus ça change, plus c'est la même chose. On the ecology and exploitation of fish in fluctuating tropical freshwater systems. Dr. Scient. thesis, Department of Fisheries and Marine Biology, University of Bergen, ISBN 82-7744-011-1. 197 pp.

Kolding, J. and Zwieten, P.A.M van, 2005 (in press). Improving productivity in tropical lakes and reservoirs. Challenge Program on Water and Food- Aquatic Ecosystems and Fisheries Review Series 1. Theme 3 of CPWF, C/o WorldFish Center, Cairo, Egypt xxx pp.

Kudhongania, A.W. and Chitamwebwa, D.B.R. 1995. Impact of environmental change, species introductions and ecological interactions on the fish stocks of Lake Victoria. pp. 19-31 In T. Pitcher and P.J.B. Hart (eds.) Impact of species changes in African Lakes. Chapman and Hall, London.

Larkin, P.A. 1977. An Epitaph for the Concept Maximum Sustainable Yield, Trans. Amer. Fish. Soc. 196: 1-11.

LVEMP 2005. Knowledge and Experience Gained from managing Lake Victoria Ecosystem. A publication of the Lake Victoria Environmental Management Project (LVEMP), Dar-es-Salaam, Tanzania. 725 pp.

Malasha, I. 2003. Colonial and postcolonial fisheries regulations: the cases of Zambia and Zimbabwe. pp. 253-266 In Jul-Larsen, E., Kolding, J., Nielsen, J.R., Overa, R. and van Zwieten, P.A.M. (eds.) Management, co-management or no management? Major dilemmas in southern African freshwater fisheries. Part 2: Case Studies. FAO Fisheries Technical Paper 426/2. FAO, Rome.

Manyala, J.O. (1992). Growth, mortality and mesh size selection of Dagaa, Rastrineobolaargentea, in the Winam Gulf of Lake Victoria (Kenya). Symposium on Biology, StockAssessment and Exploitation of Small Pelagic Fish Species in the African Great Lakes Region. Bujumbura (Burundi), 25-28 Nov 1992.

Manyala, J. O. (1990). Population Dynamics of Rastrineobola argentea (Pellegrin 1904) in the Winam Gulf of Lake Victoria, Kenya. M. Sc. Thesis. University of Nairobi.

Manyala, J. O. (1995). Length-weight relationship and Condition Factor of Rastrineobola argentea in Lake Victoria, Kenya.

Melack, J.M. 1976. Primary productivity and fish yields in tropical lakes. Trans. Am. Fish. Soc., 105: 575-580.

Misund, O.A., Kolding, J. and Fréon, P. 2002. Fish capture devices in industrial and artisanal fisheries and their influence on management. pp. 13-36 In P.J.B. Hart and J.D. Reynolds (eds.). Handbook of Fish Biology and Fisheries, vol. II, Blackwell Science, London.

Mkumbo. O.C., Ezekiel, C., Budeba, Y.L. and Cowx, I.G. 2002. Analysis of exploitation patterns for Nile perch, Lates niloticus, in Lake Victoria. Chapter 8, pp. 84-95 In I.G. Cowx (ed.). Management and Ecology of Lake and Reservoir Fisheries. Fishing News Books. 401 p.

Muhoozi, L. I. and A. N. Othina (2004). Draft SoP for Catch Assessment Surveys in Lake Victoria. 24 pp

Mwebaza-Ndawula L. 1990. The role of invertebrate organisms in the fishery potential of Lake Victoria pp. 56-60. In: Bwathodi P. O. J (ed.) Proceeding of the workshop on the prevailing activities on the Lake basin with particular reference to the fisheries of the lake. Mwanza 8-9 March 1990, 75 p.

Mugidde. R. 1993. The increase in phytoplankton primary productivity and biomass in lake Victoria. Verh. int. Ver. Limnol. 25:846-849

Njiru. A. Othina. A.N., Getabu, A, Tweddle, D. and Cowx, I.G. 2002. Is the invasion of water hyacinth, Eichhornia crassipes Solms (Mart.), a blessing to Lake Victoria fisheries? Chapter 21. pp. 255-263 In I.G. Cowx (ed.) Management and Ecology of Lake and Reservoir Fisheries. Fishing News Books. 401 p.

Njuguna, S.G. 1991. Water hyacinth: the world's worst aquatic weed infests lakes Naivasha and Victoria. Swara 14: 8-10.

NRC (2000) Ecological indicators for the nation. ISBN 0-309-06845-2

Oglesby, R.T. 1977. Relationship of fish yield to lake phytoplankton standing crop, production and morphoedaphic factors. Journal Fish. Res. Bd. Can. 34, 2271–2279.

Ogutu-Ohwayo, R. and S. B. Wandera (2000). The Biology and Ecology of Lake Victoria Fishes: Their Development and Management. 8 pp.

Okaronon (2003)

Okedi, J. (1971). Preliminary Observations on Engraulicypris argenteus (Pellegrin 1904) from Lake Victoria.

Okedi, J. (1981). The Engraulicypris "dagaa" fishery of Lake Victoria: With special reference to the southern waters of the lake. Workshop of the Kenya Marine and Fisheries Research Institute on Aquatic Resources of Kenya, Mombasa (Kenya), 13-19 Jul 198. pp. 445-484; (Proceedings of the Workshop of The Kenya Marine and Fisheries Research Institute on Aquatic Resources of Kenya, July 13-19, 1981).

Patterson et al. 2000

Pauly, D. Christensen, V., Dalsgaard, J., Froese, R., and Torres Jr., F. J. 1998. Fishing down marine food webs. Science 279: 860-863.

Peters, R.H. 1991. A critique for ecology. Cambridge University Press. Cambridge, 366p.

Pitcher T. J. and A. Bundy, 1995. Assessment of the Nile perch fishery in Lake Victoria In: T. J. Pitcher and P. J. B. Hart (Eds.), The impact of species Changes in African Lakes. Great Britain. Chapman & Hall. Pp 163-179.

Rabour et al. (2003)

Rice, J. and M.-J. Rochet (2004). A framework for selecting a suite of indicators for fisheries management. Presentation at the ICES/SCOR International Symposium on Quantitative Ecosystem Indicators for Fisheries Management 31 March - 3 April 2004. Paris. http://www.ecosystemindicators.org/Paris/Rice_files/frame.htm

Rothchild, B.J., 1977. Fishing effort, pp 96-115 In J.A. Gulland (ed.) Fish Population Dynamics. John Wiley & Sons, London.

Ryder, R.A., Kerr, S.R., Loftus, K.M. and Regier, H.A. 1974. The morphoedaphic index, a fish yield estimator - review and evaluation. J. Fish. Res. Bd. Canada, 31:663-688.

Rzóska, J. 1957, Notés on the crustacean plankton of Lake Victoria. Proc. Linn. Soc. Lond. 168:116-125.

Salz, P. 1986. Policy instruments for development of fisheries, Publication No. 574, The Hague, Agricultural Economics Research Institute.

Schaefer, M.B. 1954. Some aspects of the dynamics of populations important to the management of the commercial marine fisheries, Bulletin of the Inter-American Tropical Tuna Commission 1: 27-56.

Seehausen, O., van Alpen, J. J. M. and Witte, F. 1997. Cichlid fish diversity threatened by eutrophication that curbs sexual selection. Science 277: 1808-1811.

Seehausen, O., van Alpen, J. J. M. and Witte, F. 2003. Implications of eutrophication for fish vision, behavioral ecology and species coexistence. Pp. 269-287 In T.L. Chrisman, L.J. Chapman, C.A. Chapman and L. Kaufman (eds.). Conservation, Ecology and Management of African Freshwaters.

Silsbe, 2004

Silsbe G.M., Hecky, R.E., Guildford, S.J. and Mugidde, R. 2005. The upper limit of gross phytoplankton production in Lake Victoria, East Africa: Implications for the lake's fishery. Poster presented at the 11th World lakes Conference (ILEC). 31st October 4th November 2005, Nairobi Kenya.

Sissenwine, M.P. 1978. Is MSY an Adequate Foundation for Optimum Yield? Fisheries 3(6): 22-42.

SOFIA 2004. The State of World Fisheries and Aquaculture 2004. FAO Fisheries Department, Rome. 153 p.

Sparre, P. and Venema, S.C. 1998. Introduction to tropical fish stock assessment, Part I: Manual. FAO Fish. Tech. Pap. 306/1, Rev. 2. FAO, Rome, 407 pp.

Steele, J.H. 1998. regime shifts in marine ecosystems. Ecological Applications 8: 33-36.

Taabu A. M, B A Steinarsson and E. Hjörleifsson, (2005): Assessment of status of the stock and fishery of Nile perch in Lake Victoria –Uganda. Project report for United Nations University – Fisheries Training program 54pp.

Talling 1965, J.F. and I.B. Talling, 1965. The chemical composition of African lake waters. Int. Rev. ges. Hydrobiol. 50: 421-463

Talling, J.F. 1966. The annual cycle of stratification and phytoplankton growth in Lake Victoria (East Africa) , Int. Rev. ges. Hydrobiol. 51: 545-621

Turner, G. F. 1996. Maximization of yields from African lakes. Pp. 465-481 In. I.G. Cowx (ed.) Stock Assessment in Inland Fisheries. Fishing News Books, Oxford.

Van Oijen, M.J.P. F. Witte and E.L.M. Witte-Maas(1981). An introduction to ecological and taxonomic investigations on the haplochromine cichlids from the Mwanza gulf of Lake Victoria. Neth. J. Zool. 31: 149-174

Verschuren, Dirk, Thomas C. Johnson, Hedy J. Kling, David N. Edgington, Peter R. Leavitt, Erik T. Brown, Michael R. Talbot, and Robert E. Hecky. 2002. The chronology of human impact on Lake Victoria, East Africa. Proc. R. Soc. Lond B 269: 289-294.

Wandera, S. B, G. Namulemo, and A. M. Taabu, (2003): Fish biology and ecology report of the quaterly IFMP cruise report. July-August 2003. 12pp.

Wandera & Wanink (1995) Growth and mortality of dagaa (Rastrineobola argentea Fam. Cyprinidae) in Lake Victoria. Naga ICLARM Q 18(1):42-45.

Wandera, S.B. (1992). Seasonal abundance, vertical migration and the fishery of Dagaa Rastrineobola argentea in the Ugandan waters of Lake Victoria. Symposium on Biology, Stock Assessment and Exploitation of Small Pelagic Fish Species in the African Great Lakes Region. Bujumbura (Burundi), 25-28 Nov 1992.

Wandera S. B. (1999) The reproductive biology of Rastrineobola argentea (Pellegrin) in the Northern Waters of Lake Victoria. FIDAWOG (1999). Report of the FIDA WOG Workshop Held in Kisumu 16 – 20 August 1999. I. G. Cowx and D. Tweddle (Eds.).

Wanink, J. 1998. The pelagic cyprinid Rastrineobola argentea as a crucial link in the distrupted ecosystem of lake Victoria. PhD thesis, University of Wageningen, The Nehterlands, ISBN 90-5651-042-8, 288 pp.

Welcomme, R.L. (1964) The habitats and habitat preferences of the young of the Lake Victoria Tilapia (Pisces-Cichlidae).Revue de Zoologie et de Botanique Africaines: Vol. 70 No. 1-2 Page(s) 1-28.

Welcomme, R. L. (1967). "Observation of the biology of the introduced species of Tilapia in lake Victoria." Revue de Zoologie et de Botanique Africains 76(3-4): 421-463.

Welcomme, R.L. 1970. Studies on the effect of abnormally high water levels on the ecology of fish in certain shallow regions of Lake Victoria. J. Zool. 160:405-436

Welcomme. R.L. and Halls A., 2001. Some considerations of the effects of differences in flood patterns on fish populations. Ecohydrology and Hydrobiology, 1:313-321

Wiegert, R.G. 1988. Holism and reductionism in ecology: Hypotheses, scale and systems models. Oikos, 53:267-269.

Worthington.E.B. 1931. Vertical movement of freshwater macroplankton. Int. Rev. ges. Hydrobiol. Hydrogr. 25: 394-436

Worthington, E.B. 1930. Observations on the temperature, hydrogen-ion concentration and other physical conditions of the Victoria and Albert Nyanzas. Int. Rev. Ges. Hydrobiol. 24: 328-357

Zwieten, P.A.M. van, Goudswaard, P.C, and Kapasa, C.K. 2003a. Mweru-Luapula is an open exit fishery where a highly dynamic population of fishermen makes use of a resilient resource base. pp. 1-33 In Jul-Larsen, E., Kolding, J., Nielsen, J.R., Overa, R. and van Zwieten, P.A.M. (eds.) Management, co-management or no management? Major dilemmas in southern African freshwater fisheries. Part 2: Case Studies. FAO Fisheries Technical Paper 426/2. FAO, Rome.

Zwieten, P.A.M. van, Njaya, Weyl, O 2003b..Effort development and the collapse of the fisheries of Lake malombe: does environmental variability matter? pp. 132-164 In Jul-Larsen, E., Kolding, J., Nielsen, J.R., Overa, R. and van Zwieten, P.A.M. (eds.) Management, co-management or no management? Major dilemmas in southern African freshwater fisheries. Part 2: Case Studies. FAO Fisheries Technical Paper 426/2. FAO, Rome.

Zwieten, P.A.M. van, M. Banda, K. Mwakiyongo, M. Manase, G. Kanyerere, T. Nyasulu (2005). Potential biological state and pressure indicators to evaluate the fisheries of Lake Malawi SE arm and Lake Malombe: evaluative capacity of Fisheries Research Unit of Malawi.Literature review and indicator assessment. Case Study: South-East Arm of Malawi Knowledge in Fisheries Management Project (EU/INCO-DEV). 93 pp.

# Appendices

## *Appendix 1: Terms of Reference*

1. Concerns for the Consultancies

The LVEMP was expected "*to rectify the serious lack of knowledge about the entire aquatic population of the lake, focusing especially on non-commercial fish of great biological interest, their species composition, population structure, food and feeding habits, tropic relationships, reproduction and breeding habits, recruitment patterns, growth, oxygen tolerance, mortality and migration as well as the other organisms which play key roles in sustaining the Lake Victoria ecosystem. including specifically other aquatic vertebrates, macro-invertebrates, micro-invertebrates, phytoplankton, macrophytes and bacteria*". It was expected that the outcomes of the LVEMP activities would "*be species distribution and habitat maps, information on the genetic make-up and diversity of different populations, understanding of the causes of decline of fish species, understanding of the impact of environmental changes on the biology. behaviour and survival of declining species, guidelines for species conservation and restoration, an updated bibliography of Lake Victoria and its fisheries .........*".

Substantial progress on data acquisition has since been made through the LVEMP and from other sources but there is need to analyse them, in a quantitative manner using appropriate methods, and to summarize the information gained and place it in the context of information existing before the LVEMP and also the information that may have been generated by other entities.

To address this concern, there is need to consolidate, analyse and synthesize the data and knowledge generated by the LVEMP and from other sources in order to get a complete picture of past trends and the current status of the fisheries and biodiversity of Lake Victoria and its catchments in line with the expectation of the LVEMP. The consultancy shall, therefore, use the available data, information and knowledge to arrive at the expected outcomes of the Fisheries Research and Management Components of the LVEMP.

2. Methodology

The task will be carried out in Kenya, Uganda and Tanzania as well as regionally. This would include data consolidation, analysis, synthesis and interpretation, and shall be conducted under the guidance of three local consultants and one international consultant. This will be done through working sessions and workshops both nationally and regionally. Data will be reviewed, trends established and results correlated. Information will be disseminated through the regional workshop before the final draft report will be formally published.

3. Duration of the Work

Seven months beginning as soon as possible and no later than 15th March 2005. The synthesized Regional Lake Victoria Fisheries Research and Management Report must be ready by end of November 2005.

4. Scope of Work

This will involve the consolidation, analysis, synthesis and the development of trends; the interpretation of data, spatial and temporal variability, inter-species relationships, behaviour of species as well as impact of environmental changes on biodiversity and the causes of species decline. The international consultant shall, therefore, provide:

- Guidance on data consolidation and formatting;
- Insure that relevant data from international sources are available and used where relevant to amplify or validate LVEMP generated data;

- Guidance on data analysis and interpretation that is consistent between and among the three riparian states and which meets the requirements of the LVEMP while adhering to international standards of scientific data analysis and interpretation;
- Technique for the harmonization of outputs among the three riparian states;
- Write-up/Guidance on the use of techniques to refine the understanding of bio-energetic relationships between different components of the food web that often raises concerns about modifying any element of the food web, e.g. algal productivity, the trophic interactions of even the major fish species and the efficiency of trophic transfers that are still poorly known since this knowledge is important in discussing the potential for recovery of many of the threatened species;
- Write-up/Guidance for additional studies on the genetic diversity and population structure of most organisms in the lake basin and the dependence of the currently acceptable contaminant levels for pesticides and mercury on food web structure, system productivity and environmental conditions.

This will involve access to and use of the data produced through the activities of the Fisheries Research and Management Components of the LVEMP which include:

- All fisheries frame survey data;
- Laboratory analyses;
- Fisheries research and management databases;
- Socio-economic information and database;
- Relevant databases from other Components of the LVEMP;
- Literature sources from libraries;
- Reports from the Secretariats of the LVEMP;
- Reports, database and information from the Lake Victoria Fisheries Organization;
- Data and information from the Secretariat of the East African Community;
- Data and information from other entities operating on Lake Victoria.

The work will therefore help to address specific concerns under the various sub topics within the Fisheries Research and Fisheries Management Components of the LVEMP.

In addition to the tasks above, it is expected that the consultant will:

- Identify data gaps and recommend additional equipment where necessary to be used for sampling after the harmonization of the use;
- Provide reports to the Regional Secretariat with copies to the National Secretariats of the LVEMP in Kenya and Uganda as required in the reporting obligations. The reports will also be sent to the World Bank Task Team Leader to inform him/her on the progress of the development of the regionally integrated study plan for phase two;
- Carry out on-the-job training by collaborating with counterpart project personnel responsible for fisheries research and fisheries management in data analysis and synthesis of reports; and
- Disseminate results, priorities and recommendations in a two-day regional workshop followed by a two days of national workshops in each country.

5. Expected Outputs
    a) A draft regional Lake Victoria Fisheries Research and Management Status Report;
    b) Final Lake Victoria Fisheries Research and Management Status Report after regional/national workshops on the Draft Report;
    c) A draft of succinct summary manuscript for publication in a suitable reviewed international scientific journal to be co-authored by component and sub-component leaders, national consultants and international consultant on the current status and long term trends in the fisheries of Lake Victoria. Completion and publication of this manuscript will be external to the terms of the consultancy because timing is controlled by journal editorial processes but

will provide a quality assurance and endorsement to the results of the Fisheries Research and Fisheries Management Components of the LVEMP.

## *Appendix 2: Process of the consultancy and issues arising from the Terms of Reference*

Steps and structure of the process (pyramid)

Following the inception workshops the three national working groups, together with the national consultants wrote the National Synthesis report. Drafts of the Ugandan report were available halfway August 2005 and commented upon by the consultant before the second workshop. The Tanzanian report was received by the end of August 2005 and in part commented before the second workshop. Five further chapters were commented upon in the first week of October 2005. The Kenyan draft report was received at the second workshop in September and commented upon by the end of October 2005.

Because of the wide range of topics to be covered the national reports are a multi-authored endeavour, with as many specialists in the various fields brought in as was deemed necessary. We refer to the national reports for a full list of authors. During the drafting of the national reports the international consultants were available by e-mail to assist in data analysis and reporting where needed. This possibility, however, has not been used. The national reports formed the basis of the regional synthesis: the outline of which was discussed and consolidated during the regional workshop. The international consultants compiled a draft of the synthesis report that was presented to the LVEMP secretariat before the end of October 2005. During the first week of December the report was consolidated in a working session of the authors in Dar Es Salaam, and subsequently finalised and submitted to the LVEMP secretariat by the international consultants. The report includes an outline of a scientific publication to be published in an international refereed journal.

Roles of national/international consultants according to the ToR

The national consultant will:

1. Work with the two PCCs (Fisheries Research & Management) to prepare for the Working Sessions and Workshops
2. Work with the PCCs to produce national data summaries and reports (i.e. reports of working sessions and workshops)
3. Participate in the national and regional workshops
4. Assist the International Consultant in the drafting of the Regional Synthesis Report
5. Provide technical guidance to ensure production of quality reports

The international consultants will:

1. Guide data consolidation and formatting. This involves:
    a. Give guidance to ensure that various relevant data (electronic and hard copies) are analysed and utilised in scientifically acceptable ways to describe trends
    b. Guiding the writing process in an agreed format
    c. Outlining steps involved in consolidation and formatting data, putting into consideration temporal and spatial dimensions. The spatial dimension is referred to as "geo-referenced" data; this enables condensing the data in relation to geographical zones.
    d. Guidance in sourcing of historical data/information to supplement the current data in order to give real time series trends
2. Ensure that relevant data from international sources are available and used where relevant to amplify or validate LVEMP generated data
3. Guide data analysis and interpretation that is consistent between and among the three riparian states and which meets the requirements of the LVEMP while adhering to international standards of scientific data analysis and interpretation
4. Spearhead a format for the harmonization of outputs among the three riparian states

## Issue arising from the ToR

Foodwebs

The item in the ToR about addressing and analyzing foodwebs has been discussed. The International Consultants have indicated that they could not understand the substance and general idea behind this section in the ToR. Given the general scarcity of relevant data, scattered in literature and – often unconsolidated - databases an analysis of bio-energetic relationships would take up much more time than was available. With regard to guidance to "techniques to refine bioenergetic relationships" it was argued that well-established approaches as Ecopath, Ecosim and Ecospace are readily available through the internet accompanied with clear guidelines as to their use. The international consultants were not enlightened by the workshop participants nor by the other signatories of the consultancy on the approach to be taken here. However, the International Consultants have interpreted this item in the light of the general lay-out of the report which is to establish trends. To do so they have proposed to address this issue as indicated in the Appendix 3.

Genetics

From the onset in the correspondence and discussions between the international consultants and the LVEMP secretariat about the intended results of the consultancy, they have made reservations about this item of the ToR to the RES. Both consultants have limited experience in the field; furthermore it is not possible to express this activity in terms of trends and states. This was indicated to be understood by the RES. Furthermore, no indicators related to genetics have been identified during the initial workshops in the three countries. The international consultants have encouraged the national components to discuss and include this issue in their national reports. However, no information appeared to be available; the issue was not discussed in the national reports and no recommendations were made. This regional synthesis report therefore does not contain guidance on the matter of "additional studies on the genetic diversity and population structure of most organisms in the lake basin". The second part of this item in the ToR referring to "acceptable contaminant levels for pesticides and mercury for the food web structure, system productivity and environmental conditions of the lake" is covered by the Water Quality synthesis report. No additional information was produced in the national reports.

## Data consolidation, formatting and database management

Data availability and accessibility to the international consultants

According to the LVEMP objectives, data compiled at a regional level are to be considered a deliverable of the project. Though national fisheries databases were said to be available, this appeared to be highly limited in practice. Most of the data collected in Lake Victoria remain on individual computers, and are often considered as personal databases. Although the ToR indicates use and access to any data set necessary for the synthesis, the international consultants acknowledged that use of unpublished research based data may be a sensitive issue in some cases for individuals, as well as time-consuming if analyses should be carried out by the consultants. We have therefore agreed that national and international consultants may require data sets for further exploration and reviewing of analysis to establish trends aggregated over the lake, as well as conduct multiple regressions and correlations between different time series from different sources. Requests for data and assistance in analysis have been communicated at all times to the national consultants and the component co-ordinators.

For analysis and integration at the regional level, the aggregated results – i.e. the indicator over time, as presented by means, with standard deviation and/or standard errors included as well as sample size - were to be made available by the national consultants both in graphical format and as raw data in a spreadsheet. It was agreed at the regional workshop in September to provide the international consultants with the data related to the indicators as selected during the workshop and presented in the National Reports in order to perform the necessary comparisons and aggregations as well as present the information of the three countries in a consolidated manner. During the regional workshop in September the international consultants received some aggregated data, mostly unreferenced, in spreadsheets from the national consultants of Kenya and Tanzania. But the National Consultants of all three countries, through whom all request for data were made, appeared to have (great) difficulties to get access to the data that would form the basis for the regional synthesis. With the exception of most of the available trawl data from Uganda and Tanzania, the raw data related to the indicators in the regional synthesis report were not received by the international consultants. The National Consultant indicated that the international consultants should use the data as presented in word processed format. Wherever no data are available in a database format (excel, flat data files, tables etc.) time series will be presented here as they are in the national reports without further aggregation at the regional level. Also the statistical trend analysis of the indicators will be limited to where data have been made available to them. In all other cases an interpretation of the reporting in the national reports will be made and checked against available literature.

## Other issues arising

Additional indicators

During the inception workshops the initial list of indicators was slightly modified within each country. Each country was therefore recommended to study the lay-outs of the other countries in order to harmonise the output as much as possible. In particular the following indicators should be considered:

- Caridina by-catch in Dagaa fishing used for fishmeal reduction.
- Events of fish kills (time, location, degree) should be considered.
- A time series of previous MSY estimates (by species, referenced)
- A description of the changed roles in the decision making process of fishers, researchers, managers and the private sector in fisheries management over time

Divergence in total catch estimates in Kenya

Although harmonisation of different estimates of catch statistics is envisaged, it will at present be necessary to outline the methods of data collection and raising factors used in the estimates of total catch by the Fisheries Department and the KMFRI, in order to evaluate the status of the total catch, and the observed trends over time.

# *Appendix 3: Formats for data reporting*

**Formats for reporting quantitative data***:*

1. If repeated sampling has taken place and means and measures of variability can be calculated, the annual (monthly) data points in the time series should contain the following information:
    i. N = number of observations
    ii. Mean
    iii. $\pm$ 2 * SE
    (SE = Standard Error = (Standard Deviation)/√(Number of Observations -1)) With N30 2*SE approximates the 95% confidence limits: with that significant differences can be read directly from the graph
2. If only mean values are available they should be reported as a data point in the graph without variation
3. If only ranges of values are reported or known than this can be indicated by a bar over the range of values

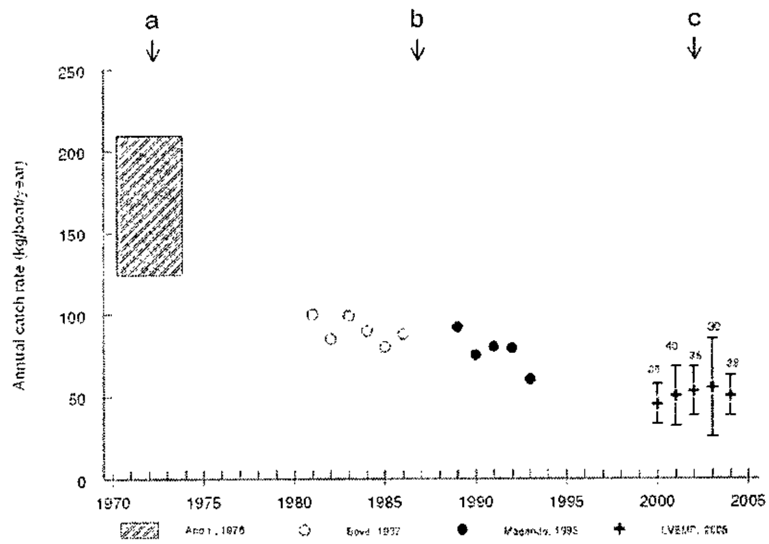



Figure 72: Hypothetical time-series of an indicator (annual catch rate) with 4 data sources referenced in the legend below the graph. a: "fuzzy" data, a known range has been reported b. Two reports on mean values per year; c: calculated mean + 2* standard error, with number of observations.

All sources of the data points should be reported in the text below the graph. If a graph contains multiple sources than each series of datapoints should be given a different symbol (open closed points, stars, triangles, squares etc.) with a legend indicating the data sources. Figure 1 gives an example of the use of different types of data in one graph.

**Formats for reporting qualitative or semi-quantitative data:**
Qualitative information can be tabulated where the first column indicates the year (or a range of years), the second column contains the description of the indicator and the third the authority. E.g.:

| Year | Indicator | Authority/reference |
|---|---|---|
| 1955 | The importance of the indicator was recognised as some strange noise was heard. | Author 1956 |
| 1956 – 1975 | Yes, no, yes, much confusion on what indicator means | Pers. comm. Mrs. X |
| 1976 | Ratatatatata, something made a lot of noise, between 200 and 500 | Author, 1980 |
| 1977 | Agreement on the noise, but it is subsiding. Reports that it is somewhere between 100 and 150. | Author,1978 |
| 1978-2000 | No news. | - |
| 2000-2005 | LVEMP revived the indicator and did extensive research, resulting in a renewed interest in the sounds the indicator makes. Noise possibly between 50 and 60. | LVEMP, 2005 |

**Format for reporting foodwebs**

Foodwebs are to be presented as follows (ref Ecopath):

| **Year of compilation of sample** | *Species 1* | *Species 2* | ...... | *Species n* |
|---|---|---|---|---|
| *Species 1* | Percentage composition | Percentage composition | | |
| *Species 2* | Percentage composition | Etc. | | |
| .... | | | | |
| *Species n* | | | | |

Note:

1. Species can also be species group
2. Time series are presented as consecutive tables.

Estimates of ecotrophic efficiencies (EE) and growth conversion ratios (GE or P/Q) can also be given tabulated with dated references.

Based on the tables, time-series of foodwebs can be represented by species as a composite percentage graph (See e.g. Jul-Larsen et al. 2003 426/2, Kariba case). No new models are envisaged.

**Format for reporting role changes in fisheries management**

With the commencement of more collaborative forms of management, the different actors will get different responsibilities in the decision making process, from setting objectives, collecting information, formulation and implementation of measures and evaluation of measures ad objectives against indicators. During the meeting in Tanzania it was suggested to report on the changes in roles of fishers, researchers, managers and private sector that have taken place in fisheries management over time. We suggest to do this as follows:

| *Position in decision making process* | *Roles* | *1955 - 1975* | *1975 – 1995* | *1995 – 2005* |
|---|---|---|---|---|
| Setting objectives | | G | G | G |
| Collection of information | collection of statistics | R, M | R, M | F |
| | Collection of experimental catch data Etc. | R | R | R,F |
| Implementing measures | registration of fishers | G | M | F |
| | Enforcement | M | M | F |
| | collection of fees Conflict resolution beach hygiene and sanitation Etc. | G | G | F |
| Evaluation of measures | Etc. | | | |
| Evaluation of management objectives | Etc. | | | |

Legend: F = Fishers M = Department of Fisheries (Fisheries Management) R = Fisheries Research P = Prinate Sector N = NGO's G = Government (Ministry of Fisheries; Local Government)

## *Appendix 4: Frameworks of selection of indicators*

Selecting indicators bears a number of risks. Choosing too few indicators may not support decisions well due to the complexity of ecosystems and issues. Too many indicators will be costly and will be confusing as understanding the relative importance of the various indicators will be an issue. An organisational setting can handle only a certain amount of complexity: too many indicators may mean that management cannot be guided by them due to conflicting directions if the indicators are not well understood by those making use of the toolkit and lead to information overload. Furthermore selective use of indicators by different stakeholders could lead to breakdown of communication. Selection criteria for indicators also require that *standards for evaluation* must be set before addressing specific cases, in order to avoid circularity in arguing for specific indicators. There is also no guarantee that the same indicators are informative in all situations, meaning that an assessment of the information value of a particular indicator should be made in each situation: local information value is therefore a criterion in itself to assess the utility of an indicator.

Selection criteria for indicators should include considerations of *meaning, cost, availability of data* and *responsiveness. Meaning* refers both to a well-established theoretical basis and the acceptance of the indicator in the scientific community, to (shared) understanding by users of the indicator and to a legal basis for action (reference points: can they be given?). Meaning also refers to the recognition by users of the different values that will be given to an indicator and with that to the interpretation of an indicator. This is important as indicators should form a basis for action, and agreement should be reached on the interpretation of indicators. *Costs* refer to both affordability and effectiveness: the actual costs of obtaining data, the broadness of application of an indicator and the statistical properties of the indicator. The third criterion, *availability of historical data*, refers to existing experience with a particular indicator: time series with a high contrast, for which data have been collected and sampled in consistent ways, over many areas with good archiving and availability, are indispensable. *Responsiveness* in the first place refers to the lag time between management action and response of an indicator, in other words the timescale of the feedback of an indicator. Secondly it also means that indicators of state should be sensitive[8] and specific to the pressures of interest, such as fishing. For instance, it is important that environmental forcing is small and systematic compared to the effects of fishing, but similarly responsiveness to other (unknown factors) also determines how responsive an indicator is. Much will depend here on the variance and bias of an indicator, and with that on the consistency and standardisation of data collections (Rice and Rochet, 2004). Further criteria to evaluate indicators include aspects of shared understanding, social acceptability and legitimacy of indicators (Degnbol and Jarre, 2004). These authors emphsize the *observability* (within economic resources for research on a sustained basis; by stake holders, either directly or by transparency in the observation process); the *acceptability (*by stakeholders in the fishery system; by the public at large /decision makers; research based substance/reflect analytical soundness; reflect features in accordance with stakeholders' understanding of the resource) and relatedness to management (management objectives (including reference values) ; responsiveness to measures; relevance to the scale of management; and compatibility with management institutions).

---

[8] Sensitivity refers to the response of an indicator to the pressure of interest, as well as the variability around a trend; specificity relates to the number of forces that affect the change.

## *Appendix 5: Additional information on several indicators presented in the main report.*

Table 15: List planktonic Crustacea of Lake Victoria from historical data (Source: Tanzania National Synthesis Report on Fisheries Research and Management)

| Species | Rzoska 1957 (9 stations) | Stuhlmanni, 1891 Mwanza Bay | Weltner 1897/98 (4 stations) | Mrazek, 1897 | Waya and Mwambungu 2004 | Chande *et al.* 004, 2005 |
|---|---|---|---|---|---|---|
| *Diaphanosoma excisum* Sars | + | - | + | - | + | + |
| *Ceriodaphnia cornuta* | + | - | | - | + | + |
| *Ceriodaphnia dubia* | + | - | | - | - | - |
| *Moina dubia* G. & R. | + | *Brachiata* sp. | + | - | - | - |
| *Moina micrura* | - | - | + | - | + | + |
| *Daphnia longispina* Leydig | + | - | + | - | + | + |
| *Daphnia lumholtzi* Sars | + | - | - | - | + | + |
| *D. barbata (Weltner)* | - | - | *jardinei* var. *barbata* | - | + | + |
| *Chydorus sphaericus* (O. F. M) | + | - | - | - | sp. | sp. |
| *Bosmina longirostris* (O. F. M) | + | - | *stuhlmanni* | - | + | + |
| *Simosa vetulus* (O. F. M) | + | - | *capensis* Sars | - | - | - |
| *Tropocyclos confinis* (Kiefer) | + | - | - | *prasinus* | + | + |
| *Mesocyclops leukarti* Cls. | + | - | - | + | + | + |
| *Thermocyclops neglectus* (Sars) | + | - | - | *C. oithonoide* Sars | + | + |
| *Thermocyclops schuurmanaes* (Kiefer) | + | - | - | sp. | - | - |
| *Thermocyclops emini* (Mrazek) | + | - | - | + | + | + |
| *Diaptomus galeboides* Sars | + | - | - | + | + | + |
| *Diaptomus stuhlmanni* Mzarek | + | - | - | + | - | - |
| **Total** | 16 | 1 | 7 | 7 | 13 | 13 |

+ n= present; - = absent.

*Appendix 6: Final abstract for the ILEC conference, Nairobi 2005.*

# How resilient is Lake Victoria? State, trends and processes of its fisheries and environment.

**Abstract**

By: Kolding, J., van Zwieten, P.A.M., Hecky, R.E., Manyala, J., Mgaya, Y.D., Okedi, J. and Orach-Meza, F.L.

Lake Victoria in East Africa has undergone major changes over the past four decades in terms of species composition and exploitation pattern. It is already known worldwide for the abrupt shift from a high diversity cichlid dominated fish fauna to a much more simplified foodweb of 3-4 species (of which two are exotic) that occurred in the early 1980s. After this shift the introduced predator, *Lates niloticus*, became totally dominant and a flourishing export fishery has since developed primarily targeting this species. Effort in terms of number of fishermen and boats has grown almost exponentially, and is now 7 times higher than the 1960's, while the yields have risen by a factor 6.5. Yet, the average standing biomass, and the average overall catch rates have remained remarkably stable over the past 30 years, albeit with large decadal fluctuations. Classical fish stock assessment methods are unable to explain this phenomenon, and therefore the results in most recent analyses are indicative of serious overfishing and collapse. Besides the spectacular changes in the fish stocks and the fishery, however, similar influential changes have occurred in the environment. Nutrient loadings to the lake from the surrounding catchments area has risen by a factor of 2, and the primary productivity in the lake has increased by a factor of 2 with 6-10 fold changes in algal biomass in both nearshore and offshore environments between 1969 (chlorophyll: 1.3 – 4.9 $mgl^{-1}$) and 1993 (chlorophyll: 17 – 21 $mgl^{-1}$). The increased eutrophication has resulted in a lake environment with favorable conditions for Water-hyacinth (*Eichhornia crassipes*) along the shores, much reduced $O_2$ concentrations in the deeper parts, and increased densities of atyid prawns (*Caridina nilotica*) and lakeflies (*Chaoborus* and *Chironomids*).

The development and present state of the lake and the fishery is described by time series of selected environmental, biological, social and economic indicators that together illustrate the large changes that have taken place. It is hypothesized from a multiple regression model that the apparent resilience and stability of the exploited stocks to the rapidly growing fishing pressure, driven by fast increase in export returns, is directly due to the increased primary productivity that has cascaded up in the simplified food chain. Thus as overall production continued to increase with increased levels of nutrient loadings, the fishery absorbed more effort and produced higher yields. The productivity-nutrients curve, however, is dome-shaped: the question is if, and at what level, the process will reverse into an accelerated decrease that would bring economic disaster to the region. The algal production in the lake is now light limited and the upper level of primary production possible has been reached. Further nutrient enrichment will only favor floating macrophytic growth or be unutilized. Reduction in nutrients especially of phosphorus would not reduce annual primary production but could favor the growth of more readily consumed species with benefit to secondary production. Fisheries management should perhaps be more concerned with controlling the increased nutrient runoff into the lake than focusing on illegal fishing practices that at present may have no significant effect on the stock dynamics. We surmise that, if eutrophication is the strongest driver of the observed changes, then the high rates of fishing (the three main commercial species and *Caridina*) are removing excess nutrients from the lake and helping to resist further eutrophication.