TECHNICAL COOPERATION REPUBLIC OF MALAWI
FEDERAL REPUBLIC OF GERMANY

PROCEEDINGS OF THE LAKE MALAWI FISHERIES MANAGEMENT SYMPOSIUM

4TH – 9TH JUNE 2001 CAPITAL HOTEL, LILONGWE

EDITED BY

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December 2001

Department of Fisheries

NATIONAL AQUATIC RESOURCE MANAGEMENT PROGRAMME (NARMAP)

Deutsche Gesellschaft für Technische Zusammenarbeit

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Speech by the Minister of Natural Resources and Environmental Affairs, Hon, Harry I. Thomson, MP, at the opening of the opening of the Lake Malawi Fisheries Management Symposium

Read by the Deputy Secretary of the Ministry of Natural Resources and Environmental Affairs Mr. E.E. Lodzeni.

The Director of Administration in the Ministry, The Director of Fisheries and all other fisheries staff, Representatives of Donor Agencies, Delegates to the Symposium, Representatives of Government Ministries and Departments, Members of the Press, Ladies and Gentlemen.

It is a great honour and privilege for me to be with you today to officially open this International Symposium on the Management of Lake Malawi and Lake Malombe fisheries resources. This is a very important symposium for Malawi, since it derives a variety of social and economic benefits from the resources these lakes provide.

First and foremost, I wish to extend a warm welcome to all participants to this symposium, in particular our international guests, who, despite their commitments at home have felt if very important that they come and contribute towards the rational management of the fisheries in Malawi. To them I would like to say 'feel at home'. I have noted that the programme does not provide for a field trip. However, I would like to encourage participants who will have spare time after the conference, to take a tour of the countryside, especially along Lake Malawi, where in addition to having a field observation of the issues to be discussed here, will also be able to admire the scenic beauty of some spots in the country, and have a feel of ***'Malawi the Warm Heart of Africa'***.

Ladies and Gentleman, I have been informed that this has been organised with a view to amalgamate all research results of previous work done on lake Malawi and Lake Malombe for purpose of formulating management recommendations that would ensure sustainability of the fisheries resources. My reaction to this, is that this gathering has come at an opportune time when the Malawi Government is looking for ways and means that would provide for the sustainable management of its natural resources including fish stocks. Recent trends in the status of our fisheries show that there is need for more management guidelines to be put in place, if the fish stocks are to be sustained. Hence Government, through the Department of Fisheries, has recommended a number of strategies aimed at nurturing and promoting efficient management of the fish resources for the benefit of the present and future generations.

Ladies and gentlemen, these responsibilities should not be taken lightly, as fish is a vital source of animal protein in Malawi, contributing about 60-70% of the nation's animal protein supply. In addition, the fisheries sector employs directly well over 50 000 full-time artisanal fishers and about 1 000 commercial fishers. Indirectly, it offers employment to 250 000 individuals working in fisheries related activities such as processing, marketing and boat building. Therefore, the social and economic significance of the fisheries sector in Malawi is well recognised by Government.

Furthermore, Malawi possesses rich aquatic resources notable of which are the diverse fish species that abound in the various water bodies, especially Lake Malawi. Malawi's fish biodiversity is unparalleled anywhere else in the World. It is documented that lake Malawi harbours more that 700 species of fish, which is more than any other lake in the world. However, less than half are scientifically described.

It is in recognition of this that the Fisheries Research Unit (FRU) was set up and has been carrying out research studies on Lake Malawi and other lakes and rivers. These are aimed at generating management guidelines for the management and sustainable exploitation of our fisheries resources. Previous activities have centred on:

1. Study of biological characteristics of fish with the aim of determining growth parameters, breeding behaviour, spawning behaviour, mortalities, feeding habits and nursery grounds;
2. Stock assessment involving exploratory survey in shallow and deep waters with a view to identifying under-utilised fish stocks, and monitoring of the status of fish stocks under exploitation especially in the southern part of Lake Malawi.
3. Studies on productivity of water and its influence on fish production; and

4. Assessment of pollutants and habitat degrading activities, and their effects on aquatic ecosystem productivity; and bio-diversity surveys.

The results generated from the various research activities have assisted the department in coming up with fisheries resource management plans, which have contributed to the formulation of various fisheries regulations, such as closed seasons, gear restrictions and controlled allocation of fishing licences to the commercial trawl fishery

Similar efforts have also been made by other organisations such as Chancellor College of the University of Malawi, which has recently concluded a project on the ecology of some Lake Malawi fishes.

However, despite all the past efforts undertaken to control and manage the fish stocks, the fisheries sector is facing serious challenges of maintaining a balance between exploitation and conservation despite a number of research projects undertaken in the country.

This is partly due to the fact that the majority of such projects were undertaken at different times without considering long-term sustainability. It has, therefore, been difficult for the Department of Fisheries to derive maximum benefit from the various recommendations made by the projects. The holding of this symposium is therefore, expected to rectify this anomaly by ensuring that all previous studies are presented, discussed and integrated into the various management guidelines that have been produced for the Lake Malawi and Malombe fisheries.

Ladies and Gentlemen, I am further informed that in addition to providing an opportunity to amalgamate recent scientific information on lake Malawi/Malombe fisheries complex, there will also be discussions with various stakeholders in order to formulate management plans/recommendations. The holding of discussions with stakeholders is in line with the government's policy of involving end users in the management of our natural resources such as fish. I therefore, wish to request all of you to actively participate in the discussion in an open and transparent manner.

Distinguished Guests, Ladies and Gentlemen, the fact that the presentations to be made at this symposium include biodiversity, fish biology and ecology, fisheries assessment and management, social dimensions and economics of fisheries management and fisheries co-management assures the Malawi Government that the symposium is of great benefit to the nation at large. Such a diversity of issues to be discussed in this symposium will definitely contribute towards the determination of management objectives and strategies for lake Malawi/ Malombe fisheries complex.

Lastly, I would like to urge this forum to look at a positive way forward for the Malawi fisheries by adopting a holistic and multi-disciplinary research approach that would always be relevant in the formulation of management guidelines and evolve with environment, equity and economics. Cognisance should also be taken of the fact that for fisheries research to be an effective tool for management it should have a reliable source of funding. Therefore, it is also my hope that the forum will identify alternative sources of funding for the research programmes being proposed.

At this juncture, I would like to thank GTZ for sponsoring this Symposium. My special thanks also go to the organisers and management of Capital Hotel for the excellent arrangements.

Distinguished Delegates, Ladies and Gentlemen, now, it is my honour to declare the International Symposium on Sustainable Management of the Fisheries in Lake Malawi/Malombe officially open.

I thank you for your attention.

Speech by the Director of Fisheries, S.A. Mapila, at the opening of the Lake Malawi Fisheries Management Symposium

The African Great Lakes are considered dynamically fragile ecosystems that are relatively resistant to changes with which they have co-evolved for a million years. Lake Malawi is one of the largest fresh water lakes in the world of its kind in the SADC region. The lake is rich in biodiversity, of which, fisheries are a major resource for the riparian communities. During the last two decades intensive non-selective fisheries in shallow waters, extreme changes in the drainage basin and lake vegetation industrialisation, and agricultural developments, have impacted upon the lake. There is a need for sound fisheries management plan to be developed and implemented, through participatory approaches, a need for sustainable utilisation of the fisheries resource through proper resource monitoring, extension and enforcement; and to increase fish production through the availability of a credit scheme to the private sector, the introduction of new technologies and the building of infrastructure.

The environment is the foundation of economic activity for the majority of Malawians. The unsustainable exploitation, and underdeveloped potentials, of some of the natural resources in the Lake Malawi basin have continued unabated and are challenged by a complex interaction of several factors including population growth, widespread poverty, high dependency on smallholder rain fed agriculture, inconsistencies in macro economic policies and institutional weaknesses with national capacity. The impacts of competing and unsustainable uses of land and water resources are partially understood, and widely manifested throughout the Lake Malawi basin. The annual costs of land related environmental degradation in Malawi have been estimated at US$ 243m or 12% of GDP.

Though guidelines are and will continue to be the backbone of Malawi’s economy, since the country is not well endowed with mineral resources, the fishing industry is set to take centre stage due to major shifts in the agricultural industry. This will thus involve boosting production from inland water resources, and a commitment on the part of the authorities.

Fishing is one of man’s oldest activities, and it remains one of the most important, especially in Malawi. Fish is a major source of high-grade protein, and fishing is the main employment in communities along the coast and around small lakes and rivers. It is obvious that the use of these natural resources is bound to raise a range of environmental issues. Chief amongst them is the conservation and management of the resources themselves, but equally important is the problem of allocating resources amongst competing individuals and social groups. This is important because without proper allocation there is usually an unrestricted activity, which can undermine management and conservation standards. The nature of the various environmental considerations will have to depend on the nature of the biological resources, the fishing operations, and their social, economic and administrative contexts.

Most of the fish resources in Malawi are shared with neighbouring countries. Regional collaboration on these shared water resources is going to be essential if biodiversity and production from these water resources is going to be sustainable. Within this context, smallholder fishermen form some of the largest constituency of the roughly 100 million inhabitants of southern Africa. For these fisherman, there is a direct and immediate cause and effect relationship between supply of fish and food availability.

The results are widely demonstrated by the amount of fish consumption and trade in the region. The supply of fish suffers seriously from the cyclic fluctuations in catch mainly due to climatic conditions, although 40% of the population and labour force relies on fisheries for subsistence as well as employment and income.

Food security cannot be divorced from poverty. Lack of sustainable income generation, vulnerability to food variability and unequal accesses to resources are issues that trap the poverty prone in food insecure situations. Increased fish production and availability can significantly affect the national nutrition.

Statistics indicate that aquatic production in terms of biomass on Lake Malawi has gone up, but fishermen’s catches have remained static or even gone down over the last 10 years due to a lack of innovative technology. The fishing industry has gone back rather than forwards due to amongst other things, structural measures. While a lot of information is known about the fisheries potential of Lake Malawi, a lot still needs to be known about their limnology, biology, physio-chemistry, hydrology and socio-economic setting. It is however known that the lake supports large biomass of fish in offshore waters, which is not being exploited.

Early aquatic resources development projects on Lake Malawi did not meet with the expected results. During the early years after independence, our government invested heavily on infrastructure using foreign assistance. However, these facilities were poorly maintained and functioned well below capacity. Some of the reasons were bad site selection; lack of government capacity to maintain operations; lack of planning and unclear objectives. Early projects were also oriented towards donor driven research projects and transfer of untested technology. Sustainable support systems, extension services and credit facilities were not established.

Following the disappointing results of this donor driven period, the Government of Malawi would like to change its project priorities to a production-oriented approach. Priority will be given to the private sector targeting the commercial and small-scale fisherman. The overall approach would be to promote fish production for the potential benefits of the population.

Pilot projects undertaken during previous projects have identified an effective approach to aquatic resources development on Lake Malawi. Considerable information on aquatic resources use and user's priorities exist.

Research for the future should focus on meeting food production needs in Malawi in ways that are beneficial to the populace and do not degrade the natural resource base. This will involve identifying the most appropriate technological and institutional changes and policies for sustainable and equitable fisheries production. Research attempts to identify appropriate policies for stressed fisheries should be given special emphasis. Nevertheless, most importantly, the research should also emphasise on extension and on property rights and collective action.

It is important to note that the most important issue in capture fisheries is the need to match the catch and marketing capacity of the fishery to the productivity of the resource. But in most donor driven projects this issue has been ignored, and the reason why it has been ignored is that usually the people drawing up national policies, either within government or aid agencies, are seldom themselves fisheries specialists.

Resource management issues dominate ecological concerns in most fisheries, except small bodies of water under sole ownership. There are in principle two sets of issues: maintaining the biological productivity, and making the optimum use of it, in social and economic terms. The latter issues are often given higher priorities. The main aim of the Department of Fisheries is to maintain biological productivity by making sure that the resource is allocated wisely between different resource users; i.e. pair trawlers, gill netters, and purse seiners. This will mean taking explicit decisions on allocation of resources. Difficulties do arise when the resource users are in conflict as to who owns what resource.

The fishes of Lake Malawi are one of the most remarkably diverse and abundant groups in the world. Some changes in species composition on the Lake Malawi fisheries have been reported. Correct identifications are necessary if ecological changes, whether or not the result of human impact, are to be taken into account in management plans. However, the systematic knowledge of these projects is very poor thereby obstructing further biological research.

Rich as it is in flora and fauna, Lake Malawi plays host to some of the poorest people in the region, an unfortunate paradox. From the Chitipa hills to its delta in Mozambique where it empties into the Zambezi River, it has made limited economic contribution to the lives of millions of Africans who live on its banks. Only subsistence survival from wetland and floodplain food resources, and building materials offer a meagre existence.

The lakeshore communities depend heavily on natural resources for a living, the result of which is a high rate of environmental degradation. Firewood is a major source of energy for the communities, contributing to increasing levels of deforestation. Its waters generate hundreds of megawatts of electricity downstream annually but none of this power find its way into the homes of the local communities. The few social amenities like schools and clinics, which are thinly spread in the fishing villages, do not benefit from the hydroelectric power schemes through either piped water or electricity. Most fishing communities do not have secondary schools or decent clinics. The people do not have a good gravel road, let alone a tarred one, or a fixed telephone network.

Lake Malawi is the largest water body in the SADC region, and yet the water is inaccessible and most often not potable and the communities who inhabit it's shore face severe water shortages each year owing to non-existent infrastructure. There has never been an attempt to draw water from this massive body for the local community's consumption.

The major economic activity on Lake Malawi is tourism, which is not fully exploited to reduce the poverty. Tourism generates substantial income for most of the countries in the SADC and is the economic mainstay of the Zambezi River basin. Top attractions include the lake itself, a unique blend of ecosystems that supports large animals, including elephant, hippo, lion, and hundreds of bird species and beautiful flora, and the colourful ornamental fishes. Communities in the Lake Malawi catchment are rated as poor in terms of monetary incomes but social scientists say they could raise their economic status if they fully exploited the fish resources and tourist dollars through sales of local arts and crafts, and game viewing. And yet, no incentives are forthcoming to help Malawians realise this potential.

The beautiful sandy beaches and impressive mixes of biodiversity are, in places, dotted with shanty dwellings, which are skilfully and shamefully tucked away amongst mansions, posh hotels and beautiful, but environmentally insensitive, leisure facilities. The large amounts of money that have been spent studying the science of the lake have not yielded much for the ordinary person who remains buried in deep poverty. The dilapidated lakeshore towns exude a sense of lost opportunities. The lake slumbers with its mighty potential, impressive geography and endless variety. The lakeshore situation can best be described as a mirror image of the rest of the region where many resource endowed communities wallow in poverty while there is plenty on their doorstep.

It is my contention that, science, strategic plans and management plans do have their place to play in the fishing industry, but it is now time that we should put more of our concern on the exploitation of the fisheries resources. We as a Department have done a lot in trying to promote this agenda, what we need now is a commitment. Government needs to come up and raise the portfolio of the fishing industry as a priority in Malawi.

It is my hope that this symposium will go a long way in trying to resolve some of these problems.

With these words I would like to declare this symposium open.

Thank you

The role of the National Research Council of Malawi in protection, conservation and management of fisheries resources in Malawi

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Abstract
The Malawi population directly depends on the genetic resources of fauna and flora for its survival in terms of food, medicines, aesthetic values and tourism. The fisheries resources contribute a significant proportion of Malawi's genetic resources. The water ecosystem of Malawi comprises between 500 to 1 000 fish species most of which are endemic to Malawi making it an important living aquatic resource to the country. Fish contributes 4% to the GNP, 60-70% to the consumption of the nation's animal protein and employs a considerable proportion of the population that is engaged in fishing, fish processing, marketing, boat building and repair, engine repair, and gear supply. In addition, a number of companies are involved in the export of aquarium fish. It is disheartening to note that despite the important role the fisheries resources play in the economy of Malawi, some unscrupulous individuals have collected and exported Malawi's fisheries resource without following proper procedures. This has led to Malawian fish being bred outside the country, making Malawi loose economic benefits and much needed foreign exchange. This situation has called for the establishment of a mechanism that allows for sustainable utilisation of fisheries resources while at the same time ensuring equitable benefit sharing from such use.

Malawi is a signatory to various protocols and agreements related to fisheries resources including Convention on Biological Diversity (CBD). Malawi does not currently have a coherent policy for the sustainable utilisation of genetic resources. Furthermore, following the decentralisation of research clearance for foreign scientists, the system has lent itself to such abuse that it has become rather open to over exploitation. To overcome these problems, the National Research Council of Malawi (NCRM) through its Genetic Resources and Biotechnology Committee (GRBC) has developed procedures and guidelines for access and collection of genetic resources in Malawi which were officially launched in February, 2001. These guidelines were developed based on the notion of controlled access which means promoting access to genetic materials and traditional knowledge while setting terms of access based upon development priorities. This leads to low to high utilisation and compensation. NCRM has also developed draft procedures and guidelines for the conduct of research in Malawi, contractual agreement forms and has formed a taskforce to draft a benefit sharing formula.

Introduction
The Malawi population directly depends on the genetic resources of fauna and flora for its survival in terms of food, medicines, aesthetic values and tourism. The fisheries resources contribute a significant proportion of Malawi's genetic resources. The water ecosystem of Malawi comprises between 500 to 1 000 fish species most of which are endemic to Malawi making it an important living aquatic resource to the country. Fish contributes 4% to the GNP, 60-70% to the consumption of the nation's animal protein, 40% to the total protein consumption of the population. In addition, fisheries employ a considerable proportion of the population that is engaged in fishing, fish processing, marketing, boat building and repair, engine repair, and gear supply. A number of companies are involved in the export of aquarium fish. It is disheartening to note that despite the important role the fisheries resources play in the economy of Malawi, some unscrupulous individuals have collected and exported Malawi's fisheries resource without following proper procedures. This has led to Malawian fish being bred outside the country, making Malawi loose economic benefits and much needed foreign exchange.

To safeguard the over exploitation of the country's fisheries resources and to ensure regulated access, conservation of the fisheries resources, sustainable use of their components, and fair and equitable sharing of benefits arising from their use, the Government through various Ministries and Departments have established various committees and working groups. These committees and working groups are looking at the policy, legislative and strategic frameworks that can ensure that the fisheries resources of Malawi are protected. Realising that most of the fisheries resources collected from Malawi end up being used for research purposes in other countries, the Government has signed and ratified a number of international agreements that are aimed at protecting the fisheries resources from erosion.

The paper aims at (1) itemising the national initiatives that have been undertaken in order to protect the country's fisheries resources, (2) the paper highlights the international agreement that Malawi has signed and some of their provisions, (3) the paper looks at the contents of the procedures and guidelines for access and collection of genetic resources in Malawi, (4) the paper outlines the summary of the procedures and guidelines for the conduct of research in Malawi, (5) the paper looks at NCRM as a co-ordinator of research, science and technology, (6) it looks at the way forward for Malawi.

National initiatives towards the protection of genetic resources

Several national initiatives have been undertaken in order to protect the fisheries resources of Malawi. There is the Genetic Resources and Biotechnology Committee (GRBC) which falls under the National Research Council of Malawi (NRCM). The Committee has the following Terms of Reference (TORs):

- To institute measures harmonious with the relevant guidelines available in the country .
- To ensure that collection of Malawi's genetic materials does not lead to loss of biological diversity and/or Government Revenue.
- To ensure that the importation of genetic resources (including genetically modified organisms) and germplasm does not adversely affect the conservation and sustainable use of biological diversity.
- To ensure that exchange of genetic resources and germplasm is done in such a way that Malawi benefits economically from whatever is exported.
- To encourage the establishment of gene banks and genetic data banks *(in-situ and ex-situ)* and formation of strong linkages with banks including the SADC gene bank.
- To advise the Government on which of the country's genetic materials should be protected against detrimental use by researchers, collectors and traders.
- To foster the dissemination of information on trends in biotechnology.
- To keep abreast with the national, regional and global trends in intellectual property rights and trade.
- To ensure that expatriate researchers work closely with competent Malawian researchers.
- To encourage and promote endogenous development of biotechnology in areas where Malawi has comparative advantage.

Secondly, the Government of Malawi developed a National Environmental Action Plan (NEAP) which was launched in December, 1994. In the NEAP, several factors that affect Fisheries resources were identified. Notable among them were, water resource degradation, high population growth, threat to biological diversity, human habitat degradation, air pollution, climate change, and depletion of fish resources.

The NEAP clearly spells out strategies and actions that need to be put in place in order to conserve, sustainably utilise and manage the fisheries resources of Malawi. Along with the NEAP, a number of policies have been put in place. Such policies include those that deal with population, fisheries, and tourism. The various policies have been enhanced through legislation to ensure that the genetic resources are protected by law. The all embracing legislation is the Environmental Management Act (EMA) which provides for the:

- Identification of biological diversity.
- Determination of threatened biodiversity.
- Preparation and maintenance of inventory of biological diversity.
- Putting in place measures for better protection and conservation of rare and endemic species of fauna and flora.
- Determination of actual and potential threats to biological diversity of Malawi and devising measures that are necessary for preventing their loss.
- Integration of conservation and sustainable use of biological diversity into sectoral or cross-sectoral plans, programmes and policies of Government, the private sector and the local communities.
- Re-introduction of *ex-situ* species in native habitats and ecosystem provided that they do not pose threat to *in-situ* species and habitats.
- Establishment of regulations and guidelines to control or restrict access by any person to the genetic resources of Malawi including.
- Prohibiting the exportation of germplasm except with government approval.
- Providing for the sharing of benefits arising from the exploitation of germplasm originating from the technology owner or the Government.
- Providing for payment of fees and charges for access and export licence in respect of germplasm.
- Promotion of such land use practices that are compatible with the conservation of biological diversity of Malawi.
- Selection and management of environmental protection areas for the conservation of various terrestrial and aquatic ecological systems of Malawi.
- Establishment and management of buffer zones near environmental protection areas.
- Prohibition and control of introduction of alien species.

- Establishment and management of germplasm banks, botanical gardens, zoos, animal orphanages, and such other facilities as may be prescribed.
- Identification and integration of traditional knowledge into the conservation and sustainable utilisation of biological diversity.

In addition to the all embracing EMA, there are sectoral legislations that also impinge on the conservation, sustainable utilisation and protection of fisheries resources. Such Acts include the Fisheries Conservation and Management Act etc.

The provisions of EMA formed the basis of the objectives of the National Biodiversity Strategy and Action Plan (NBSAP). The objectives include compiling of a complete inventory of Malawi's biological diversity, building and enhancing capacity, creating awareness of the value of conservation and sustainable use, reviewing and harmonising existing legislation, documenting indigenous knowledge and setting up of a Malawi Biodiversity Secretariat.

The Government of the Republic of Malawi, recognising the importance of biological diversity in the socio-economic development, enshrined biodiversity conservation in the new constitution in 1994 (Chapter II), Section 13(d). The constitution provides for the State to conserve and enhance biodiversity, prevent the degradation of the environment, provide a healthy living and working environment for the people, and accord full recognition of rights of the future generations by means of environmental protection in order to achieve sustainable development.

International instruments signed and ratified by Malawi

Malawi is signatory to several international agreements that have a bearing on fisheries resources. Some of these agreements are the Convention on Biological Diversity (CBD) which Malawi signed on 15th June, 1992 and ratified it on 28th February, 1994. Other agreements Convention of Wetlands of Significant Importance, Convention on International Trade in Endangered Species of Wild Fauna and Flora, African Convention on the Conservation of Nature and Natural Resources, United Nations Convention on Law of the Sea, Montreal Protocol for the Protection of the Ozone Layer, United Nations Framework Convention on Climate Change, and the Convention of Desertification and Drought. The emphasis in this section will be on the provisions of the CBD.

The CBD provides for sovereign rights over fisheries resources and calls for regulating access on mutually agreed terms with prior informed consent. Secondly, it allows member countries to create incentive measures that would promote conservation and sustainable utilisation of fisheries resources. Thirdly, it calls for fair and equitable sharing of benefits arising out of the use of fisheries resources.

The member countries are under obligation by the CBD to create incentive measures that can promote conservation and sustainable use of fisheries resources, and create sovereign rights over fisheries resources. It obliges member countries to ensure fair and equitable sharing of benefits arising out of the utilisation of fisheries resources or out of utilisation of knowledge, innovations and practices of indigenous and local communities. It requires them to regulate access to fisheries resources and traditional knowledge based on mutually-agreed terms and upon prior informed consent, and to create a mechanism to facilitate access to technology (including that which is relevant to the conservation and sustainable use of fisheries resources as well as biotechnology that makes use of these resources). Finally, it requires member countries to encourage co-operation between the government authorities and the private sector in developing methods for sustainable use of these resources (NCRM, 2000 and Ntupanyama, undated).

Procedures and guidelines for access and collection of genetic resources in Malawi

The NCRM through it GRBC has developed procedures and guidelines for access and collection of genetic resources in Malawi. The guidelines clearly stipulate the users, set out the objectives to be achieved by adhering to them, define the categories of researchers, outline the procedures and requirements for application, assign responsibilities to affiliating and certifying institutions, prescribe conditions for research and material transfer agreements and circumstances under which the certificates can be withdrawn, and oblige researchers to follow a set standard on publications and data. The guidelines also give a list of certifying institutions and contain an application form.

Procedures and guidelines for the conduct of research in Malawi

The NCRM formed a taskforce that drafted the procedures and guidelines for the conduct of research in Malawi. The procedures are meant to enhance the quality of research in order to achieve competitiveness and relevance at national, regional and international levels. These procedures aim at assisting the NCRM and sectoral institutions to:

- Appraise proposals for scientific, professional and ethnical merits.
- Provide mechanisms for monitoring and evaluation of research projects and activities.
- Provide a framework for collaboration among researchers within the country and with international researchers.
- Promote originality and complementarily in research in order to avoid unnecessary duplication.
- Promote capacity building and encourage the development of sectoral programmes and research agenda.

Ensure proper collection, acquisition, dissemination, storage and management of research information

The guidelines stipulate the need for affiliation and capacity building; provide for formats for review of research proposals, monitoring and evaluation, and dissemination of research outputs / results.

NRCM as co-ordinator of research, science and technology

NCRM has established several technical committees. The fisheries department is a member of committees such as the Agricultural Sciences Committee (ASC) and the Genetic Resources and Biotechnology Committee (GRBC). Likewise NRCM is a member of some committees that deal with fisheries. The NCRM in its quest to streamline the research agenda in the agricultural and natural resources sector formulated the Malawi Agricultural and Natural Resources Research Master Plan. One of the taskforces that worked on the Master Plan was on fisheries. Through the Agricultural Services Project, the NCRM through the ASC funded research projects on fisheries which yielded some usable technologies under the Contract Research Programme.

The way forward

For Malawi to effectively conserve, protect and ensure sustainable utilisation of fisheries resources, there a is need to do the following:

- Document all the endemic and exotic fisheries resources that are in the country.
- Put in place a strict monitoring system that will ensure that the purpose for the collection of the fisheries resources collected is known. This means that the NCRM has to speed up the completion of the procedures and guidelines for the conduct of research in Malawi.
- Ensure enforcement of the procedures and guidelines for access and collection of genetic resources in Malawi which requires building capacity in the various affiliating institutions, the NCRM and law enforces.
- Create awareness on the various stakeholders on the value of Malawi's fisheries resources and the need to protect them. This will need to include the importance of adhering to guidelines and procedures as stipulated.
- Involvement of the local communities in the protection, conservation and sustainable utilisation of fisheries resources. Where this is already being done as shown in the paper, the system needs to be intensified and internalised.
- Implement the recommendations.
- Speed up the process of designing a benefit-sharing formula.
- Adhere to international conventions and protocols that have a bearing on fisheries resources by implementing the provisions contained therein.
- Encourage the establishment of more protected areas for the conservation of fisheries resources.
- Complete the formulation of contract agreement and prior informed consent forms.
- Strengthen the technical arm of NRCM so that it can effectively play its co-ordination role.
- Another donor should be identified so that the Contract Research Programme is revitalised.

Conclusion

The paper has highlighted the importance of fisheries resources in Malawi in terms of food, income and tourism. Owing to the vital role these fisheries resources play in the well being of the Malawi population, the need to conserve, protect and use them sustainably cannot be over emphasised. Procedures and guidelines for access and collection of genetic resources in Malawi have been developed for use by various stakeholders and need to be adhered to in order to ensure that Malawi benefits from the use of its fisheries resources. Enforcement of regulations is key to protection of fisheries resources. There is a need for liaison among the various parties involved to ensure that all stakeholders understand what is required of them.

References

National Research Council of Malawi, 2000. Policy Recommendation, Procedures and Guidelines on Access to Genetic Resources in Malawi : Incorporating Sustainable Utilisation of Genetic Resources into Biodiversity Management Planning. Report presented at a National Workshop on Plant Genetic Resources Conservation and Understanding International Instruments on Biodiversity Related Issues Held at Lilongwe Hotel , 10^{th} – 13^{th} January 2000.

Ntupanyama, Y. M., Undated. Convention on Biological Diversity and Implementation in Malawi.

A general overview of fisheries research and development in Malawi

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Abstract

Historically, fisheries research and development in Malawi is strongly linked to Lake Malawi and the immense interest it has aroused to the outside world due to its sheer size (28 780 km²). Consequently, universal interest in the fisheries of Lake Malawi cropped up spontaneously, and has led to a number of research projects being commissioned, beginning with the surveys of 1939, although earlier attempts at taxonomic studies can be traced to over a century ago. The paper outlines major fisheries research projects that have been undertaken in Malawi. An attempt is made to outline how project results have influenced fisheries management strategies and policies. In addition, the implications of management policy on research programs being undertaken is also highlighted. Current research programs and future plans are outlined and their relevance to fisheries management is evaluated

Introduction

Fisheries research and development in Malawi is strongly linked to Lake Malawi and the immense interest it has aroused to the outside world due to its sheer size (28 780 km^2), manifested by the fact that it is the third and ninth largest lake in Africa and the world, respectively. Consequently, universal interest in the fisheries of Lake Malawi can be traced to over a century ago when the first fish collections were taken by the early European explorers who came to this part of Africa, notably the early expeditions of Dr. David Livingstone (Tweddle, 1991). Specimens of fish collected were deposited in natural history museums where early work was restricted to taxonomy.

This paper outlines major episodes that have characterised the development of fisheries research and the fisheries industry in Malawi by chronologically classifying to the present time the major projects that have taken place. These are classed as: (1) activities that took place during the period of limited or very low fishing effort; (2) projects that were aimed at maximising fish production; and (3) projects aimed at sustainability and conservation of fish and fisheries resources. For each research project, the funding agencies, objectives and major results or outputs are given in accordance with the fisheries policy and objectives prevailing at the particular time. This paper culminates in outlining currently running projects and a newly adopted approach to research project planning and development that is being advocated by the Department of Fisheries in Malawi. It then concludes, by emphasising the need for continuous research to provide information required for effective and sustainable fisheries management measures.

Phase 1- Period of limited or very low fishing effort (1939 – 1960)

This is a time when the population in Malawi was small, the fishing effort was low, fishing gear was relatively ineffective and canoes could only fish in near-shore waters. This effectively meant that Malawi had large fish reserves in the areas that could not be fished. Fisheries research studies were initiated at this time, but most of it was taxonomic in nature, although some fish biology was undertaken. This period marks the first phase in fisheries development.

However, documented research works date just more than 50 years ago when Bertram, Borley and Trewavas conducted the first fishery surveys on Lake Malawi in 1939, and a report was produced in 1942 (Bertram *et al.* 1942). This was followed by some biological research work on the chambo, *Oreochromis* spp. of the Southeast Arm of Lake Malawi, in 1945 – 1947, reported by Lowe (1952). These chambo studies started as a result of the operations of purse seining, which were introduced into Lake Malawi in 1943, solely for the exploitation of this species group.

A major breakthrough in fisheries research and development came in the mid-1950s with the formation of the Joint Fisheries Research Organisation (JFRO) in 1954. This was a research body that was shared by Malawi (then Nyasaland) and Zambia (then Northern Rhodesia). In Malawi it had the mandate to carry out research work on Lake Malawi. The organisation set up its base at Nkhata Bay, where it carried out biological studies on some fish species, and major work on the inshore rock-dwelling fish species, locally known as 'mbuna'. Summarily, the JFRO carried out taxonomic studies, descriptions of traditional fishing methods, experimental fishing, and also carried out limited limnological investigations. The report, by Jackson *et al.* (1963), covers information on hydrological data from the lake and affluent rivers, invertebrate studies, a check-list on fishes and ecological zonations, biology of commercially important species, experimental fishing and the traditional fisheries. The studies on mbuna, reported by Fryer (1959), contributed to evolutionary knowledge and formed a basis for subsequent studies and discussions on the topic.

Phase 2- Maximisation of fish production (1961 –1996)

The need to redirect fisheries research to comply to national food demands, and, fisheries development requirements, led to the research focus being shifted in 1962, to Monkey Bay, in the south of Lake Malawi where new laboratories had been constructed. This was necessitated by a number of reasons, which included the desire to understand the highly productive fishery that was being exploited by purse seines, and the ready availability of communication and access facilities to the outside world. At first, the new station continued some of the work that was initiated in Nkhata Bay, which included physical limnology, fish taxonomy and biology, gradually focussing more on the biology of nchila, *Labeo mesops* and Kampango, *Bagrus meridionalis*, Tweddle (1991) and gill-netting trials.

Projects

Various projects were undertaken to respond to the increased demand for protein supplies to the Malawi population. The impetus for this phase began with the introduction of experimental trawling in the Southeast Arm of Lake Malawi in 1965, which led to the development of commercial trawling in 1968. This trawling targeted virgin stocks of cichlid species unknown to science. Consequently, research studies were initiated on the taxonomy and biology of these cichlid fishes with the aim of establishing a management and monitoring regime for this new fishery. Preliminary data collected at this time was used in detailed stock assessment work which began in 1969, aiming at monitoring the effort being applied on the fish stocks and exploring the potential for trawl fisheries in other parts of the lake. These surveys produced some punctuated series of biomass estimates for the demersal fish stocks, and are regarded as core trawl sampling programs of fisheries research on Lake Malawi.

However, the first regular trawl surveys, were undertaken by the FAO Project on Integrated Fishery Development (FAO, 1976a). The main aim was to undertake studies on stock assessment to determine the optimum sustainable yield of the newly introduced mechanised trawl fishery in the southern part of Lake Malawi. It operated on the premise that the stocks being exploited by the trawl fisheries were limited and so, effort had to be monitored and management measures put in place, if sustainability was to be ensured. In addition to studies on the trawl fisheries, it also did analytical work in the artisanal fisheries of the SEA and SWA of the Lake Malawi. Management recommendations included restriction of the number of licenses to be issued in each demarcated area of southern part of Lake Malawi and the setting of the a 38 mm minimum mesh size restriction for the trawl cod-end. A recording system for the traditional fisheries in the country, the Catch Assessment Surveys (CAS), was put in place, and is still being used with minor modifications except in the Mangochi Fisheries District area in the southern part of Lake Malawi. When the regular surveys were discontinued, changes in exploited stocks were monitored through catch and effort data from the trawl fisheries. The results of the analysis of the catch and effort data showed that the numerous demersal haplochromine species, that were being exploited, were sensitive to commercial fishing operations with the average size of fish being caught decreasing. It was also observed that there was an increase in use of illegal mesh sizes and fishing in prohibited inshore areas.

These observations led to the birth of the Demersal Fisheries Reassessment Project (ODA/FRAMS Project, 1992), which re-introduced regular fishing surveys that were carried out on a quarterly basis, using the same boat and methodology as before. Partially funded by an FAO Chambo Project, the aim was to repeat the experimental trawling surveys of the early 1970s to examine the current status of the stocks with a view to assess changes that had taken place in the fishery and to determine the effect of the 38 mm minimum mesh size. These surveys showed that the exploited biomass had declined in the heavily fished areas, and that the species composition of the catches had changed from being dominated by large cichlids to mainly small haplochromines. Consequently, it was conclude that the 38 mm of the cod end was ineffective in arresting this trend. In addition, the very low levels of biomass observed in Area A led to the prohibition of trawling in the area 1992.

The quarterly stock assessment surveys were continued under an ICEIDA-funded project using the new powerful research vessel, the RV Ndunduma, Banda and Tomasson (1997). The findings indicated that there was scope for expansion of the demersal fisheries, in the deep waters of the southern part of the lake. This has resulted into the development of the deepwater fisheries in the southeast arm of Lake Malawi, and these are currently being exploited by three fishing vessels, *viz:* MV Kandwindwi, RV Ndunduma and the fishing vessel Chenga.

In line with the fisheries development agenda of the 1970s, which focussed on maximising fish production from Lake Malawi and other water bodies in the country, a series of other research projects funded by donors were implemented. These include the UNDP/FAO Fishery Expansion Project (FAO, 1982a), which explored the opportunities for fisheries development in the central and northern parts of Lake Malawi. Recognising that inshore stocks were over-fished, the project concentrated on the biology of the deepwater fishes of usipa, utaka, ncheni, ndunduma, sanjika, and, studies on plankton and the physical environment. Results showed that the usipa stock was characterised by extreme differences in the abundance of year-classes, posing a problem for commercial exploitation. Acoustic surveys showed fish density to be much less than in the south. Subsequent trawling indicated a low potential catch rate and limited trawlable bottom in the North. It was summarily concluded that pelagic fish resources were not sufficient to support a mechanised commercial fishery. As a result, the recommendation was that long-term studies on all aspects of the pelagic zone limnology and ecology be undertaken. This recommendation gave way to the birth of the UK/SADC Project, which conducted comprehensive studies to assess the fishery potential of the pelagic zone (Menz, 1995).

The UK/SADC Lake Malawi Pelagic Fisheries Assessment Project of 1991-1994, was a regional project between Malawi, Mozambique and Tanzania, which studied Lake Malawi as one ecosystem. The aim was to assess the fishery potential of the pelagic zone, through various studies that included fisheries biology, stock assessment, aquatic ecosystem trophic relationships, and quantification and determination of economically sustainable yields from new fisheries targeted at pelagic fish species. An assessment of the standing biomass for the pelagic zone was made as well as its fishery potential. The lake fly was shown to be a component of the main energy pathways. Description of the physical and chemical characteristics of the lake provided baseline data for subsequent studies including monitoring of the lake environment.

This project was followed by the GEF/SADC Lake Malawi/Nyasa Bio-diversity Conservation Project, which had a somewhat similar management arrangement to the above. The goal was to create the scientific, educational and policy basis for conserving the biological diversity of the lake, and to enable the riparian states to establish higher levels of sustainable production from the Lake's resources consistent with preserving its bio-diversity and unique ecosystem. The outputs from the project include taxonomic reviews of certain taxa, documentation of benthic macro-invertebrates in the rocky near-shore zone of Lake Malawi/Nyasa, ecological and biological studies on selected species (Duponchelle, 2000), description of physical characteristics of the lake, and the development and execution of a Lake Malawi bio-diversity awareness program. It was then recommended to continue monitoring the parameters that had been studied, and use the subsequent results to constitute an early warning system for the changes taking place in the aquatic environment.

Other Projects

Several other projects have been implemented, one of which is the Ornamental Fisheries Research Project (1980). This was a collaborative project, which was conducted by the Fisheries Research Unit and Rhodes University together with other scientific collaborators. The aim was to provide a sound understanding of the techniques of this trade, potential, sustainability and threats to the stocks, together with problems of escape and relocation of the species in the lake. It resulted in the provision of management guidelines for the government to regulate the trade. It was generally observed that the ornamental fish business was self-regulating, because of market limitations. Nevertheless, the project increased the knowledge of the ecology of the inshore fish stocks and widened the knowledge for management of the numerous mbuna fish species, and also contributed to advancements in conservation and tourism. With such information at its disposal, the project assisted in the early planning and development of the Lake Malawi National Park, which is the first lake underwater reserve in Africa. It also increased the worldwide attention in freshwater science and generated considerable awareness of Lake Malawi natural resources.

Another important study was carried out by the Chambo Fisheries Research Project, which aimed to carry out biological, stock assessment and socio-economic research to provide a management plan for the chambo fisheries of the Southeast arm of Lake Malawi, the Upper Shire River and Lake Malombe. This was in response to mounting fishing pressure in the 1980s that had caused the stocks in each fishery to be fully or over exploited.

Studies centred on the elucidation of the life histories of the three chambo species in the area. These included breeding, feeding, growth, distribution and migration; description of artisanal gears and, commercial and industrial fisheries including socio-economics; quantification of contributions of fish stocks other than chambo; and modelling of resource exploitation patterns. The management recommendations included licensing, gear use and specifications, closed seasons and future-monitoring regimes.

The project findings brought to light the crash of the chambo stocks in Lake Malombe and their serious depletion in the Southeast arm of Lake Malawi (FAO, 1993). Initially, the project aim was to study the *Oreochromis* spp., the most economically valuable component in the Malawi fisheries, but ironically it concluded in a situation where smaller, haplochromine species were taking over as the important fishery. In Lake Malombe, chambo declined to only 6% of the total catch from 90% in 1976. The results of the Chambo Project confirmed the observations of the fishing industry, which was reporting declining chambo catches and an increase in small-sized fish species as observed in Lake Malombe. These observations confirmed the fact that the fisheries sector was facing serious challenges in maintaining a balance between exploitation and conservation to achieve optimal utilisation without impairing long-term sustainability. In view of this, it was recognised that there was a need to put in place an effective fisheries management regime that would ensure the sustainability of the fish stocks. Hence, it was recommended that national core research programmes be formulated to focus on identification of new unexploited stocks as well as the management of those stocks that are under heavy exploitation in order to sustain their production potentials and, where necessary, lead to a recovery of the stocks.

In support of the objective of creating an effective management system while maximising production, an FAO Technical Consultation Paper (TCP) on data recording systems was commissioned under the Chambo Fisheries Research Project. This developed a gear-based, computerised data handling and analysis system, the Malawi Traditional Fisheries (MTF) for statistics in the Southeast arm of Lake Malawi, the Upper Shire and Lake Malombe (Alimoso *et al.* 1990). An evaluation of MTF and the comparison with the prevailing data collection system CAS led to the recommendation that MTF be adopted throughout the country . However, MTF proved to be costly, so that it is only carried out in the south of Lake Malawi in Mangochi District. However, Coulter (1993), referring to the need to review data collection systems, noted that statistical data is very important for monitoring purposes, and recommended a recording system that is sufficiently sensitive to detect changes in effort and CPUE, while saving costs.

In response to the need to develop the fisheries industry, the WB/IDA-Fisheries Development Project was commissioned, and aimed at institutional building. The main objective was to assist Malawi to realise more fully the potential contribution of the fishery sector to the economy, while ensuring that off-take did not exceed sustainable yields. This was to be achieved through increasing fish production, generating additional off-farm employment and income, conservation of the natural resource and prevention of environmental degradation and improving institutional capacity for fisheries sector policy formulation, research planning, monitoring and control. Work of the research component of the project confirmed the presence of deepwater fish stocks reported in earlier studies and led to the development of the deep water fisheries which are now being exploited by newly introduced stern trawlers. In addition, determinations and assessments were made of biomass indices and species composition of the demersal fish stocks in both heavily and lightly exploited areas, resilience of the demersal fish stocks to exploitation, and economic viability of using a big fishing vessel.

Other major studies that have been undertaken on Lake Malawi include the Project on the Comprehensive Study of Lake Malawi Ecology for Sustainable Development, which concentrated on the ecological aspects of fisheries. The goal of the project was to develop a research system and accumulate scientific knowledge on Lake Malawi and its surroundings for use by researchers, local communities and policy makers. The specific objectives were to: (1) strengthen ecological research and human capacity for sustainable utilisation and proper management of natural resources on Lake Malawi; (2) develop comprehensive research methods for sustainable utilisation of fish resources and; (3) establish bilateral research partnership, between Japan and Malawi (Lake Malawi Ecology Project, 1999). The project trained Malawians through postgraduate training, technician level training, and counterpart visits. It also established the Molecular Biology and Ecology Research Unit (MBERU) in the Biology Department of the University of Malawi, and a field station at Cape Maclear.

Environmental problems have also been addressed in the fisheries sector, one of which is the elimination of nuisance aquatic weeds. The Malawi National Water Hyacinth Control Project was set up with the aim of controlling the spread of water hyacinth in Malawi's water bodies beginning with the problems in the Shire River system. The objectives of the project are: (1) identification and development of biological control agents; (2) assessment of the effects of water hyacinth on fish and invertebrate abundance and bio-diversity; (3) assessment of the impact on riparian communities; (4) establishment of a capacity to carry out limited spot chemical treatment of water hyacinth; (5) informing of local communities and the general public of the dangers of the weed and (6) support to research activities on the economic utilisation of water hyacinth. So far, the project has been able to establish breeding sites for biological control agents at Makhanga and Mangochi and rearing and distribution of the biological agents is in progress. Creation of community awareness is ongoing in different districts.

Several other projects have been carried out on Lake Malawi and in various ways have contributed to the knowledge and understanding of the status of the fisheries, and recommended various effective and sustainable strategies for exploitation and management (Appendix 1). These include the Traditional Fisheries Assessment Project, which carried out a revision and development of monitoring and assessment systems for traditional fisheries, and made recommendations for modification of the existing fisheries regulations at the time. The Fisheries Research and Management Support (FRAMS) Project aimed at strengthening the capacity of the Department of Fisheries in development of research and formulation of policy, and this resulted in the review of management and policy options of the fisheries sector. Research under the FRAMS Project, investigated the distribution and ecology of the principal fish species of economic importance, involving investigations of catches in all parts of the lake in all habitats. Consequently, results of the FRAMS Project plus consultations with the fishing communities, led to the establishment of the 19 mm mesh size restriction for the Nkacha net which exploits small haplochromines.

Since 1966, research projects have been undertaken in other smaller water bodies with varying degrees of importance in fisheries ranging from significance at national level, to local significance to the communities in the riparian areas. The water bodies of significance are Lakes Malombe, Chirwa, Chiuta and the Lower Shire River system, which in total contribute about 30% of the total fish catch in Malawi. In general, the aim was to carry out occasional studies of salient aspects as opportunity and time permitted. The projects recommended the establishment of regular catch monitoring programs, improvement of fish processing techniques and establishment of effective communication and access to these fisheries. In perspective, it was visualised that the problems in these water bodies would encompass environmental and socio-economic aspects, emanating from the increased use of seine nets, which could lead to weed removal and a reduction in habitat diversity and exposure of fish stocks to over-fishing (Tweddle, 1983, 1991). Social-economically, it was visualised that an increase in population around these water bodies would lead to increased pressure on the stocks, so that, coupled with any large natural fluctuations in the fishery, the riparian communities would face dire social and economic problems.

Research by other organisations

Various research programs on the fisheries of Malawi are also being undertaken by other organisations, and these include the University of Malawi through its constituent colleges of Bunda College of Agriculture, Chancellor College and the Centre for Social Research. Some of the work done at Bunda College of Agriculture covers the ecology of the catfish, *Bathyclarias* spp. and cichlid species of Lake Malombe. Chancellor College has recently concluded a research project on the ‘Comprehensive Study of the Lake Malawi Ecology for Sustainable Utilisation of the Lake Environment’ and it continues the genetic classification of Malawi fishes using the facilities at the Molecular Biology and Ecology Research Unit. The Centre for Social Research is carrying out collaborative studies with the University of East Anglia, on the socio-economic aspects of fisheries and fishing communities. Rhodes University and the JLB Smith Institute of Ichthyology have collaborated with a number of institutions in Malawi and have priously participated in studies on the ornamental fisheries of Lake Malawi. In some cases, individual scientists have been able to undertake research on Lake Malawi after obtaining grants from research institutions, either in their own capacity or as students.

Phase 3 - Fisheries resource management, sustainability and conservation (1997 – to the present)

Despite the implementation of the various research projects in Lake Malawi and other water bodies, fish catches have been declining. Notable is the situation in Lake Malombe, where annual fish landings declined to less than 3 000 tons in the 1990s from an average of more than 10 000 tons in the 1980s (Bulirani *et al.* 1999). These observations were mainly attributed to overfishing although environmental problems are also reported to be taking ground.

However, the ineffectiveness of past management regulations, emanating from past research and development efforts has given important lessons to be considered in any future plans. These include:

- Limited spatial coverage of research programs.
- Need for a continuous review of fisheries management regulations.
- Resource exploitation should conform to the objectives of sustainable management and conservation of bio-diversity Research on Malawi’s water bodies should be systematic and based on themes.
- Management guidelines for the management of Lake Malawi to be formulated based on broad stakeholder consultation.
- Management recommendations have to be adhered to if the goal of sustainable utilisation and conservation of biodiversity is to be achieved.

In view of these experiences, the Department of Fisheries, with the assistance of the GTZ-funded National Aquatic Resource Management Program (NARMAP), has reviewed the fisheries policy and developed the Fisheries and Aquaculture Policy (1999), and a new Fisheries Conservation and Management Act (1997). These are now acting as a guiding torch for fisheries research and development in Malawi. Consequently, the mission of the Department of Fisheries has been reviewed, as 'to provide optimal framework conditions and excellent services to enable national fisheries industry to satisfy local demand for fish and increase incomes of people dependent on fish'. This is with the overall objective of enhancing the quality of life for fishing communities by increasing harvests within sustainable yields and promoting aquaculture as a source of income and to supplement fish supply from natural waters'.

To achieve this policy objective, the Department of Fisheries recognises the fact that harvesting of fish stocks should be based on established sustainable yields of different species/stocks and that opportunities have to be identified to expand existing and/or new aquatic resources. Therefore, the research mission is 'to provide information necessary for sustainable exploitation, management, conservation of bio-diversity and investment in the fisheries sector through appropriate biological, technological, socio-economic and environmental research programs'. The objectives are:

- Accumulate comprehensive data on all fisheries resources for all major water bodies of Malawi.
- Provide information on management of fisheries resources and aquatic environment.
- Provide information on viable investment opportunities in the fisheries sector
- Provide information necessary for the maintenance of aquatic biodiversity
- Establish a fully operational taxonomy section by the year 2003

Current and future research programs of the fisheries research unit

The Department of Fisheries relies heavily on scientific information for the development of protocols and plans with which to manage Malawi's fisheries. Essentially, sustainable management is dependent on the ability of fisheries managers to determine at what levels of fishing effort, and at which gear selectivity scenarios the catch of a target species is sustainable and the spawning stock remains adequate. Therefore, the main role of the Malawi's Government's Fisheries Research Unit (FRU) is to provide the Department of Fisheries with such information based on understanding of the biology, life history and distribution of the target species as well as an understanding of the harvesting fisheries. To achieve this, the FRU has adopted a holistic approach whereby research activities are geared towards the ultimate formulation of a management strategy for Malawi's fisheries. This is depicted in Figure 1.

Therefore, current research programs have been formulated in a way that they are aimed at addressing the immediate need of formulating strategies for the management of the fish stocks facing heavy exploitation pressure, while at the same time exploring opportunities to expand existing and/or develop new fisheries resources. Such an approach is clearly illustrated in the activities that have been planned for the July 2000 – June 2001 financial year (Table 1), where they have also been given a priority ranking depending on the state of the fisheries and the urgency with which, management information should be acquired. In this program, the research activities fall under the five categories that have been shown in Figure 1, namely gear selectivity, utilisation trends, biological surveys, population dynamics and social and economic research.

Table 1. Research projects planned for implementation in the year 2000/2001 (after Banda *et al*. 2001).

Project Title	Priority
Biological management parameters for target species in Lake Malawi	1
Monitoring of catch and effort in artisenal fisheries	1
Demersal monitoring surveys	1
Kauni Fishery selectivity survey.	2
Chilimira fishery selectivity.	2
Gillnet selectivity surveys.	2
Handline catch assessment and gear selectivity.	2
Traditional gear selectivity surveys (Northern Lake Malawi)	2
A preliminary study of the effectiveness of monofilament gillnets in Lake Malawi	2
Lake Malombe assessment programmes	2
Lake Chiuta assessment programmes	2
Commercial pair trawl selectivity	3
Trawl net selectivity survey	3
The economics of processing and distribution of small scale fishing in Lake Malawi	3
Demersal exploratory surveys	3
Pelagic exploratory surveys	3
Limnological Surveys	3
Aquatic ecology and fisheries of Lake Chikukutu	4

The research plans presented can be classified as either discrete or long term monitoring. Discrete surveys such as the determination of species and size selectivity of the chilimira, kauni, gill net and trawl fisheries in Lake Malawi, the determination of biological parameters for major target species or rapid stock assessment of small lakes are surveys with outcomes achievable during short-term research programs (1-5) years. Long-term monitoring programs, such as catch and effort surveys and trawl surveys can only yield management information if they are sustained over long periods (20 years). The classification of research programs on these criteria has major implications on sources of funding. This is because while the funding for discrete surveys could be secured on an *ad hoc* basis from a variety of sources, the sustainability of long-term monitoring programs can only be ensured if they are budgeted from within the Department of Fisheries. As a result, all the long-term research programs are being sponsored by a Fisheries Research Fund (FRF) that was set up under the Fisheries Conservation and Management Act (1997), while the majority of the discrete surveys are currently financed by NARMAP.

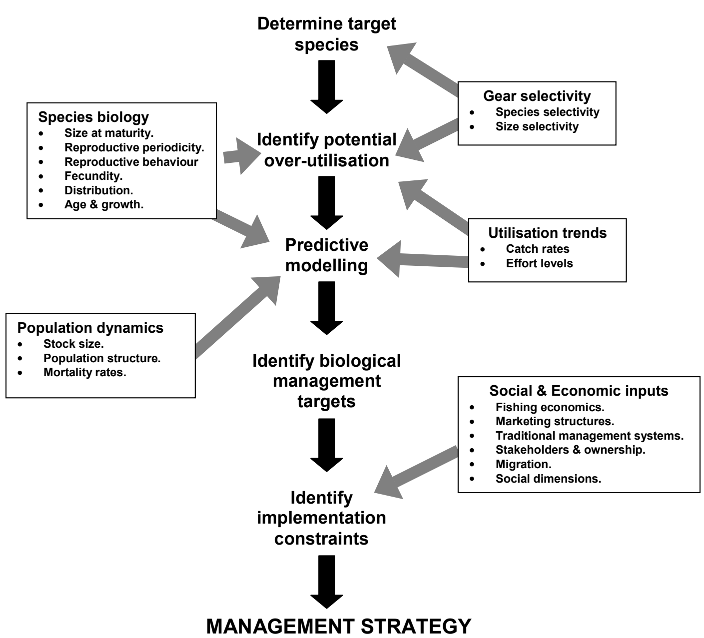

Figure 1. Input requirements for the formulation of a management strategy for Malawi's fisheries (after Banda et al. 2001).

Conclusion

Summarily, Fisheries Research and Management in Malawi has undergone an evolution process dictated by the prevailing social and economic demands of each period in time. The first fish specimens were collected by enthusiasts based on interest during the early years of contact with Europeans. At that time the population in Malawi was small, the fishing effort was low, fishing gear was relatively ineffective, and canoes could only fish in near-shore waters. This effectively meant that Malawi had large fish reserves in the areas that were unable to be fished. Most of the biological research at this time was taxonomic in nature, although some fish biology was undertaken.

The next phase focussed on expanding the fishery, increasing fish production, and attempts to improve resource management to ensure sustainability. This period saw the introduction of motorisation and the establishment of the commercial sector, which meant that fishing was now possible in previously unfished areas. The research moved towards exploratory fishing for unutilised stocks, predicting effects of intensified effort, monitoring fish stocks, refining management regulations and seeking to understand the biological basis of sustainability. Consequently, research has tended to be event-driven and reactive and has followed the occurrence of certain fisheries production efforts, which might have seriously affected the fish in a sudden manner. These events have usually been due to sudden increase and unsustainable pressure of exploitation of a finite resource. The approach was always post-mortem and focussed on finding out what had gone wrong and then working out corrective measures.

In view of the failure of previous efforts to fishery management approaches such as mesh size restrictions, closed seasons etc. the Department of Fisheries is now aiming at providing information necessary for sustainable exploitation, management, conservation of bio-diversity and investment in the fisheries sector through appropriate research studies. It is also strongly promoting the participation of the fishing communities in resource management. This means that there is a dire need for research to be undertaken to address the following:

- A review of old fisheries management regulations.
- While fisheries research should respond to the immediate needs of the fishing industry, due regard should be given to sustainable management and conservation of bio-diversity.
- Research on Malawi's water bodies should be systematic and based on themes.
- Management guidelines for the management of Lake Malawi to be formulated based on broad stakeholder consultation.
- Management recommendations have to be taken up by responsible authorities if our fisheries resources are to be sustained through time.

To ensure orderly and systematic conduct of research in Malawi, that ensures that the country benefits from its natural resources, the Malawi Government has, through the National Research Council of Malawi, launched the 'Procedures and Guidelines for Access and Collection of Genetic Resources in Malawi'. This is to be followed by all those intending to carry out research on genetic resources of Malawi.

All in all, it should be concluded that fisheries research should lead to the establishment of appropriate fisheries management regimes that ensure sustainable exploitation of fish stocks, protection of aquatic ecosystem integrity' and conservation of bio-diversity.

References

Lake Malawi Ecology Project, 1999. First Annual Report, May, 1998 – April, 1999. Department of Biology, University of Malawi, 50p.

Menz, A. (ed.) (1995). The Fishery Potential and Productivity of the Pelagic Zone Of Lake Malawi/Niassa. Chatham, UK: Natural Resources Institute.

Bulirani, A.E., Banda, M.C., Palsson, O.K., Weyl, O.L.F., Kanyerere, G.Z., Manase, M.M. & Sipawe, R.D., 1999. Fish Stocks and Fisheries of Malawian Waters: Resource Report. Government of Malawi, Fisheries Department, Fisheries Research Unit.54pp.

Ribbink, A.J. (1980). The ornamental fish project: report and recommendations

Ricardo Bertram, C.K., H.J.H. Borley and E. Trewavas (1942). Report on the fish and fisheries of Lake Nyasa. London, Crown Agents, 181 p.

Tweddle, D. (1983). The fish and fisheries of Lake Chiuta. *Luso:J.Sci.Tech.(Malawi),* 4(2):55-83.

Tweddle, D. (1991). Twenty years of fisheries research in Malawi. Fisheries Bulletin No. 7, Fisheries Department, Ministry of Forestry and Natural Resources, Malawi.

Tweddle, D. and B.J. Mkoko (1986). A limnological bibliography of Malawi. *CIFA Occ.Pap.,* 13:75 p.

Duponchelle, F. (ed.) (2000). Fish Ecology Report: SADC /GEF Lake Malawi/Nyasa Biodiversity Conservation Project; Ministry of Natural Resources and Environmental Affairs, Lilongwe, Malawi.

FAO (1982a). Fishery Expansion Project: findings and recommendations. Rome, FAO, FI:DP/MLW/75/019 Technical Report, 21 p.

Resource Report (1999). Fish stocks and Fisheries of Malawian Waters. Fisheries Research Unit, Fisheries Department, Malawi

Fryer, G. (1959). The tropic interrelationships and ecology of some littoral communities of Lake Nyasa with especial reference to the fishes, and a discussion of the evolution of a group of rock-frequenting Cichlidae. *Proc.Zool.Soc.Lond., 132(2):*153-281

Coulter, G. W. (1993). Report on Fisheries Research and Management Strategies. ODA/FRAMS Project, Malawi, 58p

Banda , M. C. and T. Tomason, 1997. Demersal fish stocks in southern Lake Malawi: Stock assessment and exploitation. Fisheries Bulletin No. 35, Fisheries Department, Malawi. 39pp.

Banda, M.C., Chisambo, J., Sipawe, R.D., Mwakiyongo, K.R. & Weyl, O.L.F. 2001. Fisheries Research Unit, research plan: 2000 & 2001. Fisheries Bulletin No. 44.

FAO (1976a). Promotion of Integrated Fishery Development, Malawi: Project findings and recommendations. Rome, FAO, Terminal Report, 36 p.

Jackson, P.B.N., T.D. Iles, D. Harding and G. fryer (1963). Report on the survey of Northern Lake Nyasa 1954-55. Zomba, Government, 171 p.

ODA/FRAMS Project (1992). Demersal Fisheries Reassessment Project, Preliminary Project Report (November, 1987 – May, 1992)

Lowe, R.H. (1952). Report on the *Tilapia* and other fish and fisheries of Lake Nyasa 1945-47. Part 2 *Fish.Publ.Colon.Off.Lond.,* 1(2): 126 p.

Alimoso, S. B., Seisay, M. D. B. & Van Zalinge, N. P. 1990. An efficient method for catch-sampling of the artisanal chambo fisheries of the Southeast Arm of Lake Malawi, the Upper Shire River and Lake Malombe. FI: DP/MLW/86/013 Field Document 6.

FAO (1993). Fisheries management in the southeast arm of Lake Malawi, the Upper Shire River and Lake Malombe, with particular reference to the fisheries on chambo (*Oreochromis* spp). CIFA Technical Paper, No. 21. Rome, FAO, 113p.

Economic Security and Sustainable Programmes for the African Great Lakes

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Abstract
Unquestionably, the responsibility for research, management and conservation of the aquatic resources of any nation reside with that nation. If resources are shared, such as is the case where different countries border on a single lake or river, then the responsibility is shared and co-management is required. In much of Africa, full responsibility for national resources has not been achieved. During post-colonial eras work on aquatic resources remained disproportionately in the hands of foreign workers. Initially this was due largely to both the lack of skilled capacity in Africa and to the economic inability of the new governments to meet the costs of this work. While the capacity in African countries has grown, despite attrition through the "brain drain" of marketable graduates, the economies have not improved to the extent where the countries can be independent of donor participation. A series of donor-driven, short-term projects, often delivered in stop-start cycles, have led to situations where sustainable programmes cannot be implemented, and long-term goals cannot be set nor achieved. The most pressing step is to provide financial security to research stations or conservation units to enable them to develop and progress towards the achievement of long-term visions. This step requires independent funding that so reduces reliance on their own and donor governments that financial security is obtained. Offshore investments that earn interest provide vehicles for such independence and could take the form of endowment trusts, section 21 companies or similar secure endeavours. Such funding, in addition to that of the government, would provide the firm foundation on which to launch sustainable programmes and around which to organise other, separately or jointly funded projects. Jointly funded projects are envisaged as partnerships between the national facility and donors or research organisations. The mechanisms for establishing endowment funds will be discussed and several examples of successful schemes will be given. Most donors and aid organisations are not favourably disposed towards making contributions to such funds, preferring rather to maintain the stop-start cycle of donor managed projects. It is questioned whether this approach is in the long-term interest of the countries receiving the support or whether it might be both advantageous and effective to persuade donors to think afresh. These issues are debated. It is concluded that long-term research, monitoring programmes and the achievement of conservation objectives are so dependent upon programmes that are driven by the nationals of the countries concerned, and funded in a secure manner for as long as funding is required, that it is necessary for those donors that are opposed to the establishment of investment funds to re-examine the situation and reconsider their policies. Ideally, to understand and manage the lakes, the programmes should have perspectives that embody the phrase "in perpetuity". And this phrase should be applied to both the nature of the work and the financial resources that support it.

Introduction
As long ago as 1962, Rachel Carson pointed out that: "It is our responsibility to safeguard our genetic heritage, which we received as a fit (in trust) from the past … to hold and to manage (in trust) for the next generation." Conservation, therefore, is a matter of trust; previous generations entrusted us with a responsibility to future generations. Although this concept has been used in numerous publications, it has not really taken hold in practical sense, partly because our role as trustees is too loose. As trusts or endowments or similar do focus attention on responsibilities and duties, and as they do provide one of the solutions to solving problems of achieving financial security for long-term programmes, we shall explore with you the value of trusts.

Although we shall refer to trusts and endowments in this paper, we do so in the knowledge that they are not the only way to go, but also in the knowledge that there is a history of success and a legal foundation for their use. Indeed, the legal basis for trusts originated in Roman times and have since evolved to be a potentially powerful tool in environmental management.

We shall be dealing with trust in two forms:

Our responsibilities or duties as trustees charged with caring for the environment (intergenerational moral trust), and
The manner in which trustees can have the financial resources to meet their responsibilities (financial or endowment trust).

Intergenerational trusts
In the intergenerational "moral" trust it is the duty of the present generation to care for biodiversity and environmental processes so responsibly that they do not compromise the capacity of the next generation to enjoy the benefits of natural resources. This or similar statements appear regularly in communications regarding conservation of resources, but have little impact in terms of the way the general public live, except perhaps to tweak the conscience of a few. Part of the reason for this is that there is no formal trust relationship that individuals have with the environment, despite general laws or commitments in many countries that are purported to serve these ends.

However, the concepts and legal framework do come into play with regard to the use of resources that are governed by governments or other authoritative bodies. The essence of the intergenerational trust is that the present generation should harvest the resource so that the capital or principal is not compromised to the point where the next generation would be compromised. For example in a fishery, the off-take or catch should not be so great that the remaining population will be unable to recover to meet the needs of the future generations. In general humans are in competition with each other to acquire a greater proportion of the environment for themselves, paying little regard to the needs of others. If altruism between individuals is not a feature of the present generation, it is unlikely that individuals of this generation are likely to meet moral responsibilities to the next generation. Therefore, until educational programmes and the poverty issues of current generations are such that individuals can afford to be altruistic, formal bodies have to assume responsibility for maintaining the environmental capital in trust for the next generation. At present this responsibility resides with central government in much of Africa, but there is a growing movement towards decentralisation, in which departments and organisations and even communities are taking responsibility for managing the resources. Each of these therefore has the moral responsibility of caring for the resources of this generation with the eye on providing for the next generation. In Africa, many of the organisations or institutes are unable to fulfil their obligations, as they do not have the financial resources or human capacity to do so. One solution is for endowment trusts to be developed that do have finances so that institutions have long-term, sustainable support. These can include village trusts where communities are charged with the responsibility of managing resources with an intergenerational perspective in mind.

The legal structures and a wealth of experience exists to provide trusts that have the responsibility to provide for future generations. Interestingly, the legal structures also exist in which subsequent generations can sue previous generations for stealing their heritage and resources if later generations are of the opinion that the resources were inadequately cared for and that they are suffering as a consequence. This underscores the need to guard the capital carefully.

Trusts, endowments and similar

The problem

As indicated in an outline of the theme of this meeting, poverty in Africa has led to donor driven research and conservation initiatives that are subject to stop-start cycles of sporadic funding and are consequently short-term in nature. It impedes the career paths of individuals and promotes the brain drain from countries that should retain trained capacity. This has led to situations where sustainable programmes cannot be implemented, and long-term goals cannot be set nor achieved.

Needs to solve problems

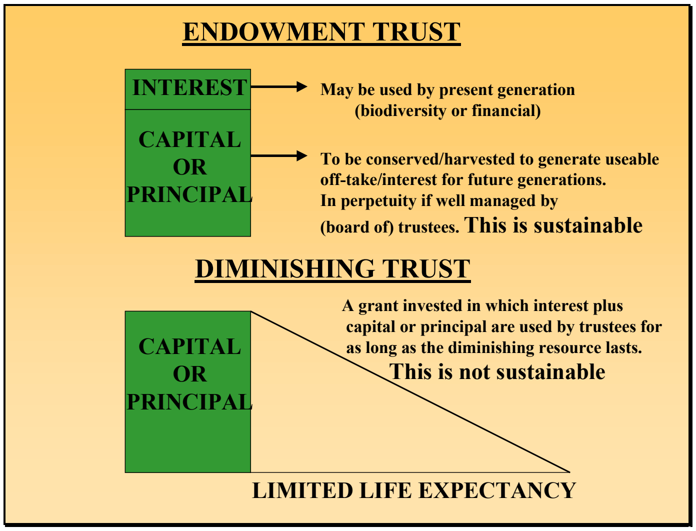
The most pressing step is to provide financial security to research stations or conservation units and to communities to enable them to develop and progress towards the achievement of long-term visions. This step requires independent funding that so reduces reliance on their own and donor governments that financial security is obtained. Endowment trusts, or similar secure endeavours offer possible solutions. Such funding, in addition to that of governments, could provide the firm foundation on which to launch sustainable programmes and around which to organise other, separately or jointly funded projects. Jointly funded projects are envisaged as partnerships between the national facility and donors or research organisations or communities.

Trust funds offer one solution

The Trust Fund mechanism offers one solution. Trust funds can guarantee a degree of permanent income, and have the potential to contribute significantly to the country's development through supporting institutional development and community initiatives, as well as assisting in the planning and development of income generating activities such as eco-tourism.

What is a Trust Fund?

As outlined by Barry Spergel (WWF, 1993), a "Trust Fund" is a fairly loose and general term to indicate a sum of money that is legally stricted to being used for a specified purpose, separate from other funds such as a government's general budget, and is managed by a board of trustees, which holds legal title to the funds. The legal form that a trust may take varies. Most of the trust funds that WWF has worked on have been "endowments", meaning that only the interest income is spent each year and not the principal, which remains invested. However, there are other forms that a trust fund may take: the entire principal may be used over a fixed number of years, or it may be set up as a "revolving fund", so that resources come into the trust as existing funds are spent .



An endowment trust can have the specific goals of serving the developmental, research, conservation, educational needs of a particular institution, in which case it is rather like a long-term project. This is an Institutional Trust. Alternatively it may provide the financial basis for a foundation that supports a variety of environmental projects of other organisations, acting rather like a donor . For the parks and research stations around the lake, the institutional endowment trust is favoured, but a foundational approach may also be desirable to 'encourage communities' participation and provide them with a sense of "ownership" of the responsibility to conservation. Thus, in certain circumstances we would encourage a mixture of both the institutional and foundational approach.

Use of trust funds for environmental programmes is not entirely new

National level trust funds for environmental or conservation purposes are an innovative financing mechanism being used by more than thirty countries. Also important are international transborder Trust initiatives (e.g. Transfrontier Natural Resource Management Areas, Trans Frontier Conservation Areas).

According to a recent report commissioned by the UNDP/GEF, between 1990 and 1995 over US$50 million has been committed to environmental trust funds. A number of donors, including USAID consider an endowed foundation as potentially a better way to provide development assistance, WWF has been instrumental in the development of conservation trust funds in more than 10 countries world-wide, and in part of an international forum to promote such initiatives in a wider range of countries.

Environmental Trusts are used mainly to cover recurrent costs of parks and protected areas and research institutions to support the overall goal of conserving/managing biological diversity, to reduce air and water pollution, to strengthen local environmental institutions, to promote sustainable development, to promote education, community participation and public awareness, to promote projects that address problems of poverty alleviation. The emphasis has been on supporting integration of conservation and human development needs.

Most such funds are independent of government in terms of their management (though government may be the main source of funds), and most include on their governing board, often in a major way, representatives of non-governmental organisations (NGOs) as well as government representatives.

Goals are to provide in the long-term, preferably in perpetuity intergenerational, secure financial capital that provides sufficient interest to enable the conservation of environmental capital to be achieved by nationals of the country. There are numerous subsidiary goals, often specific to the circumstances of the area being conserved and the needs of the institution managing the trust.

Advantages

Environmental trust funds and foundations hold the potential to meet many needs of both donors and recipients. They are attractive in that they provide stable financing for many activities that could not be met by national budgets or by short-term projects using donor funding. This long-term stability in funding provides a degree of insulation by ensuring a dependable flow of money not affected by fluctuations in international donor money or government allocations.

When they involve domestic management of assets, these funds instil a sense of ownership and responsibility for environmental conservation, build local capacity for financial management, and reduce the dependence on outside experts and international organisations.

By providing assurance of funds in perpetuity or over a long period of time, they enable long-term planning. And they give individuals building careers in such fields some assurance that jobs will be available. When tied to long-term environmental action plans, funds help donors identify priority areas for funding and avoid inadvertent duplication of efforts. By including a range of stakeholders in the governance and management, funds promote democracy, strong civil societies, accountability, and consensus building, and they build national capacity for moving towards sustainable development.

Importantly too, in an intergenerational sense, all trustees are forced to focus on long-term conservation goals, are driven by the need to achieve these and by the fact that trustees are accountable for the success or failure of such programmes. In essence, trusts of this nature powerfully underscore this generation's commitment to meeting the needs of subsequent generations by imposing duties on trustees.

There are several additional reasons too why local stakeholders can further benefit from nationally managed endowment trusts.

Disadvantages

A concern of some donors, especially when setting up an endowment is the need to release a sizeable amount of money at the start of a project rather then disbursing over time. A series of smaller appropriations could be a solution. However, making a large grant at the beginning could be viewed positively by donors as a way of reducing administrative costs and assuring programme continuity. In some respects, making a series of appropriations defeats the purpose of the endowment as a large sum needs to be invested for at least a year to earn the interest that drives the programme.

Other disadvantages can arise if the government departments see the trusts as competition rather than support. Similarly, if the communities are not included they may be opposed to the trust that could be seen as governmental not theirs. Trusts can be caught between the two: government perceives them to be too independent: communities perceive them to be too governmental. It is essential, therefore, to have adequate buy-in from all stakeholders.

One of the biggest problems facing Africa is that many donors do not believe that certain countries at least have the capacity to manage trusts. Rather than help develop that capacity and to learn from experience elsewhere, such donors simply close the door on trusts and continue to opt for short-term projects that they dominate. There are lessons from elsewhere from which everyone can benefit.

Experience from elsewhere

If trusts offer attractive alternatives to donor driven, stop-start project cycles for the African Great Lakes then it would be prudent to examine experience from elsewhere and be guided by the lessons others learned. Several case histories indicate that all are different from one another, some have had problems in gaining momentum and acceptance, but all seem to be on successful trajectories and as far as can be ascertained from the sample available, none has failed.

Belize's Protected Areas Conservation Trust (PACT) uses an innovative method of raising funds for the conservation and management of protected areas: a conservation fee charged to all foreign tourists as they leave the country. This type of free can serve as a model for other countries, because it has been successful in generating revenue even at a time of sever budgetary constraints and declining international aid. Since tourism is now the world's largest industry, charging tourists even a modest conservation fee has the potential to generate large sums for management of protected areas.

In addition to innovation, an equally noteworthy feature of PACT is that money generated by the conservation fee, which is essentially a tax, goes to an independent legal entity outside of Government (i.e. the TRUST). PACT is managed by a Board of Directors (TRUSTEES) with an equal number of members from Government and from non-governmental organisations. This represents a new kind of partnership between Government and civil society.

Ecuador is regarded as one of the richest reserves of biodiversity on the planet, and is internationally known for being host to some of the world's most precious ecosystems, located in its tropical, Andean, and coastal regions, and the Galapagos natural park and marine reserve. There are currently no active specialised facilities to finance the tremendous need for environmental management in the country. A national environmental fund, still idle, has recently been established. The creation of this fund, the Fondo Ambiental Nacional (FAN), presents an interesting case study for two reasons.
One is the participatory nature of the fund's conception process, intimately linked to innovative ideas for environmental financing. The second is those novel sources of financing themselves. The FAN is the result of initiative and work by key private and public-sector agents to grasp a historical opportunity for mobilisation of significant amounts of domestic resources toward environmental management.
Given Ecuador's unique political and economic conditions in the period from 1994 to mid-1996, including economic adjustment, armed conflict with Peru, political scandals, and presidential and congressional elections, the future of the fund is still uncertain, but its bases have been strongly established. This case study describes the fund's various stages of creation, and the hurdles faced by its initiators, with the intention of placing the FAN's experience in a real context.

The idea of mobilising funds for the environment from the proceeds of State de-investment and privatisation occurred to FAN's proponents as something almost *obvious*. Similarly, the idea of mobilising for the environment royalties and other proceeds from the exploitation of non-renewable natural resources (oil) – particularly when the exploitation takes place within fragile ecosystems – also seemed rather obvious to a broad community of concerned individuals in academia, NGOs, the productive sector, and Government. Implementing those "obvious" ideas, putting them into practice, is a different story. The *critical mass* of individuals who propelled FAN into being is aware of the resistance and difficulties that the idea will still need to overcome. However, they felt confident that the ample endorsement secured by the participatory process of creation will render both FAN and its proposed funding scheme viable for implementation under any in-coming Government.

Jamaica has two National Environmental Funds. The Environmental Foundation of Jamaica (EFJ) was founded in 1993. This fund began under the U.S. Government's Enterprise for the Americans Initiative. The fund is supported exclusively by payments from the Jamaican Government, representing interest on rescheduled and reduced bilateral debt owed by Jamaica to the United States. In addition to receiving direct payment from the Government of Jamaica (GoJ), the fund is able to take advantage of the high interest rate regime in Jamaica to earn substantial interest on its capital. The EFJ's resources, resulting from payments on reduced PL-480 and USAID debt, as well as investment earnings, are used for grants to NGOs for projects in environment and child welfare.

The Jamaica National Parks Trust Fund (JNPT) was legally registered in January 1991 and capitalised with the proceeds of Jamaica's first (and the Caribbean's second) debt-for-nature swap, on Earth Day 1992. The fund is managed primarily as an endowment and makes grants from investment income, its principal remaining untouched. The Government's Green Paper on National Parks for Jamaica indicates that the JNPT should be the major vehicle for channelling eligible funds (of public of private origin) to the part system. To this end, the JNPT allows for donations to be tied to specific projects, parks, or geographical areas. The Government of Jamaica is expected to make annual contributions to the Fund. The Government will also help to develop proposals to bilateral and multilateral funding sources.
Both funds were established through the close co-operation of the Governments of Jamaica and the United States and the Jamaica Conservation and Development Trust (JCDT), the island's leading conservation NGO. This case study focuses on the National Parks Trust Fund, although occasionally making comparisons with the EFJ.

In 1992, the Government of Peru passed legislation creating the National Trust Fund for Protected Areas (FONANPE) to assure long-term funding for the country's protected areas. At the same time, the Government created PROFONANPE as a private, non-profit organization to administer the fund. Because of the timing of its creation, the new national environmental fund faced a complex panorama in terms of its potential to capture large-scale national resources.

On the one hand, the possibility of direct Government disbursements into FONANPE was and continues to be almost non-existent. Since the election of President Alberto Fujimori in 1990, the Government has followed a policy of strict fiscal austerity and has cut spending in almost every branch of Government. Today the policy is being reaffirmed in a soon-to-be signed IMF Letter of Intent in which the Government of Peru (GOP) commits to cut spending in order to increase its primary fiscal surplus, increase domestic saving, and fend off a potential balance of payments crisis. The Government has also committed to increased tax collection, but this additional income will go to covering the lean state budget and servicing the $26 billion foreign debt.

As for non-governmental sources of national funding, Peruvians have no tradition of charitable giving to environmental or other non-profit organisations and, despite increased economic stability, most Peruvians still endure great economic hardship and have little cash to spare for donations.

But alongside this grim scenario, there is a bright spot in terms of national resource mobilisation. Since 1990, the GOP has been engaged in an all-out effort to "reinsert" Peru into the international financial community. A key component of this effort has been the negotiation of Peru's foreign debt, heavily in arrears since the early 1980's, with multilateral, bilateral, and commercial lenders. The Government's determination to restore Peru's creditworthiness through these negotiations has provided one of the most important sources of funds to FONANPE, which has received more than $10 million in debt donations to date.

Negotiating debt swaps, while not PROFONANPE's only line of effort is and will continue to be the organisation's primary focus and best hope for reaching its goal of a trust fund totalling $80 million. Other countries that face tight budgets and extensive debt negotiations may find in Peru's experience a useful example of how a bleak economic panorama may in fact hide a more hopeful scenario for the creation of a national environmental fund.

Developing trusts

Given that the advantages of environmental endowment trust out-weigh the disadvantages, and, given that there are precedents of successful environmental trusts from which one can learn, there seem to be compelling reasons to develop trust for lake conservation and research, particularly in developing countries. One of the first steps is to persuade donors and governments, which are reluctant to follow this route, of its great benefits. To do this, it is essential to be very well prepared in terms of defining visions, goals, modus operandi and, in every respect, complete thoroughly that the homework has been done. Also buy-in by stakeholders, particularly the village communities and sceptical governments, is an essential prerequisite to success.

How to fund environmental endowments

Funding can be derived from a variety of different sources. In many cases in which trusts have been formed the national government has shown strong commitment by funding directly or indirectly part or all of the trust. Probably, it is worthwhile in all cases for national governments to make a partial contribution as this is an indication of sincerity and commitment that would provide additional leverage for fundraisers to use when encouraging others to support the initiative. Even the poorest of governments can make contributions as they certainly represent an investment in the future of its people and the sustainability of the resources on which they depend.

There is a broad spectrum of donors that might fund trusts (major bilateral and multilateral donor agencies), USAID and the World Bank/Global Environmental Facility, philanthropic donors such as the MacArthur Foundation and international conservation organisations including The Nature Conservancy and WWF. Though some of those that did so in the past are no longer keen on this route, favouring instead a return to stop-start projects over which they can exercise greater donor control.

How to manage environmental endowments: Investing capital

The financial rationale of an endowment is to protect the value of assets while generating income from investments. Private donor organizations and bilateral and multilateral aid agencies tend to focus on short-term projects whose impact often dwindles after the money runs out. For these agencies, endowments offer a way to sustain commitment to long-term goals insulated from budgetary and political fluctuations. Operating an endowment, however, necessitates acquiring and managing assets in a way that maintains their value and produces income. Ideally, both the capital and the interest should grow over time if well managed, so that inflationary trends and growing needs are met. Many trusts have grown substantially since their initiation .

Management in perpetuity

Regardless of conditions in local financial markets, building a financial management capacity will pay off when the financial markets develop to the point that an endowment can be managed in perpetuity. An endowment's financial managers should anticipate the various constraints on the handling of an endowment's assets, including gift restriction imposed by donors, reporting requirements of national governments and donors, and the need for transparency and for avoiding conflicts of interest in asset management decisions. An endowment that proves able to deal with these constraints will be attractive to potential donors.

The issue of investing within the nation in which the trust is to be launched, or offshore, or in both, has to be assessed for each case. Returns on interest are often better in African nations, but the devaluation of currencies and the potential for political instability, even in what are apparently strong economies (vide recent events in Zimbabwe) has to be carefully analysed by the investment house employed to manage the finances so that the trustees are wisely informed.

It is an advantage for the fund to be independent and outside of government. This increases donor confidence that the funds will not be used inefficiently or redirected to other government concerns. It also makes the fund independent of political changes as when an election has taken place. Some donors, for example USAID, can only give funds to independent non-governmental organisations, or to funds where the management board has a majority of NGO representatives. However, the Trust needs to have a good relationship with government and be in line with government policy in order to solicit the political good will to make the fund functional. It is also clear that the fund cannot replace the government's normal budgetary commitment to environmental conservation activities, but must support them.

Long-term investments for nature, research, education

Endowments are defined as assets that are invested to earn income to be used in support of a defined purpose.
Funds can take several different forms (a trust set up by special legislation, a foundation, a common law trust, a non-profit corporation) but nearly all take the form of an endowment.

Answerability and accountability

Appointment of the board of trustees should follow the legally established procedures and should benefit from the wealth of experience that exists already (see case histories). Importantly, the trustees have to be fully accountable for their performance in both the achievement of environmental goals and in financial management of the capital and interest, preferably showing an annual growth of both.

Conclusion

Long-term research and monitoring programmes and the achievement of conservation objectives are so dependent upon programmes that are driven by the nationals of the countries concerned, and funded in a secure manner for as long as funding is required, that the establishment of trust funds or similar forms of sustainable secure funding presents an attractive option. Perhaps is it is necessary for those donors that are opposed to the establishment of investment funds to re-examine the situation and reconsider their policies. Ideally, to understand and manage the lakes, the programmes should have perspectives that embody the phrase "in perpetuity". And this phrase should be applied to both the nature of the work and the financial resources that support it. Whether in the context of lake Malawi/Niassa/Nyasa each station or park, such as a Kyela, Metangula, the lake Malawi National Park, Senga Bay and others should have independent trusts, each managed by their own trustees, or whether there should be a multi-national Trust for the entire lake are issues that need not be debated in this paper. What is clear is that trusts managed in perpetuity do offer a compelling alternative to the stop-start cycles of donor projects.

The need to maintain Maximum Biodiversity in Lake Nyasa

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Abstract

Lake Nyasa fish fauna comprises more than 1 000 species, mainly cichlids, and is thus unique among freshwater lakes. But tension exists between motives either to conserve or exploit the fish resource. In Lake Nyasa small scale fishery exploits the inshore resources, principal fish taken are mainly cichlids which comprise up to 90% of the total landings. Cichlids have low fecundity and are k-selected therefore have low rates of recovery in face of stock collapse. Thus what is happening today in Lake Nyasa has great consequences for tomorrow. Such a scenario provides the motive and desire for conservation of the Lake Nyasa fish fauna. We care about biodiversity and we wish to maintain or conserve it because we see value in biodiversity. The term, biodiversity has become so much of a buzzword dominated global environmental debate, that it is often difficult to focus on the critical issues that face society. The six categories of biodiversity values relevant to Lake Nyasa are presented and discussed and the need to maintain biodiversity in Lake Nyasa is deliberated using a poverty degradation feed-back cycle.

Introduction

Biodiversity – a new gimmick?

According to Ghilarov (1996), the term biodiversity appeared in ecological literature in the middle of the 1980s and in less than 10 years it became so popular that for the external observer the whole situation looks like a successful breakthrough in some new field of science. Today biodiversity has become an everyday word not just for ecologists but for politicians, the media and the general public too. It seems, however, that the real reason for this burst in interest in biodiversity (or rather this rapid increase in the usage of the term 'biodiversity') lies outside the sphere of science. To many professional ecologists, perhaps it sounds offensive, yet I shall dare to claim that the term 'biodiversity' became so popular, primarily because it's usage facilitates greater access to research funding. So we might consider 'biodiversity' as a useful fad that helps many ecologists to survive doing science.

The term 'Biodiversity' has become so much part of the buzzword dominated global environmental debate that it is often difficult to focus on critical issues that face the society. Biodiversity can be defined in its narrow sense as: "The variety and variability among living organisms and the ecological complexities in which they occur" (FAO, 1994). Biodiversity can be measured in terms of ecosystems, species and genes (Whittaker, 1972, Harper & Hawksworth, 1994).

But a more relevant view of biodiversity, especially to African societies comes from its larger resource oriented sense. "In Africa biodiversity is a matter of survival, it is critical for life at grass root level. It is a total variety of living matter on which society depends. It provides ecosystem resilience, to allow both people and natural communities to cope with periodic environmental stress" (FAO, 1994).

Why care about biodiversity?

We care about biodiversity and we wish to maintain or conserve biodiversity because we see value in biodiversity. This brings us back to the starting point of value to which part of the society. The debate on biodiversity revolves around two opposite poles of the society.

At one end is the developed western world interested in global values and the options values of biodiversity. It was the western world, which devised the funding mechanism such as the GEF to address these global values. At the other end are the local communities in the developing world, who depend on the biological resources of natural and man modified ecosystems for their livelihood.

We thus have polarisation of North versus South, Central government versus local government and western protectionism versus local utilisation.

Conservation International stresses that there are mainly five categories of biodiversity values.

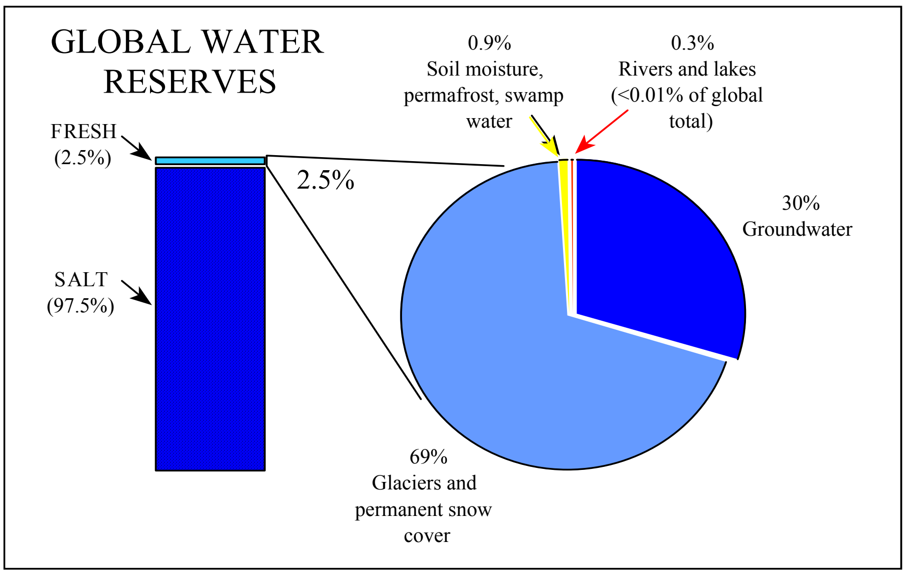
1. Major ecosystem functions (catchment, soil formation, nutrient cycling).
2. International export values (timber, beeswax, tourist spectacles, and medicines).
3. Regional and local market values (food, poles and medicine).
4. Household use values (food, cultural, construction, and fuel).

5. Global intangible values (carbon sequestration, science).

These values are, however, not all mutually exclusive, for example 'mbuna' stocks maintained for international export value will also provide global benefit. For developing countries like Malawi, Mozambique and Tanzania, emphasis for conserving the stocks of 'mbuna' is based on their utilitarian export values, not their long lists of Latin names of endemic species.

Lake Nyasa, a biodiversity 'hot-spot'

The global water reserves comprise of 97.5% salt water and 2.5% fresh water. Surprisingly, only a tiny percentage (less than 0.01%) of the global total water reserve is comprised of rivers and lakes. The remainder is ground water, glacier and permanent snow and soil moisture, permafrost and swamp water. Yet this tiny percentage holds a tremendous diversity of life. Of the 20 000+ species of fishes described so far by scientists (and many more remain to be described), 40% live in freshwater. In other words, almost half of the fish biodiversity is contained within a very vulnerable 0.01% of the earth's water.



The freshwaters of rivers and lakes are surrounded by land and they are unquestionably legitimate sinks for all the land based activities and are therefore among the most fragile of habitats. Lake Nyasa, with an estimated 700-1 000 fish species (Ngatunga, 2000), contains the richest community of freshwater fish species in the world. Lake Nyasa is therefore, justifiably regarded as the centre of freshwater fish biodiversity. Eleven fish families are represented in the lake, but the family Cichlidae shows the greatest species-richness and with over 99 percent of its species occurring only in Lake Nyasa, it has a great degree of endemicity. These cichlids occupy all the major habitats with communities characterising the sandy, muddy, open-water, vegetated and rocky habitats. Cichlids have low fecundity and are k-selected therefore have low rates of recovery in face of stock collapse. Cichlids are a family of tropical spiny-rayed fishes that has suffered one of the most dramatic human induced extinctions in recorded history (Stiassny, 1993). These extraordinary fishes are the ones that give Lake Nyasa the dubious distinction of being a unique and interesting freshwater body in the world.

Because of the situation found in this lake, these cichlids have been the subject of intensive study by evolutionary biologists – A natural laboratory of evolution and one of the natural wonders of the world. There is no question therefore that Lake Nyasa is a site of global significance. Such a scenario provides the motive and desire for conservation of the Lake Nyasa fish fauna.

Lake Nyasa, a food basket

But tension exists between motives either to conserve or exploit the fish resource. In Lake Nyasa small scale fishery exploits the inshore resources, principal fish taken are mainly cichlids with landings comprising up to 90% of the total landings.

The importance of Lake Malawi cichlids as a source of protein cannot be over emphasised; they are a crucial resource both as natural populations and subjects of fish aquaculture. Most of Lake Malawi cichlids are small and therefore can easily be dried in the sun for upcountry markets.
Under the circumstances of hunger and poverty, fish conservation is both exhilarating and controversial. Exhilarating because those fishers bear the collective wisdom, wit and will to control their resource they depend on for survival. Controversial because the need to survive drives them to fish to the last fish! Thus what is happening today in Lake Nyasa has great consequences for tomorrow.

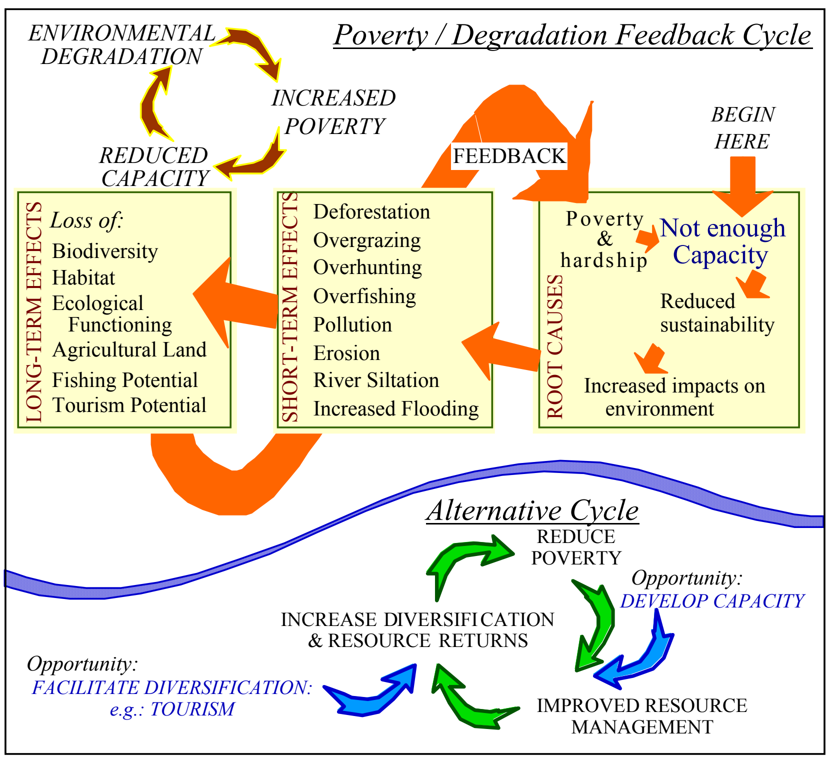
Threats to Lake Nyasa fish biodiversity

Habitat variability within the lake must have played an important role in sustaining the diversity of fish and therefore, preserving the fish biodiversity of Lake Nyasa is not possible without habitat protection of those areas of the lake where most species depends on. The most important and also most delicate habitats are the littoral zones of the rocky habitats, the shallow water zones associated with river mouths – swamps, submerged macrophyte beds, lagoons are important for spawning and nursery grounds of many fish species.

The main threat to the existence of high diversity of life in Lake Nyasa comes from human activities on the adjacent land. The root causes of the lake's environmental damage that can result in biodiversity loss are of two categories:

1. Land based causes/sources and activities affecting the quality and uses of the lake (poverty, poorly managed social and economic development programs and unsustainable consumption patterns).

2. Of the land based activities I consider the effect of fishing, both direct and indirect to be of highest priority comparable to that of the most serious land-based threats.



Strategy

Indeed the need to maintain maximum biodiversity is surely greatest as the rates of environmental change increases. The strategy to maintain maximum biodiversity of this fish resource that the local population mainly depends on should be advocated together with the strategy to alleviate poverty and hunger. An example in this case is the provision of an alternative source of cheap protein.

References

FAO, 1994. Biodiversity. News letter, East African Biodiversity Project: UNO/RAF/006/GEF.

Stiassny, M.L.J., 1993. What is a Cichlid? *Tropical Fish Hobbyist* (TFH, November, 1993), 141-146.

Ghilarov, A. 1996. What does 'biodiversity' mean – Scientific problem or convenient myth? Trends in Ecology and Evolution Vol. II, 304-306.

Harper, J.L & Hawsworth, D.L. 1994. Biodiversity: measurement and estimation. Philos. Trans. R. Soc. London. Ser. B 345, 5-12.

Marcel, A., Brechignac, F. & Thibault, P. 1994. Biodiversity in model ecosystems. Nature 371, 565.

Ngatunga, B.P. 2000. A taxonomic revision of the shallow-water species of the genera *Lethrinops, Tramitichromis* and *Taeniolethrinops* (Teleostei, Cichlidae) from Lake Malawi/Nyasa/Niassa (East Africa). PhD thesis, University of Rhodes, South Africa, 293pg.

Stiassny, M.L.J. 1993. What is a Cichlid? *Tropical Fish Hobbyist* (TFH, November, 1993), 141-146.

Whittaker, R.H. 1972. Evolution and measurement of species diversity. Taxon 21, 213-251.

Fisheries Management, Biodiversity Conservation and Genetic Stock Structure

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Abstract
Given the immense difficulties of assessing and managing fisheries on Lake Malawi/ Nyasa, it seems likely that the present approach of using intuition and rules of thumb to derive management approaches is likely to continue. It is important that the rules of thumb employed are as accurate as possible. At present, almost nothing is known of the migration patterns and movements of the major fish stocks in the lake. Both the collection of data and the setting of effort limits are presently based on rather arbitrary fishing areas. Local fisheries management will be largely irrelevant if carried out on wide-ranging stocks that are exploited elsewhere. Analysis of population structure provides an effective tool for the assessment of fish movement patterns. Tagging is likely to be impractical for most lake fish stocks. Species identification is important, but on its own, provides limited geographical resolution of stock structure. Molecular approaches using microsatellite DNA are powerful, but are critically dependent on accurate species identification. Examples are given of studies implemented on Lake Malawi. A critical advantage of this kind of study is that the information it provides need not be updated by regular monitoring, but can be used to inform management decisions indefinitely.

Introduction
Assessment and management of fishery resources on Lake Malawi/Nyasa is not easy, and there have been few success stories to date. Difficulties arise from (among other things) the sheer size of the lake, the huge number of species exploited, the lack of knowledge of fish biology and identification, the diversity and decentralisation of fishing activities, the lack of knowledge about the factors influencing fisher behaviour and lack of funding. Little is presently known about the movements of fish within the lake, which makes it difficult to define the geographical extent of stocks for the purposes of assessment and management. This raises major practical problems in the light of decentralisation of responsibility for management of fish stocks, with political authority devolving to district levels and with increasing emphasis on local co-management through beach village committees. A further problem lies in the assessment of gear and fleet interactions. This is likely to become a more pressing problem, as there are pressure to grant more trawl licenses at the same time as artisanal fishers are increasing the use of chilimira nets to target offshore benthic species such as chambo ('kauni' fishery).

A 'stock' is what fisheries managers try to manage. A group of organisms can be treated as a stock if possible differences within the group and interchanges with other groups can ignored without making the conclusions reached invalid (Sparre *et al*. 1989). Why should fishery managers care about stock definition? If a stock is overexploited, managers will wish to decrease fishing effort on that stock. This would be of limited use if another fishing fleet continues to increase its rate of exploitation of the same stock. Is there any point in the allocation of property rights to a local community to enable participatory management of a stock in one area, if rampant overexploitation of the same stock is going on somewhere else, or going on in the same area using a different method? Equally, if a stock is underexploited, this may be because it is difficult to exploit economically in part of its range. If such a stock shows a high degree of migration over its whole range, it might be worth permitting extremely heavy exploitation in the areas where it can be economically exploited, in the knowledge that local depletion of the population can be compensated by immigration from the rest of the range. Knowledge of stock limits and gear interactions is also critical in stock assessment, particular using catch and effort data. For example, there is no point in carrying out separate assessments for Salima and Nkhotakota districts if all the main fish species move freely between the two areas. If this were the case, the catch and effort data could be pooled and this might not only allow more accurate assessment, but might even allow for a reduction in data gathering effort, allowing valuable resources to be reallocated elsewhere. Thus, definition of the major fish stocks in Lake Malawi is an essential stage in the development of a rationally-based sustainable fisheries management programme.

Studies of population structure can also provide critical information for conservation biologists. If a local population in a reserve area exchanges few migrants with neighbouring populations, its protection is more important for two reasons. Firstly, it is likely that if the local population is reduced or goes extinct, immigration from elsewhere will do little to help the population recover. Further, it is likely that if migration rates are extremely low, the local population may contain unique genetic variants that will not exist in other populations. These variants may include genotypes specifically adapted to the local habitat, and if so, immigrants from elsewhere may never become as successfully established as the former residents. This can also be critical if restocking is attempted using source populations from other localities.

The present paper is aimed at summarising the uses of molecular methods in defining exploited stocks for fisheries management. I will also briefly discuss the uses of molecular methods in conservation biology, and discuss other methods which might be used to study population structure.

The basics of molecular ecology

DNA

Living organisms are constructed from recipes coded in their genes, made from DNA molecules, passed on from their parents. DNA is made up of various subsidiary molecules linked together, but the ‘message’ is spelled out in the sequence of 4 different kinds of molecules called ‘bases’, labelled A,C,T and G. An important feature of DNA is that it can make copies of itself, with the help of the enzyme DNA polymerase, which is itself made from the DNA. The messages in DNA are translated into RNA, which is in turn translated into proteins, which build bodies and transmit information around the body. In the course of sequencing the human genome (the genome is the total complement of DNA in an organism), it has been discovered that more than 95% of our DNA is not in fact used to make proteins, and indeed is not used for anything at all (International Human Genome Sequencing Consortium 2001). Much of this ‘junk’ DNA is mainly made up of bits that are good at making copies of themselves and getting them stuck into other parts of the genome. As long as they do not interfere with the workings of the useful bits of DNA, they tend to hang around as a sort of harmless parasite. This is not really as surprising at it sounds, because organisms are not ‘designed’ to be efficient, they have merely proved better than their rivals at surviving and reproducing over billions of years of evolution by natural selection.

The discipline of Molecular Ecology, of which Molecular Fish Stock Discrimination is a subdiscipline, is largely based on the analysis of this ‘junk’ DNA. Most commonly, molecular ecologists try to look at the same bit of DNA (a ‘locus’, plural ‘loci’, meaning ‘place’) in a number of different individuals. There will often be slight differences between individuals in the sequences of the DNA at the same locus- these different forms are called ‘alleles’. And because each individual has two equivalent chromosomes each containing the same set of loci (ignoring exceptions like the sex chromosomes and mitochondrial DNA), then each individual can have two different alleles (in which case it is said to be ‘heterozygous’) or two copies of the same allele (‘homozygous’). The trick is to find the same locus in each individual in the study. To do this, special ‘primers’ are used to latch on to unique sequences of DNA on either side of the region of interest. From these, chemical reactions (PCR or polymerase chain reactions) are carried out to make lots of copies of the bit of DNA that lies in between these primers, until there is enough material to analyse. The next step is often to work out the sequence of letters in the target locus, by smashing up the molecule into lots of little bits and then adding a different fluorescent marker onto the end according to which ‘letter’ is the last one. By working out the size of all the bits you can work out the whole DNA sequence. Alternatively, the target locus might consist of a very repetitive message (such as GTGTGTGTGTGT… and so on), in which case it is better just to see how long the message is. These procedures are increasingly carried out using automated DNA sequencers.

Genetic divergence of populations

If any groups of sexually reproducing organisms stop interbreeding with each other, they will begin to diverge genetically. There are three possible causes for this: selection, mutation and genetic drift (Avise 1994). In recently separated populations, drift is likely to be the major force, particularly when populations are small. Genetic drift results from the random process of chance differences in survival and reproductive success of individuals with different genotypes. This can happen even if these genotypes are equally good at surviving and breeding. Molecular estimates of migration rate assume that differences between populations are not due to natural selection. This seems a robust assumption for most populations which have become separated fairly recently (hundreds or thousands of years), but to be more sure of this, it is best to examine several different molecular markers which are selectively neutral and unlinked. By selectively neutral, it is meant that the locus is not involved in making anything useful, like a protein molecule. But, there is always the risk that the locus is next door (‘linked’) to something that is useful and has recently been subjected to strong natural selection. The risk of this can be minimised by looking at several different loci for each individual, which carries the extra advantage of allowing you to get statistically independent estimates of migration that can be averaged over to make the results more accurate. Thus, estimates of migration and population structure are based on statistical estimates of allele frequencies in different loci in many individuals from different populations.

Microsatellites

Many different molecular marker types exist, such as allozymes, mitochondrial DNA, RAPDs, AFLPs, minisatellites etc. Most have been used in studies of population structure. The advantages and disadvantages of different kinds of molecular markers are discussed in many excellent review articles and books (e.g. Avise 1994; Jarne & Lagoda 1996; Carvalho & Hauser 1998; Mueller & Wolfenbarger 1999; Sunnucks 2000). For studies of population structure the general consensus is that the method of choice is analysis of microsatellite DNA. Microsatellites are also sometimes called SSRs or Simple Sequence Repeats (e.g. Markert *et al* 1999; 2001) or, along with other larger repeats such as 'minisatellites' they are classed as VNTRs or Variable Number Tandem Repeats (Majerus *et al*. 1996). Microsatellites include the monotonous 2-letter repeats already mentioned (GTGTGT etc), although sometimes a motif can be as long as 6 letters (ACTGATACTGAT etc), and others can be a bit more complex with interruptions of the repeat by non-repetitive sequences (ATATATCGATATATAT etc). It seems that the short repeat motifs are difficult to copy accurately, and extra repeats are frequently inserted. Thus, microsatellites tend to evolve rapidly (and generally grow in length). This rapid mutation rate, coupled with their selective neutrality means that microsatellites tend to be incredibly variable and thus can provide good material for statistical comparisons between populations.

Statistical assessment of population structure

Most estimates of population structure employ variants of the F-statistics first developed in the 1950s (Wright 1951, see, for example Avise, 1994, for an explanation). For population structure, the key measure is F_{ST}, which is the variance in allele frequencies among populations, standardised as a proportion of the maximum possible for the given range of allele frequencies. Basically, it is a measure of the differences between populations in comparison to the overall amount of differences between individuals, including the differences between individuals within the same population. F_{ST} can range from 0 to 1. A high F_{ST} indicates a high degree of genetic differentiation between populations, and thus a low level of migration. Taking several assumptions into account, it is possible to estimate the number of successfully breeding migrants moving between populations per generation (Nm). This figure can also be estimated from the number of unique alleles in each population, adjusted for sample size (the 'Private Alleles Method': Slatkin 1985). Rather surprisingly at first sight, these methods give an estimate of the number of individual migrants, not the proportion migrating. There are a number of software packages to calculate F_{ST}, Nm and other parameters from raw data on microsatellite allele frequencies: most are readily available over the internet. A good starting point is the molecular ecology web site at the University of Hull. http://www.hull.ac.uk/molecol/nonmol.htm#software

Molecular stock structure analysis and species identification

Genetic analysis of stock structure is incredibly sensitive to correct species identification. This is rarely mentioned in the literature on the subject, but then in most of the world apart from Lake Malawi and Lake Victoria, it is quite easy to identify species of fish, so the question rarely arises. Confusion of closely-related species is just as dangerous as confusion of distantly-related ones. No studies of population structure using molecular methods are of any value if there is a risk that species might have been confused. The most likely result is that different proportions of different species will have been collected in different populations. The consequence of this would be to inflate the estimates of genetic differentiation between populations, and to give the impression that migrations levels were lower than they actually are. Recent studies have indicated that Lake Malawi cichlid fish cannot be told to the level of species on the basis of unique genetic markers (Parker & Kornfield 1997; Turner *et al*. 2000). So, there is no point in hoping that genetic studies in the laboratory can sort out mistaken species identification during sample collection. Properly labelled voucher specimens are thus a vital for any molecular ecology study where there might be the slightest doubt over species identification.

Protocols for sample collection for microsatellite studies

Table 1 gives a suggested protocol for sample collection for microsatellite studies of Lake Malawi fishes. It is assumed that there may be some uncertainty over species identification. In practice, it would be advisable to consult with leading experts in species identification prior to undertaking the study. This might be helpful in deciding whether to focus the collection of ripe males, or whether any stage of fish would do.

Making labels

A major cause of problems can lie in labelling of whole fish specimens. Probably the best method is make labels from Dymo tape (**www.dymo.com**). From the manufacturers, a basic manual dymo printer costs $6.80 with spare 12-foot long tapes costing $6.29 for 3. A single tape is enough to label dozens or even hundreds of individual fish. Dymo tapes and printers are sometimes available in Malawi. The more sophisticated electronic dymo printers are inferior for this purpose, as the labels are not so strong. A greatly inferior substitute is to use relatively rigid card, such as sold for file card boxes, and write labels using alcohol-resistant ink, such as is used in the Rotring Rapidograph ink drawing pen, **http://www.rotring.de/www.rotring.com/index.html**. The next problem is to attach the label to the specimen. The best method is to use a purpose-made fish-tagging gun loaded with T-bar tags. Information on fish tagging materials can be found at **http://www.hafro.is/catag/**. The best known supplier is Floytag, at **http://www.halcyon.com/floytag/**. The labels can be individually numbered or coded, but this is a lot more expensive, and it is probably better to make Dymo labels. Fish tagging guns will have a sharp hollow spike, designed to be pushed though fish muscle. To attach a Dymo label to a tag, the spike is simply pushed through the label before being pushed through the fish. A click on the trigger, and a strong plastic tag is inserted through the fish, held in place by the T-bar, which springs open on the underside. Tags are probably best inserted through the caudal peduncle above the lateral line (in case counts of lateral line scales are a useful taxonomic feature). In smaller fish, tags might have to be inserted through the main body of the fish above the lateral lines, to avoid breaking the caudal peduncle. If a tagging gun is not available, string or fine monofilament twine may be used to tie labels firmly round the caudal peduncle, or it can be threaded through the operculum and out the mouth with both ends tied together. Neither solution is ideal, as string tends to break and monofilament knots often come undone. Either can get caught among the fins and opercula of other fish. This can cause string to break, or the label to get sheared off, as fish are put in and out of the storage barrel. If the label has to tied on, it is wise to insert a duplicate label into the fish's mouth and perhaps even another under one of the opercula. The alternative to trying to attach labels is to place each fish into a separate plastic bag or jar, which also contains a label. Use of jars is usually impractical in the field. If plastic bags are used they should be well filled with preservative, for otherwise the fish may not get enough contact with the formalin for proper preservation.

Table 1. Suggested protocol for sample collection for microsatellite DNA.

Step	Procedure	Notes
1.	Select populations for study.	The sample area at each site should be as small as possible, given the need to collect sufficient samples
2.	Aim to collect a minimum of 50 live or recently killed individuals from each site.	100 is better. If samples from most sites are over 50, the occasional population sample of 30-40 could be OK.
3.	Cut off a piece of a fin and wash off any excess scales and blood (which might be from different fish). Place in a vial of 90-100% ethanol. Wash scissors before taking next sample.	If the whole specimen is to be preserved, it is best to remove the right pectoral fin, allowing taxonomic measurements to be taken from the left side.
4.	Label the vial, using alcohol-resistant ink. Best of all, as well as labelling the vial, put them into vial boxes where the rows and column are already labelled on the box.	NB if you rely solely on row and column designations on the box, and don't label the vials, it is a major disaster if you drop the box while the lid is open!
5.	Take a colour photograph of each specimen. Before taking the picture, write the vial label in large bold characters on a piece of paper and place this next to the fish, so that it appears in the photograph.	A coarse black marker pen is ideal for labelling, and stiff card, as used for file card boxes.
6.	Label the fish specimen using the same label code as for the vial and photo and place in 10% formalin.	Various methods are discussed below.
7.	Send duplicate copies of all of the photographs to one or more leading experts in identification of the fish species concerned, explaining the purpose for which the specimens are required.	It would be useful to include information on the collecting locality for each photograph when seeking advice.
8.	If required, send whole fish specimens to the identification expert, or wait until (s)he has the opportunity to visit your lab to examine the material.	
9.	Remove from the analysis any sample for which there is the slightest doubt over the species identification.	

Preserving Fish

A frequent problem with collections of fish specimens made for ID purposes is that they are often bent and twisted, and thus very difficult to identify. The main cause of this is packing fish in tightly while they are still soft and fresh. It is always best if the fish are placed into a barrel with enough room for them to float freely in the liquid. Ideally, the fish's fins should be open, rather than closed tight against the body. The best way to do this, after killing fish with an anaesthetic overdose, is to place them on a sheet of expanded polystyrene (balsa wood would also do, or a metal tray filled with about 1cm of candle wax), open out the fins, and pin them in place. Strong formalin is then drizzled from a syringe over the fin bases to fix them in place. Fish are best left like this for 10-15 minutes before placing them in the formalin bucket. If the fish have asphyxiated (often the case on deck of a trawler), the mouth may be fully extended. This also makes identification difficult. When pinning the fins, it is best to also pin back the mouth so that it is only slightly open. It is difficult to inspect the teeth, which can be an important character, if the mouth is fully closed. With fish brought up quickly from deep water, it is useful to puncture the stomach and swimbladder and squeeze out excess air, to try to combat the bloating of the fish resulting from swimbladder expansion. A final problem is with decomposition. Large fish should have formalin injected into the gut cavity, using a large syringe. The quantity should not be so much that the fish becomes bloated, a normal-looking shape is the aim. Very big chambo or ncheni can also benefit from a few injections into the dorsal musculature, carefully inserting the needle under a scale, because if you drive it right through the scale, it will come off as you remove the needle. It is worth remembering that formalin is diluted by **fish** as well as by water. The aim is get a 10% formalin solution in contact with the fish tissues. If there is more fish than water, then concentration of a 10% solution will soon be less than 5%, and fish will start to rot. Another problem with overpacking of fish is that parts of the bodies can end up sticking out of the liquid. These can quickly rot. Containers of preserved fish should be inspected regularly to maintain levels of liquid, which can drop through evaporation or spillage. Formalin is poisonous, and it is extremely unpleasant to inhale the fumes. Before any detailed examination of the specimens is carried out, the formalin should be washed out under a running tap (left outdoors for a couple of days) and then the specimens should be kept in 70% alcohol. But it is worth waiting until you have checked the quality of your photographs before you do this (see below).

Photographing fish specimens

I have often been surprised at the poor quality of photographs of fish I have been asked to identify. A common problem is that the fish is photographed from an oblique angle, usually because it is high up on a table at the time. There is no substitute for getting the specimen onto the floor! If the fish is very big, I often stand on top of a stool to get a good aerial view from far enough away. In Africa, the bright light often casts dramatic black shadows over the fish. I prefer to photograph fish in the shade where possible. There is usually enough light that a flash is not needed. In the open, I usually manoeuvre my own body to cast a full shadow over the fish. An umbrella might come in handy for big specimens. Inevitably, there is a risk that photographs will not come out or be over- or under-exposed. A digital camera allows you to view your photos immediately and see if they are of acceptable standard. Generally, they do not store many images, so it is useful to take backup disks, if it is not feasible to download them directly into a computer. If a digital camera is not available, a fallback position in the event of your photos being useless, is to photograph the preserved fish. Some element of the live colour is usually still visible if the fish has been kept in formalin, in the dark. However, alcohol rapidly bleaches specimens, especially if they are kept in sunlight. So, it is advisable to keep specimens in formalin until the quality of photographs has been determined. Live colours often fade quickly after death, so it is often useful to take a quick snap of the live fish first, and another picture once the fins have been pinned out in order to get a better impression of the shape and finnage.

Case studies of stock structure analysis in Lake Malawi

A potential problem with microsatellites is that new primers usually have to be developed for each species being studied. This can be a laborious and expensive process. For once, the fact that most of the cichlids are so closely related proves to be a plus rather than a minus, since it seems that most primers work across all the haplochromines. About half of the primers developed for tilapiine cichlids work on mbuna. Fortunately, Prof. Kocher at the University of New Hampshire, USA, has been engaged from several years in developing hundreds of sets of microsatellite loci to map the genomes of Nile Tilapia for aquaculture research (e.g. Lee & Kocher 1996, Kocher *et al*. 1998, see also **http://tilapia.unh.edu/Default.html**) and mbuna for evolution research. Consequently, there is no shortage of microsatellite primers available.

Case Study I: Population structure in mbuna

The first study to use microsatellites to investigate the population structure of Lake Malawi cichlids resulted from a research project on the evolution of mbuna, carried out by a consortium of researchers in British Universities, in collaboration with the University of Malawi. We wanted to test the hypothesis, dating back to Fryer (1959), that there is little migration between populations of mbuna separated by deep-water channels or sandy bays. An earlier study by McKaye *et al*. (1984) had looked at this question by comparing *Pseudotropheus zebra* from Nkhata Bay and Chilumba with Mumbo Islands and Domwe Islands in the southern part of the lake. Although this study clearly showed differentiation between the northern and southern populations, it employed allozyme electrophoresis, a comparatively crude method which we thought unlikely to demonstrate population differentiation at the smaller spatial scales we were concerned with. We used 6 microsatellite loci to compare populations of 4 species: *Pseudotropheus zebra, P. callainos*, and two undescribed members of the *P. tropheops* complex (*P.* 'tropheops olive' and *P.* 'tropheops mauve'). We looked at 4 populations from headlands around Nkhata Bay- each headland was separated from the next one by a sand/mud bay of 700-1,400 metres in width. Since female *P. zebra* are similar in colour to *P.* 'gold zebra' which is also found at Nkhata Bay, we only sampled males of this species, which are easily identified at this site. Our analysis yielded F_{ST} values of 0.007-0.016, very small, but statistically significant. The number of migrants between sites was estimated to range from 6-8 individuals per generation (van Oppen *et al*. 1997). This showed that there is very little movement of mbuna across sandy bays- even very small ones. Subsequent studies from Kocher's lab (and collaborators) have broadly confirmed the pattern from mbuna of other genera from the southern part of the lake (Arnegard *et al*. 1999; Danley *et al*. 2000; Markert *et al*. 1999).

Case Study II: Population structure in pelagic cichlids

The ODA/SADC Pelagic Fish Resources Project (Menz 1995) estimated Lake Malawi's offshore pelagic fish stock at 168,000 tonnes, of which around 88% is comprised of cichlids (Menz *et al*.1995). The maximum sustainable yield was estimated at around 30,000 tonnes per annum (Thompson 1995). With virtually no fishing presently undertaken offshore, important tasks remaining were to estimate the extent to which pelagic stocks could be exploited in inshore areas, and to estimate the extent to which exploitation in a limited geographical area might run the risk of exterminating local stocks. We addressed these questions through molecular stock structure analysis, during the DFID Ncheni Project (Turner *et al*. 2000). We used six microsatellite loci to screen 5 populations (479 individuals) of *Diplotaxodon limnothrissa*, a surface pelagic species also found inhabiting inshore waters, 3 populations (234 individuals) of *Diplotaxodon macrops*, more benthic species found near the bottom on deep shelf areas and 3 populations (234 individuals) of *Diplotaxodon* 'offshore', a deep-water pelagic species. The status of the latter 2 forms was then uncertain, since they are very difficult to distinguish in the field, and might have proved to be populations of the same species. This was later resolved when we discovered that ripe males of *D.* 'offshore' had different breeding colours from *D. macrops*. We had initially intended to look at population structure in *Rhamphochromis longiceps*, but we later decided that our samples (which were not individually labelled) comprised a mixture of *R. longiceps* and R. *ferox*. Consequently, we did not analyse these samples.

No evidence of linkage disequilibrium was found between any of the six loci, confirming that they can be considered as independent genetic markers. Levels of genetic variability were remarkably consistent among the three. Multilocus estimates of genetic differences (F_{ST}) indicated that there was no substantial genetic sub-structuring within the populations of any of the three *Diplotaxodon* species examined (Table 2).

Table 2. F_{ST} (genetic differentiation) values, at 6 microsatellite loci and over all loci combined (*P* = probability of overall F_{ST} not > 0), among samples of three *Diplotaxodon* species**.**

Locus	Pzeb1	Pzeb2	Pzeb3	Pzeb4	Unh130	Unh154	**Overall**	***P***
Species								
D. limnothrissa	0.0007	0.0014	0.0018	0.0012	<0.0001	0.0022	**0.0012**	**0.017**
D. macrops	0.0015	<0.0001	<0.0001	0.0081	<0.0001	<0.0001	**0.0005**	**0.261**
D. "offshore"	<0.0001	0.0005	0.0079	0.0000	<0.0001	0.0017	**0.0003**	**0.291**

The values for *Diplotaxodon limnothrissa* were statistically significant, but although sampled over a range of around 460 km, F_{ST} values were about the same as those found for mbuna populations over distances of 1 kilometre (van Oppen *et al*. 1997). Examination of all statistical differences between pairs of populations showed only a single significant difference (Exact test), after Bonferroni correction of probabilities for multiple tests: between the samples taken off the Livingstone Mountains of Tanzania and one of the samples from the SE Arm of the Malawian sector. These populations were far apart geographically, and it is not surprising that there might be a little 'isolation by distance'. In other words, although all the populations are probably exchanging lots of migrants, genes take a long time to exchange between populations at the far extremes of the range. These populations are clearly exchanging hundreds, if not thousands of migrants per generation. Samples from Cape Maclear and off the Livingstone mountains were not genetically different, nor were samples from the SE Arm and Chilumba. Likewise, for *D. macrops* and *D.* 'offshore', all of the different populations of the same species were so similar, the non-significant F_{ST} indicates that they could be no more genetically differentiated than two samples taken from the same place. The *D. macrops* populations were from Salima and the SE Arm, while the *D.* 'offshore' populations were sampled hundreds of kilometres apart, at Karonga and Nkhata Bay. Included in these analyses were comparisons between inshore and offshore samples from the same geographic region: at Chilumba and SE Arm/Cape Maclear for *D. limnothrissa*, in the SE Arm for *D. macrops* and off Karonga for *D.* 'offshore'. In no case did we find significant genetic differentiation, showing that samples taken inshore are part of the same populations as found further offshore in the same region. The implications of this study for the evolution of these fishes were presented by Shaw *et al*. (2000).

The minimal population structure we found indicates that these three species are not likely to need management as independent stocks in different parts of the lake. Artisanal or bottom trawl catches of these species are very likely exploiting the same stocks that are found in the offshore pelagic or deep-water zones. Indeed, Malawian, Tanzanian and Mozambican fishers may be exploiting the same stocks. We found clear differentiation between the stocks of *D. macrops* and *D.* 'offshore', which is consistent with our view that they are different species. *Diplotaxodon macrops* is caught in reasonable numbers by deep demersal trawls, and before they were realised to be different species, it had been hoped that exploitation of this population might provide a 'backdoor' route to exploiting the deep-water pelagic stock of *D.* 'offshore'. The standing biomass of this stock was estimated at around 33,000 tonnes (Menz *et al*. 1995). Comprising 19% of the pelagic biomass, it might be expected to yield around 6,000 tonnes per annum, and it is scarcely exploited. New ways must be tried to get at this stock.

Case Study III: Are colour forms of mbuna really species?

An important application of molecular stock structure study lies in the definition of species- the most commonly used 'unit of conservation'. Population structure analysis need not only be applied to populations from different locations, but can also be used to test whether two forms co-occurring at a single locality are interbreeding, and therefore morphs of the same species, or are not interbreeding and thus are different species. Critically, such studies need to be carried out on samples taken from exactly the same place, otherwise there can be confusion of the effects of restricted migration.

The haplochromine cichlids of Lake Malawi share a peculiarity with those of Lake Victoria. It is common to find two or more completely different coloured kinds of males in the same place, yet these colour forms show only very subtle differences in body proportions or other characteristics. The same holds for the chambo species *Oreochromis karongae* and *O. squamipinnis*. Although this tends to be taken for granted by people who work on Lakes Malawi and Victoria, it is actually an extremely unusual phenomenon. Pioneering researchers, such as Fryer (1959) considered that these colour forms were morphs of the same species, but with the advent of SCUBA equipment, later studies by Holzberg (1972) and Ribbink *et al*. (1983) showed that subtle differences in habitat preferences and behaviour were correlated with colour differences, suggesting that these forms were indeed different species.

The first studies to test genetic differentiation between sympatric (co-occurring at the same site) species used allozyme electrophoresis to investigate three forms of *Petrotilapia* spp. at Monkey Bay (McKaye *et al*. 1982) and four forms of *Pseudotropheus zebra* at Nkhata Bay (McKaye *et al*. 1984). All of the *Petrotilapia* were found to be genetically differentiated, and they were later described as new species (Marsh 1983). The *P. zebra* colour forms fell into two species groups, the blue and black striped (BB) and the orange blotch (OB) forms were genetically indistinguishable, and thus considered to be one species, while the plain blue (B) and the plain white (W) forms were considered to be a second genetically distinct species, later named *Pseudotropheus callainos* (Stauffer & Hert 1992).

We employed microsatellites to test for differences among three putative species of the *P. zebra* complex (*P. zebra, P. callainos, P.* 'gold zebra') and six of the *P. tropheops* complex ('olive', 'mauve', 'band', 'rust', 'black' and 'deep') at Nkhata Bay. In two of these comparison, *P.* 'tropheops band' v *P.* 'tropheops rust' and *P. zebra* v *P.* 'gold zebra', the females were so similar in appearance that we could not trust ourselves to identify them reliably, and we had to confine our sampling to sexually mature males in breeding colours. All nine forms showed significant genetic differentiation (van Oppen *et al*. 1998).

All three studies have consistently demonstrated that colour forms of mbuna found in the same location tend to be different species. The exception lies in the BB/OB and B/W forms of the *P. zebra* complex. These colour forms seem to represent within-species polymorphisms. It is striking that the rarer colour form (OB and W) are mostly found in females- males of these forms are extremely rare are around 100 times less abundant than females. So, the pattern seems to be one common male colour form at a site = one species.

Other applications to conservation biology

Molecular methods can also be used in the study of the genetic variability of populations that have undergone a drop in density. Sometimes, when population size is dramatically reduced, there can be a sharp loss in genetic variation, which can persist even after numbers have increased. This has the potential to limit the population's potential to persist in the long run, as there may be a lack of genetic variants that can cope with novel environmental stresses. In the most extreme cases, the population can become inbred, meaning that individuals can end up with 2 copies of harmful recessive genes, the effects of which are normally masked. This can lead to populations declining into extinction. In such circumstances, transplantation of individuals from other populations might be needed to restore variability. Loss of genetic diversity can often be a problem in captive-bred stocks, and can lead to changes in stock management practises.

Non-molecular approaches to assessing population structure

Tagging

The most obvious way to study fish movements is to catch fish, mark or tag them in some way and then wait until they are recaptured and see where they turn up. Lowe (1952) tagged 6,237 chambo in the SE Arm, with the intention of using mark and recapture data to determine growth rates. She recovered 2 fish. A tagging experiment with utaka around Likoma was carried out in the 1980s, but with little apparent success (Jennings, pers. comm.). There are several reasons why tagging is unlikely to prove effective with most Lake Malawi fishes.

First of all, the fisheries are based on catching very large numbers of very small fish. In the early 1990s, the estimate annual catch of *Lethrinops* 'pink head' from Lake Malombe was 850,000,000 fish (Turner 1996). The total population of *Diplotaxodon limnothrissa* in Lake Malawi was estimated at around 1,450,000,000 fish (Turner 1996). With such huge populations, an immense number would need to be tagged and a vast number of captured fishes examined for tags to have a hope of finding any tagged and released fish at all.

For most tagging studies, fishery biologists depend on fishermen to notice tags and return them, usually to claim a reward. This is likely to be very difficult in a situation such as pertains around Lake Malawi, where thousands of illiterate fishermen are scattered around hundreds of separate fishing villages. Perhaps radio announcements might be the only way to contact them.

The most severe problem lies in studies of the cichlid fishes, which make up by far the most significant part of the lake's catch by weight and value. Cichlids have closed swimbladders. When brought to the surface from deep water, the gas in the bladder doubles in volume for every 10 metres ascended. Fish with open swimbladders can expel excess gas via a duct to the gut, but cichlids have to rely on much slower physiological processes. In a series of experiments, Ribbink and co-workers demonstrated that mbuna required many hours to adjust to modest depth changes (summarised in Ribbink *et al*. 1983). In my own experience, few mbuna or chambo can survive being brought directly to the surface from depths in excess of 10 metres. It has been suggested that pelagic cichlids such as the 'big-eye' species of *Diplotaxodon* migrate from great depths to the surface at night (Thompson *et al*. 1995), which might indicate special adaptations to rapid pressure changes. However, in April 2001, I conducted a pilot study to see if it would be possible to collect live *Diplotaxodon* and *Rhamphochromis* from chilimira catches at Nkhata Bay. Survival of *Diplotaxodon* was zero out of more than 50 individuals, including some of the big-eye species. It seems highly unlikely that any cichlids collected by normal fishing methods, other than a few seined from shallow shores or very close to the surface, could possibly survive capture and tagging.

Thus, it seems that for more species, tagging studies can be ruled out as a practical method for the study of stock structure in Lake Malawi.

Parasite studies
Several studies of marine fish migrations have been able to show that populations of fish do not intermingle because they have distinct populations of *parasites,* which could be transmitted, were they ever in close contact. Equally, knowledge of the life histories of particular parasites may indicate that fish must have been infected in a different place to where they have presently been collected, showing that they have spent time at the site where the infective stages of the parasite can be found. The use of parasites as 'biological tags' is reviewed by MacKenzie & Abaunza (1998). Unfortunately, almost nothing is known of the taxonomy or life histories of fish parasites in Lake Malawi. It seems likely that many cichlid species will probably prove to be so closely related and recently diverged from one another that they have not had time to evolve different parasites.

Otolith microchemistry
Another recently developed hi-tech method is the analysis of chemical composition of hard tissues, such as otoliths. The method has been useful in distinguishing among fish which spend part of the time in the sea from those living entirely in freshwater (Limburg *et al*. 1998), distinguishing those spending all of their time in the sea from those spending part of the time in freshwater (Tsukamoto *et al*. 1998) and in distinguishing marine fish which had originated from different estuaries (Milton *et al*. 1997) or freshwater streams (Kennedy *et al*. 2000). It is doubtful if the method has any use in distinguishing among fishes from different parts of the same lake, although it might be worth trying out the method on river-spawning fishes, such as mpasa and sanjika.

Species identification
Given the limited amount of information on species distributions and catch compositions, much can still be learned from simply recording the species composition of fishery catches. This can give a useful rough estimate of gear interactions within a restricted geographical locality, but cannot really delimit the geographic extent of stocks.

Conclusion
Molecular studies of stock structure are expensive, and require considerable technical expertise and sophisticated equipment. Is the effort worthwhile? I suggest that it is.

Most management decisions concerning Lake Malawi fisheries are made on the basis of 'rules of thumb', rather than hard quantitative evidence. In truth, nobody really knows whether most stocks are over- or under-exploited. Beach seines are regarded as destructive on the basis of little hard evidence (Sarch & Allison 2000), based on inspection of species and sizes caught, with little knowledge of the real levels of juvenile mortality and its link to population sizes of exploited species. Closed seasons are not closely linked to any quantitative assessment of breeding seasonality, or any detailed knowledge of the effects of recruitment on exploitation during the breeding season (FAO 1993). Trawl fishery licences are allocated on the basis of crude biomass estimates from trawl surveys, with possibly unjustified assumptions made on the relationship between trawl CPUE and biomass and between biomass and MSY (FAO 1976).

None of these statements should be interpreted as criticism of the fisheries institutions of the riparian countries. The size and complexity of the lake, its fauna and its fisheries render attempts at data collection and interpretation a daunting task. But what I am suggesting is that it is important to prioritise use of research resources, particularly manpower. Molecular studies of stock structure can be carried out with the assistance of externally funded projects and external expertise, with little cost in staff time or resources from local institutions. A persistent problem with short-term externally-funded and largely externally-implemented projects is that of ensuring that the work continues after the end of the funding. Fortunately, this is not necessary with work on molecular stock structure. Occasionally, it might be useful to repeat such a study to look for temporal changes in migration patterns resulting from major changes in environmental conditions or exploitation regimes. However, in general, the work need only be done once in order to generate useful rules of thumb, which can inform management recommendations in perpetuity.

Acknowledgements
The research on which this paper was based was funded by the UK Department for International Development (DFID) Environment Research Programme and by the Natural Environment Research Council (NERC), and carried out with the co-operation of the Dept. of Fisheries, Malawi, TAFIRI and the University of Malawi.

References

Arnegard, M. E., Markert, J.A., Danley, P.D., Stauffer, J.R., Ambali, A.J. & Kocher, T.D. 1999. Population structure and colour variation of the cichlid fish *Labeotropheus fuelleborni* Ahl along a recently formed archipelago of rocky habitat patches in southern Lake Malawi. *Proc. Roy. Soc. Lond. B* 266: 119-130.

Avise, J.C. 1994. *Molecular Markers, Natural History and Evolution.* Chapman & Hall, NY.

Carvalho, G.R. & Hauser, L. 1998. Advances in the molecular analysis of fish population structure. *Ital. J. Zool.* 65S, 21-33.

Danley, P.D., Markert, J.A., Arnegard, M.E. & Kocher, T.D. 2000. Divergence with gene flow in the rock-dwelling cichlids of Lake Malawi. *Evolution* 54, 1725-1737.

FAO. 1976. Promotion of integrated fishery development, Malawi. FAO, Rome.

FAO. 1993. Fisheries management in south-east Lake Malawi, the Upper Shire River and Lake Malombe. *CIFA Tech. Paper 21,* Rome.

Fryer, G. 1959. The trophic relationships and ecology of some littoral communities of Lake Nyasa with especial reference to the fishes and a discussion of the evolution of a group of rock-frequenting cichlidae. *Proc. Zool. Soc. London.* 132, 153-281.

Holzberg, S. 1978. A field and laboratory study of the behaviour and ecology of *Pseudotropheus zebra* (Boulenger), and endemic cichlid of Lake Malawi (Pisces: Cichlidae). *Zool. Syst. Evol.- Forsch*. 16, 171-187.

Kennedy, B. P., Blum, J.D., Folt, C.L. & Nislow, K.H. 2000. Using natural strontium signatures as fish markers: methodology and application. *Can. J. Fish. Aq. Sci.* 57, 2280-2292.

Kocher, T.D., Lee, W.J., Sobolewska, H., Penman, D. & McAndrew, B. 1998. A genetic linkage map of a cichlid fish, the tilapia (*Oreochromis niloticus*). *Genetics* 148, 1225-1232.

International Human Genome Sequencing Consortium. 2001. Initial sequencing and analysis of the human genome. *Nature* 409, 860-921.

Jarne, P. & Lagoda, P.J.L. 1996. Microsatellites, from molecules to populations and back. *Trends Ecol. Evol.* 11, 424-429.

Lee, W.J. & Kocher, T.D. 1996. Microsatellite DNA markers for genetic mapping in *Oreochromis niloticus. J. Fish Biol.* 49, 169-171.

Limburg, K.E. 1998. Anomalous migrations of anadromous herrings revealed with natural chemical tracers. *Can. J. Fish. Aq. Sci.* 55, 431-437.

Lowe, R.H. 1952. *Report on the Tilapia and Other Fish and Fisheries of Lake Nyasa.* Colonial Office, Fishery Publications, London.

MacKenzie, K. & Abauza, P. 1998. Parasites as biological tags for stock discrimination of marine fish: a guide to procedures and methods. *Fisheries Research* 38, 45-56.

Majerus, M., Amos, W. & Hurst, G. 1994. *Evolution: the Four Billion Year War.* Longman, Halrow, England.

Markert, J.A., Arnegard, M.E., Danley, P.D. & Kocher, T.D. 1999. Biogeography and population genetics of the Lake Malawi cichlid *Melanochromis auratus*: habitat transience, philopatry and speciation. *Mol. Ecol.* 8, 1013-1026.

Marsh, A.C. 1983. A taxonomic study of the fish genus *Petrotilapia* (Pisces: Cichlidae) from Lake Malawi. *Bull. J.L.B. Smith Institute of Ichthyology*, 48: 1-14.

McKaye, K.R., Kocher, T., Reinthal, P. & Kornfield, I. 1982. A sympatric sibling species complex of *Petrotilapia* Trewavas from Lake Malawi analysed by enzyme electrophoresis (Pisces: Cichlidae). *Zool. J. Linn. Soc.* 76, 91-96.

McKaye, K.R., Kocher, T., Reinthal, P., Harrison, R. & Kornfield, I. 1984. Genetic evidence for allopatric and sympatric differentiation among colour morphs of Lake Malawi cichlid fish. *Evolution* 38, 215-219.

Menz, A. (ed.) *The Fishery Potential and Productivity of the Pelagic Zone of Lake Malawi/Niassa.* Natural Resources Institute, Chatham, UK.

Menz, A., Bulirani, A. & Goodwin, C.M. 1995. Acoustic estimates of fish biomass. Pp. 307-349 in Menz (ed.) *The Fishery Potential and Productivity of the Pelagic Zone of Lake Malawi/Niassa.* Natural Resources Institute, Chatham, UK.

Milton, D.A., Chenery, S.R., Farmer, M.J. & Blaber, S.J.M. 1997. Identifying the spawning estuaries of the tropical shad *Tenualosa toli*, using otolith microchemistry. *Mar. Ecol. Prog. Series* 153, 283-291.

Mueller, U.G. & Wolfenbarger, L.L. 1999. AFLP genotyping and fingerprinting. *Trends Ecol. Evol.* 14, 389-394.

Ribbink, A.J., Marsh, B.A., Marsh, A.C., Ribbink, A.C. & Sharp, B.J. 1983. A preliminary survey of the cichlid fishes of rocky habitats in Lake Malawi. *S. Afr. J. Zool.* 18, 149-310.

Sarch, M.T. & Allison, E.H. 2000. Fluctuating fisheries from Africa's inland waters: well adapted livelihoods, maladapted management. Proceedings of the 10th International Conference of the Institute of Fisheries Economics and Trade, Corvallis, Oregon. http://osu.orst.edu/dept/IIFET/2000/papers/sarch/pdf

Shaw, P.W., Turner, G.F., Idid, M.R., Robinson, R.L. & Carvalho, G.R. 2000. Genetic population structure indicates sympatric speciation of Lake Malawi pelagic cichlids. *Proc. Roy Soc. London B* 267, 2273-2280.

Slatkin, M. 1985. Rare alleles as indicators of gene flow. *Evolution* 39, 53-65.

Sparre, P., Ursin, E. & Venema, S.C. 1989. Introduction to tropical fish stock assessment. Part 1- Manual. *FAO Fisheries Technical Paper* 306/1.

Stauffer, J.R. & Hert, E. 1992. *Pseudotropheus callainos*, a new species of mbuna (Cichlidae), with analysis of changes associated with two intra-lacustrine transplantations in Lake Malawi, Africa. *Ichthyol. Explore. Freshwaters* 3, 253-264.

Sunnucks, P. 2000. Efficient genetic markers for population biology. *Trends Ecol. Evol.* 15, 199-203.

Thompson, A.B. 1995 Fisheries potential. Pp. 369-386 in Menz (ed.) *The Fishery Potential and Productivity of the Pelagic Zone of Lake Malawi/Niassa.* Natural Resources Institute, Chatham, UK.

Thompson, A.B., Allison, E.H. & Ngatunga, B.P. 1995. Spatial and temporal distribution of fish in pelagic waters. Pp. 279-307 in Menz (ed.) *The Fishery Potential and Productivity of the Pelagic Zone of Lake Malawi/Niassa.* Natural Resources Institute, Chatham, UK.

Tsukamoto, K., Nakai, I. & Tesch, W.V. 1998. Do all freshwater eels migrate? *Nature* 396, 635-636.

Turner, G.F., Carvalho, G.R., Robinson, R.L. & Shaw, P.W. 2000. *Biodiversity Conservation & Sustainable Utilisation of Pelagic Cichlid Fishes of Lake Malawi/Niassa/Nyasa.* Ncheni Project Final Report, University of Hull, UK

van Oppen, M.J.H., Turner, G.F., Rico, C., Deutsch, J.C., Ibrahim, K.M., Robinson, R.L. & Hewitt, G.M. 1997. Unusually fine-scale genetic structuring found in rapidly speciating Malawi cichlid fishes. *Proc. Roy. Soc. London B* 264, 1803-1812.

van Oppen, M.J.H., Turner, G.F., Rico, C., Robinson, R.L., Deutsch, J.C., Genner, M.J. & Hewitt, G.M. 1998. Assortative mating among rock-dwelling cichlid fishes supports high estimates of species richness from Lake Malawi. *Molecular Ecology* 7, 991-1001

Wright, S. 1951. The genetical structure of populations. *Ann. Eugen.* 15, 323-354.

Fisheries Development, Management, and the Role of Government

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Abstract
Studies conducted over the past decade have identified pelagic and deep demersal fish stocks in Lake Malawi capable of sustaining an annual yield in excess of 40,000 tonnes but only marginally exploited at present. In addition, there are underexploited stocks of small demersal cichlids in Lake Malawi in depths of less than 50m, and there are opportunities for increasing production from the existing artisanal fisheries of Lakes Malawi and Malombe by managing them better and by paying closer attention to the near-shore environment. From the standpoint of sustainable biological productivity there is no reason why annual production should not be doubled over current levels.

Translating biological potential into industrial output is not simply a matter of importing technologies and securing a source of investment capital. Development of the fishing industry will require at least as much attention to entrepreneurial development as to technological change. It is suggested that neither of the two smaller-scale categories of fishing business on Lakes Malawi and Malombe – artisanal and small-scale mechanised – function in the same way as enterprises of comparable scale in the fishing industries of developed nations. It will be necessary to break the barriers which currently limit the capacity of individual enterprises to expand, and prevent their graduation from one level to another. It will be necessary also to develop a vision for the industry which focuses on human resource development, foresees the creation of intermediate stages in business complexity so as to facilitate enterprise growth, and guides the acquisition and flow of information. The capture of information via short-term expatriate experts may be less efficient than the secondment of Malawian fishermen to overseas fishing industries and, under controlled conditions, the encouragement of joint ventures with other fishing nations. To date, Malawi's efforts in fisheries development appear clumsy and poorly researched when compared to the sophistication of scientific studies on the resource base.

Hitherto, the market has not been a constraint to fisheries development. Nationally and regionally the demand for fish exceeds the supply by a substantial margin, and, in keeping with Malawi's strength as a trading nation, the fish trade has proved vigorous and extremely adaptable. That does not mean that it could not be improved, needs no support, or might not become a constraint at higher levels of production. Ultimately, the strengthening of producer-trader linkages, the development of community-based organisations for business as well as management functions and the exploration of export markets might provide new points of departure for fisheries development.

Service provision has been a major issue in recent years. Experience gained since the early 1990s has shown that the withdrawal of government services to the fishing industry did little to stimulate entrepreneurial development but instead led to a discernible weakening of the sector, with negative economic and environmental consequences. World-wide, fishing industries tend to comprise a patchwork of private sector and state-led elements, and it is considered normal for governments to intervene in areas unattractive to the private sector and to use direct cash transfers and subsidies, both as instruments of development (fleet renewal, new technology) and management (decommissioning and buy-back). Although private sector participation in the fisheries ancillary trades must be retained as a development goal, the Government of Malawi is now faced with the need to rebuild and expand upon its former services network if the production opportunities so clearly identified are to be exploited within the foreseeable future.

The development of new mechanised and artisanal fisheries has important implications for management if it is to avoid a harmful accumulation of effort on hard-pressed traditional stocks. There are some signs that, despite the daunting size of the task ahead, Malawi is on the right course in implementing its co-management policy. But the handling of interactions between the anticipated future generations of mechanised and artisanal fisheries will require management skills of a higher order than those evident in recent years. The potential for increased economic rewards will be tempered by increasing risk as the complexity and catching power of the industry grows.

Introduction
Whoever wishes to understand the fishery sector in Malawi has to negotiate some fundamental anomalies and uncertainties. Lake Malawi is over-fished. It is also under-fished. Its fisheries are over-subscribed, and under-developed. It therefore needs both management and development, responsibility for which would until recently have been assigned without hesitation to the government. But in both of these fields the role of government is in a process of redefinition, and the lines dividing public and private responsibility have yet to be clearly drawn. This paper is a contribution to the public-private debate, and starts by proposing a framework for increasing production.

- The immediate productive potential of the fishing industry of Lakes Malawi and Malombe is defined by the following five factors:
- the extent and nature of the fish resources;
- the market for fish, both domestic and export, and the efficiency with which the fish trade is able to match landings with markets;
- the human resource base of the catching subsector, including skills in fishing and financial management, and the ability to retain and reinvest earnings;
- the availability and nature of ancillary industries and services, including boatbuilding, gear and equipment supply, ice, financial services and technical advisory support, and
- the effectiveness of fisheries management regimes, whether operated by the government, the industry itself, or jointly.

The following sections of this paper aim to take stock of the current position with regard to each of these factors, and to suggest what roles the government might properly assume in facilitating the realisation of production opportunities so clearly identified by recent resource assessments. It will be suggested that merely identifying underexploited resources and developing appropriate harvesting technologies will not be sufficient to ensure that the desired outcome is actually achieved. Instead, a conscious industrial development approach is required, with as much attention paid to assisting enterprise growth as to "transferring technology", as well as government's resumption of many of the industry support functions divested during the 1990s.

Resources and fisheries

Over the past decade a succession of scientific studies have brought about a quantum leap in our understanding of the abundance, biology and ecology of the fish stocks of the Lake Malawi system. Although some important gaps remain, it is now possible to speak with some confidence of the potential yields from currently unexploited fisheries, or of fisheries from which better management might lead to improved yields. Fish stocks in Lake Malawi that are currently unexploited or only marginally exploited are listed in Table 1.

Of the stocks identified above, some are already targeted to a limited extent by existing fishing operations. MALDECO harvests around 1,000 tonnes annually from the deep demersal stocks in the north of the South East Arm (Area C) and the South West Arm, as well as another 1,000 tonnes of pelagics, principally *Diplotaxodon* and *Rhamphochromis* spp. In addition, the artisanal fisheries take small quantities of *Rhamphochromis*, and variable – and sometimes very large – quantities of *Engrualicypris sardella*. Overall, Table 1 represents a biologically feasible increase in annual yield from Lake Malawi of around 40,000 tonnes.

Shallow water (<50m) stocks are substantially exploited by both artisanal and mechanised fisheries, and present a much more complex picture. Biomass estimates of shallow demersal stocks derived by Banda and Tómasson (1997) from trawl surveys in southern Lake Malawi were exceeded by the estimated annual catch by a factor of up to two. This may be an expression of very high productivity in the shallow fringes (<10m) not sampled by the research vessel, or of the pelagic or semi-pelagic component of the artisanal catch (under-represented in the assessment trawl catch) or a combination of the two. Nevertheless, despite the remaining uncertainties here, it may be said that:

- The artisanal fisheries focus on large demersal species and schooling semi-pelagic or pelagic species. Within the near-shore zone these fisheries are mostly very heavily exploited. There are however a few places (e.g. Sani) where the "traditional" artisanal fisheries could be expanded offshore if suitable boats were available.
- Small demersal shallow-water cichlids are not targeted by artisanal gears beyond the range of beach seines.
- Small demersal shallow-water cichlids *are* targeted by pair trawlers – which can catch them very efficiently – but this fishery is confined to the southern arms of Lake Malawi, and both effort and catches are low.

Taken together with Table 1, this list of observations may be translated into a set of distinct production opportunities, some of which (but not necessarily all) may be technically feasible and financially viable:

1. Development of a mechanised fishery for offshore pelagic species, probably by pelagic trawling. This has already been initiated by Maldeco but there is ample room for expansion.
2. Development of artisanal/small-scale mechanised fisheries for offshore pelagic species, probably targeting the high-value *Rhamphochromis* spp. and possibly based on longlines or gillnets. A small artisanal handline fishery for *Rhamphochromis* already exists in northern Lake Malawi.
3. Development of a mechanised (trawl) fishery for deep-water demersal stocks. This has been initiated by Maldeco, but again there is room for additional entrants.
4. Development of an artisanal/small-scale mechanised fishery for deep-water demersal stocks, probably by gillnetting. Small artisanal deep-water gillnet fisheries exist in Karonga and Tanzania.
5. Rehabilitation and technical development of the pair trawl fishery to target small demersal shallow-water cichlids in southern Lake Malawi. Further north the stocks would not appear to be adequate to sustain this fishery without damaging existing artisanal fisheries.
6. Development of an artisanal/small-scale mechanised fishery for small demersal shallow-water cichlids beyond the beach fringes.
7. Extension of the "traditional" artisanal fisheries further offshore in areas where suitable habitat and stocks exist.

8. Enhancement of the existing artisanal fisheries by improving management, drawing from a wide range of potential management measures including entry and effort limitation, closed or limited-fishery areas and prohibition or restriction of harmful gears.

Table 1. Biomass and sustainable yield estimates of marginally exploited stocks in Lake Malawi

Stock	Area	Author	Biomass	Yield as % of stock	Estimated sustainable yield
Demersal stocks					
Deep demersal (>50m)	South East Arm (C) 1994-96	Banda & Tómasson 1997	6,040	30	1,812
	South West Arm 1994-96		7,220	30	2,166
	Domira Bay to Chia Lagoon 1994-95	Banda& Tómasson 1996	6,865	30	2,060
	Chia to Nkhotakota 1994		850	30	255
	Nkhotakota to Dwangwa 1994		1,050	30	315
	Dwangwa to Sanga 1994		3,570	30	1,071
	Ngara to Lufira 1981	Tweddle 1981	1,588	45	715
	Total		27,183		8,394
Offshore pelagic stocks					
Diplotaxodon	Lake Malawi	Menz & Thompson 1995	119,700	19	22,700
Rhamphochromis			16,800	17	2,800
Copadichromis			8,700	16	1,400
Other cichlids			3,400	18	600
Engraulicypris			5,100	63	3,200
Opsaridium			1,300	23	300
Synodontis			13,400	17	2,300
	Total		168,400		33,300
				Total	41,694

Markets

Hitherto, the market has not been a primary constraint to fisheries development. Nationally and regionally the demand for fish exceeds the supply by a substantial margin, and the fish trade has proved vigorous and extremely adaptable. That does not mean that it could not be improved, needs no support, or might not become a constraint if fish production is significantly increased; but in Malawi the market must, for the present, be considered of secondary importance in conditioning the evolution of the sector.

The processing, distribution and ultimate retailing of fish within Malawi is mostly undertaken by a very large number of small-scale operators. Processing infrastructure is generally simple and requires little capital investment: it is frequently owned by members of the lakeshore fishing communities, and may be rented out to visiting trader/processors. Some distributors own a means of transport (bicycles, pickup trucks), but many rely on public transport. Four principal pricing points exist – the beach or landed price, a lakeshore wholesale price (usually for processed fish), an inland/urban wholesale price and the final retail or consumer price. Typically the consumer price is 2-4 times the beach price, with the major part of the margin and profit concentrated at the final retail stage. Although there is some degree of specialization into processors, wholesale distributors and retailers, the high profitability of retailing encourages many traders to engage in the entire cycle, each processing, transporting and retailing relatively tiny quantities of fish.

What is perhaps surprising, given that the fish trade is a well-established and profitable business with an annual marginal value of some US$25 millions, is that the scale of processing and trading enterprises remains so small. Only on rare occasions has any individual venture (outside Maldeco's distribution system) advanced beyond the level of the one-tonne pickup truck. The reasons for this are probably similar to those which limit the size of artisanal fishing businesses, a subject discussed below. It is a matter of debate whether large-scale fish processing/distribution enterprises would actually benefit the fishery sector – an increase in scale would lower unit distribution costs and might make it easier to improve product standards, but it would also cut into the widespread rural and urban employment opportunities afforded by this dynamic and highly accessible trade.

These statements about the fish trade are based on contemporary personal observation and quantitative studies dating from the late 1980s (e.g. Seymour 1988, 1989), but the author is not aware of recent research that might substantiate them. In view of the potential for increasing fish production from Lake Malawi, a high priority should be placed on investigations into the effective domestic and regional demand for fish products, consumer preferences and quality/price relationships, and the present and likely future impact of the September 2000 SADC trade agreement. Ultimately, the strengthening of producer-trader linkages, the development of community-based organizations for business as well as management functions (producer associations) and the exploration of export markets might provide new points of departure for fisheries development.

The fishermen

A much more important determinant of past fishery performance, and a strong indicator of development potential, is the human resource base of the catching subsector. In Malawi the fishing industry is usually – and rightly – divided into three levels of operation. These are: artisanal (mostly small-scale commercial "traditional" fisheries, with some subsistence fishing), small-scale mechanised (pair trawlers and small stern trawlers) and large-scale mechanised (MALDECO). The three have quite different human resource characteristics.

In 1999 the artisanal fisheries of Lakes Malawi and Malombe employed almost 40,000 fishermen, of which 21% were gear owners and the remainder crew (Weyl *et al*., 2000). Only a tiny proportion of the workforce has received any kind of formal training in fishing technology. From unsophisticated beginnings based on natural fibre gears and dugout canoes, the industry made substantial technical advances during the 1960s, when multifilament netting first became widely available, and the 1970s, when improved V-bottom planked boats became popular. During this period imported outboard motors were used in the more profitable – mostly chilimira – fisheries, and simple sail technology was copied from Mozambique in Likoma and Makanjira. For the past 25 years, however, very little in the way of new technology has been made available to the artisanal fishermen. Their poverty effectively isolates them from technical progress in other countries, exposure to which might otherwise be gained through travel, trade publications, exhibitions. One might have expected it to be the proper role of the Fisheries Department to keep the industry abreast of worldwide technical advances, but the fact is that the government was almost as impoverished as the fishermen, and overseas training for Fisheries Department officials focused much more on the biology and management of fish stocks than on the mechanics of catching them. Although shut off from the outside world and modern fishing materials, there is nothing to suggest that Malawi's artisanal fishermen are any less competent or inventive than those elsewhere. A great diversity of fishing techniques has evolved, including floating longlines, bottom-set monofilament longlines, towed gillnets, pair-trawling with dugouts, artificial reefs and a variety of light-attraction methods, all using various recombinations of the very limited range of vessels and fishing materials available. When interviewed, fishermen often express frustration at their backwardness, and eagerness to experiment with new materials, fishing technologies and fishing craft.

It is notable that within the artisanal fisheries, which produce an annual catch worth US$12-15 millions[1], hardly any fishermen have become wealthy, and the largest enterprises amount only to a few small fishing units and perhaps a pickup truck. There is more to this than poor catch rates resulting from overfishing – there is almost certainly a range of social and structural factors at play that contain the size of individual enterprises. The social and economic dynamics of fishing communities have not been studied in Malawi, but it is suggested that some of the following may be important:

- the extended family system, in which personal responsibility increases in proportion to personal wealth, and which operates against a background of poverty and increasing dependency resulting from HIV/AIDS;
- linked to the above, an inability on the part of artisanal fishermen to separate business finances from the household economy, leaving business capital exposed to the needs of the extended family;
- village-level social mechanisms that inhibit obvious personal success;
- an inheritance system that more or less guarantees the dissolution of a business on the death of its founder, preventing inter-generational transfer of successful businesses;
- the lack of rural banking services in lakeshore areas;
- high levels of violent crime that discourage cash-based business activity.

Artisanal fisheries have never evolved to the point at which individual enterprises could amass sufficient wealth or confidence to achieve technical development by themselves. By the same token, they have had little opportunity to learn or practice the fundamentals of financial management either. It is not therefore enough to provide new technologies and support services alone – until at least some artisanal fishing enterprises are assisted to break through the socio-economic barriers that prevent their growth, the vision of an upgraded offshore artisanal fishery will remain unfulfilled.

[1] 30,000 – 37,500 tonnes @ US$400/tonne.

The next level up – the pair trawl fishery – was essentially a development creation, financed initially under the FAO/UNDP Project for the Promotion of Integrated Fisheries Development (IFDP – 1972-76). The project identified demersal fish stocks in relatively shallow water that were not targeted by the artisanal fisheries, and designed appropriate vessels and gear to catch them. The project went on to support the construction of Mpwepwe boatyard and the training of boatbuilders and fishing crews, and put in place a government-operated loan scheme to finance the new fishery. At the time it was held up as an example of best practice in fisheries development – a conclusion supported by early successes and rapid loan repayment. With few exceptions the pair trawler owners are not "graduated" artisanal fishermen, but are mostly professionals, civil servants or businessmen who had sufficient personal credibility to attract the business loans (initially from government, later from the commercial banks) which these enterprises needed for start-up. The trawler owners do not themselves go fishing, but rely on hired crews which, although mostly paid on productivity-bonus systems, do not command the catch share normally paid to crew members. Some of these businesses have paralleled very closely to the tobacco estates established by civil servants and politicians in the 1970s and 1980s, suffering from an extractive management style, a lack of creativity, minimal maintenance of equipment, a poorly-motivated workforce and almost no reinvestment. They differ from enterprises of similar size in the developed world in that businessmen, not fishermen, run them. The only individuals within these businesses that have the personal wealth and confidence to travel and acquire new ideas are not possessed of the technical background to make use of them. In consequence today's pair trawl units are almost identical to the blueprint drawn by the IFDP: there has been no technical development within this fishery for almost thirty years.

The current demise of the pair trawl fleet is a remarkable illustration of adherence to the blueprint all of the pair trawlers were originally fitted with Sabb diesel engines, for which the commercial agent in Malawi was the Fisheries Department. When government withdrew from engine and spare part supply in the early 1990s, none of the 15 companies then in operation changed over to engines with local dealer support. As a result, only those with external connections were able to import spare parts and stay in business: now only 5 companies remain active and mean annual landings have fallen from 3,000 tonnes to less than 1,000 tonnes (Figure 1). This should be viewed against a background of healthy stocks, a strong market and potentially high profitability. Where companies have tried to innovate – for instance in occasional forays into stern trawling – these ventures have mostly failed for purely technical reasons. Sound technical advice to support these brave attempts has simply not been available.

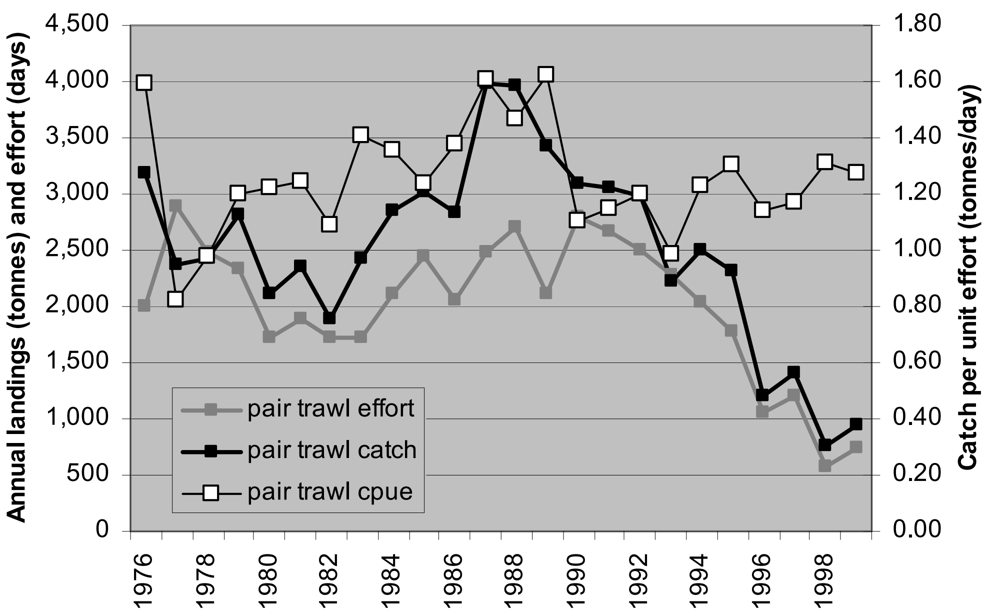

Figure 1. The decline of the pair trawl fishery, 1976-99

The large-scale mechanised fishery – represented in Malawi only by MALDECO – operates on an entirely different plane and is to a large extent independent of external support systems. MALDECO started out in the 1950s as Yiannakis Fisheries Ltd., a private company set up by Greek fishermen skilled in ring netting and trawling. The company invested in vessels, chilled and frozen storage, ice production and mechanical workshops, and trained a large locally recruited workforce. It was confiscated by government in the early 1970s and operated for many years as part of the parastatal Malawi Development Corporation. Although it continued to perform well in public ownership its profits were diverted to subsidise less viable enterprises, and necessary reinvestment in capital equipment was discontinued. After a brief period under the management of ADMARC, another parastatal, the company was acquired in 1989 by its present owner, the Press Corporation, now a public company listed on the Malawi Stock Exchange. In the 1990s the damage done by years of neglected investment was restored through a commercial loan financed (indirectly) by the Nordic Development Fund under the World Bank led Fisheries Development Project (1991-2000). The loan provided for the supply of a new 17m multi-purpose fishing vessel as well as a range of cold storage, ice-making and ancillary equipment. When the company last changed hands it was making a loss, but the impact of its new investments was quickly felt: a positive pre-tax profit was achieved in 1995 and modest growth has been sustained since then.

Perhaps more significantly, outside of the project-led programme of capital development and technical assistance, the company began to make technical advances on its own initiative. In 1993-94 it imported two *kapenta* rigs from Zimbabwe and adapted them to fish for *usipa* (*Engraulicypris sardella*), and in 2000 it acquired a pelagic trawler specifically to fish for *Diplotaxodon* and *Rhamphochromis*. Although small in themselves these are the first examples of a locally owned company importing technology from the international arena: they are the start of industry-led development.

Support industries and services

In order to function at all, fishing industries need a diverse range of subsidiary support trades and services, including boatbuilding and repair, gear supply, harbours and roads, ice and fuel. The current status of these support trades and services in Malawi leaves a great deal to be desired:

Fishing gear supply and technology development

Multifilament nylon netting of indifferent quality is manufactured in Malawi by the Blantyre Netting Company Ltd. (BNC) on rather old Japanese machines from twine spun on site from imported yarn. In recent years this has not been a very profitable business, and there has been some uncertainty as to whether BNC (whose main business is now the manufacture of polypropylene sacks) would continue it. BNC's nets and twines are distributed through a limited network of company outlets on the lakeshore, and a small range of products is also held by a number of retail shops. Annual domestic sales have fallen steadily from 80-100 tonnes in the 1980s to only 50 tonnes in 1999. This is a remarkable statistic given that the number of fishing craft has increased by 90% over the same period, although the volume of illegal imports of sheet netting from Tanzania and Mozambique is not known. Around half of BNC's annual sales are bulk twine from which fishermen braid their own nets: a sure measure of low returns from the artisanal fisheries. BNC also manufactures split-film polypropylene ropes, and imported polyethylene ropes are available from many retailers.

During the 1980s the Fisheries Department was a major retail distributor of BNC's products, with most District Fisheries Offices holding a wide range of stock purchased through the (government-owned) Mpwepwe Boatyard Treasury Fund. The legality of this business was questionable, since the gear was purchased from BNC on a surtax-free basis "for research purposes", enabling the Department to retail at the BNC wholesale price and still retain a substantial profit. Although this profit was used to the industry's benefit (by subsidising the price of fishing boats) there can be no doubt that this was a somewhat shady enterprise, and was viewed as a block to private sector participation in fishing gear retailing. Not surprisingly, the World Bank made the termination of government's involvement in gear sales a condition of the IDA Fisheries Development Project loan agreement signed in 1991. In practice, fishing gear retailing is a risky and unprofitable business, and only really works if the margins are quite high (say, 50%). BNC's recommended retail margin is 13%, and a pricing structure that has always been – to some extent – unofficially enforced (and is now reinforced by BNC's increased participation in the retail market) has always inhibited the fishing gear trade – that is why the Fisheries Department became involved in the first place.

Distribution problems aside, the range of fishing gear available to the industry must be considered extremely limited, and has barely changed in 30 years: almost no new materials have been provided, or new technologies extended. The fact that the artisanal fishery has expanded in this inefficient form poses another kind of development problem. If new materials – for instance, monofilament gill nets – were to be made instantly available at an affordable price, the impact on catching power would be dramatic, with potentially disastrous consequences for inshore stocks. Opening up Malawi's fisheries to international influences will have to be managed extremely carefully if it is not to create more problems than it solves.

Boatbuilding

Dugout canoes are constructed by village canoe-builders around the shores of Lake Malawi. Although the number of canoes operating in Lakes Malawi and Malombe has increased from 6,200 in 1985 to almost 9,000 in 1999, their size has progressively diminished with the increasing scarcity of large trees, and their mean lifespan has declined as the use of rot-prone exotic timbers has overtaken the use of indigenous hardwoods. Dugouts are inexpensive but wasteful of wood and, in their present form, unsuitable for work beyond the near-shore zone. In Botswana about half of the traditional *Pterocarpus* dugouts (*mokoros*) of the Okavango delta have been successfully replaced by GRP canoes of similar design. It took five prototypes before the GRP design was accepted by the Okavango fishermen, after which demand quickly outstripped supply. A first prototype GRP canoe has been tested in Malawi. It was not "right" but fishermen are willing to work with the designer to improve it. This may be a way at least to replicate the large canoes of former years and extend fishing range at the lower end of the technology/cost spectrum.

Village carpenters in Mangochi District have built flat-bottomed planked boats up to about 6m since at least the early 1970s. These craft are unsuitable for open-water fishing, and have a disturbing tendency to fall apart in rough seas. Altogether more than 3,000 planked boats are currently in use on Lakes Malawi and Malombe, of which less than one fifth are powered by small outboards. A significant (but unknown) number of these are strong V-bottom craft built by established boatyards at Salima and Mpwepwe.

Salima Boatyard was established by a British boatbuilder as a private business in the early 1970s. The yard produced V-bottom planked boats to 6m for the artisanal fisheries, and a few carvel-planked round bilge sailing vessels. When the owner left Malawi in 1977 the Fisheries Department acquired the yard (in the absence of a private buyer) and over the next decade expanded and improved its production. These boats became very popular with fishermen, but production levels declined during the late 1980s to 20-30 per year, and the yard had a long backlog of orders. Although the sale price did not truly reflect production costs it is notable that fishermen purchased these boats without the need for credit. Salima Boatyard was closed in 1993 in accordance with the conditions of the IDA loan that financed the Fisheries Development Project (1991-2000), but no attempt was made to privatise the yard. The skilled workforce was dismissed, and some months later the tools and equipment were auctioned to local joinery firms, while the Fisheries Department retained the site.

Several former Salima boatyard employees continue to make boats to an acceptable standard and to the popular designs developed by the Fisheries Department. However, they operate as small village businesses with very limited capital, and since they are unable to access other than locally available materials their products have a short working life.

Mpwepwe Boatyard, in Mangochi District, was a larger establishment whose main line of construction was a 7.5m V-bottom boat powered by a 30hp inboard diesel engine, the workhorse of the pair trawl fleet. By the late 1980s maintenance of the existing trawl fleet, plus vessels used in non-fishing roles, was estimated to require the construction of six new vessels annually, as well as running repairs. But output had fallen to a very low level – one or two boats per year – and the yard was in debt and in urgent need of rehabilitation and new equipment. The redevelopment of Mpwepwe was therefore included as a priority sub-component of the Fisheries Development Project.

At the time this project was prepared the prospects for privatisation appeared remote: it was therefore intended to rehabilitate the yard and to run it on lines as close to commercial as possible within the confines of government accounting and service limitations. Design studies were commissioned, and the boatyard staff reduced to a bare minimum in order to minimise losses during the reconstruction period. Stringency measures at this time included suspension of the import of marine engines and spare parts on which the pair trawlers depended. But by 1993 several entrepreneurs had expressed interest in the acquisition of the boatyard. Privatisation appeared for the first time to be a real possibility, and the rehabilitation was deferred - it was considered more appropriate to make available to the new owner, on a loan basis, those funds which had been reserved for redevelopment. The privatisation of Mpwepwe took almost six years, and was not completed until May 1999. The option selected by the Privatisation Commission was a management buy-out and the yard was sold to the Mpwepwe Boatyard Company Ltd., comprising of staff previously employed by the Fisheries Department. However, by the time the transfer of ownership took place the yard was little more than a shell, its new owners inexperienced in business and potentially crippled by inherited debts. ICEIDA made a small grant available to buy minor tools, but there was insufficient time to arrange the proposed subsidiary loan prior to project closedown. Even though the yard is now in private ownership the new company has no working capital, almost no stock of raw materials, and very possibly a large debt. It stands little prospect of growth – perhaps even survival – without swift external intervention.

The reduced availability of seaworthy boats to the artisanal fishery (and here it is necessary to distinguish between V-bottom boats built by the Salima and Mpwepwe yards and inferior flat-bottomed craft made by untrained boatbuilders) has contributed to the concentration of fishing effort in the inshore zone, to increasing poverty in the artisanal fishing communities and ultimately to the resource management problems which the Fisheries Department now has to face. The mechanised fishery has been more visibly affected. The pair trawl fleet was in a poor state when the project started, but after a decade without replacement engines or spare parts only 5 of the 15 units operational in 1990 remain in business today.

Ice supply

During the 1980s flake ice was supplied to fish traders by the Fisheries Department, from ice plants at Namiasi, Salima and Nkhotakota, and by MALDECO. The Namiasi plant became unserviceable in the late 1980s and was not replaced because a private flake-ice venture had opened in Mangochi. In 1993 the Salima fish handling depot (which provided fish washing and weighing facilities in addition to ice) was closed in accordance with the IDA loan conditions, and the machinery auctioned and later removed by the new owner to Blantyre. The small Fisheries Department ice plant at Nkhotakota was also taken out of service at this time.

The current situation is that private plants at MALDECO and Mangochi continue to function, and a new enterprise produces small quantities of block ice at Salima. Otherwise, traders from Blantyre and Lilongwe purchase block ice from the Cold Storage Company Ltd. depots in those cities. A substantial – but unquantified – unsatisfied demand for ice is believed to exist.

Harbours and roads

Harbours are not used or currently needed in the artisanal fisheries, which use beach-landing boats and canoes. Similarly, beach access roads are not of great importance where the main means of transport between the beach and the nearest public transport route is the bicycle. Some major beach landings do attract vehicles, however, and anecdotal evidence suggests that landings are becoming increasingly aggregated, i.e. that increasing volumes of fish are being landed at a diminishing number of sites. This would point towards the need for road construction at carefully selected locations. The EU-funded Central Lake Fisheries Development Project (1980-85) constructed a number of beach access roads in Salima and Dedza Districts – these had the strongly beneficial effect of concentrating landings, processing and trading activity.

Harbours are a great advantage to the pair trawl fleet, although with some ingenuity the boats may be operated from a simple beach site. The principal advantage of landing onto a jetty is that the catch may be discharged quickly, an important factor in reducing spoilage. The other main function of a harbour – shelter from rough lake conditions – is in practice very difficult to achieve in Malawi. There are few natural harbours, and medium-term variations in lake level make investments in traditional permanent harbour facilities extremely risky. The Fisheries Department constructed trawler landings with jetties in Lifuwu, Salima; Malembo, in the South West Arm, and Namiasi, in the South East Arm. Salima is no longer considered an inshore trawling ground, and the other two landings are in a very poor condition. Maldeco Fisheries Ltd. has constructed its own jetty and onshore infrastructure in Mangochi District.

Development and how to achieve it

Fisheries development is the growth and technical advancement of the fishery sector. Initially this process aims towards a condition in which all known fishing opportunities are fully exploited and the contribution of the fishing industry to the national economy maximised. Subsequent development tends towards greater catching efficiency and increased value-added through processing. In the more advanced fishing nations fisheries development is led by the industry. Even in these countries the government usually has a development role, and will undertake costly technological research and provide other services to the industry where these are not attractive to the private sector (e.g. the construction of harbours). In developing countries the role of the state tends to be more prominent, and has often included the introduction of new capture and catch handling technologies and the mechanisation of artisanal fisheries. As we have seen, fisheries development in Malawi appears not to be occurring by itself, and this implies a major role for the government in bringing it about.

Where development is to be promoted by government and financed by external donors, the approach, nature and extent of development programmes will be heavily influenced by prevailing development styles, which are subject to periodic change. Development thinking during the 1970s and 1980s appears now to have been decidedly paternalistic, and tended to ignore indigenous knowledge and capacity and impose alien technologies that quite often failed. Currently, the development philosophy of many donors and international lending institutions draws heavily on the principles of market economics. The state is encouraged to provide a liberal and enabling policy environment, within which the private sector is expected to provide productivity and growth. In the productive sectors the role of the state is expected to shrink, shedding the more recognisable development functions and focusing on research, policy formulation and regulation. This new perspective quite properly accords more respect to the ability of the target population, but it also makes a rather risky assumption – that its members will react and respond to new economic opportunities in the same way as their entrepreneur counterparts in the developed capitalist economies.

There is ample evidence to show that in Malawi, and especially in the fisheries sector, this assumption is erroneous – the pendulum has swung too far. The private sector is small, and the relatively technology-intensive fishing industry and its associated trades have to compete with far more attractive business propositions, notably in crop trading and transport. There is no better demonstration of this than the enforced withdrawal of the Fisheries Department from the provision of industry support services in the early 1990s. Locally the disastrous results of this intervention are well known, and are documented in the Fisheries Development Project Implementation Completion Report (World Bank, 2000). But the government is now left in a quandary – should it go back to begin rebuilding the services that were dismantled, or should it be looking for some alternative means of promoting fisheries development?

It is worth considering how the developed nations deal with the question of state support to fishing industries. It might be expected that, if it is in some sense inappropriate for the Government of Malawi to provide fishery services, then they must be entirely absent from those states with large, modern fishing fleets and advanced economies. But this is not the case. In almost all developed fishing nations the government invests in fishing harbours and associated infrastructure. In addition:

In the states of the European Union (EU), grants are available to individual businesses for new or experimental fishing ventures and for fish processing facilities. All European states waive duty and taxes on fuel sold to the fishing industry.

- In the United Kingdom, many local government authorities operate ice plants and supply fuel to fishing vessels. The central government operates a decommissioning grant scheme to buy out excess fishing capacity from the industry.
- The Republic of Ireland, which does not have an over-capacity problem, provides grants (of around 30%) towards the construction of new fishing craft. Here, central government operates a national network of ice plants, some of which are leased out to private operators. The government also provides grant support to exploratory fishing.
- In the United States federal support to fisheries is provided through nearly thirty different grant and loan schemes providing for fleet renewal, fish processing, research and management (including buy-back and decommissioning). Many other regional and state-level support mechanisms complement the federal services.

Malawi has been the subject of an experiment in economic purism that is not matched by practice in the outside world. Elsewhere, fishing industries tend to comprise a patchwork of private sector and state-led elements, and it is considered normal for governments to intervene in areas unattractive to the private sector and to use direct cash transfers and subsidies, both as instruments of development (fleet renewal, new technology) and management (decommissioning and buy-back). Given the small size of Malawi's private sector and the dominance of trade as a business activity, it would appear that the entry of entrepreneurs into fisheries ancillary trades will be extremely slow. The government is now faced, therefore, with the need to rebuild and expand upon its former services network if the production opportunities so clearly identified are to be exploited within the foreseeable future. This process of reconstruction may be a painful one, but it will afford the opportunity to plan a development strategy with more thoroughness than has previously been the case. It is suggested that the strategy should be based on three essential themes – technology development, industrial development and fishery services:

Technology development

Of the eight fishing opportunities listed in the second part of this paper, three require the development and evaluation of new technologies (artisanal fisheries for small demersal cichlids, both deep and shallow, and artisanal fisheries for offshore pelagics) and two require the improvement of fishing methods already in use (pair trawling, pelagic trawling). Tasks of this kind have always been seen as a proper function of government, and it is to be expected that the Fisheries Department would commission the necessary work through an externally financed technical assistance programme.

Industrial development

This term is used in order to encourage a perception of the fishing industry as something much more than a collection of individuals who fish for a living, or technologies that impact on resources. It will be necessary to learn much more than we now know about the workforce, about financial and information flows and about business strategies and how they may be supported to encourage sustained growth. Three targets for action are:

- Breaking the barriers to growth. The first requirement here is to clarify through appropriate studies exactly what are the constraints to enterprise growth, particularly in the artisanal fisheries. If, as has been suggested here, they are linked to an inability to isolate business finances from the demands of the extended family, then a carefully administered savings and loan scheme might provide a way forward. Whatever the determined constraint or proposed solution, it should not be expected that more than a minority will be ready or able to make the necessary changes in the short term. For some purposes it may be necessary to work selectively with the most progressive elements of fishing communities, however much this may go against egalitarian principles.

- Improving the structure of the industry. The most expensive artisanal fishing unit – an outboard-powered *chilimira* unit – requires a capital outlay of around US$5,000. A pair trawl unit, plus second-hand pickup truck and ancillary equipment, costs US$45-50,000. A hypothetical large-scale fishing venture, based on a single 17m trawler plus necessary onshore infrastructure, would require an investment of US$1 million upwards. The gaps between these levels of investment (an order of magnitude or more) are so large that no individual can aspire to the level above without massive outside assistance. When exploring new technologies to harvest underexploited resources in Lake Malawi, thought should be given to creating business niches at scales intermediate to the existing three levels, so as to make graduation from one level to the next easier to achieve. For the same reason, it is also essential to reverse the recent decline in the pair trawl fishery.

- Management of information. It is necessary to promote an inflow of information on fishing and fish handling technology from international sources, and to ensure that such information is (a) delivered effectively to the fishing industry, and (b) is matched by the availability of materials and services where it results in local demand. Although gear technologists may be recruited through a project-type technical assistance programme, the best source of expertise is successful fishermen from other countries. These are both difficult and expensive to recruit, for obvious reasons. Three different routes to linking Malawian with successful foreign fishermen might be feasible: (a) creating an advisory unit staffed by volunteers who are recently retired and carefully selected fishermen; (b) seconding small numbers of Malawian fishermen to appropriate fishing businesses overseas, and (c) – although this is not without risk – establishing one or more joint venture fishing operations.

Fishery services

The following service and ancillary trades are legitimate targets for government support or direct intervention, remembering always that private sector participation in these activities will be retained as a development goal:

- Fishing gear supply. BNC should not be exposed to competition from government, but it may be useful for the government to encourage BNC or another supplier (by underwriting the commercial risk involved) to import technically desirable but non-traditional fishing materials. Renewed investigation of price structures might result in recommendations that would increase the attractiveness of fishing gear retailing and enable BNC to focus on production/import.

- Boatbuilding. Every effort should be made to support the Mpwepwe Boatyard. But boatbuilding capacity needs to expand faster than Mpwepwe will be able to, even under the most favourable circumstances. Development options could include a design development project, pump-priming operations to support the construction of steel boats by existing general fabrication companies, an Okavango-style GRP canoe experiment, and/or another government boatyard in the Central or Northern Region.

- Ice supply. It is highly desirable to increase the availability of ice through a planned network of ice production and sales points that takes into account possible changes in the distribution of fish landings. The network could be designed and installed by the Fisheries Department but ultimately handed over to District Assemblies, and the possibility of leasing ice-making facilities to entrepreneurs might be a useful first step towards ultimate privatisation. The availability of ice may be essential to achieving the full financial potential of proposed offshore fisheries.

- Fisheries infrastructure. Existing trawler landings at Malembo and Namiasi should be rebuilt, and the need for additional sites investigated. This might include public investment in onshore infrastructure to support mechanised deep-water or pelagic operations in the centre or north of Lake Malawi. The need for access roads to major artisanal landings should be investigated with a view to proposing construction projects to the Malawi Social Action Fund.

- Information and advisory services. The use of experienced volunteers has been discussed above. It may be feasible to reserve (development) funds to pay for specialist technical and financial advisory services as required by the growing mechanised fisheries – what must be avoided at all costs is the wasting of hard-won investment capital through bad technical decisions.

- Financial services. This is a sensitive but important subject that deserves focused attention. The government may wish to support or encourage particular types of fishing enterprise by making available grants or subsidised loans. This would not risk distorting Malawi's financial services sector, since the commercial banks have made no investments in the fishing industry for some years; even so, business development grants may be the preferred option. It should be noted that the high local currency interest rates for commercial borrowing look less frightening when viewed in hard currency terms: the identification of export markets for some part of the catch would make commercial borrowing an easier pill to swallow. The government may also wish to make grant funding available for management purposes, for instance for fishing gear buy-back schemes.

Development, management and risk

Fisheries management is the control of fishing industries – usually by governments or, in the case of shared stocks, by an agency representing more than one government – with the primary objective of ensuring that harvesting remains within biological limits and that the sustainability of the resource base is maintained. In practice, management objectives are usually more sophisticated than simply maximising sustainable yields, and it is normal to aim for maximum economic return, or maximum employment, or some combination of the two. Development and management tend to work in opposite directions, one promoting and the other restraining, but they are not opposites: a highly managed fishery is not the same as an undeveloped fishery. The most advanced fisheries combine a high level of technical development with an intensive management regime. Worldwide, as fish resources have come under increasing pressure and new fishing opportunities have become increasingly scarce, the emphasis has shifted from fisheries development to fisheries management. There is a simple principle here: the more developed the fishery, the higher the risk of resource collapse through over-exploitation and hence the more important the profile and effectiveness of fisheries management.

In Malawi there has been more than one instance of "managing by not developing", i.e. deferring development because it was feared that government capacity would be insufficient to manage the resulting increase in fishing power. This has applied for many years to the reluctance to exposing artisanal fishermen to monofilament gill nets, and it was also used as the rationale for postponing investments in the pair trawl fleet during the course of the recent IDA-funded Fisheries Development Project. Lack of management capacity may therefore be a further and unwanted brake on the pace of fisheries development.

Participatory Fisheries Management

To a large extent fish are resources of an open-access nature, regardless of management or resource tenure regime. This is due to the sometimes-extreme mobility of fish populations, so that resource tenure can never be pinned down to the extent possible with land or trees. Even in situations of closed entry, each fisherman is aware that personal restraint means personal disadvantage, however much it may benefit the fishery. For this reason fisheries are always difficult to manage, and successful management regimes are few. Malawi's approach to inshore artisanal fishery management is to maximise local ownership by transferring use rights and control of access to local fisheries institutions, on the basis of mutually agreed management plans. There are two reasons for believing this is the right course of action:

- It would appear that a majority of artisanal fishermen support the principle of co-management, even in areas where there has been limited extension and no training. The publicity emanating from the former Malawi-German Fisheries and Aquaculture (MAGFAD) Project (now the National Aquatic Resources Management Project) has caught the imaginations of fishing communities from all corners of Malawi, and demand for extension support now outstrips system capacity.

- Early indications are that inshore demersal stocks may be highly genetically differentiated (Duponchelle and Ribbink, 2000), suggesting that physical movements are restricted and that local-level fisheries management in Lake Malawi may have a biological validity previously unsuspected. Genetic research into demersal stocks is currently very limited, and further studies should be framed with the objective of identifying unit stocks for the main commercial species groups.

There is however an attendant risk, and that is that over the short to medium term a lack of tangible improvements in fishery production and incomes could bring about a reaction or backlash against the new management regime. Part of the problem is that in their eagerness to improve their lot (and the status of their fish resources), some communities are inflicting considerable hardship on themselves by the imposition of extremely strict management regimes. These communities are unlikely to be able to maintain their commitment to co-management unless their personal sacrifices result in a swift improvement in incomes – an outcome that, given the nature of environmental management, is unlikely. A second part of the problem, and one that compounds the first, is that until new entry into the fishery is controlled, expansion of fishing effort will simply mop up all the benefits that would have accrued as a result of active co-management.

There may be potential to take co-management into some constructive new directions. Until now it has been seen as a mechanism for implementing more or less traditional fishery management measures – mesh size restrictions, close seasons, etc. But it may be possible for the Fisheries Department to work with local fishery managers to develop a management vision that takes into account the wider impacts of fishing on near-shore ecology. Future management prescriptions might include closed or restricted-fishery areas, the phasing-out or reduction of harmful gears (possibly with grant support) and the closure of fisheries to new entrants.

New fisheries and the management of interactions

Development of the fishing industry will need to contend with two opposing forces. The opportunities for incremental production lie mostly offshore and in deeper waters. Yet the intrinsic productivity of Lake Malawi and the unit value of the catch both increase inshore, and in shallower waters. There will therefore be a general profit-driven pressure shorewards, which must be strongly resisted in order to avoid damage to inshore resources and the existing fisheries that depend upon them. This is most obvious in the case of large-scale mechanised fishing, where the towing power needed for deep demersal or pelagic trawling could be devastating in the shallows, but it applies equally to the artisanal fisheries. Larger boats and better gear are not desirable if they are used to fish the same stocks that are already under intense pressure.

The tendency to "creep inshore" has already been clearly seen in the pair trawl fishery, but although the legal mechanisms to control the deployment of the trawlers are entirely adequate the government's record in this regard is conspicuously weak. It is important to note that in this case one cannot count on harnessing the power of resource ownership to drive self-regulation by the mechanised fisheries – because the offence in question is poaching on *someone else's* territory. It is pointless blaming the fishermen for this, because no fisherman anywhere would pass up the chance of a little extra illicit income if the prospects for retribution are low. If the mechanised fisheries are to be developed, then law enforcement capacity must be developed simultaneously and as part of the same package.

References

Banda, M.C. & Tómasson, T. 1996. Survey of trawling grounds and demersal fish stocks in central Lake Malawi, from Domira Bay to Nkhata Bay in 1994 and 1995. Fisheries Bulletin No. 33. Fisheries Department, Lilongwe.

Banda, M.C. & Tómasson, T. 1997. Demersal fish stocks in southern Lake Malawi: stock assessment and exploitation. Fisheries Bulletin No. 35. Fisheries Department, Lilongwe.

Duponchelle, F. & Ribbink, A.J. (eds), 2000. Fish Ecology Report. Lake Malawi/Nyasa/Niassa Biodiversity Conservation Project. SADC/GEF.

Fisheries Department. 1999. Fish Stocks and Fisheries of Malawian Waters. Resource Report 1999. Fisheries Research Unit, Monkey Bay.

Government of Malawi. 2000. National Fisheries and Aquaculture Policy. Fisheries Department, Lilongwe.

Menz, A. & Thompson, A.B. 1995. Management Report of the UK/SADC Pelagic Fish Resource Assessment Project (Lake Malawi/Niassa).

Seymour, A.G. 1988. Likoma and Chizumulu Islands: production, processing and trading in the chilimira fishery. Fisheries Department/GTZ Rural Growth Centres Project.

Seymour, A.G. 1989. Women's fish processing and trading groups at Makanjira Rural Growth Centre: report on a short field visit 31/01/89 to 03/02/89. Working paper: Project for the Promotion of Women at the Rural Growth Centres. Office of the President and Cabinet/GTZ Malawi.

Tweddle, D. 1981. A preliminary assessment of the bottom-trawling potential of northern Lake Malawi. Luso: J. Sci. Technol. Malawi, 2(2):3-13.

Turner, G.F., Carvalho, G.R., Robinson, R.L. & Shaw, P.W. 2000. Ncheni Project: Final Report. Biodiversity Conservation and Sustainable Utilisation of Pelagic Cichlid Fishes of Lake Malawi/Niassa/Nyasa. DfID Project R6414, ERP 49.

Weyl, O.L.F., Banda, M., Sodzapanja, G., Mwenekibombwe, L.H., Mponda, O.C. & Namoto, W. 2000: Annual Frame Survey September 1999. Fisheries Bulletin No. 42, Department of Fisheries, Lilongwe.

World Bank. 2000. Implementation Completion Report on an IDA Credit in the Amount of USD 8 million to the Republic of Malawi for a Fisheries Development Project (Credit No. 22250-MAI), December 29, 2000. Report No.: 21560, Rural Development Operations, Eastern and Southern Africa, World Bank.

Seeking Sustainability: Strengthening Stakeholder Involvement in Fisheries Management in Malawi

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Abstract

In response to declining fish stocks in Malawi's waters, the government and a foreign aid donor collaborated to create a new fisheries management approach. A co-management regime was introduced in a pilot program at Lake Malombe at the southern tip of Lake Malawi. Fishers elected "beach village committees" (BVCs) to work with Fisheries Department (FD) staff in several phases of management. Reviews of the program to date are mixed. BVCs are working with the FD but have unmet fishing needs. Expansion of co-management to Lake Malawi has been initiated and is reported to be progressing slowly. The co-management approach is being more widely employed as greater demands are placed on scarce government resources everywhere and the value of stakeholder involvement is recognized. Using insights from international fisheries co-management programs, suggestions for improving the successes of Malawian co-management programs are offered.

Key words: Fisheries co-management; community-based natural resources management

Introduction

A significant reduction in near-shore catch in recent years in Malawi has led to the employment of a new approach to fisheries management. In this paper, based on the most recent available data, we describe the fishery and management historically and currently. In particular, we lay out the new management approach and assess its successes and failures to date as well as speculate on its future prospects for enhancing fishery management.

Malawi is a small country situated in Southeastern Africa along the African rift. At 119,000 km^2 it is similar in size to the State of Indiana. Most of the human population is concentrated in the southern and central regions (National Statistical Office 1999) where the best fishing and most suitable agricultural land are located. While 90 percent of Malawi's citizens are engaged in agriculture (primarily subsistence), fishing and associated activities are a significant part of the economy. Fish provide an estimated 70 percent of dietary animal protein (National website 2000, Bland and Donda 1995).

Historically, five water bodies have been the major producers of fish: the Shire River and Lakes Chiuta, Chilwa, Malombe, and Malawi (See Figure 1). By far the largest and biggest producer of fish is Lake Malawi, a rift valley lake which yields 40 to 60 percent of the country's annual catch (State of the Environment Report 1998). It is the third largest lake in Africa, taking up approximately 20 percent of the country's geographical area (27,000 km^2). Moreover, it is believed to be the world's most diverse lake in terms of fish species. It is estimated that as many as 1,000 species exist there, most of which have not yet been described (National Environmental Action Plan 1994). The majority of species are believed to fall within the cichlid family, others species are also significant in the fishery. The main target species of the fishery include chambo (*Oreochromis spp.*), mpasa (*Opsaridium microlepsis*), utaka (*Copadichromis*), usipa (*Engraulicyprius sardella*), and kampango (*Bagrus meridionalis*).

According to McCracken (1987), small scale fishing has a long history in Malawi. Traditional practices were left largely undisturbed by the British colonial regime that focused its attention on agriculture. Working from shore and dugout canoes, fishers used seine nets and gill nets to harvest a variety of species, including chambo, utaka, matemba and usipa. Recent estimates gauge total fishing industry participation at more than 230,000 persons (National website 2000, Bland and Donda 1994, Ferguson *et al.*1993), including boat owners, crew members, fish processors, and fish traders. The fisher component stands at approximately 40,000 (Bland and Donda 1995). Because of relatively easy entry to the fishery, as other fields of subsistence activity have been reduced or eliminated, and as the population has grown, a substantial increase in the number of participants has occurred (Bland and Donda 1995), causing greater fishing pressure, providing in part the impetus for a new management approach.

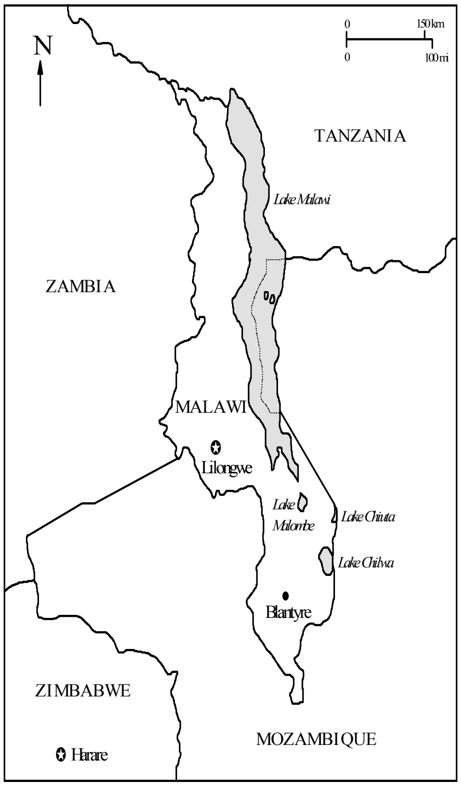

Figure 1. Malawi and its water bodies

Historical approach to fishing regulation

To understand the current situation a brief description of the historical context will be useful. According to Munthali (1994), territorial use rights, taboos and magic were employed to allocate and maintain the fisheries prior to the colonial era. Persons desiring to fish needed to secure permission from a chief or village headman to fish from a particular beach. Control by traditional authorities over the number of fishers provided protection against overfishing as well as greater equity in access in the view of Munthali (1994). Taboos making certain species inappropriate for human consumption in addition to taboos regarding inappropriate times to fish formed parts of an arrangement that protected the stocks (Munthali 1994). In addition to the reduced impact on the fishery due to the smaller populations dependent on fishing, traditional fishing methods (primarily handmade nets deployed either from shore or dugout canoes) are believed to have allowed a sustainable exploitation of the fisheries due to their relative inefficiency.

The British colonial regime of the late 1800s and early 1900s focused its attention on agriculture as the most important area of economic activity (primarily tea, coffee and tobacco estate farming), leaving fishing to the locals for the most part (McCracken 1987). Most fish were consumed within the fisher's household, but a significant indigenous commercial fishery serving local and regional indigenous markets was noted by Livingstone as early as 1861 (McCracken 1987).

European commercial competition was initiated in the 1930s. Fears that the use of European gear would dominate and significantly reduce the fishery through their higher efficiency caused the colonials to require non-Africans to obtain permits in the late 1930s. In 1949, a drought and fears of famine led to the imposition of a fish export ban and price controls. Nevertheless, by the 1950s, McCracken (1987) reports that a small number of Africans had developed substantial commercial fishing operations. Fishing rules adopted in 1974 and 1977 sought to limit fishing pressure (and raise funds) through the requirement of commercial licenses, gear restrictions and closed seasons (McCracken 1987). In the 1990s, a government parastatal organization, MALDECO, and one private company were engaged in commercial fishing, and 22 pair-trawl units engage in semi-commercial activity (Alimoso 1994, Derman *et al.*1994). The commercial and semi-commercial sectors bring in approximately ten percent of the catch (Bland and Donda 1995).

Over time the influences of western economic and religious ideologies have had their impacts on the "informal" institutions regulating fishing activities. The gradual reduction in peoples' adherence to traditional fishing taboos, and the marginalization of traditional leaders' authorities over fishing in some locations, have led to increases in fishing pressure. (Munthali 1994). When Malawi gained independence in 1964, the expatriate regulatory scheme remained in place, for many years staffed by expatriates. The gradual transition to a predominantly Malawian staff did not significantly change the Fisheries Department's regulatory approach in the short run.

Stock reductions lead to new approach to management

During the 20th Century Malawi's human population has increased tenfold to nearly 10 million persons (National Statistical Office 1999). At the same time, estate holdings, where export crops such as tobacco and tea are produced, have grown to cover ten percent of Malawi's total land area (roughly one million ha), occupying some of the country's best agricultural land (Eschweiler 1993). The average subsistence farmer's plot has shrunk below one hectare, a size considered insufficient to fulfil a family's needs (National Population Plan 1993). As a result, more and more farmers have resorted to fishing for supplementary income (Bland and Donda 1994, Derman 1995, Ferguson *et al.* 1993). The 1998 State of the Environment Report cites a 32 percent increase from 1983 to 1988. In light of the extreme poverty of many persons who depend on fishing, a potential strategy of limiting access through requiring licenses and limiting their number, has been considered and rejected (Bland and Donda 1995).

As the number of persons fishing has risen, pressure on fish stocks has caused dramatic reductions in certain key species, giving rise to concerns about the ability of near-shore fisheries to continue to produce an adequate yield for human dietary purposes as well as concerns about conserving biodiversity. For example, one of the most important catch targets in Lake Malombe, the chambo, has nearly disappeared from that lake, and elsewhere stocks have dropped as well. A 1995 report shows Lake Malombe's chambo catch dropping from slightly over 4,000 tons in 1976 to about 100 tons in 1994 (Bland and Donda 1995). Catch data indicate that the national chambo catch has decreased from 17,000 tons in 1984 to 4,000 tons in 1996 (State of the Environment Report 1998). While substitution of other species is occurring (State of Environment Report 1998), the data indicate that a high of 88,500 tons of overall catch in 1987 has fallen and remains around 70,000 tons (State of the Environment Report 1998, Bland and Donda 1995). Consequently, diminishing fish stocks is one of the nine most significant environmental problems identified in the National Environmental Action Plan (1994). It should be noted that concern centres around the near-shore catch targeted by small scale fishers. A recent Icelandic International Development Agency (ICEIDA) study of demersal stocks is reported to have revealed a large unexploited biomass far from shore (Seymour1997), where gear employed by small scale fishers, who produce 90 percent of the catch (Bland and Donda 1995), cannot reach it.

Plummeting of near-shore stocks in the 1990s (Ministry of Information 2000, Bland and Donda 1995) resulted in an increasing employment of fishing gear such as mosquito nets that harvest with almost absolute efficiency (Scholtz *et al.* 1997, Bland and Donda 1995). At the same time that this type of illegal and unsustainable activity took root, a weak economy meant that fewer resources were available for the FD to maintain, let alone expand, its management and enforcement activities (Bland and Donda 1995). Everyone, including fishers, however, could see that the fishery was in jeopardy, creating a situation in which most stakeholders were willing to consider a different management strategy. Lack of resources created an environment in which experimentation with a new approach involving the resource-using communities appeared to be a viable option, at least on a trial basis.

Government and donor recognition that action needed to be taken to conserve the fisheries provided the impetus and led to funding. In 1992 an experiment to involve local fishers in management was launched at Lake Malombe at the southern tip of Lake Malawi. Since stocks of the highly prized chambo had been nearly fished to extirpation there, and the lake was relatively small (390 km^2), with about 335 fishers (Government of Malawi 1994), it seemed a feasible site for a pilot project. While new to Malawi, fisheries co-management is a strategy that has been employed successfully in a variety of regions and situations (Pinkerton and Weinstein 1995, Pinkerton 1989). Desperate for a solution, the Fisheries Department collaborated with the German Technical Assistance Agency (GTZ) to create the Malawi-German Fisheries and Aquaculture Development Project (MAGFAD) Participatory Fisheries Management Program (PFMP) (Scholtz *et al.* 1997, Bland and Donda 1994). They thought that education and direct participation in management would alter fisher behaviour, causing them to reduce total effort to permit the stocks the time needed to recover, one of the PFMP's goals.

The strategies of the project were straight forward: provide extension education on fish biology and stock management, provide training and support on self-organization for management and leadership, and then involve the fishers in the formerly exclusive governmental domain of fisheries management (Scholtz *et al.* 1997). Increasing the difficulty in bringing about change were the vestiges of decades of political oppression (Africa Watch Report 1990, Short 1974) that ended just as the PFMP was being launched. In a 1993 election, Malawi left behind 31 years of dictatorship and chose multi-party democracy. Colonialism and the dictatorship had suppressed local level initiative and leadership and created a deep mistrust of government. These historical realities presented a challenge to PFMP organizers (Scholtz *et al.*1997, Mr. Ben Mtika, National Extension Agent, personal communication, 1996). Thus, an intensive educational and partnership-building effort was necessary along with carefully nurturing the development of the administrative and leadership skills needed to participate in fisheries co-management.

Under girding the new management strategy is the theory that shared regulatory responsibility, i.e., co-management[1], will increase management resources and enhance the fishery. Pinkerton (1989, p. 4) defines co-management as "...negotiated agreements and other legal or informal arrangements ... between groups or communities of fishermen and various levels of government responsible for fisheries management..." Another useful definition supplied by Selin and Chavez (1995, p. 190) emphasizes the operational mechanism of such arrangements, "...a joint decision-making approach to problem resolution where power is shared, and stakeholders take collective responsibility for their actions and subsequent outcomes from those actions." This type of strategy recognizes the significant role played by fishers, incorporates their needs, and draws upon their knowledge along with the often more technical knowledge of FD professional staff. In a co-management arrangement, fishers begin to feel more like partners and less like miscreants that the government seeks to control. Fisheries Department staff assume new roles as well, shifting from top-down enforcers to collaborators. Concomitantly, through the cooperation and collaboration inherent in co-management, the hostility and mistrust that existed historically in relationships between fishing communities and the Fisheries Department in Malawi began to dissipate (Scholtz *et al.* 1997).

Co-management arrangements may incorporate to varying degrees notions of shared authority, shared responsibility, stakeholder ownership of the resource, and direct benefits accruing to stakeholders. As a result of their involvement as managers, stakeholders may be held accountable and accept accountability for management outcomes which they participated in creating. Perceiving themselves as owners, and persons with responsibility for stock protection, they are more likely to develop a long term view that changes their fishing behaviour (Bland and Donda, 1994).

In the case of the PFMP at Lake Malombe, the program worked with the existing political framework to organize fishing villages. Each community elected a 10 to14 member beach village committee (BVC) to serve as an intermediary between the FD and the fishing community. Traditional authorities, village chiefs or village headmen, serve on the BVC within their jurisdiction in an *ex officio* capacity. After initial training provided by the FD and aid organizations, each BVC adopted a constitution and decided on which management activities they would undertake. According to Scholtz *et al.* (1997) BVCs became involved in a variety of important activities including:

1) discussions of fisheries regulations,
2) licensing and record keeping for fishing gear and boats,
3) control of their beach and fishing area (primarily gear and license inspection),
4) organization of extension sessions, and
5) participation in fisheries enforcement.

The FD and donor officials believed that an educated community would be more likely to actively support short-term fishing restrictions in the interest of long term gains. Thus, an extensive program of extension messages was launched by MAGFAD. The messages spoke of fish biology and appropriate fishing practices. Since most of the target population is illiterate, the primary means of reaching out were discussions with BVC members, radio

[1]"Co-management" incorporates a broad range of approaches to public involvement in resource management. Ranging from seeking the views of affected groups to involving them in problem identification, planning and implementation, to actual power sharing (IIED 1994). It also one of many terms and phrases used to refer to management by government that incorporates community members in some way, including "community-based natural resource management" and "collaborative management."

broadcasts, and performances of the MAGFAD band (Dawson 1997). The fishing villages rarely have live entertainment, so appearances by the band, singing songs about fishing, were always well attended and well received (Wilson 1993). UNDP supported the position of a full time extension expert who met regularly with the BVCs and trained their members in administration. Under his guidance they learned about group dynamics and how to run elections, draft a constitution, create and maintain records and organize and run meetings (Scholtz *et al.* 1997).

Co-management outcomes

Positive fisheries management outcomes were reported by Scholtz *et al.* in their 1997 evaluation of the PFMP. Early in its development, in 1992, BVCs proposed regulations on appropriate fishing net mesh size. They advocated a 19mm mesh while FD researchers argued for 25mm. Acceptance by the Department of the fishers' position was a significant step forward in persuading the fishers to participate in the pilot project. Other fisher-proposed regulations banned kambuzi seine nets and maintained the closed season. According to Scholtz *et al.* (1997) the FD was not in agreement with the usefulness of these two rules, but they were nonetheless adopted. The FD wished to be seen as recognizing fisher views in a significant way, and it was felt that the rules would do no significant harm to the resource. With the adoption of the rules they had advocated, the fishers knew they had been heard and heeded, in keeping with the sentiment expressed by one of them, Mr. Staubi Africa, who said in 1994, "It is for us fishermen to decide whether we want to be poor for one or two years, or whether we want to be poor forever" (Dr. J.G.M. Wilson, personal communication, January, 1996).

Adoption rates of the new net sizes were reported to be 17 percent in 1994, 60 percent in 1995, and 85 percent in 1996 (Scholtz *et al.* 1997). As the new program moved into full swing, Lake Malombe's chambo catch data show an increase from 79 tons in 1994 to195 tons in 1995 (Scholtz *et al.* 1997), perhaps the beginning of a reversal of the trend reported by Bland and Donda (1995).

The reviews of the PFMP are not all positive. Indeed, a setback for the project occurred when fishers learned that promised "sitting fees" for meeting attendance, provision of new nets, and free replacement of nets of illegal mesh size were not forthcoming (DeGabriele 1998, Scholtz *et al.* 1997). An attempt to address the net replacement problem was made through a Fisheries Department small loan program. Through this program it was hoped that adoption of regulation size nets would happen as quickly as possible as well as salving the feelings of fishers concerned about "broken promises," but fishers remained dissatisfied because the loan program did not fully meet their needs nor the original commitment of the FD (DeGabriele 1998, Scholtz *et al.* 1997).

Scholtz *et al.*(1997) observed that FD staff continued to operate in a "top down" manner after the program began, undermining messages of shared authority and trust between managing "partners." In addition, some recent attempts by BVCs to penalize violators were thwarted by FD officers (Dr. J.G.M. Wilson, personal communication, March 28, 2000). Such overt blocking of BVC management authority will continue undermine the BVC-FD relationship as well as confidence in the willingness of the FD to share authority and to honour BVC decisions.

The lack of effective communication, trust, and coordination between the FD and fishing communities was most recently highlighted by Mangochi fishermen's misunderstanding and mistrust of the Department of Fisheries's regulations establishing a closed fishing season that applied to local fishermen while excluding the commercial fishing vessels of MALDECO (Chimwaza 2000). The fact that fishermen's ignorance of the reasoning behind the regulations was dealt with using riot police and tear gas speaks volumes to the need for greater education and, more importantly, dialogue between the parties before regulations are passed (a need that can be addressed using increased participatory management (Donda 2000) . It is apparent from this incident that the reconfiguration of government officials' roles not been fully addressed, evaluations of stakeholder (including agency staff) incentives in the co-management process are needed, and that the participatory governance paradigm has not yet been fully internalised throughout the FD.

Legislation authorises co-management

From the beginning GTZ had been concerned about the absence of mandated institutional support for fisher participation in management (Scholtz *et al.* 1997). With progress to report that could be used to argue for legal status for this kind of activity, and with a proposed new fisheries law, "Fisheries Conservation and Management Act," in the parliamentary hopper, GTZ began to pressure the government for new statutory provisions to formalize fisheries co-management (Dobson 1997). A consultant was hired to prepare an analysis of the situation and to draft language that could be inserted in the proposed statute (Dobson 1996). Her report was presented to the Director of Fisheries in May, 1996. The proposed statute was enacted in 1997, and it includes a new section. "Part III," containing provisions authorizing "Local Community Participation" (Fisheries Conservation and Management Act, 1997). Broadly speaking, BVCs are responsible for "conservation and management of fisheries" within their jurisdiction (Fisheries Conservation and Management (Local Community Participation Rules, 1998). The more specific details setting forth the institutional structures and authority of BVCs (e.g., licensing of small scale fishers, vessels and gear, enforcement) appear in the Fisheries Conservation and Management (Local Community Participation) Rules, 1998. The National Fisheries and Aquaculture Policy of 1999, has gone on to support co-management in stating that "..participatory fisheries management has proven to be the most appropriate method to manage the fish resources in the lakes of Malawi."

Co-management at Lake Malawi and beyond

With legislation in place securing the position of co-management, in 1998, GTZ authorized funding to expand the program it had initiated at Lake Malombe to the fishing villages of Lake Malawi. The expansion is a substantial undertaking in view of the size of the Lake. According to a consultant who is currently reviewing co-management activities in many of Malawi's natural resources sectors, including the fisheries, his preliminary data indicate that progress is slow (Dr. J.G.M. Wilson, personal communication, March 28, 2000). According to Wilson, no co-management agreements between the Fisheries Department and local communities have yet been signed as authorized by the 1997 Fisheries Conservation and Management Act (Dr. J.G. M. Wilson, personal communication June 27, 2000). Formal agreements between the FD and BVCs would likely strengthen fishers' sense of ownership and responsibility.

Wilson (June 2000) further reports that initial BVC organization has occurred at the southern end of the Lake, but that the regular radio broadcasts on fishing appear to have induced fishers at the more remote, Northern end of the lake to organize into BVCs on their own, in a fashion similar to the Lake Chiuta fishers described below. Having come into existence only recently, it may be too soon to begin evaluating the effectiveness of the activities of the new groups.

While beyond the scope of this article, it should be noted that the Lake Malombe project gave rise to a successful fisher-initiated effort at Lake Chiuta, a small lake that sits astride the Malawi-Mozambique border (see Figure 1). Learning of the Lake Malombe approach, in 1994 fishers organized themselves to protect their fishery from approximately 300 new entrants from Lake Chilwa which had substantially dried up. With very limited assistance from the FD, they employed the model of Lake Malombe's BVCs. They established nine 14-member Fish Stock Management Committees and drove off the interlopers who were using damaging nkacha seine nets and fouling the Lake's waters with human waste (Dawson 1997, Scholtz *et al.* 1997). That effort appears to be continuing from a recent report describing the successful confiscation of two "illegal seine nets" from armed Mozambican fishers by Lake Chiuta fishers (Dr. J.G.M.Wilson, personal communication, March 28, 2000).

Involving members of the user community in management is still in its fledgling stage in Malawi, and additional time is required before impacts on the fishery can be clearly seen and fully assessed. These efforts toward increasing the participation of local communities in resource management are part of a larger pattern that is being seen in the region. An example is Malawi's northern neighbour, Tanzania, which has recently reacted to dropping fish stocks and water quality concerns by implementing a co-management approach for its Lake Victoria fishery. In response to increasing population pressures, overfishing, use of illegal gear and the introduction of a pesticide, thiodan, that were damaging the fisheries stocks and the lake water quality, 91 Beach Management Units (BMUs) have been established in Mwanza Gulf (Hoza and Mahantane 1998). It appears to be similar in form to the Lake Malombe program, with responsibility shared between the Fisheries Division of the government and the BMUs who patrol their fishing grounds to reduce illegal fishing.

It should be noted that the co-management approach is being adopted well beyond the developing nations. Policy makers and managers are realizing that working with stakeholders in planning and implementation makes great practical sense (Selin and Chavez 1995, discussing *inter alia* "collaboration models" used by the U.S. Forest Service). Just as the fishers in Malawi have useful knowledge to contribute to the management of their fishery, as one example, the U.S. Fish and Wildlife Service acknowledges the importance of the knowledge and community ownership of residents in the Bitterroot Ecosystem as it moves forward with a plan to re-introduce the grizzly bear there in the near future to be managed by a citizen board (U.S. Fish and Wildlife Service 1999).

Participatory approaches in resource management agencies

Descriptions of the factors that are conducive to making co-management effective have been described by many authors (ex. Baland and Platteau 1996, Ostrom 1990). And while most authors discuss at length the requirements for capacity-building in communities and user-groups, most give short shrift to the institutional changes that are needed in the resource management agencies, whose staff are being drastically altered by fiat. Therefore, we will discuss some of the findings of the co-management literature on these neglected participants in the co-management process: the resource agency personnel.

While most resource management field staff have traditionally enjoyed relatively high levels of authority and prestige over fishing communities, their new roles in a co-management program have stripped them of much authority and prestige. Ironically, they are the recipients of upper-agency/upper-governmental directives mandating their participation in a participatory management approach, while this same courtesy of participation is not applied to them within their department. In a study done by Gronow (1995), it was noted that the Forestry Department field staff in Nepal lacked a true understanding of the participatory approach, and failed to appreciate the legitimacy and desirability of the approach as their own lack of knowledge, lack of incentives, job tenure insecurity, and lack of agency support had not been taken into account in the design of the new program. Their inability to voice these concerns and opinions caused them to resist their gradual loss of authority and power. As a result, neither the agency's nor the communities' goals were met.

It was only in certain areas where the forestry field agency concerns were addressed that staff became enthusiastic supporters of the new programs, thereby contributing to the programs' successes. The process of reorientation was made in several stages (Gronow 1995). To initiate the process, field personnel were invited to take part in a 10-day workshop, where they were encouraged to discuss amongst themselves (with the aid of a professional facilitator) the issues surrounding forestry co-management and their roles in it. At this same workshop, they were presented with the latest information regarding the resource, co-management research, and participatory methods. Most workshops culminated with the staff's decision to adopt their newly understood roles in the co-management process, committing themselves to the process. By allowing the field staff to experience a participatory approach within the agency where they saw the value of actively addressing stakeholders' (in this case, themselves) concerns, they understood the merits inherent in doing the same with the forest-stakeholders.

The second element was to provide the field staff with "follow-up support" to consolidate the process that was started at the workshops (Gronow 1995). They were provided with short-term moral and practical support, and job security while they attempted to innovatively change the ways that their jurisdictions' forest resources were managed. The presence of competent and supportive role models was seen to be highly predictive of field staffs becoming effective and enthusiastic facilitators of the co-management processes with their forest user-groups.

The last element, which has been shown to be the most challenging is achieving the institutional change necessary within the agency as a whole ".. to provide field staff with an environment conducive to their new role."(Gronow 1995) This requires a consistent application of the participatory approach within the agency. Lacking this consistency, different levels of the agency develop highly disparate attitudes toward co-management, from pro-participatory, manipulative, incremental, to anti-participatory (Midgley *et al*. 1986). This can have the effect of stifling motivation and innovation at all levels within the agency, and the development of perverse incentives against resource conservation and resource-user participation in management.

In developing the co-management regimes with communities, the incentives of all stakeholders must be addressed. As the field staff are the main representatives of the agency in the co-management process, their roles and incentives need to receive as close scrutiny as that of the incentives and institutions facilitating community-members' actions, if these new management regimes are to achieve success. When looking at field staffs' incentives for acceptance of the participatory method, the incentives within their working environment need to be analysed and restructured in ways that encourage, rather than discourage their investment in the process. Through periodic participatory dialogues with all agency staff, the incentives and disincentives that arise can be addressed to improve staff members' productivity and to reduce the development of perverse incentives within the agency.

A brief discussion of the literature on human development will assist in understanding why and how this might work. The hierarchy of human needs was first described by Maslow (1943) to outline the motivations behind peoples' actions (Figure 2). The bottom four levels of a simplified version of Maslow's concept are called "deficiency needs," which must be met before a person is able to move to the next level. The top level is "self-actualisation," which, with Maslow's later work (1954), came to be expanded into a grouping named "growth needs" consisting of (in order of increasing human growth):

- Cognitive growth: the need to know, to understand, and explore;
- Aesthetic growth: the need for symmetry, order, and beauty;
- Self-actualization: to find self-fulfillment and realize one's potential; and
- Transcendence: to help others find self-fulfillment and realize their potential.

Closely related to Maslow's hierarchy is Herzberg's (Herzberg *et al*. 1959) "Motivation Hygiene Theory" which describes job factors that motivate employees, dividing motivations in a similar fashion to Maslow (Figure 2): hygiene maintenance factors (related to "deficiency needs"), and motivational Factors (related to "growth needs"). "Hygiene factors" are a requisite avoiding workers' dissatisfaction in their jobs, while "motivational factors" actually produce job satisfaction (and motivate). Furthermore, while hygiene factor improvements may create short-term changes in job performance, long term job performance changes are created only by increased motivational factors.

Extending Maslow's and Herzberg's theories to the roles played by resource management staff members in co-management regimes, it seems clear that in order for agency personnel to actively embrace a role in co-management that is foreign to them (and may have the potential to endanger their "deficiency/hygiene" needs), their "deficiency/hygiene" needs and "growth/motivational" needs must be addressed. These latter needs can only be sustained if they are part of an overall evaluation of the institutional infrastructure, which can best be done through an incorporation of participatory approaches in the management of the agency itself.

Agency personnel analyses also should learn from the co-management literature by addressing the same erroneous assumptions that have been applied to the identities and capacities of "community members." "Agency staff" at all levels should not be seen as homogeneous, given their unique ideologies and identities stemming from their overlapping profiles of gender, religion, ethnicity, socio-economic background, and so forth. To induce them to innovate and be pro-active in their jobs, their incentives and disincentives at every stage of the co-management process (policy making, planning, evaluation, enforcement) need to be analysed and addressed in the context of the effects that they have on the program. One of the best ways for this to be achieved is through active, consistent, and productive dialogue within the agency.

Conclusions

This assessment indicates that the evolution in the management approach for Malawi's fishery from controls through traditional methods to license-based open access may be responsible for near-crisis conditions in the near-shore fishery. Coming at least part way round the circle, Malawi is following the approach employed in other fisheries to reincorporate local participation in fisheries management. While not a panacea, given the magnitude and multitude of other social issues in Malawi (e.g., human population growth, a weak economy), co-management appears to be a management strategy with many positive potentials.

Seeing themselves as management partners with a significant role in building sustainable fisheries could cause fishers to adopt a longer term view, replacing the short term thinking which dictates taking as many fish each day as possible. Such a changed mentality is necessary to move Malawi in the direction of fishery sustainability. Care should be taken, however, to avoid the mistakes that have been made thus far that have hindered the effectiveness of the PFMP co-management arrangement, such as the failure to make good on commitments to fishers, undermining fisher enforcement efforts, and direct conflict between FD staff and fishers.

Also crucial to the success of fisheries co-management are appropriate training and redeployment of management staff as well as a shift to more of a participatory approach within the Fisheries Department itself. The mistakes to date could be more easily avoided by ensuring complete understanding, unanimity, and institutional support within the agency of the reconfigured roles to be played by the agency and its staff in fisheries management.

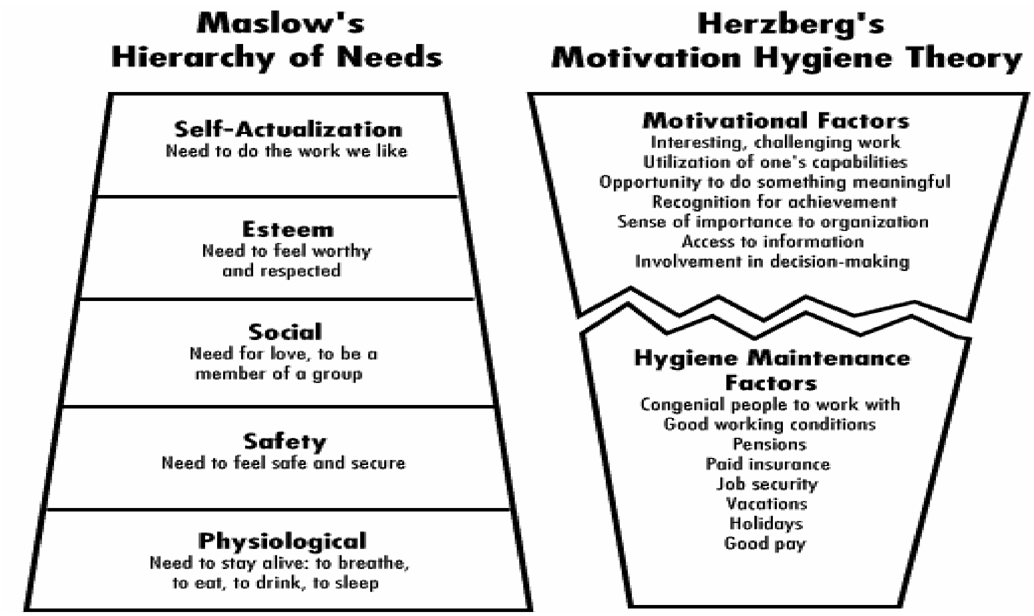

Figure 2. Maslow's Hierarchy of Needs and Herzberg's Motivation Hygiene Theory (from Allen 1998).

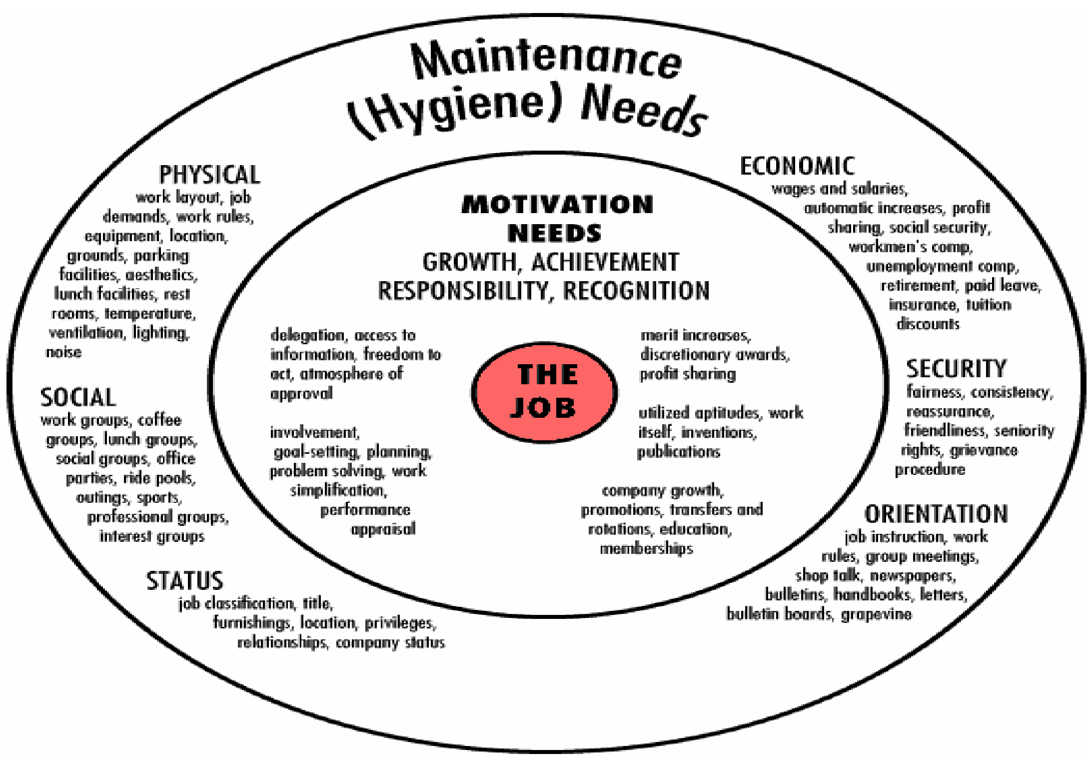

Figure 3. Herzberg's Motivation Hygiene Theory (expanded) (from Allen 1998).

References

Alimoso, S.B. 1994. *Recent Research and New Management Strategies for the Fisheries of Lakes Malawi and Malombe*. Fisheries Department Report.

Allen, G. 1998. *Supervision*. (Hyperlink-http://ollie.dcccd.edu/mgmt1374/book_intro.html).

Baland, J.M., & Platteau, J.P. 1996. *Halting degradation of natural resources: is there a role for rural communities?* New York: United Nations Food and Agriculture Organization and Oxford: Clarendon Press.

Bland, S.J.R., Donda, S.J. 1995. *Common Property and Poverty: Fisheries Co-Management in Malawi*. Fisheries Bulletin No. 30. 1-16.

Bland, S.J.R. & Donda, S.J. 1994. *Management Initiatives for the Fisheries of Malawi*. Fisheries Department Report, Government of Malawi.

Chimwaza, E. 2000. "Police tear gasses Mangochi fishermen" Malawi News, December 9-15, 2000.

Dawson, K.R. 1997. Applying Cooperative Management in Small-Scale Fisheries: The Cases of Lakes Malombe and Chiuta, Malawi, M.S. thesis, Michigan State Univ., East Lansing, MI.

DeGabriele, J. 1998. *Evaluation of the participatory fisheries management programme for Lake Malombe and the Upper Shire.* Report to GTZ, 1-32.

Department of Economic Planning and Development. 1993. *National Population Report*. Office of the President and Cabinet, Government of Malawi.

Department of Research and Environmental Affairs. 1994. *National Environmental Action Plan*., Government of Malawi.

Derman, B., Ferguson, A. & Mkandawire, R. 1994. Socioeconomic Diversity among Lake Malawi's Small-Scale Fishers: Implications for Biological Diversity and Fisheries Management. Presented at the Annual Meeting of the American Association for the Advancement of Science.

Derman, B & Ferguson, A. 1995. Human Rights, Environment and Development: The Dispossession of Fishing Communities on Lake Malawi. *Human Ecology*. 23:125-142

Dobson, T. 1996. *A Report to the Director of Fisheries on Behalf of the Malawi-German Fisheries and Aquaculture Development Project*. Submitted 24 May 1996.

Dobson, T. 1997. Radical Restructuring of Environmental Policy to Preserve Biodiversity in Southern Africa: Malawi at the Crossroads. *J. of Nat. Resources & Env. Law*. 13:149-175.

Dobson, T. 1999. Community Participation in Natural Resources Management in Malawi: Charting a New Course for Sustainability. *Colo. J. of Intl. Env. Law and Policy*, 1998 Yearbook, 153-177.

Donda, S. 2000. *Journey to sustainable fisheries management: organizational and institutional limitations in fisheries co-management, the cases of lakes Malombe and Chiuta in Malawi.* IIFET2000: Microbehavior and Macroresults, Oregon State University.

Environmental Affairs Department. 1998. *State of Environment Report for Malawi 1998.* , Government of Malawi.

Eschweiler, J.A. 1993. *Malawi Land Uses*. Consultant's Report to the World Bank. i-vii & 1-107.

Ferguson, A., Derman, B. & Mkandawire, R. 1993. The New Development Rhetoric and Lake Malawi. *Africa*. 63:1-18.

Food and Agriculture Organization of the United Nations (FAO) Fisheries Department. 1996. Fishery Country Profile: The Republic of Malawi. Http://www.fao.org/fi/fcp/malawie.asp.

Government of Malawi, Food and Agriculture Organization of the United Nations, United Nations Development Programme. 1994. *Fisheries management in the south-east arm of Lake Malawi, the Upper Shire River and Lake Malombe, with particular reference to the fisheries on Chambo (Oreochromis spp.).* Chambo Fisheries Research Project.

Gronow, J. 1995. *Shifting power, sharing power: issues from user-group forestry in Nepal*. In Nelson, N., and S. Wright, eds. *Power and Participatory Research: Theory and practice.*

Herzberg, F., Mausner, B. & Snyderman, B.B. 1959. *The Motivation to Work* (2nd ed.). New York: John Wiley & Sons.

Hoza, R.B. & Mahatane, A.T. 1998. *Fisheries Management Component: Co-Management in Mwanza Gulf.* Ministry of Natural Resources and Tourism.

Human Rights Watch. 1990. *Where Silence Rules: The Suppression of Dissent in Malawi*. An Africa Watch Report.

International Institute for Environment and Development (IIED). 1994. *Whose Eden? An Overview of Community Approaches to Wildlife Management.* A report to the Overseas Development Administration of the British Government.

Koro, E. 1999. *Where Are Malawi's Fish?*, Africa Information Afrique, May 24, 1999.

Maslow, A. 1943. *A theory of human motivation*. Psychological Review, 50, 370-396.

Maslow, A. & Lowery, R. Ed.. 1998. *Toward a psychology of being* (3rd ed.). New York: Wiley & Sons.

Ministry of Information. 2000. *Agriculture*. Http://www.maform.malawi.net/agricutlure.htm

McCracken, J. 1987. Fishing and the Colonial Economy: The Case of Malawi. *J. of African History*. 28:413-429.

Munthali, S.M. 1994. *Protected Areas and People: Sustaining Lake Malawi's Ecology*. Report to the Department of National Parks and Wildlife, Malawi. 1-36.

National Statistical Office. 1999. *Population of Malawi in 1998, 1987 and 1977 by area and sex.* Http://www.nso.malawi.net/Comparative_population.htm.

Ostrom, E. 1990. *Governing the commons: the evolution of institutions for collective action.* Cambridge: Cambridge University Press.

Pinkerton, E. & Weinstein, M. 1995. *Fisheries that Work: Sustainability Through Community-Based Management.* A Report to the David Suzuki Foundation.

Pinkerton, E. 1989. *Co-Operative Management of Local Fisheries: New Directions for Improved Management and Community Development.* Vancouver, British Columbia: University of British Columbia Press

Scholtz, U.F., Njaya, F.J., Chimatiro, S., Hummel, M., Donda, S.& Mkoko, B.J. 1997. *Status and Prospects of Participatory Fisheries Management Programs in Malawi*. A paper presented at the FAO/ODA Expert Consultation on Inland Fisheries Enhancements, Dhaka, Bangladesh, 7-11 April, 1997.

Selin, S. &Chavez, D. 1995. Developing a Collaborative Model for Environmental Planning and Management. *Environmental Management*. 19:189-195.

Seymour, A. 1997. A Fishy Tale. Notes for a presentation to the [Malawi] Donors Environment and Natural Resources meeting, Sept. 4, 1997.

Short, P. 1974. Banda.. London: Cox & Wyman Ltd.

U.S. Fish and Wildlife Service. 1993. *Grizzly Bear Recovery in the Bitterroot Ecosystem*. Environmental Impact Statement.

Wilson, J.G.M. 1993. *Lake Malawi and the Upper Shire River: Community Fisheries Management Programme.* Southern Africa Development Coordination Natural Resources Newsletter, Issue 4, October.

Governmental Statutes and Policies cited

Environment Management Act (1996) (Malawi)

Fisheries Conservation and Management Bill (1996) (Malawi)

Fisheries Conservation and Management Act (1997) (Malawi)

Fisheries Conservation and Management (Local Community Participation) Rules, 1998 (Malawi)

National Fisheries and Aquaculture Policy, October 1999.

Fisheries management and uncertainty: the causes and consequences of variability in inland fisheries in Africa, with special reference to Malawi

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Abstract

Uncertainty pervades the management of fisheries. Scientific fisheries management over the last 50 years has been based on the premise that there exists an equilibrium relationship between fish production and the level of harvest that can be taken without depleting the stocks. These equilibrium 'surplus-production' and 'yield-per-recruit' models have served to establish the principle that unregulated fishing will deplete fish stocks and dissipate economic rents from the fishery, but they have been of limited applicability for practical fisheries management when their equilibrium assumptions are violated. The influence of equilibrium models has extended beyond stock assessment into management, such that many fisheries management measures are based on a 'steady-state' view of fishery resources even when most stakeholders are aware that the assumptions are untenable.

This paper makes the case that fish production in many African inland waters is driven by climate variations. For fisheries where stocks fluctuate independently of fishing effort, management for traditional sustained-yield type objectives is inappropriate. While there have been many studies attempting to elucidate the mechanisms for environmentally-induced fishery fluctuations, there have been fewer studies of the consequences of such variability for fisherfolks' livelihoods, and for the design of appropriate fishery management regimes. A study of the livelihood strategies of fisherfolk involved in the important fisheries for small pelagic species in Lake Malawi is used to make the case for management that supports opportunistic exploitation of fluctuating resources by enabling geographical and occupational mobility. Livelihood sustainability and resource conservation are best served by support for such flexible strategies. The interdependence of fishing and other sectors of the rural economy suggests that policies and development interventions aimed at raising fishermen's incomes without addressing the wider context of rural poverty are unlikely to be successful or sustainable. Species-based fisheries management and development focused on the fishing enterprise would benefit from re-conceptualisation within a broader natural resource management and rural livelihoods framework.

Introduction

Many fisheries resources fluctuate dramatically from year to year due to climactic variability (e.g. Glantz, 1992; Bakun, 1998). There has long been widespread recognition that constant catch or constant effort approaches to management, based on the paradigm of an achievable optimum sustainable yield, are inappropriate for these types of fishery (e.g. Beddington & May, 1977; Larkin, 1977).

The problem of variability in fisheries, and consequent uncertainty in future stock size estimates can be dealt with in one of two ways. Variability can be regarded as random 'noise' that obscures underlying steady-state dynamics, or its causes and patterns can be investigated, and the results of these investigations incorporated into understanding, if not predicting, future stock and harvest levels.

Although different fisheries are known to have very different patterns of catch series, there have been few attempts to classify fisheries according to extent and patterns of variability. Caddy & Gulland (1983) classified fisheries as steady, cyclical, irregular and occasional. This latter category denotes so called 'boom and bust' stocks that sustain important fisheries episodically before disappearing for decades or even for centuries. More recently, there have been attempts at formal statistical classifications of patterns of variation in catch or biomass time-series (Spencer & Collie, 1998) and to link patterns of variation with fish life-history parameters (Kawasaki, 1983). This work has interesting implications for fisheries management, as it suggests that different management targets may be appropriate for different fishery types.

Interpreting the different categories of fisheries in terms of the factors that could drive different patterns of variability (DeAngelis & Waterhouse, 1987) suggests that steady and cyclical fisheries are likely to be driven primarily by biotic interactions (e.g. stock-recruitment relationships and catch-effort relationships). Irregular and occasional stocks could be either chaotic systems driven by strong biotic interactions (feedbacks), or systems where biotic interactions are relatively unimportant, and abiotic factors are the main influence on stock dynamics. If the latter explanation for the dynamic behaviour of fluctuating stocks is accepted, management based on regulation of biotic interactions (e.g. the effect of harvesting effort on future stock size) is much less relevant.

This paper sets out to examine whether certain fisheries in Africa's Inland waters are strongly influenced by climatic fluctuations, such that the use of management based on standard equilibrium fishery models may be problematic. The paper then explores the fishery implications of climate-driven stock fluctuations, through analysis of fisherfolks' livelihood strategies in Malawi, derived from both primary fieldwork and published information.

Finally, the paper draws out some preliminary policy and management implications of these observed livelihood strategies. These implications are framed against a context where fisheries policy and management in Malawi is undergoing a transition from centralised state-led management towards community-based or co-management (Sholtz *et al*., 1998; Allison *et al.* 2001).

Africa's inland fisheries

Fish protein has made up approximately one fifth of the animal protein consumed in Africa since 1961 (FAO, 1996). However, the contribution from inland waters has risen from less than 25 per cent in 1951 to 41 per cent of domestic fish production in 1994. In absolute terms, inland fisheries production has soared from 250 000 tonnes in 1950 to almost 1 500 000 (FAO, 1996).

In recent years, Africa's inland fisheries have produced the majority of fish consumed in many African countries and almost all of that consumed in Mali, Chad and East Africa (Figure 1). Africa's inland fisheries are important not only as a source of food, but as a source of employment and income for resource poor families. They are exploited almost entirely by artisanal fishing communities in predominantly rural areas. In 1996 FAO estimated that the number of canoes operated by artisanal fishers in Africa's inland waters had increased by 40 per cent in the preceding decade and that most freshwater fisheries were intensively exploited.

" As fishing effort continues to respond to the growing demand for fish, proper inland fisheries management is becoming more and more urgent." (FAO, 1996: 10-36).

‘Proper fisheries management’ in this context has usually meant management for equilibrium production targets such as maximum sustainable yield, with measures to achieve these targets enforced by the State (e.g., for Lake Malawi, Tweddle & Magasa, 1989; FAO, 1993; GOM, 1999).

While fisheries management in Africa shows an increasing interest in community and co-management strategies (e.g. Normann, Nielsen & Sverdrup-Jensen, 1998), these approaches too, are often based on unjustified assumptions about static equilibria and livelihoods based entirely on fishing. These assumptions lead to uncritical promotion of territorial use rights in undifferentiated and idealised constructs of a ‘community’ united by fishing interests (Allison & Ellis, 2001). The assumption in both cases is that fish yields can be both optimised and stabilised by better management. This does not allow for the possibility that optimal strategies may be opportunistic and ‘unstable’ in the conventional sense.

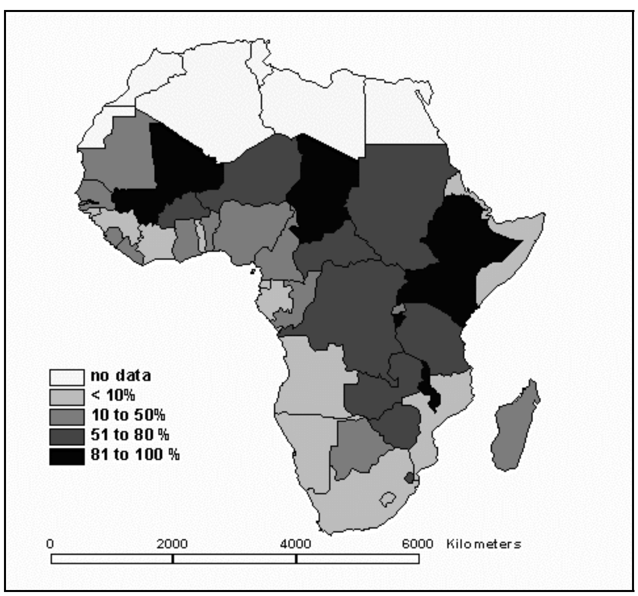


Figure 1: Inland fish production as a proportion of fish supply available per caput in sub-Saharan Africa, 1994 (Adapted from FAO, 1996).

Climate and fishery fluctuations in Africa's inland waters

Conventional fisheries management in industrialised countries over the last 40 to 50 years has been based directly, or conceptually, on the Gordon-Shaefer bioeconomic equilibrium model and its derivatives (Figure 2). This model proposes an equilibrium between catch and fishing effort, so that fishing effort can be regulated to achieve a maximum sustainable yield (F_{MSY}), maximum economic yield (F_{MEY}) and related targets. Failure to regulate fishing effort is thought to lead to a situation where fishing effort tends towards the point where economic returns from the fishery equal the costs of exploiting the resource – the 'open access equilibrium' (F_{OAE}). If signals of resource scarcity are distorted or masked by subsidies to the fishing industry (in the forms of grants for modernising fishing technology, compensation for poor fishing seasons etc), then fishing effort can even exceed the open access equilibrium, possibly leading to stock extinction.

Although the Gordon-Shaefer model provides an elegant and persuasive overview of how a fishery bioeconomic system works, it has been extensively criticised for failing to provide the basis for successful fisheries management. There are many practical difficulties with the model: it is difficult to identify the target reference points until they have been exceeded; it is difficult to dis-aggregate the models in fisheries where one stock is fished by many fleets, or one fleet fishing many stocks; and it is based on catch and effort data that are often unreliable (Hilborn & Walters, 1992). There are also the theoretical difficulties with the equilibrium assumptions, outlined in Section 2, above. All these problems have led some to question whether the model itself, as well as the fishery management systems that are built on its basis, may not be appropriate to some fisheries - particularly those that fluctuate extensively (e.g. Sarch & Allison, 2000).

How applicable are bioeconomic equilibrium (or surplus-production) models to African Inland fisheries? Three of the most important aquatic production systems in inland Africa are shallow lakes, river floodplains, and the pelagic zones of large lakes. It is also the fisheries of these systems that undergo the most pronounced climate-induced fluctuations (Kalk, McLachlan & Howard-Williams, 1979; Plisnier, 1997; Sarch & Birkett, 2000). By contrast, fisheries based on longer-lived, larger sized fish in demersal ecosystems in many of the larger and deeper African lakes seem more likely to fit with prevailing notions of equilibrium dynamics and the conventional fish stock management approaches based on them. There is a reasonable body of evidence suggesting that fisheries are significantly impacting productivity in these latter systems (reviewed in Pitcher & Hart, 1995), which is not the case for the more variable fisheries we consider in this paper.

Malawi, and the African Lakes region more generally, contain important examples of all these types of fishery system, although river floodplain fisheries are poorly documented in the region. In this paper, we use Lake Chilwa and the pelagic fisheries of Lake Tanganyika to illustrate the possible influence of climate variability of fisheries in shallow lakes and the pelagic zones of the Great Lakes, respectively.

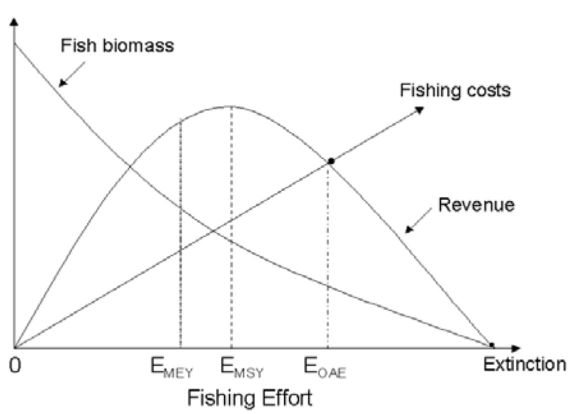


Figure 2: The Gordon-Shaefer bioeconomic equilibrium model (Gordon, 1954; Shaefer, 1954) as a basis for fisheries management.

Lake level fluctuations and fisheries at Lake Chilwa

Africa's shallow lakes are among the most productive fishery ecosystems in the tropics (Talling & Lemoalle, 1998). They are also prone to periodic lake level fluctuation, even to complete drying out in low-rainfall years. Most inland water ecosystems (with the exception of the African Great Lakes) are young, in geological and evolutionary terms, with an adaptable, resilient flora and fauna. They are, in a sense, pre-adapted to cope with a degree of human-induced change (Moss, 1992). This resilience is a feature not often emphasised in fisheries analyses, typically pre-occupied with stability as a management objective (Shepherd, 1991).

Lake Chilwa is in many ways typical of the shallower African Lakes. The Lake has recently fluctuated around 1850 km^2 including both open-water and wetland areas, is less than 3 m deep, and is subject to extreme fluctuations, including complete desiccation (Lancaster, 1979). In good years, fish catches can be as high as 25 000 tonnes (fishery statistics are rather uncertain and vary between sources) and more than 10 000 people are engaged in fishing activities. There was a major increase in fishing effort around the early 1970s, as the region became better integrated into the market economy. Minor recessions in lake level, sufficient to reduce fishing for one or two years, can be expected every six years or so (see Figure 3). Major recessions which will interfere with fishing in the open lake for 3-5 years can be expected every 60-70 years, with a possibility of an intermediate recession in 30-40 years (Lancaster, 1979). The last drying episode covered the period from late 1994 to 1996, when fishing ceased altogether. Fishing operations started again in April 1997 (GOM, 1999).

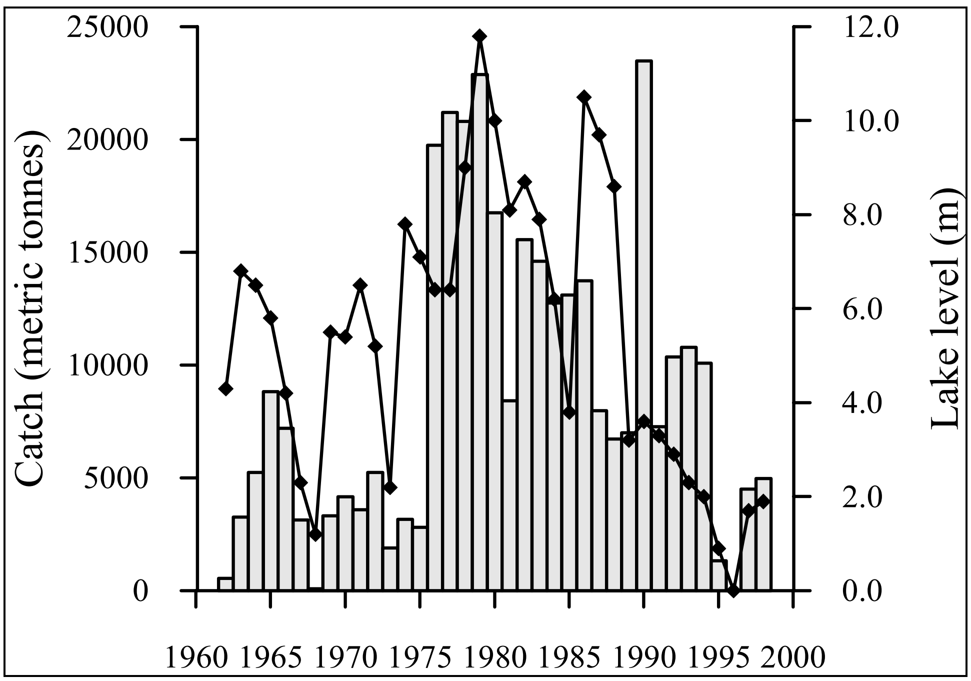


Figure 3. Catch fluctuations (shaded bars) and lake level variations in Lake Chilwa, Malawi 1962-1998. Note also that the lake gauging system was changed in 1989, and the lake level measurements from this period onwards may not be directly comparable with those in previous years (lower apparent amplitude of fluctuation). Fisheries data from Department of Fisheries, GOM (1999); Lake Level Data from Environmental Affairs Department (2000).

Climate and fisheries in the pelagic zones of the African Great Lakes

The fisheries for small pelagic fish in Africa's Great Lakes are among the most important on the continent, supplying dried fish (variously known as *kapenta, usipa, dagaa or omena* according to species and region) to markets throughout much of East and central/southern Africa. Anecdotal evidence, oral histories, ecosystem and environment studies and government fishery statistics all support the notion that of these small clupeids and cyprinids fluctuates extensively from year to year, in response to climate-driven variations in primary and secondary biological productivity (Tweddle & Lewis, 1990; Allison *et al.,* 1995; Plisnier, 1997).

An important study by Plisnier (1997) documents the relationship between fluctuations in stock size (measured by proxy as variations in commercial purse-seine CPUE) and the Southern Oscillation Index (Figure 4), demonstrating the important link between stock size and climate variations in pelagic fisheries. Evidence of climate-productivity links in Lake Malawi's pelagic fisheries are based on less extensive data, but imply a link between wind-stress, upwelling, and fish production (Tweddle & Lewis, 1990; Allison *et al*., 1995; Irvine *et al*., 2001).

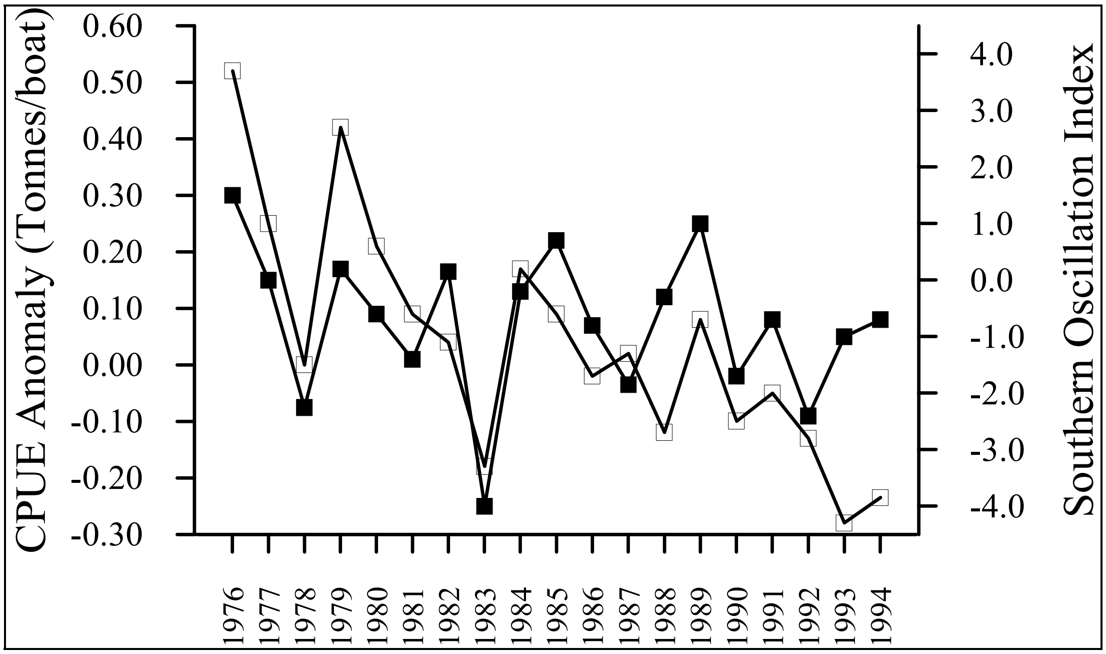


Figure 4. The relationship between stock abundance anomalies of small pelagic fish (clupeids) in Northern Lake Tanganyika (□), measured as the differences from the long-term average in Catch per unit of fishing effort by the Bujumbura-based industrial purse-seine fishery in Nov-Jan, and the Southern Oscillation Index or 'El Niño effect' (■) in the previous Feb-March. The correlation coefficient of 0.62 is highly significant. (Redrawn from Plisnier, 1997).

Given the highly variable rainfall and wind regime in sub-Saharan Africa (Conway, in press) and the evidence for existence of strong climate-fish production relationships, there is case to made for fisheries research and management agencies to incorporate fish production-climate linkages in their programmes. These could provide more relevant scientific information than the current efforts at estimating parameters for use in single-species steady-state fishery assessment models.

While there has been significant recent interest (if not formal research) in understanding the causes of variability in these fisheries, there has been little published work on the consequences of that variability for those involved in catching, processing, distribution, sale and consumption of fish. It is this gap in management-related research that we aim to address through work on the livelihood strategies of fisherfolk dependent on fluctuating resources.

The livelihoods approach and research methodology

The origins of the livelihoods approach

The livelihoods approach has its origins partly in a literature concerned with understanding the differential capability of rural families to cope with crises such as droughts, floods, or plant and animal pests and diseases. This literature focuses attention on the assets of rural people, and how different patterns of asset holding (land, stock, food stores, savings etc.) can make big differences to the ability of families to withstand shocks (Swift, 1989). This set of concerns also links to the concept of vulnerability; defined as a high degree of exposure to risk, shocks and stress and proneness to food insecurity (Chambers, 1989; Davies, 1996). Vulnerability has the dual aspect of external threats to livelihood security due to risk factors such a climate, markets or sudden disaster; and internal coping capability determined by assets, food stores, support from kin or community, or government safety net policies.

The approach also borrows ideas from an ecological literature concerned with the sustainability of ecosystems or agroecological systems (Holling, 1973; Conway, 1987). Here, sustainability is defined as "the ability of a system to maintain productivity in spite of a major disturbance, such as is caused by intensive stress or a large perturbation" (Conway, 1985). The concepts of resilience and sensitivity as livelihood attributes also originate in this context (Bayliss-Smith, 1991). Resilience refers to the ability of an ecological or livelihood system to "bounce back" from stress or shocks; while sensitivity refers to the magnitude of a system's response to an external disturbance. It follows from these ideas that the most robust livelihood system is one displaying high resilience and low sensitivity; while the most vulnerable displays low resilience and high sensitivity. These ideas are relevant to fishery-based livelihoods, as will become apparent in due course.

The concept of 'a livelihood' seeks to bring together the critical factors that affect the vulnerability or strength of individual or family survival strategies. These are thought to comprise, chiefly, the assets possessed by people, the activities in which they engage in order to generate an adequate standard of living and to satisfy other goals such as risk reduction, and the factors that facilitate or inhibit different people from gaining access to assets and activities. These considerations result in the following definition of a livelihood (Ellis, 2000, p.10):

"A livelihood comprises the assets (natural, physical, human, financial and social capital), the activities, and the access to these (mediated by institutions and social relations) that together determine the living gained by the individual or household."

The livelihoods approach is typically set out in the form of a framework that brings together the principal components that are thought to comply with the livelihoods definition, as well as demonstrating the interactions between them. There are many different diagrammatic representations of this framework (e.g. Carney, 1998; Scoones, 1998; Reardon & Vosti, 1995). Here, the framework is summarised in tabular form (Table 1).

The reference social scope of this framework is typically considered to be the extended household, including members who are away from home but send remittances back to the resident homestead. The starting point of the framework are the assets owned, controlled, claimed, or in some other means accessed by the household (column A in Table 1). The livelihoods framework recognises five main asset categories, comprising physical capital (sometimes also called produced capital or economic capital); natural capital (land, trees, fish stocks etc); human capital (people, education and health); financial capital (savings, credit); and social capital (kinship networks, associations).

Access to both assets and activities is enabled or hindered by the policy and institutional context of livelihoods, including social relations, institutions and organisations (column B). It is also affected by external factors, sometimes referred to as the vulnerability context, comprising trends and shocks that are outside the control of the household (column C). Assets permit livelihood strategies to be constructed, and these are composed of a portfolio of activities, some of which may be natural resource based and others not so (column E). Finally, this framework points to outcomes of livelihood strategies, distinguished here between livelihood security effects and environmental sustainability effects (column F).

The livelihoods of artisanal fisherfolk are readily described by this type of framework. In this instance, key assets are fishing gears (boats and nets), although many artisanal fishers may also possess land and combine fishing with farming (Bailey & Pomeroy, 1996). The policy and institutional context of artisanal fishing includes, but is not limited to, the role of state regulations and 'community' based rules that affect access to resources. Social relations can also determine who has access to fishing opportunities (e.g. the ethnicity of fishing families may differ from other families in coastal communities, and roles within fishing activities are often strongly gender-differentiated). Fishing families are no less prone than other rural dwellers to adverse events and trends, with natural fluctuations in fish stocks being especially critical for them. Finally, fishing families often engage in diverse activities in order to achieve livelihood security – an important attribute that we will return to in the context of fisheries management.

Table 1: A framework for micro policy analysis of rural livelihoods (modified from Ellis, 2000, p 30).

A	B	C	D	E	F
Livelihood platform	Access modified by	In context of	Resulting in	Composed of	With effects on
assets natural capital physical capital human capital financial capital social capital	***social relations*** gender class age ethnicity ***institutions*** rules & customs land and sea tenure markets in practice ***organisations*** associations NGOs local admin state agencies	***trends*** population migration technological change relative prices macro policy national econ trends world econ trends ***shocks*** storms recruitment failures diseases civil war	**Livelihood Strategies**	***NR based activities*** fishing cultivation (food) cultivation (non-food) livestock nonfarm NR ***non-NR based*** rural trade other services rural manufacture remittances other transfers	***livelihood security*** income level income stability seasonality degrees of risk ***env. sustainability*** soils & land quality water fish stocks forests biodiversity

Fishing livelihoods research in Malawi

The livelihoods approach is utilised in many different ways, according to the goal of the study or programme. In development practice, it is being used as a 'process' tool to enable participants in development programmes to identify key constraints and opportunities for development intervention (Ashley & Carney, 1999). In this paper, we use the livelihoods approach as a conceptual tool to interpret published literature on Lake Chilwa fisheries, and as a primary research tool to understand the livelihoods of people engaged in small-scale fishing on the shores of Lake Malawi.

Livelihoods research utilises a range of existing methodologies in the social and economic sciences, and can essentially be regarded as a framework to organise these methodologies in such a way as to reduce sectoral and disciplinary biases. The research methods used for Lake Malawi include combination of qualitative and quantitative techniques.

Assets were determined at household level by administration of questionnaires drawn from survey methods used in agricultural economics. Relatively small sample-sizes were used (typically 40 households per village) to ensure that data quality was maintained and good relationships between enumerators and respondents could be fostered. The small sample sizes also meant that each questionnaire could be verified by return visits to households if necessary. Sample selection was based on stratification following wealth ranking (based on people's self-defined criteria), to ensure that poorer households are included in the research. Based on people's own definition of wealth, three categories emerged, namely (a) the well to do (*wopeza bwino*), (b) the better off (*wopeza bwinno pang'ono*) and (c) the poor (*wosauka*). The criteria depend a lot on who has what and who does not have what. The well to do, were people that had some form of capital that enabled them to engage in some productive activities like fishing and small-scale businesses. They were said to have enough food, live in good houses, own some livestock and could afford to send their children to school. The poor were said to be lacking in most things and they did not have anything to enable them to engage in profitable productive activities. They often did not have enough food and had poor housing.

Three sites were purposely selected along the shores of Lake Malawi. The sites were Msaka in the Southern Region district of Mangochi, Lifuu in Salima (Central Region) and Tukombo in Nkhata Bay (Northern Region).

A range of qualitative tools drawn from Rapid and Participatory Rural Appraisal (RRA/PRA) and institutional analysis were used to investigate how access to assets is modified by social relations, institutions and organisations. These included wealth ranking, focus groups, key informant interviews, institutional mapping and ranking of organisations' effectiveness. Trends and shocks were analysed by documenting experiences described in focus group discussions, the use of relevant secondary social and economic data and the analysis of the political and macro-economic context (Allison et al., 2001).

Resultant livelihood strategies were described through analysis of income sources (including gifts, remittances and exchanges) from household questionnaires, and the decision-making processes that lead to choice or adoption of these strategies were explored at both intra-household and village-level.

Although the household questionnaires can provide only a 'snapshot' of current livelihood strategies, this was complemented by qualitative investigation of dynamic change, pursued though semi-structured interviews and focus group sessions, and through documentation of individual life-stories.

Effects of chosen, or enforced, strategies on both livelihood security and environmental sustainability were investigated through existing monitoring systems, such as district and national production statistics and indicators of poverty or well-being.

The research aims to investigate institutional factors that block or enhance people's ability to pursue a sustainable livelihood so that policy and development intervention can address these constraints and opportunities.

Livelihoods analysis in Malawi – results

Lake Chilwa livelihoods

Kalk *et al.* (1979) offer an interesting insight into livelihood responses to fishery fluctuation during the 1960s and 1970s at a time of gradual transition from quasi-subsistence to a partial cash economy in this area of Malawi. This insight does not appear to have been transferred to current fishery management initiatives. The fisheries of Lake Chilwa offer an economically unstable environment, determined by the seasonal and long-term fluctuations in lake level. Yet, at high production periods, the fisheries permitted readily earned cash, with "a substantial number of men gained an income five or more times greater than that prevailing for unskilled or agricultural labour" (Chipeta, 1972). In good years, Lake Chilwa supplies almost half the total fish production in Malawi, where fish is said to supply around 70% of animal protein in the diets of 12 million people (GOM, 1999).

Fishing in Malawi is largely a business, not a subsistence activity (Ferguson *et al*., 1993). Management that constrains access to fish in productive periods constrains income-generating opportunities, denies people access to much-needed protein and serves no conservation purpose in a lake where the sustainable yield concept is obviously untenable. And yet, despite wide-spread acceptance that fisheries management, in its traditional guise of stock conservation measures, is inappropriate, there have been recent measures to introduce fishery closures to allow recovery after drying periods (even though recovery in the past has been rapid). Various gear and mesh-size restrictions have also been introduced, apparently at the behest of fishing communities around the lake, who participate in an evolving co-management scheme with the Fisheries Department (Sholtz *et al.,* 1998).

Work reviewed by Agnew (1979) and Agnew & Chipeta (1979) provide a useful baseline from which to review the likely choices available to people in the latest drying episode, and how these might have been impacted by new management initiatives. These authors summarise the short-term choices of fishermen during the lake-drying period of 1967-68 as: 1) fishing on a very much reduced scale in the remaining swamps, streams and lagoons in the Chilwa catchment, 2) transfer to nearby Lakes Malombe, Malawi or Chiuta, 3) increasing the cultivation of rice, cotton, cassava and vegetables 4) a switch over to commercial handicrafts such as plaiting carpets, 5) spending considerable time trapping birds and digging for rodents or 6) seeking employment elsewhere. These responses varied according to income status, asset profiles, ethnicity and time of residence in the area.

In the drying episode of 1968, around 200 fishermen migrated to nearby Lake Malombe, and others moved to Lake Malawi. These were among the richest fishermen, whose investment in fishing-related assets meant that they could not simply cease fishing, as could those with a lower stake in this source of livelihood. Since the introduction of community-based management in Lake Malombe and Southern Lake Malawi (Sholtz *et al.* 1998, Chirwa, 1998), the option to move fishing operations between lakes is constrained. That this may also prevent Malombe's fishermen from migrating to Chilwa in productive years, thereby relieving pressure on this intensely exploited lake, does not appear to have been explicitly considered.

The repercussions of recession in Lake Chilwa waters and consequent decline of fishing are much wider than on fishing alone. The whole of the Chilwa plains and lake must be seen as an economic network. Not only are there links between fishing and various ancillary services, but also complementary flows of income between fishing and farming. The successful fishermen had larger gardens and produced more cash crops than other fishermen (Phipps 1973). Recognition that there is an "integrated small-scale economy of farming, fishing and cattle-rearing" (Kalk, 1979; p15) does not seem to have led to any specific policy support for these diversified livelihoods. Instead, sectoral concerns for the sustainability of individual natural resource systems have prevailed, even when it is known that notions of resource sustainability are questionable. "The Chilwa fishes are clearly well fitted to persist in the unpredictable Chilwa ecosystem, provided the refugium of swamps and streams is maintained", according to Moss, (1979, p411), with Kalk (1979, p431) adding: "Man must remain as generalised in activity as the lake fauna in order to succeed in the Chilwa area".

Moss (1979) also cautions that more dangerous than overfishing in this resilient system were threats to the swamps through 'reclamation' for agriculture or perhaps as irrigation reservoirs, siltation through changes in catchment land-management, and pesticides. It is these threats that have led to recent interest in environmental management in the Chilwa wetland, and its designation as a Ramsar site. (Environmental Affairs Department, 2000).

The EAD report reiterates the perceived resilience of the system. However, in an analysis of fisheries issues (EAD, 2000, Table 5.2), the report highlights "Ignorance, Poverty, Corruption, Migratory fishermen and Lack of Resources" as barriers to sustainable utilisation of fishery resources, and recommends the implementation of "community-based natural resource management for the benefit of the local people". There is clearly some difficulty in accepting that migration may be a legitimate and sustainable strategy to maximise benefits from a fluctuating resource, a factor that needs to be taken into account in the design of any community-based management scheme.

The mobility and livelihood flexibility of the fishing families making their living on the shores of Lake Chilwa in the 1970s enabled them to respond to the extreme fluctuations observed. These were not mere 'coping strategies', but represent active opportunism – adaptations aimed at maximising the contribution of fishing to household incomes. It is not particularly useful to talk of the fish stocks as sustainable in the context of this level of 'natural' fluctuation. Around Lake Chilwa, there are large-scale shifts from fishing to farming, pastoralism and other occupations when the lake dries out (and back to fishing when it refills). Such strategies highlight the importance of enhancing or maintaining the flexibility of lakeshore livelihoods rather than constraining it with fixed fisheries production quotas, seasons or areas.

Livelihoods on the Lake Malawi shoreline

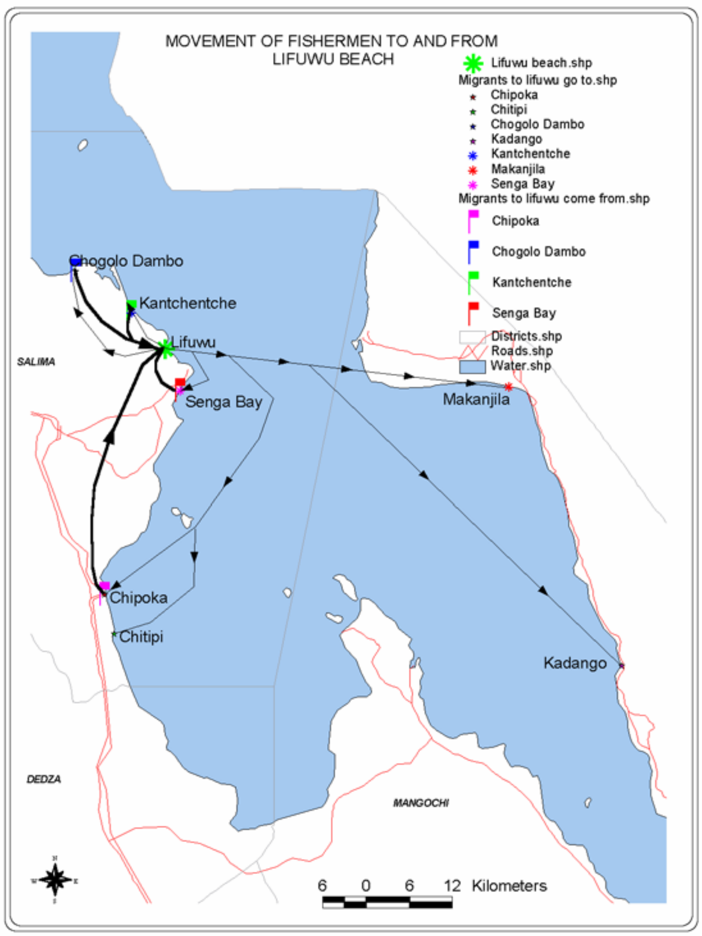
In Malawi, usipa (*Engraulicypris sardella*) is found throughout the lake, but only supports substantial fisheries in inshore areas (Thompson *et al.,* 1996; Thompson & Allison, 1997). These fisheries are mainly artisanal and carried out using chilimira seines set by two canoes or small 'plank boats'. The fishery takes place mainly at night with light attraction. There is also a substantial daytime beach-seine fishery, often for juveniles. Landings statistics are thought to be unreliable and to underestimate the true importance of the fishery, which may reach 50 000 tonnes in good years (Tweddle & Lewis, 1990). The fisheries are known to fluctuate extensively, with fishers able to identify and refer to 'good' and 'bad' years for usipa. These seem to be linked to interannual differences in productivity (Tweddle & Lewis, 1990) which in turn are generated by variations in the strength of upwelling caused by variations in wind stress (Allison *et al*., 1995).

Usipa are marketed largely in sun-dried form and, together with the small pelagic species of other African lakes, contribute significantly to dietary protein throughout Central and Southern Africa. The fishery is quite seasonal, and exploitation of 'usipa' is likely to form only part of the livelihoods of those catching it. Coupled with its interannual variability, this makes this species a useful case-study of a fluctuating fishery.

Results from the survey show that livelihood diversification and mobility are key factors enabling fishers to 'track' resource fluctuations in time and space. People along the Lake diversify in a number of activities including fishing, farming and different types of small-scale businesses.

This type of movement has been adapted for sometime by fishers tracking a 'fluctuating resource'. In the case of the usipa this has led to the establishment of special relations with people in different beaches. There are two types of movements on Lake Malawi, either long-term or short term. Long-term movement refers to fishers that have moved from their original homes and have established a permanent camp elsewhere. These often do not have access to land and thus rely solely on fish and to some extent small-scale business. With short-term movement fishers move in search of fish but operate from their original homes, only establishing temporary camps. Maintaining access to land, they are able to return to farming during poor fishing periods. The map below shows the movement of fishers around Lifuu beach in Salima District.

These strategies are well established and accepted around the Lake shore villages, where migrant fishers are seldom regarded as problematic, but are rather seen to bring benefits in the form of increased trade and economic activity in lake shore villages. Reciprocal access to fishing 'beaches' for landing catch and mending nets etc., may be more important to fishing-dependent communities than claims for territorial exclusivity of the type encouraged by efforts to promote community-based management (e.g. Sholtz *et al.* 1998). Such studies are urgently required around the other African Great Lakes, if the laudable move towards co-management is to develop models for fishery management that reinforce sustainable livelihood strategies. There is a danger that the idealised concepts of village-owned fishing grounds currently being promoted don't fit with the ecology of the fish or the livelihoods of the fishers.



Discussion

The evidence for climate-induced fluctuations in the fisheries of shallow lakes, and for small pelagic fish in the African Great Lakes indicate that the management of these stocks needs to be informed by an understanding of how fishers, distribution chains and markets cope with fluctuating supplies. Most research on fluctuating stocks has been targeted at understanding in detail the mechanisms *causing* fluctuation in stock size. This is the study of fish recruitment processes and the environmental factors driving them (e.g. Cushing, 1996). There has been much less emphasis on the study of the *responses* of fishers to stock size fluctuations (Allison & Ellis, 2001).

Review of secondary data from the Lake Chilwa area, and preliminary analysis of primary fieldwork on the shores of Lake Malawi both reveal the importance of livelihood diversity and geographical mobility as livelihood strategies of artisanal fisherfolk. Mobility and diversity are required to sustain livelihoods when confronted with resource variability that is at least partially climate-induced. The Lake Chilwa case demonstrates that livelihood coping and optimisation strategies existed prior to introduction of both State-led and co- management systems. More recent information on the impact of fisheries management measures on livelihoods is lacking, but is currently being pursued by our research team.

The results of our research in Malawi are in accord with findings in other developing countries, where several studies have suggested that fishers cope with fluctuations through geographical and occupational mobility (Bailey, 1982; Haakonsen, 1992; Geheb & Binns, 1997; Sarch & Allison, 2000; Béné *et al.* 2000). Fisheries management strategies which focus on optimal catch rates ignore both the role which inland fisheries play in the livelihoods of many Africans and the inherent stock fluctuations which have shaped such livelihood strategies.

Proposals to manage fluctuating fisheries need to be based on a better understanding of fisherfolk's livelihood strategies. In fisheries where exploitation has little demonstrable impact on fish stocks, and productivity is closely linked with climate, it is not useful to talk about sustainable yields, or of fixed limits for fishing effort. Neither are community-based or co-managed territorial use rights, in the form of geographically fixed territories, useful for fisheries management in areas where lake or floodplain levels are highly variable, or where fishers have to track mobile pelagic resources to sustain their catch rates.

In Malawi, realisation of the importance of fisherfolk's mobility is leading to a move away from management based on beach village committees (Sholtz *et al*., 1998), towards larger spatial scales – lake management areas defined in terms of movements of range of operations of artisanal fishers, and on ecological criteria (Weyl, personal communication, 2001). The mechanisms for governance of these lake spaces are still being discussed.

It is relatively straightforward to outline what management approaches should not be taken, less easy to identify appropriate management support for sustainable livelihoods from fluctuating fisheries. While removing unnecessary impediments to sustainable opportunistic exploitation strategies is one important step, it may not be enough, given the increasing pressures on resources and livelihoods in Africa. Common property institutions that have evolved mechanisms, such as reciprocal access agreements between migrants, should be considered more appropriate than territory-based approaches as a way of implementing any effort-limitations deemed necessary. Even when embryonic and of limited functionality for resource conservation, such as in Malawi, such institutions can be built upon, rather than replaced by externally-conceived 'perfect' ones.

Formal recognition, in national policy and legislation, of the legitimacy of opportunistic livelihood strategies, coupled with active removal of barriers to mobility and livelihood diversification would seem to be appropriate policy responses at national or district level. Active support for livelihood diversification (not the same as providing incentives for people to diversify out of fishing altogether) is another management option.

The apparently greater importance of climate, relative to fishing, in driving the dynamics of fish stocks in many of Africa's shallower wetlands (Sarch & Allison, 2000) also suggests that effort could be redirected at protecting wetland functions and broader ecosystem integrity and away from trying to manage fish stocks for sustainability. Management needs to lose its preoccupation with stability and gain an increased appreciation of resilience.

'Modern' fisheries management has often consisted of setting stock conservation objectives, and then finding means of modifying fishers' behaviour or investment to fit these objectives (Mahon, 1997). This has usually meant imposing closed seasons, closed areas, size limits, gear restrictions, access or 'fishing effort' restrictions. While there has been concern for the effects of different regulatory options on fishing communities, there has usually been little systematic research on their effects on fishers livelihoods. Fisheries management is becoming more consultative, and fishing communities now have greater participation in management, sometimes through co-management arrangements (Pomeroy & Berkes, 1997). There is still little systematic discussion of the effects of different management options on livelihoods. There is a requirement for both participatory research to help to identify acceptable management solutions to fishery problems, and further studies of livelihoods to understand how fishers cope with and react to both inherent fluctuations and changing externalities.

Acknowledgements

We thank Olaf Weyl and the staff of NARMAP for their help and organisational support, and for allowing us to incorporate our dissemination workshop within the National Fisheries Management Symposium. This research is funded under the Fisheries Management Science Programme of the U.K. Department for International Development (project number R7336). We also thank Terri Sarah, for contributions to a related paper (Sarah & Allison, 2000). The opinions presented in this paper are our own, and do not necessarily represent those of DFID.

References

Agnes, S. 1979. The People and the Land, pp 309-342. In M. Kalk, A. J. McLachlan and C. Howard-Williams (eds.) *Lake Chilwa: Studies of Change in a Tropical Ecosystem*. The Netherlands: Dr. W. Junk.

Agnew, S. & Chipeta, C. 1979. Fishing and Fish-trading: Socio-economic Studies, pp 343-368 in *Ibid*.

Allison, E. H., Patterson, G., Irvine, K., Thompson, A. B. & Menz, A. 1995. The Pelagic Ecosystem, pp 351-377. In A. Menz (ed.), *The Fisheries potential and productivity of the pelagic zone of Lake Malawi/Niassa.* Chatham, U.K.: Natural Resources Institute.

Allison, E. H. & Ellis, F. 2001. The Livelihoods Approach and Management of Small-scale Fisheries. Submitted to *Marine Policy*.

Allison, E. H., Mvula, P. M. & Ellis, F. 2001. Fisheries Management: by Whom, for Whom? Competing Agendas in the Development and Management of Fisheries in Lake Malawi. In Geheb, K. and Sarch, M-T. (eds.) *Broaching the Management Impasse: Perspectives on Fisheries and their Management from the Inland Waters of Africa*. Oxford: Oxford University Press.

Ashley, C. & Carney, D. 1999. *Sustainable Livelihoods: Lessons from Early Experience*, London: Department for International Development.

Bailey, C. & Pomeroy, C. 1996. Resource Dependency and Development Options in Coastal Southeast Asia. *Society and Natural Resources* 9: 191-199.

Bailey, C. 1982. Small-scale Fisheries of San Miguel Bay, Philippines: Occupational and Geographic Mobility. *ICLARM Technical Reports* 10, 57p.

Bakun, A. 1998. Ocean Triads and Radical Interdecadal Variation: Bane and Boon to Scientific Fisheries Management, pp 331-358. In T. J. Pitcher, P. J. B. Hart and D. Pauly (eds.) *Reinventing Fisheries Management*. Dordrecht, The Netherlands: Kluwer.

Bayliss-Smith, T. 1991. Food Security and Agricultural Sustainability in the New Guinea Highlands: Vulnerable People, Vulnerable Places. *IDS Bulletin* 22(3): 5-11.

Beddington, J. & May, R. M. 1977. Harvesting Natural Populations in a Randomly Fluctuating Environment. *Science* 197: 463-465.

Béné, C., Mindjimba, K., Belal, E. & Jolley, T. 2000. Evaluating Livelihood Strategies and the Role of Inland Fisheries in Rural Development and Poverty Alleviation: The Case of the Yaéré Floodplain in North Cameroon. *Proceedings of the 10th International Conference of the Institute of Fisheries Economics and Trade,* Corvallis, Oregon, July 9-14th 2000.
http://osu.orst.edu/dept/IIFET/2000/papers/bene.pdf

Caddy, J. F., & Gulland, J. A. 1983. Historical Patterns of Fish Stocks. *Marine Policy* 7(4): 267-278.

Carney, D. (ed.) 1998. *Sustainable Rural Livelihoods: What Contribution Can We Make?* London: Department for International Development.

Chambers, R. 1989. Editorial Introduction: Vulnerability, Coping and Policy. *IDS Bulletin* 20(2): 1-7.

Chipeta, C. 1972. A note on Lake Chilwa Cyclic Changes. *Journal of Interdisciplinary Cyclic Research* 3: 87-90.

Chirwa, W.C. 1998. The Lake Malombe and Upper Shire River Fisheries Co-management Programme: An Assessment, pp 61-77. In A. K. Normann, J.R. Nielsen and S. Sverdrup-Jensen (eds.) *Fisheries Co-management in Africa*. U.K.: Institute for Fisheries Management and Coastal Community Development.

Conway, D. in press. Extreme Rainfall Events and Lake Level Changes in East Africa: Recent Events and Historical Precedents. In E.O. Odada (ed.) The Second International Symposium on the Limnology, Climatology and Palaeoclimatology of the East African Lakes. In press, Kluwer.

Conway, G. R. 1985. Agroecosystem Analysis. *Agricultural Administration* 20: 1-55.

Conway, G. R. 1987. The Properties of Agroecosystems. *Agricultural Systems* 24(2): 95-117.

Cushing, D. H. 1996. Towards a Science of Recruitment in Fish Populations. Oldendorf/Luhe, Germany: Ecology Institute.

Davies, S. 1996. *Adaptable Livelihoods Coping with Food Insecurity in the Malian Sahel*. London: Macmillan Press.

DeAngelis, D. L., & Waterhouse, J. C. 1987. Equilibrium and Nonequilibrium Concepts in Ecological Models. *Ecological Monographs* 57: 1-21.

Ellis, F. 2000. *Rural Livelihoods and Diversity in Developing Countries*. Oxford: Oxford University Press.

Environmental Affairs Department. 2000. Lake Chilwa Wetland – State of the Environment. Environmental Affairs Department, Malawi Government, June 2000.

FAO. 1993. Fisheries Management in the South-east Arm of Lake Malawi, the Upper Shire River and Lake Malombe, with Particular Reference to the Fisheries on Chambo *(Oreochromis spp)*. *CIFA Technical Paper* 21. Rome: FAO.

FAO. 1996. Fisheries and Aquaculture in Sub-Saharan Africa: Situation and Outlook in 1996. *FAO Fisheries Circular No. 922 FIPP/C922*. Rome: FAO.

Ferguson, A., Derman, B. & Mkandawire, M. 1993. The New Development Rhetoric and Lake Malawi. *Africa* 63(1): 1-18.

Geheb, K. & Binns, T. 1997. Fishing Farmers or 'Farming Fishermen'? The Quest for Household Income and Nutritional Security on the Kenyan Shores of Lake Victoria. *African Affairs* 96: 73-93.

Glantz, M. H. (ed.) 1992. *Climate Variability, Climate Change and Fisheries*. Cambridge: Cambridge University Press.

GOM. 1999. Resource Report, 1999. Fisheries Department, Government of Malawi.

Gordon, H.S. 1954. The Economic Theory of a Common Property Resource: The Fishery. *Journal of Political Economy* 62: 124-142.

Haakonsen. 1992. A Regional Policy on Fishermen Migration in West Africa - Seminar on Artisanal Fishermen Migrations, Cotonou, Benin, 3-5 December 1991. *Marine Policy* 16: 237-238.

Hilborn, R., & Walters, C. J. 1992. *Quantitative Fisheries Stock Assessment: Choice, Dynamics and Uncertainty*. U.K.: Chapman & Hall.

Holling, C. S. 1973. Resilience and Stability of Ecological Systems. *Annual Review of Ecology and Systematics* 4: 1-23.

Irvine, K., Patterson, G., Allison, E. H., Thompson, A. B. & Menz, A. 2001. The Pelagic Ecosystem of Lake Malawi, Africa: Trophic Structure and Current Threats, pp 3-30. In M. Munawar and R.E. Hecky (eds.) *The Great Lakes of the World (GLOW): Food-web, Health and Integrity*. Leiden, The Netherlands: Backhuys.

Kalk, M. 1979. Focus on Social Problems, pp 417-432 in *ibid.*

Kalk, M., McLachlan, A. J. & Howard-Williams, C. (eds.) 1979. *Lake Chilwa: Studies of Change in a Tropical Ecosystem.* The Netherlands: Dr. W. Junk.

Kawasaki, T. 1983. Why Do Some Pelagic Fishes Have Wide Fluctuations in Their Numbers? Biological Basis of Fluctuation from the Viewpoint of Evolutionary Ecology. *FAO Fisheries Report* 291: 1065-1080.

Lancaster, N. 1979. The Changes in the Lake Level, pp 41-58. In M. Kalk, A.J. McLachlan and C. Howard-Williams (eds.) *Lake Chilwa: Studies of Change in a Tropical Ecosystem.* The Netherlands: Dr. W. Junk.

Larkin, P. A. 1977. An Epitaph for the Concept of Maximum Sustained Yield. *Transactions of the American Fisheries Society* 106(1): 1-11.

Mahon, R. 1997. Does Fisheries Science Serve the Needs of Managers of Small Stocks in Developing Countries? *Canadian Journal of Fisheries and Aquatic Sciences* 54(9): 2207-2213.

Moss, B. 1979. The Lake Chilwa Ecosystem – A Limnological Overview, pp 399-416. In M. Kalk, A.J. McLachlan and C. Howard-Williams (eds.) *Lake Chilwa: Studies of Change in a Tropical Ecosystem.* The Netherlands: Dr. W. Junk.

Moss, B. 1992. Uses, Abuses and Management of Lakes and Rivers. *Hydrobiologia* 243/244: 31-45.

Normann, A. K., Nielsen, J. R. & Sverdrup-Jensen, S. 1998. *Fisheries Co-management in Africa*. U.K.: Institute for Fisheries Management & Coastal Community Development.

Phipps, P. 1973. The 'Big' Fishermen of Lake Chilwa. A Preliminary Study in Entrepreneurism in Rural Malawi. In M.E. Page (ed.) *Land and Labour in Rural Malawi*. *Rural Africana* 21: 39-48.

Pitcher, T. J. & Hart, P. J. B, (eds.) 1995. *The Impact of Species Changes in African Lakes.* London: Chapman & Hall.

Plisnier, P.-D. 1997. Climate, Limnology and Fisheries Changes in Lake Tanganyika. FAO/FINNIDA: Research for the Management of the Fisheries on Lake Tanganyika. GCP/RAF/271/FIN-TD/72. ftp://ftp.fao.org/fi/ltr/TD72.PDF).

Pomeroy, R. S. & Berkes, F. 1997. Two to Tango: the Role of Government in Fisheries Co-Management. *Marine Policy* 21(5): 465-480.

Reardon, T. & Vosti, S. A. 1995. Links Between Rural Poverty and the Environment in Developing Countries: Asset Categories and Investment Poverty. *World Development* 23(9): 1495-1506.

Sarch, M-T. & Allison, E. H. 2000. Fluctuating Fisheries in Africa's Inland Waters: Well-adapted Livelihoods, Maladapted Management. Proceedings of the 10th International Conference of the Institute of Fisheries Economics and Trade. Corvallis, Oregon, July 9-14th 2000, 11 pp.
http://osu.orst.edu/dept/IIFET/2000/papers/sarch.pdf

Sarch M-T & Birkett, C. M. 2000. Fishing and Farming at Lake Chad: Responses to Lake Level Fluctuations. *The Geographical Journal* 166(2): 156-172.

Scoones, I. 1998. Sustainable Rural Livelihoods: A Framework for Analysis. *IDS Working Paper* 72. Sussex, U.K.: Institute of Development Studies.

Shaefer, M. B. 1954. Some Aspects of the Dynamics of Populations Important to the Management of Commercial Marine Fisheries. *Bulletin of the Inter-American Tropical Tuna Commission* 1: 25-56.

Shepherd, J.G. 1991. Stability and the Objectives of Fishery Management. *MAFF Laboratory Leaflet* 64. Lowestoft, U.K: Directorate of Fisheries Research.

Sholtz, U., Njaya, F. J., Chimatiro, S, Hummel, M., Donda, S. & Mkoko, B. J. 1998. Status and Prospects of Participatory Fisheries Management Programs in Malawi, pp 407 - 425. In T. Petr (ed.) *Inland Fishery Enhancements. Fisheries Technical Paper* 374. Rome: FAO.

Spencer, P. D., & Collie, J. S. 1997. Patterns of Population Variability in Marine Fish Stocks. *Fisheries Oceanography* 6(3): 188-204.

Swift, J. 1989. Why Are Rural People Vulnerable to Famine? *IDS Bulletin* 20(2): 8-15.

Talling, J. F. & Lemoalle, J. 1998. *Ecological Dynamics of Tropical Inland Waters.* Cambridge: Cambridge University Press.

Thompson, A. B. & Allison, E. H. 1997. Potential Yield Estimates of Unexploited Pelagic Fish Stocks in Lake Malawi. *Fisheries Management and Ecology* 4: 31-48.

Thompson, A. B., Allison, E. H. & Ngatunga, B. P. 1996. Distribution and Breeding Biology of Offshore Pelagic Cyprinidae and Catfish in Lake Malawi/Niassa. *Environmental Biology of Fishes* 47: 27-42.

Tweddle, D. & Magasa, J. H. 1989. Assessment of Multispecies Cichlid Fisheries of the Southeast Arm of Lake Malawi, Africa. *Journal du Conseil International pour l'Exploration de la Mer* 45: 209-222.

Tweddle, D. & Lewis D. S. C. 1990. The Biology of Usipa (*Engraulicypris sardella*) in Relation to Fluctuations in Productivity of Lake Malawi and Species Introductions, pp 67-72. In T. J. Pitcher and C. E. Hollingworth (eds.) *Collected Reports on Fisheries Research in Malawi. Occasional Papers* 1. London: Overseas Development Administration.

An overview of indigenous knowledge as applied to natural resources management

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Abstract
Historically, rural communities have acquired detailed knowledge, skills and strategies based on their interaction with the local environment over long periods of time. Local techniques and practices, which are essentially subsistence-oriented and are distinct to a particular social group and culture, have been developed and built up over centuries of experience and adaptation and are generally in harmony with the environmental conditions and responsive to constraints. This stock of knowledge is communicated in local languages and handed down from generation to generation. It is an expression of African tradition, rich in intricacies. When properly understood, this indigenous knowledge (IK) demonstrates how communities appreciate their environment and constantly seek to live in harmony with nature. Often this knowledge expresses itself and is communicated through songs, taboos, totem animals, custom laws and practices, place names and nicknames, riddles and proverbs.

Indigenous knowledge permeates the social structure. It may have been influenced by innovations emerging from within itself, from other indigenous systems or from external systems but it essentially evolved locally. It is the basis for local-level decision-making in agriculture, food security, natural resource management, and a host of other activities in the rural communities. IK, therefore, deals with folk beliefs, skills, methods and practices. Some of the practices have led to mismanagement of resources, some are less efficient than modern technologies, while IK is generally less precise as measured by international science. IK, however, offers insights into possible alternative approaches to interpreting environmental and development change.

Previously, external solutions offered in natural resource management projects often failed because they did not fit with the local knowledge and circumstances. It is now recognised that the local community's decisions to adopt or reject a new development project is strongly influenced by its existing skills, values and beliefs which are usually reflected in its indigenous knowledge. Although integration of IK in natural resources management may not be the ultimate answer in itself, there is increasing recognition of the value of local knowledge in production systems and rural development. Rural people with their detailed, holistic, integrated knowledge of local ecosystems, are experts in their own right. Utilising IK in the development process requires identification, validation, documentation and integration.

This paper advocates that the opportunity should be seized to utilise the available IK for the fisheries resource management, the stabilisation of land-use activities in the catchment, the integrated monitoring programme of the lake ecosystem, and for the design of the institutional arrangements in the Lake Malawi Environmental Management Project.

Introduction
Renewable natural resources that are currently the subject of major impacts in Malawi include land, water, fish, wildlife and forests. Natural resource management poses major challenges as environmental degradation continues to worsen as a result of high population growth rate, poverty, low agricultural productivity, dwindling smallholder farmlands and escalating input prices, which collectively build up pressure on resource utilisation and exploitation. The discounted economic cost of soil erosion, deforestation, water resources degradation, fisheries depletion and biodiversity loss amounted to 10% of the GDP by 1994 and it represented a substantial income loss to the country (EAD 1998, p.9). This calls for innovative mechanisms that take into account the participation of all stakeholders in the natural resource management in order to arrest the declining situation.

Historically, rural communities have acquired detailed knowledge, skills and strategies based on their interaction with the local environment over long periods of time. This stock of knowledge permeates the social structure and it is the basis for local-level decision-making in agriculture, food preparation, natural resource management, and a host of other activities in rural communities. It is an expression of African tradition, rich in intricacies. When properly understood, this Indigenous Knowledge (IK) demonstrates how communities appreciate their environment and constantly seek to live in harmony with nature. Often this knowledge expresses itself and is communicated through songs, taboos, totem animals, custom laws and practices, place names and nicknames, riddles and proverbs - all these have a story to tell (Matusse, 1995). Indigenous knowledge, therefore, refers to history, cultural heritage, and customs as developed in direct response to the physical and social realities...and in the context of Africa, indigenous means what is African, or what Africa has learned and adopted from other societies (Chavunduka, 1995). One scholar says that a particularly striking "philosophy of the indigens is empathy, selflessness, service to other beings, unconditional caring, honesty, accountability, respect for all members of your society ...." (Nxumalo, 1995).

Such a complex collection of knowledge, described as indigenous knowledge systems (IKS), ethnoscience or traditional wisdom (Kipuri 1995) evolves over time, has collective ownership and is communicated orally from one generation to the next. Before rural communities experienced any institutionalised foreign intervention, it is these indigenous knowledge systems that have regulated the level of exploitation and utilisation of environmental resources and ensured their survival. The land and its resources belonged to the people, held in trust by the chief, and the chief had the management authority as regards access to the resource, permission for usage, period of usage and even levels of usage. Resource utilisation was effectively regulated since this system was embedded in traditional governance structures of the society that excluded challenging authority of the chief. In the post-colonial era, the traditional structures became weakened as a result of partial or complete transfer of authority over the resource, to the different sectors of government.

The United Nations Conference on Environment and Development (UNCED), commonly known as the Earth Summit, which convened in Rio de Janeiro in June 1992 adopted a global plan of action. The Agenda 21 is considered a blueprint for a global partnership aimed at reconciling the twin requirements of a high quality environment and a healthy economy for all peoples of the world. Chapter 26 of Agenda 21 "Strengthening the Role of Indigenous People" provides a framework for recognising Indigenous Knowledge Systems (Box 1).

Box 1. Strengthening the Role of Indigenous People

“Indigenous people, who represent a significant part of the world’s population, depend on renewable resources and ecosystems to maintain their well-being. Over many generations, they have evolved a holistic, traditional scientific knowledge of their land, natural resources and environment. The ability of indigenous people to practise sustainable development on their lands has been limited by economic, social and historical factors. Governments should recognise that indigenous lands need to be protected from environmentally unsound activities, and from activities the people consider to be socially and culturally inappropriate. There should be national dispute-resolution procedures to deal with concerns about the settlement of land and use of resources. Some indigenous people may require greater control over their lands, and self management of their resources. They should also participate in development decisions that affect them, and in the creation of protected areas, such as parks.

Governments should incorporate the rights and responsibilities of indigenous people into national legislation. Countries could also adopt laws and policies to preserve customary practices, and protect indigenous property, including ideas and knowledge. Indigenous people should be allowed to actively participate in shaping national laws and policies on the management of resources or other development processes that affect them. Governments and international organisations should recognise the values, traditional knowledge and resource management practices that indigenous people use to manage their environments, and apply this knowledge to other areas where development is taking place. They should also provide indigenous people with suitable technologies to increase the efficiency of their resource management.”

Source: Keating (1993), Chapter 26

The significance of traditional knowledge is also incorporated in the International Convention on Biodiversity (Box 2). Previously, solutions offered by some development projects failed because they did not fit with the local knowledge and circumstances. Many organisations such as the World Bank and IUCN (International Union for Conservation of Nature and Natural Resources) have in the past decade began to directly address environmental issues through promoting environmental sustainability in their development efforts and emphasising country ownership (Asibey, 1995). It is now recognised that the local community's decisions to adopt or reject a new development project is strongly influenced by its existing skills, values and beliefs which are usually reflected in its indigenous knowledge. Thus, involvement of the community at all stages "is likely to improve project design by ensuring that full advantage is taken of the local technology and indigenous knowledge, and by ensuring that the project is fully adapted to the social organisation and value systems of the community" (Matusse, 1995).

Such a bottom-up approach empowers the community to take charge of resource management in development activities. It is to be admitted, however, that due to cultural hybridisation there has been inevitable loss of IKS. In any case, during the colonial era, this knowledge was often regarded as primitive, scorned at, marginalised and dismissed as worthless (Matowanyika *et al.*, 1995), so that preference towards being "modernised" or "westernised" has played a major role in eroding IKS. In addition, one of the biggest pitfalls is that most of African IKS remains unrecorded. It is, therefore, essential that researchers, extension agents and rural development experts study indigenous knowledge. Before imposing essentially foreign perspectives and technologies their appropriateness to the local setting should be examined.

This paper advocates the utilisation of available IK in the Lake Malawi Environmental Management Project. Various studies undertaken in Malawi over the previous years suggest relevant IK is available for the fisheries resource management, the stabilisation of land-use activities in the catchment, the integrated monitoring programme of the lake ecosystem, and for the design of the institutional arrangements of the programme.

Box 2. Convention on Biological Diversity

"The world's biological diversity - the variability among living organisms - is valuable for ecological, genetic, social, economic, educational, cultural, recreational and aesthetic reasons. The diversity is important for evolution, and for maintaining the life-sustaining systems of the biosphere. The conservation and sustainable use of biological diversity are of critical importance to meet the food, health and other needs of the growing world population. However, biological diversity is being significantly reduced by certain human activities, and it is vital to anticipate, prevent and attack the causes of this loss. Substantial investments are required to conserve biological diversity, but they will pay off with a broad range of environmental, economic and social benefits.

The world needs to conserve biological diversity and make sustainable use of its components in a fair and equitable way. Sustainable use means use in a way and at a rate that does not lead to the long-term decline of biological diversity. This will maintain its potential to meet the needs and aspirations of present and future generations. The uses include those of genetic material, which is any plant, animal, microbial or other material containing functional units of heredity. We also need to conserve ecosystems, which are groupings of living and non-living material that act as a unit. Countries have rights over their biological resources, but they are also responsible for conserving their biological diversity and for using their biological resources in a sustainable manner…

Many indigenous and local communities have a close dependence on biological resources, and nations should make use of this traditional knowledge of the conservation and sustainable use of biological diversity. Countries are to preserve and maintain such indigenous and local knowledge and promote its wider use. This is to be done with the approval and involvement of those who have such knowledge, and these people should benefit from the use of their practices…."

Source: Keating (1993) p.66

The scope of IK

Indigenous knowledge encompasses local knowledge that is developed outside the formal systems of science and education. It is embedded in community practices and institutions. It is locally managed and unique to a given culture or society. IK includes all information, experiences and practices community members have acquired over time to maintain or improve their livelihoods, to produce and to engage in social, cultural, and productive activities, to cope with crises or to manage natural resources. Rural people with their detailed, holistic, integrated knowledge of local ecosystems, are experts in their own right. They are capable of classifying and structuring environmental data and knowledge using their own terminology of understanding environmental processes and developing skills and strategies. IK is not static but becomes modified as the learning process demands fine adjustments. The community uses IK as the basis for decision making in agriculture, health care, food preparation, education, natural-resource management and as a coping mechanism in general. IK is primarily tacit knowledge of communities, elders, women, farmers, healers, artisans, spiritual leaders, etc. As such, it is not easily codifiable (World Bank, 1998).

Traditional ecological knowledge, traditional technical knowledge and traditional practices enable people make choices in the use of natural resources. Facets of such knowledge systems and practices include: local soil and biodiversity classification, traditional hunting norms and regulations, traditional medicine (both human and ethno-veterinary), traditional institutions of chieftainship, community based land allocation (such as for sacred groves), agricultural production systems (such as slash and burn), informal savings society, etc. Such a knowledge base persists and defines the limits of local culture. Thus in order to maintain the culture, IK must first be shared. Various methods of exchanging IK exist, including: apprenticeship; artifacts; demonstration; story telling, myths, legends, taboos and songs; training etc. Secondly, IK must be used, developed and preserved. Because IK is primarily developed and communicated outside the formal systems of science and education, it is frequently overlooked in the development process.

Rationale for integrating IK in development

The resilience of IK as it gets passed on from generation to generation implies that it is a component of human and social capital. This suggests that the community has had the opportunity to decide on what values, practices and beliefs to maintain, on the premise that there is general acceptance. Basically, community empowerment is achieved when choices are endogenous and any future activities based on such consensus are likely to be supported. In such situations, IK will increase efficiency and effectiveness, thus making IK a basis for sustainable development.

It is important to recognise that communities can be helped to make better use of IK for development. This can only happen by first learning from them (i.e. recognising and identifying the IK), validating, recording, documenting, storing it in a retrievable form, transfering it back to the communities, then disseminating successes to a wider community, and finally promoting the exchange of the successful IK between communities. Learning from the community and helping the community learn (a bottom-up approach) can lead to empowerment through enablement. The following approaches have proven to help in creating the environment for enablement:

- exchange knowledge of local practices in order to build local knowledge networks;
- engage researchers and experts in order to determine research agendas;
- engage authorities in dialogue in order to enhance good governance;
- dialogue with development partners in order to shape endogenous development agenda; and
- leverage local and global knowledge in order to integrate IK in development.

MAINSTREAMING IK INTO DEVELOPMENT ACTIVITIES

The Policy Environment

In the past, the value of harnessing global and local knowledge for development has not received the needed attention in developing countries in general and in Africa in particular. With the advent of Information and Communication Technologies this appears to be changing, especially since the early 1990's. In Malawi, the National Science and Technology Policy and the draft Science and Technology Bill have been endorsed by stakeholders in May 2001. The S&T Policy provides for the identification, development, protection and promotion of IK. This will help move IK from the realm of folklore into the development domain.

IK in Lake Malawi Environment Management Project (LMEMP)

IK could be the most important resource of small-scale fishing and farming communities in the Lake Malawi basin. There is no other resource that is owned, controlled and managed to the same extent as IK. The proposed LMEMP offers a unique opportunity to utilise the available IK for the fisheries resource management, the stabilisation of land-use activities in the catchment, the integrated monitoring programme of the lake ecosystem, and the design of the institutional arrangements.

IK-related activities would identify options and formulate actions for integrating the IK in the management of natural resources. It is a challenge in so far as the approach departs from the conventional practices of project implementation. The process will involve:
making an inventory of actors, resources, publications;
convening a national exchange involving researchers, NGOs, CBOs, local knowledge bearers, etc;
determining areas of relevant IK for the LMEMP; and
agreeing on action plan involving IK research, exchange and institutional arrangements.

The expected outcomes and impact include:
increased ownership of the management of the lake basin resource by local communities;
higher productivity of the lake basin resources; and
sustainable access to natural resources by communities.

Conclusion

There is a global recognition that indigenous knowledge has an important role to play in consonance with modern scientific and technological intervention in social and economic development and cultural and political transformation. IK is a valuable resource of the local community that needs to be used to the community's advantage. Incorporating IK in the LMEMP will provide not only a testing ground but will also offer an opportunity to understand and internalise IK in the development planning.

References

Asibey, E.O.A. 1995. Indigenous knowledge systems and prudent natural resource management. In: Matowanyika, J.Z.Z., Garibaldi,V. and Musimwa, E. (eds.). *Indigenous Knowledge Systems and Natural Resource Management in Southern African.* Report of the Southern African Regional Workshop, Harare, Zimbabwe, 20-22 April 1994, IUCN-ROSA, Indigenous Knowledge Systems Series No.1.

Chavunduka, G.L. 1995. Keynote address by Professor G.L. Chavunduka, Vice-Chancellor of the University of Zimbabwe. In: Matowanyika, J.Z.Z., Sibanda, H. and Garibaldi, V. (eds.). *The Missing Link: Reviving indigenous knowledge systems in promoting sustainable natural resource management in southern Africa. Proceedings of a Regional Workshop, held in Midmar, Kwazulu-Natal Province, South Africa, 23-28 April, 1995. IUCN-ROSA Indigenous Knowledge Systems Series No.2.*

EAD (Environmental Affairs Department). 1998. Environmental Management Framework. In: *State of Environment Report*. Malawi Government, Lilongwe.

Keating, M. 1993. *Agenda for Change: A plain language version of Agenda 21 and the other Rio Agreements, Chapter 26,* Published by the Centre for Our Common Future.

Kipuri, Naomi. 1995. International perspectives and importance of indigenous knowledge systems and institutions in natural resource management: contributions and experiences in the pastoral Maasai of East Africa. *Paper presented at the Workshop on Indigenous Knowledge Systems in Natural Resource Management. Held in Kwazulu, Natal Province, South Africa, 23-28 April 1995.*

Matowanyika, J.Z.Z., Sibanda, H. and Garibaldi, V. (eds.). 1995. The Missing Link: Reviving indigenous knowledge systems in promoting sustainable natural resource management in southern Africa. *Proceedings of a Regional Workshop, held in Midmar, Kwazulu-Natal Province, South Africa, 23-28 April, 1995. IUCN-ROSA Indigenous Knowledge Systems Series No.2.*

Matusse, R. (1995). Indigenous people and people-centred development: Are we moving South to meet ourselves? *Paper presented at the IUCN sponsored Workshop on Indigenous Knowledge Systems in Natural Resources Management in Southern Africa. Held at Midmar, Kwazulu-Natal Province, South Africa, 23-28 April 1995.*

Nxumalo, O.E.H.M. (1995). Keynote address by Professor O.E.H.M. Nxumalo: Indigenous knowledge systems and natural resource management in South Africa. *Delivered to the Regional Workshop on the Study and Promotion of indigenous Knowledge Systems and natural Resources Management in Southern Africa, at Fern Hill - Harwick, Natal Province, South Africa, 23-28 April 1995.*

World Bank. (1998). *Indigenous Knowledge for Development: A Framework for Action.* Knowledge and Learning Center, Africa Region, The World Bank.

Decentralised environmental management and the implications for fisheries co-management in Lake Malawi

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Abstract
Malawi has made a political commitment to decentralization through the recent appointment of the District Assemblies. Environment Management, has been decentralised since 1996. The Environment Act requires communities to participate actively at district level in State of the Environment Reporting (SOER) and Environmental Action Planning (EAP) and management. These processes have now become integral to the District Development Planning (DDP) system and are the responsibility of the Assemblies. Community consultation and participation is fundamental to the process. The resultant EAPs are implemented at target group level through micro-projects. As decentralised environmental management takes hold, communities will become better empowered to assess their own needs, to plan and act accordingly. In addition, the empowerment of the Assemblies as custodians of national laws through district by-laws will bring communities closer to policing and becoming resource managers. In addition, a degree of security of tenure can be secured through the by-law and this may allow a socio-economic change in community behaviour from "hunter/gatherer" to introduction of husbandry system options.

This paper elucidates the SOER, EAP and DDP process, its implications for the BVCs and the future role of community participation in the co-management of Lake Malawi.

Introduction
With the election of Councilors and the formation of District Assemblies in late 2000, Malawi has taken a great step closer towards making community based natural resource management (CBNRM) a reality. CBNRM and decentralization are inextricably linked (Balarin *et al*. 2001) in as much as the latter transfers power for administration and management from a central level to a lower, more appropriate, district, or sub-district level. Decentralization strives, through consultative processes and popular participation to empower communities to become pro-active in the planning and decision making process of development, and advocates for change in policy. It also brings them closer to being the custodians of the resource with self-imposed by laws and more secure access rights.

Tools to achieve this are now in place, described in the Local Government Decentralization Strategy (OPC, 1998)(LGDMP, 1999) and the Strategy for Decentralised Environmental Management (DEM)(EAD, 2000, 2001 a, b and c).

The 1999 Fisheries and Aquaculture Policy of Malawi has "collaborative management" as one of its key objectives. Subsequent, subsidiary legislation for the first time in the history of fisheries development in Malawi, empowered communities through the Act, to formulate by-laws that can self-govern the management of the fisheries resources in their locality. It would be myopic to think that the fisheries legislation alone is adequate. To be successful, any fisheries natural resource management strategies would need to be coupled with decentralization, and include cross-cutting elements from the recent trends in other sectors (notably forestry, wildlife, water, etc). The stage, is set, now more-so than before for Malawi to embark on some of the first steps towards fisheries co-management.

CBNRM Defined

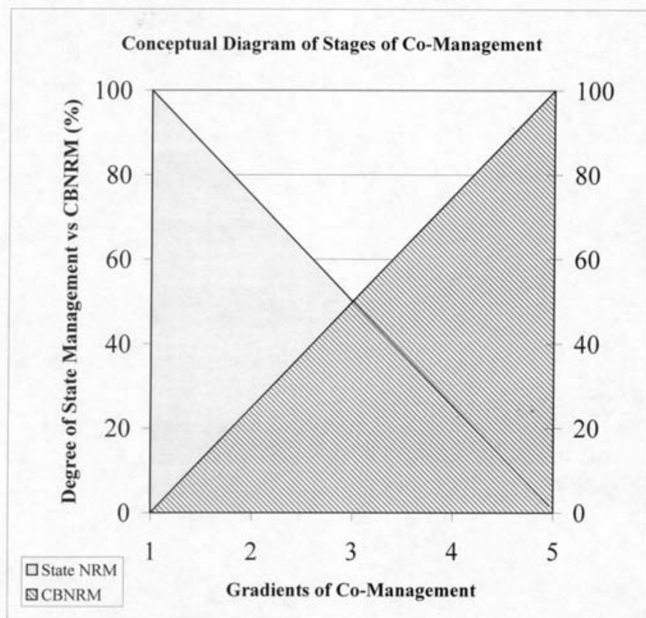
Guiding Principles of CBNRM
Some guiding principles for CBNRM are, in brief (adapted from COMPASS, 2000a):

a. Communities should be prime beneficiaries and take the lead role, actively participating in identifying, planning and implementing CBNRM activities.
b. CBNRM activities should be managed by democratically elected institutions or committees linked to the local authority.
c. Communities must develop clearly defined constitutions for their CBNRM institutions and establish by-laws for CBNRM in conformity with national policy.
d. User groups and boundaries must be clearly defined with clear rights of access, lease or ownership.
e. Natural resources should be treated as economic goods and any intervention should be seen to have tangible value added benefits to communities.

f. CBNRM programs must be gender sensitive, promote equitable sharing of costs and benefits and be supportive of community priorities.

Co-management vs CBNRM

Most natural resources in Malawi are state owned and have largely been state regulated for the benefit of all present and future generations. However, in recognition that management initiatives that do not involve the resource users, is not sustainable, CBNRM strategies aim to place responsibility for resource management at the lowest appropriate level. A spectrum of co-management options emerge (Figure 1)(Balarin *et al*. 2001). Essentially, the current situation of 100 % state management of resources, should gradually giving way to progressively more resources coming under varying degrees of joint management between state and user, until eventually, for some resources, the community is 100 % in control.



CHARACTERISTIC TRENDS			
Management System	State management	→	Community managed
Land Tenure System	State or Commons	→	Individual or Community
Policy/Laws	State policy/laws	→	Community by-laws
Resource Ownership	State owned	→	Community owned
Resource Users	Open access	→	Community regulated

Figure 1. Conceptual Diagram of the different stages of co-management

Husbandry vs Natural Resource Management

The NEAP (1994) identified that the nexus to environmental degradation in Malawi is poverty and illiteracy. Because of poverty, foraging from natural resources has been a fundamental sustainable livelihood strategy, especially in times of need. CBNRM strategies should therefore not only aim at the sustainable management of the status quo of ecosystems, (ie. cropping according to sustainable maximum yield), it should seek out sustainable economic benefit streams that offer incentives to the user to diversify into alternative, value added uses or income generating activities. For CBNRM to succeed, extension strategies would have to introduce the resource user to knowledge of "best practices" of equal or better economic significance.

Husbandry of the resource is one option capable of sustainable enhancement of production. To maintain the needs and pressures of growing human populations, implementation of CBNRM needs to bring about change in community behaviour. Communities need to change from present practices of hunter/gatherer scenario, and move a socio-economic step forward to the next stage in evolution of husbandry systems (ie. the active farming of resources) (see Figure 2)(Balarin *et al.* 2001).

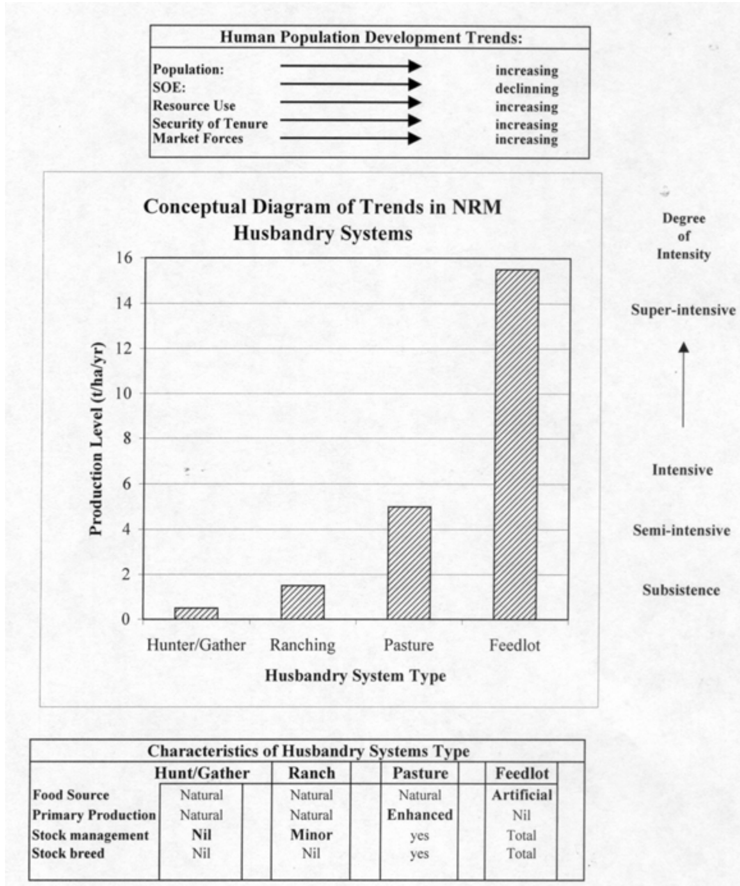


Figure 2. Conceptual diagram of evolution trends in natural resource husbandry.

Institutional Framework

History of National Environmental Legislative Framework

The history of some of the more relevant steps in legislative and policy development that have had influence on environmental management and fisheries are as follows:

- 1994: National Environmental Action Plan (NEAP)(Vol I and II)
- 1996: Environment Management Policy
- 1996: Environment Management Act
- 1996: Decentralization Policy
- 1997: Fisheries Conservation and Management Act
- 1998: EIA Guidelines
- 1998: Environment Support Program (ESP)
- 1998: First National State of the Environment Report (SOER)
- 1998: Local Government Act
- 1999: Fisheries and Aquaculture Policy
- 2000: Subsidiary legislation (Community by-laws)
- 2000: First Lake Chilwa State of the Environment Report
- 2000: First District SOERs
- 2001: First Lake Chilwa Management Plan.
- 2001: First District EAPs
- 2001: Poverty Reduction Strategy Paper (PRSP)

The NEAP was Malawi's response to Rio 1992, and set the stage for the formulation of the Environment Policy and Act. The Environment Management Act of 1996 placed responsibility for environmental management at the district level. Environmental monitoring, through State of the Environment Reporting (SOER) every 2 years and development of mitigation measure through Environmental Action Planning (EAP) every 5 years, became the responsibility of the Assemblies assisted by a Environment District Officer (EDO).

The Environment Act established a clear role for the mainstreaming of in natural resource management (NRM) in the local government structures, notably the Assemblies, Area Development Committees (ADC), Village Development Committees (VDC), and associated community institutions. Environment Impact Assessment (EIAs) were also a legal requirement for all development projects and the EIA guidelines established community consultation as an essential part of the process. Despite the Decentralization Policy of 1996, it was however not until the Local Government Act of 1998 that decentralization became a national objective, to place administrative authority for natural resource management (NRM) at the lowest appropriate level. This became effective in November 2000, when local government elections lead to the formation of the District Assemblies.

The legal and political framework is now in place to empower communities to take a more pro-active role in NRM. The Environment Act and Local Government Act have become integrated through the Environmental Affairs Department (EAD) strategy for decentralised environmental management (EAD 2000, 2001 a, b and c). SOERs and EAPs are now integral parts of the decentralised, District Development Planning (DDP) process (OPC, 1998).

The District Development Planning Framework and Fisheries Co-management

In the various stages in the District Development Planning (DDP) process, Figure 3 (OPC, 1998), community participation is essential. The DDP cycle from situation analysis, preparation of a district socio-economic profile (SEP) culminating in a District Development Planning Framework (DDPF) is synonymous with SOER. SOER is a process of information compilation and analysis and a tool for information dissemination for better planning and decision making. The process assists communities and planner alike to identify environmental problems, and to illustrate trends and spatial distribution of pressure, state and response indicators (EAD, 2001 a). Prioritization of environmental concerns or hot spots, leads to the formulation of appropriate development objectives and strategies.

The next stage of the cycle from identification of mitigating actions, development options and formulation of the DDP, for the environment sectors, is synonymous with the DEAP. DEAPs are community decisions for mitigation or environmental management of problems. Communities decide for each priority environmental concern, the action, by who, where, when and how (EAD, 2001 a.). Thereafter, once approved by the Assembly, DEAPs are implemented through community based environmental micro-projects and an element of participatory M&E is involved.

In so much as the DDP process is consultative and community based, so are the preparation of SOERs and EAPs. The process is flexible. It can be applied as a "fast track", a means to identify priority hot spots that need immediate intervention even before the SOER and DEAP process is complete. The SOER and DEAPs are divided into chapters by sector, and fisheries is dealt with as a separate Chapter. The first district based SOERs and DEAPs are now under active preparation. Table 1 summarizes the status for the fisheries sector around Lake Malawi.

Table 1. Status of decentralised environmental management in Lake Malawi Districts

District	Year DESC Formed	Status of SOER		Status of EAPs	
		DSOER	ADC SOER	DEAP	ADC EAP
Karonga	1999	Draft	Final	Draft	Final
Rumphi	2000	Draft	underway	Draft	underway
Likoma	2001	not started	not started	not started	not started
Nkhata Bay	1998	Draft	underway	Draft	underway
Nkotakota	2000	Draft	underway	Draft	underway
Salima	2000	Draft	underway	Draft	underway
Dedza	1998	Draft	underway	Draft	underway
Mangochi	1998	Draft	underway	Draft	underway

Key: DESC - District Environment Sub-Committee; DEAP - District Environmental Action Plan; DSOER - District State of the Environment Report; ADC - Area Development Committee

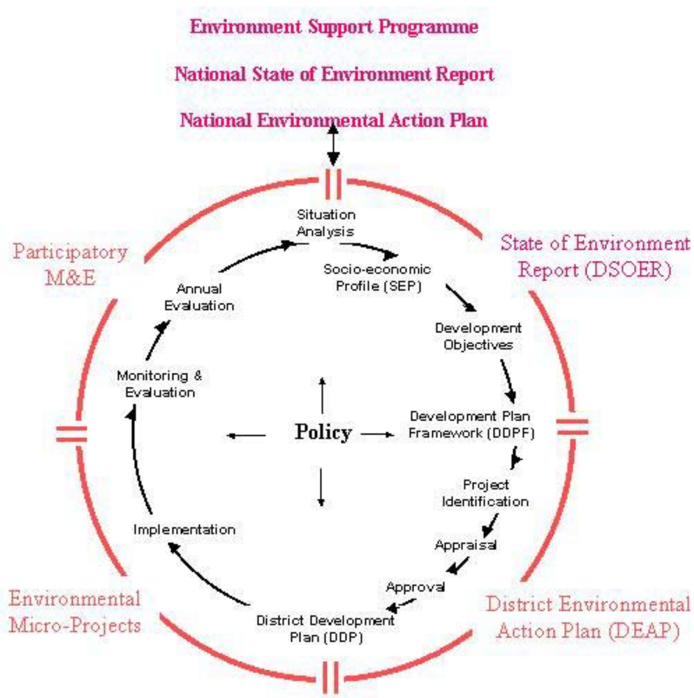


Figure 3. SOER and DEAP in relation to District Development Planning System

National Environment Management Framework and Fisheries Co-management

The framework document, the National Environment Policy of Malawi recognizes the importance of CBNRM and calls for "national, regional and district development plans to integrate environmental concerns, in order to improve environmental management and ensure sensitivity to local concerns and needs".

The DEM strategy (EAD, 2000 a) allows for community based plans, separated by sector, to feed upwards from community to VDC to ADC level and be consolidated into the DEAPs. DEAPs aggregate into the NEAP from which emerge sector investment programs (SIPS). All NRM SIPs are compiled into the Environment Support Program (ESP) and further, are consolidated into the national Poverty Reduction Support Program (PRSP), the umbrella document for all national plans and government budgeting (Fig 4 a and b).

Likewise, the SOERs from communities, pass to VDC to ADCs and consolidated in the DSOERs, are similarly aggregate into the NSOER and become the M&E tool of the NEAP. The SOERs are reported by the Minister to parliament every year and thereby provide a powerful opportunity for communities and districts to communicate their concerns and needs to the highest policy and decision making level.

The institutionalization of the SOER DEAP process as part of the tools of fisheries co-management would provide the sector with a powerful tool for communities to lobby at the highest level for resources.

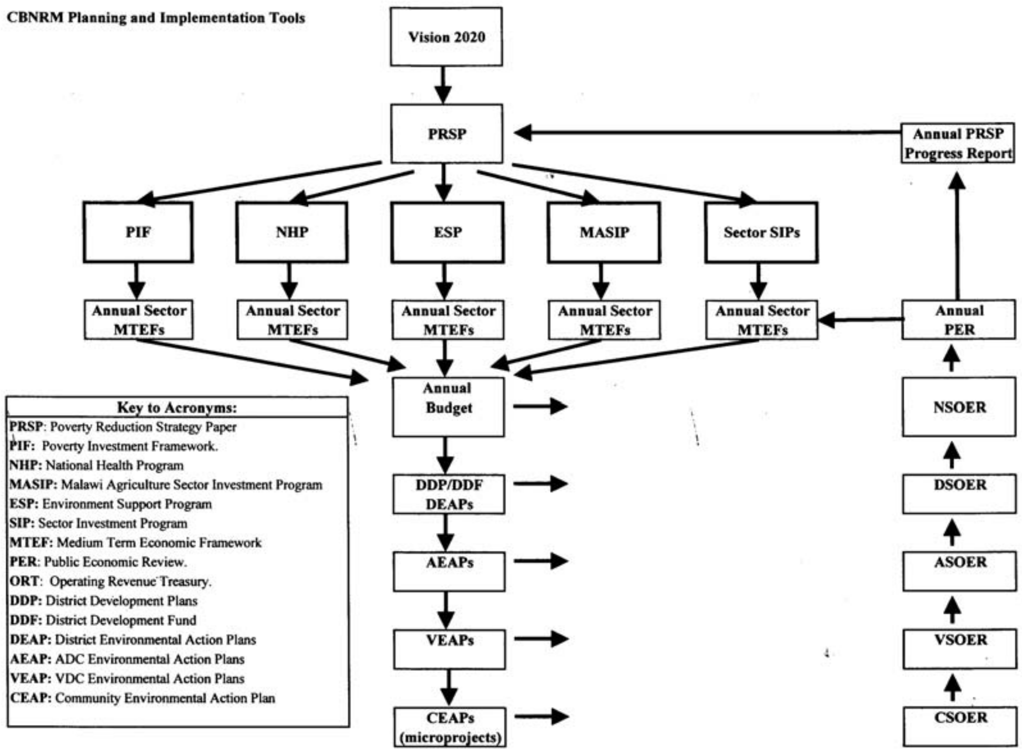


Figure 4a. CBNRM and the PRSP (adapted from the PRSP working group).

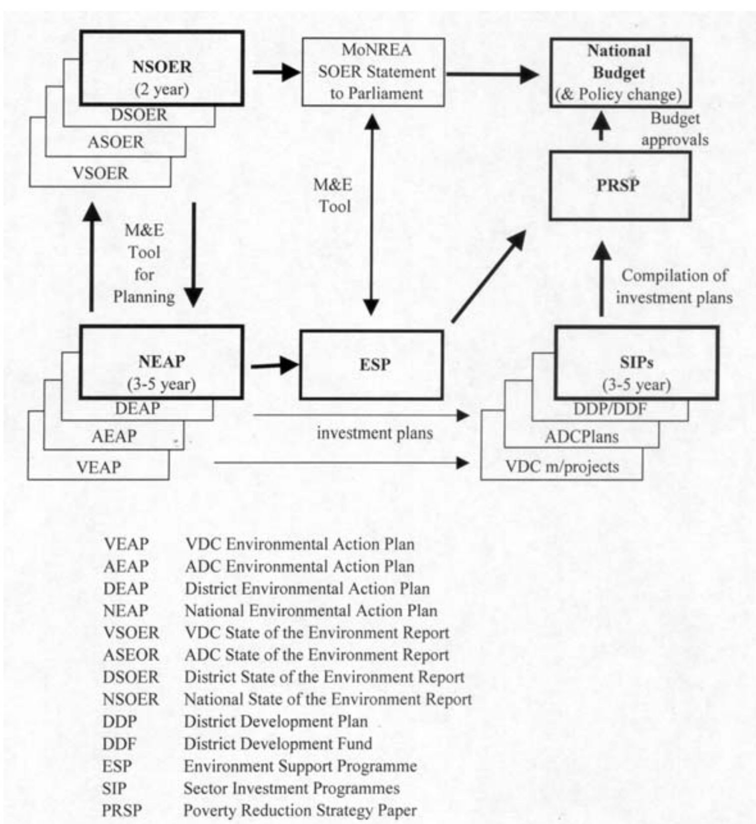


Figure 4b. The national framework for integration of EAPs into the national Budget.

National Institutional Framework for Environmental Management

Strategic objectives to achieve CBNRM would be to ensure that the emerging local government structures at District Assembly, Area Development Committee (ADC), Wards and Village Development Committee (VDC), provide a logical institutional anchor point for community based organizations such a Beach Village Committees. CBNRM should therefore be seen as a mainstreamed role of local government, and fits within the existing institutional framework for decentralised environmental management (Figure 5), notably:

- Parliament is the highest policy making authority and it is advised by a Parliamentary Committee on the Environment (PCE) that serve as the watchdog of policy and the state of the environment.
- The Ministry co-ordinates the implementation of policy, law enforcement and EIA inspections, establishing standards and maintains international representation, co-ordinating conventions and donor support. The Ministry is advised by the National Council on the Environment.
- The various NRM departments administer policy directives, formulate national plans and policy, guiding the districts, provide capacity building support, facilitate EIAs and compile sector NSOERs and NEAPs. To co-ordinate these sectors, national environmental focal points have been established and there is a National Steering Committee of these focal points, made up of the directors of each sector.
- At district level, the Assemblies co-ordinate preparation of the SOERs and DEAPs, and facilitate the implementation of micro-projects and awareness campaigns.
- The Assembly is assisted by a District Environment Sub-Committee (DESC)(Figure 6) made up of focal points from each of the Technical Directorates, assisted by the EDO and anchored in the office of the District Planning Director. They serve to prepare the SOERs and EAPs, train the ADCs and VDCs, oversee micro-projects and generally mainstream environmental management into all planning processes at all levels.
- Environment management should be mainstreamed in the roles of all the ADCs, Wards and VDCs, all the way down to the communities.

Decentralization and Fisheries Management

Fisheries management in Malawi suffers from a number of concerns (Mapila, 2001), amongst which are:

- A poor track record of enforcement of the law.
- Unrestricted access due to problem in allocating security of tenure.
- Poor access to research knowledge by the user groups.
- Slow take off of aquaculture.
- No national or regional coordination mechanism.

Under the Local Government Act, envisaged is that Assemblies will establish by laws and that these shall be extended all the way down through the subsidiary authorities to community level. In fisheries, the fishing communities could be governed by district by-laws which take their point of departure from the national law. The assemblies could mobilize their legal and administrative powers to:

- Police the resource, monitor use patterns and enforce regulations through the district police system.
- Policing by the Assembly, would free up the Fisheries Officer, allowing a change from a policeman role to becoming a friend of the community and a technical advisor whose sole purpose would be to impart knowledge to change fishermen’s behaviour.
- District by laws could provide rights of access through allocation of lease rights to VDCs who pay lease fees based on limited entry licensing. They in turn through the BVCs, allocate resource use rights and police those rights through their constitutions. Security of tenure will ultimately lead to behaviour change and see the introduction of husbandry systems.
- The Local Government Act empowers one or more Assemblies to come together to form an Inter-district Committee for common resource management like Lake Malawi. This could be extended to provincial administration in neighbouring states.

In the coming years, the Fisheries Department will have to embark upon a devolution strategy for the sector. Some of the above becomes food for thought.

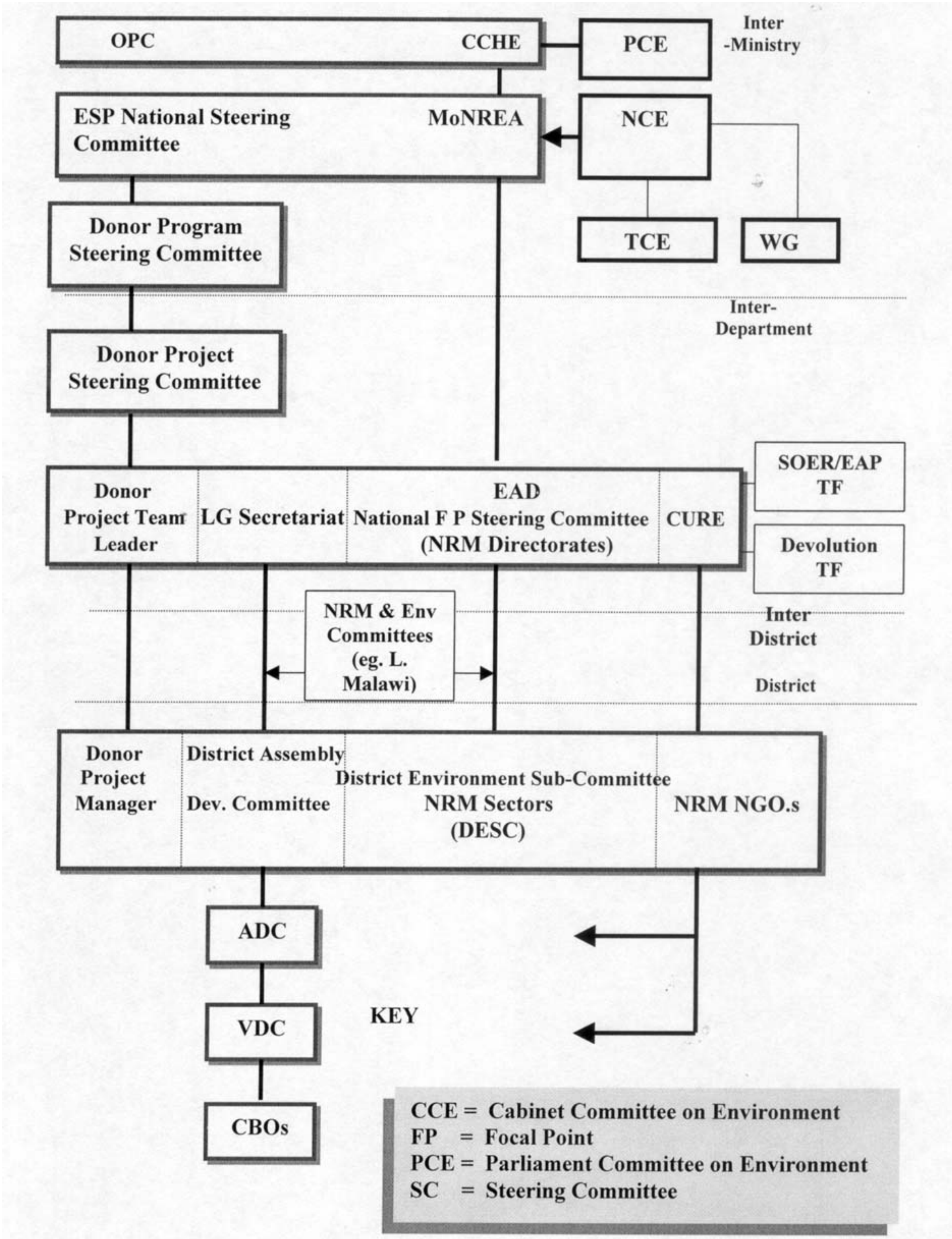


Figure 5. Institutional framework for the coordination of environmental management

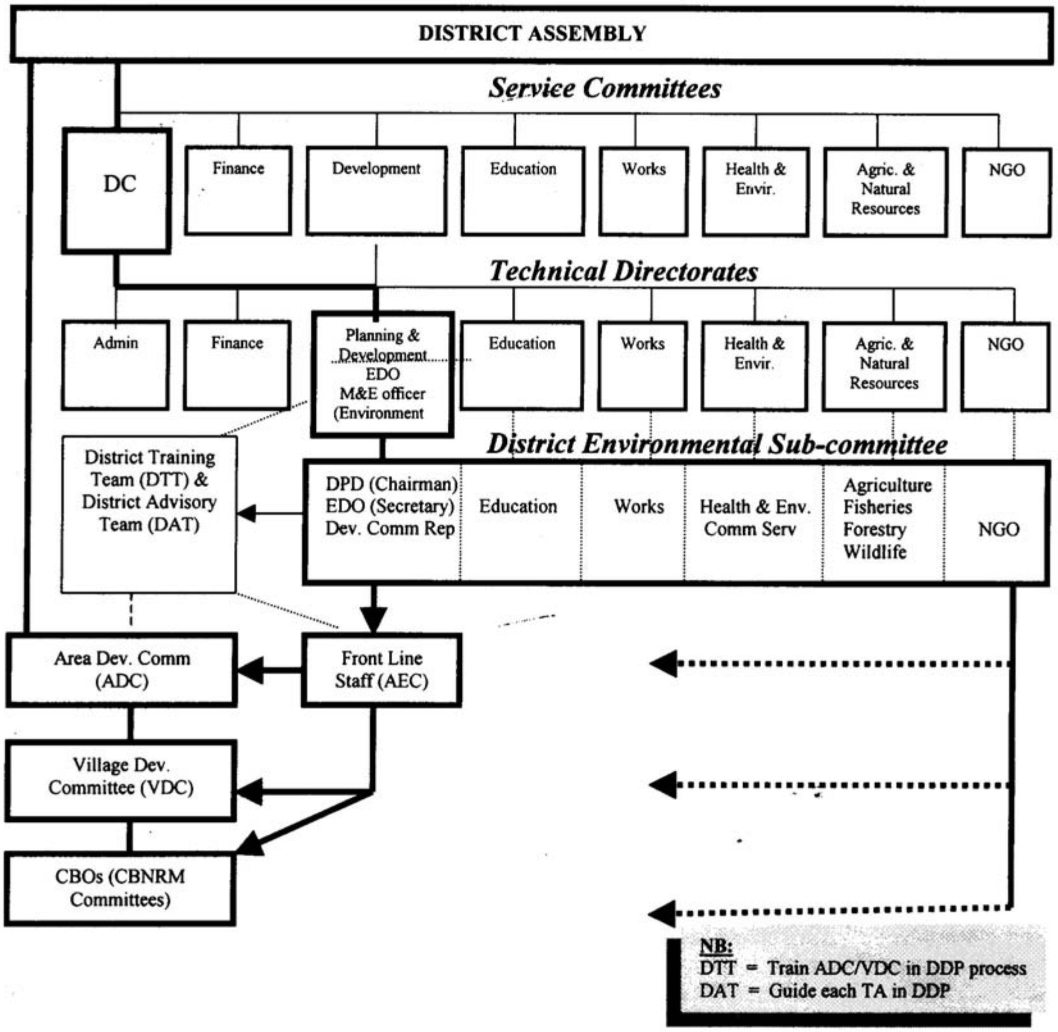


Figure 6. Institutional framework for decentralised environmental management.

Implications for Fisheries Co-management

In conclusion, in fisheries the implications of decentralization are that the Beach Village Committees (BVC) now find an anchor point in the District Assembly for legal recourse to enforce their constitutions through district by-laws. In addition, access rights through leasehold becomes possible and this will bring with it a change in behaviour favouring a more husbandry type approach to management.

In addition, the BVCs through participation in the SOER process are able to undertake a consultative situation analysis, to better understand their problems and to identify problem areas or environmental “hot spots” and bring these to the attention of the authorities. SOERs are published as district reports, consolidated into national reports and presented to Parliament every year. This provides communities a powerful tool to lobby at the highest level for support. SOERs allow community prioritization of problems to be dealt with through EAPs.

The participatory process of EAP preparation means that BVCs participate in planning and take ownership of their own remedial actions to mitigate against prioritized problems. Generally these are expressed in the form of environmental micro-projects and would be included in the DDPs. At an inter-district level, the 8 Districts surrounding Lake Malawi will be able to come together and their combined DDPs would make up a coherent and comprehensive Lake Malawi Management Plan. A similar initiative has already been completed for Lake Chilwa. Under the Local Government Act, the 8 districts could form an inter-district committee to manage Lake Malawi.

The DDPs provide the District Assemblies with a basis for seeking funding from government, donors and other agencies. Currently available to the Lake Malawi BVCs are potential environmental micro-project funds from Danida, World Bank, Malawi Environment Endowment Trust (MEET), COMPASS/USAID, EU and GTZ.

Key References

Balarin, J. D., Jensen, A. and Ndovi, W (2001) Developing CBNRM Planning and Implementation Tools. Proceedings, National conference to Develop CBNRM Strategic Plan for Malawi, COMPASS: 14 p.

COMPASS (2000a) Workshop on Principles and Approaches for CBNRM in Malawi. COMPASS Document 10: 100p (March 2000).

COMPASS (2000b) Draft Strategic Plan for CBNRM in Malawi. Compass Document 23: 56p (November 2000).

EAD (2000) Strategy for Decentralization of Environmental Management. EAD publication: 50p. (Draft October 2000).

EAD (2001a) Decentralised Environmental Management Manual. Vol. I: A guide to

SOER, DEAP and micro-project preparation. EAD: 126p. (Draft January 2001).

EAD (2001b) Decentralised Environmental Management Manual. Vol. II: Data Capture Tool for SOER. EAD publication: 75p. (Draft January 2001).

EAD (2001c) Decentralised Environmental Management Manual. Vol. III: A guide to environmental micro-projects. EAD publication: .. p(in preparation, April 2001).

LGDMP (1999) Village Action Planning Manual for AEC level facilitators. LGDMP publication:160p.

Mapila, S. A. (2001) Towards Responsible Development of the Fisheries Sector in Malawi. Department of Fisheries: 41 p.

OPC (1998) District Development Planning Handbook. OPC publication:128p. (March 1998).

Status of the small scale fishery in Malawi

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Abstract
Most of Malawi's population is dependent on fisheries directly or indirectly as a source of food security, livelihood and income. Total catch in the recent years for the major water bodies, Lake Malawi, Lake Malombe, Lake Chiuta, Upper Shire and Lower Shire have declined from an average of 60 thousand metric tons in the period 1976-1990 to 49 thousand metric tons in 1991-1999. Over the same period, the number of fishermen increased by 27%, similarly the number of fishing gears and fishing crafts has also increased.

Introduction
The fish stocks of Malawian waters are, undoubtedly among the most important natural resources of Malawi. Out of the 120000 km^2 area covered by Malawi, 20% is water (Weyl, 2001). There is therefore little doubt that a large number of Malawi's population depends directly or indirectly on the fishery as a source of food security, livelihood and income. The value of fish does not lie only in their scientific interest, but also in their primordial nutritional status. It is a known fact that fish provides some 70% of the animal protein consumed by Malawians (Mkoko 1992, cited by Ribbink (1994) and Turner (1994b)). Currently the fishery employs over 48 000 fishermen (Weyl *et al*. 2000) and fish also contributes about 4% to the Gross National Product (GNP) of the country.

However, it has been noticed in the recent years that fish catches in Malawi have declined. The reasons are: the ever increasing fishing effort in the shallow waters; the absence of alternative employment; the rapidly growing human population, which exerts an increased fish demand, on the overexploited stocks (Turner 1995) and the use of destructive fishing gears.

The aim of this report is to provide an account of the status of the different fisheries and fish stocks of the major water bodies of Malawi. In agreement with the current practices in fisheries management an attempt is made to apply the principles of the precautionary approach. The FAO Code of Conduct for Responsible Fisheries, adopted in 1995 stipulates in article 7.5: "States should apply the precautionary approach widely to conservation, management and exploitation of living aquatic resources in order to protect them and preserve the aquatic environment. The absence of adequate scientific information should not be used as a reason for postponing or failing to take conservation and management measures.''

The findings presented in this report are based on catch-effort data collected by the Department of Fisheries during the 1976-1999 period. The data was used to calculate CPUE (**C**atch **P**er **U**nit **E**ffort) and relative effort. In the analysis of catch and effort data, standard methods have been applied. For details of the methodology, a reference is made to Sparre and Vanema's Introduction to Tropical Fish Stock Assessment (FAO 1992) where treatment of catch and effort data are explained in detail.

Total catch in Lake Malawi
Lake Malawi, the southern most of the African Rift Valley Great Lakes, supports fisheries yielding some 30,000 tons of fish annually from waters controlled by Malawi (Tweddle and Magasa, 1989). Over 88% of the total landings in Lake Malawi, come from the small-scale fishery although there exists a large-scale commercial fishery.

Total catches in the small-scale fisheries in Lake Malawi, for the period 1976-1999 is shown in Figure 1. A clear increasing trend in the period 1976-1989 is observed and peaks of more than 30 000 metric tons was attained in 1987, 1989, 1996 and 1997. Catches fluctuated widely during the period 1990 – 1999 and the highest catch of 40 000 metric tons was recorded in 1996. The reason for this was the good usipa catch (*Engraulicypris sardella*) in that year.

Figure 2 shows the average contribution to the total Lake Malawi small-scale fishery by the various districts. Mangochi and Salima accounted for 45% and 18% respectively. The high fish yields from these two districts are mainly due to the suitable limnological conditions. In addition to the suitability of the area for highly productive fishing methods such as trawling and seining, the broad shallow shelf of these areas supports high benthic productivity. The shape of the lake and the direction of the prevailing winds mean that seasonal upwelling of nutrient-rich water occurs mainly in the south. (Eccles, 1974 cited by George F. Turner). Most of the rest of the lake is often rocky and very deep and the fisheries are mainly dependent on pelagic zooplankton-feeding fish, which in turn are supported by low pelagic primary productivity.

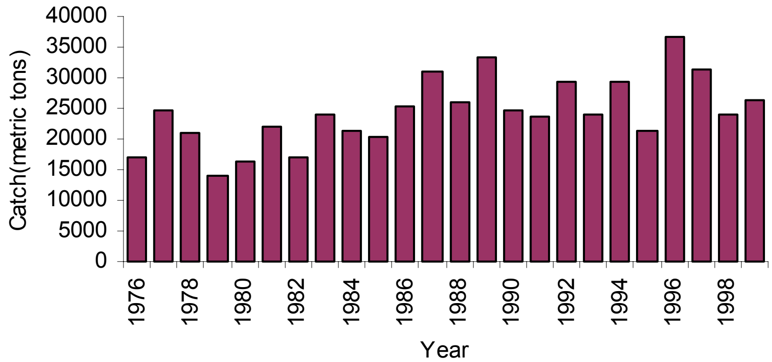


Figure 1. Total traditional catch in Lake Malawi for the period 1976 – 1999.

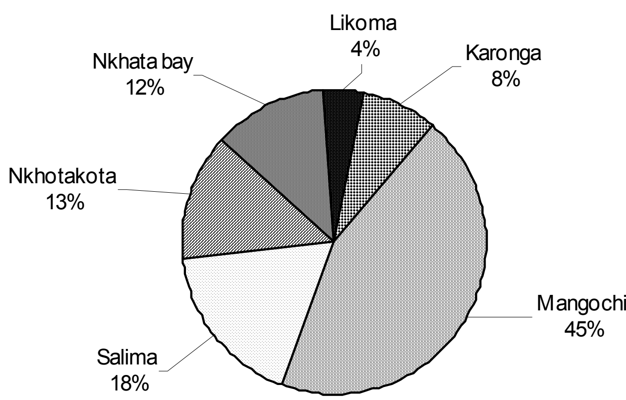


Figure 2. Contribution to the total catch in Lake Malawi by district.

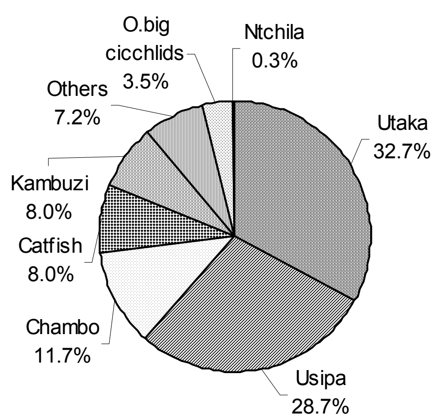


Figure 3. Average species-group contribution to the total Lake Malawi catch

Catch composition by species group reveals that utaka has been the main dominating group with an average contribution of 32.7%, followed by usipa (28.7%) and chambo (11.7%)(Figure 3). These three species groups yielded 73.1% of the total average catch. Contribution by the other species groups has been in the range 0.3%-8%.

Fisheries in Lake Malawi appear to be stable when analysed as a bulk biomass. However, when analysed at species or genus level, some of the most important stocks seem to have declined. The most apparent cases are those of chambo stocks in Lake Malawi, which are considered to be in the state of decline and precautionary management action, are recommended due to the excessive fishing effort (Pálson *et al.* 1999).

Trends in fishing units.

The number of fishermen operating in the waters of Malawi in the period 1990-94 (10 601-10 602) has been relatively stable but has increased by 27% in the following years (Figure 4). Also, within the same period, the number of assistants/crew increased by 37%. Currently, there are about 48 000 people that are directly employed in the fishery (Weyl *et al*. 1999).

Dugout canoes operating in the waters of Malawi counted 9671 – 11457 in the period 1990 – 1999 signifying an increase of 18% (Figure 5). The number of plank-boats with engines over the same period 1990 – 99 has increased by 48% (360 – 534). However figures of 1993 and 1994 (449 393) are probably errors, since a decrease or increase of 50 units within a year is very unlikely. Plank-boats without engines have also increased by 38% (2 167 – 2 991) over the same period although in 1995 only 1 361 units were counted. This again is obviously an error since a change of such a scale is by no means reasonable.

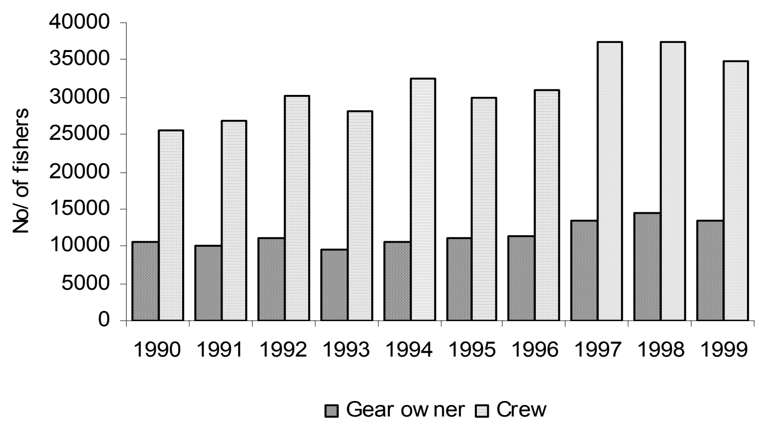


Figure 4. Number of fishermen and assistants in Malawian waters 1990 – 99.

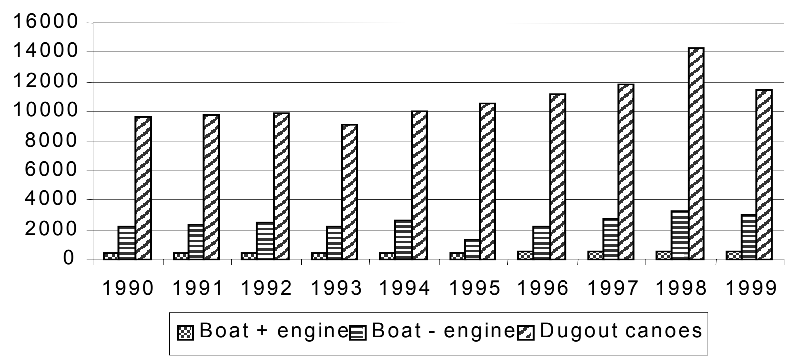
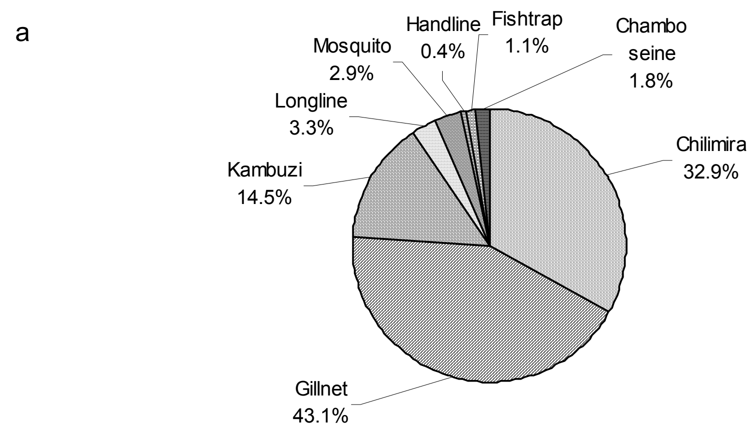


Figure 5. Number of small-scale fishing crafts Malawi for the period 1990-1999.

The most important gears in Lake Malawi are gillnets, chilimira nets and kambuzi seines. The importance has been determined by looking at the amount of catch that each gear contributes in Lake Malawi. (Figure 6). The three gears contributed over 90% to the total Lake Malawi catch, gillnet (43.1%), chilimira (32.9%) and kambuzi seine (14.5%). Long-lines, chambo seine, mosquito net, fish trap and hand-lines are of intermediate importance. They contributed less than 10% to the total Lake Malawi catches and ranged from 0.4% - 3.3%.

Contribution of the total catch by gillnets over the 24-year period has been relatively stable at an average catch of 7 thousand metric tons. However, chilimira's contribution has increased into the late 1990s from an average of 10 thousand metric tons in the 1980s to 16 thousand metric tons in the 1990s. Kambuzi seine catches have fluctuated around an average catch of 2 thousand metric tons. The number of gillnets and chilimira have increased two-fold over the period 1990-1999 (from 19 699-43 318 for gill nets and from 1 479-2 568 for chilimira nets). The number of kambuzi seines however shows a declining trend over the same period, from 654 gears in 1990 to 343 gears in 1999.



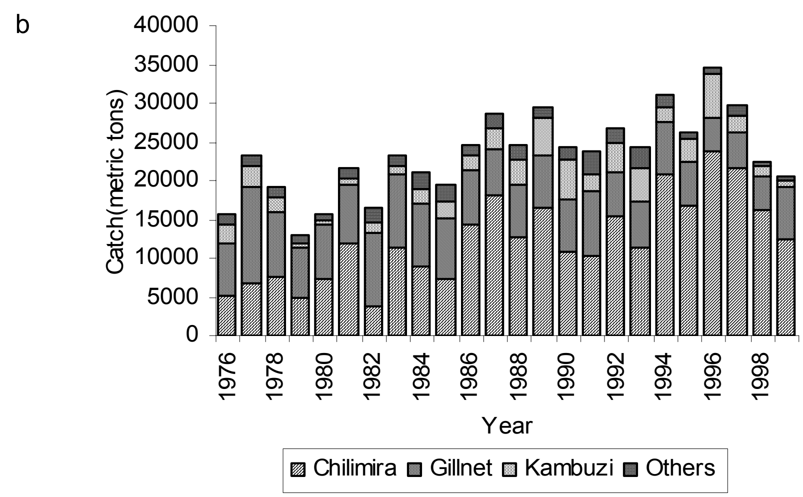


Figure 6. Gear contribution to the (a) total Lake Malawi catch and (b) annual Lake Malawi catch from 1976 to 1999.

Catch and effort in Lake Malawi.

Catch, effort and CPUE in the southeast arm small-scale fishery is shown in Figure 7. Unless otherwise stated, effort refers to the relative effort (YT(y) /R(y) where YT(y) is the total yield of all gears and R(y) is the sum of relative CPUE weighted by the yields in year (y), normalized effort where all the small-scale fishing gears have been standardized to a common effort unit. CPUE also refers to weighted, relative CPUE where relative catch per unit effort of each gear has been weighted by the catch taken by that gear (For further details see; Sparre, P. & Venema, S.C., 1992. Introduction to tropical fish stocks assessment. Part I- Manual. FAO Fisheries Technical Paper, 306/1, 376 pp).

Catches have increased into the 1990s from 5 000 metric tons in the 1970s to 10 000 tons and a highest catch of about 20000 metric tons recorded in 1996 mainly due to high usipa catches in that year. Effort increased in the mid 1980s and has been at a relatively high level in the 1990s. CPUE however has declined except the high value recorded in 1996.

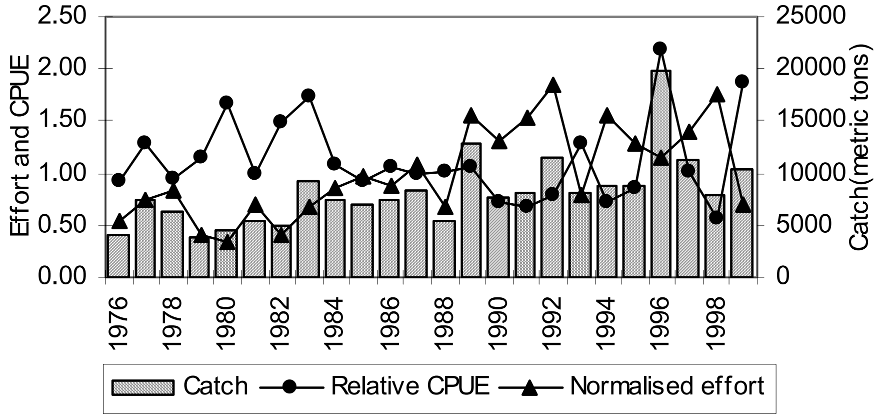


Figure 7. Catch, effort and CPUE in the South East Arm of Lake Malawi for the period 1976 – 1999.

To obtain an estimate of maximum sustainable yield (MSY) for the southeast arm of Lake Malawi, relative effort and relative CPUE for the period 1976 – 1999 was used. There was fairly good correlation between ln(CPUE) and effort. The Fox surplus production model was fitted to the data to yield initial MSY estimates for the southeast arm fishery (Figure 8).

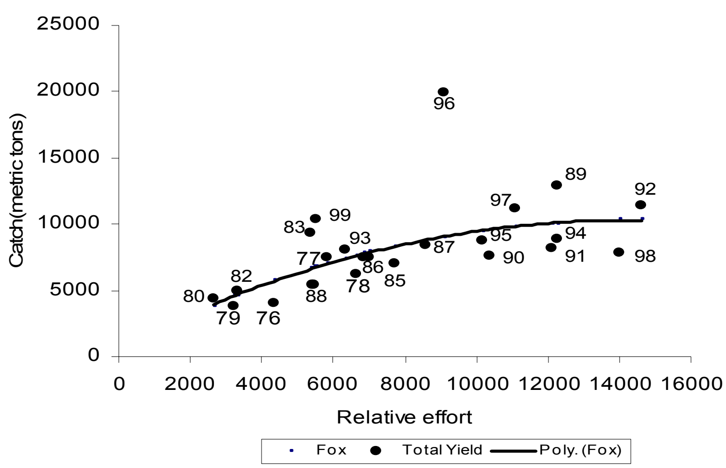


Figure 8. Fox surplus production function of the SE Arm 1976-99

The statistical quality of the data is fairly reasonable since a regression of CPUE and effort gave a coefficient of determination of 57%. The results of the Fox model are estimated at 10 502 metric tons at an effort level of 16 667 units. It is however evident that MSY of 10 000 tons was exceeded in the late 1980s to mid 1990s. Although catches seem to be increasing, the increase in effort in the recent years might have remarkable effects in the long run.

Catch, effort and CPUE in the southeast arm traditional fishery is shown in Figure 9. Catches have fluctuated throughout the period, around a mean of 6 000 tons. Effort was relatively low until late 1980s when it increased and has remained at that high level, but fluctuating in the 1990s. CPUE however has declined in the early 1980s from high values in the late 1970s and has since remained at that low level.

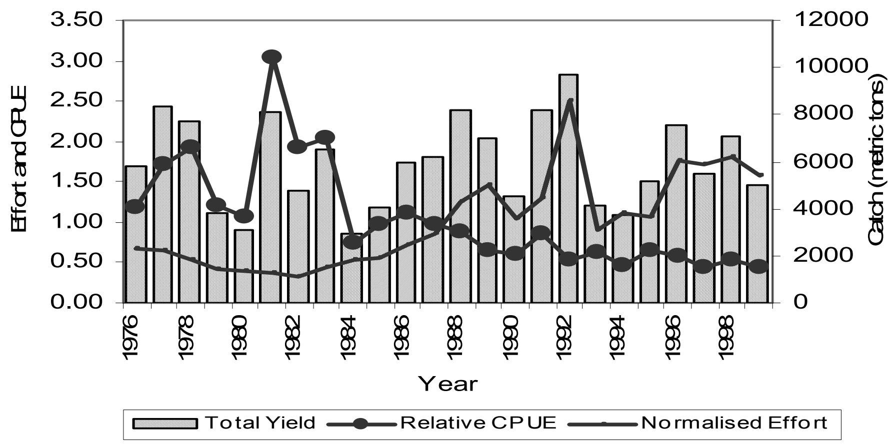


Figure 9. Catch, effort and CPUE in the South West Arm of Lake Malawi for the period 1976 – 1999.

To obtain an estimate of MSY in the South West Arm of Lake Malawi, relative effort and relative CPUE data was used. There was a good correlation between ln CPUE and relative effort. The Fox surplus production model was fitted to the data to yield initial MSY estimates for the SW Arm fishery (Figure 10). The statistical quality of the data is also fairly reasonable since a regression of CPUE and effort gave a coefficient of determination of 58%.

The results of the Fox model are estimated at 6 839 metric tons at an effort level of 10 000 units. It is however evident that MSY was attained at relative effort levels that exceeded current effort and it appears that fMSY was exceeded in the in the 1980s to 1990s with no stock recovery (Weyl *et al*, 2001 in press)

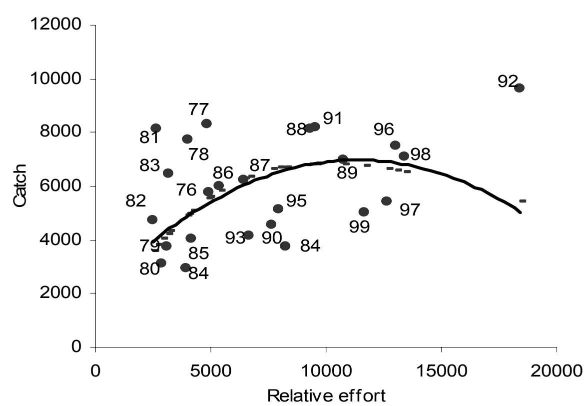


Figure 10. Fox surplus production function of the SW Arm 1976-1999.

Catch, effort and CPUE in Domira-bay for the period 1976-99 are shown in Figure 11. Catches have declined from high values in the 1970s and late 1980s. Effort however has remained relatively stable except the high value in 1989. CPUE has declined from high values in the early 1980s and has remained at that low level.

Catch, effort and CPUE in Nkhota-kota for the period 1976-1999 are shown in figure 12. Catches show an increasing trend from low values in the 1970s to high values in the 1990s. Effort was relatively low in the 1970s but increased substantially in mid 1980s and has remained at that high level. CPUE has remained relatively stable.

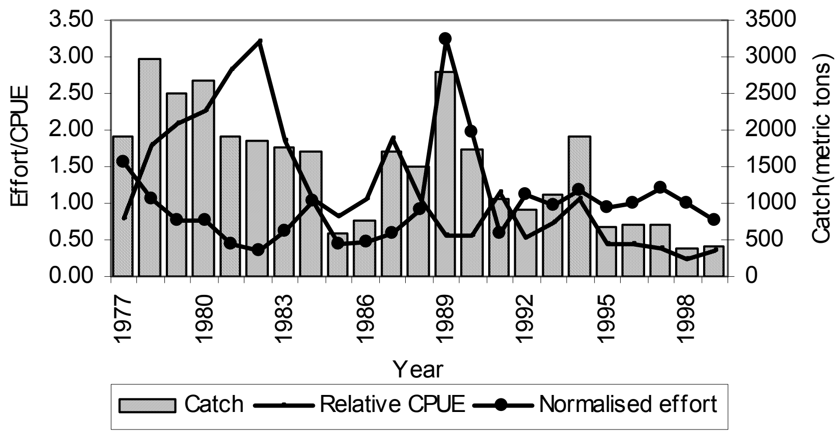


Figure 11. Catch, effort and CPUE in Domira-bay from 1976-99.

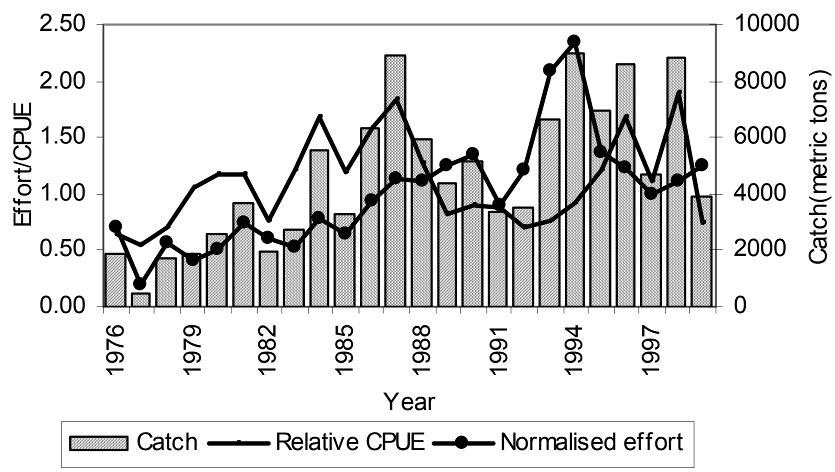


Figure 12. Catch, effort and CPUE in Nkhota-kota from 1976-99.

Catch, effort and CPUE for Nkhata-bay for the period 1976-1999 are shown in Figure 13. Catches show an increasing trend. Effort has also taken a similar trend, increasing from low values in the 1970s to high values in the 1990s except the low values in 1995 and 1996. CPUE however has remained relatively stable.

Catch, effort and CPUE in Likoma Island over the period 1976-1999 are shown in Figure 14. Catches have fluctuated without a definite trend. Effort has declined in the early 1990s from high levels in the 1970s and 1980s. CPUE has also fluctuated greatly without a definite trend.

Catch, effort and CPUE for Karonga for the period 1976-1999 are shown in Figure 15. Catches show an increasing trend from low values in the 1980s. Effort has also taken a similar trend, increasing from low values in the 1980s. CPUE however has remained relatively stable.

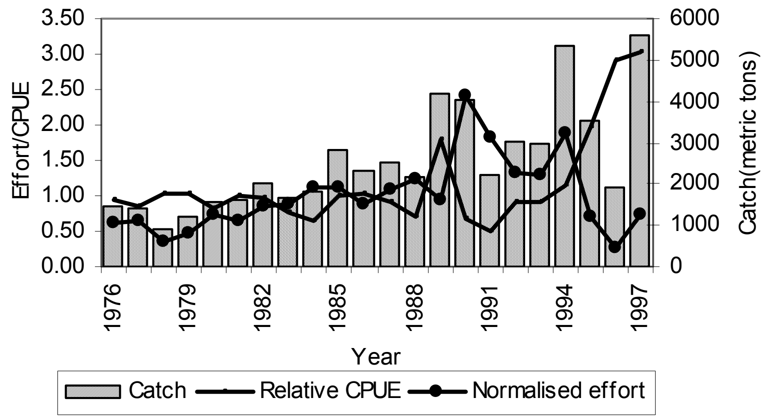


Figure 13. Catch, effort and CPUE in Nkhata-bay from 1976-99.

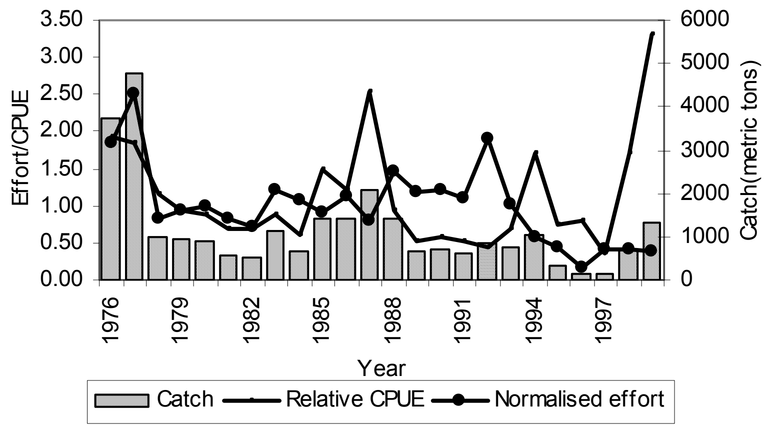


Figure 14. Catch, effort and CPUE in Likoma from 1976-99.

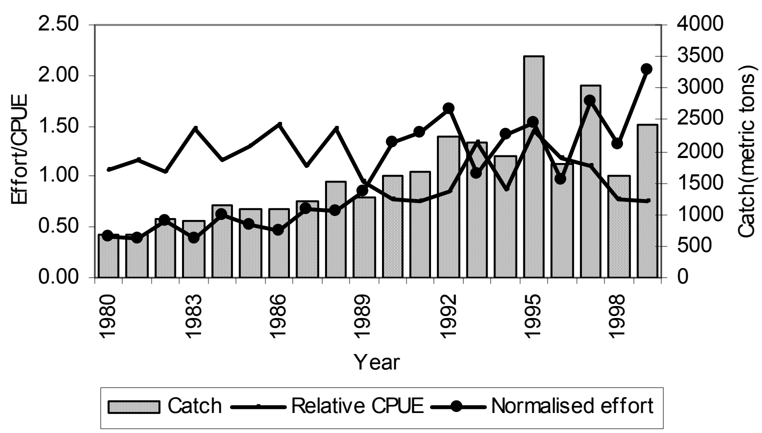


Figure 15. Catch, effort and CPUE in Karonga from 1976-99.

Trends in total catch

Total catches in Malawian waters fluctuated between 50 and 60 thousand metric tons in the period 1976-86 (Figure 16). During the period 1987-91, catches were in the range of 60-70 thousand metric tons. Catches declined in the early 1990s to a minimum of 30 thousand metric tons in 1995. The decline in total catch as seen from Figure 16 is caused by declining catches in other water bodies other than Lake Malawi, in particular in Lake Malombe, Lake Chilwa, Lake Chiuta and the Lower Shire. Also the reduced catches in the commercial fishery contributes to the decline.

Traditional catches in Lake Malawi increased into the late 1980s to a peak of 33 thousand metric tons in 1987. After which catches have remained relatively stable. The highest catch in Lake Malawi traditional fisheries was recorded in 1996 (37 thousand tons). Traditional fisheries in other water bodies other than Lake Malawi were relatively stable until early 1990s, fluctuating around 30 thousand metric tons with a peak of 45 thousand metric tons in 1990. Catches however declined by 1994 to some 20 thousand metric tons and they dropped to 6-10 thousand metric tons in 1995/96. The main reason for the low catches in these two years is primarily due to the low or zero catches in Lake Chilwa when it dried up.

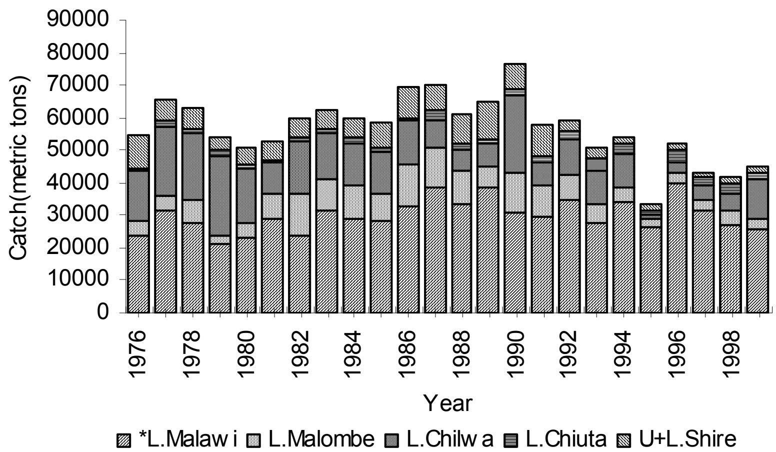


Figure 16. Annual catch contribution by water body from 1976-99 (* traditional and commercial).

Management measures

Current fisheries management regulations are based on technical restriction of fishing gears, i.e. gear mesh size or size of gear (head line length) and restrictions of fishing areas or fishing times- closed areas and seasons for other gears such as beach seines. A number of gears are without any restrictions such as longlines except for permissible setting times in Lake Malawi, hand lines, scoop nets and cast nets. Some gear types are locally prohibited such as kauni for chambo, nkacha in Lake Malawi, beach seines in Lake Chiuta, upper shire and in rivers and dams. Some species are subject to minimum size i.e. all species of chambo (*Oreochromis*) 15.0 cm, other tilapia e.g. *Oreochromis shiranus shiranus* 10.0 cm folk length and mpasa (*Opsaridium microleps*) 30.0 cm fork length.

The traditional fisheries are ''open entry'', although a license is formally needed to operate in that fishery. An annual basic fee must be paid depending on the type of gear being used. In view of the current status of fisheries and fish stocks in Malawian waters, the effectiveness of these measures appears to be limited.

The fishery in the other smaller water bodies however show declining trends in catch and CPUE and many appear currently to be at low level in terms of resource status (Table 1). The prospects for fisheries in Lakes Chilwa, Chiuta, Malombe and upper shire seem to be extremely discouraging. However due to heavy limitations of available data for Lakes Chilwa and Chiuta, precise recommendations are not given at this stage.

In summary, recommended precautionary management actions are as follows:
Lake Malawi traditional fishery:

- Total lake wide ban on chambo seines and ban on kauni for chambo in Area A in order to restore the chambo stocks.

Lake Malombe fishery:
- Total ban on gill nets and chambo seines, in order to restore the chambo stocks.
- Effort limitations of nkacha and kambuzi seine by denying new entries in order to maintain kambuzi stocks.

Lake Chilwa fishery:
- Currently no management recommendations since the fishery are seasonal i.e. the lake dries up.

Lake Chiuta fishery:
- Reduction in effort in order to restore stocks.

Upper Shire fishery:
- Total ban on seines and gill nets, in order to restore stocks.

Table 1. Summary of the status of fisheries and fish stocks in Malawian waters (after Bulirani *et al*. 1999).

Fish			**Long term trends (1976-1999)**			
Stock(s)	**Fishery/Survey**	**Waterbody**	**Area(s)**	**Catch**	**Effort**	**CPUE**
All	Traditional	South East Arm	All	Increasing	Increasing	Decreasing
All	Traditional	South West Arm	All	Variable	Increasing	Decreasing
All	Traditional	Domira-bay	All	Decreasing	Stable	Decreasing
All	Traditional	Nkhotakota	All	Increasing	Increasing	Stable
All	Traditional	Nkhata-bay	All	Increasing	Increasing	Stable
All	Traditional	Likoma	All	Variable	Decreasing	Variable
All	Traditional	Karonga	All	Increasing	Increasing	Stable
All	Traditional	Lake Malombe	All	Decreasing	Increasing	Decreasing
All	Traditional	Lake Chilwa	All	Decreasing	Increasing	Decreasing
All	Traditional	Lake Chiuta	All	Decreasing	Increasing	Decreasing
Chambo	Traditional	Lake Malawi	All	Decreasing	Increasing	Decreasing
Chambo	Traditional	Lake Malombe	All	Decreasing	Increasing	Decreasing
Chambo	Traditional	Upper Shire	All	Decreasing	Variable	Decreasing
Kampango	Traditional	Lake Malawi	All	Decreasing	Increasing	Decreasing
Bombe	Traditional	Lake Malawi	All	Decreasing	Increasing	Decreasing
Utaka	Traditional	Lake Malawi	All	Variable	Increasing	Decreasing
Usipa	Traditional	Lake Malawi	All	Increasing	Increasing	Variable
Kambuzi	Traditional	Lake Malawi	All	Increasing	Increasing	Stable
Kambuzi	Traditional	Lake Malombe	All	Decreasing	Stable	Stable

References

Bulirani A.E., Banda M.C., Pálson Ó.K., Weyl O.L.F., Kanyerere G.Z., Manase M., Sipawe R., 1999. Fish Stocks and Fisheries of Malawian Waters: Resource Report. Government of Malawi, Fisheries Department, Fisheries Research Unit.54pp.

Kolding, J. Population ecology and simple sustainable yield estimators in fisheries: a review. University of Bergen, High Technology Centre, Norway.

Pálson Ó.K., Bulirani A., Banda M, 1999. A review of biology, fisheries and population dynamics of chambo (Oreochromis spp., CICHLIDAE) in Lakes Malawi and Malombe. Malawi Fisheries Bulletin.

Sparre, P. and Venema, S.C., 1992. Introduction to tropical fish stock Assessment. Part I – Manual. FAO Fisheries Technical Paper, 306/1, 376pp.

Turner, G.F., 1995. Management, conservation and species changes of exploited Fish stocks in Lake Malawi in *The Impact of Species Changes in African Lakes.* Tweddle, D. and Magasa, J.D. (1989) Assessment of multi-species cichlid Fisheries of the Southeast Arm of Lake Malawi, Africa. J. Cons. int. Explor. Mer., 45: 209 – 222.

Weyl O.L.F., Banda M, Sodzabanja G., Mwenekibombwe L.H., Namoto W., Mponda O.C., 2000. Annual Frame Survey, September 1999. Fisheries Bulletin No.42. Fisheries Department, Lilongwe, Malawi.

Weyl, O.L.F. 2001, Small-scale fisheries statistics summary. Short communication No. 2

Effects of overfishing on reproductive potential of major cichlid fish species in southern Lake Malombe (Malawi): need for "closed area" strategy as a complementary management option?

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Abstract
The three major species *Lethrinops* 'pinkhead', *Otopharynx argyrosoma* 'red' and *Copadichromis cf. virginalis,* which used to contribute about 75% to the total catches (by weight) of Lake Malombe in the last decade were investigated. The main aim of the investigation was to assess the impact of fishing intensity on reproductive potential of the three species. Fecundity, reproductive seasonality, sexual maturity, and sex ratio were related to habitat types of the south western side (heavily fished) and south eastern side (lightly fished). The three species have low fecundity and they are synchronous spanners, with a breeding peak during July to October period. Females of all three species mature earlier than males while the sex ratio of the three species was not significantly different from 1:1 in both sides of the lake. The length-fecundity relationships for *L.* 'pinkhead' and *O. argyrosoma* 'red' indicated that fecundity was more closely related to length in the south eastern side than in the western side. The frequency occurrence of mature females and juveniles was greater in the south eastern side than in the south western side of the lake. Juveniles of *Oreochromis* spp. (chambo) were also abundant in the south eastern side. The south eastern side of the lake is characterised by low fishing intensity, muddy substratum and aquatic macrophytes. It is also functioning as a spawning area for *Oreochromis* spp. and nursery area for the three haplochromines. These findings provisionally suggest that the efficacy of closed area method as an additional management tool in Lake Malombe. Such a management tool would protect juveniles and breeding stocks of the main species, hence meet the criteria of ensuring the sustainability and utilisation of fish stocks in Lake Malombe.

Key words: reproduction, fishing intensity, closed area, management, Lake Malombe and haplochromines

Introduction
The Lake Malombe fishery has been under severe fishing pressure since 1986 (FAO 1992, Coulter 1993). The fishery provides the cheapest dietary protein to the entire human population surrounding the lake and directly employs 4660 people. During 1970-1986 period, *Oreochromis* spp. (chambo) used to dominate the catches but collapsed in 1988. The collapse of the chambo fishery prompted artisanal fishers to use fine-meshed nets with which to target the small haplochromines (kambuzi). As such, small haplochromines became predominant in the catches after the collapse of the chambo fishery. During 1986-1993, three haplochromines (*Lethrinops* 'pinkhead'*, O. argyrosoma* 'red' and *Copadichromis cf. virginalis*) contributed about 75% to the total annual catch of 8 000 tons (FAO 1993). However, five haplochromines currently constitute about 67% of the total annual catch by weight (Jambo 1997).

Recent findings indicate that catches of kambuzi have declined from 20 kg per haul in the late 1980s (Tweddle *et al*. 1995) to 3.5 kg per haul (Jambo 1997), indicating that the Lake Malombe fishery has been overexploited. The current overall decline of small haplochromines threatens both the livelihood of the rural people who depend on fish as their source of animal protein and employment, as well as the nation's animal protein supply as a whole. Considering the fact that many African Great Lakes cichlids are narrowly stenotopic, philopatric and practise mouth brooding (Ribbink *et al.* 1983), in a way to safe guard their offspring within the same habitat, such a drastic decline in catch per unit effort threatens the biodiversity of fish species in Lake Malombe. Further increase in fishing effort and inappropriate use of fishing gears on the remaining small populations would consequently lead to a total collapse of the kambuzi fishery.

Based on Roberts & Polunin (1991) views it was hypothesised, in this study, that high fishing intensity in the south western side of Lake Malombe might have depleted populations of adult fishes and reduced the average size of females, resulting in poor recruitment into the fishery. In order to test this hypothesis, aspects of reproductive biology of the three principal haplochromines were investigated in the south western side (heavily fished) and south eastern side (lightly fished) of the lake. The main aim of the investigation was to assess the impact of fishing intensity on reproductive potential of the three principal species, with a view of formulating decisions to do with the placing and size of a protected area.

Materials and methods
A monthly sample of 25 to 45 fish for each species was collected from each sampling station. A standard nkacha offshore seine net (250 metres long and 9 metres deep) was used at all stations on each sampling trip. The nkacha offshore seine net is an active gear with a gradation of mesh sizes of 39 mm and 25 mm on the wings and 19 mm on the bunt. It involves divers who pull the footrope and tie weights together to 'purse' the net. Sampling stations were

located along two transects across the lake. On each transect, two sampling stations were situated in the south western side and the other two stations in the south eastern side of the lake (Figure 1).

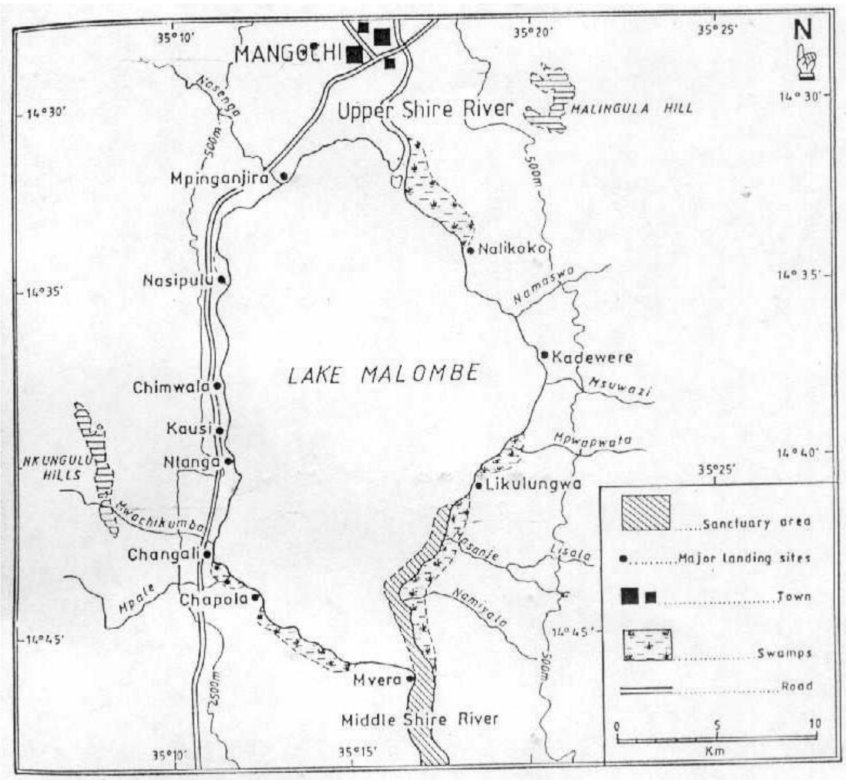


Figure 1. Map of Southern Lake Malombe showing the location of major landing sites and sampling stations. *SS* refers to sampling stations on the two transects.

For each specimen, total length to the nearest millimetre and total body mass to the nearest gram were measured. Fish mass was taken as the mass of the fish minus gut contents. The breeding seasons as well as sexual maturity were determined by a monthly visual appraisal of the gonad activity stages. The visual assessment of gonadal stages was done using the descriptions of Marsh *et al.* (1986) (Table 1). To eliminate possible error, only those data which were collected during the peak period of gonad activity, were used.

To establish the breeding seasonality, the percentage frequency occurrence of females with active ripe (AR), ripe (R) and spent (S) stages for each species, was plotted against sampling time (months). The breeding season was then identified by comparing peaks of AR, R and S stages. Only mature females with AR, R and S gonadal stages were used in this investigation to avoid the possible masking effect, which immature fish could have had on the results.

To establish the length at 50% sexual maturity, with minimal possible error, the data collected during the period of maximum gonad activity were used. Fish with active ripe, ripe and spent gonads were considered mature. For each species and sex, the percentage frequency of such mature fish was plotted against total length. A logistic curve was fitted to the percentage of sexually mature individuals by length (L), using King's (1995) equation:

$$P = 1/(1 + e^{-r(L - L_m)})$$

where r is the slope of the curve and L_m is the mean length which corresponds to size at 50% maturity. The logistic curve was used in order to minimise unreasonably high estimation of L_m.

Table 1. Criteria used for categorising gonads to reproductive stage.

Stage	**Description of female gonadal stages**
Immature (I)	Eggs were elongate, pale yellow / pale orange in colour
Active Ripe (AR)	Eggs were ovoid in shape and they were closely packed and pale orange in colour
Ripe (R)	Eggs were irregular in shape and loosely connected to one another. They were bright orange in colour.
Spent (S)	Ovaries were thin and opaque wall. Red eggs dominated with few bright orange eggs.
	Description of male gonadal stages
Immature (I)	Testes were translucent and almost colourless.
Ripe (R)	Testes were opaque and creamy.
Spent (S)	Testes were thin, flaccid and irregular.

To determine the absolute fecundity of each species the ripe ovaries for each fish were separately preserved in Gilson's solution. After keeping the ovaries in Gilson's solution for one week, the number of eggs were counted (Bagenal 1978). The length-fecundity relationship was determined by regression analysis. The best regression fit was given by the linear equation:

$$F = b\,L + a$$

where F is the absolute number of eggs counted per individual, L is the total length of fish and a, b are linear equation constants. Relative fecundity (number of eggs per gram fish weight) was used to compare reproductive strategies of the three species.

Sex ratio for each species was evaluated by recording the number of fish sampled by sex. The numbers of males and females were compared using a Chi-square test to determine whether sex ratio differed significantly from unity. This test was done to evaluate if size-selective fishing, which has been aggravated by use of small meshed nets, might have altered the sex ratios of the three species.

Results

Reproductive seasonality

For all three species, a high frequency of potential breeding females (AR and R) was evident between July and October, with prominent peaks in July and October for active ripe female and in August for ripe females. A high frequency of potential breeding ripe females was also noted for *O. argyrosoma* 'red' in December (Figure 2). From these data it is evident that all three species breed mainly from July to August.

Sexual maturity

Gonads of 991 males and 979 females were examined. More than 50 % of the males, irrespective of species and side of the lake, were mature at approximately the same size (79 mm), thus corresponding to an age of between two and three years. However, they appear to attain 100% sexual maturity at different lengths (TL). In contrast, females of the three species attained 50% sexual maturity at different lengths (Table 2)

Table 2. Comparison of length at 50% sexual maturity (L_{sm}) in millimetres and length-at-age 1 (L-at-1) in millimetres for both sexes of the three species studied in the southern Lake Malombe

Species	Male		Female	
	L_{sm}	L-at-1	L_{sm}	L-at-1
L. 'pinkhead'	79	67	66	86
O. argyrosoma 'red'	77	69	72	89
C. cf. virginalis	79	32	83	45

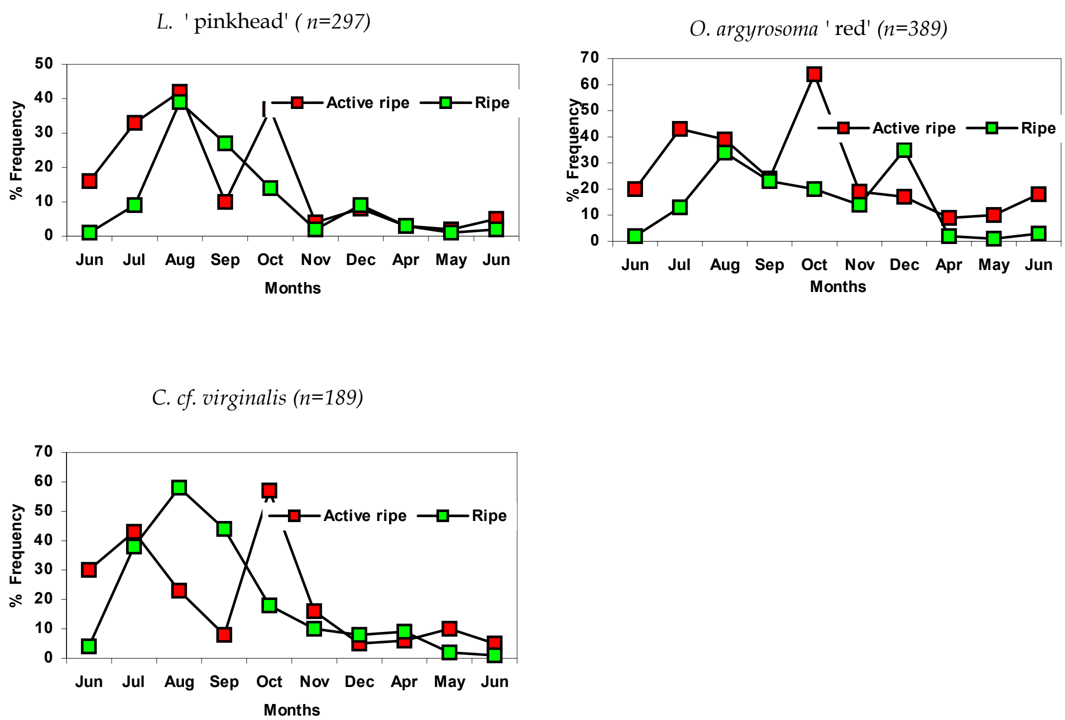


Figure 2. Frequency distribution of female fish with active ripe (AR) and ripe (R) gonads.

Size distribution and Sex ratio

The frequency occurrence of smaller mature females was greater in the south eastern side than in the south western side. Females of *L.* 'pinkhead' and *O. argyrosoma* 'red' dominated in the smaller size classes (66-75 mm) while females of *C. cf. virginalis* dominated in the larger size classes (78-90 mm) (Figure 3 a,b and c).

These results suggest that more of the immature females in the *L.* 'pinkhead' and *O. argyrosoma* 'red' populations were vulnerable to the standard nkacha net. However, there was no significant difference in size between sexes and sides (ANOVA) P>0.05 (Table 3). Similarly, the sex ratio of the three species did not differ significantly from 1:1, X^2 test; P > 0.05 (Table 4).

Table 3. Mean lengths (mm) of potential breeding males and females in the south western (SW) side and south eastern (SE) side of Lake Malombe.

Species	SW (Heavily fished)	SE (Lightly fished)
L. 'pinkhead'	78	78
	67	67
O. argyrosoma'red'	71	76
	72	71
C. cf. virginalis	79	80
	83	83

Table 4. Sex ratio of the three species sampled from southern Lake Malombe, irrespective of the sides.

Species	Male	Female	Ratio	X^2
L. 'pinkhead'	1450	1441	1:1.03	0.017
O. argyrosoma 'red'	801	1014	1:1.23	0.001
C. cf. virginalis	749	802	1:1.07	0.790

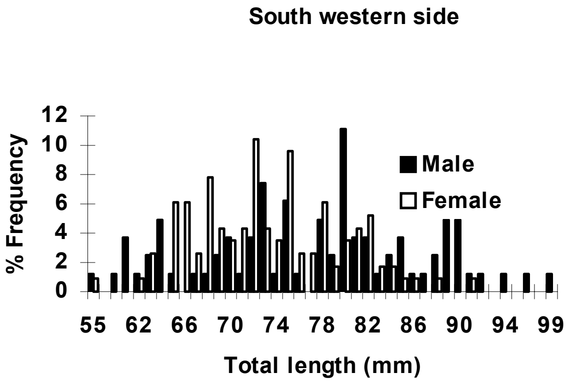
Discussion

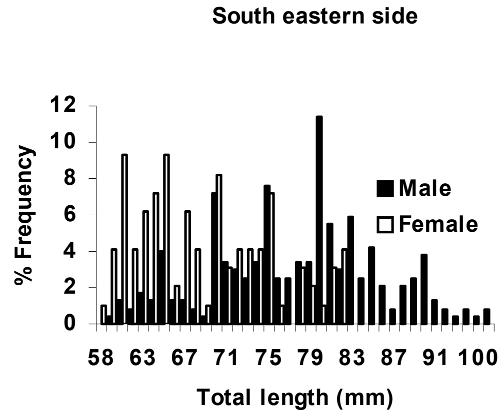
Breeding seasonality

It appears that all three species breed throughout the year with one or two distinct peaks occurring from July to October for *L.* 'pinkhead' and *C. cf. virginalis* and in September and December for *O. argyrosoma* 'red'. In general, these results confirm the findings of Tweddle & Turner (1977), Mwanyama (1993) and Banda *et al.* (1994) who found that the main breeding season for most Malawian cichlids falls between August and September. The high frequency occurrence of potential breeding fish, throughout the year, provides further evidence that the three species breed throughout the year and this makes the application of a closed season problematic. Nevertheless, high frequency of spent ovaries and juveniles after November suggests that a fine-tuned closed season would cover the month of November so that juveniles could be protected.

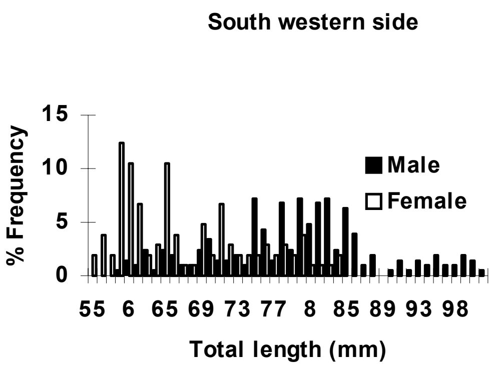
The breeding peaks of the three species occurred during the phytoplankton biomass peaks. This could be a strategy, which synchronises the breeding behaviour with availability of food. Eccles (1974), Lowe-McConnell (1987) and Mwanyama (1993) have indicated that more nutrients are available during the period June to September from sediments pertubated by the south easterly winds and between February and March during the rainy season. These findings provide some evidence that the synchrony in breeding of the three species may reflect a direct response to food availability. Similar relationships have also been found for cichlid species elsewhere (McKaye 1984 and Marsh *et al*. 1986). It was also apparent that the main breeding season of the three species occurred during the time when CPUE was also highest, indicating that the three species are more vulnerable to fishing during their breeding season. From a fishery perspective, the coincidence of greater CPUE and breeding season during the open season, suggested that the closed season (1January-31 March) was ineffective in protecting breeding stocks.

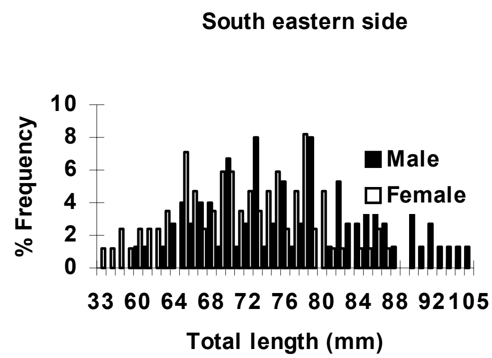
(a) L. ‘pinkhead’



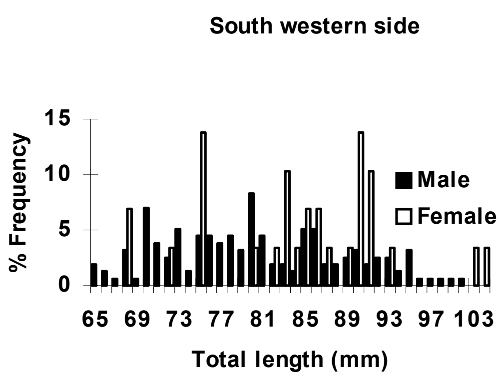


(b) *O. argyrosoma* ‘red’





(c) *C. virginalis*



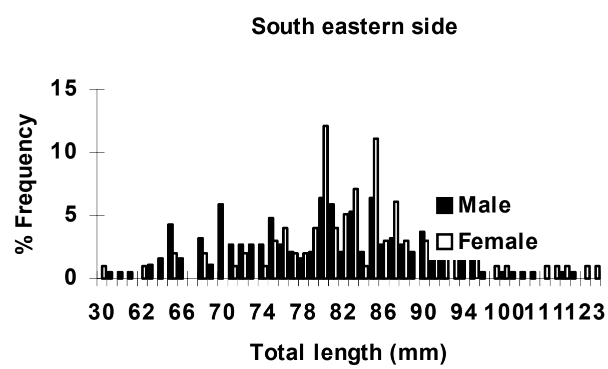


Figure 3 a, b and c Length frequency distribution of mature fish of three principal species in the southern Lake Malombe.

The spawning period of *O. argyrosoma* 'red' coincided with the onset of the rainy season in December. This species belongs to a group of small zoobenthic feeders, substrate spawners and it is most abundant in the shallower parts of the lake (Eccles & Trewavas 1989). During the rainy season the preferred habitats for *O. argyrosoma* 'red' had high turbidity values. Considering the fact that high turbidity does not prohibit breeding of some haplochromines (Greenwood 1974), it appears that breeding of *O. argyrosoma* 'red' coincides with high water turbidity.

Sexual maturity

Analysis of the data, using non-pooled data, showed that the sizes at 50% maturity of female fish, from both sides of the lake, were not significantly different. Results for the three species have shown that the females mature approximately six months to one year before the males. The early maturing of females is considered to be advantageous to the reproductive potential of the three species because females could breed at least once before they are exploited in their second year of life.

Cichlid females maturing at a small size could also mean a reduction in absolute population fecundity (Fryer & Iles 1972, Pitcher & Hart 1982) resulting in insufficient recruitment levels from such small and early maturing females. However, some scholars have argued that while mouth brooding cichlids may mature at a small size and lay few eggs, recruitment is guaranteed due to the fact that the young are painstakingly cared for by the parent. This implies that although females of the three species are maturing early, at a small size, they may still have a good recruitment potential, which may however need to be conserved by protecting the breeding grounds.

Studies on sexual maturity of related species such as *Haplochromis virginalis* (107 mm), *H. quadrimaculatus* (164 mm) and *H. pleurostigmoids* (130 mm) have shown that they all matured during their third year (Fryer & Iles 1972). Tweddle & Turner (1977) who investigated the sexual maturity of *Lethrinops. parvidens* , *L. longipinnis,* and *H. anaphyrmus* (closely related to the species studied here) also postulated that they breed in their third year.

According to Fryer & Iles (1972), reduction in size at 50% maturity in all female individuals might have been a direct adaptation to heavy fishing. It appears that the reduction in size at sexual maturity for *C. cf. virginalis* has been compensated by a faster growth rate (Jambo 1997). Pitcher & Hart (1982) and Gulland (1988) pointed out that a smaller size at sexual maturity coupled with an increasing growth rate offers the potential for compensatory adjustment to offset declining spawner stock size. This phenomenon could probably explain why these three species have been resilient to heavy exploitation and give an impression that the fishery could be restored if there is a substantial curtailment of fishing and proper management.

Sex ratio

For all three species the overall sex ratio was approximately 1:1 at 95% confidence interval. This suggests that there was an equal removal of both sexes by the standard fishing gear in southern Lake Malombe. However, it was apparent that for all three species, males slightly outnumbered females two months prior to the breeding season. This may be a reproductive strategy that could increase the reproductive success of the females through the exercise of mate choice. Lande (1981) quoted by McKaye (1986) and Turner (1993) emphasised that such preponderance of males satisfies the polygynandry of mouth brooding cichlids, whereby females have numerous males from which to choose and apportion their eggs and hence achieve greater mating success. Another explanation could be that males, as in *Tilapia moori* (Konings 1988), move about in groups prior to and during the spawning period whilst females are solitary in less accessible breeding grounds. Such a breeding behaviour could contribute to males dominating the catches during and/or prior to the breeding season.

Fecundity

In this study, the linear function best described the significant relationship between absolute fecundity and length. However, the relationships for *L.* 'pinkhead' and *O. argyrosoma* 'red' were poorer in the south western side than in the south eastern side of the lake. The possible explanation for such a poor length-fecundity relationship in the south western side could be that the high fishing intensity has influenced a shift in the size distribution of these species resulting in the impairment of reproductive output (Sadovy 1996).

This study indicates that relative fecundity indicate is variable among the three species and between the sides of the lake. Considering the fact that mean weights for each species, in both sides of the lake were not significantly different (t-test, P>0.05), it appears that the higher values of relative fecundity for *C. cf. virginalis*, in the south western side, might have been a reproductive adaptation to high fishing pressure. Pitcher & Hart (1982) and Sadovy (1996) pointed out that changes in reproductive strategy are expected to involve increases in relative fecundity at a given size and age when fish populations are subjected to high fishing pressure. The lower value of relative fecundity of *O. argyrosoma* 'red', in the south western side, could be an indication of poor habitat breeding conditions for this species in the south western side. It could be envisaged that the sandy substratum of the south western side of the lake may have contributed to the low values of relative fecundity of *O. argyrosoma* 'red' while the muddy substratum of the south eastern side of the lake may have contributed to the better habitat conditions for reproductive success of *O. argyrosoma* 'red'.

In overall, absolute fecundity estimates from this investigation showed general agreement with estimates by Mwanyama's (1993). Mwanyama (1993) documented a range of 13 to 78 eggs. The slight difference might have originated from sampling, differences in population structure in both sides and period of sampling. Comparisons of absolute fecundity values of each species with respect to sides of the lake showed that *L. 'pinkhead'* and *C. cf. virginalis* had the highest mean values of absolute fecundities (28 and 51 eggs respectively) in both sides of the lake, where as for *O. argyrosoma* 'red' the highest mean value was observed in the south eastern side of the lake. These results provide circumstantial evidence that absolute fecundity of *L.* 'pinkhead' and *C. cf. virginalis* have not been affected much by high fishing intensity.

Conclusions and recommendations

The three dominant species breed throughout the year with distinct peaks occurring between July and October. From a fishery perspective, the high frequency occurrence of breeding females during July - October period suggested that the old closed season (January- March) was ineffective in protecting breeding females. As such, a new closed season for Lake Malombe (October- December) was adopted. It was also evident that the breeding peaks coincided with phytoplankton biomass peaks, suggesting that intraspecific competition for food between adults and juveniles is reduced during the period of greater fish abundance.

Of the three species, females of *L.* 'pinkhead' and *O. argyrosoma* 'red' mature earlier than males irrespective of side of the lake while males of the three species attain sexual maturity at approximately the same size (79 mm). The relative small size at sexual maturity is of an advantage for the population because females are given a chance to spawn at least once before they are caught. However, benefits of early maturation are limited in Lake Malombe due to the current high fishing pressure. According to Jennings & Beverton (1991), a reduction in size at 50% sexual maturity for females could be a direct consequence of overfishing or response to physical and biological characteristics of the environment. These views suggest that in overall, degradation of substratum and high fishing intensity may have caused a reduction in size at sexual maturity of *L.* 'pinkhead' and *O. argyrosoma* 'red' in Lake Malombe.

In conclusion, the south eastern side of the lake is characterised by low fishing intensity, muddy substratum and aquatic macrophytes. These factors appear to have been associated with greater abundance of breeding females and higher frequency of juveniles rather than fecundity and sex ratios. Considering these results, it could be suggested that the existing sanctuary area, situated in the southern part of Lake Malombe, should be extended. It is appreciated that the optimum size of the sanctuary has to be scientifically established. However, given the seriousness of the situation, it is recommended that the sanctuary area boundary be increased immediately but in consultation with the fishers. It is anticipated that enlarged and well managed sanctuary area will protect the unique aquatic environment in the south eastern side (which tends to be the breeding ground), the breeding fish stocks, and juveniles, hence prevent the total collapse of the fishery.

Acknowledgements

Special thanks are due to Mr O.K. Mhone and A. Phiri for their assistance in identifying fish species, weighing and measuring fish, and counting eggs. We sincerely thank Dr. Tony Booth and Mr. Dennis Tweddle who enthusiastically provided statistical advice and supervised data processing. Overseas Development Agency (ODA) funded this study.

References

Bagenal, T.B. 1978. *Methods for assessment of fish production in freshwaters*, IBP Handbook 3. Blackwell Scientific Publications Ltd., Oxford.

Banda, M.C., Tomasson, T. & Tweddle, D. 1994. Assessment of trawl fisheries of the south east arm of Lake Malawi using exploratory surveys and commercial catch data. Conference on Inland Fisheries Stock Assessment, Hull England, April 1994.

Coulter, G.W. 1993. Report on Fisheries Research Strategies. The Government of Malawi Fisheries Department. ODA-FRAMS pp 58.

Eccles, D.H. 1974. An outline of the physical limnology of Lake Malawi (Lake Nyasa). *Limnol. Oceanogr.*, 19:730-742.

Eccles, D.H. & Trewavas, E. 1989. *Malawian cichlid fishes.* The classification of some Haplochromine genera. Herten (W. Germany), Lake Fish movies.

FAO. 1992. Fisheries Management in the South East Arm of Lake Malawi, the Upper Shire and Lake Malombe. *CIFA Technical paper,* Vol. 21 GOM/FAO/UNDP Chambo Fisheries Research Project.

Fryer, G. & Iles, T.D. 1972. *The Cichlid Fishes of the Great Lakes of Africa*: *Their Biology and Evolution*, Oliver and Boyd. Edinburgh.

Greenwood, H. 1974. Cichlid fishes of Lake Victoria, East Africa: the biology and evolution of a species flock. *Bull. Br. Mus. nat. Hist. (Zool.)*, *suppl.,* 6:1-134.

Gulland, J.A. 1988. *Fish Population Dynamics*: The implication for management. Wiley, London.

Jambo, C. 1997.

King, M. 1995. *Fisheries Biology, Assessment And Management*. Fishing News Books. Pp341.

Konings, A. 1988. *Cichlids Of Lake Malawi.* Tfh Publications. Neptune City. 495 Pp.

Lande. 1981.

Lowe-Mcconnell, R.H. 1987. *Ecological Studies In Tropical Communities*. Cambridge Uni. Press, Cambridge, 382 Pp.

Marsh, B., Marsh, A.C. & Ribbink, A.J. 1986. Reproductive seasonality in a group of rock-frequenting cichlid fishes in Lake Malawi. *J. Zool., London* (A) 209:9-20.

Mckaye, K.R. 1984. Behavioural aspects of cichlid reproductive strategies: patterns of territoriality and brood defence in Central American substratum spawners and African mouthbrooders. In: *Fish Reproduction,* (eds G.W. Potts and R.J. Wooten). Academic Press, London. pp245-273

Mckaye, K.R. 1986. Mate choice and size assortative pairing by cichlid fishes of Lake Jilo'a, Nicaragua. *J. Fish. Biol.,* 29 (Supp.A), 135-50).

Mwanyama, N.C. 1993. Relations entre les ressources alimentaires, I'alimentation et la reproduction des chambos (poissons tilapia's di genre Oreochromis dans les lacs Malawi et Malombe (Afrique centrale) Ph.D. thesis, Universite' de Provence-Axix-Marseille, 158p.

Pitcher, T.J.& Hart, P.J.B. 1982. *Fisheries Ecology*, Croom Helm, Beckenham, 414 pp.

Ribbink, A.J., Marsh, B.A., Marsh, A.C., Ribbink, A.C. & Sharp, B.J. 1983. A preliminary survey of the cichlid fishes of rocky habitats in Lake Malawi. *S. Afr. J. Zool.,* 18:149-310.

Sadovy, Y.J. 1996. Reproduction of reef fishery species. In: *Reef Fisheries* (eds N.V.C. Polunin and C.M. Roberts). Chapman & Hall.

Turner, G.F. 1993. Teleost mating behaviour. In: *Behaviour of Teleost Fishes* (ed. T.J. Pitcher). Chapman & Hall, London. pp.307-331.

Tweddle, D.& Turner, J.L. 1977. Age, growth and mortality rates of some cichlid fishes of Lake Malawi. *J. Fish. Biol.*, 10:385-398.

Tweddle, D., Turner, G.F. & Saisay, M.B.D. 1995. Changes in species composition and abundance as a consequence of fishing in Lake Malombe, Malawi. In: *The Impact of Changes in African Lakes* (eds. T.J. Pitcher and P.J.B. Hart). Chapman & Hall. London, pp413-424.

Management Recommendations for the Nkacha Net Fishery of Lake Malombe

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Abstract
Fish catches from the nkacha net fishery on Lake Malombe were sampled on a monthly basis from March 2000 to January 2001. Although more than 60 species were identified, the catch composition was dominated (about 80%) by only five species. These were *Copadichromis chrysonotus, C. virginalis*, *Lethrinops* sp. 'pinkhead', *Otopharynx argyrosoma* and *O. tetrastigma*. This species composition was similar to that recorded in previous assessments and indicated a relative stability in the species that drive the nkacha net fishery. This paper investigates size selectivity for ¼ inch and ¾ inch mesh size nkacha nets from a yield per recruit (YPR) perspective for three of the five species: *C. virginalis*, *L.* sp. 'pinkhead' and *O. argyrosoma.* Management recommendations for the Lake Malombe nkacha net fishery are made using two target reference points (TRPs), $F_{0.1}$ and F_{max}, derived from the YPR models.

Introduction
The Lake Malombe fishery has undergone dramatic changes both in gear use and in catch composition (Weyl *et al*. 2001). Chambo seines and gill nets dominated the fishery up to the mid 1980s when chambo (*Oreochromis* spp.) was the mainstay of the fishery. With the collapse of the chambo fishery in Lake Malombe, kambuzi seines and nkacha nets became increasingly important and currently over 90 % of total fish catch is from nkacha nets (Weyl *et al.* 2001). However, even this fishery is considered to be declining in Lake Malombe with catches fluctuating between 2000 and 4000 tones from 1995 to 1999 and over the same period the number of kambuzi seines, chambo seines and nkacha nets have also declined (Weyl *et al*. 2000). The latest count (Weyl *et al*. 2000) shows 165 nkacha nets being operated in Lake Malombe and the Upper Shire River.

Although the legal minimum mesh size for nkacha nets is ¾ inch (GOM 2000), the mesh size in most common use in nkacha nets is ¼ inch (pers obs.). This study investigates the species composition in nkacha net catches to determine whether there have been major species composition changes over the last eight years and investigates the effect of the dominance of the ¼-inch mesh size on the fishery.

Methods
Fish catches from the nkacha net fishery on Lake Malombe (14°29'–14°45'S, 35°12'–35°20'E), Malawi, were sampled (n=107) from ¼ inch and ¾ inch mesh size nkacha nets on a monthly basis from March 2000 to January 2001. No sampling was carried out between 1 October and 31 December, 2000, as this period is closed to nkacha net fishing in Lake Malombe. In most cases the landed catch was sub-sampled and all fish in the sample were identified to species level, each species component of the catch was weighed and each fish was measured for total length (TL) in millimeters. Since, age and growth data were available for only three species in the lake Malombe fishery, *Copadichromis virginalis*, *Lethrinops* sp. 'pinkhead', and *Otopharynx argyrosoma,* further analysis was restricted to these species.

Age specific selectivity
Length-specific selectivity was estimated using cumulative length frequency distributions for *Copadichromis virginalis*, *Lethrinops* sp. 'pinkhead', and *Otopharynx argyrosoma* in the nkacha net fishery. For age-specific selectivity, length frequencies were converted to age-frequencies using the von Bertalanffy growth parameters determined by Jambo (1997). Both age- and length-specific selectivity was described by a logistic distribution as selectivity was assumed to increases to, and remain at, a maximum. The selectivity pattern of the nkacha net fishery was therefore assumed to be temportally invariant and described by the logistic function:

$$S_a = \left(1 + e^{-(a-\phi)/\sigma}\right)^{-1}$$

where S_a is the selection of the gear on fish of age or length a, ϕ is the age- or length-at-50% selection and σ the width of the selectivity function.

Per-Recruit analysis

Yield-per-recruit (*YPR*) as a function of fishing mortality (*F*) were determined by:

$$YPR_F = \sum_{a=0}^{\max} w_a S_a F \widetilde{N}_a \left[1 - e^{-(M+S_a F)}\right] / (M + S_a F) \Delta a$$

where $\widetilde{N}_a$ is the relative proportion of fish at age a is defined recursively as:

$$\widetilde{N}_a = \begin{cases} 1 & \text{if } a = 0 \\ \widetilde{N}_{a-1} e^{-(M+S_{a-1}F)} & \text{if } 1 \le a < \max \\ \widetilde{N}_{\max-1} e^{-(M+S_{\max-1}F)} / (1 - e^{-(M+S_{\max-1}F)}) & \text{if } a = \max \end{cases}$$

where S_a is selectivity at age a, F is the instantaneous rate of fishing mortality on fully recruited cohorts, M is the instantaneous rate of natural mortality and *max* is the maximum recorded age. In all per-recruit models the weight-at-age was described by:

$W_a = \alpha(l_a)^{\beta}$

where l_a is the length-at-age determined by the von Bertalanffy growth equation and α and β are parameters describing the length-weight relationship. All summations were conducted with a step size (Δa) of 1/12th of a year.

Input parameters used in YPR models for the three species in the Lake Malombe nkacha fishery are summarised in Table 1. Growth and mortality parameters were obtained from data presented in Jambo (1997), mortality estimates were derived from Weyl 2001, and all summations were run using 5 years to define the parameter for maximum age (*max*). Gear specific fishing effort was standardised to the effort exerted by one nkacha unit per year.

Table 1. Input parameters used in per-recruit analysis for three species in the Lake Malombe nkacha fishery.

Parameters		*C. virginalis*	*L. pinkhead*	*O. argyrosoma*
L_∞	Predicted asymptotic length	146mm	118.4	101.7
K	Brody growth coefficient	0.88	0.6	0.52
Max	Maximum age	5	5	5
M	Natural mortality rate	0.97 yr^{-1}	0.62 yr^{-1}	0.55 yr^{-1}
F	*Fishing mortality rate*	1.59 yr^{-1}	0.81 yr^{-1}	0.71 yr^{-1}
Q	Catchability coefficient	0.0096	0.0049 $gear^{-1}.yr^{-1}$	0.0044 $gear^{-1}.yr^{-1}$
α	Parameter for length/weight equation	0.044687	0.02138	0.041687
β	,,	2.33	2.7	2.33
a_{50}: ¼	Age-at-50%-selectivity	0.706131	1.302769	1.891944
$b\delta_{50}$: ¼	Width of the selectivity logistic ogive	0.091881	0.241381	0.349569
A_{50}: ¾	Age-at-50%-selectivity	0.68007	1.426617	2.054715
δ_{50}: ¾ inch	Width of the selectivity logistic ogive	0.086659	0.250679	0.345974

Target Reference Points

In order to determine target reference point (TRP) fishing mortality for the ¼ inch and ¾ inch mesh sizes, two TRP's were investigated:

1) $F_{0.1}$ or marginal yield strategy which corresponds to the rate of fishing mortality at which the slope of the YPR curve falls to 10% of its value at the origin.
2) F_{max} which corresponds with the asymptote of the YPR curve.

Results

Species selectivity

Over sixty species of fish were identified in the nkacha net fishery, however only five dominated the catch. These were *Copadichromis chrysonotus*, *C. virginalis*, *L.* sp. 'pinkhead', *O. argyrosoma* and *O. tetrastigma*, each one of which made up >5% of the catch (Table 2). The monthly trends in catch composition for the period March 2000 – January 2001 indicated that the five most dominant species together made up between about 60% and 90% of the total nkacha net catch (Figure 1).

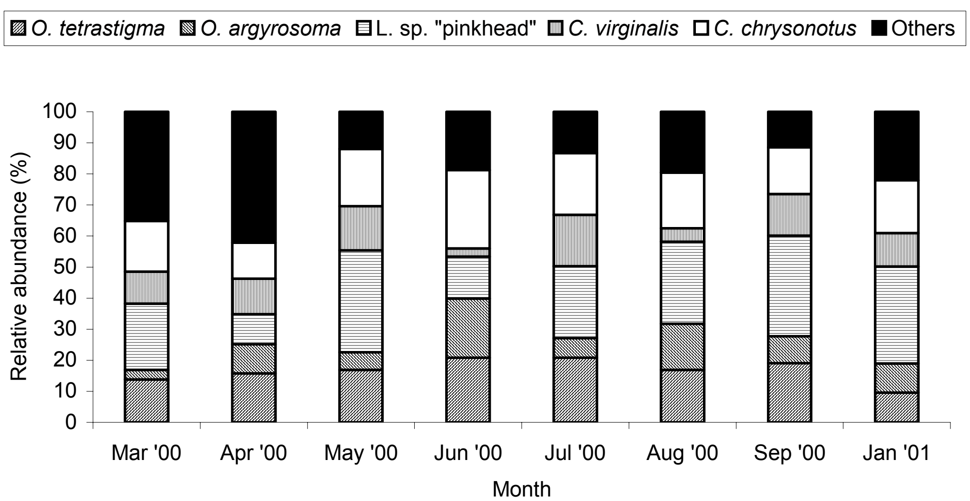

Figure 1. Monthly trends in catch composition (%) from March 2000 to January 2001.

Size selectivity

Size selectivity comparisons between ¼ inch and ¾ inch nkacha net mesh sizes for *C. virginalis*, *L.* sp. 'pinkhead' and *O. argyrosoma* are shown in Figs. 2, 3 and 4, respectively. For *C. virginalis*, the mean selectivity for ¼ inch mesh size was 67 mm versus 66 mm for the ¾ inch mesh size (Figure 2). For *L.* sp. 'pinkhead' the mean selectivities for ¼ inch and ¾ inch mesh sizes were 64 mm and 67 mm, respectively (Figure 3). The mean selectivities of *O. argyrosoma* for ¼ inch and ¾ inch mesh sizes were, respectively, 63 mm and 66 mm (Figure 4). The very small mean size selectivity differences (1 mm – 3 mm) between ¼ inch and ¾ inch mesh sizes among the three species demonstrates that there is little or no influence on fish size selection by the two different mesh sizes. Age-at –selectivity is shown in Table 1.

Per recruit analysis

The YPR curves for ¼ inch and ¾ inch nkacha net mesh sizes for *C. virginalis, L.* sp. 'pinkhead' and *O. argyrosoma* are shown in Figure 6. The response of YPR to differences in the age at capture using ¼ inch or ¾ inch nkacha nets was marginal for the three species. The number of nkacha gear units calculated for the $F_{0.1}$ and F_{max} TRP's for *C. viginalis*, *L.* sp. 'pinkhead' and *O. argyrosoma* are presented in Table 3. *C. virginalis* was the least resilient to increased fishing effort ($F_{0.1}$ = 84-85 gears; F_{max} = 154-160 gears), while *O. argyrosoma* was the most resilient ($F_{0.1}$ = 161-168 gears; F_{max} = 348-395 gears) of the three species.

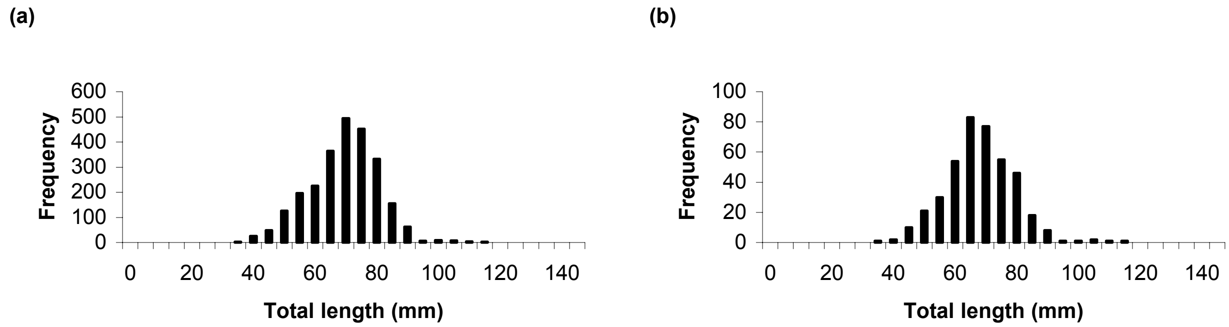

Figure 2. Size selectivity of *Copadichromis virginalis* caught by (a) ¼ inch and (b) ¾ inch nkacha net mesh sizes in Lake Malombe.

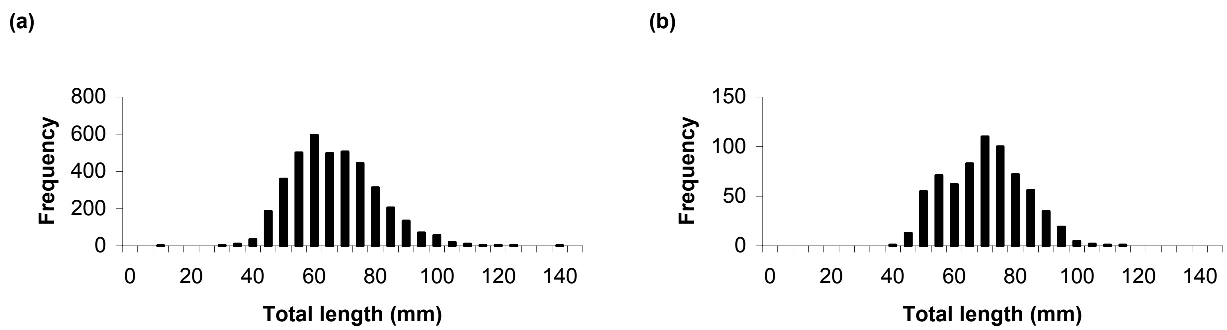

Figure 3. Size selectivity of *Lethrinops* sp. 'pinkhead' caught by (a) ¼ inch and (b) ¾ inch nkacha net mesh sizes in Lake Malombe.

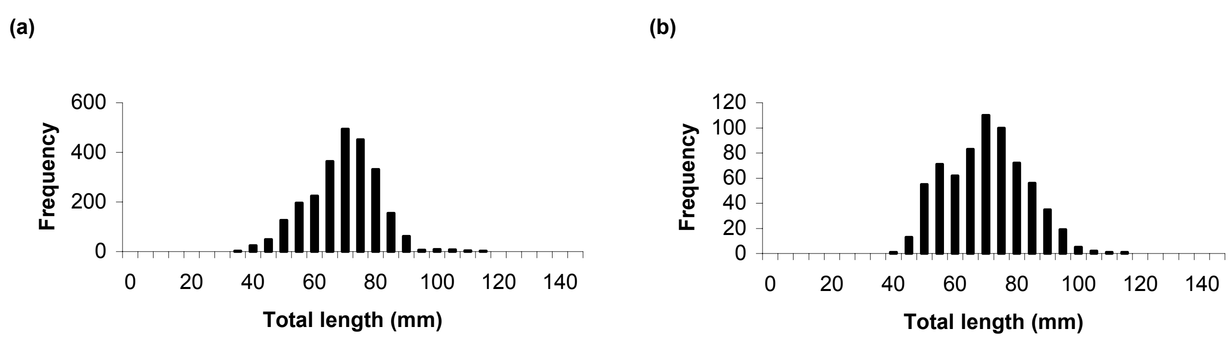

Figure 4. Size selectivity of *Otopharynx argyrosoma* caught by (a) ¼ inch and (b) ¾ inch nkacha net mesh sizes in Lake Malombe.

Table 2. Catch composition in the nkacha net fishery of Lake Malombe, all months combined. (n = 107 catches)

Family	Species name	(%)	Family	Species name	(%)
ANGUILLIDAE	*Anguilla nebulosa labiata*	0.00	CICHLIDAE *cont.*	*Oreochromis shiranus*	1.17
				Oreochromis spp.	0.52
BAGRIDAE	*Bagrus meridionalis*	0.29		*Oreochromis squamipinnis*	0.88
				Otopharynx argyrosoma	7.60
CHARACIDAE	*Brycinus imberi*	0.08		*Otopharynx* spp.	0.06
				Otopharynx tetraspilus	1.10
CICHLIDAE	*Astatotilapia calliptera*	0.12		*Otopharynx tetrastigma*	16.68
	Aulonocara guentheri	0.98		*Placidochromis subocularis*	0.75
	Aulonocara macrochir	0.10		*Protomelas labridens*	0.23
	Buccochromis atritaeniatus	0.85		*Protomelas similis*	0.33
	Buccochromis nototaenia	0.18		*Protomelas triaenodon*	0.02
	Copadichromis chrysonotus	17.98		*Rhamphochromis longiceps*	0.53
	Copadichromis cyaneus	0.08		*Rhamphochromis macrophthalmus*	0.15
	Copadichromis trimaculatus	0.04		*Rhamphochromis* spp.	0.32
	Copadichromis virginalis	11.93		*Sciaenochromis gracilis*	0.02
	Corematodus taeniatus	0.01		*Stigmatochromis woodi*	1.41
	Ctenopharynx intermedius	0.31		*Tilapia rendalli*	0.00
	Ctenopharynx nitidus	0.00		*Tramitichromis lituris*	0.13
	Ctenopharynx pictus	0.01		*Trematocranus placodon*	1.42
	Dimidiochromis compreceps	0.06			
	Dimidiochromis kiwinge	0.02	CLARIIDAE	*Clarias gariepinus*	0.67
	Fossochromis rostratus	0.00		*Bathyclarias longibarbis*	0.00
	Hemitaeniochromis discorhynchus	0.21		*Bathyclarias* spp.	0.00
	Hemitilapia oxyrhynchus	0.01			
	Lethrinops "deep water" *altus*	4.44	CYPIRINIDAE	*Barbus arcislongae*	0.05
	Lethrinops lethrinus	1.55		*Barbus litamba*	0.16
	Lethrinops longipinnis	0.28		*Engraulicypris sardella*	0.83
	Lethrinops macrochir	0.01		*Opsaridium microcephalus*	0.13
	Lethrinops parvidens	0.38			
	Lethrinops sp. 'pinkhead'	23.97	MASTACEMBELIDAE	*Aethiomastacembelus shiranus*	0.00
	Lethrinops spp.	0.03			
	Maravichromis anaphyrmus	0.05	MOCHOKIDAE	*Synodontis njassae*	0.02
	Mylochromis mola	0.05			
	Nyassachromis argyrosoma	0.66	MORMYRIDAE	*Hippopotamirus discorhynchus*	0.13

Table 3. Number of gear units calculated for the $F_{0.1}$ and F_{max} TRPs for *Copadichromis virginalis*, *Lethrinops* sp. 'pinkhead' and *Otopharynx argyrosoma* in Lake Malombe.

Species	Number of gears	
	$F_{0.1}$	F_{max}
Copadichromis virginalis	84-85	154-160
Lethrinops sp. 'pinkhead'	122-131	224-249
Otopharynx argyrosoma	161-168	348-395

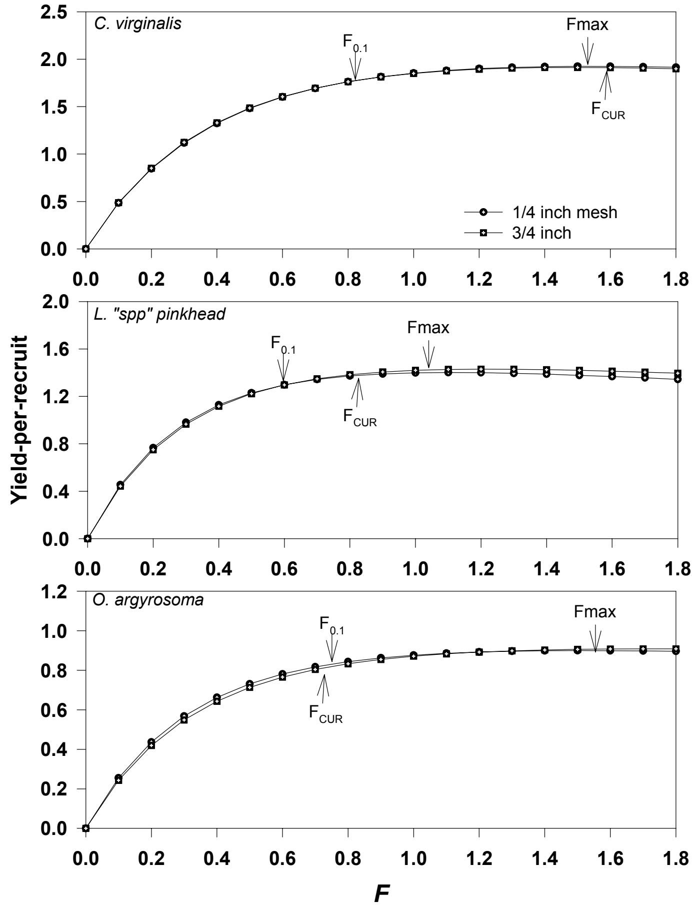

Figure 5. Yield per recruit curves for ¼ inch and ¾ inch mesh sizes nkacha nets for *Copadichromis virginalis* , *Lethrinops* sp. 'pinkhead' and *Otopharynx argyrosoma* in Lake Malombe.

Discussion

The use of TRPs for the management of a fishery is common practice (Caddy & Mahon 1995), and the Malawi Department of Fisheries recommends TRPs based on catch per unit effort (CPUE) in the small-scale fishery (Bulirani *et al.* 1999). The yield-per-recruit (YPR) approach allows for the determination of at least two commonly used TRPs: firstly, the fishing mortality which corresponds to the maximum of the yield-per-recruit curve (F_{max}) and secondly, the marginal yield or $F_{0.1}$ strategy (Gulland & Boerema 1973, Deriso 1987). The F_{max} approach has received some criticism in the past (Punt 1993), and the $F_{0.1}$ TRP is this is considered to be more robust management strategy (King, 1995).

It has long been recognised that when a single gear catches several different species it is impossible to manage each species at its optimum level (Murawski & Finn, 1988). This complicates the management of multi-species fisheries. One approach that has been applied in such cases is to manage the fishery according to the least resilient species (Weyl 1998). In the Lake Malombe scenario, *C. virginalis* was the least resilient of the three species and 85 nkacha nets are recommended if the species is to be managed at a F0.1 level. Based on surplus production models, Weyl *et al*. (2001) recommended 170 nkacha gear units for Lake Malombe in order to maintain a MSY of 5000 – 7000 tons. This study shows that from a YPR perspective, this level of fishing would exceed the $F_{0.1}$ TRP for all three species (Table 2). Management at F_{max}, for any of the three species, would allow for 150-160 gears which approximate Weyl *et al*.'s (2001) estimate for MSY. Since difference in selectivity of ¼- and ¾-inch meshes yielded only a marginal difference in YPR the failure of the nkacha net fishery to adopt the ¾-inch mesh nets is not considered drastic.

However, it should be recognized that the F_{max} and $F_{0.1}$ strategies do not take into account whether sufficient spawner biomass is conserved to ensure sufficient recruitment in the future (Deriso 1987, Sissenwine & Shepherd 1987, Clarke 1991, Punt 1993). It is also recognised that the per-recruit approach has limitations, such as its assumption of constant recruitment (Perreiro 1992), and, therefore, its use as a predictive tool is limited to short-term predictions. It is crucial that relevant long-term directed catch-at-age or –length data are collected, in all fisheries, to allow for the combination of the per-recruit data with other age-structured models in order to provide more accurate, comprehensive and sustainable strategies for long-term management.

Acknowledgements

We should like to thank Mr. Davis S. Mandere for help in fish identification. We also extend our gratitude to all the research and support staff who assisted in the programme. This study was funded by the Fisheries Department and the National Aquatic Resource Management Programme (NARMAP).

References

Bulirani, A.E., Banda, M.C., Palsson, O.K., Weyl, O.L.F., Kanyerere, G.Z., Manase, M.M. & Sipawe, R.D. 1999. Fish Stocks and Fisheries of Malawian Waters: Resource Report. Government of Malawi, Fisheries Department, Fisheries Research Unit.54pp.

Caddy, J.F. & Mahon, R. 1995. Reference points for fisheries management. FAO Fisheries Technical Paper No. 347, Rome, FAO. 83 pp.

Clark, W.G. 1991. Groundfish exploitation rates based on life history parameters. Can. J. Fish. Aquat. Sci. 48: 734-750.

Deriso, R.B. 1987. Optimal F0.1 criteria and their relationship to maximum sustainable yield. Can. J. Fish. Aquat. Sci. 44 (Suppl. 2): 339-348.

FAO. 1993. Fisheries management in south-east Lake Malawi, the Upper Shire River and Lake Malombe, with particular reference to the fisheries on chambo (*Oreochromis* spp.). *CIFA Tech. Pap. 21.* FAO, Rome. 113 pp.

Gulland, J.A. & Boerema, L.K. 1973. Scientific advice on catch levels. Fish. Bull. 71: 325-335.

Jambo, C.J. 1997. Aspects of the ecology and reproductive biology of three cichlid fish species of southern Lake Malombe (Malawi). M.Sc. Thesis. Rhodes University, Grahamstown, South Africa. 126 pp.

King, M. 1995. *Fisheries biology, assessment and management*. Fishing News Books, Oxford. 341 pp.

Murawski, S.A. & Finn, J.T. 1988. Biological bases for mixed-species fisheries: species co-distribution in relation to environmental and biotic variables. *Can. J. Fish. Aquat. Sci*., 45: 1720-1735.

Pereiro, J.A. 1992. Some conceptual remarks on yield per recruit. Fish. Res. 13: 423-428.

Punt, A.E. 1993. The use of spawner-biomass-per-recruit in the management of linefisheries. Special Publication of the Oceanographic Research Institute, Durban, 2: 80-89.

Sissenwine, M.P. & Shepherd, J.G. 1987. An alternative perspective on recruitment overfishing and biological reference points. Can. J. Fish. Aquat. Sci. 44: 913-918.

Weyl, O.L.F. 1998, The dynamics of a sub-tropical lake fishery in central Mozambique. PhD Thesis, Rhodes University, 200p.

Weyl, O.L.F. 2001. Mortality rates and catchability coefficients for three major target species in the nkacha net fishery of Lake Malombe. *National Aquatic Resource Management Programme (NARMAP) Working Paper No. 3.* 7 pp.

Weyl, O.L.F., Banda, M., Sodzabanja, G., Mwenekibombwe, L.H., Namoto, W. & Mponda, O.C. 2000. Annual frame survey: September 1999. *Fisheries Bulletin No. 42.* Department of Fisheries , Lilongwe, Malawi. 56+23 pp.

Weyl, O.L.F., Banda, M.C., Manase, M., Namoto, W. & Mwenekibombwe, L.H. 2001. Analysis of catch and effort data for the fisheries of Lake Malombe, 1976-1999. *Fisheries Bulletin No. 45.* Department of Fisheries , Lilongwe, Malawi. 53 pp.

Drifting Long Line, A Potential Fishing Method for the Northern Part of Lake Nyasa/Malawi/Niassa

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Abstract
Fishing gears commonly used in the Tanzanian Waters of Lake Nyasa consist of open water seine nets (Ndaturu/Pajero)) gillnets (vilepa) traps (migono) beach seine nets (kokoro) and hook and line (ndoano). These methods of fishing exploit mainly the near shore and riverine species. Based on recommendation of the UK/SADC Pelagic Fish Resource Assessment Project on the use of drifting long line to exploit offshore fish communities, trial fishing was carried out off Lupingu, Ikombe, Manda and Mbamba-bay villages in Tanzania. The results were encouraging and they are presented and discussed. With a mean daily catch rate of 5.8 kg/100 hooks/2hours of fishing, this method proved to local fishermen to be more profitable and environmentally friendly than using the destructive beach seine nets.

Introduction
Lake Nyasa is the most southern of the African great lakes situated in the rift valley of East Africa. It lies between 9° 30'S and 14° 30'S. It is the third largest lake in Africa with respect to surface area and the second most voluminous. The lake is long and narrow with an approximate length of 550 km and a mean width of 50-60 km. With a surface area of 28 800 km² and a volume of 8 400 km³ it gives an average depth of 292 m. (Menz 1995). The maximum depth is given as 785 m by Gonfiatini *et al*. (1979), with deepening of the basin towards the north. Tanzanian shoreline of Lake Nyasa extend 300 km in the north west to north east. Most of the inshore area of the lake on the Tanzanian side is very deep with few patches of shallow zones especially around the mouths of rivers Songwe, Kiwira, Mbaka, Rufilyo and Ruhuhu.
The fisheries of the lake are very varied exploiting most of the inshore water communities as well as the river running species and some offshore communities.

Most of the fishing in Tanzanian waters of the Lake is done with dug-out canoes. Fishing gears commonly in use consist of open water seine nets, gillnets, beach seine nets, traps and hooks. Longline has been used in Lake Nyasa to catch fish mainly catfishes (*Bagrus meridionalis, Clarias* species and *Bathyclarias* species*).* No pelagic longline has been reported on Lake Nyasa (ICLARM and GTZ 1991). The UK/SADC pelagic Fish Resource Assessment Project had recommended fishing with pelagic handline or longline using usipa or some other fish as bait in catching *Rhamphochromis* spp. especially the larger individuals that occur in 100-200 m of water (UK/SADC interim report, 1993).

Acoustic evidence strongly suggests that fish biomass further offshore remained relatively constant (Rufli, 1982). The fish in the Pelagic zone formed a simple but highly structured community. Fish biomass of the pelagic zone of Lake Nyasa was estimated to be 90 kg/ha (Rufli and Vitullo, 1982). Fish stocks in Lake Nyasa still seem to be high enough suggesting that the fish are less heavily exploited in the lake especially in the pelagic zone.

Materials and Methods
Fishing was conducted in the Tanzanian pelagic waters of Lake Nyasa in Ludewa district off Lupingu village (Figure 1). An 18 footer rubber dingy mounted with a 30Hp Yamaha out-board petrol engine was used during fishing operations. Three gangs of longlines each consisting of 100 hooks of sizes No. 7, No 11 and No. 13 were constructed. According to the numbering system of hooks number 7 was the largest and number13 the smallest. For each gang, hooks were attached to 0.5 mm thick monofilament line and individually hang 4m apart on a 0.8mm thick monofilament line 400 m long. During the fishing operations the three gangs were joined together to constitute a line 1200 m long. Each line was suspended at each end on a rope 4 x100 m deep attached to a surface buoy with a flag at both ends (fig.3). The hooks were baited with *Engraulicypris sardella* 'usipa', a bait known to be preferred by most of the predator fish found in the lake.

The long line was set early in the morning at the depth of 100 m at a point where the water depth was 130 m or more targeting for any available predatory fish at that depth. The longline was left in the water for 2hrs before hauling. This is considered as the maximum time the fish is allowed to feed and taking into consideration that the quality of the bait deteriorates with time (Allison *et al.* 1995).

The total catch from each longline was weighed and then sorted into species and the total length of each fish was recorded. These data were prerequisite for the information required; the catch rate and catch composition.

The same method was employed when setting drifting longlines at Ikombe, Manda and Mbamba-bay (Fig.1). In these demonstrations however hooks No.13, 11 and 9 were employed instead of hook sizes No.13, 11 and 7 set at Lupingu.

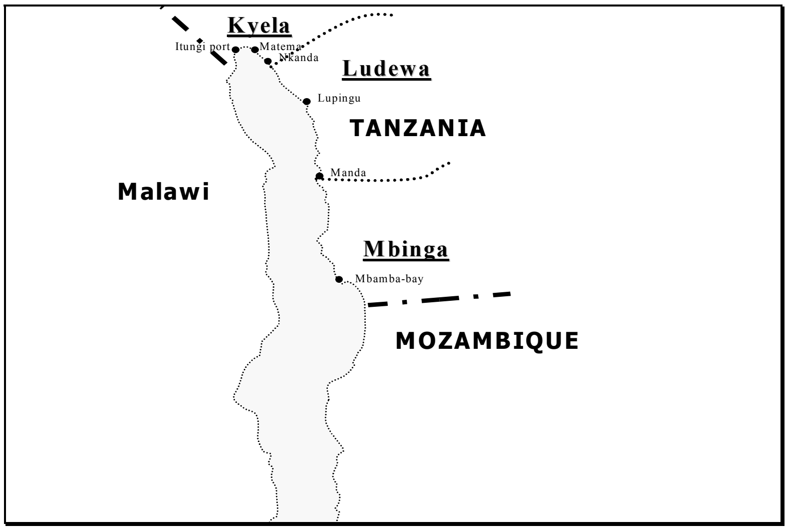

Figure 1. Lake Nyasa (Tanzania side).

Results and Discussion

Catch rates

Catch rates (kg/300 hooks/2 hours) for the three longlines from pelagic waters of Lake Nyasa off Lupingu village (Ludewa district) set for three weeks in August/September, 1995 are shown in Table 1. Total daily catch ranged between 279kg/300h/2hrs and 13.5kg/300h/2hrs (mean = 5.759kg/300h/2hrs). Catches were higher in hook size umber 11 (Average catch rate = 2.63kg/100h/2hrs) and least in hook size number 7 (Average catch rate = 0.99kg/100h/2hrs). There is no significant difference in catches with respect to varied water depth, weather and station (t-test; p.0.05).

Table 1: Catch rates (kg/100 hooks/2 hours) for three different sizes of hooks from pelagic waters of Lake Nyasa off Lupingu village (Ludewa district) caught in August/September, 1995.

				LL 7		LL 11		LL 13		TOTAL
Date	Cruise No.	Depth.	Weather	Station	Weight	Station	Weight	Station	Weight	
22.8.95AM	1	140m	Strong wind	1	3.5	3	7.29	2	2.25	13.50
23.8.95AM	2	140m	Strong wind	1	0.00	2	1.05	3	1.74	2.79
24.8.95AM	3	180m	Calm	2	1.00	3	0.15	1	1.33	3.48
25.8.95AM	4	150m	Calm	3	0.00	1	2.46	2	0.85	3.41
26.8.95AM	5	130m	Calm	3	0.35	2	4.17	1	2.94	7.46
27.8.95AM	6	130m	Calm	2	0.58	1	1.73	3	1.16	3.47
28.8.95AM	7	160m	Strong wind	1	0.85	2	0.92	3	1.37	5.14
29.8.95AM	8	150m	Strong wind	2	1.05	3	0.90	1	2.38	4.33
30.8.95AM	9	135m	Strong wind	3	1.36	2	7.21	1	4.54	13.11
31.8.95AM	10	130m	Calm	3	0.44	1	1.05	2	1.70	3.19
1.9.95AM	11	150m	Calm	3	0.00	2	2.12	1	1.95	4.07
2.9.95AM	12	140m	Calm	3	0.00	1	0.4	2	3.31	3.71
2.9.95PM	13	130m	Calm	3	0.00	1	2.45	2	0.90	3.35
3.9.95AM	14	150m	Calm	3	0.00	1	7.10	2	1.90	9.00
4.9.95AM	15	160m	Calm	2	0.84	1	0.40	3	2.97	4.21
5.9.95AM	16	140m	Calm	1	6.52	3	3.11	2	2.20	11.83
6.9.95AM	17	130m	Strong wind	2	0.36	3	2.22	1	1.80	4.38
TOTAL WEIGHT					16.86		44.73		35.29	100.43
AVERAGE WEIGHT (KG)					0.99		2.63		2.08	575.90

Catch composition

Catch composition of fish caught in three hook lines is summarized in Table 2. The species caught contribute five families out of the ten considered to exist in Lake Nyasa. The families are cichlidae (*Rhamphochromis* and *Lethrinops*), Clarridae (*Clarias* spp.) (*Bathyclarias* sp.), Bagridae (*Bagrus meridionalis*), Mochokidae (*Synodontis njassae*) and Cyprinidae (*Opsaridium* spp.). From all three longlines the catch composition showed that the predatory cichlids of the genus *Rhamphochromis* are more common in the catches followed by clariid catfishes, *Bathyclarias* spp. Other fish in the catch included *Bagrus meridionalis, Synodontis njassae, Clarias* spp., *Lethrinops* spp. and the predatory cyprinids *Opsaridium microlepis* and *O.microcephalum*. Hook number 7 caught more bigger fish *Bagrus meridionalis,* number 11 caught more medium sized fish, *Rhamphochromis ferox* while small fish-*Rhamphochromis longiceps* was caught mainly on hook number 13.

Table 2. The size composition of fish caught in three hook lines off Lupingu village in August/September, 1995

Family	Genus/Species	Weight (Kg/haul) and numbers/haul per 100 hooks					
		Line No. 7		Line No. 11		Line No. 13	
		Kg.	No.	Kg.	No.	Kg.	No.
Claridae	*Bathyclarias spp*.	0.01	0.07	1.19	0.41	0.29	0.24
	Clarias spp.	0.09	0.07	0.00	0.00	0.00	0.00
Bagridae	Bagrus meridionalis	0.53	0.60	0.15	0.24	0.30	0.18
Mochokidae	Syodontis njassae	0.00	0.00	0.01	0.06	0.01	0.06
Cichlidae	Rhamphochromis spp	0.35	0.97	1.30	3.53	1.32	3.52
	Lethrinops spp.	0.11	0.13	0.06	0.41	0.07	0.35
Cyprinidae	Opsaridium microcephalum	0.00	0.00	0.00	0.00	0.02	0.06
	Opsaridium microlepis	0.00	0.00	0.01	0.06	0.00	0.02
TOTAL		1.08		2.62		2.07	

Length distribution

Catch rates (Kg /300hooks/2hrs) for three longlines from pelagic waters of Lake Nyasa off Nkanda village (Kyela district) set for 12 days in October, 1998. Deductions as Shown in Table 3 show that the total daily catch ranged between 2.2 kg/300 h/2 hours and 18.95 kg/300 hooks/2 hours (Mean = 9:40 kg/300 hooks/2 hours). Catches were higher in hook size number 13 (Average catch rate = 3.61 kg/100h/2 hours) and least in hook size No. 9 (average catch rate = 2.57 kg/100 hooks/2 hours).

The catch composition of fish caught from the three gangs of long lines from the pelagic waters of Lake Nyasa off Nkanda Village (Kyela district) set for two weeks in October 1998 is summarized in Table 4. The species caught include *Rhamphochromis* and *Lethrinops* (cichlidae), *Bathyclarias* spp. (claridae), *Bagrus meridionalis* (bagridae) and *Synodonts njassae* (mochokidae). The catch composition show that *Bagrus meridionalis* was more common in the catches followed by predatory cichlid of the genus *Rhamphochromis* and by clariid catfishes, *Bathyclarias* spp.

Table 3. Catch rates (Kg/100 hooks/2 hours) for three different sizes of hooks from Pelagic Waters of Lake Nyasa off Nkanda Village (Kyela District) caught in October, 1998.

Date	Cruise No.	Water Depth.	LL 9		LL 11		LL 13		Total Weight
			Station	Weight	Station	Weight	Station	Weight	
8.10.98	1	120m	3	0.50	2	2.30	1	4.90	7.70
9.10.98	2	120m	2	0.10	1	0.15	3	-	0.25
12.10.98	3	119m	3	0.70	1	1.55	2	1.75	4.00
13.10.98	4	120m	1	2.35	3	8.61	2	4.45	15.41
14.10.98	5	120m	1	3.65	2	2.55	3	1.05	7.25
15.10.98	6	120m	2	9.15	1	2.75	3	4.22	16.12
16.10.98	7	120m	3	0.46	1	2.15	2	2.45	5.06
17.10.98	8	123m	3	5.10	1	7.85	2	6.00	18.95
18.10.98	9	120m	2	4.05	1	5.25	3	5.95	15.25
21.10.98	10	120m	1	4.30	3	1.25	2	5.45	11.00
21.10.98	11	120m	3	0.45	1	1.50	2	0.25	2.20
22.10.98	12	120m	3	1.50	2	1.90	3	2.05	5.45
TOTAL WEIGHT				32.31		37.81		38.52	107.09
AVERAGE WEIGHT(KG)				2.68		3.02		3.21	8.92

Table 4. The catch composition of fish caught in three hook lines off Nkanda village in October, 1998

Family	Genus/Species	Weigh (kg/haul) and numbers/haul per 100 hooks					
		Line No. 9		Line No. 11		Line No. 13	
		Kg.	No.	Kg.	No.	Kg.	No.
Claridae	*Bathyclarias spp*.	0.45	0.38	0.43	0.54	0.77	0.38
Bagridae	Bagrus meridionalis	1.80	3.50	2.48	5.08	2.05	3.77
Mochokidae	Synodontis njassae	0.00	0.00	0.00	0.00	0.02	0.15
Cichlidae	*Diplotaxodon spp*.	0.00	0.08	0.05	0.31	0.02	0.31
	Rhamphochromis spp.	0.28	0.77	0.13	0.62	0.38	0.92
	Lethrinops spp.	0.04	0.31	0.13	0.62	0.01	0.15
TOTAL:		2.57		3.22		3.61	

Catch rates (Kg/300hooks/2hrs) for three longlines from pelagic waters of Lake Nyasa off Manda village (Ludewa district) set for 14 days (June/July 1999) are shown in Table 5, the daily catch ranged between 2.70 kg/300 hooks/2 hours and 33.73 kg/300 hooks/2 hours. (Mean = 16.33 kg/300 hooks/2 hours). Catches were higher in hook size number 9 (average catch rate = 5.58 kg/100 hooks/2 hours) and least in hook size number 11 (average catch rate = 5.24 kg/100 hooks/2 hours).

The catch composition summarized in Table 6 below. Species caught include *Rhamphochromis, Diplotaxodon, Lethrinops* (Cichlidae), *Bathyclarias* spp. and *Clarias* (Claridae), *Bagrus meridionalis* (Bagridae) and *Synodontis njassae* (Mochokidae). The catch composition showed that *Bagrus meridionalis* was more common in the catches followed by *Rhamphochromis* followed by *Diplotaxodon* and by clariid catfishes *Clarias* and *Bathyclarias.* spp.

Catch rates (Kg/300hooks/2hrs) for three sets of longlines from pelagic waters of Lake Nyasa off Mhalo village (Mbamba-bay) Mbinga district set for 9 days May,2000. Table 7, show the daily catch ranged between 1.41 kg/300 hooks/2 hours and 6.72 kg/300 hooks/2 hours (Mean = 3.68 kg/300 hooks/2 hours). Catches were higher in hook size No. 13 (average catch rate 1.57 kg/100 hooks/2 hours) and least in hook size No. 9 (average catch rate 0.97 kg/100 hours/2 hours).

Table 5. Catch rates (kg/100 hooks/2 hours) from three different sizes of hooks from Pelagic Waters of Lake Nyasa off Fokland (Manda) caught in June-July, 1999

Date	Cruise No.	Water Depth(m)	Long Line Hook No. 9		Long Line Hook No. 11		Long Line Hook No. 13		Total Weight
			Station No.	Weight (kg)	Station No.	Weight (kg)	Station No.	Weight (kg)	
20.06.99	1	120	3	4.50	2	0.95	1	0.25	6.40
21.06.99	2	115	3	4.25	2	-	1	-	4.25
22.06.99	3	115	3	6.03	1	13.57	2	11.93	31.53
23.06.99	4	115	1	18.28	2	1.90	3	-	20.18
24.06.99	5	110	2	6.45	1	6.59	3	14.09	27.13
25.06.99	6	110	2	0.30	1	10.20	3	1.35	11.85
26.06.99	7	110	1	6.62	2	2.50	3	0.49	9.61
27.06.99	8	115	1	1.81	2	0.45	3	0.90	3.16
02.07.99	9	110	1	0.33	2	1.38	3	0.99	2.70
03.07.99	10	115	1	3.12	2	8.30	3	11.45	22.87
04.07.99	11	120	1	2.69	2	8.84	3	4.49	16.02
05.07.99	12	110	2	6.75	1	8.34	3	8.31	23.40
06.07.99	13	115	2	3.55	1	3.55	3	8.62	15.72
07.07.99	14	115	1	13.40	2	6.74	3	13.59	33.73

Table 6. The catch composition of fish caught in three hook line off Forkland-Manda in June-July, 1999

Family	Genus/Species	Weight (kg/haul) and number/haul per 100 hooks					
		Line No. 9		Line No. 11		Line No. 13	
		Kg.	No.	Kg.	No.	Kg.	No.
Claridae	*Bathyclarias spp*.	0.69	0.57	1.01	0.50	0.84	0.43
	Clarias spp.	0.94	0.93	1.14	0.93	0.15	0.21
Bagridae	*Bagrus meridionalis*	3.44	3.07	2.17	2.64	2.96	2.71
Mochokidae	*Syonodontis njassae*	-	-	0.04	0.07	0.01	0.07
Cichilidae	*Rhamphochromis spp.*	0.16	0.50	0.65	2.43	1.26	3.64
	Diplotaxodon spp.	0.04	0.57	0.06	0.50	0.13	1.29
	Lethrinops spp.	0.08	0.36	0.02	0.14	0.11	0.50
	Others	0.09	0.21	0.04	0.14	-	-

The catch composition of fish caught from the three sets of long lines from the pelagic waters of Lake Nyasa off Mhalo – Mbamba-bay (Mbinga district) set for 9 days in February 2000 is summarized in Table 8.

Species caught include: *Rhamphochromis, Diplotaqxodon* and *Lethrinops* (Cichlidae) *Bathyclarias* spp. and *Clarias* (Claridae) and *Bagrus meriodionalis* (Bagridae). The catch composition showed that *Rhamphochromis* spp. were more common in the catches (actually dominating the catches) followed by *Diplotaxodon* and by *Lethrinops* spp.

As pointed out earlier *Rhamphchromis* species were considered more abundant for long line fishery in the pelagic waters of Lake Nyasa. The setting of these demonstrations thus took into consideration feeding habits of this predatory cichlid. The major feeding period of which is in the morning and a minimum peak in the afternoon. However as observed from the catch composition *Bagrus meridionalis* was more common. Important also are the clariid catfishes *Bathyclarias* species and *Clarias* species. Since they constitute significantly to the long line catches in the northern part of the lake, it is imperative to consider their feeding behaviour in future demonstrations.

Table 7. Catch rates (kg/100 hooks/2 hours from three different sizes of hooks from Pelagic Waters of Lake Nyasa off Mhalo (Mbamba-bay) caught in May, 2000

Date	Cruise No.	Water Depth(m)	Long Line Hook No. 9		Long Line Hook No. 11		Long Line Hook No. 13		Total Weight
			Station No.	Weight (kg)	Station No.	Weight (kg)	Station No.	Weight (kg)	
8.02.2000	1	120	1	0.51	2	1.70	3	2.46	4.67
9.02.2000	2	115	3	1.73	2	0.65	1	0.51	2.89
10.02.2000	3	120	3	-	2	0.50	1	0.91	1.41
11.02.2000	4	120	3	1.69	2	0.53	1	2.08	4.30
12.02.2000	5	120	1	-	2	2.77	3	3.95	6.72
13.02.2000	6	120	1	0.28	2	0.82	3	1.49	2.59
16.02.2000	7	120	1	2.27	3	2.50	2	0.95	5.72
17.02.2000	8	120	2	0.35	1	0.25	3	1.05	1.65
18.02.2000	9	130	3	1.90	1	0.60	2	0.70	3.20

Table 8. The catch composition of fish caught in three hook lines off Mhalo-Mbamba-bay in February, 2000

Family	Genus/Species	Weight (kg/haul) and numbers (haul/100 hooks)					
		Line No. 9		Line No. 11		Line No. 13	
		Kg.	No.	Kg.	No.	Kg.	No.
Claridae	*Bathyclarias spp*.	0.16	0.11	-	-	-	-
	Clarias spp.	0.04	0.11	-	-	-	-
Bagridae	Bagrus meridionalis	0.04	0.11	-	-	-	-
Cichilidae	*Rhamphochromis spp*.	0.64	2.00	0.98	3.33	1.96	4.22
	Diplotaxodon spp.	0.03	0.11	0.06	0.22	0.03	0.22
	Lethrinops spp.	0.06	0.22	-	-	-	-

Table 9. Range and mean of total lengths (cm) of fish caught by long line fishery from Pelagic Waters of Lake Nyasa off Nkanda/Ikombe in October, 1998.

Fish Species	Range	Mean	N.
Bagrus meridionalis	18.0 – 84.0	37.1	154
Rhamphochromis spp.	20.0 – 45.0	31.7	33
Clarias spp.	28.0 – 72.0	59.5	14
Diplotaxodon spp.	16.0 – 23.0	19.1	9
Synodontis njassae	13.0 – 18.0	15.0	3
Haplochromis spp.	16.0 – 28.0	23.5	14

Table 10. Range and mean of total lengths (cm) of fish caught by long line fishery from Pelagic Waters of Lake Nyasa off Fokland (Manda) in June- July, 1999.

Fish Species	Range	Mean	N.
Bagrus meridionalis	19.0 – 66.5	40.7	118
Rhamphochromis spp.	17.0 – 45.0	31.64	92
Clarias sp.	19.0 – 90.0	61.0	23
Diplotaxodon spp.	13.5 – 26.0	19.3	34
Bathyclaria spp.	36.0 – 87.5	59.5	21
Lethrinops spp.	11.0 – 27.5	23.1	14
Synodontis njassae	13.0 – 15.0	14.0	2
Haplochromis spp.	21.0 – 34.5	29.3	5
Copadichromis spp.	10.0 – 10.0	10.0	1

Table 11. Size range and mean of total lengths (cm) of fish species caught by long line fishery from Pelagic Waters of Lake Nyasa off Mhalo (Mbamba-bay) in February, 2000.

Fish Species	Range	Mean	N.
Rhamphochromis spp.	13.8 – 45.5	27.7	87
Bagrus meridionalis	33	33	1
Bathyclarias spp.	31.5	31.5	1
Diplotaxodon spp.	16.0 – 24.5	21.5	5
Lethrinops spp.	18.5 – 25.0	21.8	2

Recommendations

Fishermen should be encouraged to practice drifting longline because:

- It is cost effective
- Environmentally friendly
- Targets for mainly large fish
- Hooks # 9-13 are recommended
- Other baits also be investigated
- Demonstrations should cover the entire Tz coast.

References

Gonfiatini, R., Zuppi, G., Eccles, D. H. & Ferro, W. 1979. Isotope investigation of Lake Malawi. In Isotope in lake studies. International Atomic Energy Agency, Vienna.

ICLARM & G.T.Z. 1991. The context of small scale integrated agriculture – Aquaculture systems in Africa. A case study of Malawi: ICLARM Stud. Rev.

Menz A. 1995. The fishery Potential and Productivity of the pelagic zone of Lake Malawi/Niassa. Chathan, U.K. Natural Resources Institute.

Rufli, H. 7 Vitullo, J. A. 1952. Preliminary estimate of the abundance of Pelagic Fish Stocks in Lake Malawi. In biological studies on the pelagic ecosystem of Lake Malawi. Rome/FAO/UNDP F< LDP/MLW/75/019 Technical Report I: 138/153.

UK/SADC. 1993. Pelagic Fish Resource Assessment Project. Interim Technical Report.

Walezak, P.S. 1982. Feeding habits and daily food consumption rates of the major Pelagic fish species of Lake Malawi. Supplement to: Biological Studies of the Pelagic Ecosystem of Lake Malawi, FAO Technical Report 1, FI: DP/MLW/75/019, Field document 15.

Gear and species selectivity of the chilimira kauni fishery in Lake Malawi

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Abstract
Kauni fishing in Lake Malawi occurs by using a chilimira net (an open water seine net) at night using light from paraffin lamps to attract the fish. Kauni fishing occurs in both the south-east (SEA) and south-west arms (SWA) of Lake Malawi. Catches from kauni gears landing at Kela beach (SEA) and Msaka beach (SWA) were examined for a one-year period to determine the potential effects on the fish stocks. Catch composition and length frequency assessments were performed. The kauni fishery in both areas was multi-species with 70 species recorded in the Kela fishery and 65 species in Msaka. At Kela the major genera targeted were *Rhamphochromis*, *Oreochromis* and *Copadichromis,* which made up over 75 % of the catch composition. At Msaka the major genera were *Rhamphochromis*, *Engraulicypris* and *Copadichromis,* which made up over 85 % of the catch. Length frequencies of *Oreochromis* spp. *Rhamphochromis* spp. and *Copadichromis virginalis* are examined and recommendations for managing this fishery are made.

Introduction
It is a well-known fact for Lake Malawi that there has been a decline in the chambo *Oreochromis* spp. stocks. Catches of chambo in Lake Malawi peaked at 8-9 000 tons in the late 1970s and in the mid-1980s but declined in 1986-87 (Bulirani *et al.* 1999). The south-east arm is the most important fishing ground for chambo. Catches were stable at 5-6 000 tons during 1986-92 but have declined to 1 800-2 800 tons a year (Bulirani *et al.* 1999). The bulk of the catch has been taken in the traditional fishery, which uses various gears such as gill nets, chambo seines, kambuzi seines and chilimira nets. The chambo stocks are now considered threatened and in need of management (Bulirani *et al.* 1999).

In the south-east arm of Lake Malawi it was observed that, while chambo formed only a small component of the chilimira net fishery as a whole, the high effort levels in this fishery result in the fishery contributing between 25% and 46% of the total chambo catch (Weyl, 1999). The chambo is being exploited by chilimira nets (open water seine nets; FAO, 1993), which are locally known as kauni (a term referring to the light attraction method by using lamps at night to attract fish into the nets: Banda unpublished). The chilimira that targets chambo is a derivative of the gear used for catching usipa and this derivative gear used in the kauni fishery is known to operate in both the southeast and southwest arms of the lake. It has been found that the chilimira fishers in Area A of the south–eastern arm directly target chambo (Weyl, 1999, Weyl & Banda, 2001). A preliminary report on the fishery in this area showed that over 80% of the chambo caught in the kauni fishery was immature (Banda unpublished). This indicated that the fishing method was affecting the recruitment of chambo (Banda, unpublished). Due to this observation Banda recommended the closure of the kauni fishery.

The chambo directed kauni fishery of Area A is of major concern and it has been recommended that there should be a closure of this fishery in this area since it is an important fishing ground for chambo (Weyl, 1999; Bulirani *et al.* 1999). This recommendation came about in order to restore chambo stocks to previous levels and increase production. The fisheries Conservation and Management Regulations 2000 prohibit ‘kauni for chambo’ thus catching chambo in the kauni fishery is illegal (Fisheries Management and Conservation Act, 2000).

This paper is a result of a one-year study of the chilimira/kauni fishery in the southern part of Lake Malawi. The objective of this study was to examine and compare the kauni fisheries in the south east arm (SEA) and south west arm (SWA) of Lake Malawi to determine the potential effects of these fisheries on the fish stocks.

Methodology
Catch assessment of the kauni fisheries operating at Kela (SEA) and Msaka (SWA) landing sites were conducted once for three consecutive days a month for a one-year period. At these landing sites, as many gears as possible were sampled. The weight of the entire catch was assessed and a sample was randomly selected and weighed. The species composition of the catches was assessed as each fish in the sample was sorted to species level. Each species group was weighed separately and each fish was measured for total length (TL) in millimetres.

Results
The kauni fishermen, landing at Kela, fish in Area A, south of Boadzulu Island, while those landing at Msaka usually fish close to Mumbo Island. It was observed that both the fisheries in the SWA and SEA are multi-species catching many different species, many of which were cichlids. The number of species recorded at Kela was 70 and

at Msaka 65 (Table 1). The contribution of the different species in the fishery varied from month to month as well as by area.

The fish species identified in the fishery were lumped in major species groups for species composition analysis. These major groups were *Rhamphochromis* spp. *Oreochromis* spp. *Copadichromis* spp. as well as usipa (*Engraulicypris sardella*) and 'other' group. The 'other' group consisted of all other species caught in the fishery that were not included in the major species groups.

At Msaka the main contributing species groups were *Rhamphochromis* spp, usipa and *Copadichromis* spp. However, the contribution of these various groups varied for the different months of the year. The 'other' group contributed significantly in November. There was no data collected in June, and in December there was an anomaly in the data that lead to all the data in December being discarded (Figure 1). The *Rhamphochromis* spp group contributed 51% of the total catch followed by usipa, which contributed 25%. The 'other' group contributed 14%, *Copadichromis* spp. group contributed 10%, and chambo contributed only 0.5% of the total catch (Figure 2).

In Kela the situation was different. The most important species groups were *Rhamphochromis* spp. and chambo followed by the 'other' group and the *Copadichromis* spp. group. These species groups contribution also varied each month (Figure 3). *Rhamphochromis* spp. contributed 37% of the total catch followed by chambo which contributed 34%. The 'other' group contributed 21%, *Copadichromis* spp. 5% and usipa only 3% to the total catch (Figure 4).

Length frequency analyses were conducted for some of the most important species groups i.e. *Oreochromis* spp. and *Rhamphochromis* spp. For the *Copadichromis* spp. group, one of the species that contributed significantly from this group *C. virginalis* was used in the analysis. Selectivity analyses for the different species groups were conducted by combining all the individuals caught in the different mesh sizes (0.5 to 2 inch) in the fishery. This is due to the fact that analyses with the separate mesh sizes showed no significant difference in the sizes of individuals caught.

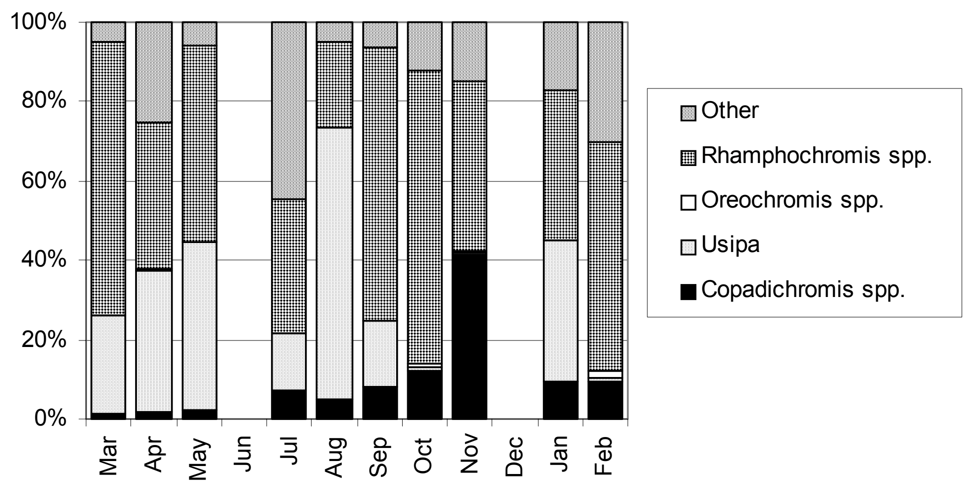

Figure 1. Monthly trends in catch composition (%) of Msaka kauni fishery.

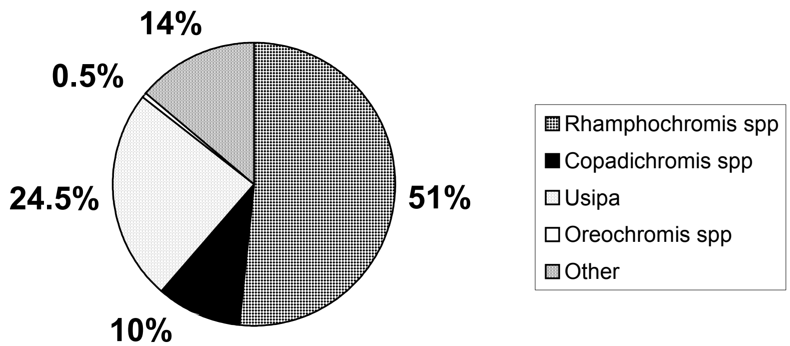

Figure 2. Cumulative species composition by weight (%) of Msaka kauni fishery (2000 Mar–2001 Feb).

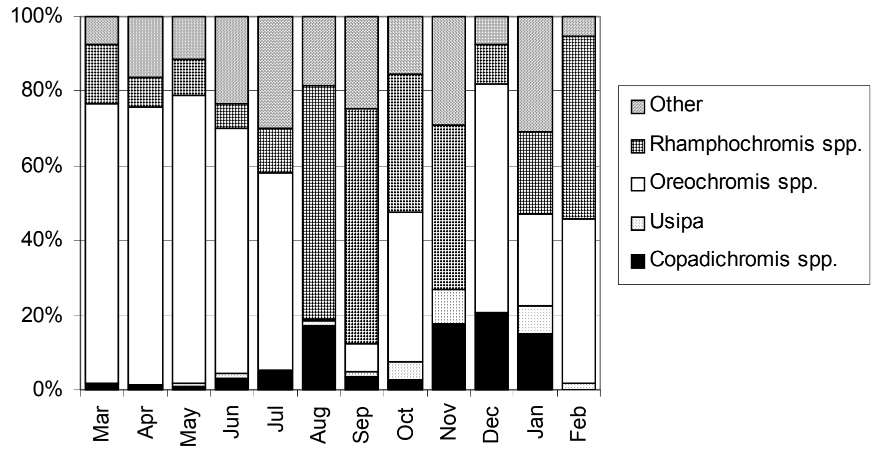

Figure 3: monthly trends in catch composition (%) of Kela kauni fishery.

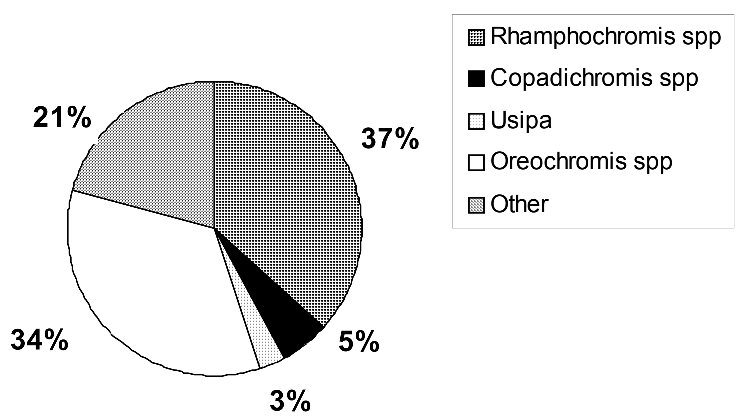

Figure 4: cumulative species composition by weight (%) of Kela kauni fishery (2000 Mar–2001 Feb).

For the *Oreochromis* spp. group, the length frequency showed that the majority of individuals caught were bigger than 150 mm TL. Few juvenile chambo were caught in this fishery, 3 % of individuals were 150 mm or less in total length. This lack of juvenile chambo in the kauni fishery is not the result of the gear selecting for the adults but rather because fishing occurs in areas where the juveniles are not found being an open water fishery (juvenile chambo are found in shallow water closer to shore). The length at 50% maturity for chambo species is 203 mm total length (Palsson *et al*. 1999). In this fishery 50% selectivity was at 210 mm showing that mature adults are mostly caught.

The length frequency for the *Rhamphochromis* spp. group showed that 97% of the individuals caught were 110 mm or bigger in total length. This group is very diverse with a length at maturity range of 109–232 mm standard length (Turner *et al.* 2000). This range reflects the fact that there are different species with different lengths at maturity caught in this fishery. Many of the individuals caught belonged to the species *R. longiceps* and *R. ferox* which are on the lower side of the maturity range having lengths at maturity of 109-130 mm SL and 138 –143 mm SL respectively. In this fishery 50% selectivity was at 183 mm TL.

The length frequency for C. *virginalis,* a major species in the *Copadichromis* spp. group showed that 89 % of the individuals caught were 110 mm or bigger in total length. The length at maturity for this species is 106 mm TL (Marechal, 1991). Mean (50%) selectivity was at 128 mm indicating that mature adults are mainly caught in this fishery.

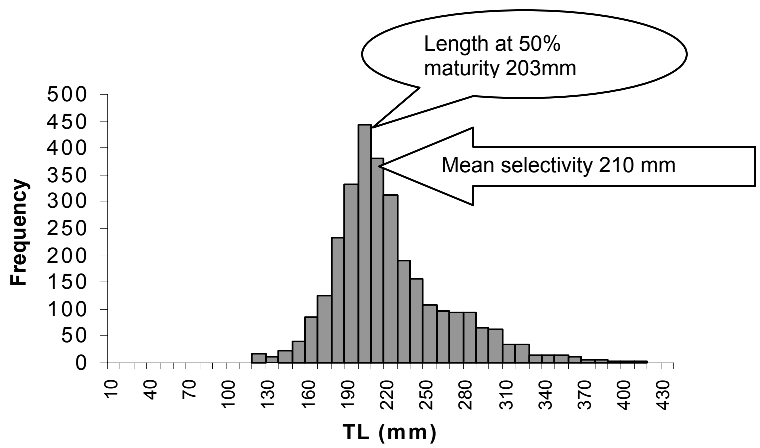

Figure 5. Length frequency for *Oreochromis* spp. sampled from the kauni fishery (n=3015).

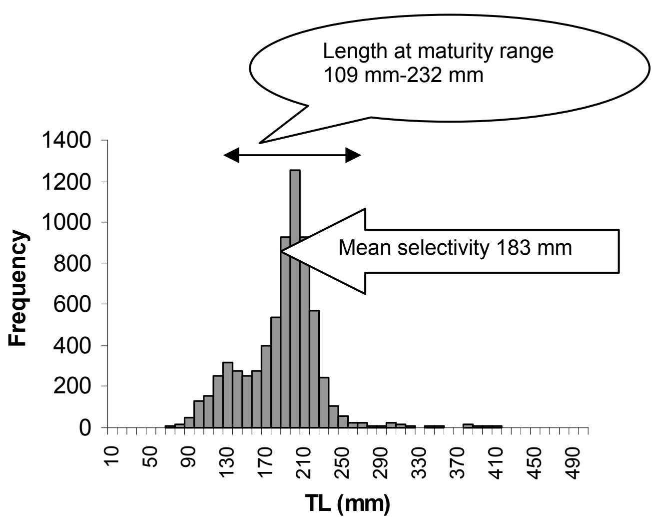

Figure 6. Length frequency for *Rhamphochromis* spp. sampled from the kauni fishery (n=6943).

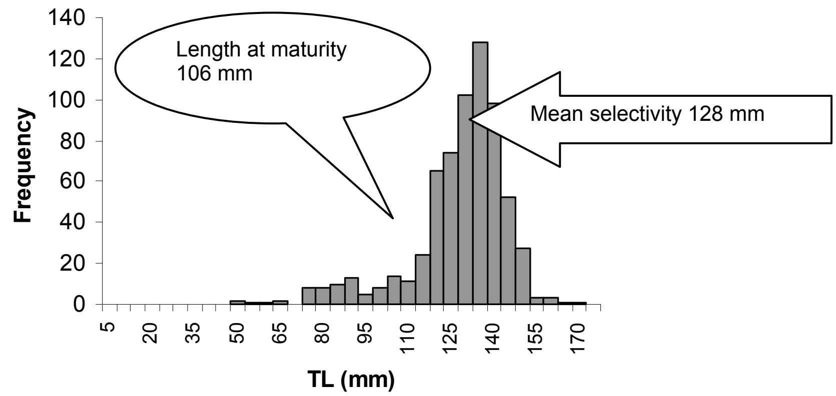

Figure 7. Length frequency for *C. virginalis* sampled from the kauni fishery (n=661).

Discussion

In Kela and Msaka it was observed that the *Rhamphochromis* spp. group was very important, contributing 37% and 51%, respectively. Usipa was more important in Msaka, were it contributed 25% to the catch, than at Kela were it only contributed 3% of the total catch. The *Oreochromis* spp. group was more important at Kela, were it contributed 34% of the total catch. At Msaka this group was of minor importance, contributing less than 1% to the total catch of the kauni fishery.

Due to the wide-ranging nature of the *Rhamphochromis* stocks, they are not considered threatened by local overexploitation at the moment and are therefore not in need of any restrictions (Turner *et al.* 2000). The *Copadichromis* stocks do not form a huge component in the fishery (contributing 5% in Kela and 10% in Msaka) and the sizes of individuals harvested are of those that have reached adult size. For this reason, the *Copadichromis* stocks do not seem to be threatened by the kauni fishery. However, it should be kept in mind that other fisheries also harvest this species group and these should be closely monitored. For the usipa stocks, no management recommendations can be given because the stock experiences large fluctuations that appear to be caused by environmental factors (Allison *et al.* 1995). However, due to the declining nature of the chambo fishery, *Oreochromis* spp. stocks need management intervention if the stocks are expected to recover.

From an area point of view, none of the species groups dominating the kauni fishery at Msaka seem to be threatened, therefore restrictions at Msaka are not necessary. However for the chambo stocks at Kela, management is necessary.

The ban of 'kauni for chambo' in the Fisheries Conservation and Management Act (2000) has not been effective because the fishermen are still catching chambo. It appears unrealistic to inform the kauni fishermen to fish but not catch chambo and if chambo is caught in their gear, they are unlikely to throw it back into the water. However it is not known whether they specifically target chambo in their fishing procedure or not. A more realistic management procedure would be to ban this fishery in a given area i.e. Area A as recommended by Bulirani *et al*. (1999) and Weyl (1999). Due to the use of lights in the fishery at night, it would be easy to monitor whether or not the fishermen are following the regulations.

From the length frequency analyses of the *Oreochromis* spp. group it was observed that the adult chambo are mainly being harvested in this fishery. The harvesting of immature chambo is not a concern in this fishery. However, since adult chambo are mainly caught, the stocks are still being depleted. Therefore, there is a need to protect the adults until a recovery of the chambo stocks can be seen.

With the aim of protecting the chambo stocks, the option of closing the kauni fishery and its consequences should be considered. With an annual estimated catch of 1500 tons (Catch statistics, 2000), the kauni fishery in Area A contributes approximately 40% to the total landings in the area. In addition, the closure of this fishery would result in a decreased yield of other major species groups such as *Rhamphochromis* spp. and *Copadichromis* spp. that are presently exploited in this fishery.

It has been reported that 40 to 60 boats land at Kela beach each day (Ganter *et al.*2001). Therefore over 400 people are directly involved in catching fish only at this beach. In Area A, there are 119 chilimira gears which are all likely involved in kauni fishing and this means that in this fishery over 1 000 people in the area are directly involved in catching fish (Weyl *et al.* 2000). Closing down this fishery would lead to a high number of people losing employment. Options of limiting effort in this fishery to levels where enough adults are protected while some fishing continues, need to be explored.

Acknowledgements

Thanks to the technical assistants and other staff of the Fisheries research unit (FRU) who assisted in the collection of data. Thanks to Dr. Olaf Weyl who assisted in the data analysis. Special thanks to the National Aquatic Resource Management Programme (NARMAP) whom funded this study.

References

Allison, E.H., Patterson, G., Irvine, K., Thompson, A.B. and Menz, A. 1995. The pelagic ecosystem. In: *The fishery potential and productivity of the pelagic zone of Lake Malawi/ Niassa.* Menz, A. (ed). Chatham, UK: Natural Resources Institute

Banda, M. 1996. (unpublished) A preliminary report on the kauni fishery. Unpublished report.

Bulirani, A.E., Banda, M.C., Palsson, O.K., Weyl, O.L.F., Kanyerere, G.Z., Manase, M.M. & Sipawe, R.D. 1999. Fish stocks and fisheries of Malawian waters: Resource report. Government of Malawi, Fisheries Department, Fisheries Research Unit. 54pp.

Catch statistics, 2000. Unpublished, Fisheries Research Unit, Monkey Bay.

Fisheries Conservation and Management Regulations. 2000. The Malawi Gazette Supplement, 14th July, 2000, containing Regulations, Rules, etc. Government Notice No. 32. Fisheries Conservation and Management Act, 1997 (No. 25 of 1997).

Ganter, E. 2001. Socio economic survey No. 2. Kela village – summary of preliminary results. NARMAP &-Dept of Fisheries, Malawi. GTZ publication, March 2001.

Marechal, C. 1991. Copadichromis. In: Check-list of the freshwater fishes of Africa (CLOFFA). J. Daget, J.P. Gosse, G.G. Teugels and D.F.E. Thys van den Audenaerde (Eds). ISNB, Brussels. Vol 4, p51-58.

Palsson, O.K., Bulirani, A. and Banda, M. 1999. A review of the biology, fisheries and population dynamics of chambo (Oreochromis spp., CICHLIDAE) in Lakes Malawi and Malombe. Fisheries Bulletin No. 38.

Turner, G.F., Carvalho, G.R., Robinson, R.L. and Shaw P.W. 2000. Biodiversity Conservation and sustainable utilisation of pelagic cichlid fishes of Lake Malawi/Niassa/Nyasa. Ncheni Project Final report. University of Southampton & Hull, U.K.

Weyl, O.L.F. 1999. Artisanal fishery catch-assessment for the south-east arm of lake Malawi; 1994-1998. NARMAP Technical Report No.2. 41pp.

Weyl, O.L.F., Banda, M., Sodzapanja, G., Mwenekibombwe, L.H., namoto, W. and Mponda, O.C. 2000. Annual frame Survey, September 1999. Government of Malawi, Fisheries Bulletin No. 42.

Weyl, O.L.F. and Banda, M.C. 2001. Notes on the chilimira net catch composition from catch and effort in Mangochi District. NARMAP Technical Report No. 5. 8 pp.

Gear and species selectivity of the gill net fishery in Lake Malawi.

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Abstract
Size selectivity of some important fish species caught in gill nets was estimated indirectly. Species composition of the catches from gill nets with mesh sizes between 1 and 2 inches showed that the catch was dominated by *C. virginalis* (74%) and that chambo contributed less than 0.2% to the catch of these small meshed gill nets. Chambo was not caught in these meshes because the size range of chambo that could be susceptible to this gear inhabits shallow waters where small meshed nets are not set. The small meshed gill nets were considered ideal for catching offshore cichlids. Gill nets with mesh sizes between 2 and 3 inches selected chambo at sizes corresponding with the size range at which this species migrates to deep water. Since this migration occurs before maturity the use of gill nets with mesh size 2-3 inches is not recommended. Gill nets with mesh sizes between 3 and 4 inches were considered ideal since they select for mature chambo. However, the study showed that gill nets with the current mesh sizes in use do not catch mature catfish. For management purposes, development and adoption of distinct gill net fisheries for specific target species is suggested.

Introduction
The gill net is one of the most commonly used gears in Lake Malawi. Its use dates back to the early 1940s. Gill nets contribute between 15 and 20% to the total annual fish landings from Lake Malawi (Bulirani *et al.* 1999) and in terms of employment, this fishery engages about 13 600 fishers, representing 30-35% of people directly involved in the fishing industry both as gear owners as well as crew members (Weyl *et al.* 2000).

The number of gill nets being operated on the lake has increased tremendously during the late 1990's (Weyl *et al.* 2000). In 1995 for example, there were over 17 000 gill nets, the number grew to 24 000 in 1997 and in 1999 there were approximately 30 000 gill nets (Weyl *et al.* 2000). In addition, recent frame survey showed that the majority of these nets were under-meshed. For instance, 90% of gill nets recorded for Mangochi District were less than 3.0 inches (Weyl *et al*. 2000) which was below the 3.75 inch legal mesh size for gill nets operated in the southeast and southwest arms of Lake Malawi.

The increase in the number of gill nets in the late 1990s coupled with the use of under-meshed gill nets in Lake Malawi, initiated the execution of this project in-order to determine species composition and size selectivity of the catches in gill nets of mesh sizes ranging from 1inch to 3.75 inches. This was done in order to assess potential impacts of small meshed nets on the fishery.

Methods

Sampling area
Catches were sampled from local fishermen's gill nets in the southeast arm of Lake Malawi. In particular, gill net samples were acquired from Makawa (Kela beach), Kadango, Nkope, Ng'ombe and Namiasi landing sites in the southeast arm of Lake Malawi. Since gill net fishers are highly migratory, the sampling programme was designed in such a way as to target beaches where most gill-netters were landing at that time.

Data collection and analysis
Fish catches from the gill net fishery of the Southeast arm were sampled from 1inch to 3.75 inch mesh size gill nets on a monthly basis from October 1998 to December 2000. The fish were identified to species level, each species component in the catch was weighed and then total length (TL) measurements were recorded to the nearest millimetre.

Retention in gill nets occurs when a fish penetrates a mesh beyond its gill covers but does not completely penetrate through, this implies that a fish is caught if its head girth is smaller but its maximum girth is larger than the mesh perimeter (Hamley, 1975). Since there is a relationship between girth and total length (Konda 1962, Burd 1963 and Kipling 1963), total length (TL) is used exclusively in this study.

The selectivity curves were fitted using a re-parameterised gamma selectivity function as outlined in Punt *et al.* (1966). A typical gill net selectivity curve is bell-shaped falling to zero on both sides of a maximum (Hamley, 1975). The gamma selection function was chosen because it easily describes all the members of the exponential family of distributions more precisely than the other functions (Manase, 2000).

Results and discussion

1-2 inch gill nets

Figure 1 shows the percent catch composition of the 7 main fish species that contributed over 90 % of the catch in gill nets with mesh size between 1 to 2 inches. Table 1 shows the catch composition and total number of fish species caught in gill nets of various mesh sizes.

In gill nets with mesh sizes between 1 and 2 inches, 120 different fish species were recorded. The majority of the species caught in such nets were those that are naturally small in size. The only exception was that 6% and 0.2% of *Bagrus* and chambo respectively (both comprising of juveniles only) were caught in these nets.

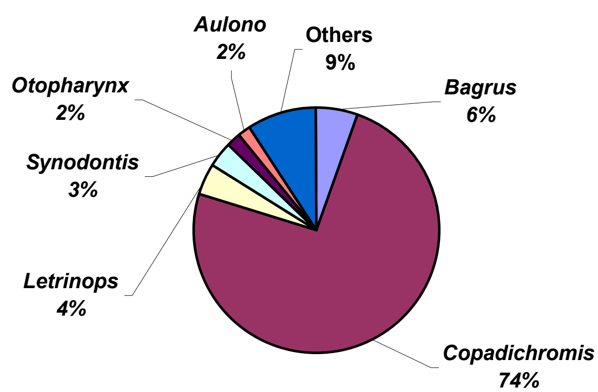

Figure 1. Catch composition in 1-2inch gill nets.

Table 2 gives the mean lengths at capture, total length ranges as well as variances for fish caught in various mesh sizes and analysed using gamma distribution. The mean length at capture of chambo in 1.5inch nets was 11cm (figure 2) while the mean length at maturity for chambo is 20.3 cm (Bulirani *et al.* 1999). For the 1.5 inch gill nets chambo varied between 10 cm and 13 cm in total length.

Table 3 gives the mean length-at-capture (l_c) divided by length-at-maturity (l_{mat}) (Lc/Lmat) values for species analysed with gamma function. When mean length-at-capture (Lc) was expressed as a proportion of the length-at-maturity (Lmat), it was found out that all chambo caught in gill nets of 1.5 inch mesh size were immature ($Lc/Lmat \geq 1$). However, chambo contributed only 0.2% of the total catch in gill nets of this particular mesh sizes. This is because small immature chambo inhabits very shallow waters (FAO, 1993) while these nets are set in deep water where they are set to target offshore pelagic fish species especially as utaka.

The length at first capture for *C.virginalis* in 1 and 1.75 inch gill nets was 13.3 and 12 cm respectively (Figure 3). These sizes are well above 10.6 cm, the length at maturity for *C. virginalis* (Marechal 1991). Though 74 % of the catch consisted of *C.virginalis,* this stock seems not to be threatened because only mature individuals are being harvested. Since approximately 90% of the catch in gill nets with mesh sizes ranging between 1-2 inches comprise small fish species that mature before capture by this gear, such nets therefore may be used as harvesting strategy for utaka.

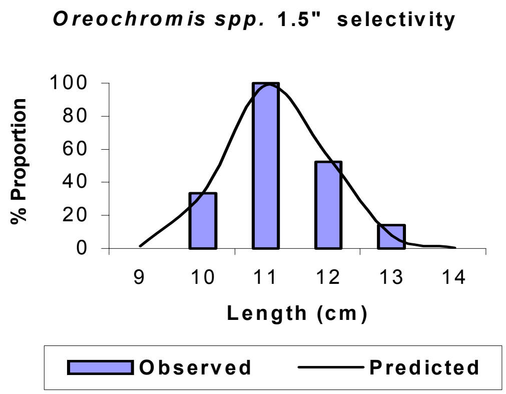

Figure 2. Chambo 1.5 inch mesh selection curve.

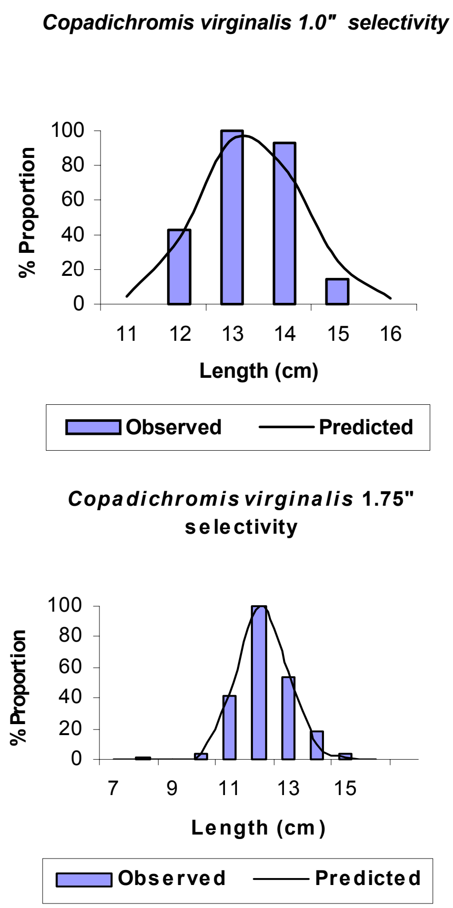

Figure 3. *C.virginalis* selection curves for 1.0 inch and 1.75 inch gill nets.

Table 1. Percent catch composition in gill nets of mesh size 1-2 inch (25-50mm), 2-3 inch (51-75 mm) and 3-4 inch (76-95mm) sampled between October 1998 and December 1999 in the southeast arm of Lake Malawi. (n= 422 kg for 1-2 inch nets; n = 23kg for 2-3 inch nets and n = 1 107 kg for 3- 4 inch nets). * Species for which Gamma analysis was done.

Species	1-2 in.	2-3 in.	3-4 in.	Species	1-2 in.	2-3 in.	3-4 in.	Species	1-2 in.	2-3 in.	3-4 in.	Species	1-2 in.	2-3 in.	3-4 in.
Alticorpus				Coreematodus				Maravichromis				Rhamphochromis*			
A. geoffreyi	0.07			C. shiranus	0.01			M. ericotaenia	0.03		0.01	R. spp_			0.26
A. macrocleithrum	0.05			C. taeniatus	0.04			M. anaphyrmus	0.43	1.08	0.27	Sciaenochromis			
A. mentale	0.13			Ctenopharynx				M. formossus	0.06			S. benthicola	0.09	0.04	
Aulonocara				C. intermedius	0.86		0.03	Mormyrus				S. gracilis	0.19		0.03
A. copper	0.14			Dimidiochromis				M. deliciosis		0.87		S. spilostichus	0.13	0.18	
A. spp_	0.01			D. compreceps			0.00	Mylochromis				Stigmatochromis			
A. blue orange	0.08			D. dimidiatus	0.01			M. mola	0.00		0.11	S. pholidophorus		0.01	
A. brevirostris	0.01			D. kiwinge	0.03	0.43	0.07	M. spilotichus	0.01			S. woodi	0.11		0.00
A. guentheri	0.15		0.36	D.strigatus	0.05			Nimbochromis				Synodontis			
A. macrochir*	0.81	0.09		Diplotaxodon				N. livingstonii	0.50			S. njassae*	3.27	0.89	
A. rostratum	0.30	0.95		D. argenteus	0.23		0.02	N. polystigma			0.07	Taeniaochromis			
A.yellow	0.06			D. greenwoodi			0.07	N. venustus	0.06	0.35		T. spp_	0.02		
Bargrus				D.intermedius	0.01			Nyassachromis				T. holotaenia	0.16		
B. meridionalis*	5.35	3.12	9.83	D.limnothrissa	0.08			N. leuciscus*		15.16		Taeniolethrinops			
Barbus				Fossochromis				Opsaridium				T.furcicauda	0.59	1.25	0.02
B. arcislongae	0.94			F. rostratus	0.13		0.02	O. microcephalus*			0.04	T. laticeps		0.01	
B. eurystomus*			1.80	Haplochromis				O. microlepis			0.10	T.praeorbitalis*			0.03
B. Johnstoni*			3.50	H. spilopterus	0.01			Oreochromis				Tramitichromis			
B. litamba	0.32		0.15	Hemitaeniochromis				O. shiranus	0.03	0.35	0.02	T.lituris*		0.43	
Bathyclarias				H. discorhynchus	0.42	0.62	0.00	O. spp*_	0.14	22.83	68.20	T. spp_	0.06		
Bathyclarias spp*			7.40	H. insignis	0.01		0.12	Otopharynx				Trematocranus			
Brycinus				H. urotaenia	0.28	0.52	0.02	O. argyrosoma*	1.40			T. labifer		0.65	
B. imberi	0.04			Hemitilapia				O. auromarginatus	0.06		0.48	T. labifer		0.65	
Buccuchromis				H. oxyrhynchus			0.00	O. cf_ productus	0.06			T. labifer		0.65	
B. atritaeniatus		0.35		Labeo				O. speciosus	0.25			T. placodon*		5.18	0.28
B. lepturus*			0.55	L. cylindricus	0.01	3.12		O. spp_	0.00			Tyrannochromis			
B. nototaenia	0.01		0.62	Lethrinops				Placidochromis				T. macrostoma*			0.08
B. rhoadesi	0.06		0.03	L. alba	0.12		0.00	P. acuticeps	0.02						
B. spp.			0.49	L. alta*	0.18			P. long	0.00						
Champsochromis	0.03			L. christyi	0.50	0.36		P. longimanus	0.04						
C. spilorhynchus	0.03			L. gossei*	0.02			P. macrognathus	0.01						
Chilotilapia	0.05		0.15	L.lethrinus	0.14	2.31	0.02	P. subocularis	1.09	0.78	0.09				
C. rhoadesii	0.05		0.15	L.long	0.08			Platygnathochromis							
Clarias				L.longimanus	0.64			P.kirkii	0.04	0.26					
C. gariepinus	0.51	16.45	1.23	L. longipinnis	0.16		0.14	Protomelas labridens			0.07				
Copadichromis				L.macracanthus			0.01	P.similes	0.07	0.69	0.03				
C. chrysonotus	0.02	0.09	0.00	L. macrochir	0.22		0.01	P. spilopterus	0.01						
C. eucinostomus*	0.22			L. matumbai	0.05			P. triaenodon			0.00				
C. inornatus	0.00			L.mylodon	0.00			Pseudotropheus							
C. pleurostigma	0.03			L.parvidens*	0.42		0.00	P. elegans	0.11	0.13					
C. prostoma	0.00			L. pink head*	0.41			P. livingstonii	0.07						
C. quadrimaculatus*	2.03			L. polli	0.18		0.03	P.tropheops		0.04					
C. trimaculatus	0.00			L. stridei	0.28			P. williamsonii	0.19						
C. virginalis*	67.90	14.73		Lichnochromis											
				L. acuticeps	0.11	0.26									

Table 2. Mean retention lengths (maximum selectivity), total length (TL) ranges and variances for fish caught in various mesh sizes and analysed using gamma distribution.

Species/Species group	(*n*)	Mesh size	Max. Sel.	Range TL (cm)	Variance
Oreochromis spp.	48	1.5	11.00	8.5-13.5	0.79
	95	2.0	13.94	11.0-17.0	0.96
	398	3.0	24.05	17.0-35.0	3.17
	2101	3.5	24.24	17.0-35.0	2.51
	135	3.75	25.30	18.0-35.0	2.28
Copadichromis virginalis	36	1.0	13.30	11.0-16.0	0.98
	393	1.25	12.07	10.0-16.0	0.73
	1814	1.5	12.48	10.2-15.0	0.96
	209	1.75	12.08	10.5-16.0	0.96
	113	2.5	12.38	10.0-15.0	0.85
Bagrus meridionalis	71	1.5	22.74	18.0-32.0	2.54
	136	3.0	34.77	36.0-50.0	3.53
	114	3.5	37.54	28.0-50.0	3.10
	83	3.75	37.66	30.0-50.0	3.30
Otopharynx argyrosoma	69	1.25	10.09	8.0-12.0	0.66
	135	1.5	10.63	7.0-17.0	1.74
Rhamphochromis spp.	131	3.5	38.28	36.0-47.0	1.80
	102	3.75	38.76	37.0-47.0	1.64
Synodontis njassae	239	1.5	13.39	11.0-20.0	1.45
	35	2.0	13.58	11.0-19.0	1.19
C. quadrimaculatus	123	2.0	16.64	13.0-21.0	1.33
	47	3.0	16.95	13.0-21.0	1.30
Bathyclarias spp.	69	3.5	49.98	41.0-62.0	3.02
	79	3.75	49.45	40.0-62.0	3.19
Lethrinops pinkhead	43	1.25	9.62	7.50-12.0	0.78
	48	1.5	10.10	8.00-14.0	0.93
Trematocranus placodon	81	3.0	19.57	16.0-24.0	1.18
	31	3.5	20.51	18.0-24.0	0.95
Barbus johnstoni	62	3.5	34.00	10.0-38.0	2.23
Barbus eurystomus	39	3.75	38.00	33.0-44.0	2.72
Opsaridium microcephalus	36	3.5	47.00	44.0-50.0	0.91
Tyrannochromis macrostoma	52	3.5	20.00	18.0-23.0	1.11
Nyasachromis leuciscus	51	2.5	17.00	14.0-20.0	0.82
Tramitichromis lituris	34	1.5	11.00	8.50-14.5	1.28
Taeniolethrinops praeorbitalis	76	3.0	23.00	21.0-26.0	1.07
Lethrinops parvidens	34	1.5	12.00	10.0-14.0	1.50
Lethrinops longimanus	81	2.5	17.00	14.0-22.0	1.31
Lehrinops gossae	43	2.5	16.50	14.0-20.0	0.93
Lethrinops alta	33	1.5	10.80	9.0-14.0	0.80
Copadichromis eucinostomus	38	2.0	11.30	9.0-13.0	0.74
Buccochromis lepturus	52	3.5	26.04	23.0-30.0	1.35
Aulonocar macrochir	33	2.0	11.70	10.0-14.0	0.70

2-3 inch mesh gill nets

Figure 2 shows the percentage catch composition of the 7 main species that contributed almost 90% of the total catch in gill nets with mesh sizes between 2 to 3 inches.

In gill nets with mesh sizes ranging between 2-3 inches, 99 fish species were recorded. Chambo dominated the catch; it comprised 25% of the catch by weight. The importance of small fish species in the catch started to decrease because these meshes selected for slightly larger fish species.

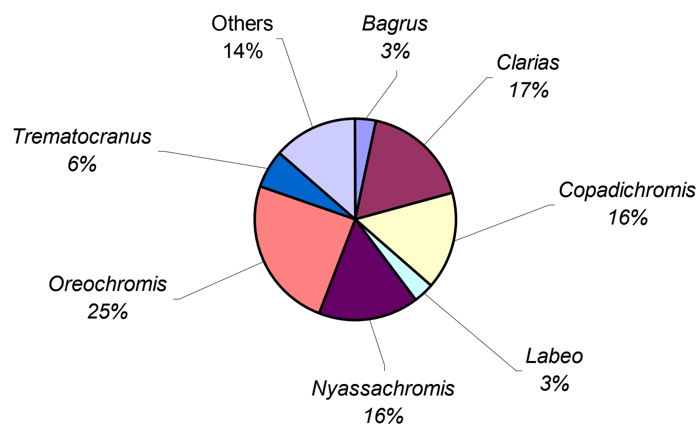

Figure 4. Catch composition of main species in 2-3 inch gill nets

The mean length at capture for chambo in these nets was 14 cm and the largest chambo caught was around 17 cm (figure 5). Therefore, chambo caught in these gill nets, were immature. The vulnerability of the chambo caught in gill nets of 2-3 inch mesh sizes increases due to its migratory behaviour, since at this size the chambo moves from shallow to the deep water where it meets the nets.

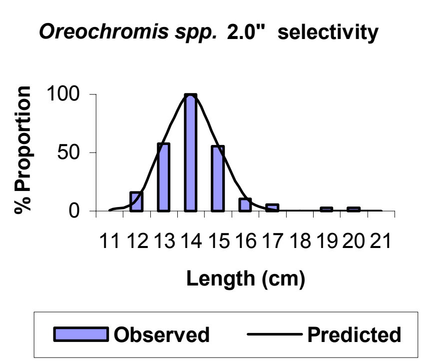

Figure 5. Chambo 2.0 inch gill net selectivity curve.

Table 3. Mean length-at-capture (l_c) expressed as a proportion of the length-at maturity (L_{mat}) for the main target species analysed with gamma function. Adapted from Weyl *et al*. 2000.

Species	Lmat	L_c/L_{mat}								
		Mesh size in inches for sampled species								
		1.0	1.25	1.5	1.75	2	2.5	3	3.5	3.75
Aulonocar macrochir	13.5 cm*					0.9				
Buccochromis lepturus	31.5 cm[2]								0.83	
Copadichromis eucinostomus	10 cm*					1.1				
Copadichromis quadrimaculatus	17.7 cm[2]					0.9		0.96		
Copadichromis virginalis	10.6 cm[2]	1.25	1.14	1.18	1.14	1.2				
Lethrinops alta	11.25 cm*			1.23						
Lethrinops gossie	14.7 cm*						1.12			
Lethrinops longimanus	15.9 cm*						1.14			
Lethrinops parvidens	15.3 cm*			0.71						
Lethrinops pinkhead	9.0 cm*		1.07	1.12						
Nyasachromis leuciscus	12.0 cm[2]						1.9			
Oreochromis spp.	20.3 cm[1]			0.5		0.7		1.18	1.19	1.25
Otopharynx argyrosoma	11.4 cm[2]		0.89	0.93						
Rhamphochromis spp.	28.71 cm*								1.33	1.35
Taeniolethrinops praeorbitalis	22.5 cm*							1.05		
Tramitichromis lituris	13.5 cm*			0.87						
Trematocranus placodon	18.8 cm[2]							1.04	1.09	
Tyrannochromis macrostoma	18.1 cm*								1.11	
Barbus eurystomus	30.0 cm[2]								1.18	1.19
Barbus johnstoni	30.4 cm[2]								1.15	1.15
Opsaridium microcephalus	35.6 cm*								0.94	
Bagrus meridionalis	52.2 cm[1]			0.43				0.66	0.72	0.72
Bathyclarias spp.	60.0 cm[1]								0.83	0.82
Synodontis njassae	10.0 cm[1]			1.34		1.4				

*Lmat was derived from * estimated at 75% of the maximum length for species given in Turner 1996,*
1- Bulirani et al. 1999, 2- Weyl 2000.

3-4 inch mesh gill nets

Figure 6 shows the percent catch composition of the 5 main species that contributed 95% of the total catch by weight in gill nets with mesh sizes between 3 to 4 inches. In all, 70 fish species were recorded from this category of nets (Table 3). Chambo comprised 70% of the total catch in these gill nets and for the 3.5 inch gill nets, the mean length at capture for chambo was 24.5 cm, 2.2 cm longer than the length at maturity. Therefore, gill nets with mesh sizes between 3-4 inches catch mature chambo.

The mean length at capture for *B. meridionalis* in 3.5 inch gill nets was 37.5 cm while the length at maturity is 52.2 cm (Bulirani *et al.* 1999). This showed that the length at first capture was less than the length at maturity.

The mean length at capture for *Bathyclarias* spp. in 3.5 inches was 49.5 cm while the length at maturity is 60.0 cm. This means that individuals caught in this mesh size were immature. The range of capture for both *Bagrus meridionalis* and *Bathyclarias* spp. was very wide and individuals were caught outside the selection curve in both cases reflecting the fact that two methods of capture were involved (Hamley, 1975). These were entanglement and wedging. Catfish are vulnerable to entanglement because they have dorsal and pectoral spines.

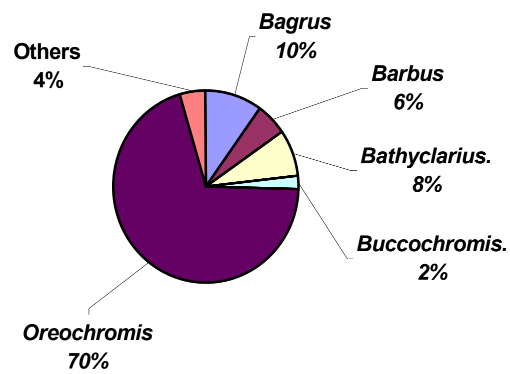

Figure 6. Catch composition of main species in 3-4 inch gill net.

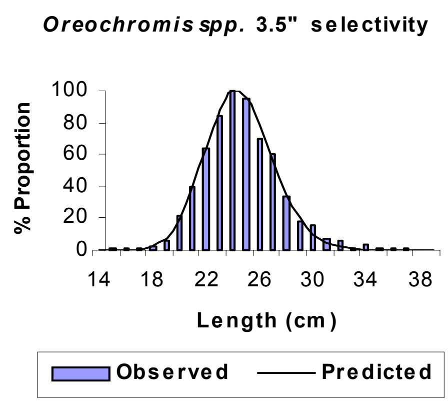

Figure 7. Selection curve for chambo in 3.5 inch gill nets

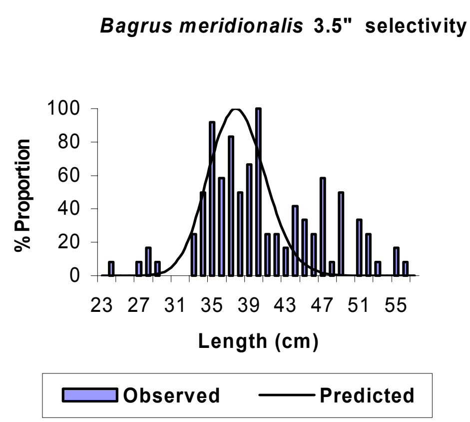

Figure 8. *Bagrus meridionalis* 3.5 inch gill net selection curve.

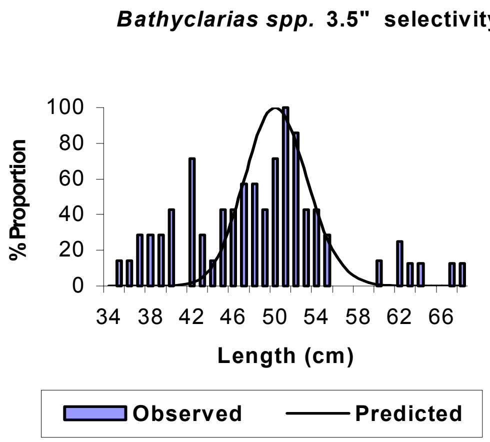

Figure 9. *Bathyclarias* spp. 3.5 inch selection curve.

Conclusion.

Gill nets with mesh sizes between 1-2 inches have the potential to catch immature chambo. However, they do not as small chambo inhabit very shallow waters of less than 5 metres (FAO, 1993) while the nets are set in water deeper than 40 metres where they are set to target small offshore cichlids especially utaka.

Gill nets with mesh sizes between 2-3 inches catch immature chambo normally of less than 17 cm TL that migrate from the shallow into the deep waters. Gill nets with mesh sizes between 3-3.75 inches catch mature chambo. Gill nets with mesh size of 3.75 inches and less, that are currently in use, catch immature catfish. Any mature catfish caught in these nets do so by being entangled.

Therefore, we recommend the development of distinct gill net fisheries for specific target species. This may be achieved by identifying the most important fishing grounds or areas in the lake and then by adopting and promoting the best harvesting strategy for each target species. We also discourage the use of 2-3 inch gill nets as these catch immature chambo in deep waters.

Acknowledgements

Funding for this study mostly came from the European Union (EU) and the Department of Fisheries' Fisheries Research Fund (FRF). Some additional data came from the gear selectivity surveys sponsored by the GTZ supported National Resource Management Programme (Narmap). Special thanks are due to Dr. Olaf Weyl, the Narmap Research Advisor and Dr. M. Banda the officer-in-charge for Fisheries Research station.

References.

Bulirani, A.E., Banda. M.C., Palsson, O.K., Weyl, O.L.F., Kanyerere, G.Z., Manase. M.M., Sipawe, R.D., 1999. Fish and Fisheries of Malawian waters: Resource report. Government of Malawi, Fisheries Research Unit.

Burd, A. C., 1963. On selection by the drifter fleets in East Anglia herring fishery. J. Cons. Int. Explor. Mer 28: 91-120.

Hamley, J. M., 1975. Review of gillnet selectivity. J. Fish. Res. Board can. 32: 1943-1969.

FAO, Fisheries management in the South-east arm of Lake Malawi, upper Shire River and Lake Malombe, with particular reference to the fisheries on chambo (*Oreochromis spp*). CIFA Technical Paper. No. 21. Rome, FAO 1993. 113p.

Konda, M., 1962. The relation between the size of the mesh of salmon gill net and the length of salmons in the catches. (in Japanese with English summary) Bull. Hokkaido Reg. Res. Lab. 24: 138-147.

Kipling, C., 1957. The effects of gillnet selection on the estimation of weight-length relationship. J. Cons. Int. Expor. Mer. 23: 51-63.

Manase, M. M., 2000. Traditional Gear Selectivity in Southeast arm of Lake Malawi. GTZ-NARMAP Tech. Rep. No. 4.

Marechal, C. 1991. Copadichromis. *In the check-list of the freshwater fishes of Africa (CLOFFA*). I Daget, J. –P. Gosse, G. G. Teugels and D> F. E. Thys van den Audenaerde (eds.). ISNB, Brussels, MRAC, Tervuren; and ORSTUM, Paris. Vol. 4: 51-58.

Weyl, O.F.L., Banda, M.C., Sodzapanja, G. Mwenekiombwe, L.H., Namoto, W. and Mponda, O.C., 1999. Annual Frame survey. Malawi Government. Fisheries Bulletin No. 42.

Fisheries activities in northern Lake Nyasa (Kyela District)

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Abstract

When compared with the other East African Great lakes, the fisheries activities of Lake Nyasa are very low. This might be due to poor fishing vessels and gears used by the artisanal fishermen and the ultra-Oligotrophic nature of the lake. The present paper looks at the fisheries potential of Lake Nyasa in Kyela district and suggests strategies for development.

Introduction

Lake Nyasa lies at the Southern end of the East African rift valley. The lake is long and narrow. It is 560 km long and has a surface area of 30 800 km² ranking ninth in order of size among the lakes of the world. On a south, north transect, the lake shows a remarkable increase in depth, with the north being deeper and the south shallower. It is one of the deepest lakes in the World with an average depth of 275 m ranging from 200 m to 700 m (Ngatunga *et al*. 1997). The lake is shared by three riparian states Malawi, Mozambique and Tanzania (Figure 1).

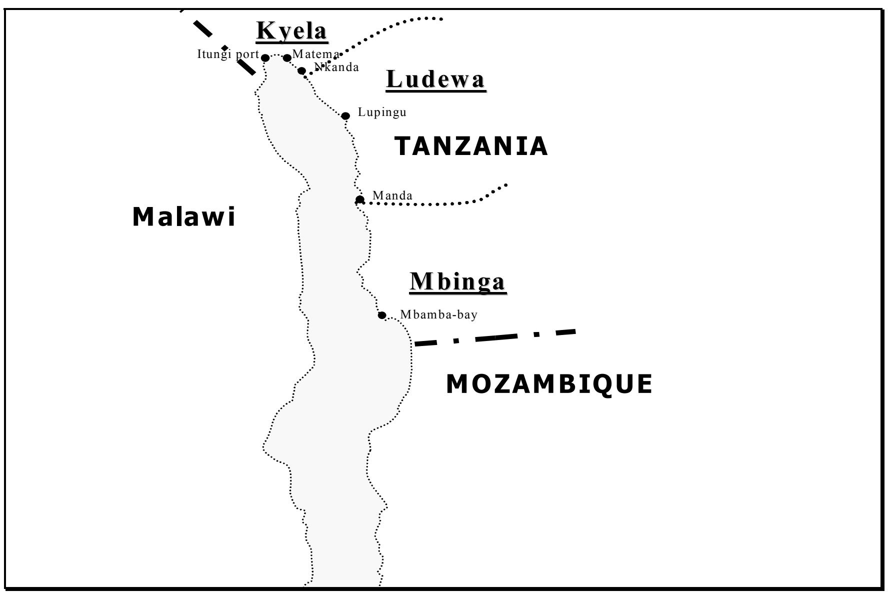

Figure 1. Lake Nyasa (Tanzania side).

An area of 5 569 km², which is about 18% of the lake in the north, is within Tanzania jurisdiction. Three administrative regions namely Ruvuma, Iringa and Mbeya share the lake. Kyela district, which is a focus of the present paper, falls within Mbeya Region

In Tanzania the shoreline of the lake is 258 km long, and has three main ecological zones: First is the rocky shore of the north east shoreline which is characterised by deep slopes from the Livingstone mountains. The mountains which reads high as 3 000 m in the north extend along the lake shore from Matema to Manda, curve in land eastwards and reappear after Ndumbi, where they become lower and less steep. In the southern part of the range the shore is characterised by reefs, inshore rocks and small uninhabited islands; second is the wide sandy beaches which occur in few areas such as Matema, Lupingu, Manda, Njambe, Liuli and Mbamba-bay. Third are the river estuaries associated with swampy areas covered with reeds. They are found in two areas: Wissman Bay from Songwe river on the Malawi border to Matema were four rivers flow into the lake (Songwe, Kiwira, Mbaka and Lufilyo) and in Amelia Bay, around the Ruhuhu delta which covers an area of 400 km² (Ng'ang'a 1993) from Manda to Ndumbi Reef. The shoreline in these areas is characterised by sand and mud the water is predominantly muddy.

The lake is of enormous importance to Tanzania as a means of transport, reservoir of fresh water and a source of food (i.e. fish). Characteristics of the shoreline are very important in understanding the distribution of the fishes and hence the fisheries of Lake Nyasa in the Tanzania waters. Fishing activity is mainly artisanal, using traditional crafts and gear. However, the lake is characterised by very rough weather conditions, which make the traditional fishing with canoes a very dangerous venture. Moreover, because of the depth, nutrient levels available to phytoplankton are generally very low and based on nutrient; the lake is considered Oligotrophic (nutrient poor). An exception to the above is the shallow south and around river mouths, areas which are considered to be highly productive. The present work tries to evaluate the fish resource potential of Lake Nyasa in Kyela district and suggests strategies for development.

Fish Exploitation

The capture fisheries of Kyela are divided into two main sectors namely food and Ornamental fisheries. The latter is useful to the nation as a source of foreign money, however the food capture is the most important sector constituting a major source of income and protein for coastal population.

Fishing on the Tanzania side is under developed and has received very little attention. The common fishing vessel is the dugout canoes (3-4 m length). The canoes are small, unstable and propelled by paddles; one or two fishermen normally operate them. The fishery is mainly restricted to inshore waters within 2 km of the shoreline.

The principal fishing gears are gillnets, seines, hook and lines scoopnets and traps. In Kyela, the anadromous piscivorous cyprinids *Opsaridium microlepis* and *O.microcephalus* are of great importance. Several major affluent rivers (Songwe, Kiwira, Mbaka and Lufilyo) provide suitable habitats for spawning. Fisheries around and in the river mouths have long been intensive whereby gillnets and sometimes seines are used to exploit these cyprinids and other species during spawning period. This type of fishery makes the anadromous species more vulnerable to over fishing leading to destruction of stocks.

Gillnets of stretched mesh size of 2 inch are used for catching cichlids (haplochromine and tilapine sp.), 2½ inch-3½ inch for bigger tilapine sp. and *Opsaridium microcephalus*, 3½-6 inch used for catching bigger fish species (*Opsaridum microlepis, clarias* sp. and *Bathyclarias* sp.).

With the introduction of open water seine nets from Malawi, artisanal fishing units have been concentrated at Itungi, Mwaya, and Matema, (Wissman Bay). The open water seine known as ndaturu which is similar to the chilimira nets of Malawi, use light to attract *Engraulicypris sardella* (usipa) and small *Rhamphochromis* sp(Ngelwa) during moonless nights. During the day the gears are used to catch *Diplotaxodon* sp. (mantura) and *Copadichromis* sp. (vituwi) from deep inshore waters, and Tilapiine cichlids (magege) in the shallow waters of the Bay.

Handline is commonly operated by most of the fishermen for catching tilapine species while bottom-set longlines are used for catching bigger demersal species (*Clarias* and *Bagrus sp.*).

Recently fishermen in Kyela district have adopted drifting pelagic longlines after successful demonstrations to fishing communities of Itungi, Mwaya and Matema by TAFIRI. The gear target for large predatory fish such as large *Rhamphochromis* sp. (lumbulu/hangu) and *Bathyclarias* sp. (Ngoshora). The relationship between fish production and different components of artisanal fishery in Kyela district between 1990 and 1996 is shown in Figure 2. The yield has fluctuated between 1 664.7 tons and 2 142.7 tons. Production is observed to drop from 1 428.5 tons in 1991 to 264.2 tons in 1992 and increased abruptly in 1992 to 1 423.1 tons. Canoes decreased from 295 in 1990 to 205 in 1992 and increased from 312 in 1993 to 374 canoes in 1996 while fishermen decrease from 682 in 1990 to 412 in 1992 and initially increased from 542 in 1993 to 709 in 1996.

Catch composition of fish landed at beaches of Kyela district in 1996 is summarised in Figure 3. Catch was dominated by *Engraulicypris sadella* registering 28% followed by *Rhamphochromis* sp. (18%), Tilapines (17%), Others (15%) and Haplochromines (11). *Bagrus meridionalis* and *Clarias* sp. each contributed 4% while *Opsaridium* sp. and *Labeo* sp. contributed 2% and 1% respectively. *Barbus* species contribution was less than I% to the total catch.

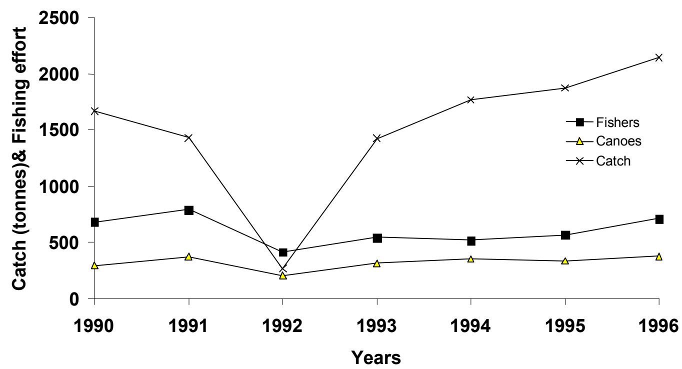

Figure 2. Fishing effort (fishers and canoes) and annual catch for Kyela district (Fisheries data 1990-1996).

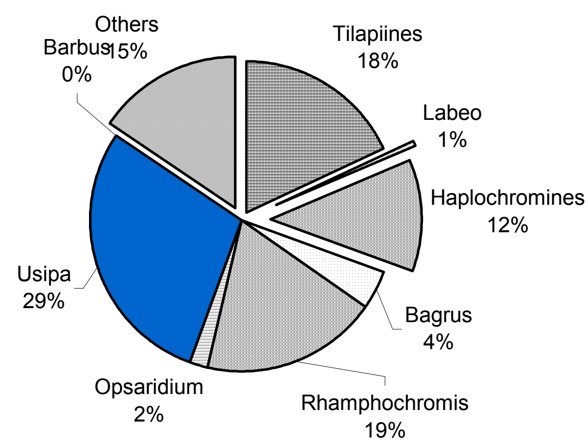

Figure 3. Catch composition by weight of fish landed at Kyela beaches (Fisheries data).

Fish processing

The production of fish from Lake Nyasa does not meet the demand and thus most of the fish from the lake is consumed fresh. Processing activities are in most cases done for immediate consumption. Frying is the most common method. A big fish like *Opsaridium microlepis* is first cut into small pieces. The pieces are fried in oil and sold on the rural market,"pombe" (local brew beer) shop and bars, occasionally, when there is a bumper catch or when fish cannot fetch immediate market fish is hot smoked in the evenings.

Fish Marketing

As mentioned earlier most of the fish is consumed fresh. At the landing sites the fresh fish is displayed in canoes or on sand. The fish is sold to different buyers who include consumers and fish mongers. A fishermen who owns the gears may sell his catch to his relatives or traders and other people. Some fishermen obliged to sell the catch to boat/gear owner who will then retail the catch. The price is normally reached by negotiations and experience, sometimes butter trade operates.

The fish traders comprise adult men and women. The fresh fish buyers carry their fish to either rural markets or Kyela Central market on the head or on bicycles. The fish are put in bamboo baskets and gunny bags.

At the rural markets fish are displayed on raised racks with or without roof. At Kyela Central market there is a well-established fish-receiving block erected since 1987. Inside the fresh fish is displayed on raised concrete tables supplied with tap water. There is also a room installed with measuring balance for recording weights of fish received every day.

In rare cases smoked fish (*Opsaridium* sp*.)* and sun-dried dagaa (*Engraulicypris sardella*) from Ludewa (Iringa Region) and Mbinga (Ruvuma Region) reach Itungi Port by ship. Most of the processed fish find market in the villages and Kyela Central market.

Future Strategies

The future strategies for fisheries development in Kyela district should focus on the following areas.

Boat construction

The dugout canoes used in the lake are quite inefficient as fishing crafts and are risky because the lake becomes rough quite often. The poor development in the fishery of the Tanzania side of the lake is partly due to poor fishing crafts. Offshore pelagic fishing require better fishing crafts. Investors should look into the possibility of constructing appropriate boats in Kyela area for the northern lake zone (Tanzania side). Hard wood-"Mninga" (*Pterocarpus angolensis)* used for constructing boats is available and the demand for such boats is high which justifies investment in boat building. So far there is only one centre (at Liuli in Ruvuma Region) which trains few people how to build modern boats. That of Itungi Port should be rehabilitated.

Exploitation of pelagic resources by use of open water seine nets -chilimira nets (ndaturu)

Suitable gears for Kyela area are known to be chilimira nets, gillnets and longline. Chirimila nets however are gaining popularity especially in capturing *Copadichromis* sp., *Diplotaxodon* sp., *Oreochromis* sp., *Rhamphochromis* sp. and *Engraulicypris sardella* as mentioned earlier.

With this gear there has been a marked shift of fishing effort from shallow inshore waters, which serve as nursery areas for many cichlid species towards deeper waters. Therefore investment in chilimira nets is viable, as the target fish species is plentiful. A proper write up on the investment however should be made before investment is undertaken. TAFIRI is proposing to do a study on the open seine fishery within the Tanzanian water with the objective of alleviating poverty through increased income and protein consumption.

Exploitation of pelagic resources by use of drifting longline

After recommendation of long lining in the pelagic zone by UK/SADC Lake Malawi Fisheries Project, TAFIRI carried out a project on the long lining in Kyela area and the results are encouraging (Mlay *et al*. 1994). Investment in longlining is rather low as the prices of hooks and twines are relatively cheap. Ordinary artisanal fishermen can afford them. The only expensive part of the project is the purchase of boat and engine. Investors would need to make feasibility studies before investing but on the whole it will need small investment.

Fish marketing

Most fish consumers prefer eating fresh fish. With the good tarmac road connecting Dar es Salaam and Kyela and the major towns in the country fresh fish from Lake Nyasa could be transported from the lake area to the towns if the traders invest in insulated containers. These containers are now being made locally in Dar es Salaam. The use of iced insulated containers will reduce post harvests loses of the fish and improve the quality of fish that reach the consumer.

Ornamental fish trade

Lake Nyasa is known for its unique fish species. The lake ranks very high in ornamental fish trade. In Kyela two companies are engaged in ornamental fish trade. TAFIRI is considering collaborating with any institution into the identification of the ornamental fishes together with the fishing grounds. Investors are invited to take up the ornamental fish trade, which could be done, on joint venture basis. The potential is high. For proper management suitable areas for ornamental fish should be mapped out and Lake Shore communities should benefit from the trade.

References

Mlay, M.K.L., Mwambungu, J.A. and Kihedu, K.J.1994. Longline Fishery Prospects in Lake Nyasa. TAFIRI Annual Research Report. Tanzania.

Nga'ng'a, P.1993.Deltaic sedimentation in a lacustrine environment of Lake Malawi, Africa.J. Afr. Earth Sci. 16,253-264.

Ngatunga, B.P., Mwambungu, J.A., Kihedu, K.J., Mlay, M.K.L.and Waya, R.1997.Biodiversity Conservation and Fisheries Management on Lake Nyasa, Tanzania. Proceedings of the Workshop of the Senga Bay,Malawi, February 1997.

Hard choices for chambo management in Area A of the southeast arm of Lake Malawi

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Abstract
Management of the fishery in Area A of the southeast arm of Lake Malawi (SEA) is complicated by multi-gear utilisation and by the multi-species nature of the catch. One option for management is to prioritise key species for management. The suitability of chambo (*Oreochromis*) species as a key management species group for Area A is discussed. The stocks were modelled using multi-gear yield- and spawner biomass-per-recruit models to investigate four management target reference points (TRP's). These TRP's were F_{max}, $F_{0.1}$ and F_{SB40} and F_{SB50} . F_{max} corresponds with the asymptote of the yield-per-recruit curve and approximates Maximum Sustainable Yield, $F_{0.1}$ is the rate of fishing mortality at which the slope of the yield-per-recruit curve falls to 10% of its value at the origin, F_{SB40} and F_{SB50} are the points on the spawner-biomass-per-recruit curve corresponding to a reduction of 40% and 50% of the pristine spawner-biomass. It was estimated that the current fishing mortality rate (F) for Area A chambo approximated 0.34 yr^{-1}. This exploitation level was below the F_{max} TRP but exceeded the more conservative $F_{0.1}$ TRP. In addition, current exploitation rates exceeded both spawner biomass based TRP's. To attain the F_{SB40} TRP a 10% reduction in fishing effort was necessary and a 23% reduction in effort was necessary to attain the F_{SB50} TRP. Different management options taking into account the effect in total landings and employment are discussed.

Introduction
Through the participatory fisheries management (PFM) framework of the Department of Fisheries (DoF), fishing communities have the right to obtain fisheries management recommendations for their specific fishing grounds (GOM 2000). The provision of such management recomendations is the responsibility of the Fisheries Research Unit (FRU) of the DoF. Since these recommendations are to cover finite areas for PFM, they have to refer to localised areas that are small enough to allow for community based management but large enough so that management interventions will have an effect on the fish stock. Furthermore, management recommendations should be based on the best scientific knowlege available and take into consideration the multi-gear and multi-specie nature of the fisheries in Malawi.

The fishery in Area A of the southeast arm of Lake Malawi (SEA; Figure 1) has both small scale and large scale commercial components. The small scale fishery comprises some 420 gill nets, 119 chilimira nets, 27 kambuzi seines, 18 chambo seines and at least 12 nkacha nets (Weyl *et al.* 2000). This small scale fishery currently employs in excess of 1900 fishers (Weyl *et al.* 2000). The commercial fishery currently comprises 2 pair trawl units and one ring net unit. However, 4 pair trawl licences and two ring net licences are issued (Banda & Chirwa 2000). However, the consolidation of area A under one PFM management unit is considered feasible (Weyl 2001).

Fisheries management in Area A is complicated by the multi species nature of the catch, and over 100 species contribute to the catches in Area A (Chisambo 2001, Manase 2001, Sipawe 2001, Nyasulu 2001). It has long been recognised, that when a fishery harvests a number of species it is impossible to manage each species at its optimum level (Murawski 1984). In such cases, one possible option is to base management on the least resilient species in a multi-species fishery (Weyl 1998). However, this requires prior knowledge of the biological and life history information on all target species. Such information is not available for most of the species targeted by Malawi's small-scale fisheries. Until such data is available, it is recommendable to prioritise key species for management in specific areas. Such key species should contribute significantly towards the fishery and show declining catch trends that indicate that management intervention is necessary and the species should have life history traits such as limited distribution ranges, limited migration patterns, localised spawning and localised nursery areas, which would make locality specific management feasible.

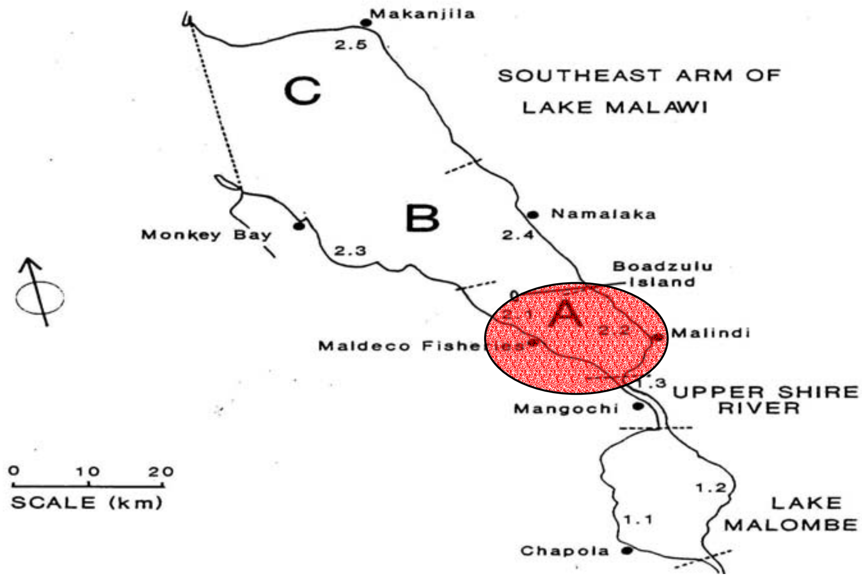

Figure 1. The south east arm of Lake malawi showing Area A.

The chambo (*Oreochromis* 'Nyasalapia' spp.) stock in Area A fulfills these criteria. It has been shown that chambo contributes more than 30% to the total catch in Area A and therefore contributes significantly to the fishery (Figure 2). The decline in the chambo stocks (Figure 2) in the SEA is well documented and management for this species is considered necessary (FAO 1993, Tweddle *et al.* 1994, Palsson *et al.* 1999, Bulirani *et al.* 1999). Kanyerere (2001) showed that the chambo stock of the SEA was concentrated in Area A and over 70% of the SEA chambo catch originates from this area (FRU unpublished catch data). While migration of chambo from the SEA into Lake Malombe have been considered, there is currently little substantiating evidence (FAO 1993) it is likely that Lowe's (1952) observation that the chambo stock is localised and prone to local overfishing remains valid. Hence the management of the chambo population in Area A is feasible.

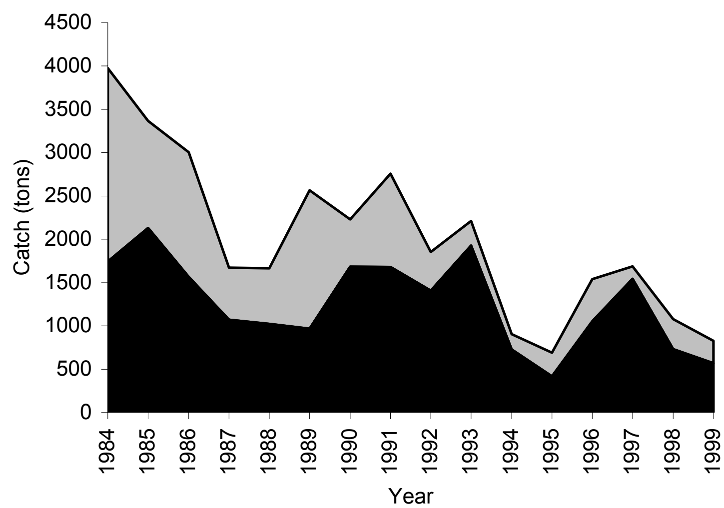

Figure 2. Chambo catch in the southeast arm of Lake Malawi. The contribution of Area A to the total chambo catch is represented by the shaded portion.

In an attempt to define optimum fishing mortality from a per-recruit perspective the use of target reference points (TRPs) has become common practice in fisheries management (Clarke 1991, Punt 1993, Caddy & Mahon 1995, Booth & Buxton 1997, Griffiths 1997, Bulirani *et al.* 1999). The TRP approach is already advocated by the DoF and the 1999 Resource Report makes management recommendations for the fisheries based on TRP's based on catch per unit effort in the small scale fishery (Bulirani *et al.* 1999).

The yield-per-recruit (YPR) approach allows for the determination of at least two commonly used TRPs: firstly, the fishing mortality which corresponds to the maximum of the yield-per-recruit curve (F_{max}) and secondly, the marginal yield or $F_{0.1}$ strategy (Gulland & Boerema 1973, Deriso 1987), which is the rate of fishing mortality at which the slope of the yield-per-recruit curve falls to 10% of its value at the origin. However, the yield-per-recruit approach assumes that recruitment is constant and independent of spawner biomass. Since, there is little doubt that in most fish species the stock-recruitment relationship is density dependent (Shepherd 1982, Sissenwine & Shepherd 1987). Since, *Oreochromis* species are mouthbrooders with extended parental care (Trewavas 1983), a density dependent spawner biomass-recruitment relationship is implied. For similar reasons, scientists concerned with the management of marine species have tended to base their TRP recommendations on the results of spawner biomass-per-recruit (SBR) models (Butterworth *et al.* 1989, Smale & Punt 1991, Booth & Buxton 1997, Griffiths 1997). The definition of a spawner-biomass TRP ($F_{SB(x)}$) involves setting the fishing mortality to a level at which spawner biomass-per-recruit is reduced to x% of its pristine level. Although there is no conventional $F_{SB(x)}$ TRP, spawner biomass-per-recruit recommendations lie between 25% and 50% of unexploited levels (Deriso 1987, Sissenwine & Shepherd 1987, Butterworth *et al*. 1989, Smale & Punt 1991, Clark 1991, Punt 1993, Booth & Buxton 1997). In the absence of information on the spawner biomass-recruitment relationship, the $F_{SB(x)}$ TRPs are currently considered the most robust, allowing for the determination of a fishing mortality rate that will provide relatively high yields at lower risks (Clarke 1991, Punt 1993).

Three *Oreochromis* species *O. squamipinnis*, *O. lidole* and *O. karongae*, comprise the chambo stock, identification of juveniles to species level is problematic (FAO 1993). However, the similarity in age-at-maturity and growth rate in the three species allows for their treatment of all three as a single management unit. This allows for the application of fisheries models such as the multi gear yield per recruit MGYPR (Djama & Pitcher 1997) and multi gear spawner-biomass per recruit MGSBR (Weyl 1998) to determine the effect of yield and spawnner biomass to varying levels for fishing mortality.

The aim of this study was to investigate the effect of the management interventions suggested by the Fisheries Management and Conservation Act (GOM 2000) on the chambo fishery in Area A. These management interventions include: a closed season for seines during November and December, total bans on nkacha and kambuzi seines, a total ban on the light attraction chilimira/kauni fishery for chambo and minimum mesh size restrictions for gill nets from a per-recruit perspective. In addition, MGYPR and MGSBR approaches were applied to investigate four Target Reference Points (TRP's). These were the YPR based F_{max} and $F_{0.1}$ TPRs and the SBR-based F_{SB40} and F_{SB50} TRP's. as well as two spawner biomass dependent TRPs.

Methods

Per Recruit Models

The multi-fishery per-recruit models used in this paper are based on an extension of the traditional per-recruit models (Djama& Pitcher 1997, Weyl 1998). Input parameters for the per-recruit simulations were derived from the literature available on the chambo stocks (Table 1). Yield- per recruit was calculated by the equation:

$$YPR = \sum_{a=0}^{\max} \left[(w_a \widetilde{N}_a (1 - \exp(-(M + \sum_j S_{aj} F_j)))) \frac{\sum_j S_{aj} F_j}{M + \sum_j S_{aj} F_j} \right] \Delta a$$

and spawner-biomass-per-recruit for each species i (SBR_i) in a multi-gear fishery was determined by:

$$SBR = \sum_{a=0}^{max} \psi_a w_a \tilde{N}_a \Delta a$$

where w_a is the weight-at-age a, described by:

$W_a = \alpha(l_a)^{\beta}$

where l_a is the length-at-age determined by the von Bertalanffy growth equation; α and β are parameters describing the length-weight relationship; S_{aj} is the selectivity for age class a by fishery j, F_j is the instantaneous rate of fishing mortality (yr^{-1}) for all fisheries j under consideration, M is the rate of natural mortality, and *max* is the maximum recorded age. $\tilde{N}_{ia}$ is the relative number-at-age of species i and was described as:

$$\tilde{N}_{ia} = \begin{cases} 1 & \text{if } a = 0 \\ \tilde{N}_{i,a-1} \exp(-(M + (S_{a1}F_{a1} + S_{a2}F_{a2} + ...S_{a5}F_{a5}))) & \text{otherwise} \end{cases}$$

where S_{ax} *is* the selectivity of gear x for age class a and F_{ax} *is* the proportional fishing mortality rate (yr^{-1}) for that fishery. F_{ax} was determined by the proportional contribution of each gear to the total chambo catch in all gears under consideration. Catch estimates for the year 2000 in the SEA were used (Table 2). All summations were conducted with a step size (Δa) of 0.10 of a year.

Input parameters

Growth parameters

The average value for K (0.23) and L∞ (40.7cm) presented by Seisay *et al.* (1992) for *Oreochromis* spp. was used in all computations, while a t_o value of 0.26 was used as this gave realistic lengths at low ages (Palsson *et al.* 1999). The input parameters for the length weight equation (Equation 3) were derived Seisay et al. (1992).

Mortality rates

To obtain estimates for the instantaneous rate of total annual mortality (*Z*), length frequency data collected from trawl surveys undertaken by the R.V. Ndunduma in Area A in December 1995, January 1997, January 1998, June 1999 and January 2000 were analysed by means of a linearised length-converted catch curve (Pauly 1983, 1984a, 1984b). This method uses von Bertalanffy growth parameters[1] to plot of ln (*F/dt*) against *t*, where *F* is the frequency of individuals in each length class, *t* is the relative age of the fish. The value *dt* is the time taken for the fish to grow through a particular length class and allows for decreased growth with increased age. The negative of the slope of the resultant linear regression line through the descending data points gives a first approximation of Z. For natural mortality, the FAO (1993) estimates $M = 0.4$ yr^{-1} for fish younger than 2 years, $M = 0.3$ yr^{-1} for fish between 2 and 4 years old and $M = 0.2$ yr^{-1} for fish older than 4 years were used. Having obtained *Z* and *M*, fishing mortality was derived by subtraction ($F = Z – M$).

Age specific selectivity

Age-specific selectivity was estimated by age-converting length-based selectivity functions for chambo. Length based selectivity was obtained from available literature (Sipawe 2001, Chisambo 2001, FAO 1993). Both the re-parameterised Gamma (Punt *et al.*, 1996) and Logistic distributions were investigated to approximate gear selectivity patterns. The Gamma distribution was considered most suitable for gill nets as selectivity increases to a maximum and then decreases. The selectivity pattern of chambo seines, kambuzi seines, chilimira/kauni and the commercial fisheries was described by logistic distribution as selectivity was assumed to increases to, and remain at, a maximum.

[1] The average value for K (0.23) and L∞ (40.7cm) presented by Seisay *et al*. (1992) for *Oreochromis* spp. was used in all computations, while a t_o value of 0.26 was used as this gave realistic lengths at low ages (Palsson *et al*. 1999).

Both distributions are described as

$$S_a = (\frac{a}{\phi})^{\frac{\phi}{p}} e^{(\phi - a)/p} \qquad p = \left(\sqrt{\phi^2 + 4\sigma^2} - \phi\right)/2 \qquad \text{(Gamma distribution)}$$

$$S_a = \left(1 + e^{-(a-\phi)/\sigma}\right)^{-1} \qquad \text{(Logistic distribution)}$$

where S_a is the selection of the gear on fish of age a, ϕ is the age at maximum selectivity (in the Gamma distribution) or age-at-50% selection (in the Logistic distribution) and σ the width of the selectivity function.

Table 1. Input parameters used for the application of yield and spawner-biomass-per-recruit models for the chambo (*Oreochromis* spp.) stock in Area A of the southeast arm of Lake Malawi.

Parameter	Value	Function
Growth Parameters	K= 0.23; L_∞ = 40.5cm; t_o = -0.23	Von Bertalanffy
Maximum age	*10 yrs*	
Maturity	ϕ =2.93 yrs; σ = 0.64 yrs	Logistic
Length Weight	α = *0.017;* β = 2.99	Equation 3
Natural mortality	Age 0-2 = 0.4 yr^{-1} ; Age 2-4 = 0.3 yr^{-1}; Age 4+ = 0.2 yr^{-1}	Exponential decay
Fishing Mortality		
F (all fisheries)	0.34 yr^{-1}	Exponential decay
2" gill net	0.0003 yr^{-1}	Exponential decay
3" gill net	0.046 yr^{-1}	Exponential decay
Chilimira/Kauni	0.25 yr^{-1}	Exponential decay
Nkacha/Kambuzi seine	0.001 yr^{-1}	Exponential decay
Chambo seine	0.03 yr^{-1}	Exponential decay
Commercial fisheries	0.01 yr^{-1}	Exponential decay
Selectivity		
2" gill net	ϕ = 1.6; σ = 0.16	Gamma
3" gill net	ϕ = 3.68; σ =0.67	Gamma
Chilimira/Kauni	ϕ = 3.17; σ = 0.43	Logistic
Nkacha/Kambuzi seine	ϕ = 0.878; σ = 0.156	Logistic
Chambo seine	ϕ = 3.5; σ =0.4	Logistic
Commercial fisheries	ϕ = 3.19; σ = 0.48	Logistic

Results

Per-recruit analysis

Input parameters used in the per-recruit analysis are summarised in Table 2. Length-converted catch curves for *Oreochromis* spp. are shown in Figure 2. Estimates of Z varied between surveys ranging from 0.50 $yr^{-1}$to 0.69 yr^{-1}. The mortality rate estimated from the January 1998 survey (0.69 yr^{-1}) was considered exceptionally high and was therefore not used in further analysis. An average of the remaining Z estimates was used as a first approximation of Z in Area A. Z was estimated to be 0.54yr-1. The resultant Fishing mortality rate was therefore 0.34 on fish older than 4 years. Estimates for gear specific fishing mortality and selectivity are shown in Table 1.

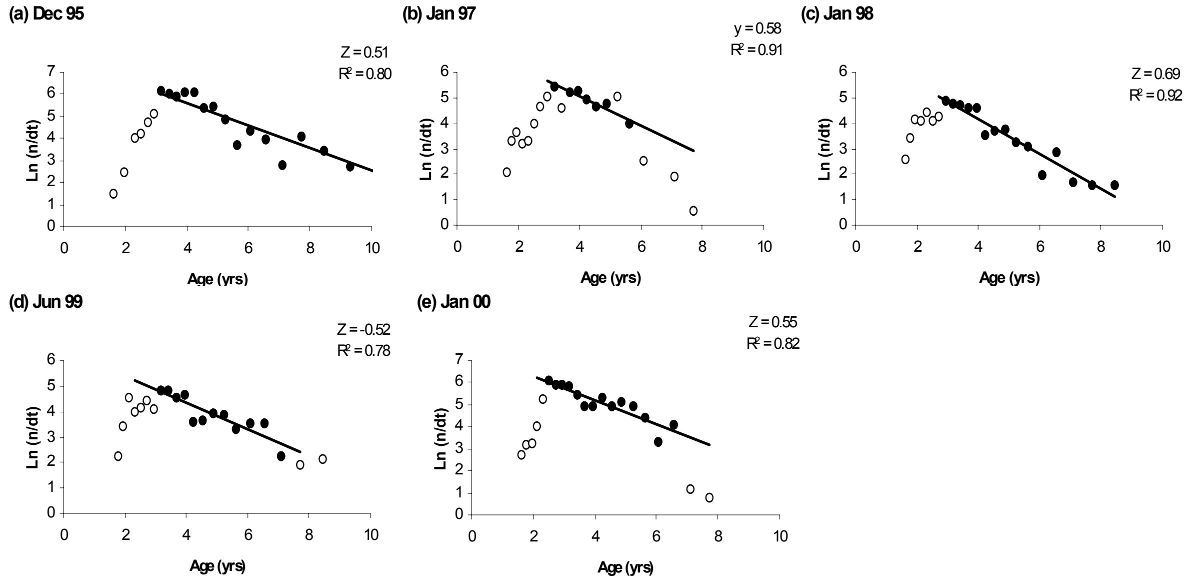

Figure 3. Length converted catch curves for *Oreochromis spp.* derived from trawl net length frequency distributions in Area A of the southeast Arm of Lake Malawi from December 1995 to January 2000.

Yield- and spawner biomass-per-recruit as a function of fishing mortality are presented in Figure 3. Current fishing mortality (F_{cur}) was below the F_{max} TRP (0.54yr^{-1}) but it was higher than the more conservative $F_{0.1}$ TRP ($F_{0.1}$ = 0.32 yr^{-1}). At F_{cur}, the chambo spawner biomass was reduced to 37% of pristene levels (Figure 1). At F_{max} SBR would be reduced to 25% of pristene levels. The F_{SB40} strategy approximated the $F_{0.1}$ TRP.

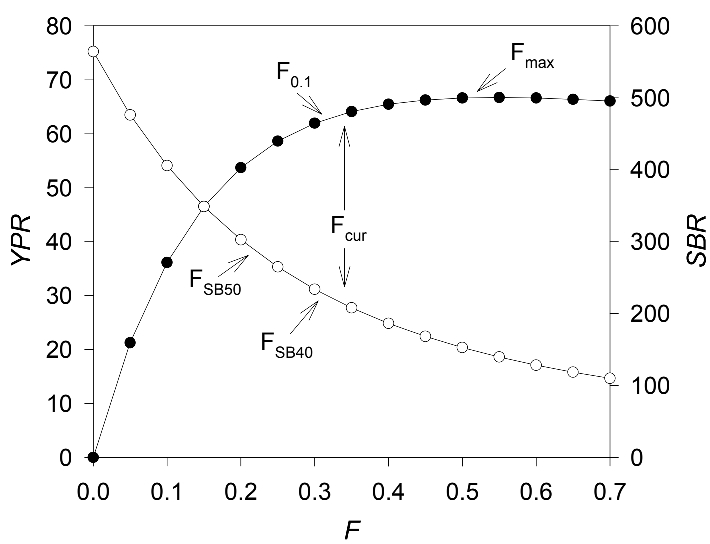

Figure 4. Yield-per-recruit (YPR, closed circles) and spawner biomass-per-recruit (SBR; open circles) as a response to fishing mortality (*F*) for *Oreochromis 'Nyasalapia'* spp. In Area A of the SEA of Lake Malawi. Common target reference points are shown.

Using the multi-fishery per-recruit models it was possible to assess the response of chambo SBR to different combinations of *F* in the fisheries. Various management options were explored and resultant effort at the F_{SB40} and F_{SB50} TRP are shown in Table 2. Effort limitations to below current levels were necessary to attain the F_{SB40} and F_{SB50} TRP in all scenarios investigated. With all fisheries active, 10% reduction in *F* was necessary to obtain and F_{SB40} TRP and a 23% reduction was neccesary to obtain an F_{SB50} TRP. The closure of the 2 inch gill net fishery or the nkacha net and kambuzi seine fishery only resulted in marginal increases in the allowable effort at F_{SB40} and F_{SB40} TRP. In all scenarios that maintained the chilimira/kauni fishery at current effort levels an F_{SB50} TRP was not attainable and the F_{SB40} TRP was only attainable with large effort reductions in all other fisheries.

Table 2. Allowable effort levels at different management scenarios maintaining F_{SB40} and F_{SB50} TRPs with proportional increase in effort in all fisheries.(GN2 = 2inch gill net, GN3 = 3inch + gill net, NK = Nkacha net, KS = Kambuzi seine, CH = Chilimira/Kauni, CS = Chambo seines, PT = Pair trawl fishery.

Management strategy		Number of gears						
		F	GN2	GN3	CH	PT	KS+NK	CS
Current Fishery		0.34	75	343	119	2	39	18
All fisheries active	F_{SB50}	0.22	49	222	77	1	25	12
	F_{SB40}	0.31	68	313	109	2	36	16
Ban of NK + KS	F_{SB50}	0.23	50	229	79	1	-	12
	F_{SB40}	0.32	70	319	111	2	-	17
Ban of GN2	F_{SB50}	0.22	-	225	78	1	25	12
	F_{SB40}	0.32	-	313	109	2	36	16
Ban on Pair Trawl	F_{SB50}	0.23	56	232	80	-	26	12
	F_{SB40}	0.32	78	323	112	-	37	17
Ban on all seines	F_{SB50}	0.24	54	245	85	1	-	-
	F_{SB40}	0.34	76	346	120	2	-	-
CH maintained at current levels	F_{SB50}	Not attainable						
	F_{SB40}	0.16	35	162	119	1	18	8
CH + CS maintained at current levels + ban on NK + KS	F_{SB50}	Not attainable						
	F_{SB40}	0.01	1	6	119	2	-	18
KS + NK banned and all other fisheries except CH maintained at current levels	F_{SB50}	0.20	75	343	69	2	-	18
	F_{SB40}	0.31	75	343	108	2	-	18

Discussion

Current exploitation rates for chambo in Area A lie between the $F_{0.1}$ and F_{max} TRP levels and corresponds to an SBR reduction to 37% of pristene levels (Figure 2). The declining chambo catch in the SEA of Lake Malawi over the past 10 years (FRU unpublished catch statistics, Weyl 1999, Bulirani *et al*. 1999) imply that this level of SBR is too low to sustain the chambo stock. This may, in part, be a consequence of the reproductive behaviour of chambo. *Oreochromis* spp. are mouthbrooders which brood their eggs and young for extended periods (Trewawas 1983). For this reason the recruitment of chambo is likely to be highly dependent on the density of adult fish and chambo directed management should focuss on the maintenance of the SBR at F_{SB40} or even F_{SB50} levels. Management at these TRPs would require a decrease in 10% in *F* to attain the F_{SB40} and a 23% reduction in *F* to attain the F_{SB50}.

The declinning catch rates for chambo indicate that current management strategies (GOM 2000) have not adequately protected chambo and have failed at the maintenance of sustainable yields. For this reson it is believed that the closed season is an inadequate measure to sustain catches in this fishery. While the use of small meshed seines and nkacha nets is already banned in the SEA, it is evident that their use is continued in the SEA Arm (pers obs). However, due to the low contribution of these gears to the total chambo catch, the removal of these gears from the fishery only had a marginal effect on chambo YPR and SBR. However, it has been noted that in addition to catching predominantly juvenile chambo (Manase 2001, FAO 1993), nkacha nets and beach seines cause considerable habitat damage by scouring the lake bottom and the destroying weedbeds (Tweddle *et al.* 1994) and is recommended that these gears remain prohibited in the SEA. The removal of gill nets with mesh sizes of less than 2 inches from the fishery would also only have a marginal effect on YPR and SBR of chambo. This is a result of this gear not actively targeting chambo (Sipawe 2001). Management therefore needs to foccuss on effort reductions in all chambo harvesting fisheries rather than on the removal of a few highly destructive fishing gears.

An isopleth diagram showing the response of SBR to increasing effort in the number of chilimira/kauni nets and gill nets (with nkacha and kambuzi seines removed from the fishery and chambo seine and commercial effort set at current levels) in Area A are presented in Figure 3. Essentially this isopleth shows that the number of allowable gill nets is dependent on the number of chilimira nets and vice versa. If F_{SB50} TRP was to be maintained, then any combination of the two gears following the F_{SB50} contour would be appropriate. At F_{SB40}, slightly higher effort levels would be feasible. While the removal of the the kauni fishery would allow for well over 3000 gill nets in Area A, a total ban of kauni may not be feasible. The chilimira net is an important gear for the harvest of species other than chambo and a closure of this fishery would reduce landings of non-chambo species by an estimated 1500 tons (FRU catch statistics). In addition, consideration must be given to the current employment of over 1000 fishers in this fishery in Area A. It is therefore recommended that an acceptable effort balance between the chilimira/kauni and other fisheries be considered rather than a a total closure.

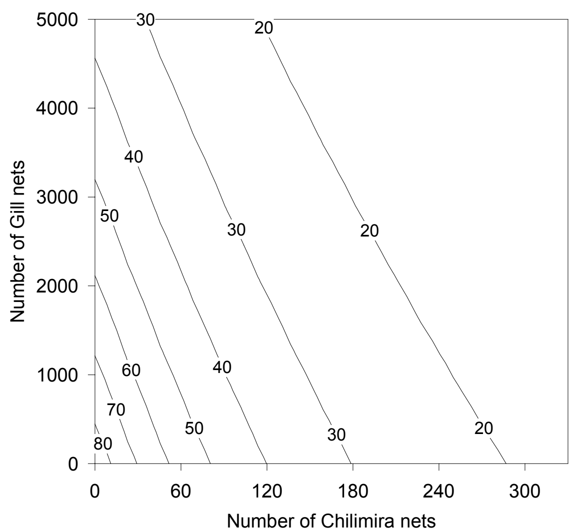

Figure 5. Isopleth diagram showing chambo spawner-biomass-per-recruit as a proportion of pristine levels for different combinations of effort in the gill net and chilimira/kauni fisheries in Area A of the SEA of Lake Malawi.

An example of different management options maintaining an F_{SB40} TRP, with a limit of 90 chilimira/kauni units is shown in Table 3. With the ban of nkacha and kambuzi seines and all other current fisheries active at 1999 levels, the reduction of the chilimira/kauni fishery to 90 gears would allow for 1100 gill net licences in "Area A'. At this level a total of 1400 people could be employed and a total yield of 2800 tons could be attained (assuming no change in catch rate for species other than chambo). If all commercial licences were activated, (a total of 4 pair trawlers), only 900 gill net licences could be sold, employment would decrease to about 1300 fishers, but production would increase to 3600 tons. The closure of chambo seines would allow for an increase in the number of gill nets, but only 1200 fishers would be employed in the small scale sector and the yield would be arround 3300 tons. The closure of the commercial sector in area A would increase allowable gill nets to 1600, allow for 1600 fishers to be employed and a yield of 2600 tons.

It is evident that the management of the chambo stocks in Area A will have costs. None of the suggested strategies would be able to employ all 1900 fishers currently employed in the fishery. A maximisation of employment in the small scale sector would decrease potential landings of species other than chambo. Alternatively, maximisation of landings through commercialisation would decrease potential employment. A management strategy for chambo in Area A therefore needs to take into account both socio-economic as well as biological constraints.

Table 3. Estimated number of gill net units, employment and total annual yield for all species in Area A of the SEA of Lake Malawi at different management scenarios maintaining an FSB40 TRP for Chambo, when Chilimira/Kauni effort is limited to 90 gears.

	All fisheries Active	All possible commercial licences	Closure of all seines	Closure of the commercial fishery
Number of gill nets	< 1100 gill nets	<900 gill nets	<1600 gill nets	<1300 gill nets
Total employment	<1400 fishers	<1300 fishers	<1400 fishers	<1600 fishers
Total Y	<2800 tons	<3600 tons	<3300 tons	<2600 tons

Acknowledgements

I would like to thank my colleagues at the Fru for their support in the preparation of this paper. The research was facilitated by the GTZ supported National Aquatic Resource Management Programme (NARMAP).

References

Banda, M. & Chirwa. 2000. Fish licensing for commercial fisheries on Lake Malawi. A working paper for the Fisheries advisory board meeting September 2000. Fisheries Department Headquarters, Lilongwe.11pp.

Booth A.J. & Buxton C.D. 1997. Management of the panga *Pterogymnus laniarius* (Pisces: Sparidae) on the Agulhas Bank, South Africa using per-recruit models. Fish. Res. 32: 1-11.

Bulirani, A.E., Banda, M.C., Palsson, O.K., Weyl, O.L.F., Kanyerere, G.Z., Manase, M.M. & Sipawe, R.D., 1999. Fish Stocks and Fisheries of Malawian Waters: Resource Report. Government of Malawi, Fisheries Department, Fisheries Research Unit.54pp.

Butterworth, D.S., Punt, A.E., Borchers, D.L., Pugh, J.B. & Hughes, G.S. 1989. A manual of mathematical techniques for line-fish assessment. S. Afr. Nat. Sci. Prog. Rep. 160: 1-89.

Caddy, J.F. & Mahon, R. 1995. Reference points for fisheries management. FAO Fisheries Technical Paper No. 347, Rome, FAO. 83 pp.

Chisambo 2001, Gear and species selectivity of the chilimira kauni fishery in Lake Malawi. pp. 127 - 132, *In: Weyl, O.L.F. & Weyl, M.V. (eds) Lake Malawi Fisheries Management Symposium – Proceedings. 4th – 9th June 2001.* NARMAP, Department of Fisheries, Malawi. 248 pp.

Clark, W.G. 1991. Groundfish exploitation rates based on life history parameters. Can. J. Fish. Aquat. Sci. 48: 734-750.

Deriso, R.B. 1987. Optimal F0.1 criteria and their relationship to maximum sustainable yield. Can. J. Fish. Aquat. Sci. 44 (Suppl. 2): 339-348.

Djama, T. & Pitcher, T.J. 1997. The differential effects of changing management regimes on yields from two fisheries exploiting the same resources. Fish. Res. 29: 33-37.

FAO, 1993. Fisheries management in the south-east arm of Lake malawi, the Upper Shire River and Lake Malombe, with particular reference to the fisheries of chambo (*Oreochromis spp.*) CIFA Tech. Pap. 21, Rome FAO. 113p.

GOM 2000. The Malawi Gazette Supplement, 14th July, 2000, containing Regulations, Rules, etc. (No. 12A) Government Notice No. 32.. Pp 277-318.

Griffiths, M.H. 1997. The application of per-recruit models to *Argyrosomus inodrus,* an important South African sciaenid fish. Fish. Res. 30: 103-115.

Gulland, J.A. & Boerema, L.K. 1973. Scientific advice on catch levels. Fish. Bull. 71: 325-335.

Kanyerere, G.Z. 2001. Spatial and Temporal distribution of some commercially important fish species in the Southeast and Southwest arms of Lake Malawi: A geostatistical analysis. Malawi Fisheries Bulletin No. 43.

Lowe, R.H., 1952. Report of the Tilapia and other fish and fisheries of lake Nyasa 1945-47. Part 2. Fish. Publ. Colon. Off. Lond., 1(2), 126p.

Manase, M.M. 2001, The nkacha fishery in Lake Malombe and the southeast arm of Lake Malawi. pp 156 – 162, *In: Weyl, O.L.F. & Weyl, M.V. (eds) Lake Malawi Fisheries Management Symposium – Proceedings. 4th – 9th June 2001.* NARMAP, Department of Fisheries, Malawi. 248 pp.

Murawski, S.A. 1984. Mixed-species yield-per-recruit analysis accounting for technological interactions. Can. J. Fish. Aquat. Sci. 41: 897-916.

Nyasulu, T. 2001, Resource use overlaps between pair trawl and small scale fisheries in the southeast arm of Lake Malawi – Preliminary results. pp 195 – 199, *In: Weyl, O.L.F. & Weyl, M.V. (eds) Lake Malawi Fisheries Management Symposium – Proceedings. 4th – 9th June 2001.* NARMAP, Department of Fisheries, Malawi. 248 pp.

Palsson, O.K., Bulirani, A. & Banda, M. 1999. A review of biology, fisheries and population dynamics of chambo (Oreochromis spp., CICHLIDAE) in Lakes Malawi and Malombe. Malawi Fisheries Bulletin No. 38.

Pauly, D. 1980. On the interrelationship between natural mortality, growth parameters and mean environmental temperature in 175 stocks of fish. J. Cons. Int. Explor. Mer, 39: 175-192.

Pauly, D. 1983. Length-converted catch curves: a powerful tool for fisheries research in the tropics. ICLARM, Fishbyte 1(2): 9-13.

Pauly, D. 1984a. Length-converted catch curves. A powerful tool for fisheries research in the tropics. ICLARM. Fishbyte 2(1): 17-19.

Pauly, D. 1984b. Length-converted catch curves. A powerful tool for fisheries research in the tropics (conclusion). ICLARM, Fishbyte 2(3): 9-10.

Pikitch, E.K. 1987. Use of a mixed-species yield-per-recruit model to explore the consequences of various management policies for the Oregon flatfish fishery. Can. J. Fish. Aquat. Sci. 44: 349-359.

Punt, A.E. 1993. The use of spawner-biomass-per-recruit in the management of linefisheries. Special Publication of the Oceanographic Research Institute, Durban, 2: 80-89.

Seisay M.D.B., van Zalinge N.P & Turner G.F., 1992. Population Dynamics and stock estimates of Chambo (Oreochromis spp.) in the south east arm of Lake Malawi and lake Malombe-Length based approach. FI:DP/MLW/86/013. Field Document 19. 34p.

Shepherd, J.G. 1982. A versatile new stock-recruitment relationship for fisheries, and the construction of sustainable yield curves. J. Cons. Int. Explor. Mer, 40: 67-75.

Sipawe, R.D. 2001. Gear and species selectivity of the gill net fishery in Lake Malawi. pp 133 –141, *In: Weyl, O.L.F. & Weyl, M.V. (eds) Lake Malawi Fisheries Management Symposium – Proceedings. 4th – 9th June 2001.* NARMAP, Department of Fisheries, Malawi. 248 pp.

Sissenwine, M.P. & Shepherd, J.G. 1987. An alternative perspective on recruitment overfishing and biological reference points. Can. J. Fish. Aquat. Sci. 44: 913-918.

Smale, M.J., & Punt, A.E. 1991. Age and growth of the red steenbras *Petrus rupestris* (Pisces Sparidae) on the southeast coast of South Africa. S. Afr. J. Mar. Sci. 9: 249-259.

Trewawas, E. 1983. Tilapiine Fishes of the genera Sarotherodon, Oreochromis and Danakila. British Museum (Natural History) Publication No. 878. 583pp.

Tweddle, D., Alimoso, S.B. & Sodzapanja, G. 1994a. Analysis of catch and effort data for the fisheries of the South East Arm of Lake Malawi 1976-1989. Government of Malawi, Fisheries Department Bulletin No. 13.

Weyl, O.L.F. 1998, The dynamics of a sub-tropical lake fishery in central Mozambique. PhD Thesis, Rhodes University, 202p.

Weyl, O.L.F. 2001. Area management (area management committees) as a concept for PFM implementation – Discussion Paper. Appendix I(g), *In:* National Aquatic Resource Management Programme (NARMAP), Report on the participatory Fisheries Management programme (PFMP) strategy review workshiop. Sun 'n' Sand Holiday Resort, Mangochi, 30 January – 1 February, 2001.

Weyl, O.L.F., Banda, M., Sodzqabanja, G., Mwenekibombwe, L.H., Namoto, W. & Mponda, O.C. 2000. Annual Frame Survey, September 1999. Government of Malawi, Fisheries Bulletin No. 42.

The nkacha fishery in Lake Malombe and the southeast arm of Lake Malawi

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Abstract

The nkacha net is an open water seine with a uniform mesh size ranging from 6 to 25 mm and is rectangular in shape. It is a main fishing gear of the small-scale fishery in Lake Malombe but is prohibited in Lake Malawi. However, this gear is used illegally in the southeast arm of the lake since the mid 1990s. This study compares catch and effort data as well as the catch composition of the of the nkacha net fishery for Lake Malombe and the southeast arm of Lake Malawi. Higher catch per unit effort (CPUE) in the southeast arm as opposed to Lake Malombe might be the primary drive for this gear's usage in Lake Malawi. Species size-classes caught in the southeast arm were considerably larger than of those species constituting catches from Lake Malombe. This suggests that catches from the southeast arm fetched higher market prices than Lake Malombe catches. Considering the impact of the nkacha net with regard to growth over-fishing and habitat degradation, management recommendations are therefore made for this fishery.

Introduction

Lake Malombe has a maximum length of 29 km and a maximum width of 17 km with a maximum depth of 17 m and a surface area of about 390 km^2 (FAO, 1993). The lake is about 16 km from Lake Malawi through the Upper Shire River, and this makes it easier for fishers to migrate between Lake Malombe and the southeast arm of Lake Malawi (Figure 1).

In the 1980s, the more valued chambo fishery (*Oreochromis* spp.) in Lake Malombe was reported to be in a state of collapse and that the fishery was eventually replaced by a fishery for the less valued haplichromine cichlid species called kambuzi using open water seines called nkacha nets. Mesh size for this gear is uniform ranging from 6 mm to 25 mm across the net panel. The nkacha net is operated by small-scale fisheries in Lake Malombe using small plank boats and dug out canoes. The operation of this gear does not involve use of light during night fishing. Recent studies on Lake Malombe indicate that this kambuzi fishery is also in a declining state (Banda & Hara 1994, Weyl 1999, Weyl *et al.* 2001).

Though nkacha gear is legal only in Lake Malombe, there has been unprecedented increase in the use of this gear in Lake Malawi since the mid 1990s, particularly in the southeast arm of the lake. Operation of this gear in Lake Malawi is prohibited on account that the gear destroys nursery grounds for some important fish stocks, including the chambo (Banda & Hara 1994). As such, this gear is likely to compromise the economic value of the fisheries of Lake Malawi. The purpose of this study was to describe and compare the nkacha net fishery in Lake Malombe with that of the southeast arm of Lake Malawi in reference to catch rates, catch value, species and size composition. This study will aid in the development of appropriate management interventions that will go a long way towards safeguarding the existing high valued fish stocks of Lake Malawi.

Materials and methods

Data from research surveys undertaken by the Fisheries Research Unit of the Fisheries Department on Lake Malombe and the southeast arm of Lake Malawi were used. On each sampling day, gears were described by type, mesh size, gear length and mode of operation. Catch samples were selected at random and every fish in each sample was sorted to species level. Each species group was weighed and each fish in the sample was measured for total length (TL) to the nearest millimetre. Catch and effort data collected during routine monitoring surveys by the Department of Fisheries for Lake Malombe and southeast arm of Lake Malawi for the period 1994-1999 were also used in this study to compare catch rates and catch value for these water bodies. Methods used in the collection of catch and fishing effort data from the traditional fisheries of Malawi followed the Malawi Traditional Fisheries (MTF) system described by FAO (1993).

Results and discussion

Ownership of nkacha gear is shown in Figure 2. The nkacha net fishery started booming up around 1993 in the southeast arm of Lake Malawi and registered a high level of some 70 gears in 1999. This showed a sharp contrast with the situation of Lake Malombe where ownership of nkacha nets started decreasing from a high level of over 300 gears in 1995 to a level of 164 in 1999. This suggests some driving force that has been attracting nkacha gear owners to operate in Lake Malawi apart from Lake Malombe where the gear is recommended.

The species composition for the nkacha fishery in Lake Malombe is not distinct from the species composition of the nkacha fishery of the southeast arm of Lake Malawi. Catch composition of the nkacha fishery in Lake Malombe as well as the southeast arm of Lake Malawi has been predominantly kambuzi species. The main species for nkacha fishery in Lake Malombe and the southeast arm of Lake Malawi include species belonging mainly to the genera *Copadichromis, Lethrinops* and *Otopharynx* (Figure 2).

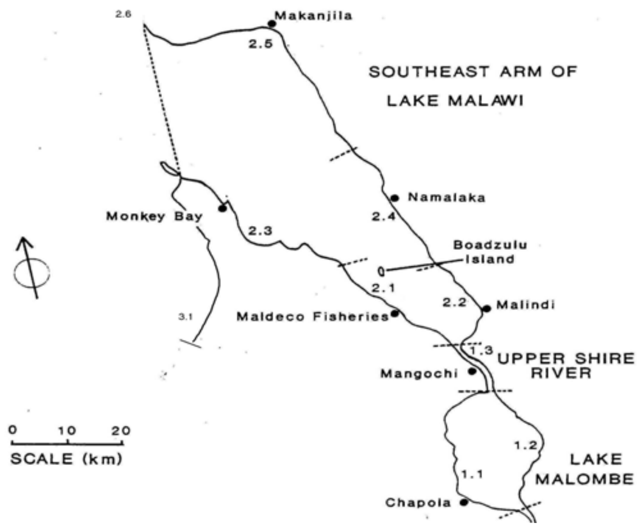

Figure 1. Map of the study area.

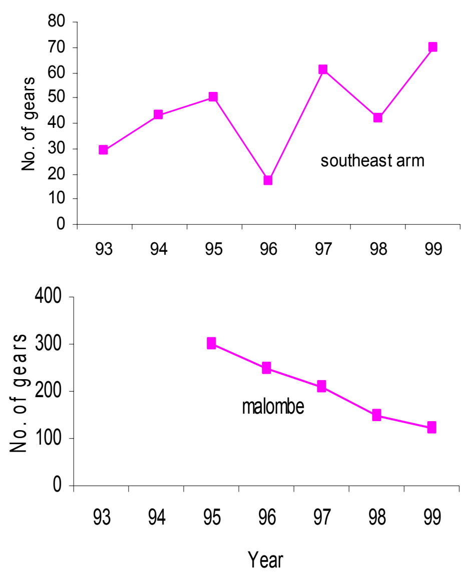

Figure 2. Ownership of nkacha nets in Lakes Malawi (southeast arm) and Malombe, 1993-1999.

Catch per unit of effort (CPUE) for nkacha net fishery in the southeast arm was significantly higher than that of Lake Malombe between 1995 and 1997 (Figure 3). The highest CPUE of 140 kg per trip was attained in southeast arm nkacha net fishery in 1996. Relating the CPUE levels with catch value, catches from the southeast arm have been registering consistently high value. In 1999, the value of the catch reached a level of MK 1,400.00 per fishing trip whereas catch value from Lake Malombe was MK 1,175.00 per trip in the same year. This indicates that the high catch rates in the southeast arm of Lake Malawi from 1995 might have attracted nkacha gear owners from Lake

Malombe. These nkacha net operators have not withdrawn from southeast arm, despite high CPUE levels from 1997 in Lake Malombe, due to low economic value of the harvested species in Lake Malombe (Table 1).

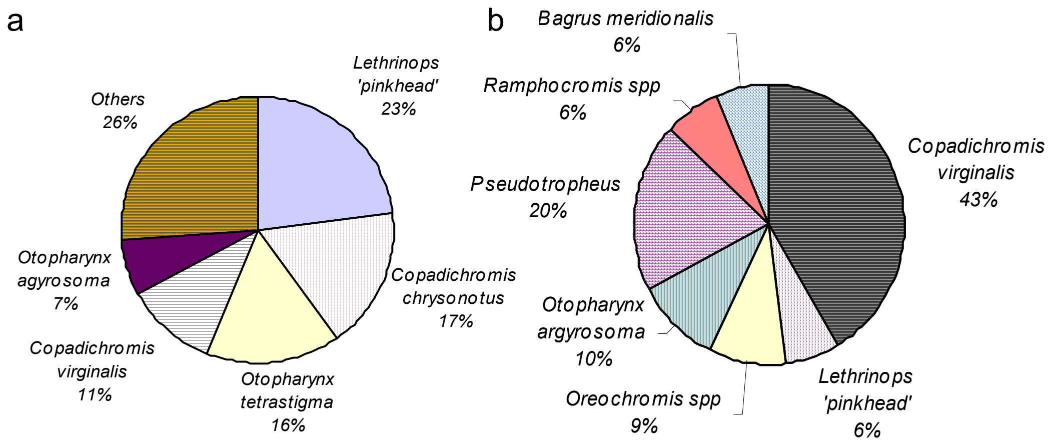

Figure 3. species catch composition for nkacha nets in a) Lake Malombe and b) the southeast arm of Lake Malawi.

Table 1. Mean beach price ± 95% confidence interval for kambuzi at landing sites at Lake Malombe and the southeast arm of Lake Malawi

Year	Lake Malombe			Lake Malawi		
	Mean (MK/kg)	std	n	Mean (MK/kg)	std	n
1994	1.16	1.04	1466	1.98	0.97	958
1995	4.45	2.48	1590	4.62	2.60	782
1996	4.23	1.43	928	4.92	1.88	309
1997	4.87	1.70	652	5.42	2.02	442
1998	5.86	2.99	877	11.49	3.96	379
1999	9.00	4.11	1537	16.33	8.78	583

Other than catch rates, it appears that length frequency distributions of species could also be playing an attractive role for nkacha netters in Lake Malawi since the value of the harvested species is related to size of fish offered for sale at the markets.

For *Copadichromis virginalis* (utaka), most of the fish harvested from Lake Malombe were of 65 mm TL whereas those from the southeast arm registered 110 mm TL (Figure 5). On the other hand, *Otopharynx argyrosoma*, another Kambuzi species, registered 60 mm TL in the southeast arm of Lake Malawi compared to 65 mm TL from Lake Malombe and a good number of fish sampled in southeast arm registered over 80 mm TL (Figure 6). In overall terms, mean lengths for *Otopharynx argyrosoma* were 69 mm TL and 64 mm TL in southeast arm of Lake Malawi and Lake Malombe respectively (Table 2). As for *Lethrinops* 'pinkhead' (Figure 7), the catches from southeast arm registered 90 mm TL whereas those from Lake Malombe registered 60 mm TL. Interestingly, a relatively high proportion of the catch from nkacha net fishery operating in the southeast arm of Lake Malawi constituted chambo (Table 1). Although chambo registered only 9% of this gear's total catch, the situation is more threatening considering the fact that small sized individuals of chambo, locally known as kasawala, were targeted (Figure 8).

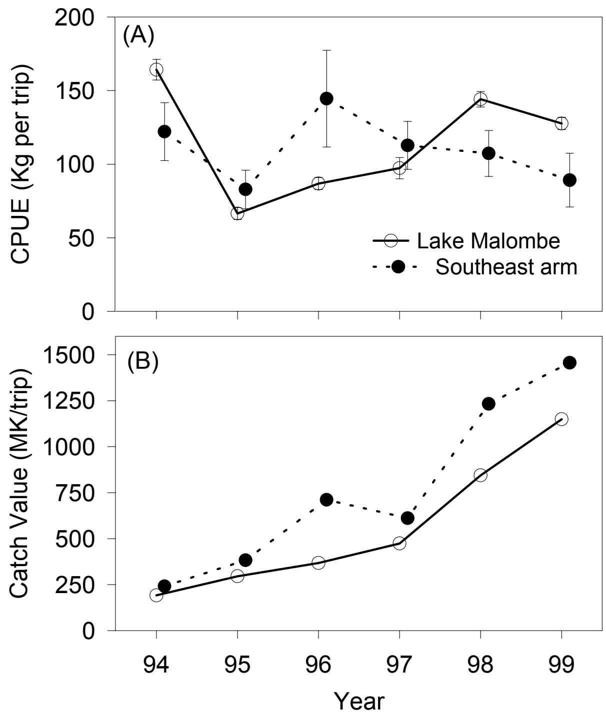

Figure 4. Nkacha net (A) catch per unit effort ± 95 % confidence intervals and (B) Mean catch value in Malawi Kwacha in Lake Malombe and the southeast arm of Lake Malawi from 1994 to 1999.

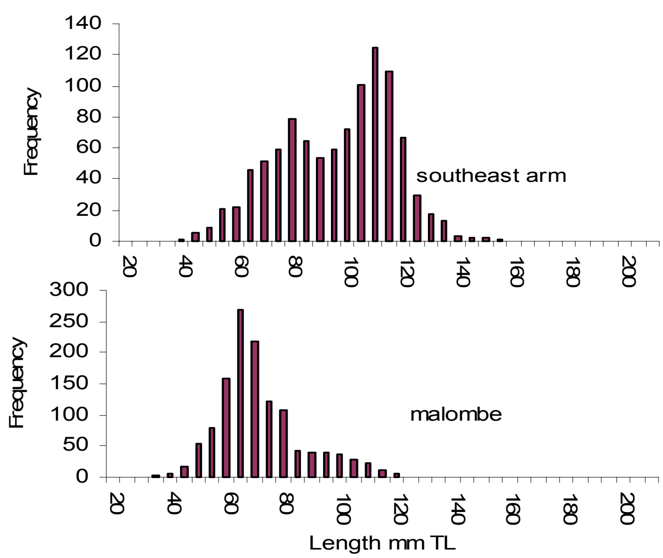

Figure 5. Length frequency distribution of *Copadichromis virginalis* (Utaka)

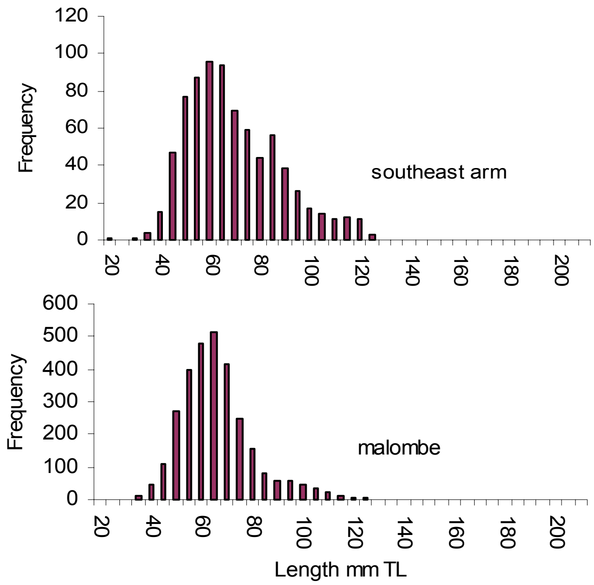

Figure 6. Length frequency distributions of *Otopharynx argyrosoma* (Kambuzi)

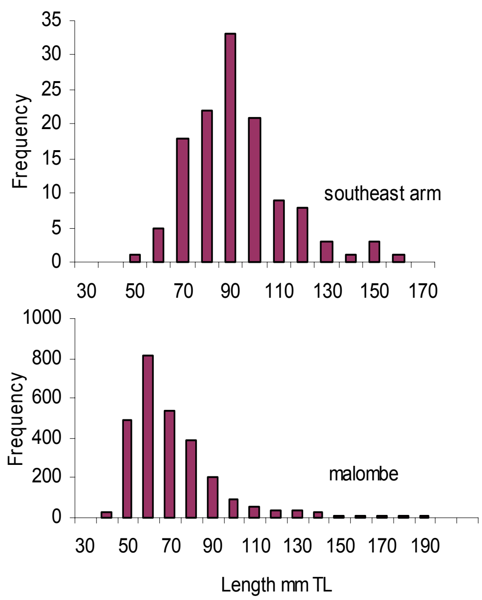

Figure 7. Length frequency distributions of *Lethrinops* '*pinkhead*' (Kambuzi).

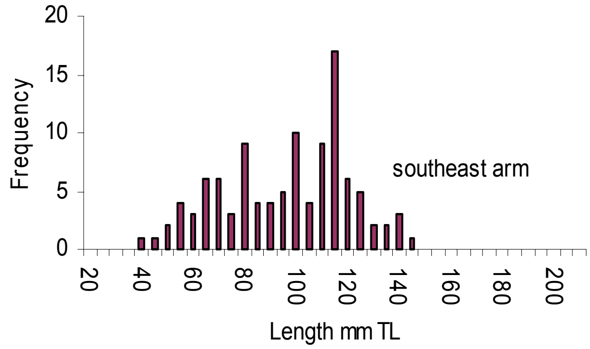

Figure 8: size distribution for juvenile *Oreochromis* sp. caught in the southeast arm

According to breeding studies done on chambo in the southeast arm of Lake Malawi, length at maturity for this species is 200 mm TL (Palsson *et al.* 1999), and this was not reflected in the individuals of chambo caught by the nkacha net fishery. Most of the species registered 110 mm TL at capture, with a length range of 40 to 145 mm TL (Figure 8). This indicates that the nkacha net fishery was targeting immature fish in this area. Chambo, being one of the threatened fish species in Malawi, therefore deserves appropriate exploitation regimes that would seek sustainable harvesting of this important fishery (Alimoso, 1987).

Table 2. Mean length TL mm, 95% confidence interval for the species caught in southeast arm of Lake Malawi and from Lake Malombe.

Species	Lake Malawi			Lake Malombe		
	mean	95%CI	n	mean	95%CI	n
Copadichromis virginalis	96.18	1.27	1012	70.82	0.83	1260
Otopharynx argyrosoma	69.42	1.31	782	64.70	0.52	2971
Lethrinops 'pinkhead'	89.84	3.53	125	67.76	0.82	2761
Oreochromis spp.	96.06	4.66	107	NA	NA	NA

Size distributions for target species of nkacha in the southeast arm of Lake Malawi were generally larger that those of Lake Malombe (Table 2). This implies that the market value of fish from Lake Malawi was superior to those of Lake Malombe. Based on this scenario, it appears market forces are among the main factors that relate to the continued existence of nkacha net fishery in the southeast arm of Lake Malawi although this gear is illegal in this area. This could be supported by the fact that small-scale fishers are increasingly becoming business-orientated in nature other than subsisting on their fishing operations (Turner and Mdaihli, 1992).

It is also vital to consider that managing the nkacha fishery in Malawi has a considerable level of difficulty in the sense that it is legal to operate nkacha gear in Lake Malombe but illegal to operate in Lake Malawi, a nearby water body. Such types of regulations are complex bearing in mind the many attributes that one would expect to be accomplished by the fisheries enforcement section of the Department of Fisheries.

Furthermore, the nkacha net fishery promotes loss of nesting habitat for sand nesting cichlids due to scouring effect of the gear (Banda and Hara, 1994). The problems of the nkacha net fishery will eventually lead to loss of biodiversity of Lake Malawi's fish fauna and flora if proper management interventions are not put in place and followed. Against this background, management options for nkacha net fishery would include complete withdrawal of all nkacha netters and all small-meshed seine nets from Lake Malawi. Furthermore, a review of all existing fisheries regulations seems pertinent with regard to conflicting interests among stakeholders of the fisheries resources of Malawi.

There is adequate evidence that migration of nkacha netters does occur between Lake Malombe and the southeast arm of Lake Malawi due to their close proximity to each other. This scenario can also be attributed to a lack of effective enforcement of fisheries regulations and therefore calls for multi-sectoral collaboration in the management of fisheries resources of Malawi.

Acknowledgements
The author extends gratitude to the following sponsors- GTZ assisted National Aquatic Resource Management Programme (NARMAP), Icelandic International Development Agency (ICEIDA) and Fisheries Research Fund (FRF) for financing target oriented research surveys that yielded the data used in this report. Special regards also extend to fellow researchers at Monkey-Bay Fisheries Research Station for their valuable criticisms as well as proof reading of the manuscript. Special thank you goes to Dr Olaf Weyl, NARMAP Research Adviser, for fruitful contributions.

References
Alimoso SB, 1987 An Assessment of the effects of traditional fishing on Chambo (Oreochromis spp.) in Lake Malombe. LUSO: J.Sci. Techn. (Malawi) (1987) 8 (1&2) :1-10.

Alimoso SB and Tweddle D, 1994 Seine net fisheries of Lake Malombe. Traditional Fisheries Assessment Project Working Paper TFAP/1.

Banda MC and Hara MM, 1994 Seine nets and habitat degradation: How they have caused collapse of the Chambo (Oreochromis spp.) fishery of Lake Malombe and the Upper Shire.

Bazigos GP, 1972 The Improvement of the Malawian fisheries Statistical system. A report to the integrated project. FAO/MLW/16. Zomba, Malawi.

FAO, 1993. Fisheries management in the southeast arm of Lake Malawi, the Upper Shire River and Lake Malombe, with particular reference to the fisheries of chambo (*Oreochromis* spp.) CIFA Tech. Pap. 21, Rome FAO. 113p.

Palsson OK, Bulirani A and Banda M 1999 A review of biology, fisheries and population dynamics of chambo (*Oreochromis* spp., CICHLIDAE) in Lakes Malawi and Malombe. Fisheries Bulletin No.38. Fisheries Department. Malawi

Turner G.F. and Mdaihli M. 1992 A Bioeconomic Analysis of the Industrial and Semi-Industrial Fisheries of Southern Lake Malawi. FI:DP/MLW/86/013 Field Document 22, July 1992.

Weyl, O.L.F. 1999. Lake Malombe artisanal fishery catch assessment 1994-1998. NARMAP Technical Report No. 1. 23p.

Weyl, O.L.F., Banda, M.C., Manase, M.M., Namoto, W. & Mwenekibombwe, L.H. 2001. Analysis of catch and effort data for the fisheries of Lake Malombe, 1976-1999. Fisheries Bulletin No. 45.

The state of the large scale commercial fisheries on Lake Malawi

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Abstract
The large-scale commercial fisheries are mechanised and based in the southern part of the lake. This report is based on the data collected from monitoring surveys as well as an analysis of fisheries statistics in the past decade. The data were analysed by area and depth ranges: shallow < 50 m, 51-100 m and very deep >100 m. The catch was dominated by cichlids and the cpue decreased with increasing in depth in both areas. Biomass estimates based swept area methods and the principal precautionary approach indicate that the fishery is not overexploited.

Key words: Large-scale fishery, biomass, swept area method, principal precautionary approach.

Introduction
The large-scale commercial fisheries in Lake Malawi are mechanised and capital intensive and use mainly trawling and purse seining (‘ring net’). The fishery consists of pair trawlers, (wooden boats about 8 m long with a 20-40 hp inboard engine), stern trawler (90-385 hp) units and ring nets (90 hp), which are confined to the southern part of the lake. The origins of the large-scale commercial fishery can be traced back as early as 1943 when purse seining started for chambo in the south east arm by the Europeans (FAO, 1976). In the mid 1960s experimental trawling led to the establishment of a pair trawl fishery to harvest the demersal fisheries in the shallow parts of the south east arm in 1968 (Tarbit, 1972). This fishery developed rapidly in the shallow waters of the southern part of the lake and in 1976 it was established on the western side of the lake. The more powerful stern trawlers were introduced in 1972 for bottom trawling (85 hp) and in 1976 for mid water trawling (180 hp) in the south east arm (FAO, 1976; Turner, 1977). Four bottom trawlers have joined the fishery since then; one started fishing in the same area in 1983; the other two in 1997 and the fourth one in 1998 (Banda, 2000). There are five stern trawlers now operating, although a new 380 hp boat replaced one bottom trawler. Bottom trawling was restricted to depths ranging between 50 and 70 m, but it has been expanded to deeper water (up to 100 m) by the two new powerful boats (380 hp). The reported average large-scale commercial catch is currently around 5,600 tons per annum, approximately 21% of the total annual fishing landings from Lake Malawi.

The management framework of the commercial fishery is based on the recommendations from monitoring programmes carried out by the Fisheries Department, which include the assessment of sustainable yields and allowable effort through biomass surveys, and the investigation of changes in the species composition of the catches and size distribution. Sustainable yields were estimated from the data for the fishing areas using the Schaefer (1954) surplus production model with the assumption of equilibrium conditions (Pitcher and Hart, 1982). However, continuous changes in species composition and population structure render this assumption invalid (Turner, 1995). Consequently, the precautionary principle was used as stock status indicator to generate interim management measures in the absence of stock assessment. The monitoring surveys were started in the early 1970s and have continued to date with some discontinuation (FAO, 1976; Turner, 1977; FAO, 1993; Turner, 1995; Banda *et al.*, 1996; Banda and Tómasson, 1997; Pálsson *et al*. 1999).

The fishing regulations include restriction on the number of licences to be issued in each demarcated area and the minimum mesh size of the trawl cod-end to be used. At present the number of the fishing fleet is 100% i.e. all licences have been issued, although not all are operational, especially the pair trawl units. The stern trawlers are licensed to fish waters greater than 50 m and the pair trawlers between 18 and 50 m water depth, or not less than one nautical mile from the shoreline. The recommended mesh sizes for the gears are 102 mm for the ring nets and 38 mm for other vessels.

In this study, data from monitoring surveys and historical trends of catch and effort from the commercial fishery have been analysed to assess the state of the commercial fisheries with particular reference to changes in species composition, mean size and catch rates. The results could be used to improve current and future management of the commercial fishery.

Materials and methods

Monitoring trawl survey

The data in this study were collected during the ongoing regular stock assessment surveys carried out by the Fisheries Department in the south east arm (SEA) and south west arm (SWA) of the lake (Figure 1). These surveys were designed to monitor changes taking place in the southern part of the lake, which is heavily exploited. The 17 m long Fisheries Department research vessel, *Ndunduma* powered with a 380 hp engine which pulls a Gulloppur bottom trawl net with a 23 m headrope and a 38 mm mesh cod end was used. The effective mesh size in the cod end was 4 mm due to the net liner used to ensure that escape through the meshes was minimal.

A total of 97 fixed trawl stations (54 in the SEA and 43 in SWA) were sampled during each survey. The stations were stratified into shallow 0-50 m, deep 50-100 m and very deep 100-150 m (Figure 1). Each trawl lasted for 30 minutes. All trawling was done during the day at depths between 10– 150 m; it was not possible to sample in water less than 10 m deep because of restrictions imposed by the draught of the vessel.

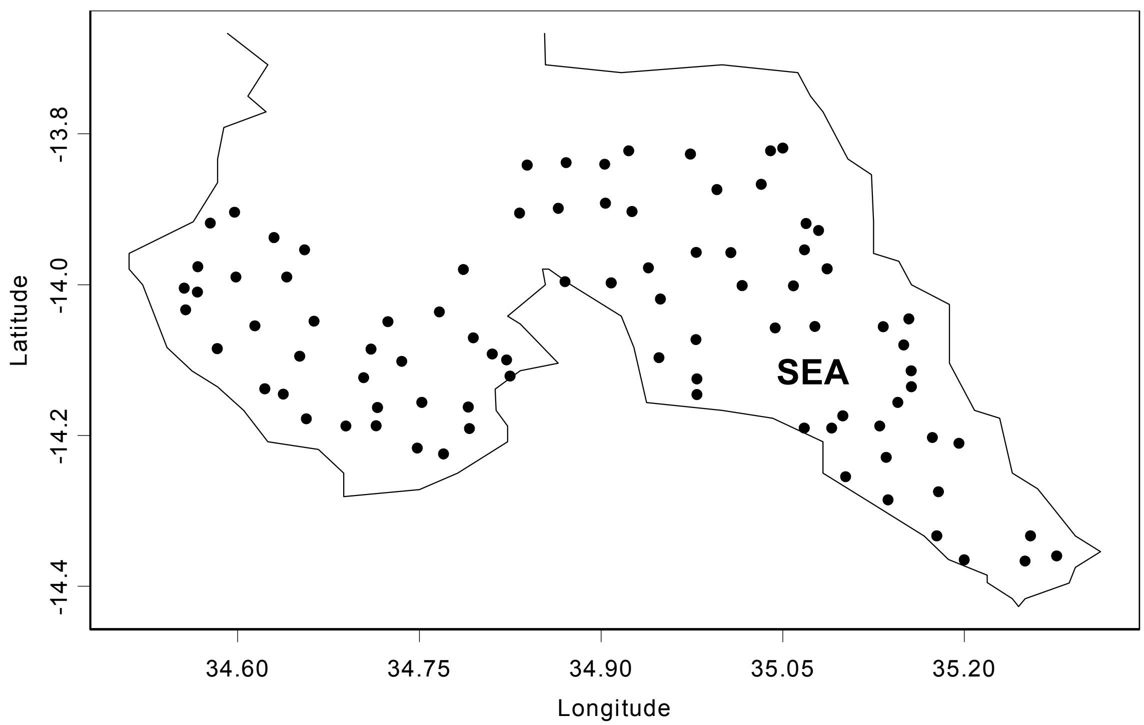


Figure 1. Map of southern of Lake Malawi showing the sampling stations used in the monitoring surveys.

The catch was sorted into four categories: Clariid catfish, *Bagrus meridionalis,* small cichlids and others (including cyprinids, mormyrids and large cichlids such as *Buccochromis* spp. and *Oreochromis* spp.). Each of them was measured on board the vessel to the nearest 0.5 cm (total length) and most fish were weighed to the nearest 0.01 kg and those that were not weighed individually were collectively weighed as a species group to the nearest 0.1 kg.

The catch per unit effort (C/f) assumed as index of abundance was expressed as:

$$C/f = \text{catch (kg)} / \text{swept area (ha)},$$

and sustainable yields were estimated to be 40% of the stock biomass (Banda *et al.* 1996).

Commercial trawl data

The catch and effort data from monthly-submitted returns of the commercial fishing companies from 1980 to 2000 were used in this analysis. Four datasets were summarised according to the operational fishing method: inshore demersal (pair trawlers), offshore demersal (stern bottom trawlers), midwater (midwater trawlers) and ringnet (chambo) fisheries. Trends in effort were described using boat-days and trends in cpue using catch/day except for the purse seines. The effort for the purse seine were expressed as pulls and cpue and catch/pull. Effort for all the fisheries has been standardised according to Sparre and Venema (1992) because fishing power has changed with time.

The precautionary reference points for the exploitation of the fisheries resources using standardised cpue as an estimator of stock biomass or size was adopted as described in Bulirani (*et al.* 1999). Four reference points were calculated: maximum biomass (B_{max}), biomass at precautionary approach (B_{pa}), biomass limit (B_{lim}) and current biomass point estimate (B_{cur}). The mean cpue over a period of relatively high cpue represented maximum biomass (B_{max}) and 45% of the B_{max} was considered as B_{pa}, a precautionary point where management must be undertaken. B_{lim} was calculated as 20% of the B_{max} and was considered as a point where management must be undertaken and B_{cur} was defined as the current level of biomass (cpue) relative to $B_{max.}$

Results

Monitoring surveys

The catch composition

The dominant species (by weight) throughout the surveys are shown in Figure 2. *Copadichromis virginalis, Otopharynx argyrosoma*, *Oreochromis* spp, *Bagrus meridionalis* and *Bathyclarias* species were the dominant species groups in the shallow waters of both arms of the lake (Figure 3). *Lethrinops longipinnis* and *C. eucinostomus* were also important in the south west arm of the lake. Years of high catches of *C. virginalis* coincided with low catches of *C. eucinostomus* and visa versa. *Capadichromis virginalis, Bagrus meridionalis*, *Bathyclarias* spp. *Diplotaxodon limnothrisa*, *Lenthrinops gossei*, *L. oliveri*, *L. alba* and *Synodontis njassae* remained generally an important component of the catch throughout the surveys in the deep waters of the southern part of the lake (Fig.4).

Catch per unit of effort (cpue)

The cpue for each year is shown in Figures 5 & 6 and where there was more than one survey conducted an average cpue was calculated. The mean cpue in shallow water from the SEA and SWA were 931.5 and 714.7 kg hr^{-1}, respectively, and were significantly different (t-test, $p < 0.05$) while that from the water depth > 50 m was 849.5 and 532.1 kg hr^{-1}, respectively, which was also significantly different (t-test, $p < 0.05$). The cpue in the shallow water < 50 m show a general decline since 1995 in the SEA and 1994 in the SWA (Figure 5). In contrast, the cpue in waters > 100 m seemed to have no proper trend in both arms (Figure 6).

Biomass

The biomass estimates and calculated MSY are shown in table 1. The biomass and MSY estimates of the SEA were generally greater than those from the SWA. Similarly, the biomass and MSY estimates are greater in waters < 50 m than in waters > 50 m in both arms.

Table 1. Biomass and Maximum Sustainable Yield (MSY) estimates from *RV. Ndunduma* surveys in the southern part of Lake Malawi from 1994 to 2000.

	SEA		SWA	
	0-50 m	> 50 m	0-50 m	> 50 m
Biomass	7230	8410	3130	6190
MSY	2890	3360	1250	2480

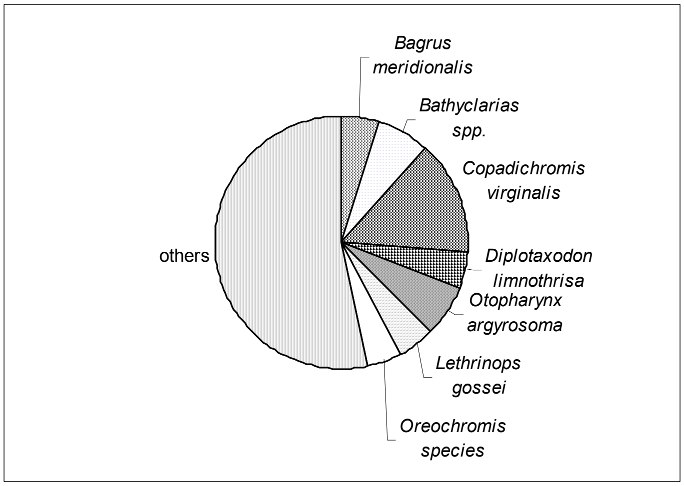


Figure 2. Species composition of the bottom trawl catch in the southern part of Lake Malawi from surveys from 1994 to 2000.

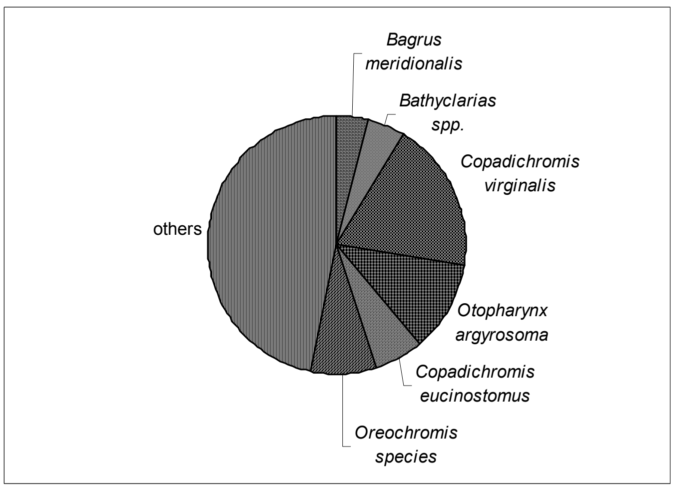


Figure 3. Species composition of the bottom trawl catch in the shallow waters (0-50 m) of the southern part of Lake Malawi from surveys from 1994 to 2000.

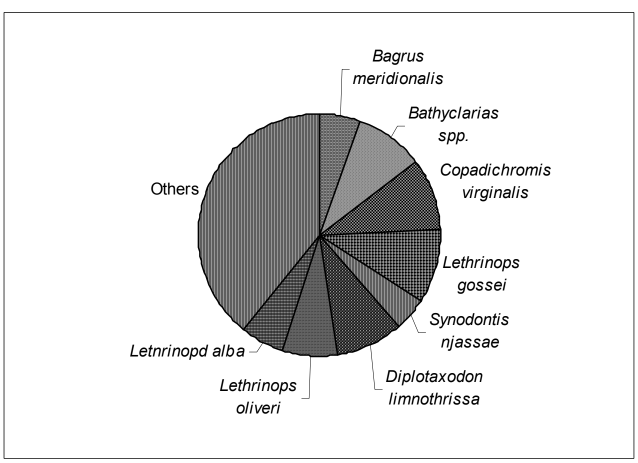


Figure 4. Species composition of the bottom trawl catch in the shallow waters (0-50 m) of the southern part of Lake Malawi morning surveys from 1994 to 2000.

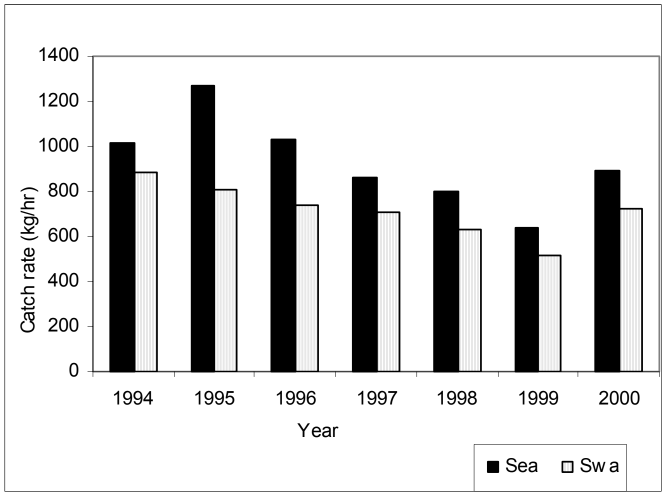


Figure 5. The mean catch rate (kg/hr) made from *RV. Ndunduma* surveys from 1994 to 2000 in waters (0-50m) of the southern part of Lake Malawi.

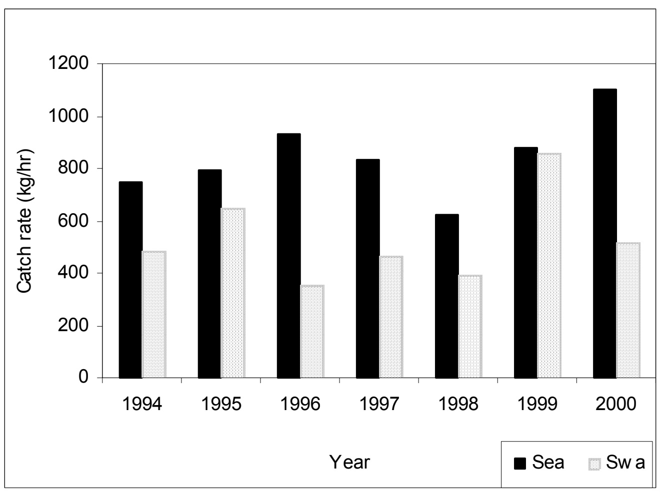


Figure 6. The mean catch rate (kg/hr) made from *RV. Ndunduma* surveys from 1994 to 2000 in waters (> 50 m) of the southern part of Lake Malawi.

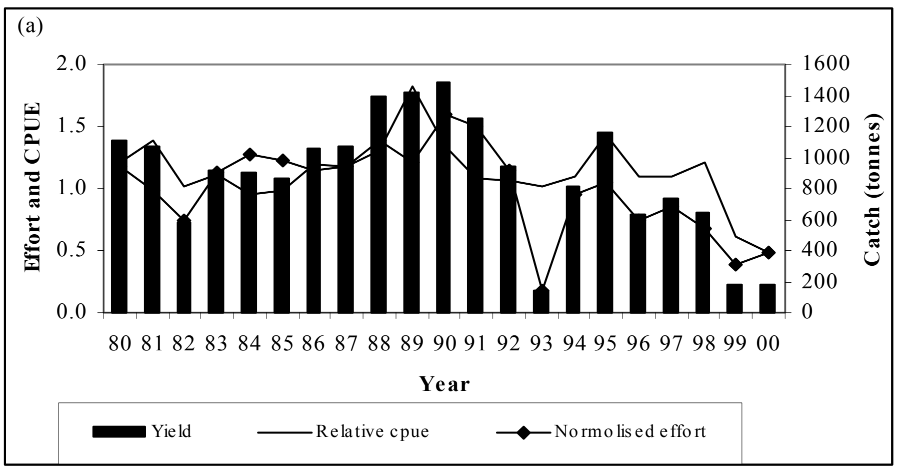
Commercial fisheries catch and effort data

Pair trawl fishery

The catches of the pair trawl fishery have been relatively stable between 1980 and 1988, and peaked up in 1990 to about 1 700 tons in the south east arm and since then there has been a general decline. The sudden drop in catch in 1993 was due to the closure of the fishery in Area A, south of Boadzulu Island (Figure 1). The cpue and effort showed a similar pattern to that of the catch. In contrast, the catches in SWA increased from lowest levels of about 150 tons in 1980 to highest levels of about 2 200 tons in 1988 and then stabilised around 1 500 tons between 1989 and 1994. After 1994, the catches have dropped down to levels of about 600 tons and have remained relatively stable since then. The effort has followed the same pattern as the catch while the catch rates have remained relative constant around 1.2 tons a day from 1980 to 2000. The Surplus Production Models did not fit the data as a result the precautionary approach principle was applied (Table 2). The pair trawl fishery in the SEA operates close to B_{pa} while that in the SWA above B_{pa} and hence no need for immediate action.

Table 2. Precautionary approach reference points for various large scale commercial fisheries in the southern part of Lake Malawi. PTF = pair trawl fishery, SBTF = stern bottom trawl fishery, MWTF = midwater trawl fishery and Ring net fishery.

	PTF	PTF	SBTF	MWTF	RNF
Reference points	SEA	SWA	SEA	SEA	SEA
Bmax	1.5	1.5	1.5	1.3	1.5
Bpa	0.7	0.7	0.7	0.6	0.7
Blim	0.4	0.4	0.4	0.3	0.4
Bcur	0.8	1.1	0.7	0.8	0.4



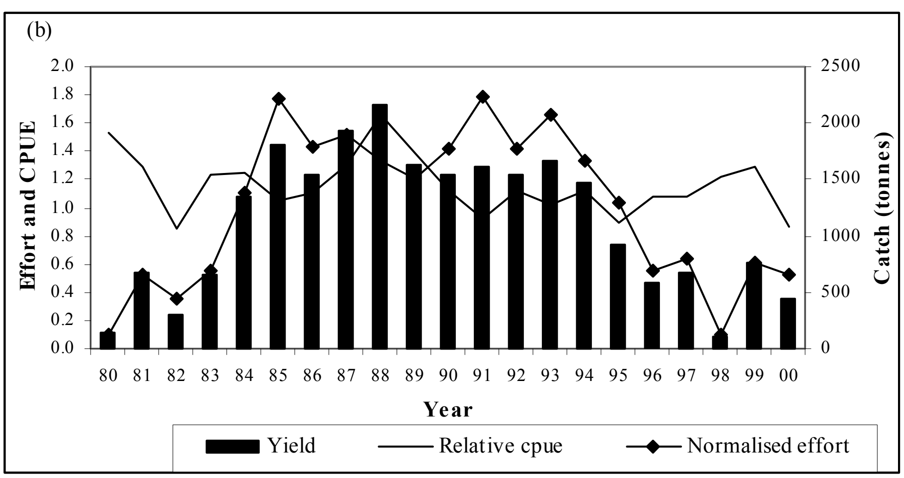


Figure 7. Catch, effort and CPUE in Pair trawl fishery in (a) south east arm and (b) south west arm of Lake Malawi from 1980 to 2000.

Stern bottom trawl fishery

The catches of the demersal fisheries based in the SEA reached the highest levels of around 2 400 tons in 1984 and then since it started declining reaching levels below 400 tons in 1993 (Figure 8). After 1993 the catch rose to 2 100 tons in 1995 and since then it has stabilised to around 1 500 tons/year. The trend of effort follows that of the catch while the catch rates indicate a down trend since the early 1980s. The Surplus Production Models did not fit the data as a result the precautionary approach principle was applied (Table 2). The stern bottom trawl fishery in the SEA currently operates at B_{pa} which calls for immediate action.

Midwater trawl fishery

The midwater fishery catches, which is also confined in the SEA were relatively stable between 1980 and 1992 and ranged between 1 500 and 2 200 (Figure 9). The total catch dropped to half in 1993 and has steadily increased since then. The catch rates trend was similar to that of the total catches. The total effort has been stable throughout except in 1997 (Figure 9). The Surplus Production Models did not fit the data as a result the precautionary approach principle was applied (Table 2). The stern bottom trawl fishery in the SEA currently operates above B_{pa} and hence no need for immediate action.

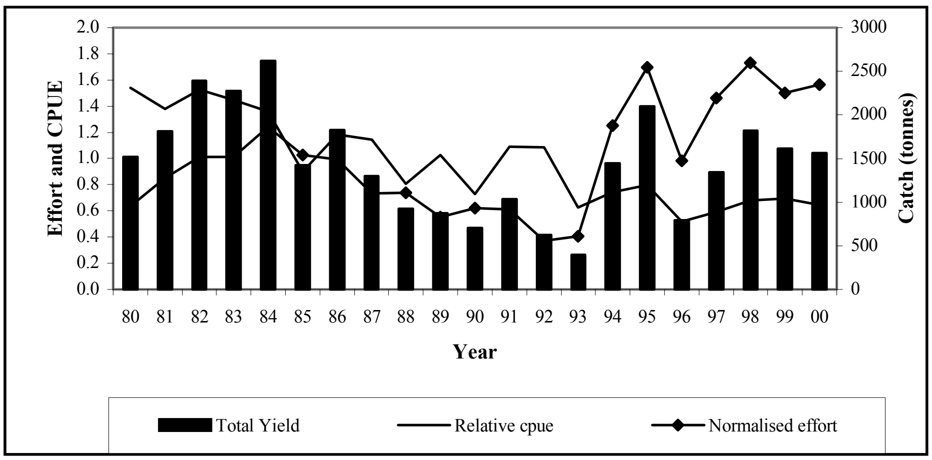


Figure 8. Catch, effort and CPUE in stern bottom trawl fishery in the south east arm of Lake Malawi from 1980 to 2000.

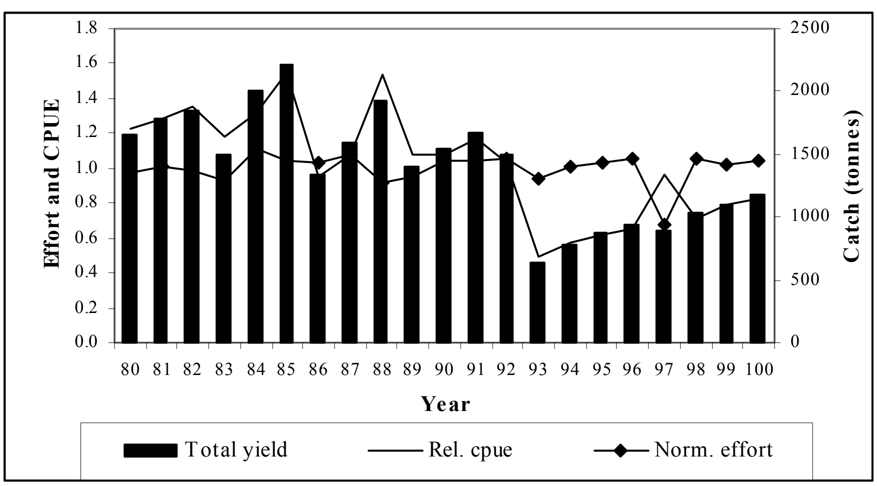


Figure 9. Catch, effort and CPUE in midwater trawl fishery in the south east arm of Lake Malawi from 1980 to 2000.

Ringet fishery

Unlike the other fisheries, the ringnet fishery targets chambo (*Oreochromis* spp.) south of Boadzulu Island in the SEA (Figure 10). The highest catches of chambo were manifested in 1983 and have declined steadily since then, reaching their lowest levels in 1997. From 1998 to 2000 there has been a slight increase in the catches. The total effort and catch rates have followed the pattern of the catch. Similarly, the Surplus Production Models did not fit the data as a result the precautionary approach principle was applied (Table 2). The ringnet fishery in the SEA currently operates at B_{pa} which calls for immediate management action.

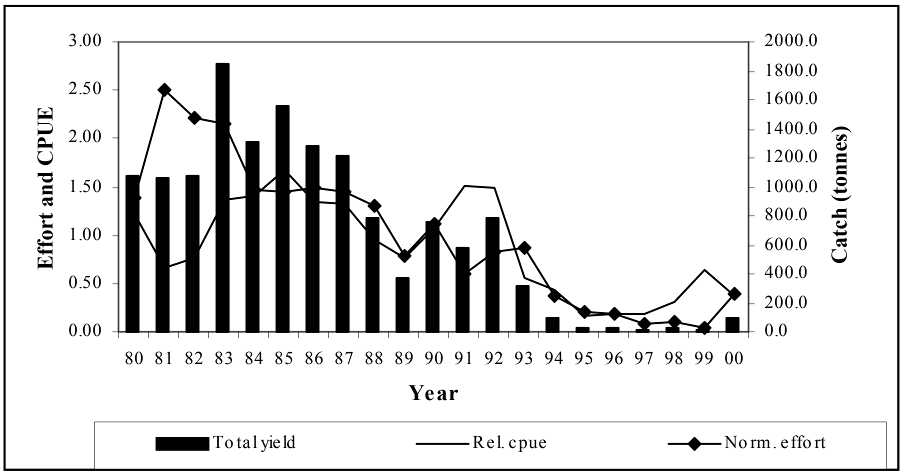


Figure 10. Catch, effort and CPUE in ringnet fishery in the south east arm of Lake Malawi from 1980 to 2000.

Discussion

Changes in species composition, cpue and catch contribution have been used as indicators of stock status for the commercial fisheries in Malawi (Turner, 1977; Banda, *et al.* 1996). In this case, declines of 75% of the cpue or more indicate overexploitation (Bulirani *et al.* 1999). The 75% reference point was however, determined arbitrarily.

Species composition, cpue and catch

No changes in species composition was noted during the survey period. The catch was dominated by small cichlid species such as *C. virginalis*, *C. eucinostomus*, *O. argyosoma* and a few large species such as *B. meridionalis*, *Bathyclarias* spp. and *Oreochromis* spp. which is consistent with the earlier studies (Banda *et al.* 1996;Turner *et al.* 1997). All the dominant species in this survey were dominant in both small- and large-scale fisheries (Manase 2000; Nyasulu, 2001). This is indicative of resource use overlap between the small- and large-scale fisheries. The Fisheries Conservation and Management Act 1997 regulations specify that different fisheries should operate in specific areas, time and depth to reduce conflicts. Therefore, this overlap can mainly be attributed to non-compliance of the regulations by fishers resulting in all different fishers operating in the same fishing grounds. Indeed large scale fisheries such as pair trawlers have been observed to fish in waters < 20 m in both arms. It has also been noted recently that *RV. Ndunduma* has damaged many gillnets during its fishing experimental surveys in waters depth of 50-60 m. The small-scale fishers set their 2 inch size gillnets during daytime to catch (Utaka) *Copadichromis virginalis* which is contrary to the law. The gillnets are supposed to be set between 6.00 p.m. and 6.00 a.m. The small scale fishers have also thrown stumps or nkokwe as fish aggregates in some trawlable grounds. The presence of the fishers waiting for their nets during daytime and stumps of trees makes trawling in these grounds difficult.

The standardised index of abundance which is assumed to be linearly proportional to exploitable biomass, indicate that the relative abundance has decreased between 23% and >80% since the early 1980s in various large-scale fisheries. The highest decrease was evident in the cambo fishery (> 80%) and the lowest in the pair trawl fishery (23%) in the SWA. Since the pattern of effort corresponds with the catch, the changes in catch rates can be attributed to changes in fishing effort especially for the pair trawl fishery in the SWA, demersal, chambo and midwater fisheries. The same argument applies to the pair trawl fishery in 1980's in the SEA but not between 1999 and 2000. The catches for the last two years were around 185 tons annually as opposed to the expected catch of 448 tonnes based on the B_{cur}. Therefore, the low catches were perhaps a result of other factors such as poor maintenance of the boats and inefficient fishing power of the engines. Currently, of the sixteen licensed pair trawl units only six are operational and their operational schedule is sporadic.

Biomass

The Surplus Production Models are fitted to catch and effort data with the assumption that the fishery is in equilibrium and catch rates decrease with increasing effort. There was no significant relation between cpue and effort in all large-scale commercial fisheries indicating that the models did not fit the data. The misfit was indicative that the fisheries are not in equilibrium perhaps because of frequent break down of fishing vessels and changes in fishing power, inaccuracy of catch and effort data submissions, fluctuations in stocks of dominant species such as *C. virginalis* and changes in species composition, mesh size, areas fished and depth.

A comparison of the estimated MSY (Table 1) and the present catch landings (~ 180 and 440 t in the SEA and SWA, respectively for pair trawl fishery, 1570 t for stern trawl) show that the pair trawl and stern bottom trawl fisheries are operating below the MSY which means that there is no need for management recommendation. The fisheries resources of the SWA deep water (> 50 m) remain untapped because of the non-existence of the fishing activities in the area. A comparison of the estimated MSY and the actual landings by the pair trawlers however, need to be taken with caution because of differences in fishing powers. The *RV. Ndunduma* fishing power needs to be calibrated in relation to the pair trawlers.

Unlike the swept area method, which can be applied only to the bottom trawl fisheries, the precautionary approach application is cross-cutting. The adoption of the precautionary approach indicates that there is currently no need for management recommendations for the pair trawl and mid water fishery but there is a need to consider reduction in effort of the stern bottom trawl and ring net. The recommendation of reduction in effort for the stern bottom trawl using the precautionary approach contradicts with that by the swept area method. This may be attributed to the fact that the cpue for the stern bottom trawl fishery does not represent mean Figure for the entire area because the fishery tends to be localised i.e. effort is not wide spread covering the entire area (Banda *et al.* 1996).

In view of the above it is clear that there is competition among small and large scale fishers over various stocks such as *Copadichromis virginalis*, *Oreochromis* spp. *Bagrus meridionalis* etc. The pair trawl and midwater trawl fishery are not fully exploited. The pair trawl fishery needs rehabilitation for it to reach its maximum potential production while there is room for expansion for the midwater trawl fishery. The stern trawl fishery is currently fully exploited whereas the Chambo fishery is overexploited.

Management

The conventional management techniques for the sustainable utilisation for the commercial fisheries resources have been included in the Fisheries Conversation and Management Act 1997 and regulations include a limited number of licenses in demarcated areas, trawling in specific areas, time and depth and a minimum codend mesh size of 38 mm. The management of this fishery has been emphasized mainly by effort control and fishing area. However, the fishers have followed none of these regulations and this has been exacerbated by ineffective enforcement. All recommended licenses have been issued but very few are operational especially the pair trawl fishers. This is attributed to lack of capital for new licences and poor business management. Some people have had licenses for a very long time and have never fished. Equally, some fishers in the industry have failed to maintain their fishing fleet, which has led them to stop fishing. The factors have led to the reduction in fishing effort and decreased catching efficiencies of the fishing vessels. Of the eight and twelve licences allocated to the shallow waters of the SEA and SWA, respectively, only two are operational in each area. In contrast, the stern trawlers performance is better than that of the pair trawlers. All the existing stern trawlers are operational although they are fishing in the same areas of the SEA. Four licenses are recommended for this area but six are fishing there.).

Despite the fact that each fishing vessel is licensed to fish in a specific area and depth range, pair trawlers usually fish in shallow of less than 6 and 20 m while stern trawlers start fishing in depth > 30 m. Some fishers have never fished in areas according to their licences and yet, the returns still indicate operation in the licenced area. One stern trawl is licensed for the deep waters of the SWA but fishes in the SEA. Experiments on gear selectivity indicate that clogging of the 38 mm mesh size happens within the first 10 minutes of trawling while that of the 50 mm mesh size in 15 minutes (Kanyerere, 2000). Consequently, the present recommended mesh size at the codend has been ineffective.

In view of the above, there is a need for effective enforcement of fisheries regulations to reduce the conflict amongst different fishers and if effort is to be reduced. The control of the large-scale fisheries should be feasible because they are small and confined to a relatively small area. However, there is also an urgent need for detailed studies on stock identification and identification of resources overlaps between the small-scale and large- scale fisheries.

Acknowledgements

Thanks to the staff of Malawi Fisheries Research Institute especially to Technical Assistants for commercial data compilation.

References

Banda, M.C. 2000. The biology and ecology of the catfishes of the Genera *Bathyclarias* and *Bagrus* in Lake Malawi. PhD. Thesis. University of Zimbabwe. 188pp.

Banda, M.C. and T. Tomasson. 1997. Demersal fish stocks in southern Lake Malawi: Stock assessment and exploitation. Government of Malawi, Department of Fisheries. Fisheries Bulletin No.35.

Banda, M.C., Tomasson, T. and Tweddle, D. 1996. Assessment of the deep water trawl fisheries of the south east arm of Lake Malawi using exploratory surveys and commercial data. In: Stock Assessment in Inland Fisheries. Cowx, I.G. (Ed.). Oxford: Fishing News Books, pp. 53-75.

Bulirani, A., M.C. Banda, O.K. Palsson, O.L.F. Weyl, G.Z. Kanyerere, M.M. Manase and R.D. Sipawe 1999. Fish stocks and fisheries of Malawian waters: Resource report. Government of Malawi, Department of Fisheries, Fisheries Research Unit. 54 pp.

FAO, 1993. Fisheries management in the south east arm of Lake Malawi, the Upper Shire River and Lake Malombe, with particular reference to the fisheries on chambo (*Oreochromis* spp.). FAO, Rome, CIFA Technical Paper, 21, 1-113.

FAO, 1976. Promotion of intergrated fishery development, Malawi. Analysis of the various fisheries of Lake Malawi. FAO, FI:DP/MLW/77/516. Technical report 1.

Kanyerere, G.Z. 1999. Trawl selectivity and the effect of clogging on selectivity in standard trawl surveys in Lake Malawi. . Government of Malawi, Department of Fisheries. Fisheries Bulletin No. 39.

Manase, M. 2000. Traditional gear selectivity. (in press).

Nyasulu, T.E. 2001. Resource use overlaps between pair-trawl and small-scale fisheries in the south east arm of Lake Malawi: preliminary results (Proceedings of this symposium).

Palsson, O.K., M.C. Banda and A. Bulirani. 1999. Review of demersal monitoring surveys in southern Lake Malawi. Government of Malawi, Department of Fisheries. Fisheries Bulletin No.40.

Pitcher, T.J. and Hart, P.J.B. 1982. Fisheries ecology. Croom Helm, Beckenham, 414 pp.

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

Sipawe, R. 2001. Gear and species selectivity of the gillnet fishery in Lake Malawi. (Proceedings of this symposium).

Tarbit, J. 1972. Lake Malawi trawling survey – Interim report 1969-1971. Malawi Fisheries Bulletin , (2), 16 pp.

Turner, J. L. 1977. Some effects of demersal trawling in Lake Malawi (lake Nyasa) from `968 to 1974. Journal of Fish Biology, 10, 261-71.

Turner, G.F. 1995. Management conservation and species changes of exploited fish stocks in Lake Malawi. In: The Impact of the Species in African Lakes. Eds. Pitcher, T.J. and Hart, P.J.B. Chapman & Hall, London.

Turner, G.F., Tweddle , D. and Makwinja, R.D. 1995. Changes in demersal cichlid communities as a result of trawling in southern Lake Malawi. In: The Impact of the Species in African Lakes. Eds. Pitcher, T.J. and Hart, P.J.B. Chapman & Hall, London.

Spatial and temporal distribution of some commercially important fish species in the southeast arm of Lake Malawi: A Geostatistical Analysis.

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Abstract
The spatial and temporal distribution of the following fish species; *Alticorpus mentale*, *Buccochromis lepturus, Copadichromis virginalis, Diplotaxodon elongate,* and *Oreochromis* spp. in the southeast arm of Lake Malawi were analysed using bottom trawl catch per unit effort (CPUE) data collected during the annual demersal monitoring surveys of 1995 and 1999. Geostatistical techniques were used to model and estimate the spatial structure of abundance and ordinary kriging was used to predict local abundance. Small-scale intra-area variation that was detected was used to model the spatial structure. Experimental variograms were calculated and fitted using the spherical variogram model. Generally the structure of the variograms varied with population density. The results indicate that *A. mentale* occurs mainly in deep waters of Area C with density increasing slightly over the past four years from 13 kg nm^{-2} in 1995 to 15 kg nm^{-2} in 1999. However its distribution has shrunk especially in Area B over the same period. *C. virginalis* principally occurs along the inshore waters of southeast arm especially in Area C off Makanjila and in Area B off Masasa and Nkhudzi Bay on the western shore and off Kadango on the eastern shore. The species has declined in abundance in Area C. Density has decreased from 1,100 kg nm^{-2} in 1995 to 680 kg nm^{-2} in 1999. *D. elongate* is distributed widely occurring in offshore waters of southeast arm from Area A to Area C in relatively high densities. The species occurs in highest densities in Area B, the distribution in Area C is not as wide as it used to be. The density has declined from 20,000 kg nm^{-2} in 1995 to 14,000 kg nm^{-2} in 1999. *Oreochromis* spp. occur mainly in Area A and to a smaller extent in shallow inshore waters of Area B. Over the past four years there has been a marked decrease in the distribution range with a corresponding decline in density from 319 kg nm^{-2} to 26 kg nm^{-2} in 1999. *B. lepturus* is evenly distributed in shallow waters of the southeast arm. The 1999 distribution pattern indicates that the species has slightly declined in abundance in the northeastern part of Area C and Area A. However density has increased from 37 kg nm^{-2} in 1995 to 222 kg nm^{-2} in 1999. Although sampling was not originally designed specifically for geostatistics, these results indicate that geostatistics can be successfully used to detect changes in the spatial and temporal distribution of fish stocks or species in lake Malawi using the existing data.

Introduction
Lake Malawi, situated in the African rift valley between 9°30"S and 14°30"S and bordered by Malawi, Mozambique and Tanzania, is the third largest lake in Africa with an average depth of 292 m. The shallow Areas are the most productive and are found in the southeast and southwest arms of the lake (Patterson & Kachinjika, 1995).

The fisheries on Lake Malawi are mainly distinguished by their degree of mechanisation and are classified into traditional and commercial components. The commercial fisheries which are relatively mechanised and capital intensive are dominated by stern and pair trawlers (Banda & Tomasson, 1996). Of all the fishing gears, bottom trawl nets are the most important. Pelagic trawl nets and pulse seine nets are seldom used.

The commercial fishery was established in 1968 after successful experimental trials revealed the existence of large demersal stocks in the southern portion of the lake (Turner, 1976). All commercial fishing now occurs in the southern part of the lake.

As the trawl fishery intensified, large changes in species composition were observed. Large cichlid species mostly belonging to the genus *Lethrinops,* clariid catfishes and *Bagrus meridionalis* have declined in abundance. This decline was followed by a corresponding increase in small cichlids most of which were *Otopharynx* spp. and *Pseudotropheus* spp. (Turner, 1976). Several follow-up projects like the "Demersal Fisheries Re-assessment Project (1989-1994)" were initiated in 1991 and one of the main findings of this project was that there was a 50-70% decline in biomass estimates in Areas A, B and C (Figure 1). Some changes in species composition were also noted, particularly in Area B where the relative contribution of some of the larger cichlid species to the catch had decreased (Turner *et al*, 1995).

In view of these developments, the government of Malawi through the Department of Fisheries introduced standardised demersal surveys in 1994 to monitor the status of the stocks in the two arms of the lake. These surveys were initially conducted on quarterly basis but due to logistical problems and lack of adequate funding the frequency was reduced to two surveys a year. Recent information from these surveys and other sources indicate that the chambo (*Oreochromis* spp.) stocks in Lake Malawi have declined to the lowest level ever and as such it was proposed that all gears targeting Chambo be banned in Area A (Bulirani *et al*, 1999). Declining catch per unit effort

(CPUE) is also observed for the stocks of bombe (*Bathyclarias* spp), kampango (*Bagrus meridionalis*) and utaka (*Copadichromis* spp.) but the fisheries for usipa (*Engraulicypris sardella*) and kambuzi (small non-catfish spp.) have remained relatively stable. The findings also indicate that despite the decline of some individual stocks, the overall CPUE for the deep-water stocks has remained relatively stable (Bulirani *et al*, 1999).

The fact that the overall CPUE has remained relatively stable, despite the decline in CPUE of the large species suggests that the small species are gradually increasing in abundance at the expense of the larger ones. Unfortunately these small species fetch low market prices. Due to low catch rates of commercially important species and the increasing abundance of small species, most trawlers and other fishermen have resorted to targeting specific Areas in the lake where most of the species are caught in reasonable quantities. At present, the species that are highly sought after are chambo (*Oreochromis* spp.), utaka (*Copadichromis* spp.), ndunduma (*Diplotaxodon* spp.), ncheni (*Rhamphochromis* spp.), kampango (*Bagrus* spp.) and bombe (*Bathyclarias* spp).

Concentrating fishing effort on a particular stock can have serious management implications especially in cases where the stock involved is localised and has a low fecundity. For instance, most mouth brooders produce relatively few offspring because of limited brooding space. Most of the Malawi cichlids fall into this category. In situations of intense fishing pressure and the use of small-meshed gears, chances of such stocks being depleted are high. At this point, it is worth noting that the 38 mm cod-end currently in use on the Lake Malawi trawl fishery is too small, and most of the demersal species being caught are immature (Kanyerere, 1999). Such factors have undoubtedly contributed to the depletion of stocks in the lake.

The decline of some stocks within the southern portion of the lake suggests that the fishery is already facing serious problems, which might include intense and localised fishing pressure, growth over-fishing and recruitment failure. It is imperative that regulatory management procedures such as closed seasons and aggregate quotas, controlled Area fishing and restrictions on fishing gears and technology be instituted where necessary. However, identification and formulation of such regulations require that;

i) Areas or localities where significant reduction in CPUE and species abundance has occurred be identified.
ii) those Areas where commercially important species are found and what changes the species might have undergone be identified.
iii) temporal changes of abundance for species with wide distributions and those with localised distributions in relation to Area, depth and time be assessed.
iv) maps of species abundance by Area, depth and time be produced.

The spatial and temporal distribution of commercial species needs to be assessed over a suitable time period. This can only be accomplished through the use of geostatistics as no traditional method is suitable for such assessments. Geostatistics takes the spatial autocorrelation between samples into consideration and through kriging, allows the analysis and modelling of the variability of a population in space (Freire 1992). Ignoring spatial patterns when using catch per unit effort (CPUE) data to estimate stock abundance can sometimes lead to inaccurate assessments (Pelletier and Parna, 1994). As geostatistics is a relatively new technique to the Malawian fisheries, this study is preliminary and will investigate the feasibility of using geostatistics:

- to model the abundance, spatial and temporal distribution of *Alticorpus mentale, Buccochromis lepturus, Copadichromis virginalis, Diplotaxodon elongate* and *Oreochromis* spp. and
- to assess if the existing sampling locations meet the requirements of geostatistical analysis.

Materials and Methods

Sampling sites

The data were collected onboard the research vessel, *R.V. Ndunduma* using demersal trawl gear. A total of 54 and 43 fixed stations are sampled bi-annually in the southeast and southwest arms of Lake Malawi respectively (Figure 2). The southeast arm is divided into Areas A, B and C and the southwest arm into Areas D, E and F for management purposes (Figure1). A Global Position System (GPS) was used for fixing the position of shooting and hauling for each station, with each trawl lasting 30 minutes.

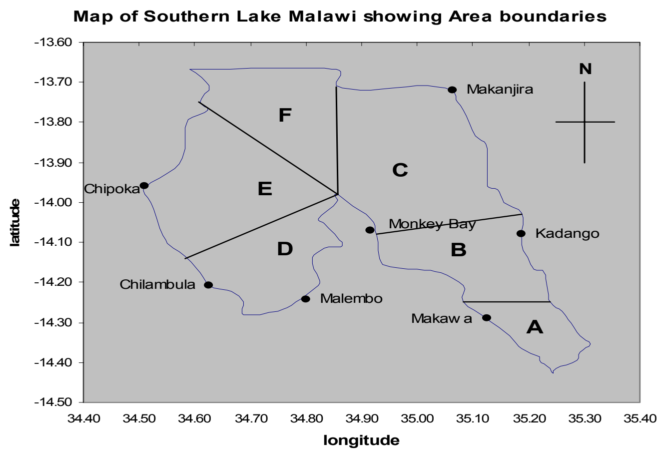

Figure 1. Area boundaries for both southeast and southwest arms of Lake Malawi.

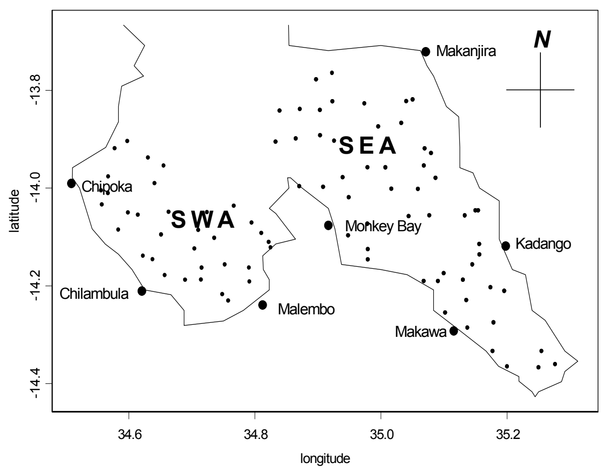

Figure 2. Map of southern Lake Malawi showing sampling stations in southeast (SEA) and southwest (SWA) arms.

Data Collection

All trawling was conducted during the day (between 6 am and 5 pm) and for each station depth (m), trawling speed, actual time trawled and position at start and end of each haul (latitude and longitude) were recorded. A total of 8 surveys covering the southeast and southwest arms of lake Malawi have been conducted between 1995 and 1999. Data for only 1995 and 1999 was, however, used in this analysis.

The sampling and recording of the catch closely followed guidelines outlined by Sparre *et al*, (1989). All catfish of the genera *Bathyclarias, Clarias* and *Bagrus* as well as extremely large cichlid and non-cichlid species were sorted out of the main catch. Thereafter the catch was sub-sampled; the fraction of which depended on the quantity of catch landed. The catch was then divided on deck into four categories namely; small fish (mainly cichlids but also including *Synodontis njassae*), *Bagrus meridionalis*, Clariid catfishes and all large cichlid and non-cichlid fishes. Each category was sorted into species, length measured to the nearest half centimetre and weighed.

Data analysis

Geometric mean

From the trawl data, estimates of the percentage composition and CPUE for *A. mentale, B. lepturus, C. virginalis D. elongate and Oreochromis* spp. were obtained. The geometric mean (GM) was used to calculate mean CPUE. This estimation was chosen over the arithmetic mean because preliminary analysis showed that the data had an asymmetric right-skewed distribution. It was therefore assumed that abundance was also log-normally distributed. The GM was obtained by calculating the mean across stations of the log-transformed values and back transforming (Rosner, 1995) such that;

$$GM = 10^{\frac{1}{n}\sum_{s=1}^{n}\log\left(CPUE_S+1\right)} - 1$$

where $CPUE_s$ is the catch per unit effort of station *s*.

Geostatistical analysis

The abundance of a species measured at fixed locations in a lake or ocean is known as random field data and such data is suitable for geostatistical analysis. Geostatistical data often exhibit small-scale variation that may be modelled as spatial correlation and incorporated into estimation procedures. Spatial variability is modelled as a function of the distance between the sampling sites, where the sites closer together in space have more similar data values than those that are far apart. The variogram provides a measure of such correlation by describing how sample data are related with distance and direction (Kaluzny *et al*, 1998).

Exploratory data analysis

In two-dimensional space, a sampling location is defined by a longitude and latitude position. In order to successfully model an underlying random spatial process it must be assumed that:

i) the observation and the spatial process differ only through white-noise measurement error and that

ii) the spatial distribution of the species in question was stable throughout the survey period so that all CPUE observations reflect the same underlying spatial process (Pelletier and Parma, 1994).

Although fish movement might make the second assumption difficult to satisfy, Lake Malawi fishes are typically resident and therefore, at a broader spatial scale, their distribution can be considered relatively stable. The spatial process in geostatistical data can be decomposed into a large-scale deterministic component and a small-scale stochastic component with the random field in this case not having a constant mean. As the existence of the variogram is based on a process with a constant mean and variance defined only through the magnitude of distance**,** then a variogram based on a random field with both large-scale trend and small-scale random variation will not meet the necessary assumption (Kaluzny *et al*, 1994). This implies that the first step in geostatistical data analysis is the detection and removal of trend from the data before using the variogram to estimate the underlying random process.

Detecting and removing spatial trends

Procedures used in this study for purposes of detecting and removing trend from data are those outlined in Kaluzny *et al* (1998). They include:

i) rotation of the longitude and latitude axes to assess spatial invariance.
ii) modelling the logged data as a smooth function of the longitude and latitude using a generalised additive model (GAM) and
iii) fitting a local regression model (loess) to the whole trend surface.

Residuals from this model are later on used to form kriging predictions.

Trend in the southeast arm

In the southeast arm the major trend was generally from south east to northwest. The angle of rotation was positive and therefore towards the north (90°) and ranged between 16° and 45°.

Analysis

The empirical variogram provides a description of how the data are correlated with distance. The semi-variogram function, γ(h), is defined as half the average squared difference between points separated by a distance h (Kaluzny et al, 1998) and is described as:

$$\gamma(h) = \frac{1}{2|N(h)|}\sum_{N(h)}\left(z_i - z_j\right)^2$$

where $N(h)$ is the set of all pairwise Eucledian distances $h = i - j$, $|N(h)|$ is the number of distinct pairs in $N(h)$, and z_i and z_j are data values at spatial locations i and j, respectively. The letter h represents a distance measure with magnitude only but when direction is also considered, it becomes a vector h˜ (Kaluzny *et al*, 1998).

A variogram has at least three parameters namely the nugget effect, sill and range. The nugget effect represents micro-scale variation or measurement error and is estimated from the empirical variogram as the value of $\gamma(h)$ for $h = 0$. The sill is the variance of the random field while the range is the distance (if any) at which data are no longer autocorrelated.

Additional parameters used in this study to customise the variograms were the maximum distance over which the variogram is calculated, minimum number of pairs used for calculating the variogram of which 30 is the minimum, lag and number of lags. The variograms were estimated using the robust variogram estimation method as it has the advantage of reducing the effect of outliers without removing specific data points from a data set (Kaluzny *et al*, 1998). The robust estimation method is based on the fourth power of the square root of absolute differences as follows:

$$\bar{\gamma}(h) = \frac{\left\{\frac{1}{2|N(h)|}\sum N(h)^{|z_i - z_i|^{1/2}}\right\}^4}{0.457 + 0.944/|N(h)|}$$

Modeling the Empirical Variogram

Anisotropy occurs when the spatial autocorrelation of a process changes with direction. A variogram from an anisotropic process is not purely a function of the distance h, but is a function of both the magnitude and direction of h˜ (Kaluzny *et al*, 1998). An anisotropic variogram is geometrically anisotropic if:

$$2\gamma(h) = 2\gamma^{o}(||\boldsymbol{A}h||), \quad h \in \Re^d$$

where $\boldsymbol{A}$ is a d x d matrix and $2\gamma^{0}$ is a function of a real variable.

In this situation, the Eucledian space is not appropriate for measuring distance between locations, but a linear transformation of it is (Cressie, 1993). Since variograms are only valid for an isotropic process, anisotropy has to be corrected before fitting a theoretical model to the empirical one. In this study geometric anisotropy (range of the variogram changing in different directions, while sill remains constant) was identified by using directional variograms and was subsequently corrected by a linear transformation of the lag vector h˜.

After estimating the parameters of the empirical variogram, a theoretical model is then fitted to it. This is necessary because it ensures that the variance of predicted values is positive. This study makes use of the spherical model. Other models tested besides the spherical were exponential, gaussian, linear and power. Its choice was mainly based on the observation that it was the one that fitted well with the shape of the empirical variogram. Besides this, Freire *et al* (1992) state that the spherical model is the most common in the analysis of animal populations and geostatistics in general. According to Cressie, (1993) the spherical model has the form:

$$\gamma(h;\theta) = \begin{cases} 0, & h = 0 \\ C_O + C_S\{(3/2)(\|h\|/a_s) - (1/2)(\|h\|/a_s)^3\}, & 0 < \|h\| \le a_s, \\ C_O + C_S & \|h\| \ge a_s \end{cases}$$

where θ = ($\mathbf{c_o}$,$\mathbf{c_s}$,$\mathbf{a_s}$)', $\mathbf{c_o} \ge 0$, $\mathbf{c_s} \ge 0$, $\mathbf{a}_s \ge 0$ and C_0 is the nugget effect, due to the variability between samples, the microstructure which remains undetected because of the size of the sample, or errors in measurement or location. C_s represents the sill-nugget effect, where the sill is the asymptotic value of semivariance, reached with a value of $h = a$, the range, which represents the maximum distance at which spatial effects are detected.

The spherical model was fitted to the empirical variogram by minimising the residual sum of squares between the theoretical model and the empirical variogram using the weighted least-squares estimation as follows:

$$\sum_{j=1}^{K} |N(h(j))| \left\{ \frac{\overline{\gamma}(h(j))}{\gamma(h(j);\theta)} - 1 \right\}^2$$

where K is the number of lags, θ = (c_o,c,a), $\gamma(h(j))$ = spherical variogram model and $\overline{\gamma}(h(j))$ = empirical variogram.

A summary of variogram parameters that were used in this analysis is displayed in Table 4. The prediction process also requires the values that are used for correcting anisotropy in addition to the range, sill, and nugget. Parameters used for correcting geometric anisotropy in this study were angle and ratio. The ratio ranged from 1.25 to 2 while the angle ranged from 45^o to 180^o. These were different for each species and year.

Spatial prediction using kriging

Kriging is a linear interpolation method that allows predictions of unknown values of a random function from observations at known locations. Kriging incorporates a model of the covariance of the random function when calculating predictions of the unknown values. There are two categories of kriging namely universal and ordinary (Kaluzny *et al*, 1998). Ordinary kriging uses a random function model of spatial correlation to calculate a weighted linear combination of available samples, for prediction of abundance and standard errors for unsampled locations. Weights for this model are chosen to ensure that the average error for the model is zero and that the modelled error variance is minimised.

In this analysis, ordinary kriging was used to predict the value of the spatial process S(x) for every location $\boldsymbol{x}$ (latitude, longitude) in the Area, from a linear combination of the observed values {Z(x_i), i = 1,…,g}. Based on the assumption that Z(x) and S(x) differ only through measurement error (Pelletier and Parma, 1994), it is possible to model the spatial covariance of Z(x) directly instead of that of S(x). Ordinary kriging requires the stationarity of the first differences of Z(x) as demanded by the intrinsic hypothesis of Matheron (Cressie, 1993) such that:

$E(Z(x + \tilde{h}) - Z(x)) = 0,$

$V(Z(x + \tilde{h}) - Z(x)) = 2\gamma(h)$

where $\tilde{h}$ is a vector of length $h = |h|$. The first equation means that Z(x) has the same expected value over the whole Area regardless of location. In ordinary kriging, this value is assumed to be unknown. In the second equation, the variance of the difference is a function of $\tilde{h}$ only. If second-order stationarity is assumed (as is usual for kriging) such that:

$Cov(Z(x + h), Z(x)) = C(h),$

the covariance between two points is only a function of their relative position, the semivariogram can then be expressed in terms of the spatial covariance as:

$\gamma(h) = \delta^2 - C(h)$

where the sill δ^2 is the variance of Z(x) in the model (Pelletier and Parma, 1994).

Thus the spatial correlation structure of Z(x) is characterised by the variogram, $\gamma(h)$. The kriging variable was the residuals from the spatial loess model, while spatial locations were the rotated coordinates. The spatial correlation was modelled as spherical covariance based on the spherical variogram model fitted to the empirical variogram. The sill used was specified as the sill minus the nugget effect.

Results

Observed CPUE and catch composition

Presented in Table 2 is a summary of CPUE for all five species.

Table 2. CPUE (kg. $0.5hr^{-1}$) for each of the species in southeast arm of lake Malawi for 1995 and 1999.

	South East Arm (CPUE- kg 0.5 hr^{-1})	
Species	**1995**	**1999**
A. mentale	0.93	1.00
C. virginalis	7.79	2.18
Oreochromis spp.	1.58	0.59
B. lepturus	0.54	0.61
D. elongate	2.65	4.65

In Table 3 is a summary of the percentage composition for each species presented separately for each Area.

Table 3. Percentage composition in the total catch for each of the species in southeast arm of lake Malawi.

	A		B		C	
Species	**1995**	**1999**	**1995**	**1999**	**1995**	**1999**
A. mentale	0.00	0.00	0.06	0.20	1.55	2.1
C. virginalis	0.10	15.26	30.87	14.50	28.74	0.91
D. elongate	0.32	4.28	7.01	21.46	1.48	8.80
Oreochromis spp.	31.22	11.78	0.51	0.29	0.02	0.00
B. lepturus	0.10	0.41	0.36	0.48	0.24	0.53

Variograms

Table 4 presents summaries of variogram parameters for both the southeast and southwest arms of lake Malawi respectively.

Table 4. Variogram parameters for species analysed from the southeast arm of lake Malawi for 1995 and 1999.

	Southeast Arm -1995			Southeast Arm - 1999		
Species	**Nugget**	**Sill**	**Range**	**Nugget**	**Sill**	**Range**
A. mentale	0.005	0.33	0.19	0.005	0.36	0.28
C. virginalis	0.005	5.2	0.18	0.005	0.75	0.2
Oreochromis spp.	0.005	0.21	0.2	0.005	0.04	0.22
B. lepturus	0.005	0.13	0.36	0.005	0.19	0.3
D. elongate	0.005	2.35	0.18	0.005	2.8	0.19

Table 5. Changes in density for each of the species in southeast arm of lake Malawi for 1995 and 1999.

	Density (kilogrammes/nm^{-2})	
Species	**1995**	**1999**
A. mentale	13	15
C. virginalis	1100	680
Oreochromis spp.	319	26
B. lepturus	37	222
D. elongate	20000	14000

Results presented correspond to isotropic variograms.

A Mentale

A. mentale attains a maximum size of about 25 cm total length (TL) and attains maturity at a relatively large size. It occurs in water depths of between 60 and 128 m (Turner, 1996). It is of significance to deep water bottom trawling where it contributes about 2% to the total catch (Table 3).

The 1995 and 1999 variograms for *A. mentale* differ (Figure 3, Table 4). The range at which the data is no longer spatially correlated is higher for 1999 (0.28 nm) than for 1995 (0.19 nm) suggesting that a change in the distribution pattern of the species has occurred. The sill value for 1995 (0.33) is lower than that of 1999 (0.36) suggesting that there was more variance in the random field in 1999 than in 1995. Both observations indicate that a change in the density and distribution pattern of the species has occurred over the past four years.

The distribution maps in Figure 4 indicate that *A. mentale* occurs mainly in the deep waters of Area C and the distribution seems to have generally shrunk over the past four years as indicated by the 1999 distribution map. However density has slightly increased from 13 kg nm^{-2} in 1995 to 15 kg nm^{-2} in 1999 (Table 5). This agrees with the observed increase in percentage composition from 1.6% in 1995 to 2.1% (Table 3) and the increase in CPUE from 0.93 kg 0.5 hr^{-1}in 1995 to 1.00kg 0.5 hr^{-1}in 1999 (Table 2).

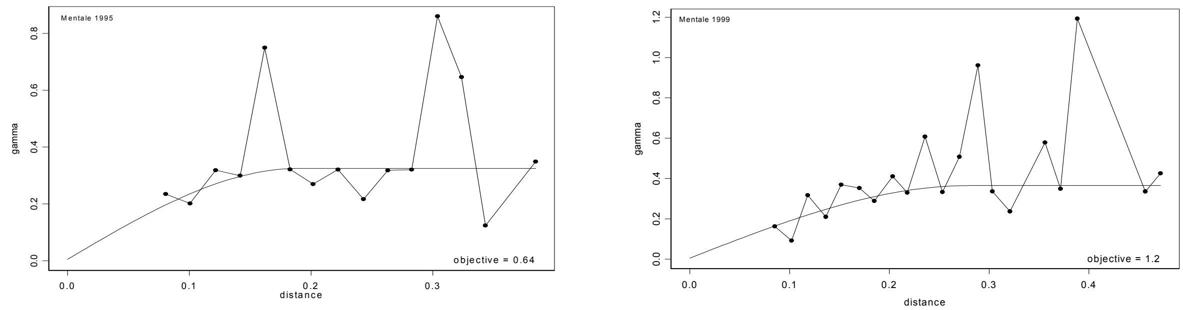

Figure 3. Variograms for *A. mentale* in the southeast arm of lake Malawi.

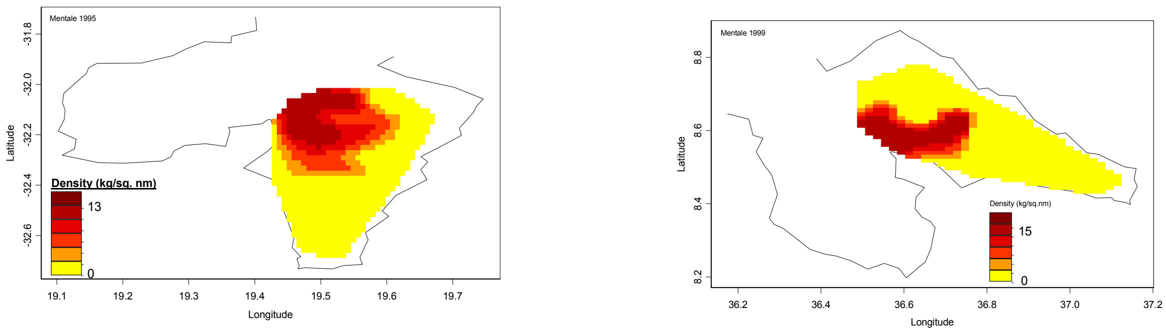

Figure 4. *A. mentale* abundance and distribution patterns during 1995 and 1999 in the southeast arm of Lake Malawi.

C. virginalis

C. virginalis is a small shoaling species that is very abundant on steep rocky coasts or submerged rock reefs of Lake Malawi. The species attains a maximum size of about 11-15 cm TL. It has been recorded at depths ranging from 9 m to 74 m. It is a very important species to a variety of mechanised and artisanal fisheries (Turner, 1996).

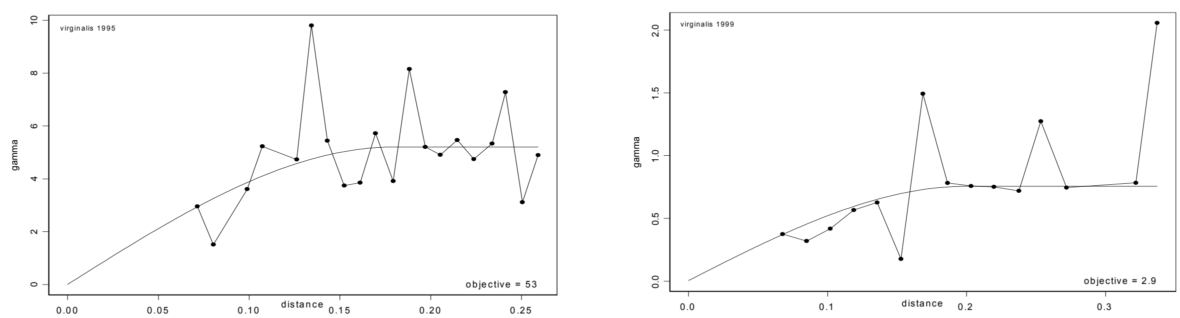

Figure 5. Variograms for *C. virginalis* in the southeast arm of lake Malawi.

The 1995 and 1999 variograms for *C. virginalis* differ (Figure 5, Table 4). The range at which the data is no longer spatially correlated is higher for 1999 (0.2 nm) than for 1995 (0.18 nm) suggesting that a change in the distribution pattern of the species has occurred. The sill value for 1995 (5.2) is much higher than that of 1999 (0.75) suggesting that there was more variance in the random field in 1995 than in 1999. Both observations indicate that a change in the density and distribution pattern of the species has occurred over the past four years.

The distribution maps in Figure 6 indicate that *C. virginalis* occurs in Areas A, B & C. However the distribution seems to have generally shrunk over the past four years especially in Areas B and C as observed from the 1999 distribution map. Density has decreased from 1100 kg nm^{-2} in 1995 to 680 kg nm^{-2} in 1999 (Table 5). This agrees with the observed decrease in percentage composition from 30.87% in 1995 to 14.5% in Area B and from 28.74% in 1995 to 0.91% in 1999 in Area C (Table 3). CPUE has likewise decreased from 7.79 kg 0.5 hr^{-1}in 1995 to 2.18 kg 0.5 hr^{-1} in 1999 (Table 2).

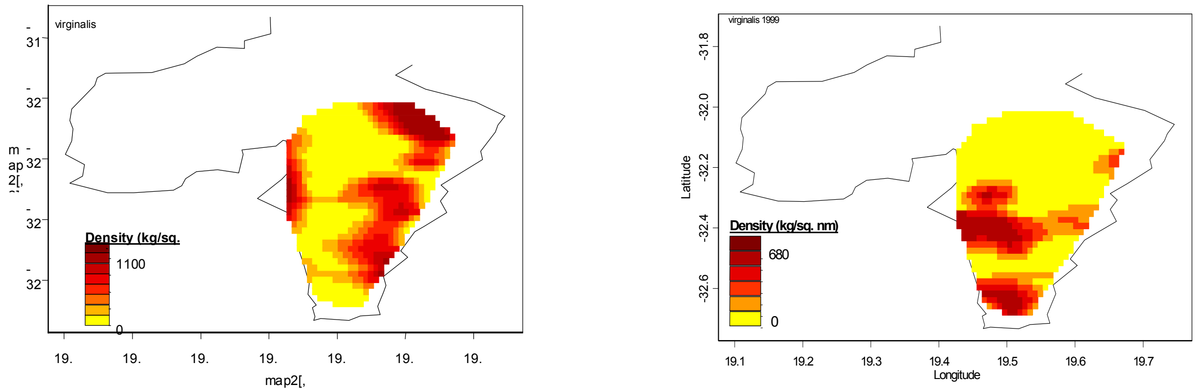

Figure 6: *C. virginalis* distribution pattern and abundance during 1995 and 1999.

Oreochromis spp.

In Lake Malawi, the genus *Oreochromis* is composed of four species of which three are endemic to the lake. The endemic ones are *O. squamipinnis* (37 cm TL), *O. karongae* (38 cm TL) and *O. lidole* (37 cm TL) while *O. shiranus* (37 cm TL) is the only non-endemic species (Turner, 1996). They occur mainly in shallow waters and have been recorded at depths ranging from 2 m to 50 m although they are most abundant at depths greater than 20 m (Palsson *et al,* 1999).

The 1995 and 1999 variograms for *Oreochromis* spp. differ (Figure7, Table 4). The range at which the data is no longer spatially correlated is slightly higher for 1999 (0.22 nm) than for 1995 (0.2 nm) suggesting that a change in the distribution pattern of the species has occurred. The sill value for 1995 (0.21) is much higher than that of 1999 (0.04) suggesting that there was more variance in the random field in 1995 than in 1999. Both observations indicate that a change in the density and distribution pattern of the species has occurred over the past four years.

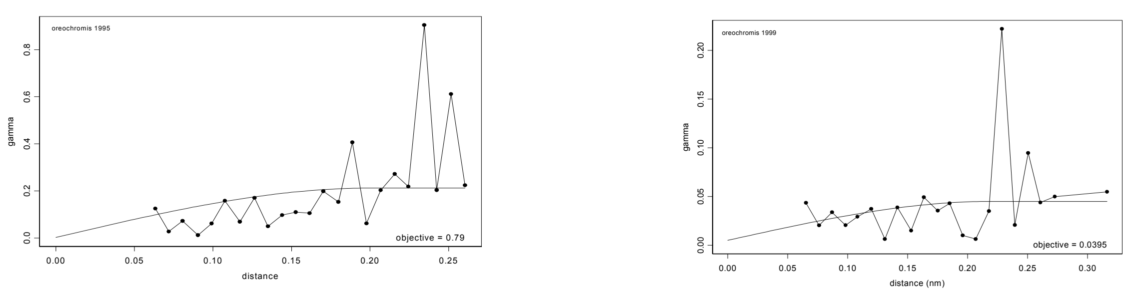

Figure 7. Variograms for *Oreochromis* spp in the southeast arm of Lake Malawi.

The distribution maps in Figure 8 indicate that *Oreochromis* spp. occurs mainly in Area A and parts of Area B. However the distribution has generally shrunk over the past four years especially in Areas A as observed from the 1999 distribution map. Density has likewise decreased from 319 kg nm^{-2} in 1995 to 26 kg nm^{-2} in 1999 (Table 5). This agrees with the observed decrease in percentage composition from 31.22% in 1995 to 11.78% in Area A and from 0.51% in 1995 to 0.29% in 1999 in Area B. CPUE also decreased from 1.58 kg 0.5hr^{-1} in 1995 to 0.59 kg 0.5 hr^{-1}in 1999.

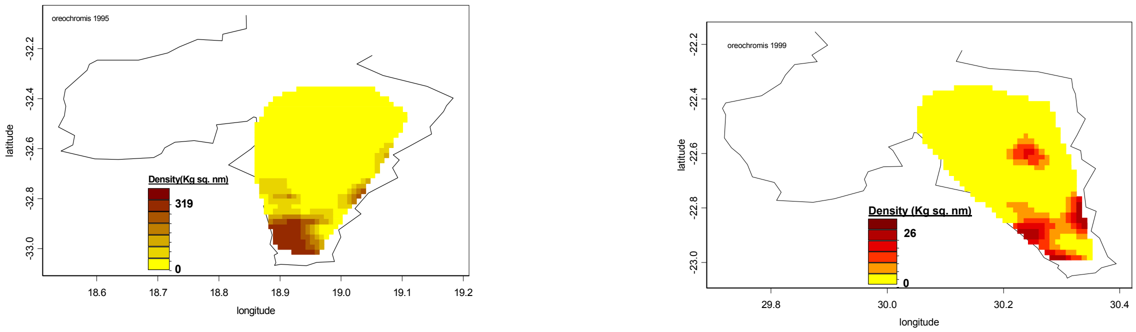

Figure 8. *Oreochromis* spp. abundance and distribution patterns during 1995 and 1999.

B. lepturus

B. lepturus like all other members of the genus is a large heavily-built species that attains a maximum total length of about 42 cm. It is a shallow water species, and has often been sampled from depths ranging from 10 to 26 m (Turner, 1996). It is probably one of the most delicious fishes of the lake although it is not found in large numbers.

The 1995 and 1999 variograms for *B. lepturus* differ (Figure 9, Table 4). The range at which the data is no longer spatially correlated is slightly higher for 1999 (0.22 nm) than for 1995 (0.2 nm) suggesting that a change in the distribution pattern of the species has occurred. The sill value for 1995 (0.21) is much higher than that of 1999 (0.04) suggesting that there was more variance in the random field in 1995 than in 1999. Both observations indicate that a change in the density and distribution pattern of the species has occurred over the past four years.

The distribution maps in Figure 10 indicate that *B. lepturus* occurs mainly in the shallow waters of Areas B and C. However the distribution has shrunk over the past four years in both Areas as observed from the 1999 distribution map.

Density has however increased from 37 kg nm^{-2} in 1995 to 222 kg nm^{-2} in 1999 (Table 5). This agrees with the observed increase in percentage composition from 0.36% in 1995 to 0.48% in 1999 in Area B and from 0.24% in 1995 to 0.53% in 1999 in Area C. CPUE also increased from 0.54 kg 0.5 hr^{-1} in 1995 to 0.61 kg 0.5 hr^{-1} in 1999.

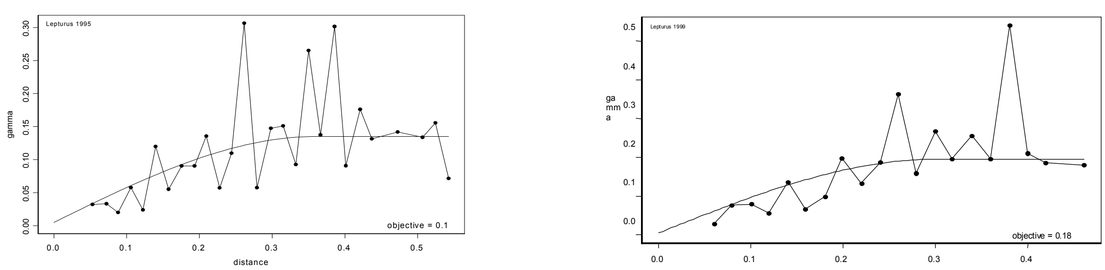

Figure 9. Variograms for *B. lepturus* in the southeast arm of lake Malawi.

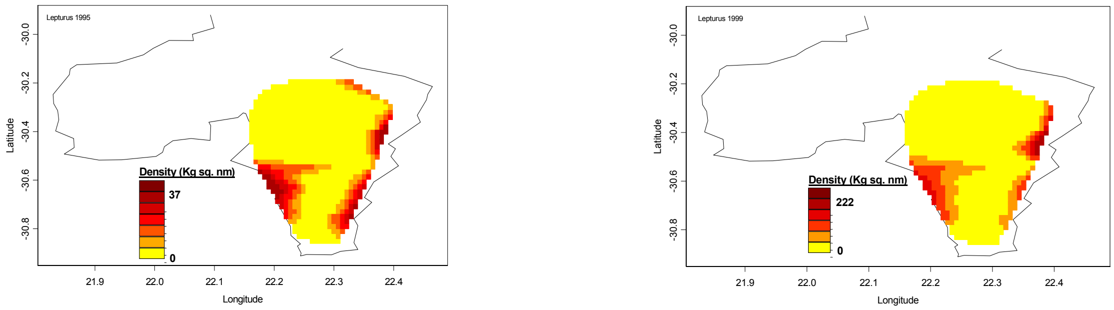

Figure 10. *B. lepturus* abundance and distribution patterns during 1995 and 1999 in the southeast arm of Lake Malawi.

D. elongate

Members of the genus *Diplotaxodon* belong to the "Ndunduma" group of fishes that are principally deep-water piscivores and zooplanktivores with upwardly angled mouths. *D. elongate* and its relatives are truly pelagic zooplankton feeders, which occupy the feeding niche of the "Utaka" (*Copadichromis*) in offshore waters. The species attains a total length (TL) of about 19 cm. It has been recorded throughout the pelagic zone of the lake from the surface to a depth of at least 220 m (Turner, 1996). Commercially, it is also an important species to both the commercial and artisanal fisheries.

The 1995 and 1999 variograms for *D. elongate* differ (Figure 11, Table 4). The range at which the data is no longer spatially correlated is slightly higher for 1999 (0.19 nm) than for 1995 (0.18 nm) suggesting that the distribution pattern of the species has not changed much. However the much higher sill value for 1999 (2.8) than that of 1995 (2.35) suggests that there was more variance in the random field in 1999 than in 1995. The increased variance in the random field indicates that a change in the density of the species has occurred over the past four years. The distribution maps in Figure 12 indicate that *D. elongate* occurs throughout the pelagic waters with highest concentration occurring in Area B.

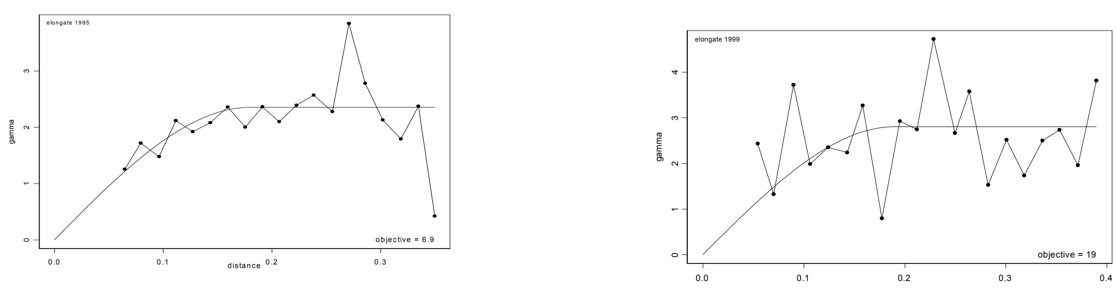

Figure 11. Variograms for *D. elongate* in the southeast arm of lake Malawi.

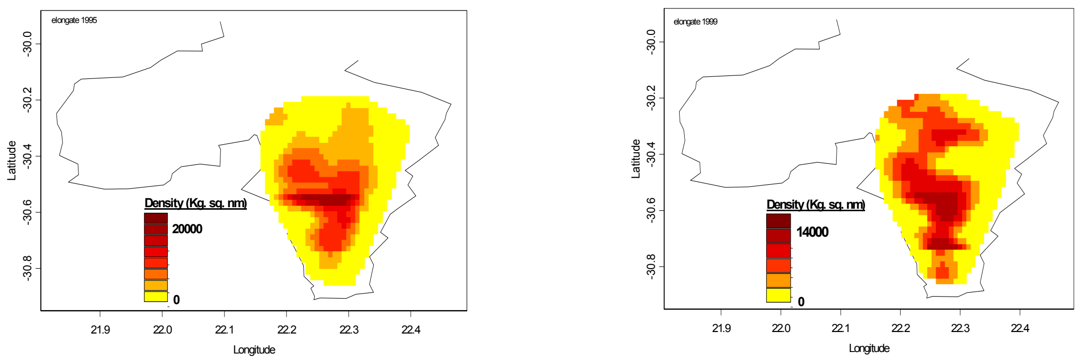

Figure 12. *D. elongate* abundance and distribution patterns during 1995 and 1999 in the southeast arm of lake Malawi.

As observed from the 1999 distribution map the species has disappeared in shallow waters of Areas B and C but has instead extended into Area A and deeper parts of Area C. This agrees with the increase in percentage composition from 0.32% in 1995 to 4.28% in 1999 in Area A, from 7.01% in 1995 to 21.46% in 1999 in Area B and from 1.48% in 1995 to 8.8% in 1999 in Area C (Table 3). This is also reflected in the overall increase in CPUE from 2.65 kg 0.5hr^{-1} in 1995 to 4.65 kg 0.5 hr^{-1}in 1999 (Table 2). Density has however decreased from 20000 kg nm^{-2} in 1995 to 14000 kg nm^{-2} in 1999 (Table 5).

Discussion

Stock assessment methods that disregard spatial distribution of species may provide inaccurate information pertinent to management. This is so because such methods usually assume that the existing density Areas or strata are internally homogeneous unless the sampling design is perfectly random (Freire *et al*, 1992). Having the ability to map abundance gradients and integrating them into space, geostatistics gives a more realistic view of a species distribution. This information can also be used to trace the spatial and temporal allocation of fishing effort for both effort-controlled and open-access fisheries.

All the five species assessed in this study show different distribution patterns. This is expected because distribution patterns are in most cases linked to food availability, water temperature, dissolved oxygen, bottom sediment type and other ecological factors such as presence or absence of aquatic vegetation and submerged rocky reefs. The distribution pattern can at times be highly influenced by human interference such as excessive exploitation that can bring about localised extinction of a species or group of species.

Alticorpus mentale

The results from this study indicate that *A. mentale* mainly occurs in deep waters of both the southwest and southeast arms. In southeast arm it mainly occurs in deep waters of Area C. It is however more abundant in southwest arm than in southeast arm. The restricted distribution range greatly endangers the continued existence of the species in the southeast arm because of high fishing pressure from deepwater demersal trawlers. However, the results from the same southeast arm indicate that the species has gradually increased in abundance over the period from 1995 to 1999 despite intense fishing pressure. This can only be attributed to the fact that because deepwater species have a poor market value, fishing pressure has over the years been redirected to high value shallow to medium water-depth (20-70m) species such as *C. virginalis, D. elongate* and *Oreochromis* spp. among others. The decline in the catch rates and distribution of species such as *C. virginalis, D. elongate* and *Oreochromis* spp. bears testimony to the redirection of fishing effort away from deep waters.

Copadichromis virginalis

This study has shown that *C. virginalis* occurs along the shores of the southeast arm especially in Area C off Makanjila, and in Area B off Masasa, Chirombo and Nkhudzi bay on the western shore and to a smaller extent on eastern shore just off Kadango fishing village (Figure 1). The results based on the 1999 data indicate that the species has greatly declined in abundance in Area C but there is instead a marked increase in abundance of the species in Area A.

The decline in the abundance of this species in Areas C and B can be attributed to the uncontrolled fishing pressure that is exerted on the species from both the artisanal, commercial and semi-commercial fisheries. Fishers along the shores of the southeast arm know exactly where to fish for this species resulting into localised declines in abundance within its preferred grounds while the abundance has increased in Areas that are less known to fishers. An example here is Area A.

Diplotaxodon elongate

The results from this survey indicate that *D. elongate* is a widely distributed species occurring in offshore waters of the southeast arm from Area A to Area C in relatively high densities. The species occurs in highest densities in Area B. As observed from the distribution pattern for both 1995 and 1999 respectively, the species has over the period 1995-1999 increased in abundance with much higher densities occurring in Area B and partly extending into the southern portion of Area C. However its distribution range has decreased over the period between 1995 and 1999.

D. elongate being a pelagic species, is not always available to bottom trawlers and therefore suffers relatively less fishing mortality than other species that are permanently demersal. There is also relatively less fishing pressure from the lone midwater trawler operating in Area B which occasionally lands about 53% of *D. elongate* as bycatch (Turner, 1996). Although there are indications that the current distribution is not as wide as it used to be especially in Area C, the species unlike the others, is not greatly affected by fishing activities. It seems to be more or less governed by the existing environmental conditions.

***Oreochromis* spp.**

These species are commonly called "Chambo" and have for decades been the mainstay of both the commercial and artisanal fisheries in southern Lake Malawi. Results from this study indicate that *Oreochromis* spp. occur mostly in Area A and to a smaller extent in shallow inshore waters of Area B. The species have greatly declined in abundance and their distribution range has narrowed very much.

The drastic decline in the abundance and distribution of the species has mostly been blamed on localised and excessive fishing pressure from both commercial and artisanal fisheries over the years. Much of the blame has been laid on the light attraction fishery commonly known as Kauni, beach seines, and undermeshed gillnets. To redress the situation, it was recently proposed that beach seines and Kauni fisheries be banned in Area A (Bulirani *et al*, 1999).

The situation in southeast arm requires urgent intervention from the fisheries department because if nothing is done to curb the current trends in fishing practices, the remaining few pockets will also disappear.

Buccochromis lepturus

The results from this study indicate that in the southeast arm, *B. lepturus* is evenly distributed in shallow waters of Areas B and C. Abundance has generally increased as manifested by the higher biomass in 1999 than in 1995. However by 1999 the species had disappeared from the eastern part of Area C and the southern most portion of the lake (Area A). Thus the distribution range has decreased. The general decline in abundance of this species in parts of Area C and Area A can be attributed to excessive fishing effort in these Areas mainly because of localised fishing effort in Area A for *Oreochromis* spp. and in Area C for *C. virginalis*.

Conclusions

This study has demonstrated that geostatistics can be successfully used to analyse the existing CPUE data in Lake Malawi to detect changes in the spatial and temporal distribution of fish stocks. The reasonably low nugget effect (0.005 max) indicates that the micro-scale variation or measurement error is small for all the species analysed. Biomass estimates are generally good for species found offshore or in deep water. This is because during kriging, this part of the water body is analysed more thoroughly than shallow waters. However, there is another method that can be used to improve biomass estimates for shallow water species. This method was not employed in the current analysis because a lot of time is required to manually define the Area to be kriged.

In order to enhance the efficacy of this new technique, the number of stations needs to be increased in southeast arm especially in Area B. The seven stations in Area A need to be evenly redistributed.

Generally, all the species studied show localised occurrence in various Areas of the lake, and as such they are very vulnerable to overfishing and are in imminent danger of facing localised extinction. To protect these stocks it is suggested that stock-specific management measures be constituted and implemented as soon as possible. Options to be considered include closed seasons and aggregate quotas, controlled-Area fishing, restrictions on fishing gear and technology.

Acknowledgements

I would like to thank ICEIDA (Malawi) for sponsoring my studies at Rhodes University and my project supervisor, Dr. A. Booth, who untiringly guided me through all the data analysis and write-up.

References

Banda, M.C. and Tomasson, T. (1996). Surveys of Trawling Grounds and Demersal Fish Stocks in Central Lake Malawi from Domira Bay to Nkhata Bay in 1994 and 1995. Government of Malawi, Fisheries Department. Fisheries Bulletin No. 33,34 pp.

Bulirani, A.E., Banda, M.C., Palsson K.P., and Weyl, O.L.F. (1999). Fish Stocks and Fisheries of Malawian Waters. Resource Report 1999. Government of Malawi, Fisheries Department. 54pp.

Cressie, N.A.C. (1993). Statistics for Spatial Data. John Wiley & Sons, New York. 900 pp.

Freire, J., Gonzalez-Gurriaran, E. & Olaso, I.(1992). Spatial Distribution of *Munida intermedia* and *M.sarsi* (Crustacea:Anomura) on the Galician Continental Shelf (NW Spain): Application of Geostatistical Analysis. *Estuarine, Coastal and Shelf Science* (1992) **35,** 637-647.

Gulland, J.A. (1983). Fish Stock Assessment: A Manual of Basic methods. Volume 1. FAO, Rome. 223 pp.

Hall, S.J. (1999). The Effects of Fishing on Marine Ecosystems and Communities. Blackwell Scientific Publ., London. 274pp.

Kaluzny, S.P., Vega, S. C., Cardoso, T.P., and Shelly, A,A (1998). S+Spatial Stats- Users Manual for Windows and Unix. Springer- Verlag New York, Inc., New York. 321 pp.

Kanyerere, G.Z. (1999). Trawl Selectivity and the Effect of Clogging on Standard Trawl Surveys on Lake Malawi. Government of Malawi, Fisheries Department. Fisheries Bulletin No. 39. 25pp.

Palsson, O.K., Bulirani, A., and Banda, M (1999). A Review of Biology, Fisheries and Population dynamics of Chambo *Oreochromis* spp., Cichlidae) in Lakes Malawi and Malombe. Government of Malawi, Fisheries Department, Fisheries Bulletin No. 38. 35 pp.

Patterson, G. & Kachinjika, O. (1995). Limnology and Phytoplankton Ecology. In A. Menz (ed.), The Fishery Potential and Productivity of the Pelagic zone of Lake Malawi/Niassa. Natural Resources Institute, Chatham, UK. pp307-349

Pelletier, D. & Parma, A.M.(1994). Spatial Distribution of Halibut (*Hippoglossus stenolepsis):* An Application of Geostatistics to Longline Survey Data. *Can. J. Fish. Aquatic*(1994). *Sci.* **51**, 1506-1517.

Turner, G.F. (1996). Offshore Cichlids of Lake Malawi. Cichlid Press, D-31864 Lauenau, 236 pp.

Turner, G.F.,Tweddle, D., and Makwinja, R.D. (1995). Changes in Demersal Cichlid Communities as a result of Trawling in Southern Lake Malawi. In T.J. Pitcher and P.J.D. Hart (eds.), The Impact of Species changes in African Lakes. Chapman and Hall, London, pp.397-412.

Turner, J. (1976). Promotion of Integrated Fishery Development-Malawi. An Analysis of the various fisheries of Lake Malawi. Technical Report 1, Rome, FAO. 73pp.

Rosner, B. (1995). Fundamentals of Biostatistics. Wadsworth Publ. Company, California 94002. 661 pp.

Sparre, P., Ursin, E. & Venema, S.C. (1989). Introduction to Tropical Fish Stock Assessment. Part 1-Manual. FAO, Fisheries Technical Paper No. 306/1, 337 pp.

Preliminary Investigations of Community Level Responses to Benthic Trawling in the Demersal Fish Fauna of Lake Malawi/Niassa, Africa.

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Introduction
A demersal trawl fishery was initiated in 1968 in the far south of the South East Arm (SEA) of Lake Malawi in an area since designated as "Area A" (Tarbit 1971) (Fig. 1). The fishery in Area A has a mean annual yield of 800 metric 'red' (Bulirani *et al.* 1999) and targets an estimated 70-80 species, mostly from the family Cichlidae. Management has been largely based on the application of single species models (Tweddle & Magasa 1989) which are unable to account for species specific responses to fishing which result from the wide range of life histories expressed (see (Adams 1980) for a review of life history influence on response to fishing). Life history characteristics of the target species range from those maturing at 37mm (*Pseudotropheus livingstonii*) with a mean fecundity of 25, to those maturing at 160mm (*Buccochromis lepturus*) with an estimated mean fecundity of 450 (Duponchelle & Ribbink 2000). Growth rate estimates for these species still remain uncertain but include values of K ranging from 0.49 - 1.82 (Iles 1971; Tweddle & Turner 1977; Duponchelle & Ribbink 2000).

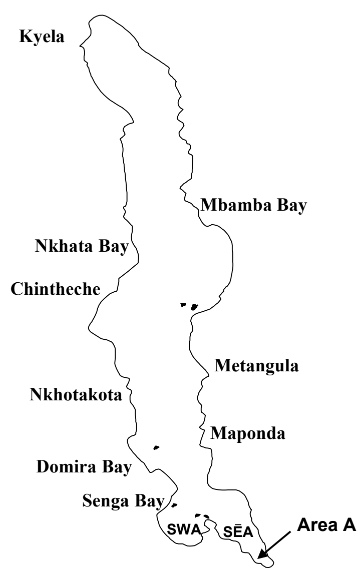

Figure 1. Lake Malawi showing the location of the study area, Area A, in the South-East Arm (SEA).

Previous studies in Area A have already identified a reduction in fishing yields, changes in species composition, local extirpation of species, decline in abundance of large species, increased abundance of small species, and an initial decline in species richness (FAO 1976; Turner 1977a; Turner 1977b; Turner *et al.* 1995; Stauffer J.R. *et al.* 1997). The application of multispecies models, which may attempt to account for the varied species responses to fishing, is unlikely to be successful because not only are the data requirements extensive but it would be hard to implement management recommendations based on a whole suit of measures tailored for each individual species, or group of species. An alternative approach is to assess and manage the fishery at the level of the fish community or ecosystem. The ecosystem / community level approach to fishery management is becoming more accepted at the global level (Hollingworth 2000) and, given the multispecies, multigear nature of the fishery, it should be considered for Lake Malawi.

In this paper community level responses in the demersal fish fauna of Area A were investigated throughout the thirty year period of benthic trawling with an aim to identifying a suitable "indicator" parameter for future monitoring of community level changes in the fishery. The study includes analyses of both species and trophic composition.

Methods

Species Compositions
Species compositions were obtained from experimental trawl surveys conducted by the Malawi Fisheries Research Unit (FRU) since 1970. Analyses were restricted to catches from within the 20-40m depth range which is mainly targeted by the trawl fishery in Area A. Inconsistencies in taxonomic identifications and catch sampling methodologies combined with the replacement of the research vessel Ethelwyn Trewavas with the RV Ndunduma in 1993/4 necessitated extensive standardisation of data.

Data standardisation

Sampling methodologies
There were a number of inconsistencies in the way trawl catches were sampled through the years. The large catfish and 'others' (large cyprinids, mormyrids and large cichlids such as *Oreochromis* spp. and *Buccochromis* spp.) had already been discarded from the data obtained for the 1991-92 surveys (Turner *et al.* 1995). Consequently, community changes can only be assessed for the 'small' fish subset of the community, mainly comprising cichlids[1]. There may still be inconsistencies between survey periods for *Oreochromis* and *Buccochromis* spp. as the size at which they were considered to be "large" and thus excluded from the "smalls" category has not been strictly determined such that different surveys may have discarded different proportions of these species.

Taxonomic inconsistencies
The data set for this study spans a period of 30 years during which time many of the species names and cheironyms used have changed. Considerable effort has been put into tracing these changes in nomenclature and in the production of a standardised list of species names that can be applied to all surveys. Many name changes were successfully traced through the literature or sorted out following discussions with Prof. George Turner who was responsible for many of the new cheironyms introduced during the 1991-92 survey. For all remaining cases with potential for taxonomic confusion taxa have been consolidated into species complexes or identification has been restricted to the level of genus.

Standardisation of catches from Ethelwynn and Ndunduma trawls
In 1993 both the RV Ethelwynn Trewavas and RV Ndunduma operated simultaneously allowing a direct comparison of trawl catch rates from the two vessels (Banda *et al.* 1996). The difference in codend mesh size, 38mm on Ndunduma and 25mm on Ethelwynn, was reported not to have a major impact on catch biomass and the two gears were considered to have "identical selectivity curves for the size at first capture". Size frequency distributions for catches from each vessel were very similar for fish below approximately 10cm (TL) above which the Ndunduma catches were significantly greater. The greater catches by the Ndunduma were said to be a product of its greater trawling speed enabling increased capture rates for larger fish such as catfish, cyprinids and large cichlids. The greater swept area, for both horizontal and vertical dimensions, would also have accounted for the greater yields. Unfortunately no detailed comparison of species compositions for catches from the two vessels was reported and the original data for these trawls appears to have been lost (Banda pers. comm.). The reactivation of the Ethelwynn Trewavas would be most beneficial for direct comparison of the species selectivities of the two vessels.

In recognition of the differences in catch compositions from the two vessels all shoaling 'off-bottom' species which would be caught preferentially by the Ndunduma but not by the Ethelwynn Trewavas were excluded from the analyses. Species groups excluded under this category were all *Copadichromis* spp., *Diplotaxodon* spp, and *Rhamphochromis* spp. The larger, faster swimming species, also preferentially caught by the Ndunduma, were automatically excluded as they would have been sorted into the 'large fish' portion of the catch. The remaining portion of the catch, for which time series analyses could be conducted, comprises the group of fish known locally as 'Chisawsawa' which constitutes the truly demersal cichlid community. The only non-cichlid included is the small catfish, *Synodontis njassae*. As all species compositions are presented as percentages of total biomass standardisation of trawling times and swept areas was not required.

Fish diets and allocation of trophic guilds
Trophic analyses were based on the results of dietary studies. Fish dietary components were determined from stomach analysis of 114 species from across the whole demersal fish community. Over 3,000 fish were sampled with the sample sizes weighted towards those species most dominant in the catch. This sampling program provided

[1] Data on the "large fish" component has since been obtained and will be included in future analyses.

dietary data for 95% of the mean catch biomass. The results of stomach analysis were confirmed in a number of cases by results from analysis of stable isotope ratios.

Statistical analysis
Dominance curves, diversity indices, and Multi-Dimensional Scaling (MDS) ordination techniques were used in the analyses of temporal changes in community composition (Primer Software 1994). MDS ordinations were based on Bray-Curtis Similarity matrices of 4^{th} root transformed percentage biomass for each species or trophic guild. The sample unit was taken as each individual trawl catch.

Results

The demersal fish community
The trophic structure of the demersal fish community includes 4-5 trophic levels based predominantly on the consumption of detritus and diatoms (Fig. 2). The main food items were, in descending order of dominance, detritus and diatoms (combined in a "diatomaceous ooze"), molluscs, copepods (mainly cylcopoids), other fish, chironomid larvae, cladocera, other insect larvae, and oligochaetes.

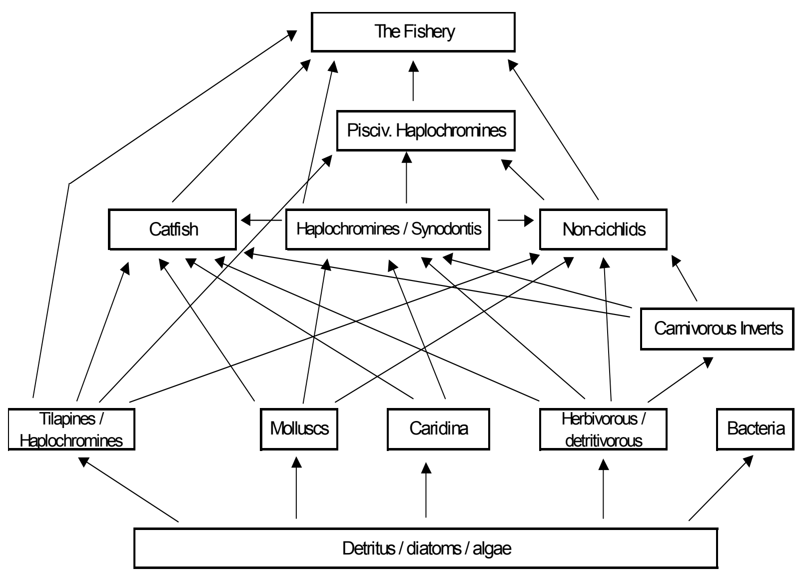

Figure 2. Schematic diagram of the demersal fish community food-web.

Temporal changes in community composition

Species composition
Species compositions were obtained from surveys over the 1970-75 period and from 1990 to 1998. No surveys were conducted during the 1980's. MDS ordination demonstrates a clear temporal reduction in diversity between individual trawl catches within each survey period (Fig. 3). In effect the similarity between individual trawl catches within a survey period has increased in more recent years (the mean similarity between trawls was 38.89 in 1973 and 54.28 in 1998 - Bray-Curtis similarity index). *K*-dominance curves show that the community has become dominated (in terms of biomass) by fewer species in recent years (Fig. 4). There was no significant reduction in species richness (at the restricted taxonomic level used in the analyses) or change in species distributions over time. The temporal trend for increasing dominance was reversed during the last survey period (1995-98) when dominance was shown to have declined. This apparent reversal towards the original state of evenness may indicate a degree of community resilience to fishing, as originally suggested by Tweddle and Magasa (1989).

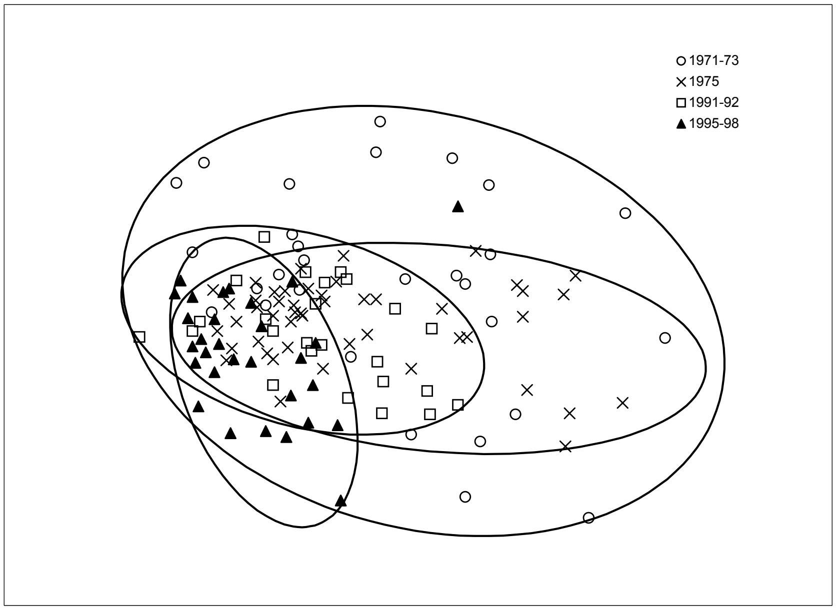

Figure 3. MDS ordination in which each point represents the species composition of a single trawl catch. The distance between points is a measure of their similarity where points closest together are the most similar. Trawls from each survey period are enclosed in ellipses.

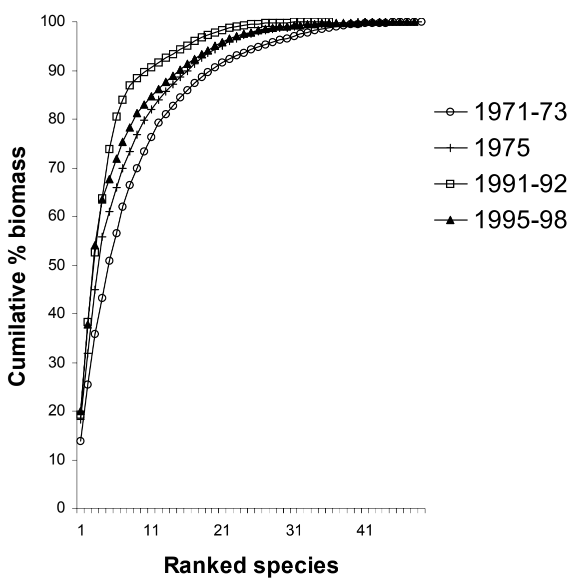

Figure 4. *K*-dominance curves for species biomass.

Trophic guilds

Species were allocated to one of ten trophic guilds defined as collections of species using similar combinations of food types. MDS ordination shows a clear change in guild composition over time (Fig. 5). The most significant change was seen between the 1971-73 and 1975 survey periods in the early stages of development of the fishery (ANOSIM, R statistic = 0.316, $p < 0.001$). Little change was observed between 1975 and 1991-92 but by the time of the 1997-98 survey guild composition showed no significant difference from the original 1971-73 state. The return to the original state following a period of change follows the pattern of change described above for species compositions.

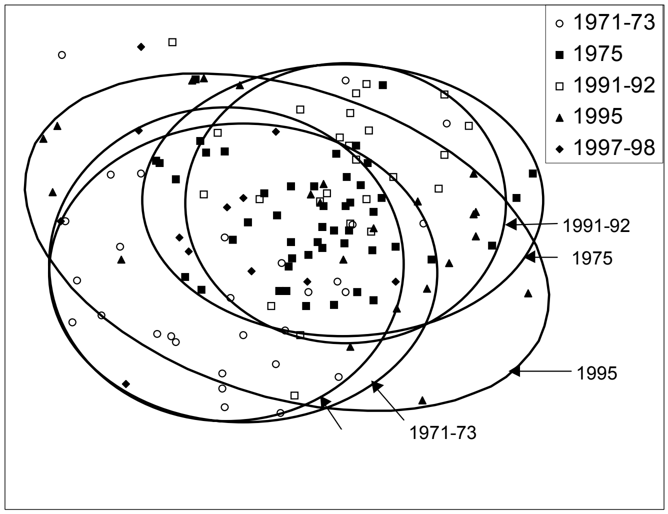

Figure 5. MDS ordination of trophic guilds. Each point represents the trophic guild composition of a single trawl catch. The distance between points is a measure of their similarity where points closest together are the most similar.

Trophic biomass pyramids

Pyramids of biomass were constructed by multiplying the percentage compositions of food items for each species by the species percentage composition in the community (Fig. 6). The mean trophic level dropped from an initial value of 3.02 in 1971-73 to a low of 2.71 in 1975. By the time of the 1995-98 survey period the trophic level had risen back to near its original level at 2.95.

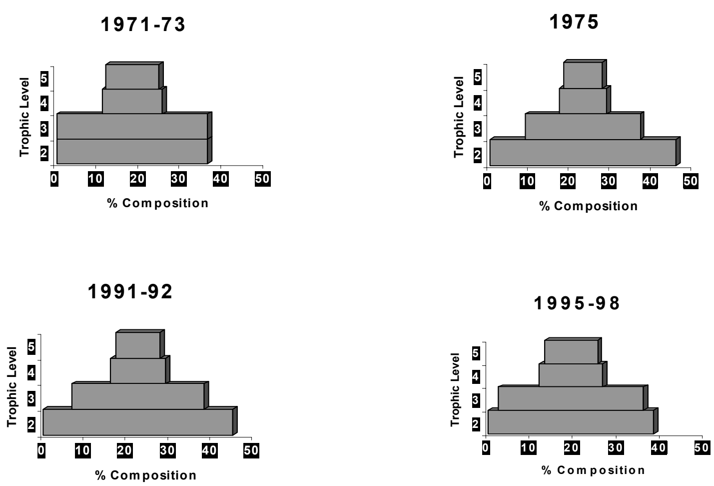

Figure 6. Pyramids of biomass. Each plot depicts the mean relative proportion of each trophic level within the community for that period of survey.

Conclusions and Recommendations

Species compositions, species diversity (dominance/evenness) and trophic composition have all changed significantly over the 30 year period of study. All of these community descriptors have followed a similar pattern of change. If these patterns are to be interpreted as a community response to fishing it would appear that the initiation of the fishery has stimulated a rapid alteration in community structure followed by a period of relative stability and, finally, a gradual return towards the original state by the 1995-98 period. Such a response would be typical of that expected from a community resilient to change. A more useful interpretation of this last observation, however, awaits the analysis of an extended time series (including data from 1999-2000) combined with analyses for possible correlation of dominance with levels of fishing effort, primary productivity and other environmental variables (work in progress).

Changes in species dominance parallel the changes recorded for all other aspects of community structure investigated in this study and may, as such, serve as a suitable "indicator" for monitoring community level responses to fishing pressure. It is well documented that alterations to community structure following fishing may lead to significant changes in fishery productivity and stability (Jennings & Kaiser 1998). Such community level changes would not be detected by the current approaches to fishery assessment in Lake Malawi. As species dominance can easily be calculated from the data already being collected as part of the regular program of monitoring by the FRU it is recommended that this measure be included as a monitoring parameter for future fishery assessment on Lake Malawi.

Acknowledgements

Thanks are given to Mr Davis Mandere (FRU) who was responsible for all recent species identifications and to Valerie Choiseul (EU project) and Tony Mhango (FRU) for their work on the dietary analysis. This work is based on data obtained as part of the EU funded INCO-DC project: "The trophic ecology of the demersal fish community of Lake Malawi/Niassa, Africa."

References

Adams, P. B. 1980. Life history patterns in marine fishes and their consequences for management. *Fishery Bulletin*, 78, 1-12.

Banda, M., Tomasson, T. & Tweddle, D. 1996. Assessment of the deep water trawl fisheries of the South East Arm of Lake Malawi using exploratory surveys and commercial catch data. *Stock Assessment in Inland Fisheries* (ed I. G. Cowx), pp. 53-75. Fishing News Books, Oxford.

Bulirani, A. E., Banda, M. C., Pálsson, O. K., Weyl, O. L. F., Kanyerere, G. Z., Manase, M. M. & Sipawe, R. D. 1999. Fish Stocks and Fisheries of Malawian Waters. Resource Report. 1999. Lilongwe, Malawi, Government of Malawi Fisheries Department.

Duponchelle, F. & Ribbink, A. J. 2000. Fish Ecology Report: Lake Malawi/Nyassa/Niassa Biodiversity Conservation Project. 1-139. SADC/GEF.

FAO. 1976. Promotion of integrated fishery development, Malawi. FI:DP/MLW/75/109, Technical Report 1. Rome.

Hollingworth, C. E. 2000. Ecosystem Effects of Fishing. *ICES Journal of Marine Science*, 57, 465-792.

Iles, T. D. 1971. Ecological aspects of growth in African cichlid fishes. *J.Cons.int.Explor.Mer.*, 33, 363-385.

Jennings, S. & Kaiser, M. J. 1998. The Effects of fishing on Marine Ecosystems. *Advances in Marine Biology*, 34, 201-352.

Stauffer J.R., Arnegard M.E., Centron M., Sullivan J.J., Chitsulo L.A., Turner, G. F., Chiotha S. & McKaye, K. R.1997. Controlling vectors and hosts of parasitic diseases using fishes. *Bioscience*, 47, 41-49.

Tarbit, J. 1971. Lake Malawi Trawling Survey: Interim Report 1969-1971. 2, 1-16. 1971. Zomba, Malawi, Ministry of Agriculture & Natural Resources. Fisheries Bulletin Ref Type: Report.

Turner, G. F., Tweddle, D. & Makwinja, R. D. 1995. Changes in demersal cichlid communities as a result of trawling in southern Lake Malawi. *The Impact of Species Changes in African Lakes* (eds T. J. Pitcher & P. J. B. Hart), pp. 397-412. Chapman & Hall, London.

Turner, J. L. 1977a. Changes in size structure of cichlid populations of Lake Malawi resulting from bottom trawling. *Journal of the Fisheries Research Board of Canada*, 34, 232-238.

Turner, J. L. 1977b. Some effects of demersal trawling in Lake Malawi (Lake Nyassa) from 1968 to 1974. *Journal of Fish Biology* , 10, 261-272.

Tweddle, D. & Magasa, J. H. 1989. Assessment of mulitspecies cichlid fisheries of the Southeast Arm of Lake Malawi, Africa. *J.Cons.int.Explor.Mer.*, 45, 209-222.

Tweddle, D. & Turner, J. L. 1977. Age, growth and natural mortality rates of some cichlid fishes of Lake Malawi. *Journal of Fish Biology*, 10, 385-398.

Resource use overlaps between the pair trawl and small-scale fisheries in the southeast arm of Lake Malawi: preliminary results.

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Abstract
Since the development of the pair trawl fishery, there has been a conflict between the small-scale and this fishery. This study assesses the abundance, species composition and size distribution of fish exploited by small-scale and pair trawl in Lake Malawi. Preliminary results have shown that pair trawlers appear to target some shallow-water fish species at small sizes. Furthermore, there appears to be overlaps in the species harvested by pair trawl and small-scale fisheries.

Introduction
Lake Malawi, the southernmost of the great lakes of Africa covers an area of about 30,800km^2 which ranks it ninth in order of size among the world's lakes. Experimental bottom trawling in 1965 revealed the presence of commercially exploitable stock of demersal fish, mostly cichlids (Turner 1975). In 1968 a commercial trawl fishery was initiated in the southeast arm of Lake Malawi (Figure 1) in Areas A & B by Maldeco Fisheries Ltd. The pair trawl fishery was developed to eliminate the expensive winching machinery and by 1972, trawling started in Area B (Turner 1975). In the early 1970s, the pair trawl fishery realized a mean CPUE value of approximately 2 tons per day and a total of 22 pair trawl units were, then, licensed in this fishery (Jambo, in press). However, only five units presently operate in both southeast and southwest arms of the lake and present catch-effort data for the same area indicates that the CPUE is approaching 1 ton per day (Banda and Tomasson 1997). This decline in the number of units in operation and the catch per unit effort suggests that the fishery is collapsing.

The pair trawlers are restricted to fish in areas more than 20 metres deep and at least 1 nautical mile from the shore. This is similar to the area fished by the small-scale fishery and there are indications that there is competition between the pair-trawlers and the small-scale fisheries is over the fishing ground. Small-scale fishers operate using a variety of gears including open water seines, beach seines, gill nets and hook and line (Weyl *et al.* 2000). During the early days of operations, there were no restrictions over the type of fishing gears to be used neither were there any restrictions on any fishing activity until 1952 when a minimum of 102 mm mesh size for seine nets with the headline length of greater than 274 metres was put in place (Lowe 1952). Presently most of the small-scale fisheries involve traditional gears which operate manually while a few chilimira, kauni and gill netters use motorized boats.

Chambo was the main species caught in the 1970s by both the commercial and the small-scale fisheries. The collapse of the chambo fishery in the southern arms of Lake Malawi and Lake Malombe (Banda *et al* 1997, Weyl et al 1999) and the growing demand for fish by the growing Malawi population has aggravated some conflicts between pair-trawlers and the small-scale fishers, each sector accusing the other over the depletion of the fish stocks. This paper tries to look at the causes and effects of the conflicts and provide possible preliminary recommendations that would be applied to both fishing sectors. This survey was designed to determine if there is any resource use overlaps between the small-scale and pair trawl fishery in the southeast arm of Lake Malawi and attempt to determine the causes for the conflicts which exist between the pair trawl and small-scale fisheries over the fisheries resources in the study area. It should however be noted that this study is in its initial phase and that results presented here are preliminary.

Methods of data collection
The survey was conducted in the southeast arm of Lake Malawi (Figure 1) and small scale and pair trawl catches were sampled at Kela beach, Mpwepwe and Namiasi.Fish samples were collected from pair-trawlers and all small-scale fishermen to determine the species composition and size selectivity of the catches. A representative sample was taken from the total catch which was later sorted to the species level. Each species component in the sample was weighed and all fish in the sample were measured for total length to the nearest millimetre.

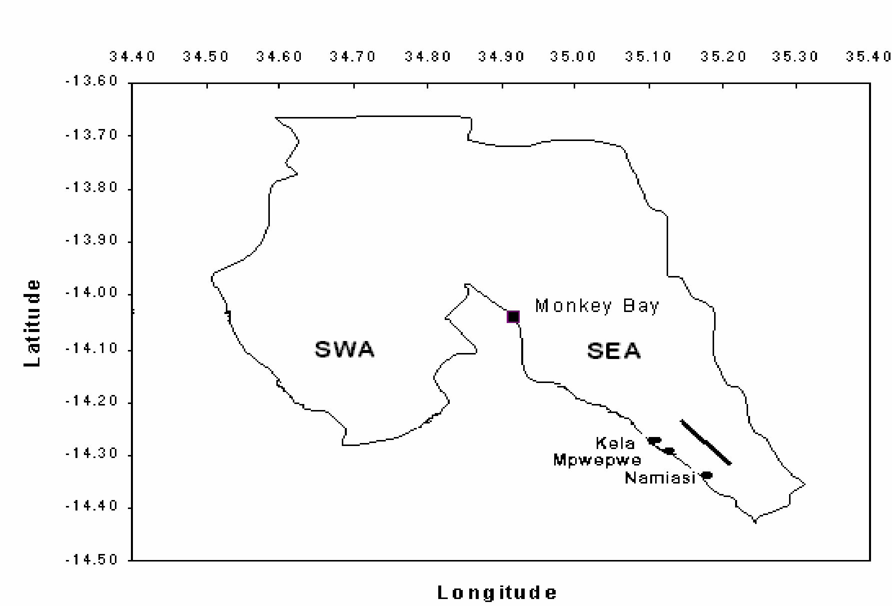

Figure 1. Map of the study sites in the southeast arm (SEA) of Lake Malawi.

Results and discussion

The in both pair-trawl and small-scale fisheries, the species composition is multi-species and target species are determined by the mode of operation of the gear rather than by the preference of the fisher. More than 60 species were recorded from the small scale fishery and the pair trawl fishery. The genera comprising the majority of the pair trawl catch composition and their contribution to various small scale gears is shown in Table 1. It is evident that there is considerable overlap in the genera harvested by the small-scale and pair-trawl fisheries (Table 1).

Furthermore, a number of shallow water species, including *Otopharynx argyrosoma, Nyassachromis argyrosoma,* and *Pseudotropheus livingstonii* were recorded in pair trawl catches. This indicates that the 1-nautucal mile offshore rule is not abided to by the pair-trawl fisheries.

Table 1. Percent contribution of the genus *Oreochromis, Nyassachromis, Ctenopharynx, Lethrinops, Otopharynx, Rhamphochromis* and *Copadichromis* to the catch in the pair trawl fishery, gill net fishery, chilimira/kauni, hand line and beach seine fishery.

	Pair Trawl	GN 1-2 inch	GN 2-3 inch	GN 3inch +	Chilimira	Kauni	Hand lines	Beach seines
Oreochromis	2.3	0.2	24.0	68.0	9.9	34.0	3.5	14.5
Nyassachromis	4.0	0.0	15.2	0.0	0.0	0.0	0.0	0.0
Ctenopharynx	5.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lethrinops	8.3	3.4	2.7	0.0	0.0	0.2	2.6	11.2
Otopharynx	12.9	1.8	0.0	0.0	1.5	0.0	18.5	8.2
Rhamphochromis	17.1	2.5	0.0	2.7	42.5	37.0	13.3	5.7
Copadichromis	21.3	70.2	14.8	0.0	25.0	5.0	4.1	12.2

Table 1 shows that the main areas of overlap between the pair trawl and the small scale fishery are in the genus *Oreochromis*, *Rhamphochromis* and *Copadichromis*. While *Oreochromis* was not a major component of the pair trawl catch (<5%) the genus contributed significantly to the gill nets, kauni and the beach seine catch and there is some overlap between these fisheries. The genera *Copadichromis* and *Rhamphochromis* contribute considerably to the catch in the pair-trawl and small-scale fisheries. It was estimated that the pair trawl fishery accounts for 24% of the annual *Copadichromis* and 10 % of the annual *Rhamphochromis* yield from shallow (<50m) areas of the southeast arm of Lake Malawi.

Detailed length frequency analysis was performed on *Rhamphochromis* spp. and *Copadichromis* spp., to investigate potential effects of the pair trawl fishery on these two stocks. Since various *Rhamphochromis* species mature at different length sizes within the range of 110 cm and 230 cm. From Figure 2 it is clear that a high proportion of *Rhamphochromis* spp. caught by the pair-trawlers were immature (Figure 2). In the small-scale fishery, on the other hand, a large proportion of the catch was mature. In the gill net fishery almost all the fish caught were mature. The chilimira kauni and the beach seine fisheries on the other hand appear to target smaller *Rhamphochromis*. Although, greater amounts of the fish caught in the chilimira/kauni fishery are mature, there is also a considerable amount of immature fish in the catch. This contrasts with the pair-trawl fishery in which immature individuals dominated the catch. It is therefore evident that there is very high competition for this resource between the two fishing sectors, both for the mature and the immature fish.

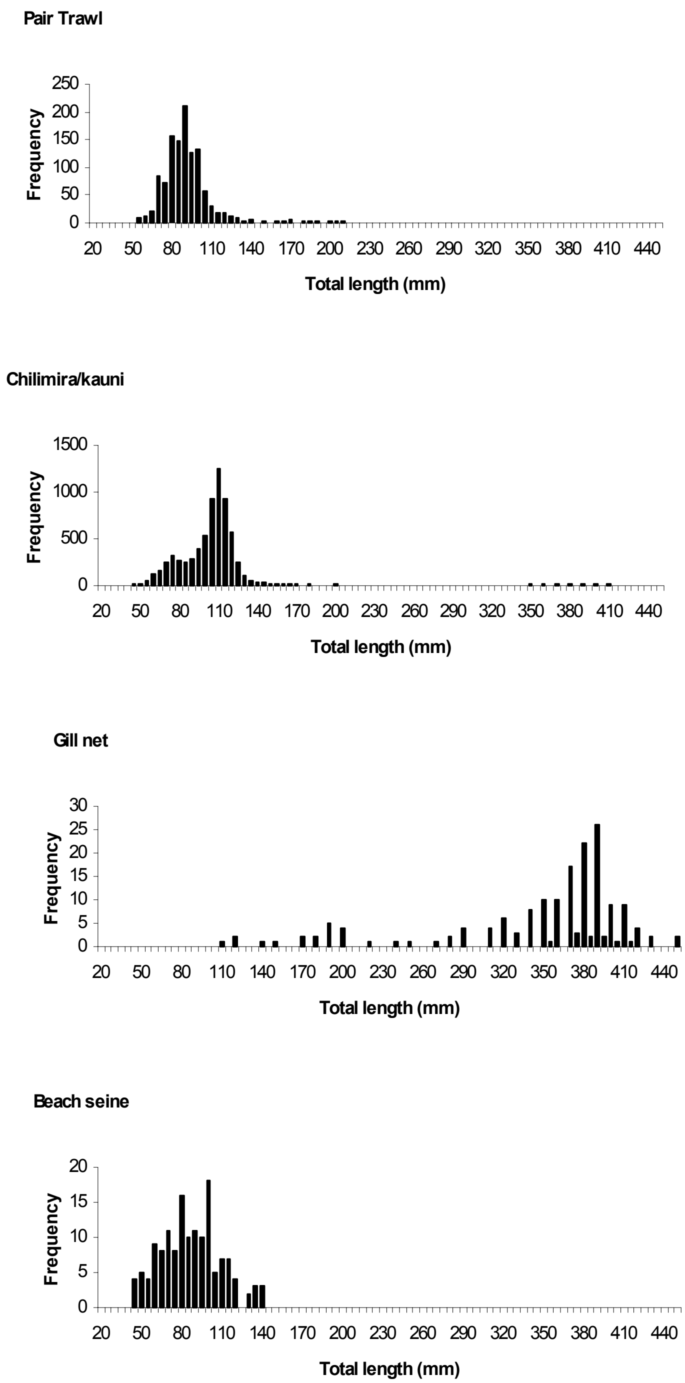

Figure 2. Length frequency of *Rhamphochromis* spp., in the pair trawl, chilimira/kauni, gill net and beach seine fisheries of the southeast arm of Lake Malawi.

Copadichromis virginalis matures at lengths of 10.6 cm. This species is one of the most abundant and economically important fish in the lake. This fish is by most fishing gear and there appears to be a degree of user overlap in this resource. *Copadichromis virginalis* are harvested by the pair trawl fishery before maturity and there was only small contribution of mature individuals to the total catch (Figure 3). The situation, in general, differs from chilimira/kauni fishery where most of the fish caught were mature (Figure 3). Gill nets are selective for mature individuals and most of the catch is dominated by fish that range between 115 mm and 140 mm (Figure 3). However, not all the fish found in gill nets are mature since there some evidence of fish which were less than 106 mm. This shows that both fishing sectors harvest a wide length-range of *C. virginalis* there is high competition between these two fishing sectors for *Copadichromis virginalis.*

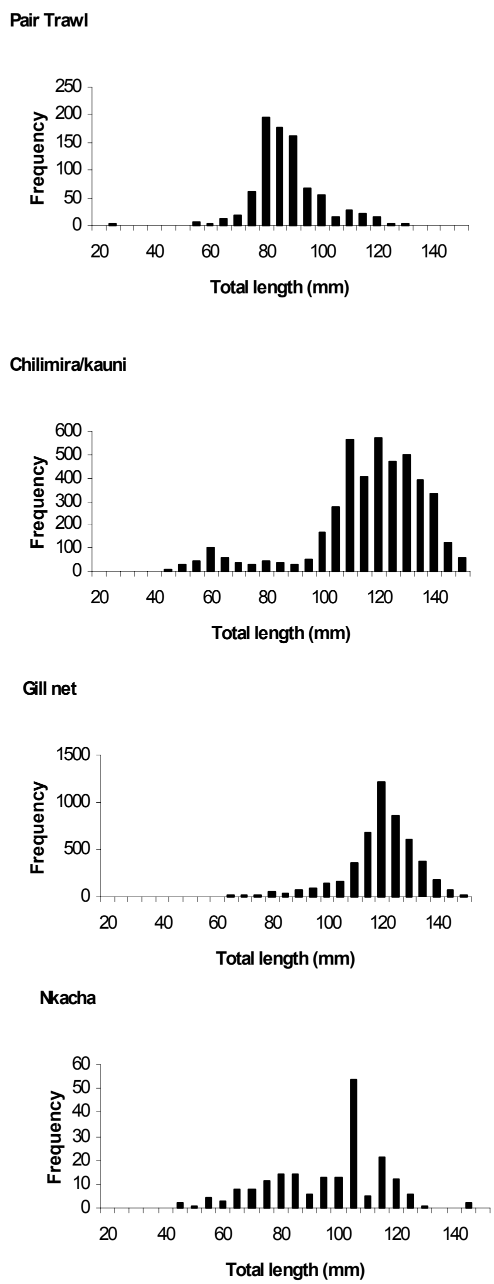

Figure 2. Length frequency of *Copadichromis virginalis* in the pair trawl, chilimira/kauni, gill net and nkacha net fisheries of the southeast arm of Lake Malawi.

Conclusions and recommendations

These preliminary results have indicated that there is some evidence of an overlap for some species between pair trawl and small-scale fisheries. This has been due to the fact that both fisheries fish in water less that 50 m deep. While pair trawlers are licensed and bound by the regulation to fish in areas that are at least 1 nautical mile offshore and deeper than 18 meters, the presence of shallow-water species like *Otopharynx argyrosoma, Nyassachromis argyrosoma* and *Pseudotropheus* spp. shows that chances are very high that the pair-trawl fishery operates in waters shallower than 20 meters and closer than one nautical mile from shore.

While the catch compositions in small-scale gears such as chilimira/kauni and gill nets have shown that most of the fish caught in these fisheries are mature, juvenile fish predominate the catch in the pair-trawl fishery. In addition, juvenile cichlids, too small to be identified even down to the genus level, were also found in the catch sampled from the pair trawlers at Namiasi fish landing site. This composition contributed to about 2% of the total catch sampled from two fishing units from the Namiasi landing site. A different scenario became evident from Mpwepwe where the unit belongs to the Fisheries Department. All fish collected from this pair-trawl unit were comparatively large and approximated the size at maturity for individual species. While pair-trawlers are bound by the regulation to use a 38 mm mesh at the bunt, the presence of juvenile fish from these private-owned units from Namiasi indicates that these pair-trawlers use very small meshed bunts for their trawl nets.

It is therefore imperative that there is a strong need for some management efforts to be put in place for the pair-trawl fishery before the situation gets out of hand. Some of the many management efforts required for the fishery are to enforce the 1-nautical mile/18m depth limitation of the gear and to enforce the 38mm minimum mesh size for pair-trawlers.

Acknowledgements.

This Programme was funded by the Department of Fisheries and NARMAP. Thanks to my fellow researchers, Moffat Manase, Richard Sipawe and Jacqueline Chisambo for jointly using part of their data.

References

Banda, M., and Tomasson, T., 1997. Demersal fish stocks in Southern Lake Malawi: Stock Assessment and Exploitation. Fisheries Department of Malawi, Bulletin No. 35, pp 39.

Eccles, D. H., and Trewavas, E., 1989. Malawi Cichlid fishes. The classification of some Haplochromine genera. Herten (W. Germany), Lake Fish Movies, pp335.

Jambo, C. M. (in press). Commercial and artisanal fisheries in Lake Malawi: Who is to blame for the declining catches?

Lowe, R. H. 1952. Report on the Tilapia and other fish and fishes of Lake Nyasa1945-47, Part 11. London, HMSO, Colonial Office Fisheries Publ. 1(12), pp126.

Turner, G. F. 1992. The mechanised fisheries of Lake Malawi. *FI:DP/MLW/86/013 Field Document 23.FAO, Rome,* 24pp.

Turner, J. L. 1975. Some effects of demersal trawling in Lake Malawi (Lake Nyasa) from 1968 to 1974.

Weyl, O. L. F., Banda M. C., Manase, M., Namoto, W., Mwenekibombwe, L. H., 1999. Analysis of Catch and Effort Data for the Fisheries of Lake Malawi.

Population biology of the catfish *Bagrus meridionalis* from the southern part of Lake Malawi.

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Abstract
The study investigated the endemic catfish, *Bagrus meridionalis* of Lake Malawi in order to understand their ecological relations, distribution, abundance and life history. The catfish are the second most important group of targeted species in Lake Malawi's fisheries. Surveys were done using the research vessel, *Ndunduma*, using a bottom and mid-water trawl from June 1994 to March 1996. The management implications of the ecology in relation to development of the deep trawl fishery are discussed.

Key words: Catfish, ecology, distribution, abundance, life history, Lake Malawi.

Introduction
The demersal catfish *Bagrus meridionalis* (Günther) (local name: kampango), is the only bagrid species that occurs in Lake Malawi. It is one of the large fish species found in the lake and is a predator endemic to the lake and feeds mainly on small lake demersal cichlids. *B. meridionalis* is one of the most common and widely distributed species in the lake, and inhabits a variety of habitats (Jackson *et al.* 1963).

B. meridionalis is important commercially and is valued as a food fish by the rural community. It is caught mainly by gillnets and long lines in the small-scale commercial fisheries and by bottom trawlers in the large commercial fisheries (Jackson *et al.* 1963, Tweddle 1982, Sipawe 2001). The small-scale fisheries operate mainly in waters shallower than 20 m and the large-scale commercial fisheries operate in deeper water (Alimoso 1989). The mean total annual landings are about 1300 tonnes representing approximately 2.5 % of the mean annual total fish catch in Malawi for the past decade (Banda 2000).

While several authors have described some aspects of its biology, previous studies have focused mainly on feeding (Jackson *et al.* 1963, McKaye 1986, LoVullo *et al.* 1992) and reproductive biology (Jackson *et al.* 1963, Tweddle 1982, FAO 1976, McKaye 1985, LoVullo *et al.* 1992, McKaye *et al.* 1992). Three notable exceptions have looked at the age and growth (Tweddle 1975, Roberts 1990, LoVullo *et al.* 1992). However, no full account of the biology and ecology of Kampango in a single area has been published.

This study provided information on the distribution and biology of the Kampango around the southern part of Lake Malawi, which is under ever-increasing pressure from both the small- and the large-scale commercial fisheries. The paper contributes to the knowledge of the life history of *Bagrus*, and may be of great importance to the assessment and implementation of the management plan for the sustainable use of the deep-water fishery, which is rapidly expanding.

Materials and methods
The data in this study were collected during the stock assessment and biological surveys, from June 1994 to July 1996, carried out in the southeast arm (SEA) and southwest arm (SWA) of Lake Malawi (Figure 1) by the Fisheries Department. Stock assessment surveys were done on a quarterly basis and were designed to monitor changes taking place in the SEA and SWA, the heavily exploited areas, whilst biological surveys were done in between the stock assessment surveys to provide additional information on the reproduction of the fish. The 17 m long Fisheries Department research vessel, *Ndunduma* powered with a 380 hp engine which pulls a Gulloppur bottom trawl net with a 23 m headrope and a 38 mm mesh cod end was used. The effective mesh size in the cod end was 4 mm due to the net liner used to ensure that escape through the meshes was minimal.

Eight stock assessment surveys were done and during each survey a total of 97 fixed trawl stations (54 in the SEA and 43 in SWA) were sampled. The stations were stratified into shallow 0-50 m, deep 50-100 m and very deep 100-150 m. Each trawl lasted for 30 minutes. Twelve additional surveys were done in between the quarterly surveys and 29 stations were sampled in each survey in the same depth ranges. The duration of each pull varied between 30-120 minutes in order to obtain a large sample. All trawling was done during the day at depths between 10 and 150m depth. It was not possible to sample in water less than 10 m deep because of restrictions imposed by the draught of the vessel.

B. meridionalis were sorted out from the main catch which was always composed of many small cichlids and some larger fish. Each of them was measured on board the vessel to the nearest 0.5 cm (total length) and most fish were weighed to the nearest 0.01 kg and those that were not weighed individually were collectively weighed as a species group to the nearest 0.1 kg.

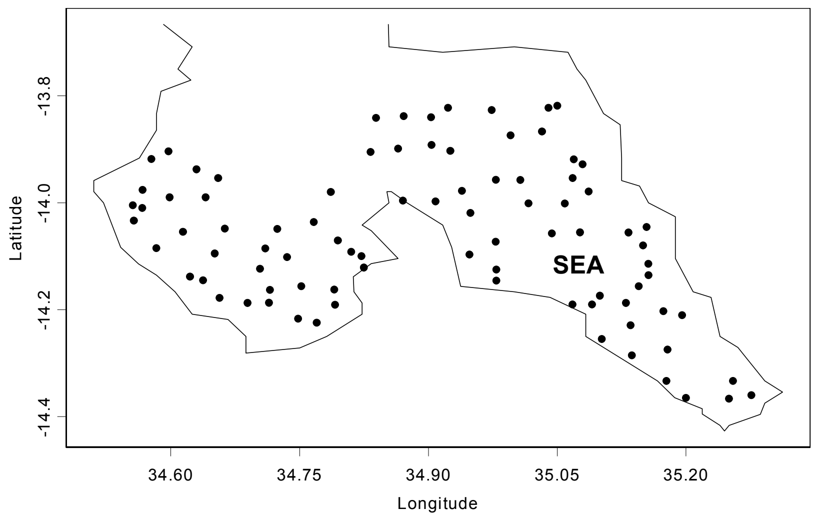

Figure 1. Map of southern of Lake Malawi showing the sampling stations used in the monitoring surveys.

Sex was determined after dissection and, in some cases the gonads were removed and weighed to the nearest 0.1g. The state of sexual maturity was assessed by the Nikolsky (1963) method, based on the external appearance of the gonads. The average length at first maturity was estimated by using the logistic equation:

$$p= 1/(1 + e^{-r(L-Lm)})$$

where p = the proportion of fish with ripe gonads, r = the slope of the curve, L = the length of fish and L_m = the mean length at 50% maturity.

The catch per unit effort (C/f) assumed as index of abundance was expressed as:

$$C/f = catch (kg) /swept area (ha).$$

Results

Distribution and relative abundance

The distribution and abundance of the total number of individuals caught during the stock assessment surveys are shown in Figure 2. *B. meridionalis* was widespread, being found at each station, in both arms. The mean biomass of *B. meridionalis* from the SEA and SWA were 4.8 and 4.0 kg ha^{-1} respectively and the mean biomass from the former was significantly different (t-test, $p < 0.05$) from the latter. The mean biomass decreased with increasing depth and it was not significantly different in the 0-50 and 51-100 m depth strata, but the average biomass in the > 100 m depth strata was significantly (t-test, $p < 0.05$) lower in both arms (Table 1). There was no significant difference between biomass values in different surveys (t-test, $p < 0.05$) (Table 2).

Size structure

The length-frequency distributions of the *Bagrus* in different depth strata in both SEA and SWA were generally unimodal with few at fish < 5.0 cm (Figures 3-6). This absence was not attributed to net selectivity because the cod end was covered with a liner, which retained small cichlids of about 1.0 cm. *B. meridionalis* ranged from 4.5 cm to 105 cm TL with single modes which varied with depth. The smaller size- classes generally dominated and showed asymmetrical distribution, particularly in waters deeper than 50m. In contrast, bimodal distribution patterns were noticeable in 0-20 m depth range, especially in the SEA indicating the presence of two distinct sizes of fish, small and large (Figures 7-10). The mean length decreased with increasing depth and many large individuals were caught in shallower water (< 20 m) in both arms (Figures 3-6). Females were significantly larger (t-test, $p < 0.05$) than males in both arms and also fish (both sexes) caught in the SEA were generally larger than those from the SWA (Table 3).

Sex ratios

The sex ratio, based on all Kampango sampled, did not deviate from 1:1 ratio (Table 4). Similarly, the sexes were equally represented in all depth strata except in shallow water of the SWA in which there were significantly more males (χ^2–test, $p < 0.05$) than females. Sex ratios grouped into 5-cm length classes varied within the length intervals and in some cases there were significant departures (χ^2–test, $p < 0.05$) from the 1:1 ratio (Table 5). Males predominated in all the small size intervals and female in the large size intervals.

Table 1. The mean biomass (kg ha^{-1}) and density (number per unit area) with standard error (s.e.) of *Bagrus meridionalis* in the southern part of Lake Malawi, June 1994 – March 1996.

Area	Depth (m)	Biomass		Density	
		Mean	s.e.	Mean	s.e.
SEA	0-50	4.90	(1.47)	5	(2.03)
	50-100	5.40	(1.50)	11	(2.74)
	>100	2.20	(1.63)	5	(5.24)
	0-150	4.80	(0.98)	8	(1.77)
SWA	0-50	5.20	(1.84)	8	(4.13)
	50-100	4.40	(1.34)	16	(4.82)
	>100	1.20	(0.72)	5	(3.70)
	0-150	4.00	(1.01)	11	(2.96)

Table 2. The mean biomass (kg ha^{-1}) with standard error (in brackets) of *Bagrus meridionalis* in the southern part of Lake Malawi during the quarterly surveys, June 1994 – March 1996.

	SEA		SWA	
Surveys	Biomass	s.e.	Biomass	s.e.
1	22.1	(2.16)	15.5	(2.33)
2	26.9	(2.90)	21.1	(3.00)
3	21.2	(2.56)	25.3	(3.93)
4	25.1	(2.70)	24.2	(2.87)
5	31.6	(3.53)	19.1	(2.51)
6	23.3	(2.36)	25.1	(2.92)
7	22.2	(2.43)	15.6	(2.14)
8	20.4	(3.09)	17.6	(2.73)

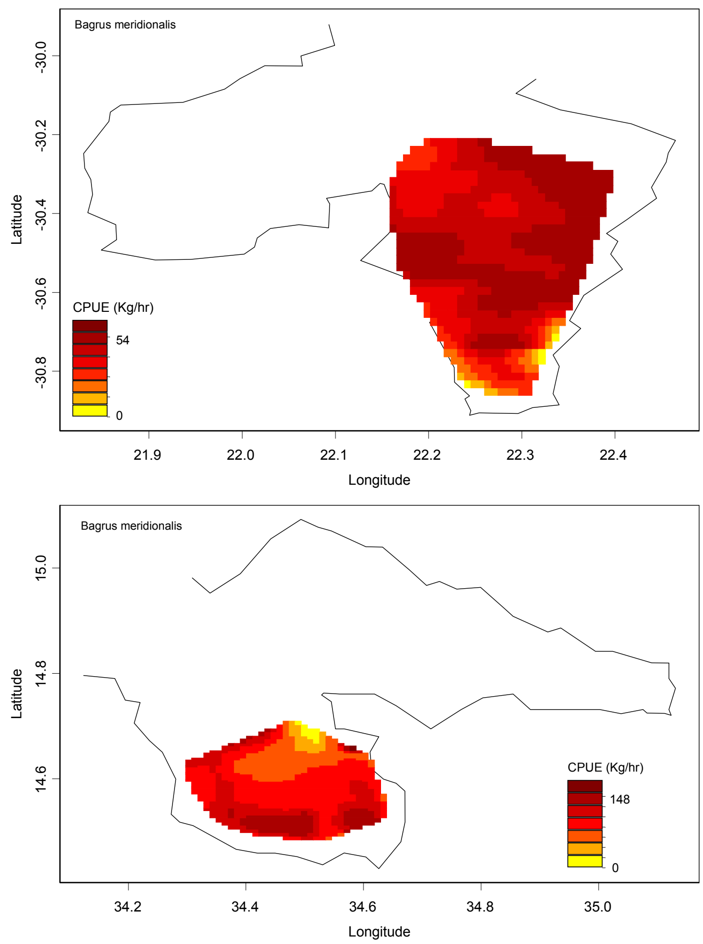

Figure 2. The distribution of *Bagrus meridionalis* caught by trawling during monitoring surveys in the south east arm (above)and south west arm (below) of Lake Malawi.

Table 3. The mean length (cm TL) with standard error of *Bagrus meridionalis* in the southern part of Lake Malawi during the quarterly surveys, June 1994 – March 1996.

Area	Sex	Mean	s.e	Total
SEA	Male	34.2	0.13	7582
	Female	38.4	0.18	7708
	both sexes	36.4	0.11	15290
SWA	Male	30.0	0.11	9002
	Female	31.3	0.15	8753
	both sexes	30.5	0.09	17753

Table 4. The ratio of males to females in relation to area of *Bagrus* in the southern part of Lake Malawi. * denote values that are significantly different (χ^2–test, $p < 0.05$) from a 1:1 ratio. N = number of fish examined.

Area	Depth (m)	Ratio
SEA & SWA	0-150	1.0
SEA	0-50	1.0
	51-100	1.0
	>100	1.0
SWA	0-50	1.1*
	51-100	1.0
	>100	0.9

Table 5. The ratio of males to females in relation to size (20 cm size classes) of *Bagrus* in the southern part of Lake Malawi. Asterisks denote values that are significantly different (χ^2–test, $p < 0.05$) from a 1:1 ratio. N = number of fish examined.

	Depth (m)					
	SEA			SWA		
Length class (m)	0-50	51-100	>100	0-50	51-100	>100
0-20	1.1	1.1	1.0	1.5*	0.9	1.0
21-40	1.2*	1.1*	1.0	1.1*	1.0*	0.9
41-60	1.3*	0.9*	0.7	1.5*	0.8*	0.4
61-80	0.1*	0.1*	0.5	0.2*	0.1*	0.4
81-100				0.1*		

Length-weight relationships

The length-weight relationships of *Bagrus* indicated that the growth is isometric i.e. the body length of an individual fish grows in proportion to the cubic root of its body weight. The relationship between log total length and log weight is:

$$\text{Log}_{10}W = -5.13 + 3.04 * \text{Log}_{10}L.$$

Reproductive patterns

The breeding periodicity of Kampango is shown in Figure 11. Ripe individuals were found throughout the year indicating that continuous breeding occurs, although there was a considerable seasonal variation in the proportion of adult fish with ripe gonads. The breeding peak, which was between November and December, coincided with the rainy season. Breeding individuals were recorded at all depths, but the species appear to prefer shallow water (< 50 m) (Table 6). *Bagrus meridionalis* reached sexual maturity at 52 cm TL in females and 43.8 cm TL in males in the southern part of Lake Malawi and the difference between sexes were significant (χ^2-test, $p < 0.05$) (Figure 12).

Table 6. The percentage of ripe *Bagrus* in relation to depth in Lake Malawi. N = number of fish examined.

Area	N	0-50	51-100	>100 m
SEA	3403	77.4	22.3	0.3
SWA	2292	78.1	21.6	0.3

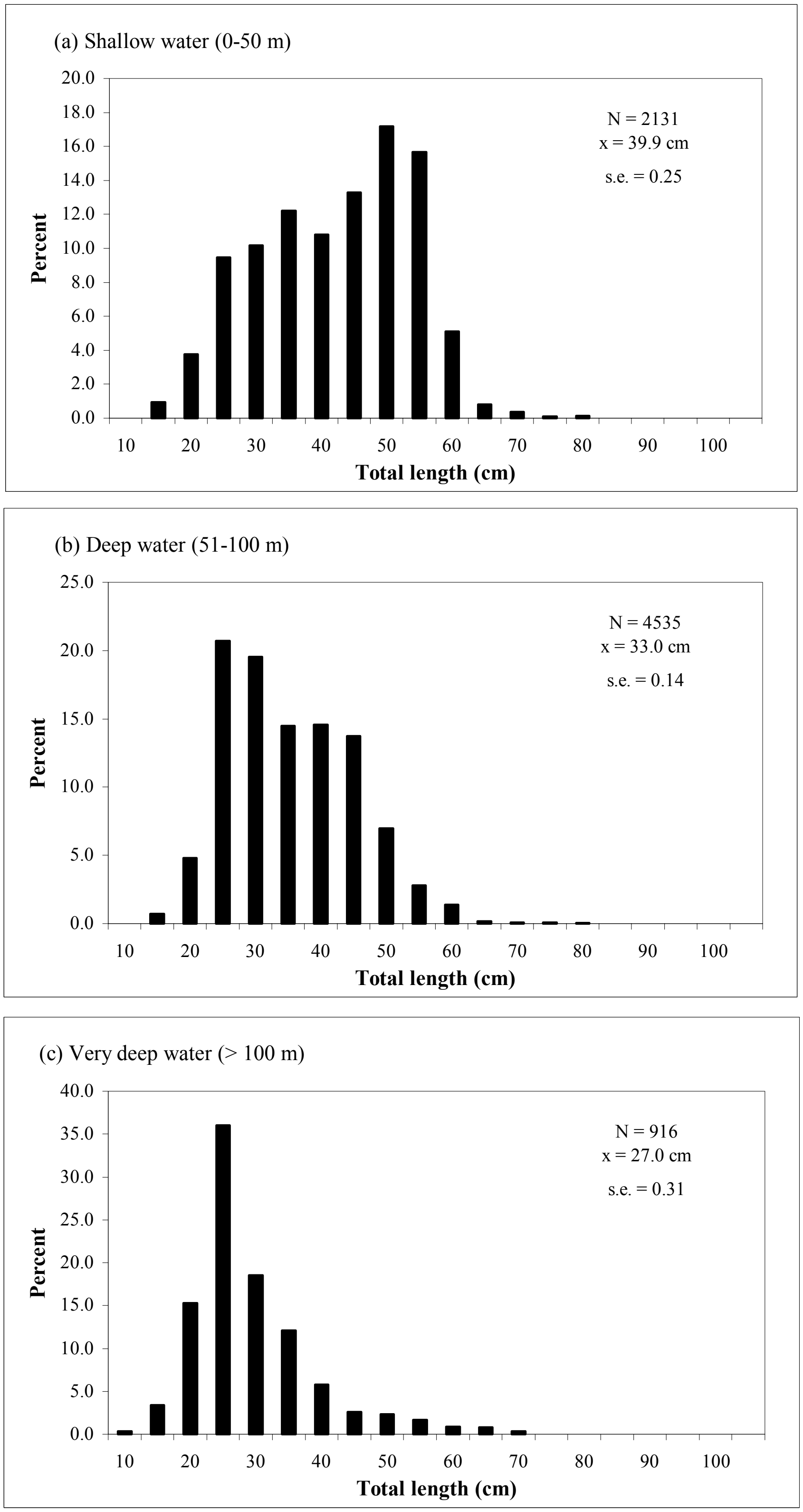

Figure 3. The length-frequency distribution of male *Bagrus meridionalis* in the south east arm of Lake Malawi collected between June 1994 and March 1996. All mean length numbers (x) are significantly different (t-test, $p < 0.05$).

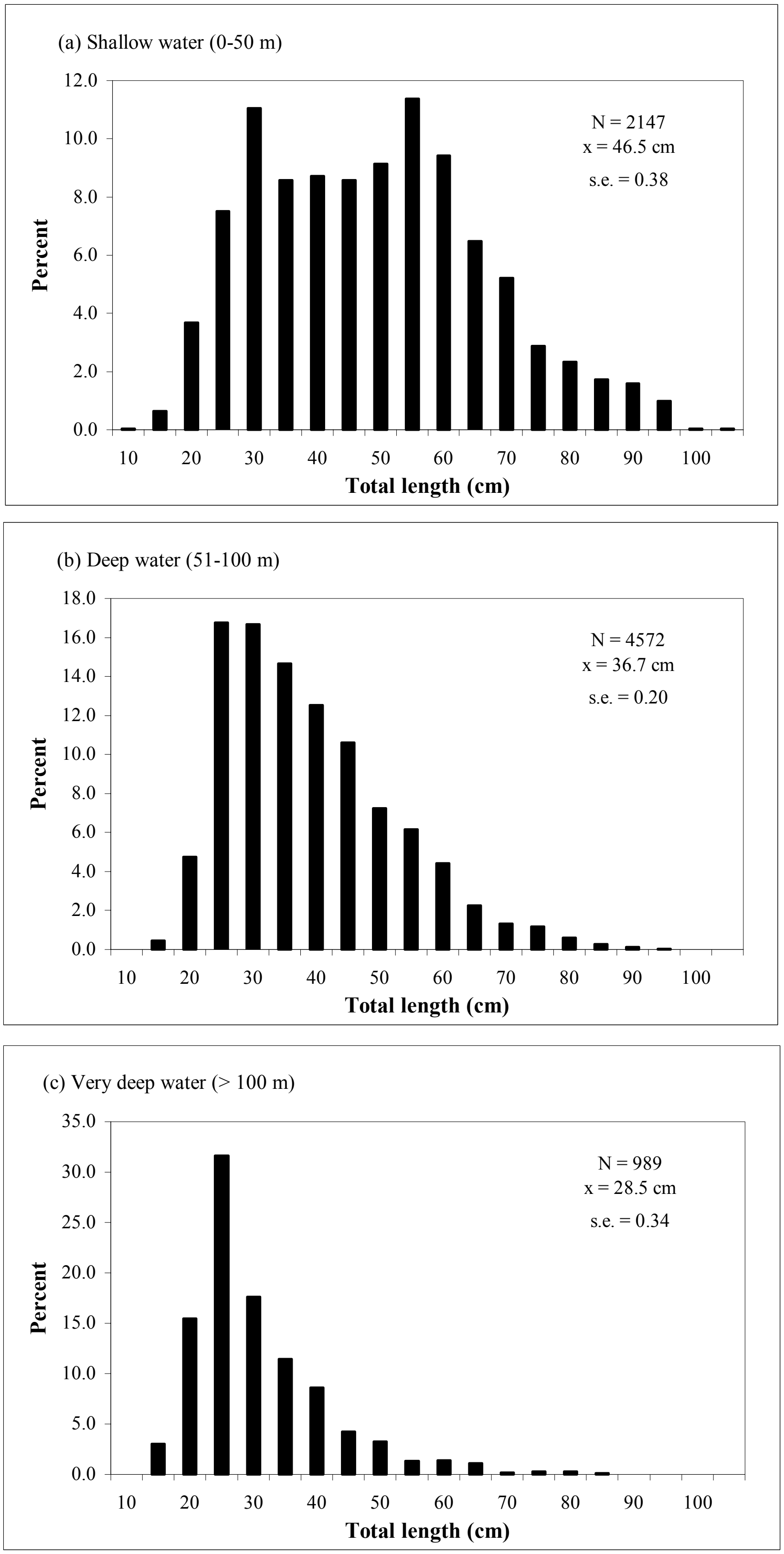

Figure 4. The length-frequency distribution of female *Bagrus meridionalis* in the south east arm of Lake Malawi collected between June 1994 and March 1996. All mean length numbers (x) are significantly different (t-test, $p < 0.05$).

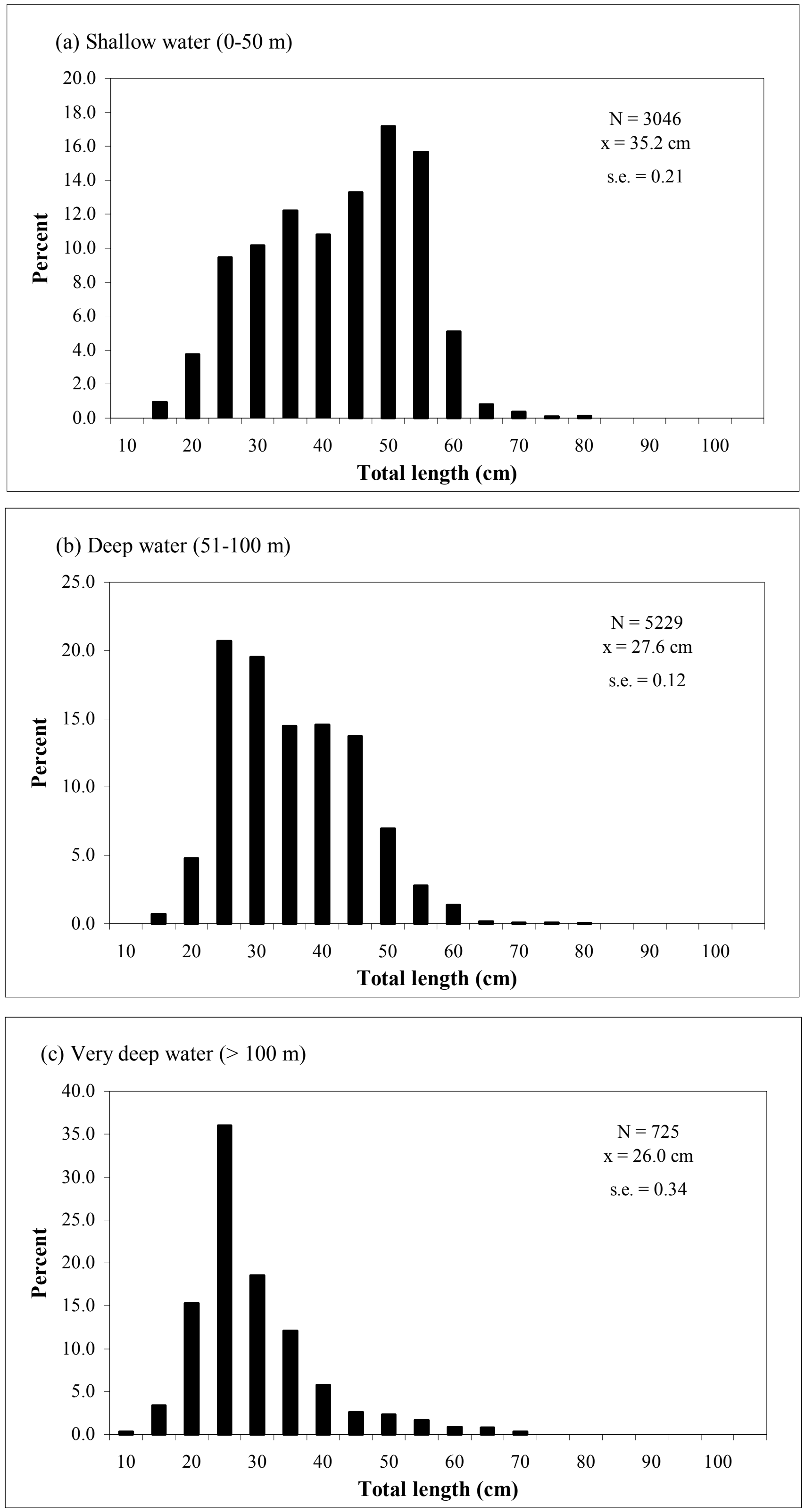

Figure 5. The length-frequency distribution of male *Bagrus meridionalis* in the south west arm of Lake Malawi collected between June 1994 and March 1996. All mean length numbers (x) are significantly different (t-test, $p < 0.05$).

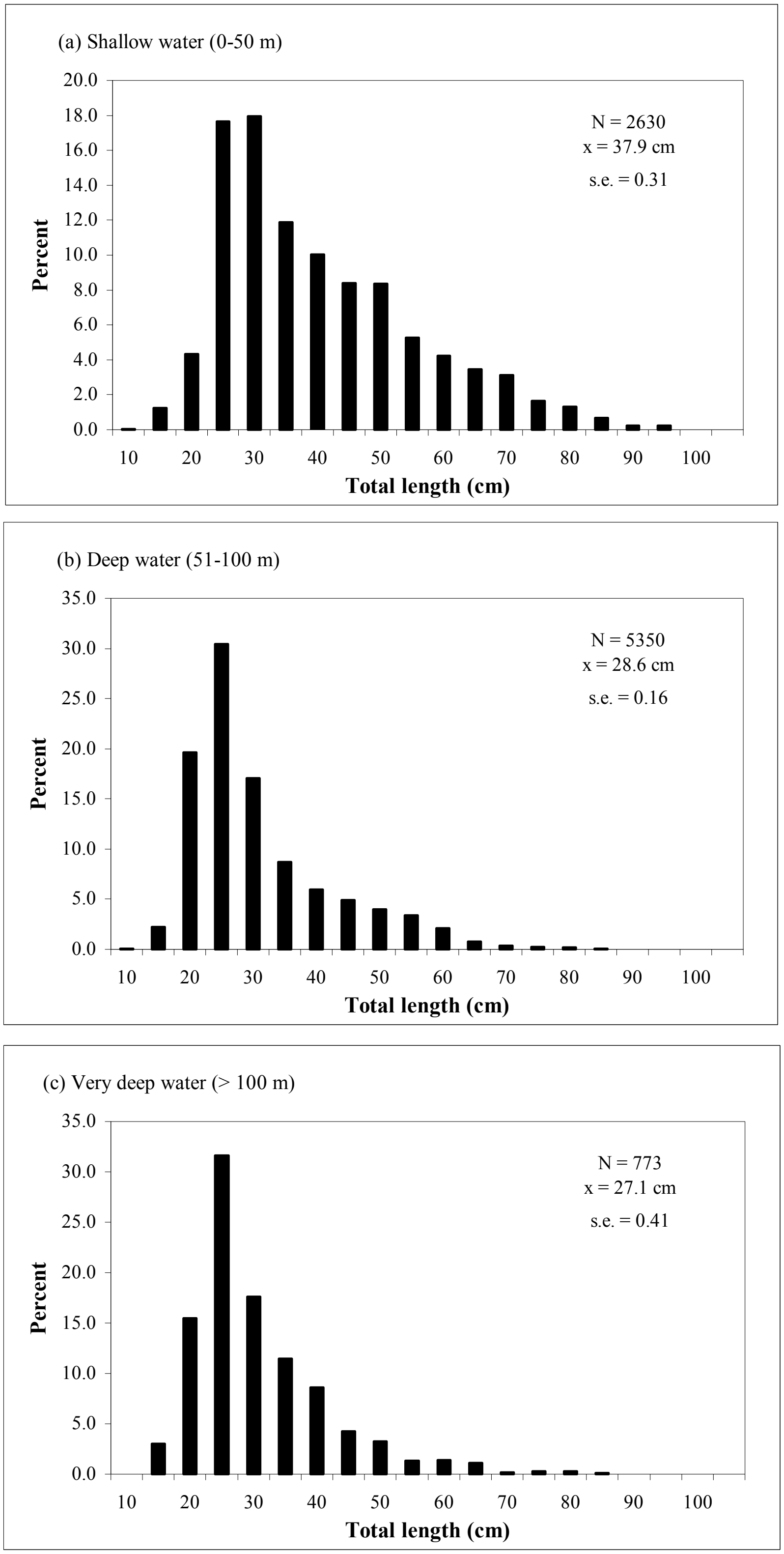

Figure 6. The length-frequency distribution of female *Bagrus meridionalis* in the south west arm of Lake Malawi collected between June 1994 and March 1996. All mean length numbers (x) are significantly different (t-test, $p < 0.05$).

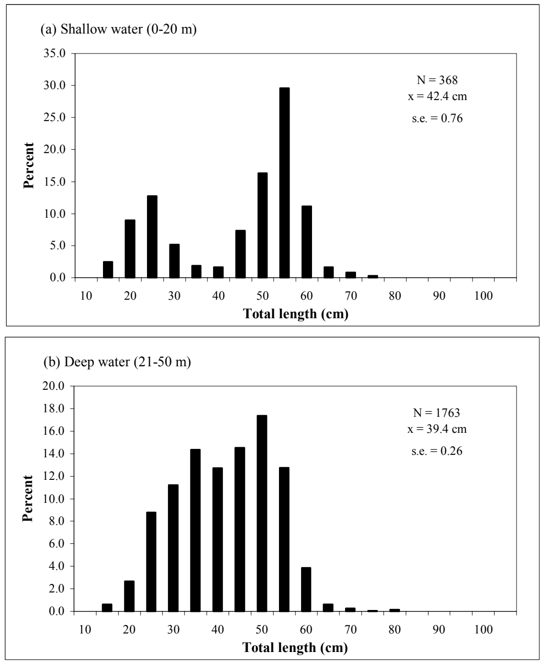

Figure 7. The length-frequency distribution of male *Bagrus meridionalis* in the south east arm of Lake Malawi collected between June 1994 and March 1996. All mean length numbers (x) are significantly different (t-test, $p < 0.05$).

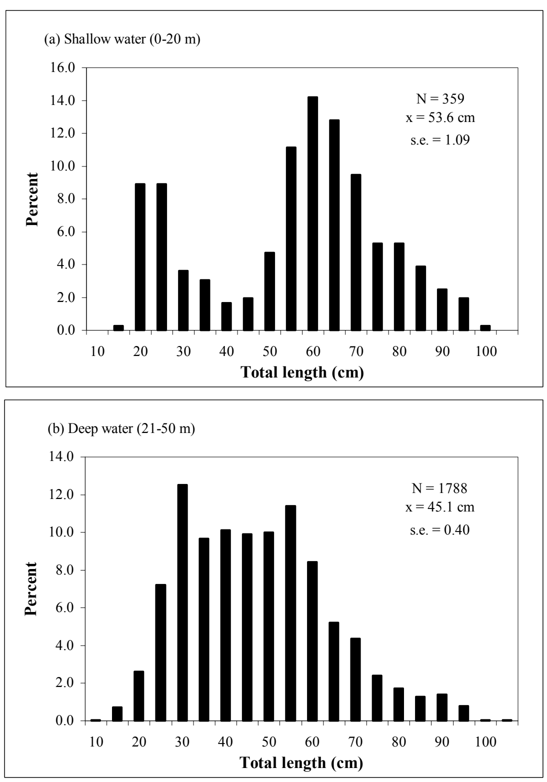

Figure 8. The length-frequency distribution of female *Bagrus meridionalis* in the south east arm of Lake Malawi collected between June 1994 and March 1996. All mean length numbers (x) are significantly different (t-test, $p < 0.05$).

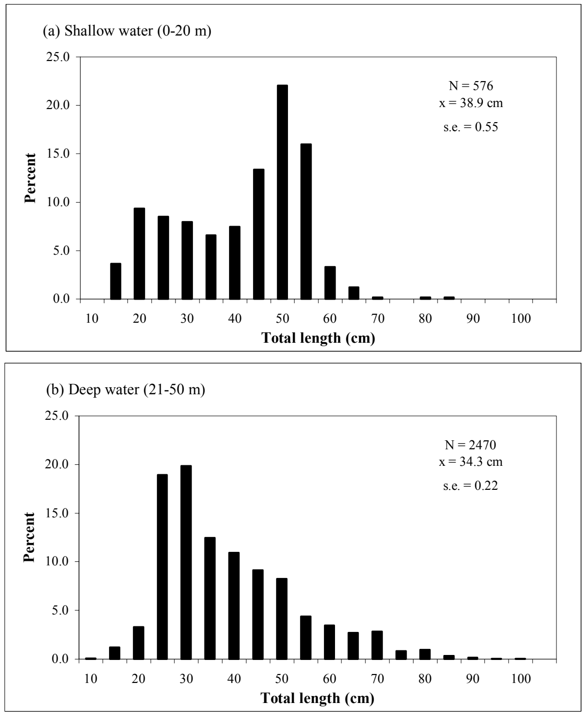

Figure 9. The length-frequency distribution of male *Bagrus meridionalis* in the south west arm of Lake Malawi collected between June 1994 and March 1996. All mean length numbers (x) are significantly different (t-test, $p < 0.05$).

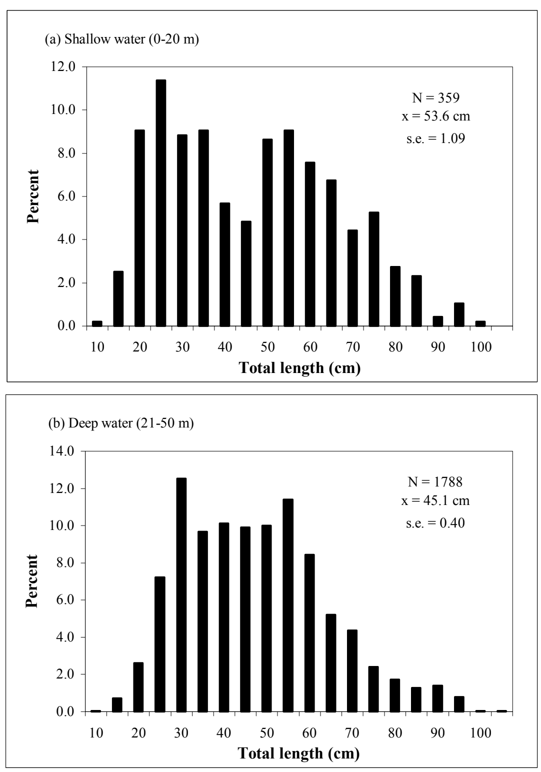

Figure 10. The length-frequency distribution of female *Bagrus meridionalis* in the south west arm of Lake Malawi collected between June 1994 and March 1996. All mean length numbers (x) are significantly different (t-test, $p < 0.05$).

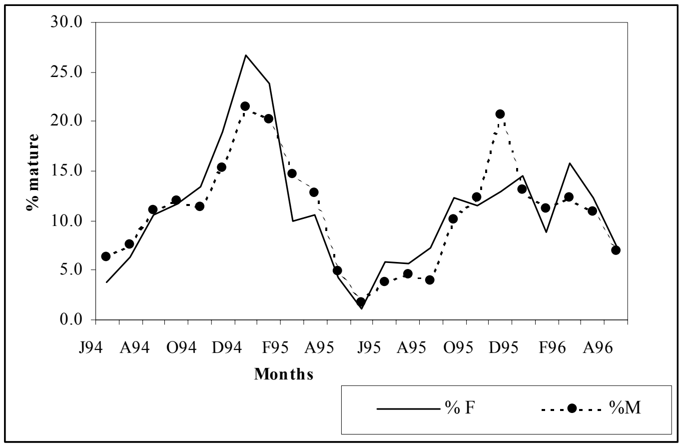

Figure 11. Breeding periodicity of male and female *Bagrus meridionalis* in the southern part of Lake Malawi. Samples were collected between June 1994 and April 1996.

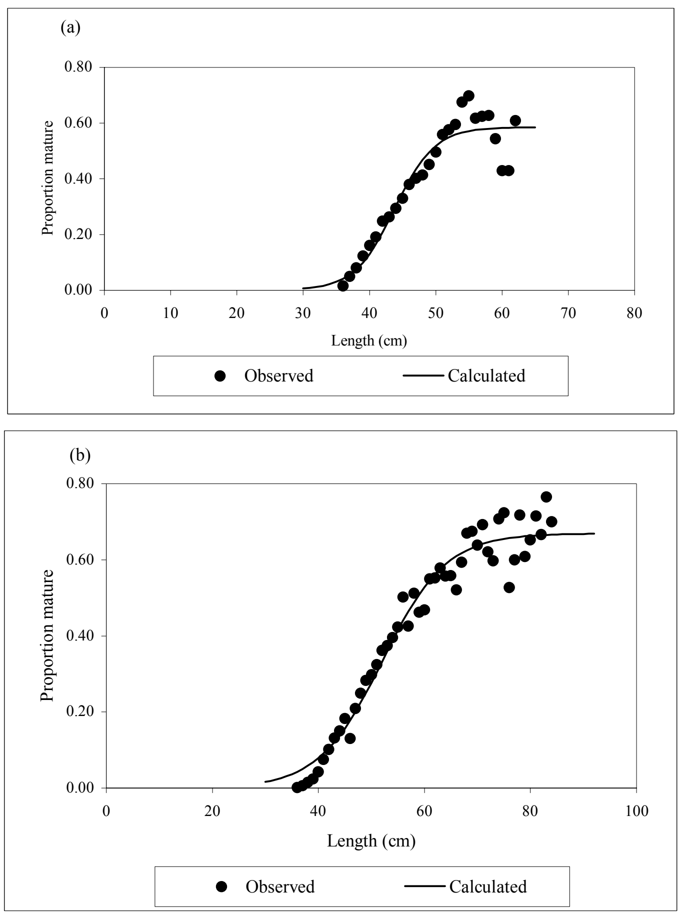

Figure 12. The mean length at first maturity in (a) male and (b) female *Bagrus meridionalis*. (L_m = 43.8 cm TL for males and 52.0 cm TL for females).

Discussion

Bagrus meridionalis were commonly caught in the bottom water trawl, which is consistent with previous studies (Turner 1982, Thompson *et al.* 1996). Depth is the most important factor determining its distribution. *B. meridionalis* were described as broadly eurytopic in their distribution patterns because they have a wide geographical distribution and inhabit a variety of habitats (Figure 2). They can live in a wide range of conditions, often moving from one habitat to another.

The length-frequency distributions of *B. meridionalis* are 'dome-shaped', a phenomenon usually attributed to gear-selectivity, in particular gillnets (Ricker 1975). In this case it is negated because the gear used in this study is almost non-selective (since the smallest specimen of *Bagrus* caught in this gear was about 4.5 cm TL). These distributions probably reflect the size gradation of *Bagrus* with depth in the lake. The absence of the smallest length classes of *Bagrus* suggests that they occur in water < 10 m deep or in areas where trawling was not possible. These small fish are being guarded in their nests, which are often situated adjacent to rocks (Jackson *et al.* 1963). The decrease in the numbers of large fish in shallow waters may reflect high fishing pressure by the small-scale commercial fisheries. The bi-modal distribution *Bagrus* in < 0-20 m water depth range was attributed to gillnet fishery (Figures 7-10). The gillnet selectivity studies (Jackson *et al.* 1963, Tweddle 1975, Sipawe, 2001 in prep.) indicate that the gill-net selectivity peak is between 35-55 cm TL if all meshes are combined. Therefore, fish over 40 cm TL were less liable to be caught, and fish less than 35 cm TL more exposed to higher fishing mortality.

There was size gradation with depth indicating that some zonation or restricted movement occurs (Figures 3-6). The presence of adults in shallow water (< 50 m) and juveniles in deeper water (> 50 m) may be a way of avoiding interspecific competition and cannibalism. The difference in mean length between fish caught in the SEA and SWA may be explained by the following: 1) the fish stocks of Kampango from the SEA is different from that of the SWA, and 2) there is less competition of food resources in the SEA than SWA which perhaps promotes faster growth of *B. meridionalis* in the former. The numbers of fish per km^2 are 473 and 813 in the SEA and SWA, respectively. Fishing pressure is higher in the SEA than in the SWA if the number of fishing gear and fishermen are considered to be indicative of fishing mortality (Table 5). Similar fishing pressure could account for the reduced number of large fish in the 0-50 m depth stratum. The intensity of gillnet fishing pressure on the Kampango population structure is evident in Figures (7-10).

B. meridionalis was most abundant in < 100 m water depth. The variation in abundance with depth reflected depth preferences and numbers. Size gradation indicates that their depth distribution was determined by depth preferences. The effect of numbers on estimates of abundance is clearly observed in this species where few large fish in the 0-50 m depth range gave a similar estimate of biomass to that of many small fish in the 51-100 m depth range. The abundance of *Bagrus* throughout the study period was remarkably constant and there was no evidence of seasonality. This suggested that recruitment remained constant because its population structure was mainly composed of small individuals.

The spatial distribution of the overall sexes was within the expected ratio. The sex ratio however, was different in shallow water (< 50 m) in the SWA and in the length classes and this discrepancy was mainly attributed to fishing pressure. Studies by Jackson *et al.*, (1963) and Tweddle (1982) indicated that more females were caught in gillnets than males and the most vulnerable fish size was between 35-55 cm TL. This is confirmed by this study because 61.3% (32.8% males, 28.5% females) of the 33052 fish examined were in the 35-55 cm TL range. The difference in sex ratio was also significant between 45-55 cm TL (Table 3). Females were fished more than the males probably because of their fast growth rate. The significant difference in sex ratios above 55 cm TL could be attributed to growth pattern. Males seemed not to grow as big as females.

The main breeding period of *Bagrus meridionalis* occurred in the rainy season and the actual duration depends on the length of the rains, which is consistent with other studies (McKaye 1986: Jackson *et al.* 1963, Tweddle 1975, 1982) and other bagrids (Dadzie and Ochieng-Okach 1989). The breeding peak coincided with the zooplankton production peak (Irvine 1995) that ensures that food is available for the young. Breeding occurred within the same depth range in which they foraged (Table 6) which suggests that there was no spawning migration (Banda, 2000). The inshore migration in spawning *B. meridionalis* (Jackson *et al.* 1963, Tweddle 1982) may reflect the need for breeding fish to find suiTable spawning sites.

The length at first maturity differed in male and female *B. meridionalis*, with females maturing at a larger size, probably because of different growth rates between sexes. The results were similar to estimates by Eccles (1972), but not to those by Tweddle (1982) and Bernacsek *et al.*, (1983). The difference in mean lengths could be explained by: 1) the difficulty in determining the gonadal stages, thereby erroneously including or excluding small fish in the ripe category, 2) different stocks were studied and 3) the sample size was too small in the early studies as higher values were obtained by Eccles (1972) with a larger sample (1409) compared to Tweddle (1982) and Bernacsek *et al.* 1983 who examined about 200 and 170 specimens, respectively.

Conclusion

The present study indicates that fishing is having a major impact on the population structure of *Bagrus*. Different fisheries have different impact on the population. The selective cropping of certain length classes most of which are immature is carried out by small-scale commercial fisheries (gillnet fishery and longline fishery) in shallow water while unselective fishing is undertaken by trawlers in deep waters. The result is that both fisheries will invariably eliminate large fish species including *B. meridionalis*.

B. meridionalis has maintained a substantial relative stable population especially in the southern part of the lake where both fisheries operate because the fisheries have been limited to coastal areas and the decline in large fish has always been compensated by improved recruitment and the fact that the nursery areas are in the less exploited deep water. The contention that the decline in the catches of *B. meridionalis* was caused by high fishing pressure on the immature fish (FAO 1976, Fryer 1984, Alimoso 1989, Alimoso, *et al.* 1989) is not substantiated by these studies because of their life history. Therefore, this decline may reflect the absence of certain length classes of fish as the small-scale commercial fisheries are selective in nature. This raises a question as to whether the noted general decline in the catch is indicative of overfishing or gear selectivity. However, the population of *Bagrus* will definitely decline with the expansion of the expansion of the deep-water fishery and may lead to a collapse because both adults and juveniles will be vulnerable to exploitation.

This size structure of *Bagrus* from the two arms indicates that the populations seem to be different which necessitates the establishment as to whether these populations are indeed distinct fish stocks. Future research priorities should focus on mapping the populations and distinguishing them for management purposes. These studies should be accompanied by studies on the biology and population dynamics of the most important commercial fish species.

Acknowledgements

This work forms part of my PhD studies, which was funded by Icelandic Development Agency.

References

Alimoso, S.B., 1989. Management of catfish (*Bagrus meridionalis* Günther) in southern Lake Malawi. Fishbyte, 7(2):10-12.

Alimoso, S.B., Magasa, J.H. and van Zalinge, N.P. 1989. Exploitation and Management of fish resources in Lake Malawi. In: Fisheries of the African Great Lakes. Wageningen, Netherlands, Occassional Paper No. 3, 83-95.

Banda, M.C. 2000. The biology and ecology of the catfishes of the Genera *bathyclarias* and *Bagrus* in Lake Malawi. Unpublished PhD. Thesis. University of Zimbabwe.

Bernacsek, G.M., Massingo, A. and Contreras, A. 1983. Exploratory gillnetting in Lake Niassa, Moszambique, with biological profiles of the main taxa caught. FAO/GCP/MOZ/oo6/SWE (phase II). Field Document, 5, 129 pp.

Dadzie, S. and Ochieng-Okach, J.L. 1989. The reproductive biology of a suluriod catfish, *Bagrus docmak* (Forsskål)(Cypriniformes, Bagridae) in the Winam Gulf of Lake Victoria. Revue Zoology of Africa, 103, 143-154.

Eccles, D.H. 1972. *Bagrus meridionalis* (Kampango). Department of Agriculture and Fisheires Annual Report 1964-65, Part II:6-13.

FAO, 1976. Promotion of intergrated fishery development, Malawi. Analysis of the various fisheries of Lake Malawi. FAO, FI:DP/MLW/77/516. Technical report 1.

Fryer, G. 1984. The conservation and rational exploitation of the biota of Africa's Great Lakes. In: Conservation of Threatened natural Habitats. Hall A.V. (Ed). South African Natural Science Programmes Report (92), CSIR, Pretoria, pp. 135-146.

Irvine, K. 1995. Standing biomasses, production, spatial and temporal distributions of the crustacean zooplankton. In: The Fishery Potential and Productivity of the pelagic Zone of Lake Malawi/Niassa. Menz, A. (Ed). Chatham, U.K: Natural Resources Institute, pp. 85-108.

Jackson, P.B.N., Iles, T.D. Harding, D. and Fryer, G. 1963. Report on the survey of northern Lake Nyassa, 1954-55. Joint Fisheries Research Organisation. Government Printers. Zomba, Malawi.

LoVullo, T.J., Stauffer, J.R. and McKaye K.R. 1992. Diet and growth of brood of *Bagrus meridionalis* Günther (Siluriformes: Bagridae) in Lake Malawi, Africa. Copie, 4, 1084-1088.

McKaye, K.R. 1985. Cichlid-catfish mutualistic defence of young in Lake Malawi, Africa. Oecologia, 66, 358-363.

McKaye, K.R. 1986. Trophic egg and parental foraging for young by the catfish *Bagrus meridionalis* of Lake Malwi, Africa. Oecologia, 69(3), 358-363.

McKaye, K.R. Mughogho, D.E. and LoVullo, T.J. 1992. Formation of the shellfish school. Environmental Biology of Fisheries, 35, 312-218.

Nikolsky, G.V. 1963. The ecology of fishes. New York: Academic Press.

Ricker, W.E. 1975. Computation and interpretation of Biological Statistics of Fish Populations. Bulletin of the Fisheries Research Board of Canada, 191, 1-382.

Roberts, K.S. 1990. Ageing the Lake Malawi catfish *Bagrus meridionalis* using otoliths. Unpublished MSc. Thesis. University of Wales.

Sipawe, R. 2001. Gear and species selectivity of the gillnet fishery in Lake Malawi. (**Proceedings of this symposium**)

Thompson, A.B. Allison, E.H. and Ngatunga, B.P. 1996. Distribution and breeding biology of offshore pelagic cyprinids and catfish in Lake Malawi/Niassa. Environmental Biology of Fishes, 47, 27-42.

Turner, J.L. 1982. Analysis of purse seine and gillnet catch data off Nkhata Bay, Lake Malawi, from March 1980 to April 1981. In: Biology Studies on the Pelagic Ecosystem of Lake Malawi, FI: DP/MLW/75/019, Technical Report 1, FAO, Rome, pp. 154-162.

Tweddle, D.1975. Age and growth of the catfish *Bagrus meridionalis* Günther in the southern Lake Malawi. Journal of Fish Biology, 7, 667-685.

Tweddle, D. 1982. Fish breeding migrations in the North Rukuru area of Lake Malawi with a note on gillnet colour selectivity. Journal of Science and Technology (Malawi), 3(2), 67-74.

Feeding habit and development of feeding-related morphological characters in *Oreochromis shiranus* (Boulenger, 1896) larvae and juveniles in Malawi

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Abstract
Stomach content, gut length, morphology of pharyngeal teeth and gill rakers of *Oreochromis shiranus* larvae and juveniles were investigated in order to elucidate the timing of feeding habit conversion, and the relationships between feeding habit and the feeding-related morphological characters. Stomach content showed that the feeding habit of fish drastically changed between 14-20 mm TL from zooplanktovorous to herbivorous (phytoplanktovorous). Pharyngeal plate and teeth were already ossified in the smallest fish of this study (9.95 mm TL) and teeth number increased as fish grew. Percentage length of gut ((gut length/TL) x 100 %) became more than 100 % when TL reached 15-20 mm, falling mostly under the size with feeding habit conversion. Gill rakers in 4^{th} gill arch started appearing at 14 mm TL when the feeding habit started converting. Consequently, the conversion of feeding habit in *Oreochromis shiranus* started when the percentage intestine length became over 100 % and gill rakers in 4^{th} gill started appearing, and pharyngeal teeth did not seem to relate directly with such feeding habit conversion.

***Key words**: Oreochromis shiranus, feeding habit, morphological development, zooplanktovorous, phytoplanktovorous*

Introduction
Lake Malawi provides the main fish protein resources to the Malawian public. However, the fish catch in Malawi has declined since the late 1980s from over 70,000 t in 1989 to 40,000 t in 1999 (Zidana, 2000), leading to the decrease of fish consumption by the Malawian public. Therefore, the government of Malawi has attempted to promote the finfish aquaculture since late 1980s. However, there have been no remarkable developments in aquaculture production in Malawi, although the number of small-scale aquacultural farmers and their production has recently increased (Sidira, 2001).

It is well known that *Oreochromis* species are phytoplanktovorus (Appler, 1985) and that the protein requirement, for a relatively high growth rate, is low. Therefore, *Oreochromis shiranus* is considered to be the most recommendable species for aquaculture in Malawi, and the majority of the small-scale farmers (92.9 %) grow this species *(*Sikawa, 1999). However, the feeding performance of larvae and juveniles of *Oreochromis shiranus* in Malawi has been scarcely reported so far, although the feeding and growth of fish larvae and juveniles are indispensable aspects for further development of seed production and nursing techniques in aquaculture.

When considering the feeding performance of fish larvae and juveniles, the morphological development relevant to feeding habit and/or behavior, as well as the internal secretion, should be elucidated. In this study, therefore, the stomach content and the feeding-related morphological characters, such as gut length, gill rakers, pharyngeal teeth and stomach content of *Oreochromis shiranus* larvae and juveniles were investigated and the relation between the morphological development and feeding habit was discussed.

Materials and methods
This study was conducted using larvae and juveniles of *Oreochrommis shiranus* collected from the experimental earthen pond (15 x 50 m/m, 60 cm depth) of Bunda College of Agriculture, University of Malawi, during 24 May ~ 15 June 2000. Water temperature during this period was 17.5 ~ 21.0°C. In this pond, 333 males and 667 females were stocked in September 1999. The fish mostly relied on natural food (plankton) although 20 kg of maize bran was given as supplemental diet to the fish once a week.

Fifty larvae and juveniles were used in this study. The size (total length) rage of fish was 9.95 ~ 50.30 mm. Fish were preserved in 5-10 % formalin immediately after collection. Twenty specimens were treated as the double stained transparent specimen, following the method described by Kawamura and Hosoya (1991). These specimens were used for determination of the number of pharyngeal teeth on the posterior edge of lower pharyngeal plate and the ossified gill rakers of 4^{th} gill arch. Other specimens were used to observe the stomach contents and intestine length (mm). The percentage length of intestine (PLI) was then calculated (PLI = [intestine length / total length] x 100 %). The percentage of zooplankton mass and algal mass in stomach in each fish was obtained on the basis of the acreage of each organism in the microscopic image. The identification of zooplankton and phytoplankton in stomachs were attempted to higher than family level.

Results

Development of pharyngeal teeth and gill rakers

Both lower and upper pharyngeal plates were already ossified in the smallest fish used in this study (9.95 mm TL). The number of pharyngeal teeth on the most posterior portion of lower pharyngeal plate increased as fish grew from 8 at 9.95 mm TL to 36 at 43.65 mm TL (Figure 1). The relationship between TL and the number of pharyngeal teeth was expressed by the following two regressions intersecting at (19.91, 22.66); P = 1.29·L – 3.02 (91 = 0.95, n=9) and P = 0.50·L + 12.71 (r = 0.86, n = 11) where P is the number of teeth of lower pharyngeal plate and L is total length. The width of lower pharyngeal plate linearly increased as fish grew (Figure 2). The relationship between TL and the width of the lower pharyngeal plate was expressed by W = 0.097·L - 0.059 (r = 0.99, n = 20), where W is width of lower pharyngeal plate and L is total length. Algal cells attached on the surface of pharyngeal plate with mucus were frequently observed in fish larger than 20 mm TL.

Gill rakers in the 4th gill arch did not appear in fish smaller than 14.00 mm TL although the 4th gill arch was already formed. Gill rakers in 4th gill arch started appearing at 14.05 mm TL and increased in number as fish grew (Figure 3). The relationship between TL and the number of gill rakers of the 4th gill arch, after gill rakers appeared, was expressed by GR=1.52·L-14.46 (r=0.98, n=17) where GR is the number of gill rakers and L is total length.

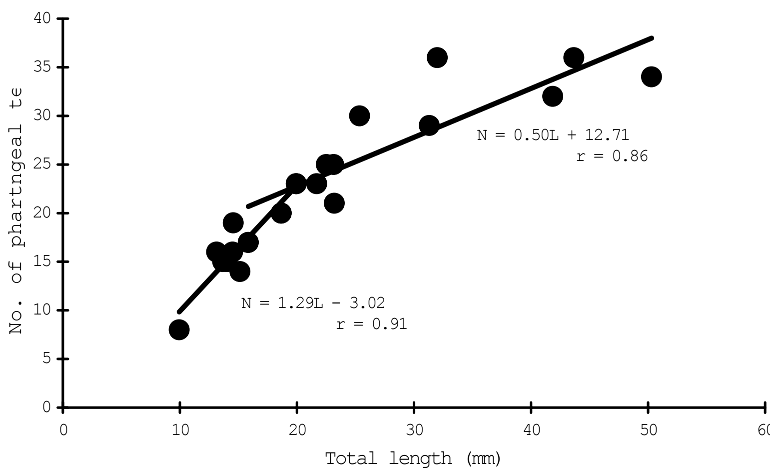

Figure 1. Relationship between total length and the number of pharyngeal teeth in *O. shiranus* larvae and juveniles.

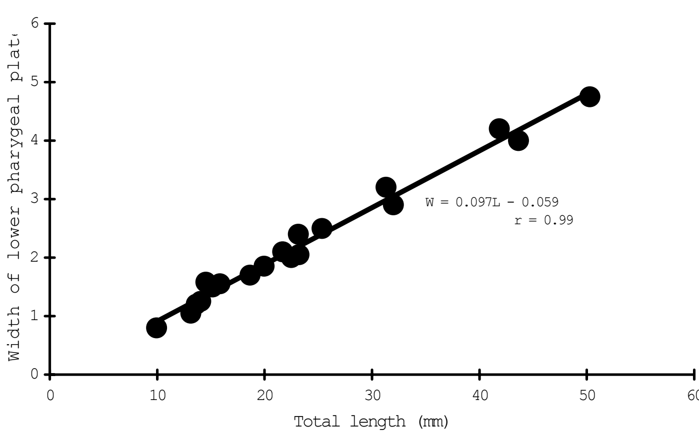

Figure 2. Relationship between total length and the width of lower pharyngeal plate.

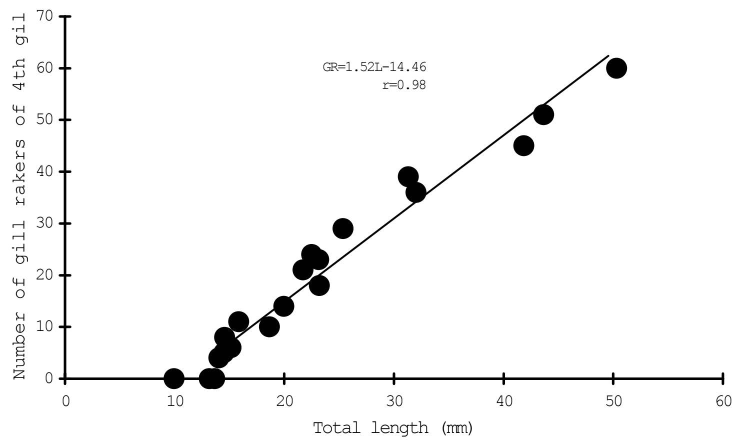

Figure 3. Relationship between total length and the number of gill rakers of 4th gill arch.

Intestine length

Gut length was measured in 30 specimens and the intestines were elongated from 8.00 to 215.00 mm in 12.75 ~ 41.30 mm TL of fish. Percent length of intestine (PIL = [intestine length / total length] x 100 %) smaller than 15.00 mm TL was less than 100%. It increased as fish grew and reached more than 500% when TL was over 40 mm. The relationship between TL and PIL was expressed as $PIL = 1.01 \cdot L^{1.64}$ (r = 0.95, n=30), where PIL is percent intestine length and L is total length.

Feeding habit

Fish smaller than 14.00 mm TL mainly fed on zooplankton, such as Rotifers, Copepods, Brachiopods (Table 1). Feeding habit was changed drastically between 14.00 and 20.00 mm TL from zooplanktovorous to phytoplanktovorous including mono-cellular green algae, diatoms etc. (Table 1). Fibrous matter was occasionally observed in the stomach contents and seemed to originate from water-plants (Table 1). Fish larger than 20.00 mm TL dominantly fed on phytoplankton or algae even though zooplankton existed in water, as indicated by the stomach content of smaller fish that mainly fed on zooplankton.

Table 1. Zooplankton and algae found in stomachs of *Oreochromis shiranus* larvae and juveniles.

Fish size	Main content in stomach
< 15.00 mm TL	Rotifers Branchionidae, Euchlandae Copepods Diatomidae, Cyclopidae Branchiopods Daphnidae
>15.00 mm TL	Diatoms Rhizosoleniaceae, Naviculaceae, Nitzschiaceae Green algae Characiaceae, Palmellaceae, Coelastraceae Zygnemataceae Blue-green algae Chroococcaceae Water plant (unidentified)

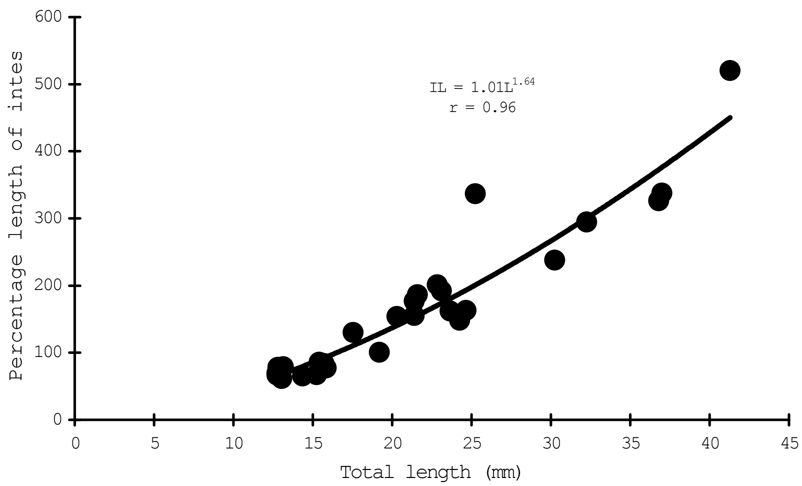

Figure 4. Relationship between total length and the percentage length of intestine.

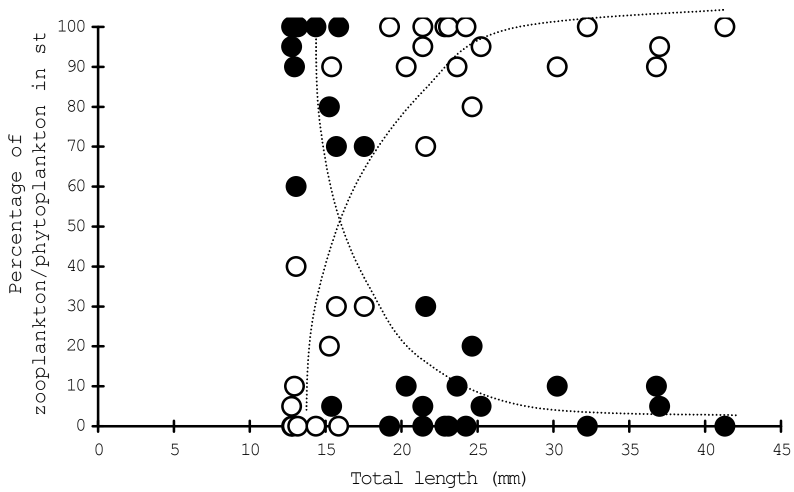

Figure 5. Relationship between total length and the percentage contents of zooplankton/algae in stomach.

Discussion

Although *Oreochromis* species are known to be phytoplanktovorous or herbivorous (Appler, 1985, Hofer, 1988), the feeding performance at larval and early juvenile stages has scarcely been considered. In this study, the conversion of feeding habit from zooplanktovorous to phytoplanktovorous or herbivorous was observed to take place between 14.00 and 20.00 mm TL on the basis of stomach content analysis (Table 1). This observation elucidated that *O. shiranus* changed the feeing habit when TL reached more than 20 mm TL, although they may be able to adapt to feed on zooplankton if phytoplankton is insufficient in quantity. When the conversion in feeding habit took place, the gill rakers of 4th gill arch had just appeared (Figure 5) and percentage intestine length was over 100 % (Figure 4). In herbivorous and omnivorous fish, the function of the gill raker as a filter for phytoplanktonic organisms is well known. So, in *O. shiranus*, the development of gill rakers was also strongly related to herbivorous feeding habit development. Digestive ability of fish increases with the development of digestive organs and the enzyme production systems. Morioka (1993) reported that the increase in percent intestine length drastically increased after the transitional phase from larval to juvenile stages in a tropical omnivorous fish *Chanos chanos*. During the transitional phase from larvae to juveniles, the digestive systems develop morphologically and physiologically and they subsequently have the specific peculiarity in feeding habit (Tanaka, 1975). In *O. shiranus*, the transitional phase from larval to juvenile stages and the drastic changes in morphology and physiology are considered to take place at lengths of 15 – 20 mm TL.

Although characters in pharyngeal teeth, i.e. the number of pharyngeal teeth (Figure 1) and the width of lower pharyngeal plate (Figure 2), may be related with the feeding habit conversion, the function of pharyngeal teeth for feeding could not be identified in this study. The decline of increasing rate of pharyngeal teeth after 20 mm TL (Figure 1) may demonstrate that the pharyngeal teeth are more functional for feeding on zooplankton and less functional when fish becomes herbivorous or phytoplanktovorous. In addition, the algae adhering to the surface of the pharyngeal plate by mucus was often observed in this study as well as in *Tilapia rendalii* (K. Utsugi, pers. comm.). This suggests that the pharyngeal teeth (plate) may function to transport phytoplankton to the digestive tract after the filtering of planktonic organisms by the gill rakers.

In this study, the larvae and juveniles were sampled in May and June, this period was the dry season and water temperature was relatively low as 17~21ºC. This indicates, as additional information, that *O. shiranus* breeds almost throughout the year even though the lowest water temperature were less than 20ºC. This is in contrast to Yata and Miyashita (1988) report that *O. niloticus* did not breed under less than 23ºC.

Consequently, the stage at the occurrence of feeding habit conversion and the development of several characters relevant to feeding of *O. shiranus* larvae and juveniles were elucidated in this study. We believe that this information is useful not only for the technical development in aquaculture but the resource management fields for further understanding the performance of the species in the wild. Since the decline in resource level has been recently pointed out especially in the lake chambo (*O. karongae* etc.) (Zidana, 2000). Researches on the early life history of fish are indispensable when considering the resource management aspects, and the surveys on feeding biology of fish larvae and juveniles have important roles for providing the information relevant to fish survival at early developmental phases which influences recruitment success. Taking the recent decline in the fish resource level into account, the research on the early biology of fish should be more emphasized in order to obtain more information for understanding the early life history of fish.

Acknowledgements

We express our great thanks to DR. J.S. Likongwe, Department of Aquaculture and Fisheries Science, Bunda College of Agriculture, University of Malawi, for his advisory comment. We also thank Mr. O. Matambo and technical staff of the department for sample collection. Lastly, We are grateful to Japan International Cooperation Agency (JICA) to give us the opportunity to conduct this research.

References

Appler, H.N. 1985. Evaluation of *Hydrodictyon reticulatum* as protein source in feed for *Oreochromis* (*Tilapia*) *niloticus* and *Tilapia zillii*. J. Fish. Biol., 27: 327-334.

Brooks A.C and Maluwa A.O., 1997, Technical Supplement, Fish Farming in Malawi, A case study of the Central and Northern Regions Fish Farming Project, Malawi Government, Ministry of Natural Resources. Malawi.

Hofer, R. 1988. Morphological adaptations of the digestive tract of tropical cyprinids and cichlids to diet. J. Fish. Biol., 33: 399-408.

Kawamura, K. and K. Hosoya (1991) A modified double staining technique for making a transparent fish-skeletal specimen. Bull. Natl. Res. Inst. Aquaculture, 20: 11-18.

Morioka, S. 1993. Ecology of milkfish *Chanos chanos* larvae in the surf zone. Doctoral dessertation, Tokyo University of Fisheries. (in Japanese)

Sidira, F.D. 2001. Annual report on the fish farming activities for the year 2000, Lilongwe, Mchinji, Kasungu and Dowa West. Department of Fisheries, Lilongwe.

Sikawa D.C. 1999. On station and on farm investigation of optimal conditions for mass fingerling production of Tilapia, *Oreochrmois shiranus* (Boulenger 1896) in small scale hatchery systems in Malawi. Fish Farming Center, Mzuzu, Malawi.

Tanaka, M. 1975. Digestive system of fish juveniles. Pages 7-23. In: Development and feeding of fish juveniles (eds.) T. Iwai and H. Tsukamoto, Koseisya Koseikaku, Tokyo.

Zidana F.G. 2000, Malawi annual statistical bulletin. Ministry of Agriculture and Irrigation, Lilongwe. 56pp.

Yata, T. and T. Miyashita. 1988. Seed production of Tilapia. In: Tilapia (ed.) T. Hidaka, Midori-shobo, Tokyo.

Otolith growth increments in three cyprinid species in Lake Malawi and information of their early growth

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Abstract

Otoliths features and growth increments of three Malawian cyprinids, i.e. usipa *Engraulicypris sardella*, sanjika *Opsaridium microcephalum* and mpasa *Opsaridium microlepis* were investigated. The sagittae of all the species were not suitable for otolith increment reading due to the increment invisibility and fragile structures in rostrum portions. The asterisci have ambiguous core structures and fewer increment counts than the actual age (in Mpasa) or the ones in the lapilli (all species). This feature shows that the asteriscus is not applicable for daily increments analysis. The lapilli of them had clear increments from the core to edge, and were considered to be the best otolith for increment analysis. Hence, the lapilli were employed to elucidate the breeding periods and growth patterns in three species. The breeding period of Usipa was observed to take place almost throughout the year and the one of Sanjika was observed to take place at least 8 months from November to July. The growth in larvae and juveniles of both Usipa and Sanjika was relatively slower in the dry season and faster in the rainy season. Such difference in growth is considered to be due to the difference in water temperature between the dry and rainy season.

Key words: Cyprinidae, sagitta, lapillus, asteriscus, growth, Lake Malawi

Introduction

Information on the early growth of fish is indispensable for both the development of resource management and aquacultural activities. The three cyprinid species inhabiting Lake Malawi, Usipa *Engraulicypris sardella*, Sanjika *Opsaridium microcephalum* and Mpasa *Opsaridium microlepis*, are all important for commercial fishing and sports fishing in the latter two. However, the current situation of fishery production in those species is not positive. In Usipa *Engraulicypris sardella*, for instance, the mechanism for the great yearly catch fluctuation (Zidana 2000) has not been well elucidated, and little biological research has been made on the species (Thompson *et al.* 1995). In Mpasa *Opsaridium microlepis*, the recent decline in catch has been pointed out (Makimoto, *pers. com.*), and no research has been made on the species recently although Tweddle (1982, 1987) conducted preliminary surveys on the biological aspects of the species. Much of the biology on Sanjika *Opsaridium microcephalum*, is still unknown, such as breeding season, growth, seasonal distribution etc.

Among the biological features of fish, the information of the early developmental stages is extremely important because the early biology could explain lots the subsequent features of fish species, i.e. the breeding activity, biomass fluctuation, recruitment success and so on. To obtain the information on the early biology of fish, the utilization of otolith daily increment has been broadly applied since Pannella (1971) and the growth analysis in larvae and juveniles with daily increments was developed thereafter (Brothers and McFarland 1981,Campana and Neilson 1985, Campana 1990, Watanabe and Kuroki 1997). In most of the earlier studies employing otoliths, the sagitta was used to age fish in days. However, the sagitta is occasionally unsuitable for the determination of age in days due to the structural complexity (occurrence of sub-daily increments or fragility) and the lapillus has resulted to be better material in such cases (Hoff *et al.* 1997, Morioka and Machinandiarena 2001, Morioka *et al*. 2001).

In this study, the detection of the applicable otoliths among the sagitta, lapillus and asteriscus were primarily conducted on Usipa *Engraulicypris sardella*, Sanjika *Opsaridium microcephalum* and Mpasa *Opsaridium microlepis*. Secondly, the elucidation of the breeding season and early growth pattern of the species were considered using the growth increments of the otolith that was observed as the applicable one in the primal achievement in this study.

Materials and Methods

Fish used in this study were the larvae, juveniles and sub-adults of three cyprinid species, i.e. Usipa *Engraulicypris sardella*, Sanjika *Opsaridium microcephalum* and Mpasa *Opsaridium microlepis*. Larvae and juveniles of Usipa and the juveniles of Sanjika were collected from Nkhotakota and Chia beach (Figure 1) using seine nets (1 mm mesh, 1 m height, 8 m and 30 m width) operated along the shore. Collection of these two species were made on 20 July, 17 August 2000, January 18, February 28, 5 April and 3 May 2001 (n = 149 and 15.00 – 96.7 mm TL for Usipa, n = 181 and 14.30 - 77.45 mm TL for Sanjika). Juveniles of Mpasa were hatched at the National Aquaculture Center, Domasi, Malawi by artificial fertilization (dry method) and 20 juveniles were sacrificed at 65 day-old after hatching

(12.75-22.25 mm TL). Ten wild sub-adults of Mpasa were also collected from Salima on 1 May 2001 and Nkhotakota on 3 May 2001 (131.40 – 181.10 mm TL).

Fish was preserved in 70% ethanol immediately after collection and the otoliths (sagitta, lapillus and asteriscus) were extracted. Extracted otoliths were embedded on the glass slides with epoxy resin. When otoliths were opaque, they were ground with sand paper (# 1500) and lapping films (12 μm, 9 μm, 6 μm mesh) for being thin proximal sections, following the method described by Nishimura (1993). Ground surfaces of otoliths were occasionally etched by 0.1 N HCL to emphasize the contrast of the continuous and discontinuous zones in otoliths. Otolith microstructures were observed under the optic microscopy with transmitted light (x 200 - 400). For all species, otolith increment counts were counted and the radii of every five increments in Usipa's lapilli were recorded. In Usipa, TL was back-calculated every 5 days using the relationship between otolith radii and TL, following the method of Watanabe and Kuroki (1997).

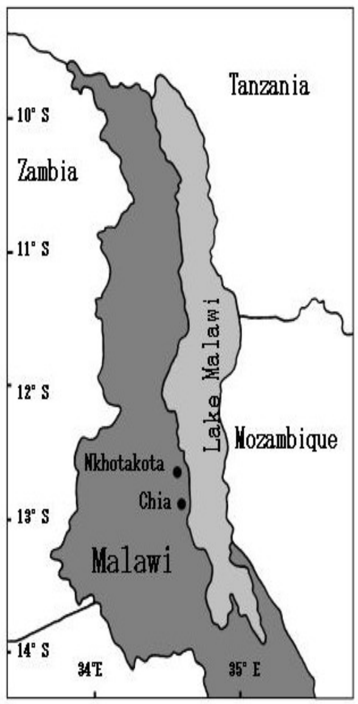

Figure 1. Collection sites of fish.

Results

Otolith features

External and internal features of otoliths were more or less similar among three species of this study. The sagitta was arrow head shaped and had an obvious nucleus with two projections (rostrums) on anterior/posterior sides (Figure 2). The increments in the sagittae were deposited clearly from the nucleus up to c. 30th increment at the bases of both anterior- and posterior-rostrums, then, they became invisible in rostrum portions (Figure 2). Rostrum portions, in addition, were fragile and often destroyed by otolith extracting and grinding treatments. These features indicated that the sagitta was not a suitable material for the age determination in days.

The lapillus was oval-shaped and had a clear nucleus (Figure 3). The increments in the lapilli were clearly visible from the nuclei to edge portion after grinding (Figure 3). The increment counts in the lapilli of laboratory-hatched/reared Mpasa juveniles agreed with the actual age in days (65 days after hatching). Thus, the lapilli were considered to be the applicable otolith for daily increment analysis in the species used in this study.

The asteriscus was oval-shaped and had an ambiguous nucleus (Figure 4). This ambiguous nucleus made the 1st increment identification impossible. In the asterisci, additionally, the increment counts were much fewer than the ones in the lapilli or, they were much less than the actual age in days in laboratory-hatched/reared Mpasa juveniles. These features demonstrated that the asterisci were also not useful for daily increment analysis.

On the basis of the upper observations, the lapilli were resulted to be the best material for the increment analysis of otolith. Hence, the lapilli were employed for the subsequent analyses.

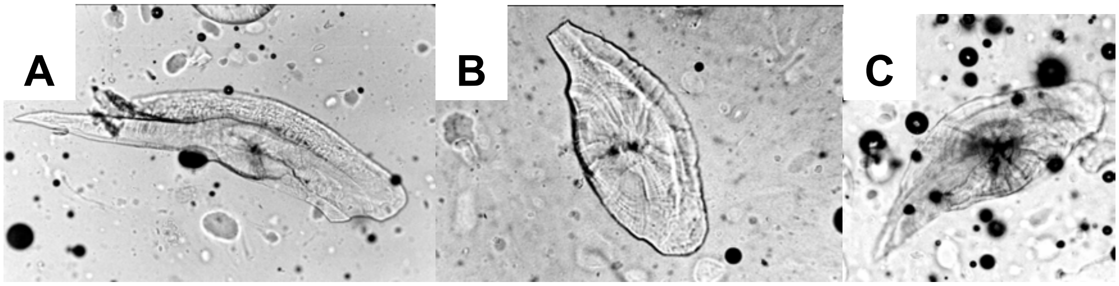

Figure 2. Sagittae of juveniles in *Engraulicypris sardella* (A), *Opsaridium microcephalum* (B) and *Opsaridium microlepis* (C). Bars indicate 100 µm.

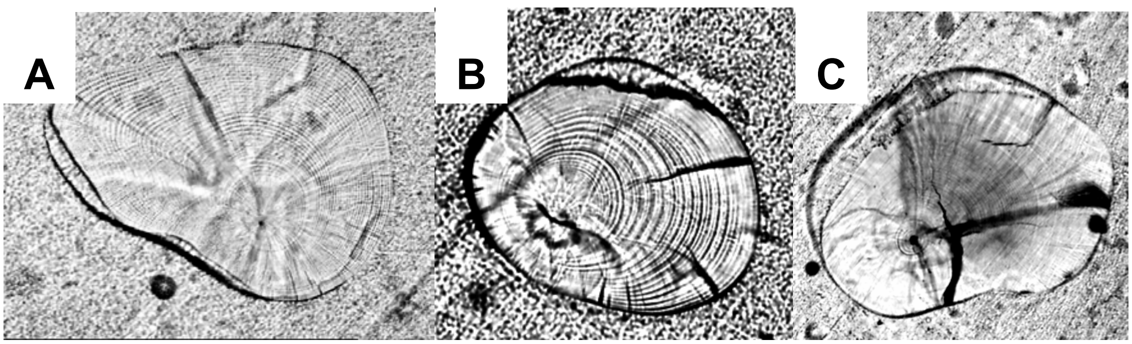

Figure 3. Lapilli of juveniles in *Engraulicypris sardella* (A), *Opsaridium microcephalum* (B) and *Opsaridium microlepis* (C). Bars indicate 100 µm.

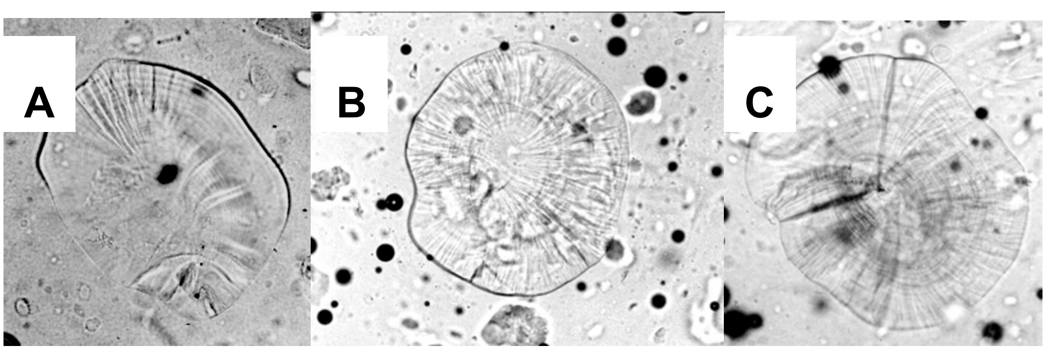

Figure 4. Asterisci of juveniles in *Engraulicypris sardella* (A), *Opsaridium microcephalum* (B) and *Opsaridium microlepis* (C). Bars indicate 100 µm.

Breeding seasons

Breeding season of each species was estimated by the increment counts in the lapilli. In Usipa, the hatching months were observed almost throughout the year except January, March, May and August although the frequencies of the hatching month varied in each month, being particularly higher in December and April (Figure 5A). This suggested that Usipa bred almost throughout the year. In Sanjika, the hatching months were observed consecutively from late November to early July (Figure 5B), suggesting that Sanjika bred at least during 8 months a year. The highest frequency was observed in May and the second highest was in January. In Mpasa, the hatching months were observed from September to December although the number of specimens was only 10.

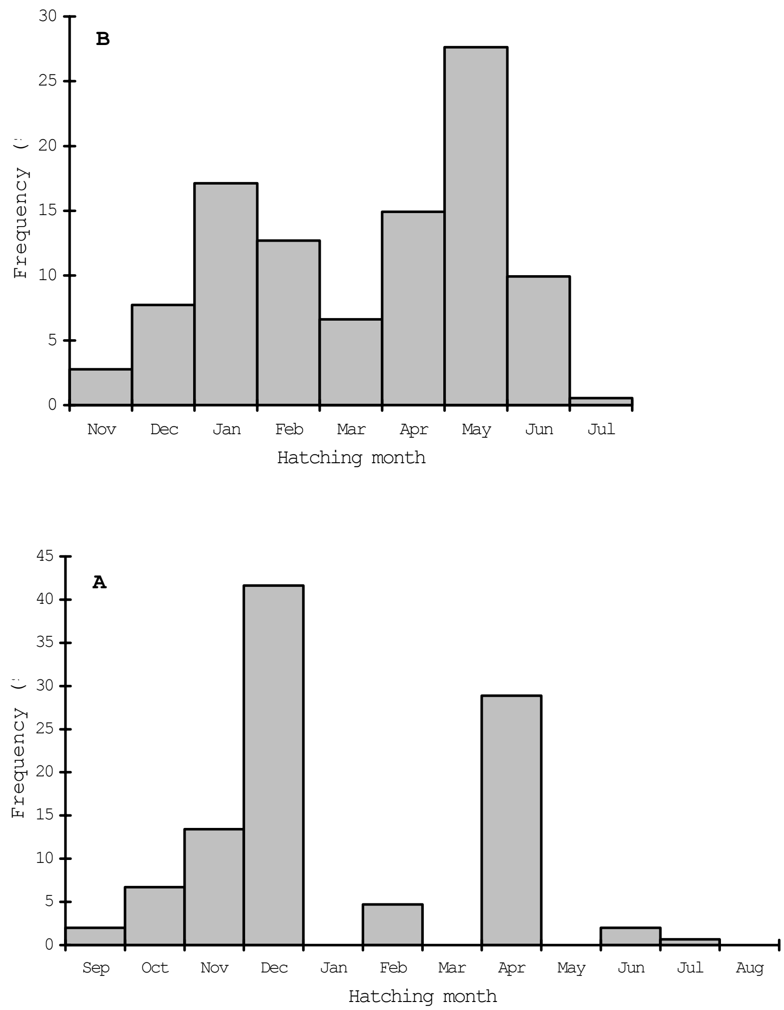

Figure 5. Hatching months of *Engraulicypris sardella* (A) and *Opsaridium microcephalum* (B) estimated by the lapilli increment counts.

Growth patterns

Growth of Usipa larvae and juveniles born in the rainy season (November to February) was faster than the one born in the dry season (June and July)(Figure 6). The growth rate of Usipa in the rainy season was more than 0.70 mm TL per day while less than 0.50 mm TL in the dry season. Sanjika juveniles also showed that the growth in fish born in the rainy season was higher than the one born in the dry season (Figure 7). Sanjika could be separated into the following 3 groups: fish born and grown in the rainy season (n = 74, referred to as the summer-born group), fish born in the rainy season and grown during both the rainy and dry seasons (n = 3, referred to as the intermediate group), and fish born and grown in the dry season (n = 104, referred to as the winter-born group). Growth rate in the rainy season was more than 0.70 mm TL while less than 0.60 mm TL per day in the dry season. In Mpasa, the largest specimen (181.60 mm TL) was aged 221 days after hatching and the smallest one (131.40 mm TL) was aged 151 days, demonstrating that Mpasa grew at the rate of more than 0.80 mm TL per day.

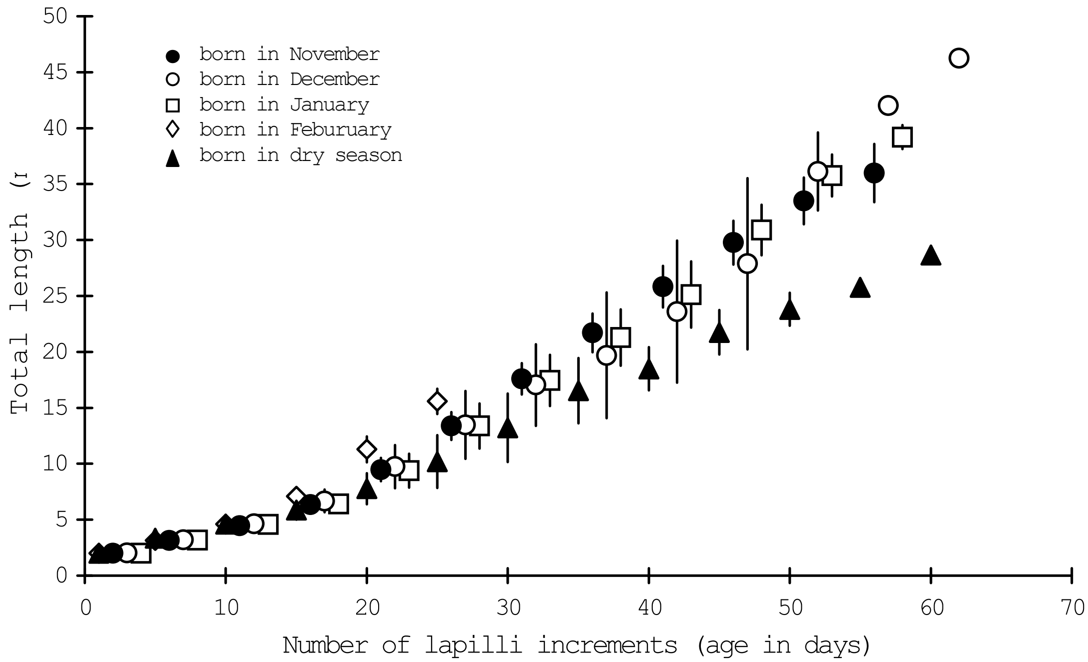

Figure 6. Relationship between lapilli increment counts (age in days) and back-calculated total length at ages (mm) in *Engraulicypris sardella*. Back-calculated TL was individually expressed the fish groups hatched in different months or season. Closed circle: fish born in November, opened circle: in December, opened square: in January, opened diamond: in February and closed triangle: in dry season, respectively.

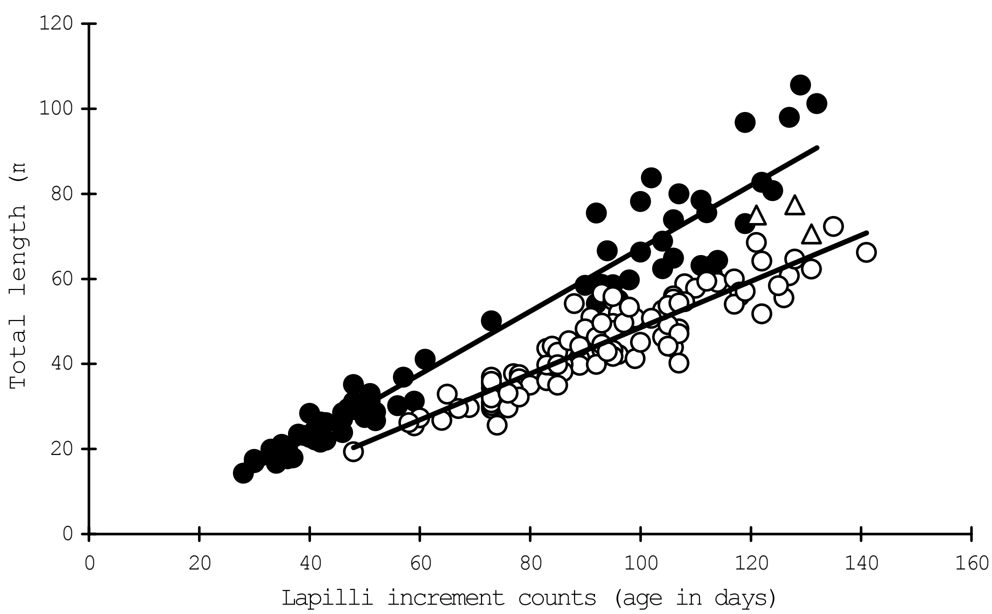

Figure 7. Relationship between lapilli increment counts (age in days) and total length (mm). Closed circle: fish born/grown in rainy season, opened circle: fish born/grown in dry season, opened triangle: fish born in rainy season and grown in rainy/dry season.

Discussion

Difficulties in use of the sagittae for the determination of age in days have been occasionally pointed out because of the structural complexity or the occurrence of sub-daily increments (Hoff *et al.* 1997, Morioka and Machinandiarena 2001, Morioka *et al.* 2001). In the three cyprinid species used in this study, the sagitta was considered inappropriate material for the daily increments analysis due to the fragility and invisibility of increments in rostrum portions (Figure 2). In the asteriscus, the difficulty in 1st increment identification due to the ambiguous nuclei was observed (Figure 3). Moreover, in general, the asteriscus was observed to be formed later than the sagitta and lapillus, a certain period after hatching such as observed in *Anguilla japonica* (Umezawa 1988), *Delitistes luxatus* and *Chasmistes brevirostris* (Hoff et al. 1997). Such information also demonstrates the disadvantage of the asterisci in the analysis of daily increments. Thompson *et al.* (1995) described that the asterisci had two projections and the sagittae were formed later than the lapilli and asterisci in Usipa. We suspect that they misidentified the sagittae as the asterisci. Additionally, they employed the sagittae and asterisci in combination for the increment analysis instead of using the lapilli although they found the readable increments in the lapilli and the upper-noted unsuitable characteristics were found in other otoliths. As shown in this study, as well as observed in other cyprinids (Hoff *et al.* 1997), the lapilli are apparently superior to others for the increment counts with the consecutive readability of increments. The sagittae have been mainly applied for the otolith increments analysis so far. But, with taking the superiority in the lapilli found in cyprinids (this study and Hoff *et al.* 1997) and other species (Morioka and Machinandiarena 2001) into account, the use of the lapilli should be emphasized more and developed.

Breeding period of Mpasa estimated in this study was from the latter half of the dry season and the beginning of the rainy season (September to December). However, the sexually matured adults were captured in earlier months (July and August)(P.B. Kataya, *pers. comm.*). This indicates that the breeding season of Mpasa may extend from July to December.

Breeding period of Usipa was observed to take place almost throughout the year and Sanjika's one was at least over 8 months (Figure 5), although the water temperature in the lake seasonally varies between 23 ºC and more than 28 ºC (Patterson and Kachinjika 1995). These long-term breeding periods in Usipa and Sanjika strongly suggest the existence of the plural stocks in both species, that is, the different stocks adapting to the different optimum temperature for reproduction.

The growth of Usipa larvae and juveniles and Sanjika juveniles in the rainy season was higher than the one in the dry season (Figures 6 and 7). The differences in growth also suggest the existence of the plural stocks in both Usipa and Sanjika in the lake as well as the long term breeding periods discussed above. Differences in growth may be able to be explained by the water temperature in the lake that is higher in the rainy season and lower in the dry season as referred above (Patterson and Kachinjika 1995). In addition, the larger water inlet from the rivers during the rainy season may provide more nutrients to promote the larger biomass of the planktonic organisms that is the main diet of fish larvae and juveniles. However, Irvine (1995) observed that the zooplankton biomass was more abundant during the dry season than the rainy season (1995).

Conclusive note

In this study, several fundamental biological features of Usipa, Sanjika and Mpasa, the important species for both the commercial and sports fishing in Lake Malawi, were preliminary elucidated. More information is necessary to clarify the biological aspects of the early-staged fish especially in relation to the fish resource management. Additionally, the biological information of fish larvae and juveniles is indispensable for the further development of the aquacultural activity. In both senses, the long-term research on the important fish larvae and juveniles is strongly recommended.

Acknowledgements

We thank Mr. S. Matsumoto and his colleagues for assisting us in fish sample collection. We are also grateful to Japan International Cooperation Agency (JICA) for giving us the opportunity to conduct this study.

References

Brothers, E.B. and W.N. McFarland (1981) Correlation between otolith microstructure, growth and life history transitions in newly recruited French grunts (*Haemulon flavolineatum*). Rapp. P.-V. Reun. Cons. Int. Explor. Mer., 178, 369-374.

Campana, S.E. (1990) How reliable are growth back-calculation based on otoliths? Can. J. Fish. Aquat. Sci., 47, 2219-2227.

Campana, S. and J.D. Neilson (1985) Microstructure of fish otoliths. Can. J. Fish. Aquat. Sci., 42, 1014-1032.

Hoff, G.R., D.J. Logan and D.F. Markle (1997): Otolith morphology and increment validation in young Lost Liver and shortnose suckers. Transact. Amer. Fish. Soc., 126, 488-494.

Morioka, S, L. Machinandiarena (2001) Comparison of daily increment formation pattern between sagittae and lapilli of ling (*Genypterus blacodes*) larvae and juveniles collected off Argentina. New Zealand J. Mar. Freshwater Res., 35(1): 111-119.

Morioka, S., L. Machinandiarena and M.F. Villarino. 2001. Preliminary information on internal structures of otoliths and growth of ling, *Genypterus blacodes* (Ophidiidae), larvae and juveniles collected off Argentine. Bull. Jpn. Soc. Fish. Oceanogr., 65(2): 9-16.

Nishimura, A. (1993): Age determination of walleye pollock based on the otolith (Review). Sci. Rep. Hokkaido Fish. Exp. Stn., 42, 37-49. (in Japanese)

Thompson, A.B., E.H. Allison, B.P. Ngatunga and A. Bulirani. 1995. Fish growth and breeding biology. In: The fishery potential and productivity of the pelagic zone of Lake Malawi / Niassa (ed.) A. Menz. Natural Resources Institute, UK.

Tweddle, D. 1982. Fish breeding migrations in the north Rukuku area of Lake Malawi with a not on gillnet colour selectivity. Journal of Science and Technology in Malawi 3(2); 67-74.

Tweddle, D. 1987. An assessment of the growth rate of Mpasa, *Opsaridium microlepis* (Gunter, 1864) (Pisces: Cyprinidae), by length frequency analysis. Journal of Limnological Society of South Africa 13(2): 52-57.

Watanabe, Y. and T. Kuroki (1997) Asymptotic growth trajectories of larval sardine (*Sardinops melanosticus*) in the coastal waters off western Japan. Mar. Biol., 127, 369-378.

Zidana F.G. 2000, Malawi annual statistical bulletin. Ministry of Agriculture and Irrigation, Lilongwe.

Development of African catfish *Clarias gariepinus* larvae during the transitional phase between endogenous and exogenous energy intake.

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Abstract
Development of newly hatched African Catfish *Clarias gariepinus* larvae in an aspect of energy intake conversion was investigated. The anus and mouth of larvae opened by 16 and 22 h after hatching, respectively. However, the onset of feeding was observed from day 3 (67 h) after hatching when the jaw structure started being ossified and the nerve in barbel appeared. Yolk was completely absorbed on day 7 after hatching (166 h after hatching). These observations demonstrated that the larvae had the transitional period to utilize both endogenous and exogenous energy sources for c. 100 h. Mass-mortality in larvae reared under starvation after hatching took place from day 11 to day 14, all specimens being dead on day 16. These phenomena indicated that the food-derived larvae had survived using the energy sources in their body tissues after yolk absorption for more than 4days (maximum 7 days). This fact showed the larvae of this species having a stronger starvation tolerance than the marine fish larvae reported in earlier studies. The delayed feeding experiments showed that the PNR (point of no-return) existed on day 9-10 after hatching, demonstrating that larvae should start feeding by 9-10 days after hatching to survive before reaching the PNR.

Key words: *Clarias gariepinus* larvae, yolk, onset of feeding, survival

Introduction
African Catfish *Clarias gariepinus* (Burchell 1815) are widely distributed over Africa. This species is known as having an omnivorous feeding habit although the higher protein level in diet is recommendable (Viveen *et al.* 1985, Haylor 1992). Catfish species is the one of the main species under aquaculture especially in temperate and tropical freshwaters because of the omnivorous feeding habit and rapid growth such as observed in *C. gariepinis* (Haylor 1992), *Parasilurus asotus* (Tsuchiya 1976) and *Ictalurus punctatus* (Watanabe 1988). In such background, the aquacultural aspects, e.g. seed production/rearing techniques and nutritional features have been broadly surveyed so far in catfish species.

For further development of aquacultural techniques, the understanding of biological view in the larval stage is indispensable. Especially, the information on the survival, feeding performance and morphological development in early larvae should be well grasped in view of this critical period (Kohno 1998). Major achievements in such aspects have, so far, been made mainly in marine fin fish (Wiggins *et al.* 1985, Yamashita and Aoyama 1985, Khono et el. 1990). However, such features in catfish species have been scarcely made as yet. In addition, such information also contributes for further understanding the fish biology in the natural water in relation to the resource management aspects.

In this study, therefore, the survival, onset of feeding and the early development of morphology in newly-hatched African catfish larvae were investigated and the features during the energy intake conversion from endogenous to exogenous were discussed.

Materials and methods
Some 30,000 African catfish larvae used in this study were produced with artificial fertilization (dry method) at the Department of Aquaculture and Fisheries Science, Bunda College of Agriculture, University of Malawi, on 15 March (batch 1) and 15 April (batch 2) 2001. Newly-hatched larvae were stocked in 1000 *l* or 200 *l* plastic tanks immediately after hatching. Water temperature during rearing was 22-25 ºC. *Artemia* sp. naulii and natural zooplankton (Copepoda, Branchiopoda, Ploima etc.) were given at the density of 5 – 10 ind. per m*l* once a day. The hatching time was recorded in batch 1 as when the 1st specimen hatched. Thereafter, some 500 larvae were intermittently sampled with the interval of more frequently than every 12 hours. Using these specimens, the trend in decrease of the yolk sac volume and the morphological development were observed. Yolk sac volume can be calculated with the formula $V = 4/6 \cdot \pi R^3$ if the shape of yolk sac is spherical, where R is the yolk radius. But, we applied the formula $V = \pi/6 \cdot LH^2$ (Blaxter and Hempel 1963), where L is length (mm) and H is height (mm), because the shape of yolk sac was not spherical in this species. One hundred nine of them were treated as being the double stained transparent specimen using the method of Kawamura and Hosoya (1991) to observe the jaw structures and barbel development.

Sixty-five larvae from batch 1 were stocked in 1 *l* beaker and reared without feeding and survival rate was recorded until all larvae were died by starvation. Some 400 larvae from batch 2 were separately stocked in 7 beakers and 7 different timings (delayed feeding) of first diet supply were set (Table 1). The survival rates in each setting were recorded.

Table 1. Experimental design of delayed feeding.

Settings	Timings of 1st diet supply
D-4	Diet given on 4 days after hatching
D-6	6 days after hatching
D-8	8 days after hatching
D-10	10 days after hatching
D-12	12 days after hatching
D-14	14 days after hatching
Starvation	Without diet until dead

Results

Yolk sac absorption and survival in food deprived specimens

Total length (TL) of larvae at hatching was 4.07 ± 0.11 mm (mean ± SD, n = 10). TL, then, continuously developed and reached 9.23 ± 0.71 mm (n = 5) at 166 h when yolk sac completely absorbed (Figure 1). Yolk sac of newly-hatched larvae drastically declined from hatching to 97 h after hatching as expressed by the formula $V = -0.0102 \cdot T + 1.0208$ ($r = 0.986$). It gradually decreased thereafter as expressed by the formula $V = -0.0002 \cdot T + 0.0329$ ($r = 0.732$). The complete yolk sac absorption was observed at 166 h (7-day) after hatching (Figure 2). The food deprived (starved) larvae from batch 1 highly survived until the 10 days after hatching and the mass mortality took place thereafter (Figure 3). They all died on day 16 after hatching. In the larvae (from batch 2) under the different timings of 1st diet giving, the ones of D-4, -6 and -8 survived with relatively higher survival rates (more than 50%) while the ones of D-10, -12 and -14 showed the close patterns in mortality observed in starved larvae and all died after 17 days after hatching in D-12, -14 and starvation (Figure 4). In D-10, only one larva survived.

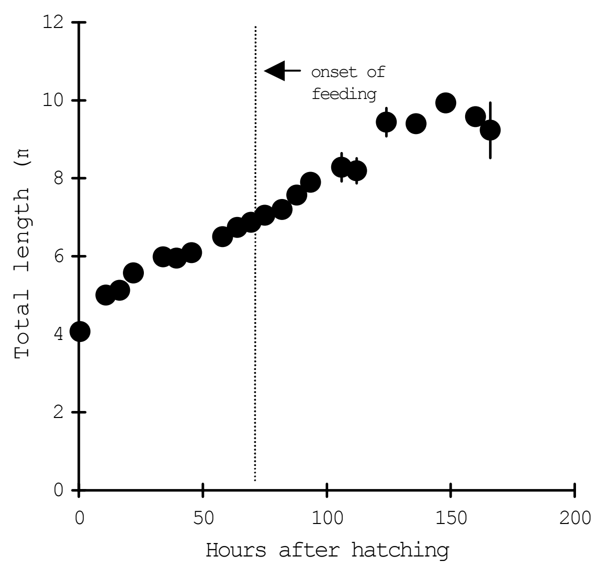

Figure 1. Relationship between hour after hatching and total length (mm) in *Clarias gariepinus* larvae. Dotted line indicates the onset of feeding.

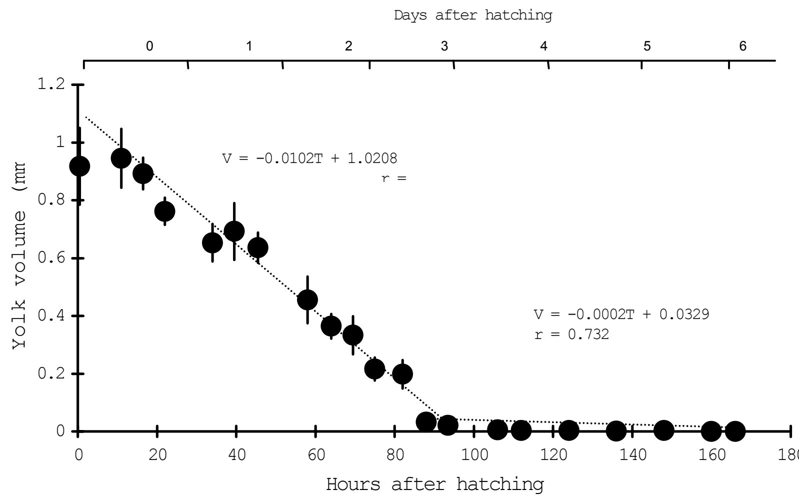

Figure 2. Relationship between hours after hatching and yolk sac volume (mm^3) in *Clarias gariepinus* larvae.

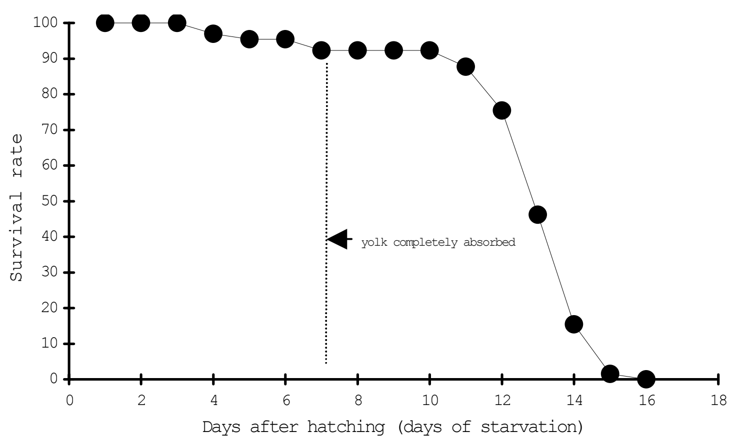

Figure 3. Relationship between days after hatching and survival rate (%) in starved *Clarias gariepinus* larvae.

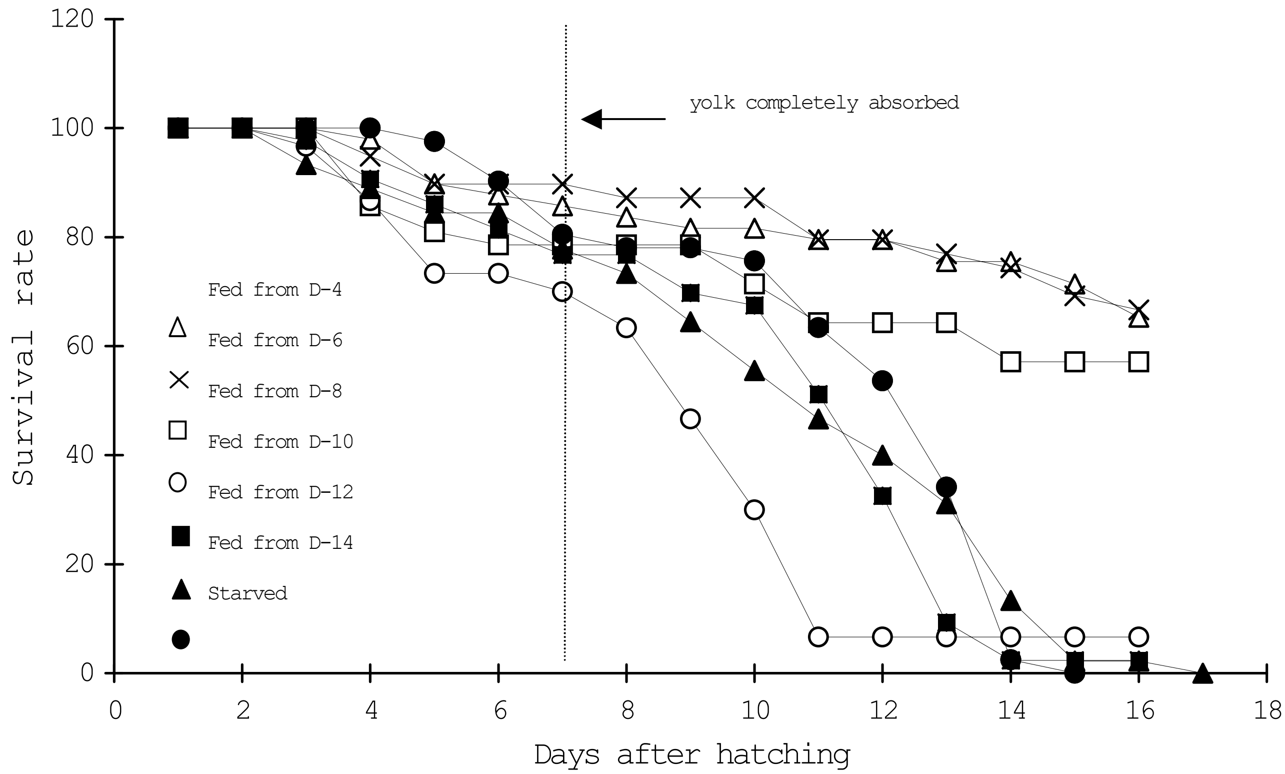

Figure 4. Relationship between days after hatching and survival rate (%) in delayed feeding experiments of *Clarias gariepinus* larvae. See Table 1 for experimental design and symbols.

Morphological development and feeding performance

At hatching, the bony structure and barbel did not exist. The anus was observed to open at 16 h after hatching and the mouth opened at 22 h. The eye pigmentation was observed from 34 h and the development of barbel started as well. The cartilage structure of the upper / lower jaws appeared at 39.5 h. At 58 h, the upper / lower jaw structures started being ossified and the taste bud cell in the barbel started developing. At 67 h, the onset of feeding was observed. The bony structure thereafter developed and the cleithrum appeared at 70 h. At 112 h, the pectoral fin bud appeared and the cartilage of pectoral fin support appeared at 118 h. Morphological development at hours after hatching was described in Table 2.

Table 2. Morphological development at hour after hatching.

Hours after hatching	Morphological features and feeding performance
0	No bony structures and the eyes not pigmented
16	Anus opened
22	Mouth opened and barbel appeared
34	Eye pigmentation started and upper / lower jaw structures appeared
58	Upper / lower jaws started being ossified and taste bud cells in barbel appeared
67	Onset of feeding
70	Cleithrum appeared
112	Pectoral fin bud appeared
118	Pectoral fin support appeared
166	Yolk completely absorbed

Discussion

Viveen *et al.* (1985) reported that the yolk sac of this species was absorbed by 3-day after hatching. However, in this study, the yolk sac was observed to retain until 166 h after hatching (7-day after hatching) although c. 98% of yolk sac was absorbed by 100 h (Figure 1). In other marine fish, the same trend, such as the drastic decrease in yolk sac volume in initial phase while it continued retaining with gradual decrease thereafter, was observed (Khono *et al*. 1990). The onset of feeding was observed at 67 h after hatching and the period to utilize both endogenous and exogenous energy sources was elucidated for 100 h (more than 4 days) in this species. In pelagic marine fish larvae, generally, the overlapping period with endogenous and exogenous energy sources was much shorter such as observed in *Chanos chanos* (Kohno *et al.* 1990).

The survival rate in food-deprived larvae was high until 10 days after hatching (Figures 3 and 4). In addition, the larvae that were given diet 8 days after hatching showed relatively high survival (more than 50%) while the ones not given diet for more than 10 days after hatching died (Figure 4). This indicates that the PNR (point of no-return, (Blaxter and Hempel 1963)) of *C. gariepinus* exists at around 9~10-days after hatching at 22.0-25.0ºC water temperature. This demonstrates that the larvae need to start feeding by the 8th day after hatching, although the lower water temperature may give more allowance in time until reaching the PNR. In species that have an oil globule, i.e. *Psetta maxima* (M. Moteki, *unpubl. data*), the yolk sac is absorbed at around onset of feeding and the oil globule is retained longer. In such species, the survival of larvae after onset of feeding relies mainly on energy supply from the oil globule. However, *C. gariepinnus* is a species that does not have an oil globule, and the survival is considered to be influenced by the performance decline in the yolk sac.

Rana (1985) reported that the yolk sac in *Oreochromis mossambicus* larvae was mainly consumed for the maintenance of body, not for growth. In this study, however, the larvae showed a continuous growth in TL even during the phase before the onset of feeding (0~67 h, Figure 1). This shows the larvae of this species utilizing the yolk sac both for the maintenance and growth of body.

Although the anus and mouth opened at 16 and 22 h after hatching, respectively, the onset of feeding was observed at 67 h (Table 2). At the time of the onset of feeding, the initial ossification of jaw structures was observed as well as the occurrence of taste buds in the barbels. This process demonstrates that the larvae do not possess the feeding function before the start of ossification in jaw structures and the appearance of taste buds in barbel (Table 2). In several marine species as reported earlier, e.g. *Chanos chanos* (Morioka 1993) and *Psetta maxima* (M. Moteki, pers. comm.), the pectoral fin bud appeared before or at the onset of feeding. However, in C. *gariepinus*, the cleithrum appeared at 70 h (Table 2) and the pectoral fin structures appeared thereafter (112 h) (Table 2), showing that the pectoral fin is functionally not related with the onset of feeding in this species. This suggests that the larval *C. gariepinus* have different feeding manners from *Chanos chanos,* in an aspect of the utility of pectoral fin being relevant to swimming manner. In addition, Taki *et al.* (1987) reported that the swimming manner shifts from the undulation to caudal propulsion when the structures in caudal fin are ossified in *Chanos chanos* larvae, while it was observed that the larval *C. gariepinus* was not likely to have such change in the swimming manner. Although lots of fish species have pelagic larval stages and feed on suspended organisms as reported in marine fin fish species (Tanaka 1975), *C. gariepinus* are rather benthic even in pre-larval stage with negative phototaxis and it does not have the planktonic / pelagic larval phase. Such ecological differences seem to be relevant to the above-mentioned differences in morphological development.

Conclusive note

In this study, the preliminary information of the larval biology in relation to the onset feeding was obtained. The elucidated features are; 1) *Clarias gariepinus* larvae have the strong starvation tolerance supported by the long-term retention of yolk sac, 2) this species has a relatively long period to utilize both endogenous and exogenous energy sources, 3) the PNR of this species is around 9~10-days after hatching that indicates the larvae require to start feeding before reaching the PNR for higher survival, and 4) the larvae of this species are able to start feeding when they possess the ossified jaw structures and the appearance of taste buds in barbel. However, the survival of fish larvae is strongly influenced by the quality of bloodstock and eggs that also affect the subsequent development of feeding functions. In addition, the development of feeding functions is relevant to the development in morphology, especially in skeletal structures as shown in Taki *et al.* (1987). For further consideration on the survival and feeding aspects relevant not only to aquaculture but the biological features in the wild, the detailed investigation on the maternal factors such as egg quality and skeletal development would be necessary.

Acknowledgements
We thank Mr. O. Matambo and his colleagues for assisting us in the hatchery activities. We are also grateful to Japan International Cooperation Agency (JICA) for giving us the opportunity to conduct this study.

References
Blaxter, J.H.S. and G. Hempel. 1963. The influence of egg size on herring larvae (*Clupea harrengus*). J. Cons. Int. Explor. Mer., 28:211-240.

Haylor, G.S. 1992. African catfish hatchery manual. Institute of Aquaculture, University of Stirling, Stirling.

Kawamura, K. and K. Hosoya. 1991. A modified double staining technique for making a transparent fish-skeletal specimen. Bull. Natl. Res. Inst. Aquaculture, 20: 11-18.

Kohno, H. 1998. Early life history features influencing larval survival of cultivated tropical finfish. In: Tropical mariculture, (ed.) S.S. De Silva, Pages 71-111, Academic Press, London.

Kohno, H., M. Duray, A. Gallego and Y. Taki. 1990. Survival of larval milkfish, *Chanos chanos*, during changeover from endogenous to exogenous energy sources. Proc. Sec. Asian Fish. Forum, 437-440.

Rana, K.J. 1985. Influence of egg size on the growth, onset of feeding, point-of-no-return, and survival of unfed *Oreochromis mossambicus* fry. Aquaculture, 46: 119-131.

Taki, Y., H. Kohno and S. Hara. 1987. Morphological aspects of the development of swimming and feeding functions in the milkfish *Chanos chanos*. Japan. J. Ichthyol., 34(2): 198-208.

Tanaka, M. 1975. Digestive systems in fish juveniles. In.: Feeding and Development of Fish Juveniles, Pages 7-23, (eds.) T. Iwai and H. Tsukahara, Kouseisya Kouseikaku, Tokyo. (in Japanese)

Tsuchiya, M. 1976. Aquaculture of catfish. In: Freshwater Aquaculture, Pages 429-434, (ed.) D. Inaba, Kouseisya Kouseikaku, Tokyo. (in Japanese)

Viveen, W.J.A.R., C.J.J. Richter, P.G.W.J. van Oordt, J.A.L. Janssen and E.A. Huisman. 1985. Practical Manual for the culture of the African catfish (*Clarias gariepinnus*). Ministry of foreign affairs of the Netherlands, Agricultural University of Wageningen and University of Utrecht, Hague.

Watanabe, T. 1988. Fish nutrition. In: Fish Nutrition and Mariculture, Pages 1-77, Japan International Cooperation Agency, Tokyo.

Wiggins, T.A., T.R. Bender, Jr., V.A. Mudrak and J.A. Coil. 1985. The development, feeding, and survival of cultured American shad larvae through the transition from endogenous to exogenous nutrition. Prog. Fish-Cul., 47: 87-93.

Yamashita, T. and T. Aoyama. 1985. Hatching time, yolk sac absorption, onset of feeding, and early growth of the Japanese sand eel *Ammodytes personatus*. Nippon Suisan Gakkaishi, 51: 1777-1780.

Effect of temperature on oocyte development of *Oreochromis karongae* (TREWAVAS)

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Abstract
Oreochromis karongae (Trewavas) is one of the indigenous Tilapias that exhibit favorable traits for aquaculture in Malawi. However, fingerling production has been a problem. An experiment was therefore carried out to find the effect of temperature on oocyte development of the fish. Female *O. karongae* were reared under two temperature regimes, room (20.3± 0.8°C) and raised (26.5 ± 0.5°C) for 90 days while changes in gonadosomatic index (GSI) and oocyte developmental stages were followed every 45 days. Fish samples from the pond in which experimental fish were collected were used for comparison. Results showed that raising temperature to 26.5 ± 0.5°C significantly enhanced oocyte development. Higher GSI ($p<0.05$) were obtained after 45 and 90 days in fish cultured in raised temperature (0.817 ± 0.657 and 1.133 ± 0.471 %, respectively) than those from room temperature (0.057 ± 0.027 and 0.367 ± 0.045 %, respectively). GSI of fish samples from the pond were not different from that of fish from room temperature. Relative frequency of mature oocytes was higher ($p < 0.05$) in fish from raised temperature (60.42 ± 3.63 %) than in fish from room temperature (1.760.84 %) and pond (2.43 ± 1.38 %) after 45 days. After 90 days, the frequency of mature oocytes in fish from raised temperature was not different from that in fish from the pond (8.68 ± 2.40 and 10.99 ± 3.41 % respectively). Fish from room temperature had a low ($p<0.05$) frequency of mature oocytes (3.12 ± 2.03 %,). The results suggest that *O. karongae* has the potential to spawn throughout the year if temperature is manipulated.

Keywords: *Oreochromis karongae,* temperature, oocyte development

Introduction
Under natural conditions, reproduction in fish is timed by changes in the external environment (Barnabe 1994, Bromage 1995). Although seasonal reproduction is of considerable adaptive significance to wild stocks of fish, it is a disadvantage in intensive farming where supplies of fingerlings are required throughout the year (Barnabe 1994). Knowledge of the reproductive responses of fish to specific environmental cues offers means by which the timing of spawning can be adjusted to provide fry and fingerlings on demand.

Feed, temperature, photoperiod, physical and chemical factors are among the factors that have been implicated in the control of the reproductive cycle (Das and Ponniah 1993). Temperature has indirect and direct effects on fish reproduction. Indirectly, it plays a determining role on general activity and feeding, which in turn affect reproduction. Temperature has a direct effect on gametogenesis. Gametogenesis only takes place within a given range of temperature for each species (Barnabe 1994). It also has a direct effect on the production of gonadotropic hormone (GtH) by the hypothalamo-hypophyseal complex.

Msiska (1998) reported that maximum air temperature, among other factors, is positively correlated with fry production in *Oreochromis karongae*. However, the actual temperature levels suitable for the reproductive processes in the fish have not been quantified. Determination of effects of environmental parameters on reproduction can be used in the choice of hatchery technology (Subasinghe and Sommerville 1992). As artificial hatchery rearing of tilapias has become important in aquaculture, the establishment of tolerance levels and effects of environmental variables on reproductive processes needs further investigation. The information on effects of temperature on reproductive processes can be used in hatcheries to maintain fingerling production throughout the year. The present study was conducted to determine the effect of raising temperature to 27°C on oocyte development in *O. karongae*.

Materials and methods

Experimental layout and design
An experiment to investigate the effect of temperature on oocyte development was carried out at Bunda College of Agriculture for 90 days. The experiment was laid in a completely randomized design with two treatments replicated three times. Nine fish weighing 40.47 ±10.53g were randomly stocked in each 200-litre aquarium. The treatments were room temperature and 27°C. Raised temperature was maintained using an electric water heater with a thermostat. The aquaria were placed in a 2000-litre tank, which was used as a water bath. The water in the bath was

circulating throughout the experimental period and temperature was monitored daily in the morning and in the afternoon.

The fish were fed twice per day at 3 % body weight. Apart from the two treatments, some fish samples from the pond in which experimental fish were collected were used for comparison.

Sampling of oocytes

Nine fish from each treatment were sacrificed after every 45 days. The fish were weighed and dissected. Ovaries were removed, weighed and gonadosomatic index (GSI) was calculated as:

GSI = gonad mass (g) x 100/ total body mass (g) (Crim and Glebe 1990)

Macroscopic stages of the gonads were observed and classified according to Ricker, (1971). Ovaries from 3 fish in each treatment were fixed in Bouin's solution for histological purposes immediately after *post mortem*. After 4-24 hrs, they were washed in 50 % ethanol and stored in 70 % ethanol.

Water quality management

To maintain suitable water quality, biofilters were placed in each aquarium and air was supplied continuously. Fish excreta and leftover feed were siphoned out daily. Water in the aquaria was changed once every week. Apart from temperature, dissolved oxygen, pH, and ammonia levels were monitored.

Histological analyses

Histological analyses were done at the College of Medicine, University of Malawi, in Blantyre. The middle, distal and proximal ends of each ovary were prepared according to Hinton (1990). In summary, tissues was washed in a series of formalin, alcohol, wax and toluene and then embedded in wax blocks. The wax blocks were cut and stained with hematoxylin and eosin (H & E). The samples were then mounted on slides and observed under a microscope.

Observations on ovarian tissue from histological samples were classified into five stages of maturity based on the abundant gametogenic cell types present (Table 1) after modification of the classification by Crim and Glebe (1990). Oocytes were observed under the microscope at x100 magnification. Three fields were sampled in each histological section and the different types of oocytes observed were counted. The number of a particular type of oocyte was then expressed as a percentage of the total number of oocytes observed in the three fields.

Table 1. Classification of maturity stages of oocytes in *Oreochromis karongae*

Stage	Description
Immature	Previtellogenic oocytes: small, spherical ovarian cells containing a central nucleus and increasing amounts of cytoplasm. The type of oocytes were the perinucleolar oocytes.
Maturing	Vitellogenic oocytes: oocytes that had incorporated the yolky material produced by the liver. This consisted of early yolk vesicle and primary yolk granule oocytes.
Mature	These were largest oocytes and were filled with tertiary yolk granules
Post ovulatory follicles	Consisted of empty follicles and *corpora lutea*
Dying	Oocytes that showed signs of dying.

Data analysis

A *t*-test was used to analyze for differences in the GSI of fish. Percentages of oocytes from histological sections were transformed to natural logarithm (ln) and subjected to the general linear model (GLM) of Statistical Analysis System (SAS) package to test differences in the relative frequency of oocyte stages. Where significant differences appeared, means were separated using Scheffe's test at 5 % probability.

Results

Gonad development

Raised temperature was maintained at 26.5 ± 0.5°C. Room temperature fluctuated between 18.5 ± 0.8°C in the morning and 19.2 ± 0.8°C in the afternoon during the first 45 days. In the next 45 days temperature was 21.4 ± 0.7°C in the morning and 22.0 ± 0.8°C in the afternoon. In ponds the temperature was 22.0 ± 1.9°C. Some fish died during the acclimatization period. The mortality rate in raised and room temperatures was 4 and 37 %, respectively.

Fish from raised temperature had higher GSI than fish at room temperature ($p<0.05$) throughout the experimental period (Table 2). GSI values ranging from 0.06 to 0.37 % were obtained in fish from room temperature compared to 0.82 to 1.33 % in those from raised temperature. Just like in the first experiment, the results showed that raising and maintaining temperature at 26.5 ± 0.5°C has a positive effect on oocyte development of *O. karongae*.

Table 2. Mean gonadosomatic index of *Oreochromis karongae* females from raised and room temperature

Day	Raised temperature		Room temperature	
	Mean GSI	SE	Mean GSI	SE
0	0.13	0.012	0.13	0.012
45	0.817	0.657^a	0.057	0.027^b
90	1.133	0.471^a	0.367	0.045^b

[a, b] Means with different superscripts in the same row are significantly different ($p<0.05$).

The GSI of fish from raised temperature were higher than that of fish samples from the ponds (Figure 1). The mean GSI were significantly different ($p<0.05$) during all the sampling days (Table 3). However, there was no significant difference in GSI between samples from the pond and room temperature (Table 4).

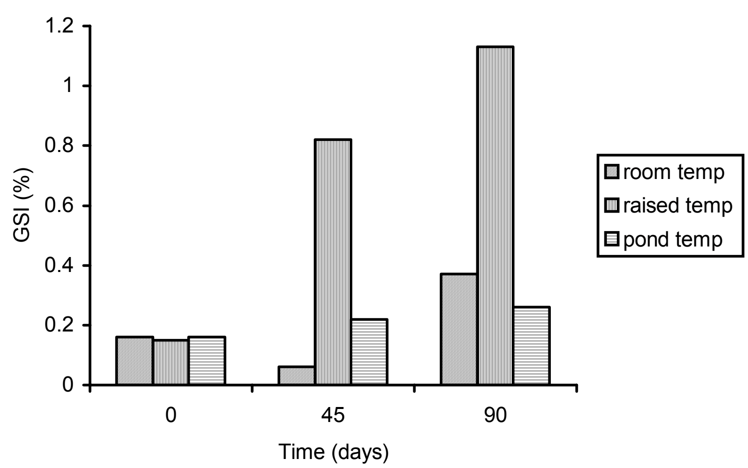

Figure 1. Gondosomatic index of female *Oreochromis karongae* raised under different temperature regimes (pond, room and raised temperature)

Table 3. Mean gonadosomatic index of *Oreochromis karongae* females from raised and pond temperature

Day	Raised temperature		Pond temperature	
	Mean GSI	SE	Mean GSI	SE
0	0.13	0.012	0.13	0.012
45	0.817	0.657[a]	0.217	0.012[b]
90	1.133	0.471[a]	0.257	0.027[b]

Means with different superscripts in the same row are significantly different ($p<0.05$)

Table 4. Mean gonadosomatic index of *Oreochromis karongae* females from room temperature and ponds.

Day	Room temperature (n=9)		Pond (n=9)
	Mean GSI	SE	Mean GSI ± SE
0	0.130	0.012	0.13 ± 0.012
45	0.057	0.027	0.217 ± 0.012
90	0.367	0.078	0.257 ± 0.027

Oocyte types in histological sections

Five oocyte developmental stages were observed from histological sections and these were postovulatory follicles, immature, maturing, mature, and dying oocytes. At the onset of the experiment, 63 % of all the oocytes were immature (Figure 2). The abundance of maturing, mature, atretic and dying of oocytes was below 20 %. The proportions of immature oocytes in the subsequent sampling days are shown in Figures 3 and 4.

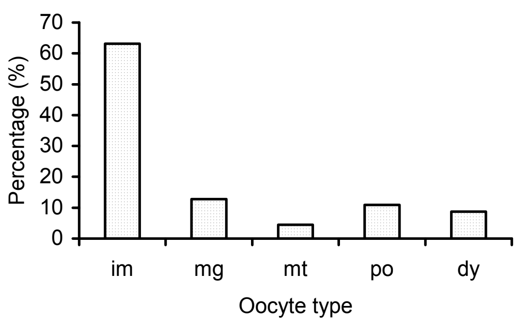

Figure 2. Number of immature (im), maturing (mg), mature (mt), dying (dy) oocytes and post ovultory follicles (po) expressed as a percentage of the total number of oocytes in each histological section at the onset of the experiment

After a period of 45 days in the experiment, there was no significant difference in the relative frequency of immature oocytes (Table 6) among the treatments. However, treatment affected the frequency of maturing oocytes after 45 days (Table 7). High frequencies were obtained in samples from the pond (90.88 %) and room temperature (59.84 %) but these were not significantly different. Samples from raised temperature gave the lowest frequency of 23.11 % (Figure 3) and this was different from the rest ($p<0.05$). The highest and lowest ($p<0.05$) frequency of maturing oocytes was obtained at the onset of the experiment and after 90 days, respectively (Table 5).

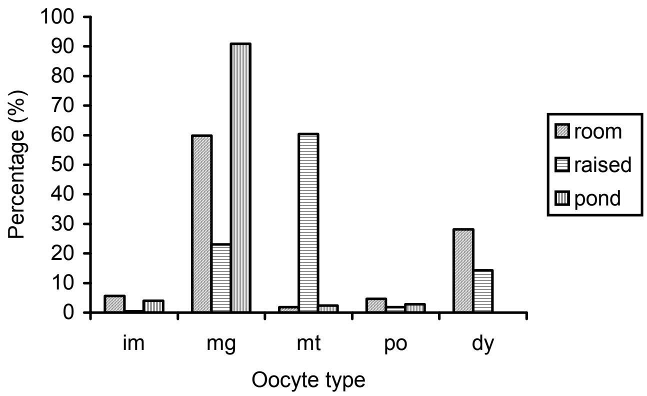

Figure 3. Number of immature (im), maturing (mg), mature (mt), dying (dy) oocytes and post ovultory follicles (po) expressed as a percentage of the total number of oocytes in each histological section after 45 days of the experiment

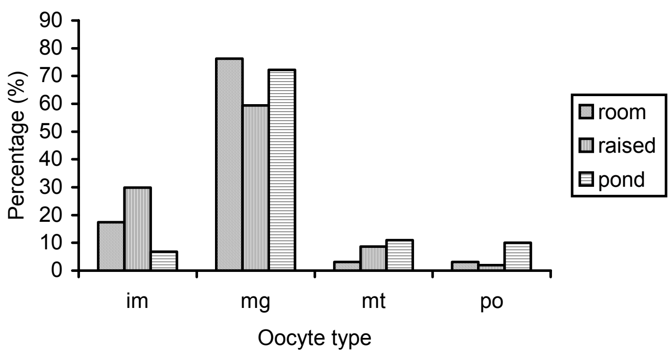

Figure 4. Number of immature (im), maturing (mg), mature (mt) oocytes and post ovultory follicles (po) expressed as a percentage of the total number of oocytes in each histological section after 90 days of the experiment

Temperature influenced ($p<0.05$) the presence of mature oocytes in the ovaries (Table 5). The highest frequency of mature oocytes was obtained from raised temperature both after 45 and 90 days. The frequency of mature oocytes in samples from the pond and room temperature was not different. Mature oocytes were present throughout the sampling days (Figures 2, 3 and 4).

The effect of temperature on the frequency of empty follicles was significant ($p < 0.05$) after 90 days (Table 5). Fish samples from the pond had the highest frequency of empty follicles (10 %). The frequency of empty follicles in fish samples from room and raised temperature (1.95 and 3.15 %, respectively) were not different (Figure 4).

Dying oocytes were observed at the onset of the experiment (Figure 5) and after 45 days (Figure 3). There was a higher frequency ($p<0.05$) of dying oocytes in samples from room temperature than in raised temperature. Dying oocytes were not present in samples from the pond, after 45 days. After 90 days, no dying oocytes were observed in all the treatments.

There were no differences in the distribution of immature, maturing, mature and dying oocytes in the distal, proximal and middle parts of the ovaries. However, the frequency of empty follicles in these three parts was different ($p<0.05$). The highest frequency was at the distal end. The frequency of the empty follicles at the middle and proximal end was not different (Table 6). Figure 5 shows the histological sections of ovaries from the three treatments.

Table 5. Mean number of immature, maturing, mature, dying oocytes and post ovulatory follicles expressed as a percentage (transformed to natural logarithm) of the total number of oocytes in each histological section at different times and temperature regimes.

Period	Treatment	Oocyte type/Mean percentage transformed to natural logarithm				
		Immature	Maturing	Mature	*POF	Dying
Initial		3.21	1.79	1.2	0.87	0.81
Day 45	Room	0.90±0.45[a]	4.49±0.67[a]	0.45±0.38[b]	1.11±0.33[a]	2.78±0.55[a]
	Raised	0.14±0.28[a]	1.54±0.41[b]	3.15±0.24[a]	0.45±0.20[a]	0.83±0.34[b]
	Pond	1.06±0.46[a]	4.82±0.68[a]	0.13±0.39[b]	0.57±0.34[a]	1.12±0.56[b]
Day 90	Room	1.63±0.44[b]	4.30±0.36[a]	0.07±0.30[b]	0.73±0.33[a]	0
	Raised	3.47±0.38[a]	4.13±0.31[a]	1.33±0.26[a]	0.78±0.29[a]	0
	Pond	1.34±0.28[b]	4.05±0.23[a]	1.72±0.19[a]	2.02±0.21[b]	0

[a, b] Means with different superscripts within the same column and period are significantly different ($p<0.05$)
*POF = post ovulatory follicles

Table 6. The effect of part of ovary on mean number of immature, maturing, mature, and dying oocytes, and post ovulatory follicles expressed as a percentage (transformed to natural log) of the total number of oocytes in each histological section.

Part of ovary	N	Oocyte type/Mean transformed percentage (ln)				
		Immature	Maturing	Mature	*POF	Dying
Proximal	24	1.85[a]	3.39[a]	1.75[a]	0.59[b]	0.35[a]
Middle	27	1.65[a]	3.51[a]	1.66[a]	1.02[b]	0.48[a]
Distal	28	1.57[a]	3.44[a]	1.52[a]	1.62[a]	0.24[a]

[a, b]Means with different superscripts are significantly different ($p<0.05$)
*POF = post ovulatory follicles

Discussion

The results clearly showed that raising and maintaining temperature at 26.5 ± 0.5°C has an effect on oocyte development of *O. karongae*. These results confirm that temperature is important in regulating gonadal maturation in tilapias as reported by Srisakultiew and Wee (1988). Similar results were obtained in *O. mossambicus* (Chmilevskiy and Lavrova 1990). Chmilevskiy and Lavrova (1990) reported that during low temperature (20°C), division of the primary sex cells and gonia was inhibited, completely blocking their transition to early prophase meiosis. Lowering temperature from 26-28 to 20-22°C for 15 days reduced oocyte diameter and delayed onset of vitellogenesis in the same species (Chmilevskiy 1995b). In another experiment Chmilevskiy (1995a) reported suppression of differentiation of the female gonads in reduced temperature. Dying oogonia and oocytes were found where temperature was maintained at 20-22°C. Therefore, the low GSI and presence of dying oocytes that were obtained at room temperature in the current experiment could be alluded to the low prevailing temperatures.

The maximum GSI recorded in this experiment was 2.13 % and this was obtained from raised temperature after 45 days. The value was close to the maximum value of 2.25 % reported by Msiska (1998) for *O. karongae* females reared in ponds. Maximum GSI values correspond with the spawning season of fish. For instance, Barnabe (1994) reported that high GSI of seabass were found at the peak of the spawning season, Admassu (1996) reported that GSI of *O. niloticus* peaked twice in Lake Awassa, which corresponded to the peak spawning periods of *O. niloticus* in that lake. The results of this study show that after 45 days, some fish that were reared in raised temperature almost reached their peak GSI under culture conditions indicating that there is a possibility for the fish to spawn during the cold season if temperature is raised to 26.5 ± 0.5°C.

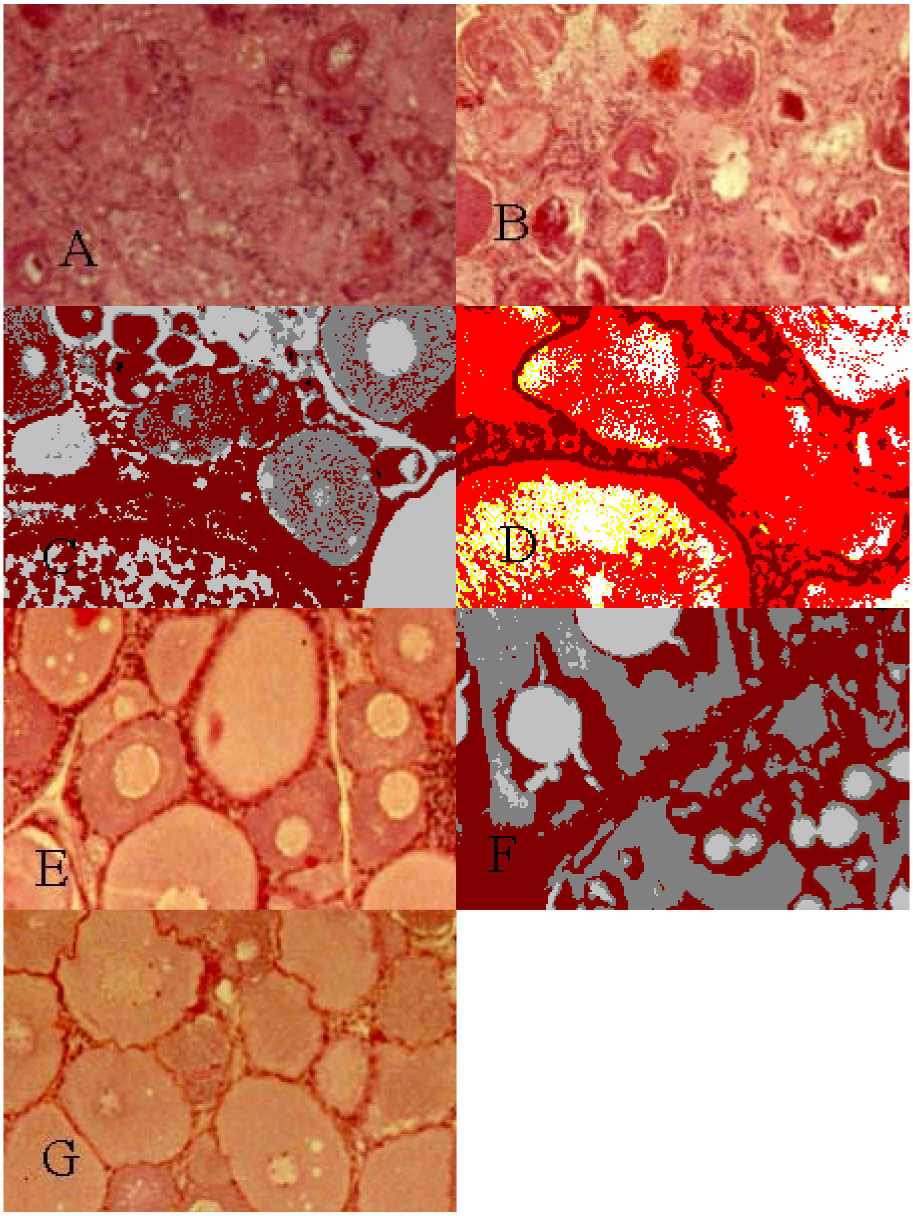

Figure 5. Oocytes from *Oreochromis karongae* reared at room, raised and pond temperature. A: Oocytes from fish samples at the onset of the experiment (24th July 2000); B, C, and D: Oocytes from fish samples from room, raised and pond temperature after 45 days, respectively. E, F and G: Oocytes from fish samples from room, raised and pond temperature, respectively after 90 days

Brummet (1995) suggested that temperatures outside the range of 22-36^{o}C during normal reproduction might act as a terminating cue (a factor that may interfere with final ovulation and spawning) in Tilapia. Since room temperature was outside the ideal range for oocyte development, oocyte development in fish from room temperature was inferior to that from raised temperature. Poor oocyte development observed at room temperature may mean that the low temperature interfered with the release of GtH by the hypothalamo-hypophyseal complex, which in turn slowed down vitellogenesis. Barnabe (1994) stated that temperature directly affects the production of GtH and eventually affect the vitellogenesis process. Jalabert and Zohar (1982) reported that exogenous vitellogenesis seems to be completely inhibited by low temperatures and all yolk-bidden oocytes disappear during the cold season.

Low temperatures (below 20°C) also reduce activity and feeding of tilapias (Chervinski 1982, Piper *et al.* 1982). Reduced feeding could be the other factor that might have contributed to poor ovarian development in fish raised under room temperature. Generally, a relatively lower feed intake was observed in fish under room temperature. The reduced feeding may have resulted in the fish using fat reserves from the body to provide metabolites for survival. Barnabe (1994), reported that if fat reserves are totally depleted, gonads provide the metabolites which allow the animal to survive. This may have occurred in fish that were kept at room temperature thereby resulting in poor gonad development in the fish.

At the onset of the experiment, there were more immature oocytes than during the rest of the sampling days. This was expected for two reasons. Firstly, the experimental fish were still growing and therefore oocytes were just developing at that time. Secondly, this was the coolest time of the year (July), which is outside the breeding period of *O. karongae* (Brooks and Maluwa 1997). Therefore, it was expected that the ovarian activity would be dormant, hence the advanced oocyte stages were not expected to dominate. The percentage of immature oocytes was lowest after 45 days of the experiment and increased again after 90 days. Increase of immature oocytes after 90 days may mean that the gonadal regression that was taking place in the ovaries stimulated development of more oocytes. Mature oocytes were most abundant in raised temperature. This was expected because this temperature level was within the range suitable for normal oocyte development in Tilapia (Chervinski 1982, Brummet 1995). The mature oocytes were also present throughout the experimental period because immature and maturing oocytes that were present were developing further.

The high relative frequency of maturing oocytes from the pond and room temperature may reflect the unfavorable conditions for oocyte development. Oocyte development may have been arrested to this stage while waiting for suitable conditions for development. It is however interesting to note that the proportions of maturing oocytes increased with time and were highest after 90 days implying that development from immature to maturing oocytes was enhanced with time. As room and pond temperatures were not controlled, the temperature increased with time due to change in season. The temperature was thus getting more favorable for the oocytes to develop from immature to maturing types.

The presence of almost all the maturity stages of oocytes in the ovaries are in agreement with what Msiska (1998) found. The results show that *O. karongae* has asynchronous ovaries. DeVlaming (1983) as cited by West (1990) reported that most fish with asynchronous ovaries have protracted spawning seasons with multiple spawnings. Therefore there may be a possibility that *O. karongae* can have protracted spawning seasons and/or multiple spawnings. This is evident from studies on the breeding season of *O. karongae*, which show that it has a prolonged spawning period in Lake Malombe (July-October) while in Lake Malawi it has two spawning peaks, August-October and December-February (Pálsson *et al* 1999). In the southern part of Malawi (Thyolo), farmers report that *O. karongae* spawns throughout the year except during the cold season, which is from May to July (Jamu 2001, personal communication). The results of the current experiment show the possibility to circumvert the seasonal breeding of *O. karongae* in hatcheries by raising temperature to 26.5 ± 0.5°C during the cold season.

References

Admassu, D. 1996. The breeding season of Tilapia, *Oreochromis niloticus* L. in Lake Awassa (Ethiopian rift valley). Hydrobiologia, 337:77-83.

Barnabè, G. 1994. Biological basis of fish culture. In Barnabè, G. (ed.) Aquaculture: Biology and ecology of cultured species. Ellis Horwood. New York. pp. 227-372.

Bromage, N.R. 1995. Broodstock management and seed quality. *In* Bromage, N.R. and Roberts, R.J. (eds.). Broodstock management and egg and larval quality. Blackwell Science Ltd. Oxford UK. pp. 1-24.

Brooks, A. C. & Maluwa, A. O. 1997. Fish farming in Malawi: A case study of the Central and Northern Regions Fish Farming Project. Technical Supplement: On-station trials. Government of Malawi and European Commission. 37p.

Brummett, R. E. 1995. Environmental regulation of sexual maturation and reproduction in Tilapia. Reviews in Fisheries Science, 3:231-248.

Chervinski, J. 1982. Environmental physiology of Tilapias. *In* R.S.V. Pullin and R.H. Lowe-McConnell (eds.) The biology and culture of Tilapias. ICLARM Conference Proceedings 432p. International Center for Living Aquatic Resources Management, Manila, Philippines. p.119-128.

Chmilevskiy, D.A. 1995a. Effect of reduced temperature on oogenesis of the mouth brooder, *Oreochromis mossambicus* 2. Effect on fish twenty-two days after hatching. Journal of Ichthyology, 35:72-80.

Chmilevskiy, D.A. 1995b. Effect of reduced temperature on oogenesis in Tilapia, *Oreochromis mossambicus*. 3. Impact on fish at age 30 and 60 days after hatching. Journal of Ichthyology, 35:119-129.

Chmilevskiy, D.A. and Lavrova, T.V. 1990. The influence of temperature on oogenesis in Tilapia, *Oreochromis mossambicus*. Journal of Ichthyology, 30:14-24.

Crim, L.W. & Glebe, B.D. 1990. Reproduction. *In* Shreck, C.B. and Moyle, P.B. (ed.) 1990. Methods for fish biology. American Fisheries Society. Bethesda, Maryland. pp. 529-553.

Das, P. & Ponniah, A.G. 1993. Research needs in fish breeding and genetics in aquaculture for the year 2000. *In* aquaculture research needs for 2000 A.D. AA Balkema/Rotterdam. India. pp. 181-195.

Hinton, D.E. 1990. Histological techniques. *In* Shreck, C.B. and Moyle, P.B. (ed.) 1990. Methods for fish biology. American Fisheries Society. Bethesda, Maryland. pp. 191-211.

Jalabert, B. & Zohar, Y. 1982. Reproductive physiology in cichlid fishes with particular reference to *Tilapia* and *Sarotherodon*. *In* R.S.V. Pullin and R.H. Lowe-McConnell (eds.) The biology and culture of Tilapias. ICLARM Conference Proceedings 432p. International Center for Living Aquatic Resources Management, Manila, Philippines. p.129-140.

Msiska, O.V. 1998. Reproductive biology and growth of *Oreochromis (Nyasalapia) karongae* in ponds and open water in Malawi. Ph.D. Thesis. University of Malawi. 221p.

Msiska, O.V. & Costa-Pierce, B.A. 1997. Factors affecting the spawning success of *Oreochromis karongae* (Trewavas) in ponds. Aquaculture Research, 28:87-99.

Pálsson, Ó. K., Bulirani, A. & Banda, A. 1999. A review of biology, fisheries and population dynamics of chambo (*Oreochromis spp*., CICHLIDAE) in Lakes Malawi and Malombe. Government of Malawi. Fisheries Department. Fisheries Bulletin No.38. 35p.

Piper, R.G., McElwain, I.B., Orme, L.E., McCaren, J.P., Fowler, L.G., & Leonard, J.R. 1982. Fish Hatchery management. US Department of the Interior Fish and Wildlife Services. Washington D.C. 517p.

Ricker, W.E. 1971. Methods for assessment of fish production in fresh waters. IBP Handbook 3:348p.

SAS. 1996. The Statistical Analysis System. SAS Institute Inc. Cary, NC 27513. USA.

Srisakultiew, P. & Wee, K.L. 1988. Synchronous spawning of Nile Tilapia through hypophysation and temperature manipulation. *In* Pullin, R.S.V.,Bhukaswan, T., Tonguthai, K. and Maclean, J.L. (eds.). The second international symposium on Tilapia on aquaculture. 623p. Department of Fisheries, Bangkok, Thailand and International Center for Living Aquatic Resources and Management. Manila, Philippines. ICLARM conference proceedings. p.275-284.

Subasinghe, R.P. & Somerville, C. 1992. Effects of temperature on hatchability, development and growth of eggs and yolk-sac fry of Oreochromis mossambicus (Peters) under artificial incubation. Aquaculture and Fisheries Management, 23:31-39.

West, G. 1990. Methods of assessing ovarian development in fishes: A review. Aust. J. Mar. Freshwater Res. 41:199-222.

The Effect of Feeding Density on Survival 0f African Cat Fish *Clarias gariepinus*

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Abstract
Results on the study of the relationship between feeding density and survival of *Clarias gariepinus* fry are presented. This study was carried out at National Aquaculture Centre with the objective of finding out the optimum number of zooplankton that can improve the survival of fry to fingerling stage. *C. gariepinus,* fry 4 days, old were stocked in 50 litre tanks for 30 days at a rate of 20 fry in each tank. Four zooplankton densities were used 5, 10 and 30 zooplankton/ml of water, the control was 0 zooplankton /ml of water. Each density was replicated 3 times and every 3 days the number of fish in each tank was counted. Highest survival rates (80%) were obtained from tanks in which the fish were fed 30 zooplankton/ml and these were significantly different ($P<0.05$) from all the other densities. There were no significant differences in the survival rate (50%) at zooplankton density 5/ml and survival rate (67%) zooplankton density 10/ml. However all the feeding densities were significantly different from the control ($P<0.05$), feed density 0 zooplankton/ml survival rate 0%.

Introduction
Clarias gariepinus is one of the commonly raised indigenous fish species in Malawi. The farmers prefer to raise this species due to its fast growth as compared to the Tilapia species. Dickson and Brooks (1997) reported a range of growth rates for *Oreochromis shiranus* as 0.10-0.40 g/day and 0.20-0.48 g/day for *Oreochromis karongae*, while growth rate for cat fish was reported as high as 2.53 g/day in a pond receiving untreated pig wastes.

Compared to Tilapias, there are two set backs for farmers to raise this species in ponds. Firstly, *C. gariepinus* do not breed naturally in ponds, therefore there is need for artificial induced technique to induce its spawning. The second set back is the high cannibalism rate during the fry stage which reduces the survival rate to fingering stage and reduces the production. Suzuki and Umezawa (1993) reported a survival rate of fry at 70% in concrete bottom ponds and 50% in earth bottom ponds in Japanese catfish.

Many research activities have been carried out to define ways and means of inducing the catfish to breed and how farmers themselves could easily do this activity. The main problem is how to raise the catfish from larvae to a fingerling stage. Dickson and Brooks (1997) reported that survival rate of catfish from the fry to fingerling stage was improved to 20% when fry were transferred from the hatchery to nursery ponds 14 days after hatching.

In order to improve the survival rate of *C. gariepinus* fry, enough and appropriate feeds have to be supplied to the fry so that cannibalism can be reduced. The objective of this study is to investigate the amount of zooplankton that can be fed to fry to improve their survival rate. This study reports on the optimum number of zooplankton that can be used to improve the survival rate of fry to fingerling stage.

Materials and methods
Sexually mature brood stock that are maintained at National Aquaculture Center, were induced to spawn by means of hormone injection from pituitary gland of common carp at a rate of 2mg/kg body weight, the males received half the female dose. The fish were left to breed naturally in 500 L conical tank in the hatchery.

The four-day old larvae were stocked in 50 L tanks at a rate of 20 fish/tank in a laboratory at the National Aquaculture Center. The experiment was carried out for 30 days and the fish were sampled every 3 days to check the survival rate in each tank. Three feeding densities were used as follows:- 5 zooplankton/ml, 10 zooplankton/ml and 30 zooplankton/ml, 0 zooplankton/ml was taken as a control and each feeding density was replicated three times.

The zooplankton was collected from fertilized ponds at the National Aquaculture Center using a 0.06 mm net. The fry were fed zooplankton every morning at 8:00 a.m. and before feeding, water quality parameters were recorded i.e. pH, temperature and dissolved oxygen. Three types of zooplankton, depending on availability, were used in this experiment and these are Copepoda, Cladocera and Rotifer, which are shown in Figure 1.

The experimental design was completely randomized design (CRD) and random numbers were used to allocate the feeding levels to their respective tanks as shown in table 1: The data collected was number of fry in each zooplankton feeding level and analyzed using the Analysis of Variance (ANOVA) at 5% level of significance for each feeding level.

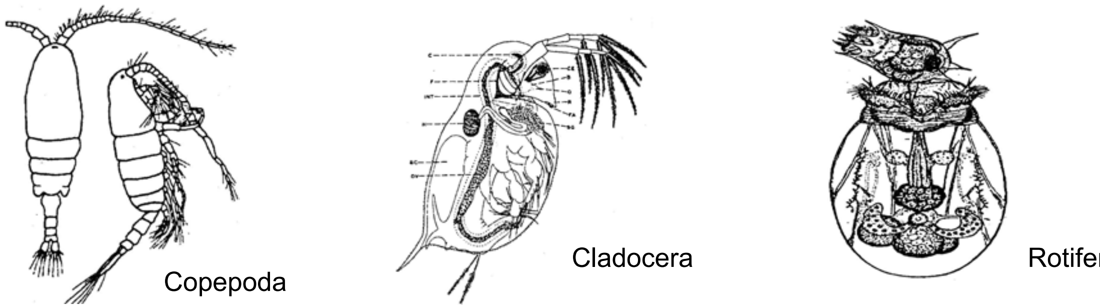

Figure 1. Zooplankton used in the feeding experiment.

Table 1. The lay out of the experiment according to different feeding levels

Tank1 5 zooplankton/ml	Tank4 10 zooplankton/ml	Tank7 30 zooplankton/ml	Tank10 0 zooplankton/ml
Tank2 10 zooplankton/ml	Tank5 5 zooplankton/ml	Tank8 0 zooplankton	Tank11 30 zooplankton
Tank3 30 zooplankton/ml	Tank6 0 zooplankton/ml	Tank9 10 zooplankton/ml	Tank12 5 zooplankton/ml

Results and discussion

After 30 days of carrying out the experiment, the results showed that fish fed with 30 zooplanktons/ml had 80% survival rate, fish fed with 10 zooplanktons had survival rate of 67%, fish fed with 5 zooplanktons had a survival of 50% and fish not fed with zooplankton had 0% survival rate.

All the fish in the 0 zooplankton/ml were dead by the 15th day of the experiment and the experiment continued with the other three feeding levels as shown in Figure 2.

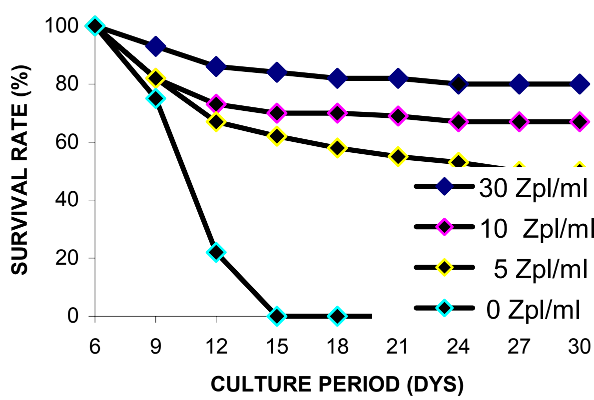

Figure 2. The trend of survival rate % of African catfish fed different density of zooplankton/ml of water during the period of the experiment.

The results showed that there is a positive relationship between the zooplankton density and the survival rate of the fry i.e. the higher the zooplankton density the higher the survival rate of fry. However the number of zooplankton can only be increased up to a certain point, if the number of zooplankton increases up to 50/ml all the fry were dead within 3 days of culture.

Apart from the feed density other factors also contributed to the death of the fry in this trial. In 30 zooplankton/ml feeding density the death of fry was mainly contributed by the aggressive territorial behavior of the fry. This was also reported by Hetch and Applebaum (1988), in their trial apart from cannibalism death of fry was due to fatal aggressive territorial encounters between two or more individuals which is a common behavior in young *Clarias gariepinus*.

The lowest survival rate was in the 0 zooplankton/ml density was due to starvation. There were evidences of type-1 cannibalism during the first 7 days of culture and after that the fry were very weak so much and they died due to starvation.

The data analysis showed that there is a significant difference ($P < 0.05$) in feeding the fish with 30 zooplankton/ml against all the feeding densities and that there is no significant difference ($P < 0.05$) in feeding the fish with 5 and 10 zooplankton/ml. However all the feeding densities were significantly different ($P<0.05$) from the control (Table 2)

Table 2. The mean survival rate of African catfish after 30 days of culture in tanks

Treatment (feeding level)	Survival rate after 30 days of culture
0 zooplankton/ml	0 % ^{a}
5 zooplankton/ml	50 % ^{b}
10 zooplankton/ml	67 % ^{b}
30 zooplankton/ml	80 % ^{c}

Survival rate % with the same superscript for each treatment are not significantly different ($P < 0.05$).

The water quality parameter results were within the acceptable range for fresh water species e.g. the pH was 7.3, Dissolved oxygen 7.49 and water temperature 25 ^{O}C. Haylor (1992) reported that good growth rates of cat fish larvae and fry can be achieved at temperatures between 25 – 33 ^{O}C, at temperatures below this range growth is slower and the size variation in the population is greater however survival is still good.

Acknowledgements

This work forms part of the JICA Aquaculture Project activities at the National Aquaculture Centre. The project was jointly funded by the Malawian and Japanese Governments.

References

Dickson, M. W., & Brooks, A. C. 1997. Fish Farming in Malawi: A case study of the Central and Northern Regions Fish Farming Project. University of Stirling, Stirling. U. K.

Haylor, G. S. 1992. The African catfsh hatchery manual. Central and Northern fish farming project, Malawi. University of Stirling, Stirling. U.K.

Hecht, T. & Appelbaum, S. 1988. Observation on intraspecific aggression and sibling cannibalism by larval and juvenile *Clarias gariepinus* under controlled conditions. *Journal of Zoological Society of London* 214, 21-44.

Susuki, E.& Umezawa, K. 1993. The influence of stoking density on survival rate of Japanese cat fish. A research report at Saitama prefecture fisheries experimental station, Saitama, Japan.

Determination of the time interval between the prime and resolving dosages of *Cyprinus carpio* hormone dose to artificially induce *Opsaridium microlepis* to breed

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Abstract
The Results on the study of final oocyte maturation of *Opsaridium microlepis,* " Mpasa", in response to the first (prime) dose and the second (resolving) dose of *Cyprinus carpio* pituitary gland are presented. The objective was to determine the optimum time interval between the prime and resolving dosages to induce ovulation in the fish. Mature broodstock of 250g, that were collected directly from their wild source, i.e. Linthipe River, were injected with *C. carpio* pituitary gland extract at the rate of 5mg/kg female body weight. This dose was split into two, the prime and the resolving dosages. The fish received 10% of the total dose as a prime and 90% as the resolving dose, at three time intervals of 9, 12 and 15 hours separating the dosages. All fish ovulated when the time interval between the first and second injection was 12 hours. When the eggs were fertilized, hatchability was 76.6%. The fish did not ovulate when the resolving dosages were given at 9 and 15 hours. The results are discussed with reference to application of the protocols developed in this study to produce mass fingerling of this species for aquaculture.

Introduction
Opsaridium microlepis locally known as 'mpasa' is endemic to Lake Malawi and it attains a weight of at least 2.5kg (Msiska 1990). The fish is commonly caught in the northern and central regions of Malawi, where it ascends rivers like Songwe, Bua and Linthipe to breed in clear running water in the rivers. *O. microlepis* is an important commercial species of Lake Malawi. The fish fetches high prices on the market and this has led to its over exploitation and hence the catches from the wild have declined (Tweddle 1981 in Msiska 1990).

Research on the suitability of indigenous cyprinids for aquaculture has not been done in detail, despite the fact that Malawi has cyprinids in the genera, *Barbus, Labeo* and *Opsaridum* (Maluwa *et al.* 1997). In other countries cyprinids have been farmed in aquaculture for their high value and export potential, for example the Norwegian Salmon and Rainbow trout.

The National Aquaculture Centre is screening indigenous cyprinids for their suitability in aquaculture in Malawi and *O. microlepis* would be the most suited candidate for commercial aquaculture development in Malawi because of its large maximum body weight, high market value and demand.

Initial studies on the Gonad Somatic Index (GSI) show that the breeding season for the species is between May and August. As a fish that migrates to breed in clear running waters in the river, *O. microlepis* require artificial induced breeding. Previous efforts to breed the fish did not succeed because the time interval between the prime and resolving dosages were unknown. The objective of this study was to determine the optimum time interval between the prime and resolving dosages that would induce ovulation in the fish.

Materials and Methods
This study was conducted in the hatchery at National Aquaculture Centre (NAC). Mature females and males, of 250g body-weight were collected from Linthipe river in the central region. The fish were collected during the months of January – October, as they migrated to breeding grounds. The fish were transported to NAC and after initial quarantine exercise in tanks they were taken into hatchery for artificial induced breeding.

The fish were given a dose of 5mg/kg body weight of *C. carpio* pituitary gland extract. Of this dose, 10% was given as a prime dose and the rest 90% was given as a resolving dose. The gland was removed from a donor C. *carpio* obtained from the farm at NAC. The treatments were the time interval between the prime and resolving dosages. There were 3 time intervals that were tested, which were, 9, 12 and 15 hrs. Each treatment was replicated 4 times. The males were given 50% of the female dosege i.e. 2.5mg/kg body weight only once, when the females were given the resolving dose.

The oocyte maturation stages were determined by sampling the oocytes from the ovary by using a plastic tube, and then observing oocytes under the stereoscopic microscope. In order to observe the nucleus of the oocytes, they were placed in petri dish with Sera's solution (60 % ethanol, 30 % formalin and 10% acetic acid). In maturing oocytes the nucleus (Germinal Vesicle) migrates to the animal pole where it breaks and disappears in mature oocytes. This phenomenon known as geminal vesicle migration and break down was used as a biological indicator to determine the oocyte maturation stages as shown in

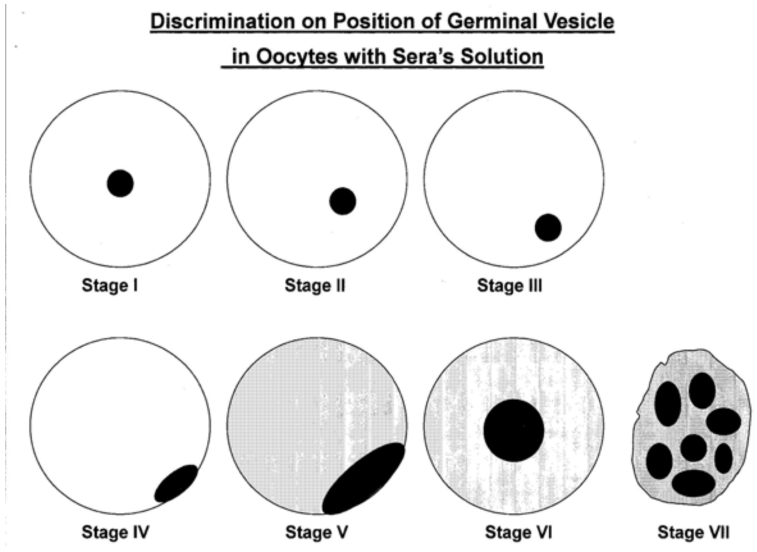

Figure1: Discrimination on position of Germinal Vesicle in Oocytes with Sera's solution

When oocyte development processes are completed (vitellogenesis), the oocytes reach stage I of maturation, in which the germinal vesicle is at the center. The final oocyte maturation process follows the migration of the germinal vesicle from the center to the animal pole, where it breaks down at stage V and the oocyte is ovulated into a fertilizable egg in stage VI. When the egg reaches stage VII, it is degenerated and hence not fertilizable. This phenomenon is known as over ripening. The injected brood stock were put in 500 litre conical tanks at a ratio of 1:1 (Male:female). The fish were expected to ovulate within 18 hours at the incubation temperature of 26 ^{0}C. After 18 hours, the fish were stripped off their eggs and artificially fertilized with sperm contained in milt that was stripped from the males. The fertilized eggs were incubated in zug jars in the laboratory at NAC. The incubation temperature was 26^{0}C. The eggs hatched after 24 hours and hatchability was determined from the total number of fertilized eggs and that number which hatched.

Results

All the fish that were given the second resolving dose 9 hrs and 15 hrs after the prime dose did not ovulate. The oocytes in fish given the resolving dose at 9 hours passed through the stages of oocyte maturation and degenerated in stage VII. These eggs did not hatch when fertilized. The fish that were given a resolving dose 15 hours after the prime dose, their oocytes never matured beyond stage IV, i.e. the oocyte maturation processes were arrested at stage IV. These eggs when stripped and fertilized after 18 hours, did not hatch. Ovulation at stage VI occurred when the fish were given a resolving dose 12 hours after the prime dose. These eggs when stripped were fertilizable and hatched after 24 hours of incubation. The hatchability rate was 76.6%. The relationship between time intervals, number of eggs stripped, fertilization and hatchability rates is shown in Table 1.

Table 1: The relationship between time interval separating the prime and resolving dosages and number of eggs produced and fertilization and hatchability rates.

Time Interval (Hours)	Eggs Produced	Fertilization rate (%)	Hatchability (%)
9	6,500	0	0
12	6,994	84	76.6
15	6,000	0	0

There was no significant difference in the number of eggs stripped across the three time intervals. However, the 12 hour interval gave significantly ($P< 0.01$) higher rate of fertilized eggs and hatchability (Table 1).

Discussion

Most of the work on induced breeding of cyprinids, show that the fish require two injections, i.e. the prime and resolving dosages. The prime dose is used to induce final oocyte maturation and the second dose to induce ovulation. Similar work on cyprinids with the Indian major carps, the time period between the prime and resolving dosages was 6 hours. The priming dose was 20% and the resolving dose was 80%. With these dosages and times, spawning was expected 4 to 6 hours after the resolving dose (Pullin and Jhingran 1985). The results in this trial show that *O. microlepis* has lower priming dose of 10% and higher resolving dose of 90%. In addition *O. microlepis* has a longer oocyte maturation period (18 hours).

Having defined the right time interval for the fish to breed successfully, further work is underway to establish the production of mass fingerlings using the protocols developed in this study.

Acknowledgements

This work forms part of the JICA Aquaculture Project activities at the National Aquaculture Centre. The project was jointly funded by the Malawian and Japanese Governments.

References

Maluwa, A. O., Kamakura, M & Sakai, K. 1997. Induced Maturation and Ovulation of Grass Carp (*Ctenopharygodon idellus*). In proceedings of the first Regional Workshop on Aquaculture, Bunda College of agriculture, Lilongwe, Malawi. 1997:86-92.

Msiska, O.V. 1990. Reproductive Strategies of two cyprinid fishes in Lake Malawi and their relevance for aquaculture development. In aquaculture and Fisheries Management 1990, 21, 67-75.

Msiska, O. V. 1991. Induced spawning and Early growth of Mpasa (*Opsaridium microlepis)* and Ntchila (*Labeo mesops)* in tanks and earthern ponds. In Aquaculture Research in Africa, Pudoc Wagenigeni,:P 159-168.

Pullin, R. S. V & Jhingran, V.G.1985. A hatchery manual for the common, Chinese and Indian major carps. ICLARM studies and Reviews 11, 191 p. Asian Development Bank, Manila, Phillipines and International Centre for Living Aquatic Resources Management, Manila, Phillipines.

Tweddle, D. 1987. An Assesment of the Growth Rate of Mpasa, *Opsaridium miclolepis,* by length frequency analysis. In Journal of Limnology Society Southern Africa 13(2), 52-57.

Determination of biological reference points for Lake Malawi cichlids

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Abstract

Biological reference points (BRPs) - values that represent the state of a fishery or population - are commonly used to guide management decisions. BRPs are expressed as a function of fishing mortality and are derived from models that describe the population dynamics of a resource. These models include dynamic pool, spawner-recruit and production models. Unfortunately, in the absence of long-term fisheries data, such as abundance indices and catches-at-age, it is only dynamic pool models, usually known as yield-per-recruit and spawner biomass-per-recruit models, that are known with any degree of certainty. BRPs that have been proposed in the literature have been calculated for temperate demersal marine species with life-history characteristics that include high fecundity, pelagic spawning and little or no parental care. In contrast, cichlids have low fecundities and exhibit varying levels of parental care ranging from guarding to mouthbrooding. Cichlid specific BRPs, calculated with combinations of two spawner-recruit relationships within deterministic and stochastic frameworks, were shown to be highly dependent on the degree of density-dependence in the spawner-recruit relationship. Overall, cichlid specific BRPs were similar to than temperate groundfish species and it is suggested that fishing mortality be maintained at no more than that required to reduce spawner biomass-per-recruit to 40% of pristine levels if the form of the spawner-recruit relationship is unknown. If a Beverton-Holt spanwer-recruit relationship is assumed, a biologically plausible relationship given cichlid life-histories, then it is suggested that spawner biomass-per-recruit is not reduced below 50% of unfished levels.

Introduction

Biological reference points (BRPs) are commonly used to guide management decisions. BRPs are values that represent the state of a resource and whose characteristics are believed to be useful for the management of a unit stock through the provision of information regarding its status relative to an acceptable value or range (Caddy and Mahon, 1995). There is also a need by management to quantify potential long-term trade-offs between maximising yield, either by mass or economic gain, while limiting the risk of possible reproductive failure. Applying a constant fishing mortality to maximise yield i.e., F_{MSY}, would clearly be advantageous, however, knowledge of the biomass required to achieve *MSY* is difficult to determine, principally because of the lack of information on the functional form of the spawner-recruit relationship, hampering understanding of the biomass-production relationship (Sissenwine and Shepherd, 1987; Clark, 1991).

BRPs are most often expressed as a function of fishing mortality and are derived from models that describe the population dynamics of a resource. These interrelated models include dynamic pool, spawner-recruit and production models. For a graphical illustration see Sissenwine and Shepherd (1987). Unfortunately, in the absence of data, which is usually the case for most fisheries including those that are cichlid dominated, only the dynamic pool models, often termed as yield-per-recruit and spawner biomass-per-recruit, are known with any degree of certainty. Quantifying and understanding the spawner-recruit relationship and the productivity of the resource at various abundances is, therefore, imperative.

BRPs that have been proposed in the literature have been calculated for temperate marine species with life-history characteristics that include high fecundity, pelagic spawning and little or no parental care (Clarke, 1991; 1993; Mace 1994). In contrast, cichlids have relatively low fecundities and have various levels of parental care ranging from guarding to mouth brooding (Lowe, 1959; Trewavas, 1983). Could BRPs be similar for two groups of fishes with different life-history characteristics? This study provides the first quantitative examination into the relationships between yield and spawner biomass-per-recruit for a wide variety of cichlid specific life-history parameters, in an attempt to propose BRPs that would be beneficial for management.

Materials and methods

Modelling framework

A two-phase age-structured modeling framework was developed. Firstly, a deterministic model incorporating a stock-recruit (S-R) relationship was used to estimate instantaneous rates of fishing mortality (*F*) required to achieve several BRPs. The procedure was based on those outlined by Sissenwine and Shepherd (1987) and Clarke (1991). The second phase included a stochastic extension to test the robustness of the BRPs and to assess the trade-offs between yield and spawner biomass, and the potential risk of reproductive failure.

The stochastic model was similar to the deterministic model but incorporated recruitment variability and simulated an age-structured population that was fished at the desired fishing mortality necessary to achieve the desired BRP. Age-structure within the population was estimated with stochastic recruitment $R = e^{\varepsilon - \sigma^2/2}$ with $\varepsilon \sim N(0, \sigma^2)$. The constant $e^{-\sigma^2/2}$ ensured that $E[R] = 1$. Age-structure was estimated by projecting the population forward by 20 years at the required fishing mortality rate. This "burn-in" period provided the initial age structure for a 50-year projection at the required fishing intensity. It was assumed that a CV of 0.4 was sufficient for the recruitment variability such that $\sigma \approx CV = 0.4$. Error was assumed to occur in the BRP determination (for reasons such as sampling and ageing errors) such that $F = \hat{F}_{BRP} e^{\varepsilon - 0.1^2/2}$ where $\hat{F}_{BRP}$ is the predicted BRP fishing mortality and $\varepsilon \sim N(0, 0.1^2)$. A total of 100 50-year simulations were conducted.

Dynamic pool models

Two dynamic pool models, yield-per-recruit and spawner biomass-per-recruit as functions of fishing mortality *F*, were calculated as

$$YPR_F = \sum_{a=0}^{\max} \left[w_a \tilde{N}_a \frac{S_a F}{S_a F + M_a} (1 - e^{-S_a F - M_a}) \right] \Delta a \qquad SBR_F = \sum_{a=0}^{\max} \left[w_a \tilde{N}_a \right] \Delta a$$

where w_a is the mass at age *a*, S_a is the selectivity for age class *a*, M_a is the rate of natural mortality at age *a*, ψ_a the maturity-at-age *a* and *max* is the maximum recorded age and is considered a lumped-plus group. A time step of one month (Δa) was used in the simulations.

The relative proportion of fish at age *a* ($\tilde{N}_a$) was expressed as recursively as

$$\tilde{N}_a = \begin{cases} R = 1 & a = 0 \\ \tilde{N}_{a-1} e^{-FS_{a-1} - M} & 0 < a < \max \\ \dfrac{\tilde{N}_{a-1} e^{-FS_{a-1} - M}}{1 - e^{-FS_{\max} - M}} & a = \max \end{cases}$$

Weight-at-age was described as $W_a = \psi \left[L_\infty \left(1 - e^{-Ka} \right) \right]^\omega$ where ψ and ω describe the length-weight relationship, selection-at-age (S_a) and maturity-at-age (ψ_a) was estimated by a logistic of the form $P_a = \left(1 + e^{-(a - a_{50})/\delta} \right)^{-1}$ where P_a is the proportion selected/mature at age *a*, a_{50} the age-at-(50%) selection/maturity and δ the steepness of the ogive.

Spawner-recruit models

The Beverton-Holt (1957) and Ricker (1954) stock-recruit (S-R) curves are expressed as $R = S(\alpha + \beta S)^{-1}$ and $R = \alpha' S e^{-\beta' S}$, respectively where α, α', β and β' determine the shape of the curves, *R* is the predicted recruitment at a specified level of spawner biomass *S*.

Both S-R curves were reparameterised as a function of a "steepness" parameter h, which expresses that fraction of pristine recruitment (R_0) when spawner biomass (S_0) is reduced to θ % of pristine levels, such that $hR_0 = f(\theta S_0)$ where $f(\cdot)$ is the S-R curve of interest (Figure 1). This formulation reduces valid portion of the S-R curve between the origin and the replacement point (S_0, R_0). The "steepness" parameterisation was originally proposed by Mace and Doonan (1988) but most commonly ascribed to Francis (1992).

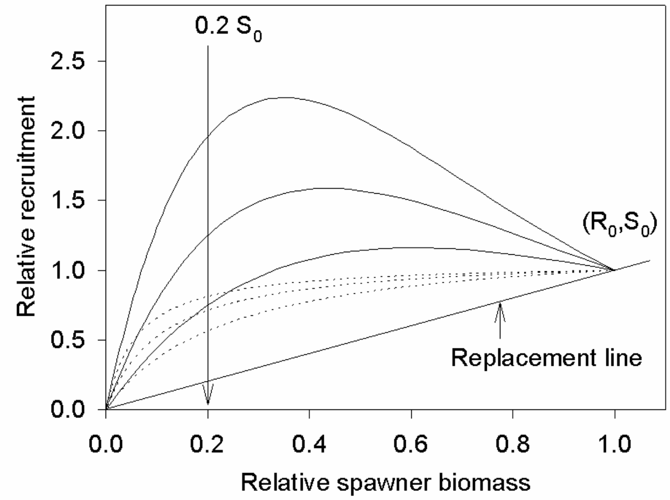

Figure 1. Relationship between recruitment and spawner biomass to the replacement line that joins the points (0,0) and (R_0, S_0) and can be used to reparameterise the spawner-recruit relationship to a single "steepness" parameter *h*. The "steepness" parameter *h* expresses the fraction of pristine recruits when spawner biomass is reduced to θ% of pristine levels. In this scenario θ = 0.2. The solid lines are the Ricker and the dotted lines the Beverton-Holt curves used in the analysis.

When the S-R shape parameters are simultaneously estimated then

$$\alpha = \frac{\theta S_0(1-h)}{hR_0(1-\theta)},\ \beta = \frac{h-\theta}{hR_0(1-\theta)}$$ for the Beverton-Holt curve, and

$$\alpha' = \exp\left[\ln\left(\frac{hS_0^{\theta}R)}{\theta S_0 R^{\theta}}\right)/(1-\theta)\right],\ \beta' = \frac{\ln(h\theta)}{S_0(1-\theta)}$$ for the Ricker curve.

When h = 0.2, the replacement line in Figure (1), then the equations for the Beverton-Holt curve reduce to the familiar $\alpha = \frac{\theta S_0(1-h)}{4hR_0}$, $\beta = \frac{5h-1}{4hR_0}$. For the purposes of this study, pristine recruitment was set to unity, and therefore, in the S-R model pristine biomass (S_0) was replaced by unexploited spawner-biomass per-recruit (SBR_0).

As recruitment was estimated from a per-recruit perspective, equilibrium spawner biomass as a function of fishing mortality F was calculated as $S_* = \frac{SBR_F - \alpha}{\beta'}$ for the Beverton-Holt and $S_* = \frac{\ln(\alpha' SBR_F)}{\beta'}$ for the Ricker curves. Equilibrium recruitment R_* was estimated by substituting S_* into the relevant S-R curves (Figure 5).

Production model

Equilibrium yield as function of spawner biomass or spawner biomass-per-recruit was calculated as $Y_* = YPR_F R_*$ because spawner biomass-per-recruit was calculated as a function of fishing mortality F. Yield as a function of spawner biomass or spawner biomass-per-recruit was obtained by iteratively solving for a specific fishing mortality required to reduce the spawner biomass or spawner biomass-per-recruit to the desired level.

Parameter estimates used in the simulations

A review of the cichlid literature summarizing trends between growth, maturity and natural mortality is illustrated in Figure 2. Growth and mortality data were selected from studies that aged fish with hard tissues such scales and otoliths, with natural mortality calculated using Hoenig's (1983) empirical formula that relates mortality as a function of maximum age where $\ln(M) = 1.44 - 0.982\ln(max)$. Length frequency methods of ageing are fraught with error because cichlids are long lived and their growth zones often stack in their otoliths (Booth *et al.*, 1995; Booth and Merron, 1996; Weyl and Hecht, 1998) decreasing age estimates of old fish. Length frequency analysis, therefore, over-estimates the growth co-efficient of the von Bertalanffy growth equation and introduces substantial errors into the commonly used Pauly's (1980) estimate of natural mortality. It was assumed that Hoenig's formula was most suitable for cichlid species because of life-history characteristics such as longevity, low fecundity and parental care. The regression results of natural mortality vs the growth co-efficient was unfortunately weak, only explaining 16% of the variation, but illustrates a slight negative correlation between M and K.

Based on the regression equations in Figure 2, and the average growth co-efficient from the literature cited in Figure 2, parameter estimates used in the base-case simulations are L_∞ = 200 mm, K = 0.38 .yr^{-1}, ψ = 0.01 mm, ω = 3 .yr^{-1}, M = 0.45 .yr^{-1}, $\psi_{50} = S_{50}$ = 2.16 yrs, and $\delta_\psi = \delta_S$ = 0.25 .yr^{-1}. A base-case scenario assumed that both the maturity and selectivity schedules coincided, whereas an alternative scenario, closely resembling most cichlid harvesting gears, assessed selection by the fishing gear one year prior to maturity i.e., ψ_{50} = 1.16 yrs.

Selection of values that determine maximum theoretical length and the length weight parameters are essentially arbitrary, provided that growth in weight is (close to) isometric to length. The most influential parameters are, therefore, the ratio of K to M and the ratio between selectivity and maturity. A maximum age of 10 years was considered sufficient as a plus group and had little effect on the analyses.

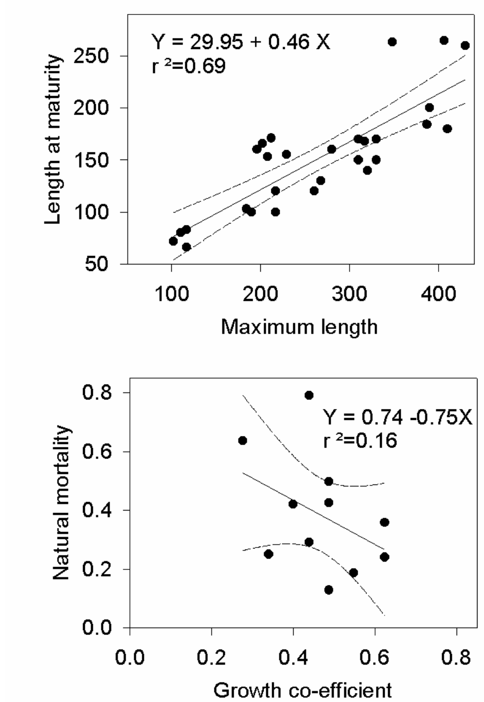

Figure 2. Relationships between length-at-maturity (ψ_{50}) and maximum length (L_∞) (top panel), and natural mortality (M) based on maximum age (*max*) and Brody's growth coefficient (K) (lower panel). Lines represent linear regression and their 95% confidence intervals. Data from Bruton and Allanson (1974), Bruton and Boltt (1975), Tweddle and Turner (1977), Hecht (1980), Van der Waal (1985), Booth *et al.* (1995), Booth and Merron (1996), Jambo, (1997) and Weyl and Hecht (1998).

The S-R curve reparameterisation expresses relative recruitment as a function of relative spawning biomass, both measured relative to unfished levels, and described by the "steepness" parameter θ. The value of the "steepness" parameter determines the potential for density-dependent increases in specific reproductive rate – the relative increase in recruits per unit spawning biomass. Three curves were estimated corresponding to relative increases in reproductive rate of 4, 8 and 16 times. Essentially when spawner biomass is reduced to extremely low levels spawning is 4 - 16 times more successful. Clarke (1991) argued that this range is acceptable as it covers the extremes of most known S-R relationships, albeit for temperate groundfish species. The values of *h*, when $\theta = 0.2$, were estimated as 0.749, 1.249, 2.070 for the Ricker and 0.566, 0.711, 0.823 for the Beverton-Holt S-R curves. These values were estimated by setting $\theta = 1\times10^{-5}$ and $h = 4 – 16$ times θ and solving for the fishing mortality that would result in extinction, i.e., $R = 0$. The resultant extinction *F* estimates are used to recalculate *h* when $\theta = 0.2$, a commonly used value for this parameter used in meta-analysis of stock-recruit data for stock assessments (Myers *et al.*, 1985).

Estimation of biological reference points

Various commonly used BRPs were calculated in this study. These were F_{MAX} (that fishing mortality that maximise yield-per-recruit in the absence of a S-R relationship), $F_{0.1}$ (that fishing mortality that is 10% of the slope of the yield-per-recruit curve at the origin in the absence of a S-R relationship) (Gulland and Boerema, 1973), F_{SB40} (that fishing mortality that reduces spawner biomass-per-recruit to 40% of unfished levels in the absence of a S-R relationship) and F_{MMY} (that fishing mortality that is the maximum of all minimum yields given the predetermined S-R relationships) (Clarke 1991).

During the stochastic simulations, cumulative catch over the simulation period, depletion (spawner biomass as a fraction of pristine levels) at the end of the 50-year simulation, the lowest deletion during the simulation and the number of times depletion was reduced below 20% were noted.

Results

Typical per-recruit effects can be noticed in Figures 3 and 4 (top left panels) with relative yield-per-recruit increasing quicker if fish are harvested before sexual maturity. Similarly, spawner biomass-per-recruit decreased more rapidly with small increases in fishing mortality in the second scenario with earlier gear selection.

The relationship between spawner biomass-per-recruit and yield provides a proxy strategy to the spawner biomass approach (Figures 3 and 4 - bottom panels). If spawner biomass-per-recruit was dropped with the range of 20-60% of unfished levels, at least 75% of MSY was realised. In contrast to spawner biomass, relative yield as a function of relative spawner biomass per recruit was more strongly dependent on the choice of S-R curve. The maximum of the minimum yields - F_{MMY} – suggests that at least 75% of MSY can be attained if spawner biomass-per-recruit was not depleted below 20 and 60% of unfished levels.

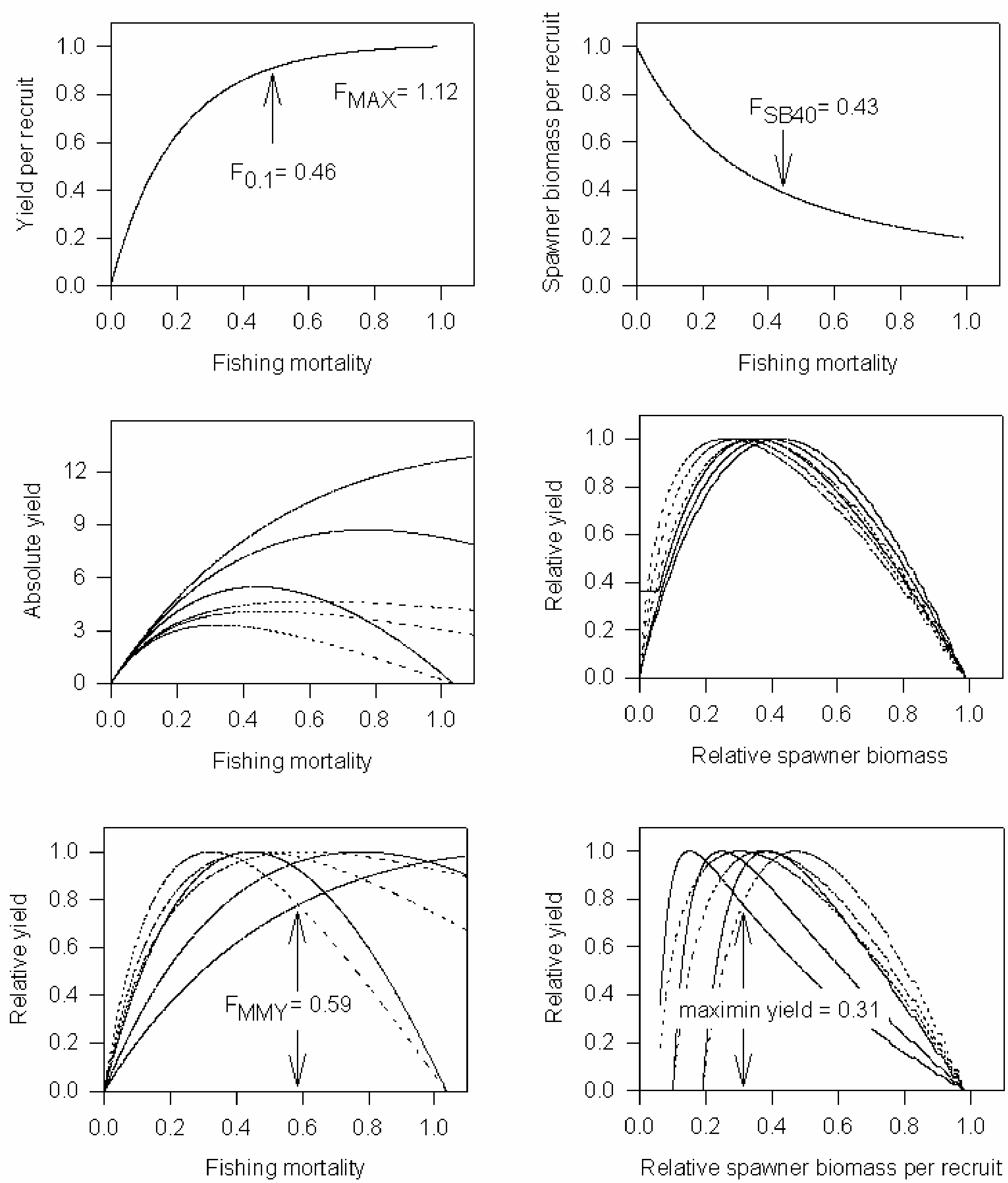

Figure 3. Per-recruit and yield for a typical cichlid fish that with co-incidental gear selection and maturity schedules. The solid lines are the Ricker and the dotted lines the Beverton-Holt curves.

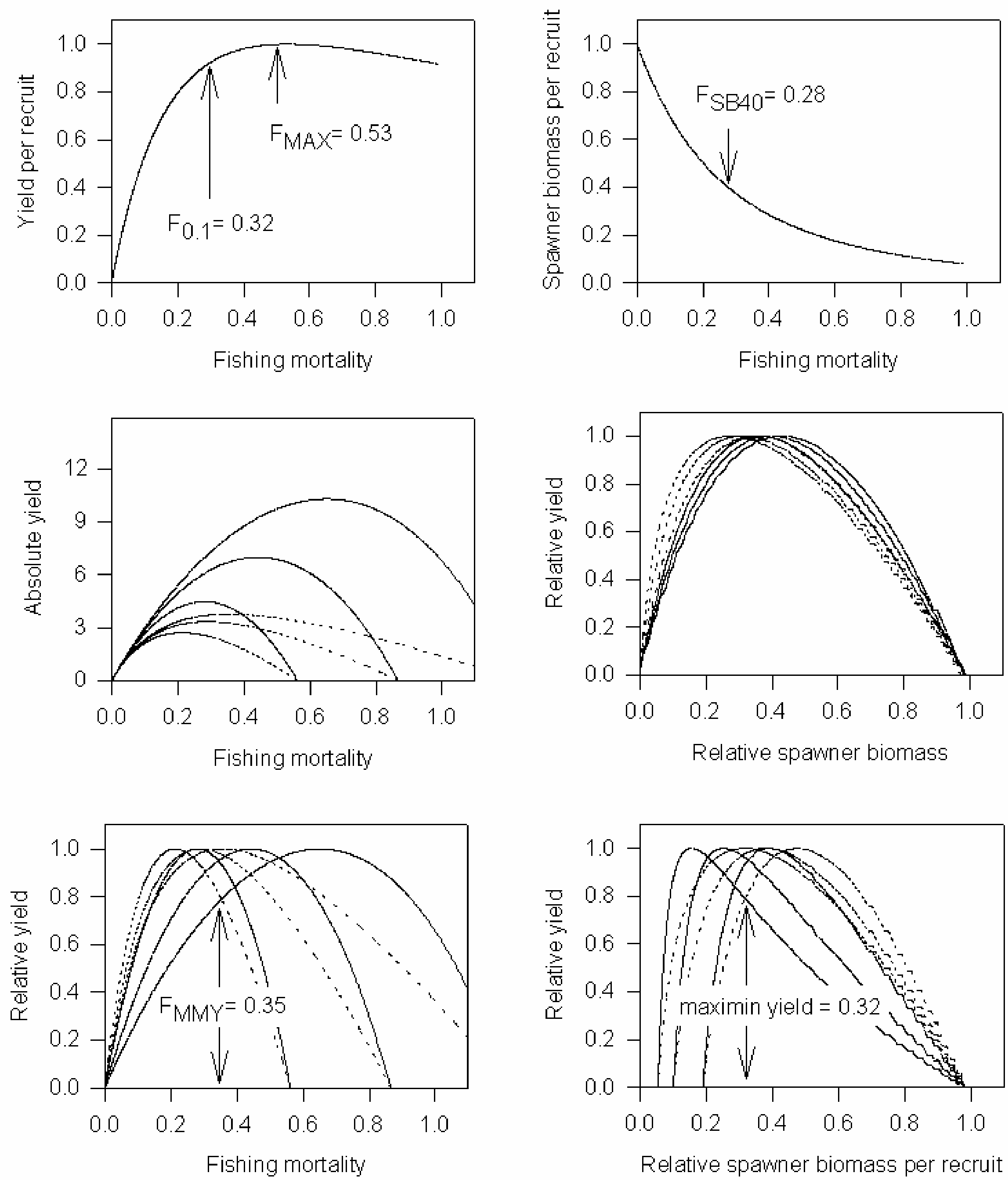

Figure 4. Per-recruit and yield for a typical cichlid fish that with selection by the fishing gear occurring 1 years prior to maturity. The solid lines are the Ricker and the dotted lines the Beverton-Holt curves.

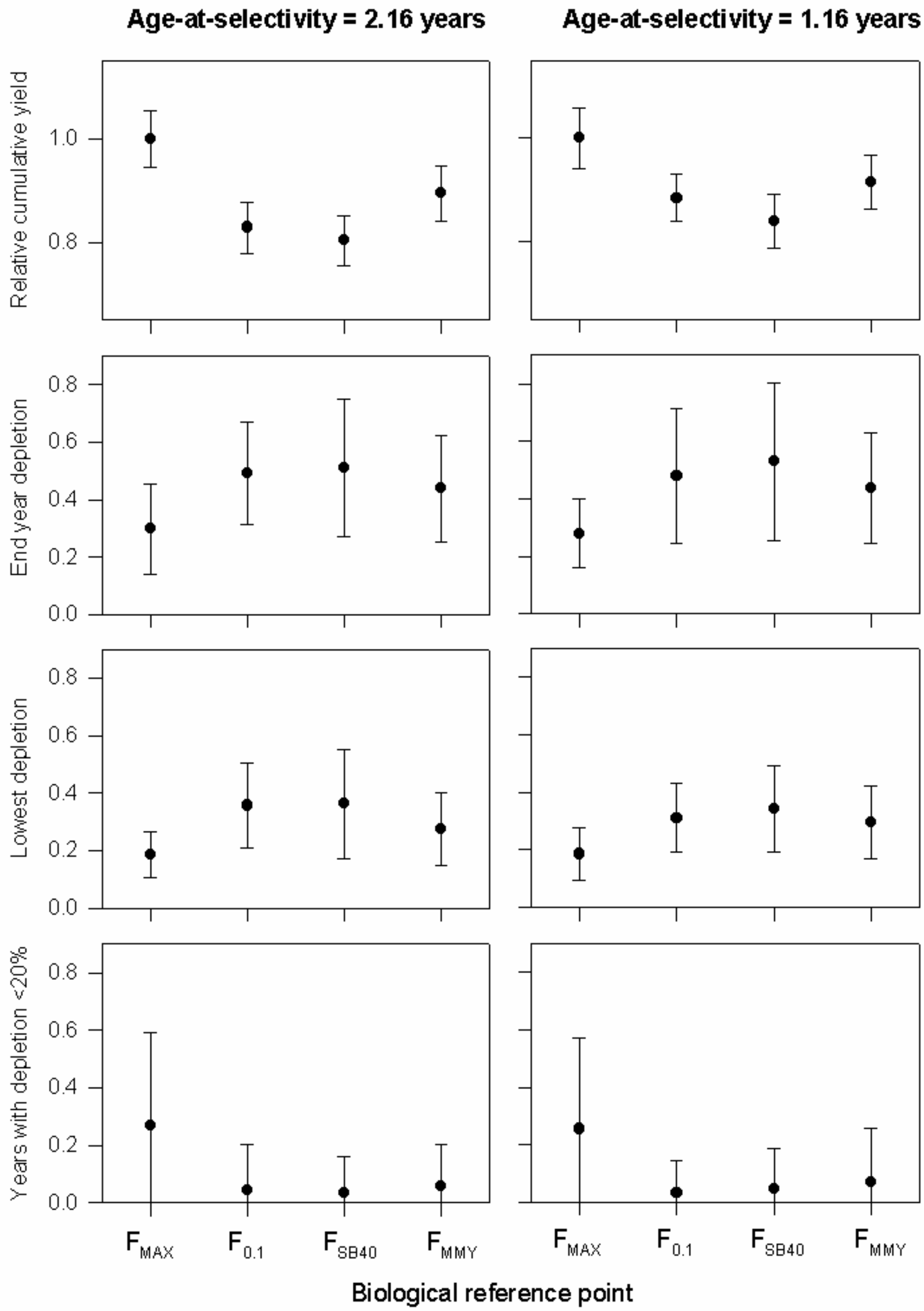

Figure 5. Mean and standard deviation of 100 simulations of four management quantities to assess the robustness of four biological reference points to two scenarios of life-history parameters and fishery characteristics. Cumulative catch is expressed as the fraction of the highest mean value for all biological reference points.

The $F_{0.1}$ and F_{SB40} BRPs were similar, estimated between 0.43 and 0.46.yr^{-1} for the base-case scenario and between 0.28 .yr^{-1} and 0.32 .yr^{-1} when fish are exposed to fishing pressure prior to maturity. F_{MAX} was consistently the highest BRP estimated, ranging between 0.53 .yr^{-1} and 1.16 .yr^{-1}. Spawner biomass-per-recruit was reduced the most with the F_{MAX} BRP. F_{MMY} had intermediate values to the other BRPs ranging between 0.59 for the base case scenario and 0.35 .yr^{-1} in the lower selection scenario. Both F_{MMY} BRPs reduced spawner biomass-per-recruit to ~32% of unfished levels. As fish are selected later into the fishery fishing mortalities required to harvest the resource at levels approaching *MSY* were increased due to per-recruit effects where a "reserve" of spawner biomass-per-recruit was unfished, thereby reducing extinction at higher levels of fishing mortality.

Results from the stochastic trials were not unexpected (Figure 5). Fishing the F_{MAX} strategy resulted in slightly higher yields at the expense of reducing spawner biomass to the lowest levels. In contrast the F_{SB40} and $F_{0.1}$ strategies maintained spawner biomass at the expenses of ~10% of maximum yield. F_{MMY} was intermediate and achieved 95% of *MSY* while maintaining spawner biomass above 35% of pristine levels. The number of simulations where spawner biomass dropped below 20% - effectively the risk of possible recruitment failure - was the highest for F_{MAX} and lowest for the F_{SB40} and $F_{0.1}$ BRPs.

Discussion

Fisheries dominated by one or more cichlid species are common in tropical and subtropical Africa, Central and South Americas. Cichlids also dominate Sri Lanka freshwater catches since the introduction of *Oreochromis mossambicus* and *O. niloticus* (De Silva, 1988). Gears utilised are varied and range from mosquito meshing to harvest juveniles and "fry", hook and line and different net configurations. With the exception of size-selective gillnets, fish are usually harvested prior to sexual maturity as fish are usually caught for subsistence or marketed by number rather than mass (Weyl and Booth, unpublished data). Management is at best *ad hoc*, with most fisheries in an overfished state with catches and catch-rates dropped steadily over time (Pálsson *et al.*, 1999; Ogutu-Owayo, 1990).

Lake Malawi is no exception. Chambo, a complex comprising four economically and socially important *Oreochromis* species, has dominated landings. Unfortunately these stocks are considered to heavily depleted with large fish rarely seen in catches and catch rates at all-time low levels (Pálsson *et al.*, 1999). Effort has now been shifted onto less utilised pelagic cichlid resources. Management intervention is urgently required.

Cichlid life-history patterns are complex and have evolved in various habitats differing in biotic and abiotic variability. Overall, cichlids are considered K-selected as they have a high longevity, lay relatively few but large eggs, exhibit parental care and mature at a high fraction of their maximum length (Bruton, 1989). Parental care has been shown to resolve taxonomic issues as *Sarotherodon* spp. are paternal mouthbrooders, *Oreochromis* spp. mouthbrood, and *Tilapia* spp. are guarders (Trewavas, 1983). All cichlid genera in Lake Malawi, with the exception of *Serranochromis* and *Tilapia,* are considered to be maternal mouthbrooders. Nests of those species residing on unconsolidated sediments are usually constructed within a lek (McKaye, 1984).

Other aspects relating to the interaction between cichlid life-histories and the characteristics of their harvesting fisheries are that maturity and gear selectivity schedules rarely co-incide and that natural mortality is, deduced from other life-history traits, probably density dependent. Considering the dependence on suitable inshore habitats for juveniles and space required for elaborate nest building, fish are easily targeted and spawning habitat destroyed by gears such as large seine nets. Lake Malawi cichlids are also highly habitat specific. All of these factors have management implications.

It would appear that BRPs based on groundfish life histories (Clarke 1991; 1993; Mace; Thompson) are similar to those of cichlids. The stochastic trials, however, suggested that the deterministic BRPs were too low and prompted the need for a slightly more conservative approach in selecting for suitable spawner biomass–per-recruit level to sustain a fishery indefinitely. Conserving more spawner biomass-per-recruit would have a marginal difference in yield.

Two management strategies emerged from the analysis. If spawner biomass can be estimated and then maintained between 30 - 60% of unfished levels then surplus production can be safely harvested. Alternatively, spawner biomass-per-recruit should be maintained at levels of >40%. The broad summit between relative yield and relative spawner biomass suggests that a biomass based strategy would be the most suitable than one based on the regulation of fishing mortality. At least 75% of *MSY* can be attained by simply maintaining the spawner biomass in the range of

30-50% of pristine levels without increasing the risk of recruitment failure beyond an unacceptable limit. Unfortunately, for cichlid directed fisheries, the second option is the most feasible prompting an investigation into a suitable S-R curve to fine-tune BRP recommendations.

The Beverton-Holt (1957) S-R curve is probably the most biologically plausible in a cichlid context. The derivation of the curve assumes that juvenile competition leads to linearly dependent mortality rate relative the number of fish alive in the cohort at any point in time. When the cohort grows in number then individuals will disappear faster. If fecundity remains constant then there will be compensation, i.e., recruits per spawner decrease as a function of the number of spawners. The net result is a plateau in recruits per spawner. This model has also been shown to approximate situations with territorial interactions, disruption of nesting, gradation in habitat suitability for nesting and juvenile survival, and competition for food or space (Hilborn and Walters, 1992).

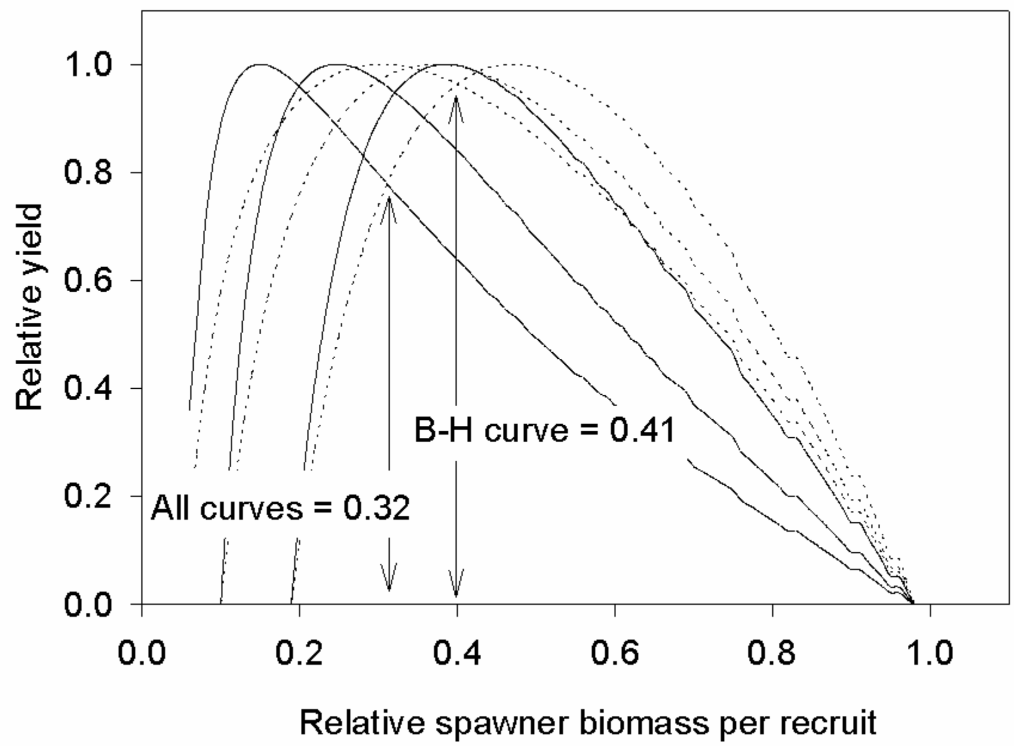

Figure 6. Relative yield as a function of relative spawner biomass per recruit for a typical cichlid fish given that harvesting occurs prior to sexual maturity. The maximin yield is illustrated for all the spawner-recruit curves and only the Beverton-Holt curves. The solid lines are the Ricker and the dotted lines the Beverton-Holt curves.

Consider cichlid reproduction from a simplified perspective. Spawning occurs within a lek with males constructing nests that are often large and elaborate (McKaye, 1984). Habitats are also species specific and could be considered a limited resource. Utaka are an exception as they do not construct nests but form dense reproductive shoals above deep rocky outcrops in upwelling areas. Female mating success is not necessarily hampered by a reduction in suitable habitat as they have the opportunity to choose suitable mate(s) (Kellogg *et al.*, 1995). After spawning, females gather the eggs and mouthbrood them before releasing few, well-developed juveniles into suitable nursery habitats – inshore areas in the case of the sandy substrate spawners such as *Oreochromis* spp. and *Lethrinops* spp., or near the parent's territories in the case of the rock dwelling haplochromine mbuna. It can also be assumed that paedophagy would linearly dependent on mouthbrooding females. Suitable nursery ground habitat would unfortunately facilitate differential mortality compounding depensation resulting in a S-R curve approximating that of the Beverton-Holt form.

The Beverton-Holt S-R curve is also the most conservative from a harvesting perspective, because with the lack of depensation (or at least reduced compensation), recruits decrease with a reduction of spawning biomass. A conservative approach is not necessarily a poor management option given the largely artisanal nature of cichlid directed fisheries. Figure 6 illustrates an alternative management strategy when the maximin BRP is calculated for the Beverton-Holt curve only, and is contrasted when the BRP is calculated with all S-R curves combined. Fishing at F_{MMY} decreases fishing mortality and increases spawner biomass-per-recruit by ~10% than the previous BRP, a substantial difference in the provision against recruitment failure. Yield is unfortunately compromised for the maintenance of sufficient spawner biomass but only marginally, at levels of ~80% that of *MSY*. The deterministic model as shown by the stochastic simulations is probably over-estimates fishing mortality and it is therefore proposed that the revised BRP be decreased to increase spawner biomass-per-recruit to 50% of unfished levels. The precautionary approach prevails in the cichlid situation, and if effective fishing mortality is maintained at this rate, could assist with sustaining the livelihood of artisanal fishing communities.

References

Beverton, R.J.H and Holt, S.J. 1957. On the dynamics of exploited fish populations. *Fish. Invest. Ser. II (London)* 19: 1-533.

Booth, A.J., Merron, G.S. and Buxton, C.D. 1995. The growth of *Oreochromis andersonii* (Pisces : Cichlidae) from the Okavango Delta, Botswana, and a comparison of the scale and otolith methods of ageing. *Env. Biol. Fish.* 43: 171-178.

Booth, A.J. and Merron, G.S. 1996. The age and growth of the greenhead tilapia *Oreochromis macrochir* (Pisces:Cichlidae) from the Okavango Delta, Botswana. *Hydrobiologia* 321: 29-34.

Bruton, M.N. 1989. The ecological significance of alternative life-history styles. In *Alternative life-history styles*. M.N. Bruton (ed.) Kluwer, Dordrecht. 503-553.

Bruton, M.N. and Allanson, B.R. 1974. The growth of Tilapia mossambica Peters (Pisces:Cichlidae) is Lake Sibaya, South Africa. *J. Fish Biol.* 6: 701-705.

Bruton, M.N. and Boltt, R.E. 1975. Aspects of the biology of *Tilapia mossambica* Peters (Pisces: Cichlidae) in a natural freshwater lake (Lake Sibaya, South Africa). J. Fish Biol. 7: 423-445.

Caddy, J.F. and Mahon, R. 1995. Reference points for fisheries management. *FAO Fish. Tech. Pap.* No. 347.

Clark, W.G. 1991. Groundfish exploitation rates based on life history parameters. *Can. J. Fish. Aquat. Sci.* 48: 734-750.

Clark, W.G. 1993. The effect of recruitment variability on the choice of a target level of spawning biomass per recruit. In *Proceedings of the International Symposium on Management Strategies for Exploited Fish Populations*. Kruse, G., Eggers, D. M., Marasco, R. J., Pautzke, C. and T. J. Quinn (Eds). University of Alaska, Fairbanks; Alaska Sea Grant College Program Report 93-02: 233–246.

De Silva, SS. 1988. Reservoir of Sri Lanka and their fisheries. *FAO Fish. Tech. Pap*. No. 298. 128pp.

Francis, R. I. C. C. 1992 – Use of risk analysis to assess fishery management strategies: a case study using orange roughy (*Hoplostethus atlanticus*) on the Chatham Rise, New Zealand. *Can. J. Fish. Aquat. Sci.* 49: 922–930.

Gulland, J.A. and Boerema, L.K. 1973. Scientific advice on catch levels. *U.S. Fish. Bull.* 71: 325-335.

Hecht, T. 1980. A comparison of the otolith and scale methods of ageing, and the growth of *Sarotherodon mossambicus* (Pisces:Cichlidae) in a Venda mpoundment (Southern Africa). *S. Afr. J. Zool*. 15: 222-228.

Hilborn, R. and Walters, C. J. 1992 – *Quantitative Fisheries Stock Assessment. Choice, Dynamics and Uncertainty*. Chapman and Hall, New York. 570 pp.

Hoenig, J.M. 1983. Empirical use of longevity rates to calculate mortality rates. *U.S. Fish. Bull.* 82: 898-903.

Jambo, C. M. 1997. Aspects of the ecology and reproductive biology of three cichlid species of the southern Lake Malombe (Malawi). Unpublished MSc thesis, Rhodes University. 126pp.

Kellogg, K.A., J.A. Markert, J.R. Stauffer Jr. and T.D. Kocher. 1995. Microsatellite variation demonstrates multiple paternity in lekking cichlid fishes from Lake Malawi, Africa. Proc. R. Soc. Lond. B.260:79-84.

Lowe [McConnell], R.H. 1959. Breeding behaviour patterns and ecological differences between *Tilapia* species and their significance for evolution within the genus *Tilapia* (Pisces: Chlidae). *Pro. Zool. Soc. Lond.* 132: 1-30.

Mace, P.M. 1994. Relationships between common biological points used as thresholds and targets of fisheries management strategies. *Can. J. Fish. Aquat. Sci.*51: 110-122.

Mace, P.M. and Doonan, I.J. 1988. A generalized bioeconomic simulation model for fish population dynamics. *N.J. Fish. Assess. Doc.* 88/4.

McKaye, K.R. 1984. Behavioural aspects of cichlid reproductive strategies: patterns of territoriality and brood defence in Central African substratum spawners and African mouthbrooders. In G.W. Potts. & R.J. Wooton (Eds.) *Fish reproduction: strategies and tactics*. Academic Press, London. pp 245-273.

Myers, R. A, Bridson, J. And Barrowman, N. J. 1995 – Summary of worldwide spawner and recruitment data. *Can. tech. Rep. Fish. Aquat. Sci.* 2024: iv + 327 pp.

Ogutu-Ohwayo, R. 1990. The decline of the native fishes of Lakes Victoria and Kyoga (East Africa) and the impact of introduced species, especially the Nile perech *Lates niloticus*, and the Nile tilapia, *Oreochromis niloticus*. *Env. Biol. Fish*. 27: 81-96.

Pálsson, Ó.K., Bulirani and Banda, M. 1999. A review of biology, fisheries and population dynamics of chambo (*Oreochromis* spp., Cichlidae) in Lakes Malawi and Malombe. Government of Malawi, Fisheries Bulletin. 38. 35pp.

Pauly, D. 1980. On the interrelationship between natural mortality, growth parameters and mean environmental temperature in 175 stocks of fish. *J. Cons. Int. Explor. Mer.* 39: 175-192.

Sissenwine, M.P. and Shepherd, J.G. 1987. An alternative perspective on recruitment overfishing and biological reference points. *Can. J. Fish. Aquat. Sci.*44: 913-918.

Trewavas, E. 1983. Tilapiine fishes of the genera *Sarotherodon*, *Oreochromis* and *Danakilia*. London.

Tweddle, D. and J.L. Turner, 1977. Age, growth and natural mortality rates of some cichlid fishes of Lake Malawi. *J. Fish Biol.* 10:385-395.

Van der Waal, B.C.W. 1985. Aspects of the biology of larger fish species of Lake Liambezi, Caprivi, South West Africa. *Madoqua* 14: 101-144.

Weyl, O.L.F. and Hecht, T. 1998. The biology of *Tilapia rendalli* and *Oreochromis mossambicus* (Pisces: Cichlidae) in a subtropical lake in Mozambique. *S. Afr. J. Zool.* 33: 178-188.

Appendix I: Abstracts of papers not submitted for publication

(with comments from floor)

Ecological aspects of the ornamental fish of Lake Malawi and their implications in relation to exploitation and conservation

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Abstract

Lake Malawi has diverse ichthyofauna estimated at over 1000 species. The food fish industry (artisanal and mechanized commercial fisheries) exploit many species with the exception of the colourful rock dwelling cichlids locally known as mbuna. The mbuna are exploited by licenced exporters for the aquarium trade. The food fish exploitation industry has enjoyed monitoring and management attention from the Fisheries Department that the aquarium fish export industry has not. Management regulations of a fishery are based on the way the fish are exploited and the biological and ecological information concerning the fish. Due to this background some biological and ecological aspects of mbuna were studied at the three Maleri Islands in Lake Malawi National Park with a view to assessing the impact of their exploitation for ornamental trade. The mbuna were sampled by 1 hour gillnetting at 2, 5 and 10 m depths around the three Maleri Islands between January and May 2000. The following aspects were assessed: the distribution and relative abundance, female reproductive stages and size at maturity and sex ratios. Two licenced exporters of mbuna were visited to assess species and numbers exploited. All sites sampled had diverse fish species ranging from 19 to 25 mbuna species and 15 to 34 non-mbuna species per site. A majority of these species were found at all three islands with a few restricted to one or two of the three islands. There were significant ($p<0.0001$) variations in numerical proportions of different species with only a few species dominating specific islands. There were significant variations ($p<0.05$) in numerical abundance among depths and in time but insignificant ($p>0.05$) among sampling localities. Breeding occurred throughout the entire four months in almost all the species with varying temporal proportions of breeding individuals. Individuals of immature size were not common in all species. At any point in time there were significantly more males ($p<0.05$) in breeding colour than ripe females. Visits to two licenced exporters of mbuna indicated that many species were exported but most of the trade names used are different from those scientifically described or temporarily used in scientific publications. The exporters of mbuna capture only those of mature size. The captured and exported for any species depended on the demand of that species on the export market and the more rare the species the more demanded it is. These results are discussed in relation to the effects this exploitation may have on the mbuna fish stock and to the existing fishery management and conservation strategy. Recommendations on how the ornamental fishery can be managed are suggested and they include: Fisheries Department to give same attention in the management of ornamental fish as the food fish, populations of mbuna in all places licenced exporters exploit to be monitored, quotas to be set for all species of restricted distribution and abundance, and involvement of a taxonomist in the ornamental fish industry to standardize trade names and scientific or temporal but recognised names of fish.

Questions and Comments

Q: What is the economic value of the ornamental fishery?
A: The economic value is very high, e.g. a male and female pair cost anything between US$1 and US$5.

Q: What is the cost of monitoring these resources?
A: Monitoring is not too expensive. There are only three licensed exporters, and visits are made to areas where they exploit the fish. Monitoring consists of periodic dives in these areas: setting transects, studying populations to detect any changes in the fish communities (i.e. change in relative abundance over time).

Q: Has any work been done to establish the distribution and abundance of the fishery and what recommendations have been put forward?
A: Ribbink *et al* (1983)'s survey studied distribution around the lake but not abundance.

Comment: If work can be done to determine abundance in various areas around the lake and compare the figures with those in the exploited areas, one can get an idea of the natural densities, and compare with the sites being exploited before coming up with recommendions. One therefore compares exploited versus unexploited areas (T. Hecht).

Comment: I note that you have not included fish translocations, which in my point of view, are the biggest monitoring issue concerning the ornamental fishes. I further note that fish translocations have not stopped. For example species from Likoma have been translocated to Nkhata Bay and there has been no attempt to remove these translocated fish while the populations are still small. In Nkhata Bay, the aliens have the potential to spread along the whole coastline as it consists of continuous rocky habitat. It is difficult to study the whole lakeshore for densities, however one can calculate roughly the natural densities of the fish from certain areas and work out their estimated distributions along the whole lakeshore (G.F. Turner).

Determination of species diversity in various areas of Lake Malombe

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Abstract
Lake Malombe is the third largest lake in Malawi and contributes substantially to the country's fish production. The lake's fishery started to decline since the early 1980s when the Oreochromis Nyasalapia species were replaced by the small cichlids collectively known as Kambuzi. The fishery has currently collapsed and in attempt to improve the situation, the Government of Malawi established a reserve area in the lake that acts as stock recovery area. The study assessed species diversity in the eastern and western fishing sites and sanctuary area. A total of 39 species were sampled; 33 in the eastern side and 25 in the western side. Fish species diversity was high in the eastern than the western sites, mean H' value 2.127 and 1.77, respectively. Fish species are more abundant in eastern sites than western sites, mean D' value 3.93 and 2.57, respectively and more evenly distributed in eastern sites than western sites, mean J'' value 0.73 and 0.63, respectively. Laboratory studies are currently underway to determine whether the sanctuary is contributing to recruitment in the fishing grounds and if there is migration between the eastern and western sides

Questions and Comments

Q: What is the difference between total alleles and effective alleles?
A: Total alleles are all alleles present. Effective alleles are those that affect the character controlled by that locus and can be used as a measure of inbreeding or migration between populations.

Q: What mesh size did you use in your sampling? Does your low sample species richness (39) as opposed to Kissa's over 60 species not invalidate your findings?
A: My results are in agreement with FAO's and Jambo's findings, with around 40 species for the lake. We used 19 mm mesh size nets since that is the mesh size used by the nkacha net fishermen.

Q: Did you get samples from fishers or did you conduct experimental fishing as this is important in relation to depth?
A: My samples were obtained from fishermen; I followed up from Jambo's study by using a similar strategy for sampling.

Comment: The low species number obtained in this study may be due to species identification problems (B. Ngatunga).
A: For identification, the Fisheries Research Unit, Monkey Bay, staff were used.

Q: How many samples did you use in this study?
A: I used four replicates per site.

Comment: It should be kept in mind that the number of samples in this study were much less than Kissa's study who used over 100 samples, thus it is not surprising that Kissa had a higher number of species in his study (G. Turner).

River discharge and water quality

M. Gondwe, M. Kingdon, H. Bootsma, J. Mwita, B. Mwichande & R. Hecky

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Abstract

Phytoplankton in Lake Malawi support a high fish biodiversity. On the other hand phytoplankton productivity and composition in the productive layer of the lake water is largely determined by nutrients availability. One of the major ways nutrient loading into the productive layer occurs is through river discharge. The level of nutrient loading by a river depends on land use and human activities in the watershed of the river. Deforestation, bush fires and washing away of farmland due to poor agricultural practices have been observed to increase nutrient levels in runoff to lakes. Such situations have led to eutrophication of the lakes and consequent decline and/or extinction of biodiversity as experienced in Lake Victoria.

The importance of rivers in respect of the foregoing was recognized by the SADC/GEF Lake Malawi Biodiversity Conservation Project. As such, Limnology section of the project sampled Lake Malawi rivers from 1996 through 1999 with the aim of:
Determining the annual loading of nutrients and sediments into the lake from the rivers for inclusion in the whole lake budget. Assessing the current water quality of the in-flowing rivers, especially for parameters such as phosphorus, nitrogen, silica and suspended solids that are most likely to affect the limnology of the lake and its budget. Suggesting sensitive chemical parameters that are particularly important to the lake's water quality and biodiversity and which should be the focus of the future monitoring/research programs.

Among the many findings are: No statistically valid relationship was observed to exist between daily river discharge and nutrient concentration. For all rivers the early part of the flow season exhibited a flushing effect for most nutrients. In December 1996, TSS, TDN and TDP were 79.03mg/l, 1.352 and 0.075 mmoles/m2 lake surface area while in May 1997 concentrations were 0.45mg/l 0.138 and 0.005 mmoles/m2 lake surface area. Loading of all nutrients and sediments was significantly higher in the southwestern catchment and northeastern catchment of the lake. Northwestern catchment accounts for only 6.3% of the total for all nutrients. Loading of all dissolved nutrients except SO4 was similar in southwestern catchment and northeastern catchment, however loading of total suspended solids (TSS) and all suspended nutrients was higher in northeastern catchment than in southwestern catchment. Majority of the flux to the lake was in form of particulate nutrients, and the concentrations of total nitrogen (N), total phosphorus (P) and available silica (Si) were all correlated with suspended solids concentration.

NOTE: Southwestern catchment has Linthipe, Bua and Dwangwa rivers. Northwestern catchment has Songwe, South and North Rukuru rivers. Northeastern catchment has Ruhuhu river.

Questions and Comments

Q: Are algal blooms the only factor causing fish kills?

A: No, but mostly it is due to algal blooms. When diatoms die they sink and do not fix nitrogen; whilst some green algae (some of which fix nitrogen) do not sink, thus contributing to oxygen depletion.

Q: Is there any information on the phytoplankton for Lake Malawi or the blue-green algae composition?

A: Yes it is available, a UK/SADC publication edited by Menz.

Metals, Pesticides And Other Persistent Contaminants In Water, Sediments And Biota From Lake Malawi/Nyasa

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Abstract

Lake Malawi is a valuable resource to the populations along its shores in the riparian countries. Among the major resources are fish that provides about 75% of the much essential animal protein and water for irrigation, domestic use and recreation. In the event of the availability of micro-contaminants such as PCBs and organochlorine pesticides at toxic concentrations in the lake, these uses would obviously constitute health risk for the people. Previous work elsewhere on PCBs and organochlorine pesticides has shown that they reach toxic concentrations through bioaccumulation in food chains as a result of their very strong persistency in soil, air and water. One strong effect of micro-contaminants such as these PCBs and organochlorine pesticides at toxic concentrations to fish in a lake is fish kills. In 1999, PCBs and organochlorines were linked, in the minds of some many individuals in Malawi, to the famous lake-wide fish kills experienced in Lake Malawi during the windy August - November period, which was unusually long.

One of the research interests of the SADC/GEF Lake Malawi Biodiversity Conservation Project was to determine the concentration of microcontaminants such as PCBs and organochlorine pesticides in fish, mud and wake water.

The project's research findings on PCBs and organochlorines in the lake water and fish biota did not confirm the fears and suspicions that they were a possible cause for the fish kills. Organochlorine pesticides and PCBs were detected at low concentrations in surface as well as in subsurface waters of the lake. PCBs were the major organochlorines in surface waters and their concentrations ranged from 165-854pg/l. Deep water samples (e.g. 80m) gave lower concentrations ranging from 100-187pg/l. Oftenly the results were found to be below the detection limit which is approximately 100pg/l.

Concentrations of persistent pesticides and PCBs in fish from Lake Malawi were low in all fish analysed. Examination of the Canadian Bureau of Chemical Safety's tolerable daily intakes (TDIs) of 1.0ug.kg body weight-1day-1 for PCBs and their concentrations in Lake Malawi fish revealed that a 60kg person can safely consume on a daily basis over a lifetime up to 34.6kg/day Mcheni, 235kg/day Chambo, 2.9kg/day Mpasa, 4.1kg/day Usipa and 17.7kg/day Kampango. This confirms that consumption of Lake Malawi fishes does not pose any health risk to humans especially because fish is never consumed daily and in these quantities.

Questions and Comments

Q: What is the significance of using muscle tissue rather than using bony structure in the analysis?
A: To my understanding people consume the fleshy part of the fish thus the analysis used muscle tissue.

Q: Is there any plan to study how different fish eating habits of people reflect the levels of contamination?
A: The contamination levels so far are too low to be of concern, therefore there are no plans to do research on the eating habits of people.

Q: How do chemicals accumulate in upper layers when your colleague (M. Gondwe) indicates that most of the chemicals accumulate below the thermocline? How do the contaminants that have settled down below the thermocline affect the fish?
A: Due to wave action and upwelling, the contaminants from the bottom reach the upper layers where the fish are and eventually accumulate in the food web.

Q: Why did you not use the World Health Organization's (WHO) or the Malawi Bureau of Standards standards for tolerance levels of contaminants?
A: The Canadian standards were adopted because the contract was awarded to a water quality analysis institute of Winnipeg, Canada. The values were thought to be representative.

The Traditional Gillnet Fisheries In Metangula, Lake Malawi/Niassa, East Africa

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Abstract

Metangula is the principal village on the Mozambique coast of Lake Malawi/Niassa. It has 9 human settlements where fishing occurs over about 40 km of shoreline. This village is one of the few places where the gillnet catches of *Labeo mesops* (nchila), and *Opsaridium microcephalus* (sanjika) occur, due perhaps to the low fishing pressure in that area. Although the gillnet fishery catches a wider variety of commercial fish than any other gear type used by the fishermen, nchila, and sanjika are the most important species in the catches. The seasonality of habitats appears to be a key factor affecting many interrelated aspects of life cycle for this species. Their movements to feed or spawn are tied up with seasonal and other changes in the environment.

The traditional fisheries of *Labeo mesops*, and *Opsaridium microcephalus*, mainly from gillnets, have decreased seriously in the past 10 years over the lake. These species are reported as being missed from the catches in gillnet fisheries of Malawi. Smith (1993a) found CPUE = 0 for those species in Chembe village. Few years ago, *L. mesops* was the most important fish in the riverine fishery in Malawi. It has been depleted due to intensive gillnetting of gravid individuals on breeding migrations.

This paper presents preliminary results on traditional gillnet fisheries in Metangula, focusing on 2 important commercial species referred above. I'm also trying to arise here the concrete need for fisheries management and biodiversity conservation particularly related to these species. It's not clear yet whether these species are represented by a single population that is widespread in the lake, or by different populations with distinctive morphometric, genetic and life history characteristics. Therefore, the studies in near future will focus on distribution along the shore, comparison of its morphometric and genetic characteristics, and life history, in order to know whether these species return to the same rivers for reproduction or they go to any river. The studies will also include issues of economic value and conservation status.

Questions and Comments

Q: The gillnet effort per 100m; are they mounted or not?
A: Mounted gear used for effort estimate.

Q: Don't you think that the sampling duration of December 1998 to March 1999 was too short to come up with reliable conclusions and solutions?
A: I agree.

Q: Do fishermen use multi or monofilament gill nets?
A: The fishermen use both types, however monofilament gill nets are uncommon.

Comment: There is data available for the next 8 months after this study and it should be included in the analysis (G.F. Turner).

Q: The disappearance of adults (Cyprinids) in December may be due to migration and not due to fishing. What is known about the migratory patterns of the fish studied?

A: There is a possibility that migration may be playing a role, however it has not been studied. It may be looked into next time.

Genetic diversity distribution of tasselled tilapias (*Oreochromis nyasalapia* spp.: Cichlidae) in Lake Malawi using microsatellite DNA markers

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Abstract
A study was carried out to investigate the genetic diversity distribution of three species of *O. Nyasalapia* in Lake Malawi. Five polymorphic loci were scored in 12 populations. The total number of alleles ranged from 13.0(4.4 to 18.4(5.9; mean effective number of alleles ranged from 8.0(4.0 to 11.09(4.0 in *O. karongae*, 9.09(2.3 to 10.2(3.8 in *O. lidole* and 8.8(4.8 to 11.9(4.7 in *O. squamipinnis*. The mean heterozygosity per population ranged from 0.45(0.17 to 0.66(0.16, which is higher than reported in allozyme loci. There is high genetic variation in *O. squamipinnis*, followed by *O. karongae* and *O. lidole*. The populations are not highly differentiated. These results suggest that the *O. Nyasalapia* flock has still maintained a reasonable level of genetic variation in the face of intense fishing pressures.

Comments from floor

Q: With what gears were the samples collected from?
A: Nkacha nets.

Q: What about species identification, for instance, how did you deal with the juvenile chambo?
A: We used FRU technicians for identification and small chambo were not included in the analysis.

Q: If two populations are not genetically different, does it mean that there is migration?
A: Not always true.

Q: Did you statistically test for genetic differences among the three species from the same location?
A: Yes. There was no difference between the species. The F_{st} values were very small and therefore cannot be considered as significant. There was a lot of overlap even among species of the same area.

Q: What does the 5 migrants per generation mean?
A: It refers to actual individuals (i.e. 5) migrating out per generation from a population.

Genetic population structure of *Oreochromis mossambicus* in the Shire River system

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Abstract
An investigation in the Lower Shire River fishery was carried out to assess the status of genetic variation of *O. mossambicus* using microsatellite DNA markers. Five polymorphic loci (OS08, OS64, OS75, UNH154 and UNH103) were scored in 11 populations. Number of alleles per locus ranged from 4 in OS64 to 40 in UNH154. Cluster analysis grouped populations into three, (1) those found in Chikwawa, (2) those that are found at Elephant Marsh and (3) those that are found at Ndinde Marsh.

Genepop program was used to calculate allelic diversity of each of the 11 populations. The mean number of alleles ranged from 8.2 to 11.0 with mean heterozygosity range of 0.48 to 0.68. All populations exhibited considerable genetic diversity. WHICHRUN program was used to assign individuals to their right strata/populations based multi-locus genotype data. Probability of assigning of a population to its right strata ranged from 52-100%. Probability of assigning of an individual to its right population ranged from 57-95%. Populations from the market were assigned to different sources than indicated by the fish traders and these tended to reduce the probability of right assignment of individuals to source.

Comments from floor

Q: Have you used fish from the ponds, e.g. from Domasi and those in the Lower Shire?
A: Yes, some work has been done on *O. mossambicus* from the ponds in Domasi by Dr. A. Ambali.

Q: What are the differences between the fish from the ponds and those in the Lower Shire?
A: From Dr. Ambali's samples from Domasi he identified three alleles, however, in this study (samples from the Lower Shire) four alleles were identified. This may be due to different environmental conditions encountered by fish in captivity.

Q: How cost effective is your analysis process?
A: It is a very expensive process. The cost is about MK15,000.00 per 20 samples.

Zoogeographical distribution and population structure of *Taeniolethrinops praeorbitalis* exploited by artisanal fishermen in the inshores of Lake Malawi

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Abstract

Lethrinops species flock (Chisawasawa/mbaba) is among the major commmercially important fish species exploited in Lake Malawi. Their catches started declining as early as 1975 due to overexploitation especially in the southern part of the lake yet there are no deliberate measures put in place to conserve these vital populations. A study was carried out to determine the genetic diversity and population structure of *Taeniolethrinops praeorbitalis* populations in traditional fisheries of Southeast and Southwest arms of the lake, Mangochi District and Nkhota -kota lakeshore area. A total of 10 populations with 40 individuals as sample size were analyzed at 6 polymorphic microsatellite loci. The populations were not in Hardy-Weinberg equilibrium possibly due to Wuhlund effect. This is supported by inter-deme migration of more than seven individuals per generation as determined by a multilocus estimate of number of migrants using private alleles method. However this rate of migration has not reduced population differentiation in *T. praeorbitalis*, mean Fst of 0.152.

Comments from floor

Q: Are the Nkhota-kota and Mangochi populations of *Taeniolethrinops praeorbitalis* different?
A: Yes.

Q: Who identified the species used?
A: Dr. B. Ngatunga did the identification.

Comment by Dr. B. Ngatunga: I was involved in the initial start-up of the research by helping the student with the identification of the fish species, however, I wish to express that one of the pictures in the student's presentation showing the fish species he analysed was not *Taeniolethrinops praeorbitalis* as he claimed, but I suspect that it was an *Aulonocara* species.

Feeding ecology of *Bathyclarias nyasensis* (Siluroidei: Clariidae) in Lake Malawi

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Abstract

The ecological role of *B. nyasensis* in Lake Malawi was identified from studies on life history raits, ecological and functional morphology in addition to diet and food habits of the species conducted between 1996-1998. The maximum age for *B. nyasensis* was estimated at 14 years. Growth was best described by the four parameter Schnute model:

$$l_t=\{42+(81^{1.8}-42^{1.8})\text{x}\ \frac{1-e^{-0.05(t-1)}}{1-e^{-(-0.05)(11)}}\}^{1/1.8}$$

for female and

$$l_t=\{41+(98^{1.2}-41^{1.2})\text{x}\ \frac{1-e^{-0.02(t-1)}}{1-e^{-(-0.02)(13)}}\}^{1/1.2}$$

for male fish. Age-at-50% maturity for females and males were estimated at 7 years and 4 years, respectively. Typically, fish grew rapidly in the first year, but slower during subsequent years. Smaller fish were found inshore while larger fish were found in offshore regions. It was hypothesised that the rapid growth in the first year and slower growth later is a consequence of change in diet from high quality and abundant food source to a more dilute food and that this may be associated with a shift in habitat.
Changes in fish growth synchronised with dietary changes and morphology particularly changes in buccal cavity volume. These changes occurred when fish reached 500-600 mm TL, concomitant with habitat shifts that probably imply a mechanism to open the inshore habitat to the next cohort, thereby maintaining a stable population. In inshore areas, *B. nyasensis* was primarily piscivorous and was zooplanktivorous in offshore regions.

On the basis of the theoretical migratory life history cycle of *B. nyasensis*, and "bottom-up" and trophic cascade theories, it is postulated that perturbations of the *B. nyasensis* stock would be discernible both at the top and lower trophic levels. As a piscivore and therefore apex predator, effects of overfishing *B. nyasensis* in the inshore region could cascade to unpredictable ecological changes in inshore areas and, due to the ontogenetic habitat shift, in the offshore regions. It is recommended that the current interest in increasing fishing effort in offshore areas should proceed with caution.

Questions and Comments

Q: In your presentation you pointed out that *Bathyclarias nyassensis* is a pelagic species, yet during the UK SADC project only 27 specimens were caught. Is it really pelagic?
A: It is not really pelagic, although sometimes it can behave like a pelagic species.

Q: The deepwater fishery targets the small species (chisawasawa), and the catfishes caught as bycatch and are not considered in management. How do you manage this fishery?
A: There is no policy for the catfishes at present.

Q: How did you validate your aging?
A: I used marginal zone analysis for validation.

Q: Concerning your observation on feeding aggregations of juveniles and adults, could you verify this observation?
A: My data indicated that feeding aggregations of *Bathyclarias nyassensis* took place.

Land use patterns in the Domasi and Likangala catchments and their effects on soil erosion, water quality, river flow rates, siltation rates and *Barbus* reproduction in Lake Chilwa

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A study to examine trends in land use practices, and to establish linkages between river flow, soil erosion rates, catchment sediment yield, river water quality, migratory patterns and reproductive success of *Barbus* species in the Likangala and Domasi rivers was conducted between November 2000 and November 2001. Participatory rural appraisals, to obtain information on current and past land use and management practices and the effects of these practices on the river ecosystem health, were conducted in four villages in the Likangala catchment and in Mtwiche village in the Domasi catchment. Land use cover change analysis was accomplished by aerial photograph interpretation of black and white aerial photographs for 1982 and 1995 covering the study area. Soil erosion rates were estimated using the Soil Erosion Model for Southern Africa (SLEMSA) by delineating soil erosion management units with homogeneous areas with similar slope, class, soil group, annual mean rainfall, and vegetation cover type and density. Catchment sediment yields were obtained by multiplying the estimated soil loss for each soil erosion management unit with a delivery ratio, which was defined as the ratio of soil eroded that had been carried downstream to that remaining within the field. *Barbus* and water quality sampling in the Likangala and Domasi Rivers was conducted biweekly from December 2000 up to June 2000 and thereafter monthly until November 2001. The *Barbus* were sampled at the river mouth using a multi-mesh gillnet to determine their total number and they were assessed for their position in the net to determine direction of migration. Adult females were assessed for their gonadosomatic index. The gonadosomatic index was used to determine the seasonal reproductive status of *Barbus*. The water quality parameters measured were dissolved oxygen, electrical conductivity, pH and total suspended solids. River flow rate was measured using a current flow meter and the float method. Water quality, river flow, sediment yield, reproductive and fish migration data were subjected to multiple regression analysis to determine the major factors affecting reproductive status and migration. The land use analysis results showed that land use practices in the two catchments are characterized by a combination of destructive forces mainly the expansion and intensification of cultivation of maize on marginal land using inappropriate practices. The participatory rural appraisal sessions in both catchments revealed that the number of trees in the upland and along the rivers, the size and number of fish caught in the two rivers had drastically declined over the past fifty years. The highest amount of soil loss (>100t.ha^{-1}.yr^{-1}) was estimated in the upland areas of the Likangala River catchment and field walks in the area revealed wide spread evidence of very severe erosion, exposed soils and numerous deep gullies. The most critical factors contributing to high soil loss were rainfall high kinetic energy and poor vegetation cover. High vegetation cover and relatively flat plains resulted in low soil loss in the wetland. The Likangala River catchment had a higher annual sediment yield of 374 t.km^{-2}.yr^{-1} compared to 315 t.km^{-2}.yr^{-1} for the Domasi catchment. A situation analysis for the Likangala River catchment showed that increasing maize yield was more efficient in reducing soil loss than contour ridging, and the highest reduction in soil loss was predicted when a combined 20% increase of contour ridging, maize yield and tree canopy was assumed. Multiple regression analysis results showed that reproductive success of females migrating upstream was negatively correlated with total suspended solids and positively correlated with electrical conductivity in the Domasi River. On the other hand, the upstream migration of *Barbus* juveniles was positively correlated to sediment yield in both rivers, and also to river flow rate in the Domasi River. The *Barbus* reproductive status was not correlated to any of the physico-chemical variables that were measured in the Likangala River. The major recommendations of the study were as follows: (i) land use practices that tackle the most critical soil loss factor should form an integral part of soil conservation measures in each soil erosion management unit; (ii) a combination of contour ridging, increases in crop yield and vegetation cover should be promoted as strategies for reducing soil loss in the Likangala River catchment; (iii) appropriate management actions that reduce fishing pressure on breeding *Barbus* females in the influent rivers should be formulated to ensure the success of spawning migrations of breeding females into the influent rivers, and (iv) marginal vegetation in the breeding grounds along the lake should be protected from burning and other forms of destruction in order to maintain breeding and feeding grounds for juvenile *Barbus* in the dry season.

Questions and Comments

Q: How does maize reduce soil erosion?
A: Maize grows faster and provides the best canopy to reduce soil erosion during the period when the rains are the heaviest.

Q: What factors were considered to use *Barbus* as an ecosystem indicator?
A: *Barbus* species migrate from the lake to breed in the rivers and, therefore, their reproductive success is related to the condition of the rivers.

Q: What mechanism would be put in place to protect breeding individuals?
A: The Fisheries policy needs to take into consideration no fishing during the breeding season, i.e. considering banning fish traps or fish weirs that cross the entire river system.

Appendix II: List of participants

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Acknowledgements

The Lake Malawi Fisheries Management Symposium was organised and funded by the GTZ supported NARMAP Programme of the Department of Fisheries. However, considerable inputs and support to participants was received from the SADC/GEF Project, the World Bank, ICLARM, JICA, Rhodes University, the EU and the ODG funded Malawi/Indonesia Fluctuating Fisheries Project. In addition, this symposium would not have been possible without the commitment of the authors, whose presentations are the basis for the symposium. In addition, we would also like to thank the symposium committee for their committed work on this project.