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REVIEW OF MANAGEMENT MEASURES FOR LAKE CHILWA, MALAWI

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ABSTRACT

This paper reviews management measures for Lake Chilwa, which is a highly variable ecosystem. The seasonal and periodic water level fluctuations of the lake pose some challenges in applying the conventional fisheries management models, with the aim of achieving sustainable yields. There is need to review the four-month closed season for the seine fishery through research to maximize utilization of the commercial *Barbus paludinosus*. The gill net fishery requires control through enforcement of mesh sizes set at a minimum of 69 mm to facilitate recovery of *Oreochromis shiranus* stocks which collapsed after the 1995 recession. As a shared ecosystem, any management plan needs to incorporate a common management strategy between Malawi and Mozambique. Conflicts on the use of water from the catchment areas for agricultural production and domestic use should also be considered in the plan. Issues on pollution and other environmental issues should be addressed through a proper enforceable legal framework. The on-going co-management arrangement should be consolidated and some of the local level institutions should be transformed into co-operative societies for equity of the benefits and efficiency of the management of the fisheries resources. An adaptive management strategy is recommended for the variable ecosystem.

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1. INTRODUCTION

Lake Chilwa is the second largest lake in Malawi. It is a shallow lake, saline and not exceeding 6 m depth at peak water levels. Because of its shallowness, nutrient recycling is efficient, making Lake Chilwa one of the most productive lakes in Africa (Chiotha 1996). In some years, the annual catch can approach 25,000 tons, but the average is around 13,000 tons. In 1979 fish production from Lake Chilwa contributed approximately 43%, while in 1990 its contribution was 33% to the total annual catches in Malawi. This means that the lake has an important bearing on the nutritional requirement of Malawi's population. Supply of fish to the local population and the fishing-related activities can, therefore, be some of the appropriate means through which food security and poverty eradication policy objectives of the Government of Malawi can be achieved.

The importance of Lake Chilwa as a commercial fishery (Kalk *et al.* 1979) was first recognized in 1963, when it was 'conservatively' estimated that 9,000 tons of fish were being cropped annually from the lake. It was also reported that catches of fish were reduced at times of low water levels when fishing became difficult and the water notably alkaline and unstable for some species.

In a survey on fish exports, Salama and Jones (1982) reported that dried *Barbus paludinosus* locally called *matemba,* from Lake Chilwa was exported to neighbouring Zimbabwe and Zambia around 1980. Other commercially valuable fish species such as *Oreochromis shiranus chilwae* commonly known as *makumba* and *Clarias gariepinus* (*mlamba*) are supplied on domestic markets.

It becomes necessary to formulate regulatory measures and plans suitable for sustainable economic benefits of the Lake Chilwa fisheries resources. A number of regulations for Lake Chilwa have been formulated since the 1970s. Within the on-going co-management set up, the community has also been involved in formulating regulations since the lake dried up in 1995. The development of a management plan for Lake Chilwa was completed in 2000.

However, there is need to review both the fisheries regulations and management plan to take into account the present ecological conditions. The need for regular reviews of management plans is also emphasized in the Fisheries Conservation and Management Act. It is against this background that the past and present management measures are examined and recommendations on management strategy options are presented.

1.1 A general overview of the fisheries sector in Malawi

The surface area of Malawi is 118,484 km^2 of which 20.6% is covered by water (FAO 1994). The main fishing waters include Lakes Malawi, Chilwa (Figure 1), Malombe and Chiuta. The Shire River system also contributes to the supply of fish from the capture fisheries sector.

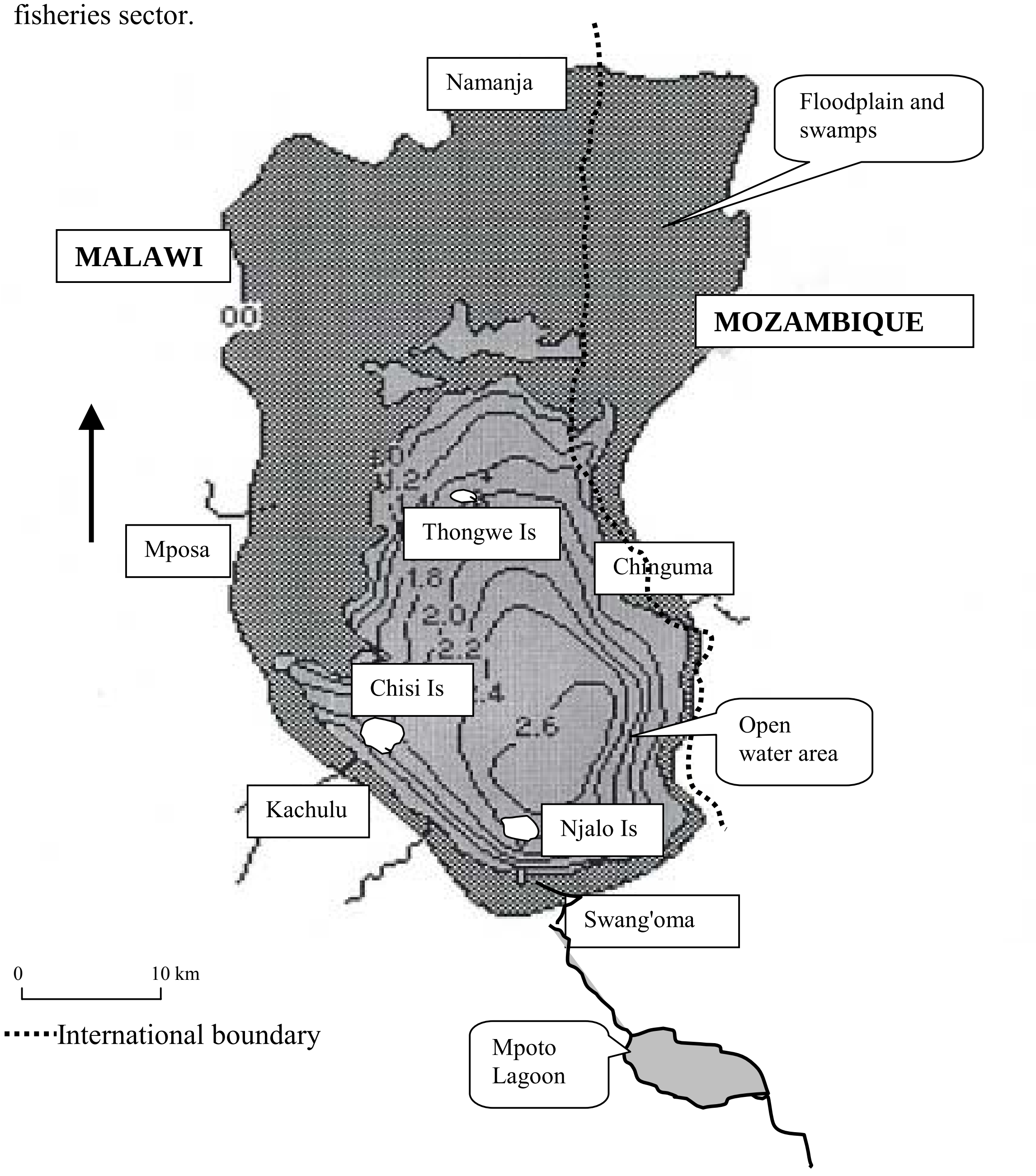

Figure 1: Map of Lake Chilwa (Adapted from Kalk *et al.* 1979)

Is = Island

The capture fisheries sector in Malawi plays a major role to the population which is currently estimated at 10 million with an estimated annual growth rate of over 2.0%. Fish constitutes a major part of the animal protein in the diet of the Malawians (Kent 1987). It provides employment opportunities to a number of people in fishing, processing or trading activities. A study conducted by ICLARM/GTZ (1991) indicated that small-scale fisheries provide the principal livelihood for a large number of rural households. The 1999 frame survey showed that the fisheries sector directly employs about 40,000 people (Fisheries Department 2000b). In addition, an estimated number of over 200,000 people are involved in the ancillary activities (FAO 1999).

The capture fisheries are comprised of three main sectors. These include the traditional sector, which lands over 85% of annual fish production and is the dominant fisheries sector in all lakes in Malawi; the commercial sector, landing between 10-15% of the annual total catch and is confined to the southern Lake Malawi; and, lastly, the flourishing aquarium trade.

In the 1960s, the annual fish production in Malawi was between 11,600 tons and 41,700 tons. However, since 1970, the annual production of fish has been fluctuating between 53,900 tons recorded in 1996 and 88,400 tons in 1988. The lowest figure was partly due to the drying up of Lake Chilwa, which in some years contributes between 9,000 tons and nearly 24,000 tons to the national fish catches.

Fish farming in Malawi dates back to the 1920s with the introduction of trout for sport fishing (Njaya and Chimatiro 1999). However, small-scale fish farming only started in the 1950s with establishment of fish farming stations at Nchenachena in Rumphi and Domasi in Zomba. Fish production from this sector is very small, about 200 tons per year produced by some 2,500 fish farmers. The present major challenge is to promote production of fish from ponds on a commercial basis as a way of increasing the fish supply in Malawi.

Fish processing and trading is a major occupation among many fishing communities. Most of the fish is dried for easy storage and sold to distant markets. There are a number of fish processing facilities ranging from the traditional open pits and drying mats to the introduced facilities such as kilns and wire drying racks.

Fish and fish trading have been increasing since the Second World War in response to the doubling of the population between 1945 and 1966. The introduction of nylon thread in 1958 by a machine in Blantyre factory instead of fibre of local plants was the most dramatic innovation of the fishing industry (Agnew and Chipeta 1979).

Fish imports have generally been increasing for the past few years. In 1997, about 760 tons of fish products were imported into Malawi while in 1999 and 2000 the figures went up to 2,808 tons and 1,630 tons respectively. On the other hand, fish exports have been negligible (National Statistical Office 2000; Njaya 2001).

Malawi's fisheries policy is being drafted to include various issues such as a focus on participatory fisheries management, training, aquaculture, enforcement, and research components. A new Fisheries Conservation and Management Act was approved in October 1997, with new emphasis on community participation, resource ownership and empowerment of local communities.

1.2 Lake Chilwa

Lake Chilwa is situated in the center of the low-lying Chilwa-Phalombe plain in the southern part of Malawi at 35°45' E and 15°15' S (Ratcliffe 1971). It is the second largest lake in Malawi and the twelfth largest natural lake in Africa. It an enclosed lake with a surrounding reed belt widest on the north and north-east side and a seasonally flooded plain. The water is saline ranging from 1-2 ‰ up to 12 ‰ during minor recessions. Its open water area is around 678 km^2, which is surrounded by about 600 km^2 of *Typha* swamps, 390 km^2 of marshes and 580 km^2 of seasonally inundated grassland of floodplain. (Lake Chilwa Wetland Project 1999). These vary with the level of the lake in any year.

The 1998 population census showed that the Chilwa basin had a population of 916,447 with a density of 162 per km^2. The catchment area is about 8,349 km^2 with 5,669 km^2 located in Malawi and 2,680 in Mozambique (Lake Chilwa Wetland Project 1999).

Out of 27 fish species, the most important fish species of Lake Chilwa are a small minnow, *Barbus paludinosus*, the African catfish, *Clarias gariepinus* and two tilapiine species, *Oreochromis shiranus chilwae* and *Tilapia rendalli* (Kalk *et al.* 1979). The first two species have been the most valuable commercial species in the lake. The maximum size of *Barbus paludinosus* is about 12 cm while *Oreochromis shiranus* grows to 25 cm and reaches maturity at 12-15 cm (Furse *et al.* 1979a).

Lake Chilwa has dried up several times since 1879 (Lancaster 1979). Records show that reduced catches and fish mortalities occurred during the minor and moderately severe recessions of 1900, 1914-15, 1922, 1931-32, 1934, 1954, 1960-61, 1967, 1973 and 1995. (Kalk *et al*. 1979; Njaya 1998) A 25-year record of lake levels fluctuations was analysed which gave a clearer picture of periodicity of the behaviour of the lake (Agnew and Chipeta 1979).

The fishery usually takes 3 to 4 years to fully recover following a severe recession but considering its enhanced fertility due to drying and oxidation of the organic matter, catches can be doubled after recovery (Kalk *et al.* 1979; Kabwazi and Wilson 1996). Nicholson (1998) reports that rainfall in the basin is around 1,000 to 1,200 mm per year. However, water is lost through evaporation processes. This causes vulnerability to drying up of the lake during prolonged drought spells (Chavula 2000).

At present the fishery can be characterized as artisanal. Commercial fishing operations using trawlers were reported in the 1970s and 1980s but did not succeed mainly due to poor infrastructure. There were 2,406 gear owners and 6,250 ancillary workers recorded on Lake Chilwa in 2000 (Fisheries Department 2000b).

Most of the minnow catch is dried and sold domestically. In some years, it is exported to Zambia and Zimbabwe (Salama and Jones, 1982). The larger species such as *mlamba* and *makumba* or *chambo* are smoked. Less than 10% of the landed catch is supplied fresh to the nearby surrounding local markets including the nearest urban center (Zomba). A considerable number of women take part in fish processing and marketing.

After the recession in 1995, the Department of Fisheries (DoF) developed strategies to work with the fishing community to facilitate recovery process of the collapsed fish stocks. These included banning the use of seines and poisonous plants (*katupe*) in the adjacent Mpoto Lagoon and inflowing rivers as they were considered sources for repopulating the lake after refilling.

The decline and finally the cessation of the fishing operations in 1995/96 caused considerable hardship among the fishers. However, the lake refilled rapidly during the heavy rainy season in 1997. Consequently, the annual catches have been increasing with a catch of about 12,500 tons recorded in 1999 (Fisheries Department 2000a).

In 1996, the Government of Malawi ratified the Ramsar Convention and Lake Chilwa became a designated wetland of international importance. In this context, Malawi as a member state is obliged to promote the conservation of wetlands included on the list and as far as possible the wise use of wetlands within her territory.

2. DEFINITION OF THE PROBLEM FOR THIS STUDY

The fish per capita consumption in Malawi has been declining for the past two decades. In 1988, per capita fish consumption was estimated at 9.6 kg (Njaya and Chimatiro 1999), but this had dropped to 5.6 kg in 1996 (FAO 1999). This necessitates development of fisheries in water bodies where resources are under-exploited. Promotion of fish farming can be another viable option to increase fish supply in Malawi.

Stock assessment surveys have identified some expansion possibilities for fisheries on Lake Malawi. Banda and Tomasson (1996 and 1997) reported that Domira Bay had potential to sustain yields of over 2,000 tons over a year, while deep and very deep waters of Area C and the South West Arm of Lake Malawi, can supply about 4,000-5,000 tons per year. Smaller water bodies such as Lake Chilwa should also be investigated to assess the yield. Commercial and subsistence fish farming can be developed in areas where water supply is adequate. There is a high demand for increased fish supply in Malawi, which is the driving force for importation of dried fish products from neighbouring countries like Tanzania and Zambia.

An assessment of the fishery in Lake Chilwa is needed. After major recessions it has provided high catches of nearly 25,000 tons per year, such as in 1979 and in 1990. Its contribution to the total catches of the country has been around 20% on average but in some years figures of over 33% have been recorded. This project study will provide an input into the assessment of resource utilization in Malawi as a way of increasing its fish supply.

A review the fisheries regulations and management plans for various fishing waters in Malawi has been stipulated in the new Fisheries Conservation and Management Act. The Lake Chilwa management plan was developed in 2000 with technical and financial support from the now phased-out Lake Chilwa Wetland and Catchment Project funded by the GOM and the Danish International Development Agency (DANIDA).

Two important outcomes have emerged from the DANIDA project. Firstly, consolidation of the community-based management, which started in 1996 as a strategy to facilitate recovery of the collapsed fishery following the recession. Secondly, the project supported the development of a management plan of the lake, which could be considered a milestone as it is the first of its kind in the history of fishing in Malawi. What makes it a great achievement is the fact that the entire process of developing the plan fitted into the policy framework of various natural resource-related sectors such as fisheries and environmental affairs. The focus was on community participation as an option to gain legitimacy of the planned project activities taking place within the Chilwa basin. Furthermore, the process of developing the management plan was based on several biological and socio-economic studies and a consultative approach among various stakeholders.

2.1 Objectives of the study

The overall objective of the study is to review management measures that have been implemented on Lake Chilwa taking account its periodic recessions. Specifically the study will address the following objectives:

(a) To review past and current management systems of Lake Chilwa.

(b) To determine the exploitation level of the commercial species (*Barbus paludinosus*) since fishing resumed in 1997 after the 1995 recession.

(c) To propose some management strategies that would ensure sustainable fish supply in the Chilwa basin.

2.2 Methodological approach and data analysis

Data used in the study include catch and effort by gear type and species obtained from the Fisheries Research Unit based at Monkey Bay. Beach prices and prices of inputs such as *matemba* seines and craft and wages were collected in a survey conducted by the author in 2001. Basically, the data collected, lecture notes and the researcher's experience are used to provide a basis for analytical work although subsequent field research is necessary to supplement and expand this study.

Selected approaches and theoretical conceptual frameworks are applied to analyze the catch data and information that was available for this study. In particular, time series data analysis has been done on catch and effort of gear, especially seines, to determine variability of the resource exploitation patterns.

A basic sustainable yield curve based on the catch and effort is estimated by using a 4-year (1984 to 1987) catch between the two recessions in 1968 and 1995 (Appendices 1 and 2). During this period the lake level was relatively low for the first two years while the rest had the highest water levels (average of 2.4 m). Effort was determined in terms of headline length of the seines, which in the 1970s and 1980s were longer than at present, with some being more than 1,000 m. For this study, one unit of effort has been defined as headline length of 500 m.

In this study, the seine fishery is assumed as a single species fishery. Seines mostly target *matemba*. To obtain MSY, a relationship between effort (number of seines) and catch per unit effort (CPUE) which is catch per seine, was worked out and the following function was obtained:

$$\text{CPUE} = -43.1x + 189.95 \qquad (1)$$

where CPUE is tons per seine per year.

The CPUE was consequently obtained by substituting the *x* effort unit at varying rates of 0.02 into the equation (Appendix 3). Using the normalized effort (number of seines) at an interval of 5, a series of effort trend was obtained alongside the CPUE. Yield was obtained by the following formula:

$$\text{Yield} = \text{CPUE} \times \text{Effort} \qquad (2)$$

where Yield is in tons, CPUE is catch per seine (tons/seines) and Effort is number of seines.

A sustainable yield curve was plotted by using Effort (*x-axis*) and Yield (tons) on the *y-axis* and the MSY is where yield is highest.

Using Malawi Kwacha currency (MK) 14 per kg (1999 beach price for *matemba*), revenue, costs and profit were obtained as follows:

$$\text{Revenue} = \text{Yield (tons)} \times \text{price} \qquad (3) \qquad \text{thus,}$$

$$\text{Revenue} = \text{Yield (tons)} \times 1000 \text{ kg/ton} \times 14 \text{ MK/kg}$$

Costs of effort are estimated at $6,693.02 per seine fishing unit. This includes costs of a new seine net, new boat, license and all operational costs for 1 year (Appendix 4).

Therefore, rent ($\prod$) was obtained as follows:

$$\prod = \text{Revenue} - \text{Costs} \qquad (4)$$

By plotting effort against revenue and costs, a sustainable revenue curve was obtained. The highest amount of revenue was estimated as the MEY, while the greatest difference between the revenue and costs was the maximum rent. The conversion into US$ was done by using the approximate exchange rate of 1999 (MK43 equivalent to 1 US$).

3. FISHERIES MANAGEMENT: CONCEPTS AND PRACTICE

Fisheries management is defined as the pursuit of certain objectives through the direct or indirect control of effective fishing effort or some of its components (Panayotou 1982). Several models and concepts have been developed to emphasize the need to control harvest levels of fisheries resources following the Hardin's (1968) theory of the 'tragedy of the commons', which provided a pivotal reference for resource managers in the western world. Hara (2001) points out that the Hardin model led to the conclusion that resources should be either privatized or controlled by a central government authority to ensure sustainable use.

Unregulated fisheries tend to be characterized by overexploitation of the stocks (van der Burg 2000). In relation to this, there has been an extensive search for management measures to reduce fishing effort. The basic objectives in managing a fishery are very general. Part of the general social and economic objectives include more food, a better living for a fisher and more employment (Bagenal 1978).

Several management strategies have been developed and applied in both developed and developing countries since the 1950s:

> "The dominance of open access prior to 1970s, combination of regulations with market-led (private or corporate) incentives and stakeholder participation in fisheries management around 1980s and 1990s such as fishing rights systems that allocate private property rights by establishing individual transferable quotas (ITQs), effort quotas and limited entry including the introduction of buy-back schemes and, lastly, modifications to rights of access (e.g. closed areas) which have become popular in the developed countries" (Ahmed and Delgado 2000, pp. 227).

Successful management of fisheries resources needs to be based on successful modeling (Wagh 1984). This requires the biological characteristics of the fish. It is the abundance, size and age structure of the population which, in general, determine the rate of growth of the population.

Fisheries management objectives can be classified into three groups (Wagh 1984). Firstly, there are those objectives which are concerned with the attainment of some level of physical yield from the fishery, usually a maximum sustainable yield. However, the author reports that sustainable yield is an equilibrium concept and there is considerable doubt that such equilibrium can be maintained in an ecosystem over long periods of time. Secondly, the injection of economics into fisheries research led to the consideration of maximum economic yield as a possible objective of management, whereby benefits are measured in value terms and economic costs are taken explicitly into account. The specific objective can be stated as the maximization of the discounted net benefits over time. However, the main problem noted with this objective is that it is not dependent on any particular biological model. Thirdly, as a reaction against maximum economic yield, the objective of optimum yield has, more recently, been proposed.

A number of neo-classical economists have argued that two measures will reduce fishing effort in an efficient way: taxes and individual transferable quotas (ITQs). Other measures such as non-transferable quotas, a total allowable catch with temporary closure of the fishery and effort regulations are not *pareto* efficient (van der Burg 2000). Arnason (1999) reports that the fisheries problems would disappear, if only the appropriate property rights could be defined, imposed and enforced. However, he states that there are substantial technical and social problems to defining, imposing and enforcing sufficiently good property rights in many fisheries. This agrees with the observation made by van der Burg (2000) that institutional economists have criticized neo-classical theory for neglecting political problems, enforcement problems, and transaction costs. It is argued that because of such problems, the superiority of taxes and ITQs for fisheries management is questionable. Matthiasson (2000) reports that while the ITQ-based system management appears economically efficient, its evolution in Iceland has been described as historical rather than logical.

However, as of recently, there has been a search for fisheries management systems that encompasses socio-economic, technological and political domains. Where centralized or conventional fisheries management regime has failed as has been in most cases in the world, social scientists have considered community based or co-management arrangements as an alternative. As noted by Jentoft (2000), the community is absent in the Hardin's model. The examination of institutional and organizational arrangements and design has been neglected in fisheries management. Fisheries researchers have been more concerned with the means of fisheries management such as ITQs than with institutional and organizational aspects (Noble 2000). Jentoft and McCay (1995) note that fisheries managers pursue multiple goals. Rarely is the task of fisheries management defined in biological terms only.

Community participation is the active, meaningful and influential involvement of individuals or groups in an activity (Campbell and Townsley 1996). If management is to succeed, fishers must support management efforts (Wilson *et al.* 1994). However, as observed by Jentoft and McCay (1995), the degree of user group involvement may differ from one country to another. Co-management, as defined by Sen and Nielsen (1996), is an arrangement where responsibility for resource management is shared between the government and user groups, and is one possible solution to the growing problems of resource over-exploitation. The concept focuses on the recognition that user groups have to be more actively involved in fisheries management if the regime is to be both effective and legitimate.

Apart from the continued search for appropriate fisheries management models, some authors have outlined some challenges of managing fluctuating ecosystems, which are mainly caused by climatic influence. Winpenny (1991) stated that fisheries are highly prone to natural variability in their environment, which can be both complex and unpredictable, and may interact with human interventions to produce serious consequences. Sverdrup-Jensen (1999) observed that accurate assessments of the resource situation are obscured by the rapid responses of many fresh water fish stocks to fluctuating environmental conditions even more so than with marine fisheries. Sarch and Allison (2000) noted that fish stocks in many African inland waters fluctuate considerably, and that these fluctuations are climate driven and cannot be stabilized by conventional measures.

Lae (1997) indicated that among other factors, African ecological systems have been deeply affected by the appearance of an extended drought period. It was reported by Breuil (1997) that the relationship between potential and actual production in African inland waters was not sufficient as a basis for definite development policies, mainly for the following reasons: the unreliability of potential and actual fish production estimates in a varied and often changing physical environment; the unreliability of catch data; the high fishing levels in the major fisheries (large lakes and floodplains); and the level of technology. In a study by Kolding (1994), it was found that experimental artisanal and offshore *kapenta* catch per unit of effort were all highly significantly correlated with mean annual lake level fluctuations, but not with absolute lake levels. Furse *et al.* (1979a) stated that the yields and species composition in the shallow Lake Chilwa varied as a function of the lake level.

4. FISH SPECIES AND TRENDS IN LAKE LEVELS, EFFORT AND CATCH

Understanding of the ecological characteristics and socio-economic profiles of the fishing community within the Lake Chilwa basin is important to design and review a management plan. The variability of the ecosystem and the responsiveness of catches by gear type and species both in space and time and biological information about the fish species can provide a basis for the development of a management plan for the fishery. Based on previous studies, fish stocks in Lake Chilwa can recover within 3-4 years after a recession.

4.1 Biological characteristics of the major fish species in Lake Chilwa

The most valuable fish species in Lake Chilwa include *Barbus paludinosus*, *Oreochromis shiranus chilwae* and *Clarias gariepinus*. Other species which are of less commercial importance but can be caught in substantial quantities in some years include *Alestes imberi* and *Gnathonemus* spp. The biology of the valuable fish species has been described by various researchers.

Howard-Williams *et al.* (1972) reported that *Barbus paludinosus* matures at 5 cm (total length, and reaches a maximum length of 11.2 cm. Spawning is from September to December. This means that the current regulation of closing riverine fishing from May to October partially serves the intended purpose of protecting the spawning stock. The fishing community should review this regulation for protection of the spawning *B. paludinosus* stock. There is a fall in catches of *B. paludinosus* from September to February in the open waters probably due to spawning (Furse *et al.* 1979a).

Oreochromis shiranus chilwae is a cichlid which grows to a maximum of 12.5 cm for females and 15 cm for males (Msiska 1991). It spawns in surrounding pools, springs and lagoons. It has an extended breeding season from September to May. It prefers to breed in shallow waters. In comparison to *Oreochromis shiranus* from Lake Malawi, Furse *et al.* (1979) reported that the endemic cichlid subspecies of Lake Chilwa had a number of characteristics which are advantageous in a fluctuating environment including early maturity and has two main spawning periods in an extended breeding.

Moss (1979), reported that *Oreochromis* appears to be more associated with the open water than *Barbus* and *Clarias*, which move into the swamps to breed, and its relatively lower resistance to the drying out of the lake, reflected in the delayed recovery of its populations, might reflect its evolution during a period when the lake was much less turbid and in which open water conditions were normally less extreme.

Based on total length, *Clarias gariepinus* matures at 18.5 cm (unsexed) in Lake Chilwa while in Lake Kariba it matures at 34.0 cm (female) and 37.0 cm (male) (Teugels 1986). In Lake Tana it was found to mature at 30.5 cm for females while in smaller reservoirs in Burkina Faso it matures at 37.5 cm. This shows that *C. gariepinus* in Lake Chilwa matures earlier than in other water bodies. Spawning takes place during the rainy season in flooded delta areas. The fishes make a lateral migration towards the inundated plain to breed and return to the river or the lake soon afterwards. Furse (1979) reported that spawning of *C. gariepinus* usually begins in September.

Most of Lake Chilwa fishes display a high degree of r-selection. This is reflected in their ability to adapt quickly to changing environment. They are highly fecund, reproduce at a relatively early age, are able to persist in the swamp and streams as well as in the open lake, have broad diets with considerable overlap and show much opportunism in feeding. They have unspecialized spawning habits and are highly tolerant of a wide range of environmental factors, though these ranges are inevitably exceeded as the lake dries up (Moss 1979)

4.2 Changes in lake levels

Variability in water level is one of the main factors that causes fluctuations in fish landings. Furse *et al.* (1979b) stated that yields and species composition in the shallow Lake Chilwa varied as a function of the lake level.

Figure 2 shows that since 1962, highest water levels of between 2.5 m and 3 m were recorded in 1974-1976, 1986-87, and 1990-91. For the past three decades, lowest water levels (major recessions) were experienced in 1968, and 1995. A minor recession was recorded in 1973. The average annual water level was significantly high from 1986 to 1991 compared to the periods before and after. Water levels started receding in 1991 until 1995 when the lake eventually dried up. After that, the water levels increased to the average level of 1.45 m in 1999.

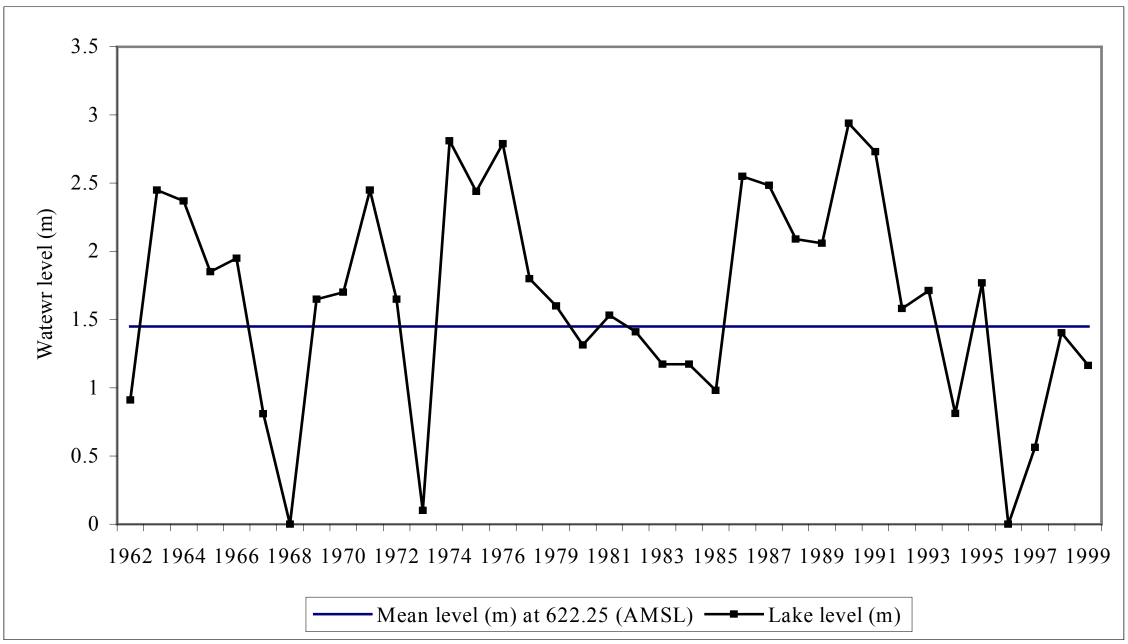

Figure 2: Lake level changes recorded at Kachulu (Water Department 2000)

4.3 Effort changes

There has been an increase in fishing effort in terms of fishing gear, craft, number of gear owners and crew members as shown in Table 1. Njaya and van Zwieten (2000) noted that from 1976 to 1999, trends in numbers of gear owners, assistants, boats, gillnets and long lines indicate a three-fold increase while traps and seines increased five-fold.

All gears types, including low investment gear such as traps, long lines and hand lines as well as high investment gear such as seines, exhibit a continuous increase in units from 1976 to1999 (Njaya and van Zwieten 2000). However, as the ratio of gear owners to assistants exhibits a steady decrease over the period from 1983 to 1998. The effort was highest in 1998 due to factors such increased number of migrating fishers from other water bodies such as Lakes Malombe and Chiuta.

However, there has been an increase in number of plank boats from 112 in 1986 to 758 boats in 2000, representing an increase of about 85 %. The number of dug-out canoes has declined, reducing by around 30% from around 2,000 in mid 1980s to 1,400 in late 1990s. Reasons are twofold: scarcity of suitable tree trunks for canoes and the sustained activities of the Malawi Germany Fisheries and Aquaculture Development Project (MAGFAD). The project was implemented from 1987-1997. Among other objectives achieved, is the sustained capacity of local boat builders in constructing plank boats. This can be a good lesson for future development interventions, which aim at development of small-scale fisheries in Malawi and other African countries.

In the 1980s the number of fishing operators including gear owners and ancillary workers in Lake Chilwa ranged from 2,060 to 3,403 while in the 1990s they ranged from 3,955 to 9,466 in 1998, two years after refilling of the lake. This figure represents the highest number of fishermen and assistants ever registered on Lake Chilwa. This was, in part, due to some *nkacha* (an open water seine net) fishers who migrated to Lake Chilwa from other water bodies such as Lake Malombe. However, most of the increase could be attributed to phasing out of work permits for many Malawians who were migrating to South Africa to work in mines. It is assumed that many returning migrants have been investing in seine fishery operations, as landholding capacity for the Chilwa plain area is small due to increase in population and poor soils for agricultural production especially in the northern Lake Chilwa area.

Table 1: Effort changes recorded on Lake Chilwa (Fisheries Department 2000)

Year	Boat with engine	Planked boat	Dug-out canoe	Gear owner	Crew member	Gill net	Long line	Fish trap	Seine
1983	1	97	789	806		2,752	509	8,846	95
1984	8	71	1,289	527	1,186	1,149	384	4,455	63
1985	13	75	1,180	750	1,312	697	646	8,187	96
1986	15	112	1,802	1,167	1,962	2,818	463	12,690	129
1987*									
1988	10	146	1,683	1,383	2,020	8,594	929	10,616	182
1989	11	116	1,373	1,185	1,579	3,364	723	11,315	231
1990	5	297	2,083	2,342	3,076	7,585	1,014	20,701	281
1991	25	385	2,380	2,202	3,853	4,928	1,267	18,629	327
1992	6	424	2,130	2,829	4,017	5,472	1,346	32,676	346
1993	27	440	1,201	1,718	3,958	3,576	725	21,611	353
1994	1	501	688	1,043	5,053	865	240	7,174	444
1995*									
1996*									
1997	5	352	1,673	2,291	2,885	6,965	563	21,649	394
1998	4	583	4,090	5,388	4,060	6,598	1,361	27,512	498
1999	19	392	1,306	2,015	3,375	7,658	764	21,255	422
2000**	0	758	1,487	2,406	6,250	9,289	815	21,894	735

* Frame survey was not conducted

** For the first time in Malawi the frame survey was conducted by the fishing community

Fishing operations are suspended during recession periods. Many fishers especially those operating seines and gillnets stop fishing or migrate to other water bodies, though recently such fishers have encountered resistance from resident fishers like in Lake Malombe due to different mesh sizes of seines permitted.

4.4 Gear types and water level changes

The Lake Chilwa fishery is predominantly artisanal. Fishers operate various gears depending on season, investment level, water level and species targeted. Seines mostly target *B. paludinosus*, but sometimes can catch other species like *O. shiranus chilwae* during a drying phase. Gill nets mostly target *Clarias gariepinus* and *O. shiranus chilwae* while fish traps target *B. paludinosus* and *O. shiranus chilwae.* Long lines (a long line with several hooks) which are being replaced by the recently introduced *chomanga* (a baited hook and float set in swampy areas) target *C. gariepinus*.

A recent study has shown that the interaction of water level and gear (fish traps, gill nets and long lines) was significant and positively related to catch rates, except with seines (Njaya and van Zwieten 2000). In the data series both highest numbers and low numbers of gear were encountered during periods with relatively low water levels, while highest water levels around 1990 are associated with a period of build-up of fishing effort with all gears. The drop in water level towards the recession in 1996 and 1997 is thus associated with the highest numbers of gears counted in the time series of fishing effort. Theoretically, increased fishing effort would be associated with decreased catch rates.

4.5 Annual and seasonal variations

Kalk *et al.* (1979) noted that the highest catches of *Barbus* spp. were recorded from December to April, with a peak in February in the northern marsh, while in the southern sector the catches were highest in September. Catches of *Clarias* were highest in December in the northwest and northeast while in the south it was in January. In April and June, at the highest seasonal lake level, *Clarias*, the dominant species was caught in the northern swamp. These variations confirm that there are migrations of fishes and that fishing is especially good when the fishes are intercepted in the breeding migration routes. It is observed that fishing in the cooler months from May to August is generally not so good; catches are lower than in the warmer months. The reasons for the poorer fishing include very strong winds which prevent fishers from operating their canoes on the lake.

In an experimental trawling conducted in 1978, it was found that juvenile *Oreochromis* spp. locally called [1]*kasawala* concentrated in the northeast sites in February, but by March they had disappeared. Examination of gonads showed an extended breeding season for *Barbus* spp. and very few spent fish were recorded in the lake itself offshore. On the other hand, the breeding period of *Clarias* was restricted to October to February and again few spent fish were seen in the lake. *Haplochromis callipterus* (a mouth-brooding cichlid, similar in size to *Barbus*) occurred in significant numbers on the

[1] In the case of Lake Chilwa, *kasawala* is juvenile *chambo* or *makumba* less than 4 inches (100 mm).

northeast periphery and its breeding season was from March to October. *Oreochromis* spp, on the other hand had a longer breeding season than *Haplochromis* (Kalk 1979).

4.6 Estimated catch levels in Lake Chilwa

There is no complete catch data recorded from the previous major recession of 1968, as the catch assessment survey (CAS) started in 1976. The methodology for collecting catch data in traditional fisheries in Malawi has been outlined by Alimoso (1988) and Alimoso *et al.* (1990). It has been observed that the catch data collected in Malawi may be unreliable (Weyl *et al.* 1999). Despite the variability in data, it is still possible to determine catch rates during limited period of 2-3 years (Njaya and van Zwieten 2000).

The analyses in this study have been done by following phases including 1976-1994, 1992-1994 (drying phase) and 1997-1999 (refilling phase). Estimated annual fish landings are presented in Figure 3.

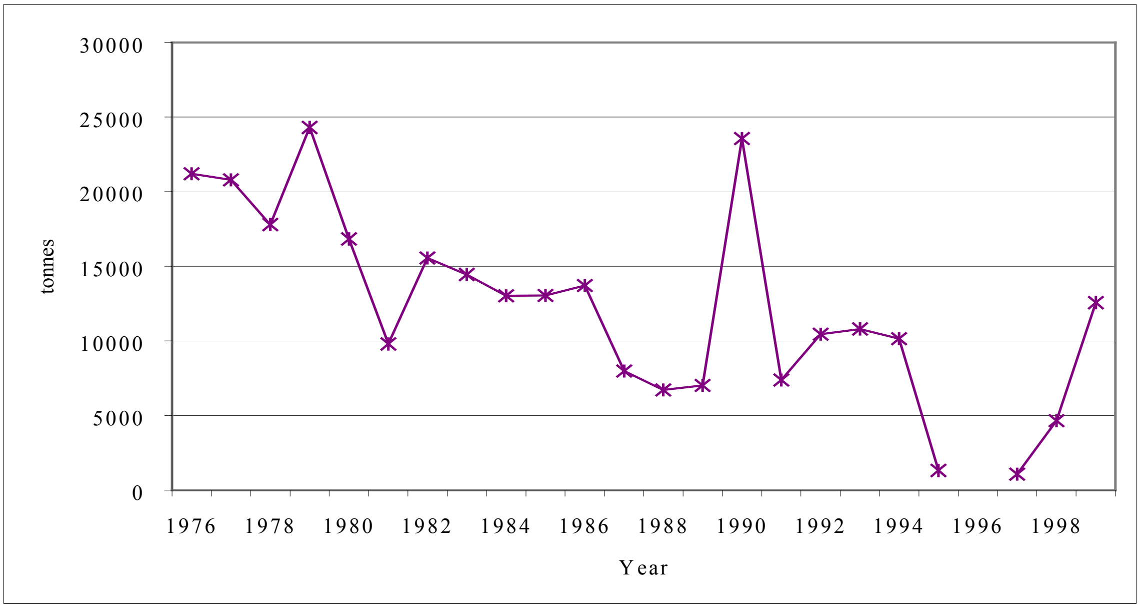

Figure 3: Estimated catch (tons) for Lake Chilwa (Fisheries Department 2000).

4.6.1 Estimated annual fish landings from 1980-1994

Fish landings by species showed that *B. paludinosus* made up almost half and *O. s. chilwae* was 24% of the total catch. Other species such *Alestes imberi* and *Gnathonemus* spp. contributed 15% and the lowest catch contribution was from *C. gariepinus* with a record of 13% (Figure 4). In 1976, the overall composition of the total catch analyzed was 48% *B. paludinosus*, 30% *C gariepinus*, 12% *O. s. chilwae* and 10% other species, Kalk *et al.* (1979). While the results agree on the *B. paludinosus* catch, they differ on the trend regarding *O. s. chilwae*, *C. gariepinus* and other species. This could be due to annual variations rather than long term changes in species composition.

On average, seines accounted for 57% of the catch from 1980 to 1994, fish trap for 22%, gill nets for 15% and long lines 5%. Other gear, which included scoop nets and hand lines contributed 1% to the total catches (Figure 5).

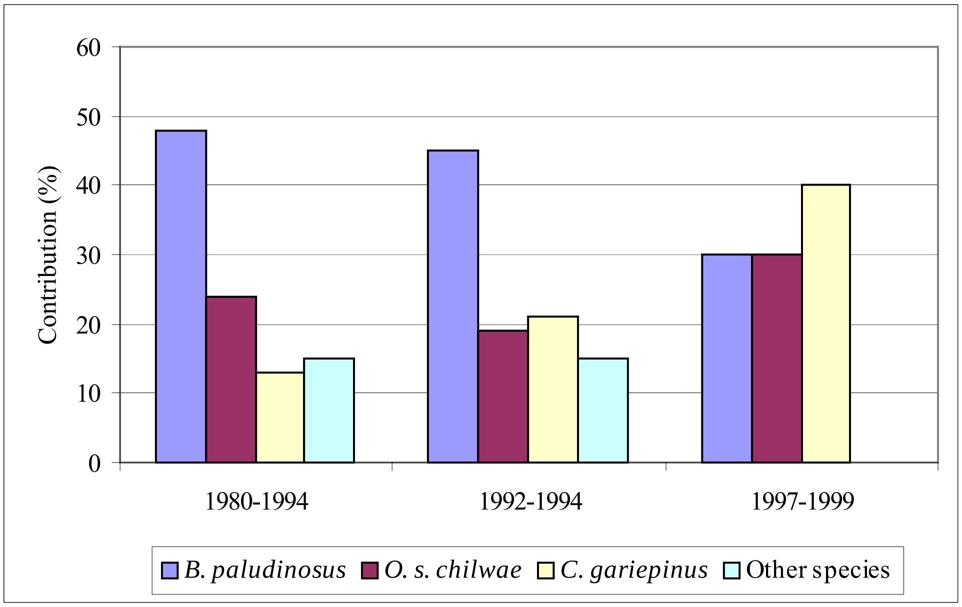

Figure 4: Catch by species during three phases (1980-94, 1992-94 and 1997-99)

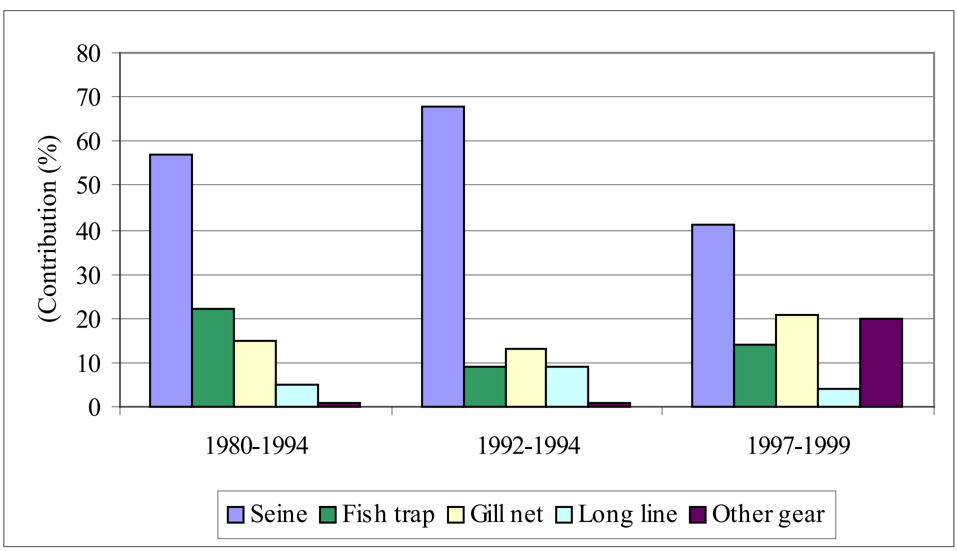

Figure 5: Catch by gear during three phases (1980-94, 1992-94 and 1997-99)

4.6.2 Drying phase (1992-1994)

As shown in Figure 4, *B. paludinosus* catch was the highest (45%), while *C. gariepinus* recorded 21%, and *O. s. chilwae* contributed 19%. The lowest contribution was from the other species (15%). The trend is similar to that of 1980-1994. It was reported (Njaya

1998) that some dead fish especially *Barbus* spp. were observed floating in some areas during the time when the water level was very low (about 0.3 m) in 1994. This was also noted by other authors:

> "Anaerobic conditions up to the water surface can develop rapidly in African shallow lakes. In Lake Chilwa, the development of deoxygenated conditions in shallow water during the drying phases resulted in fish kills. An extensive fish kill in Lake Chilwa in October 1966 when the water level was 0.3 m resulted from strong winds, after a period of a few days of calm, during which anaerobic sediments were rapidly mixed through the water column. However, it should be recognized that although such deoxygenation of the water in shallow lakes is a likely cause of fish mortality, the sudden simultaneous release of NH_3 (particularly if the pH is above 9.0) and SO_4 from the sediments might also contribute to mortality" (Kalk *et al.* 1979, pp. 104).

During the drying phase (1992-94), seines landed the highest catch (68%), while gill net catch contributed 13%. Contributions from fish traps and long line were 9% respectively and other gear was 1% (Figure 5). The reason for the highest seine catch was that as the water level was dropping, and hence the area of seining was reducing which resulted in an increase in catchability.

4.6.3 Refilling phase (1997-1999)

On average *C. gariepinus* was the highest (40%) while *O. s. chilwae* and *B. paludinosus* contributed 30% each (Figure 4). As shown in Figure 5, seine nets landed the highest catch (41%), and gill net contributed 21%. A new fishing gear (*chomanga*), which is a baited hook with a float set in swampy areas and mostly targets mlamba, contributed 20%, fish traps landed 14% while the long line catch was the lowest (4%).

There are several points to consider based on these results. Firstly, as stated by Kalk *et al.* (1979) *C. gariepinus* is the first to recover after a recession that is why the catches from that species are the highest. Secondly, *chomanga* gear targets *Clarias* and is set in swamps. This means that the new technology introduced by the artisanal fishers is more efficient than long lining. Thirdly, there has been a closed season for seining from December to March since fishing resumed in 1997. This is a regulation that has been imposed by the local community in the on-going co-management arrangement. While the initial objective was to facilitate repopulation of the lake after the recession, the regulation appears to have been fixed. This could be another contributory factor to the landing of *Barbus* catch to be second to *Clarias*.

5. PAST AND PRESENT MANAGEMENT SYSTEMS

A need to study past management strategies has been recommended by various scholars, especially with respect to application of scientific principles and management paradigms. Mullner *et al.* (2001) pointed out that the extent of societal consideration of and involvement in renewable resource decisions has been evolving over the past century. In the early twentieth century, the public was generally content to enjoy or use renewable resources and allow managers to continue making decisions based on science.

However, as evidence of overexploitation and damage to renewable resources management came to the public's attention, the public began to demand more involvement in renewable resource management decisions, and this demand continues to grow. Figure 6 presents an illustration of how science and society are integrated into decision-making processes. They include three paradigms: autocratic natural-science-based management (ANM), interactive natural-science-based management (INM), and collaborative natural- and social-science-based management (CNSM).

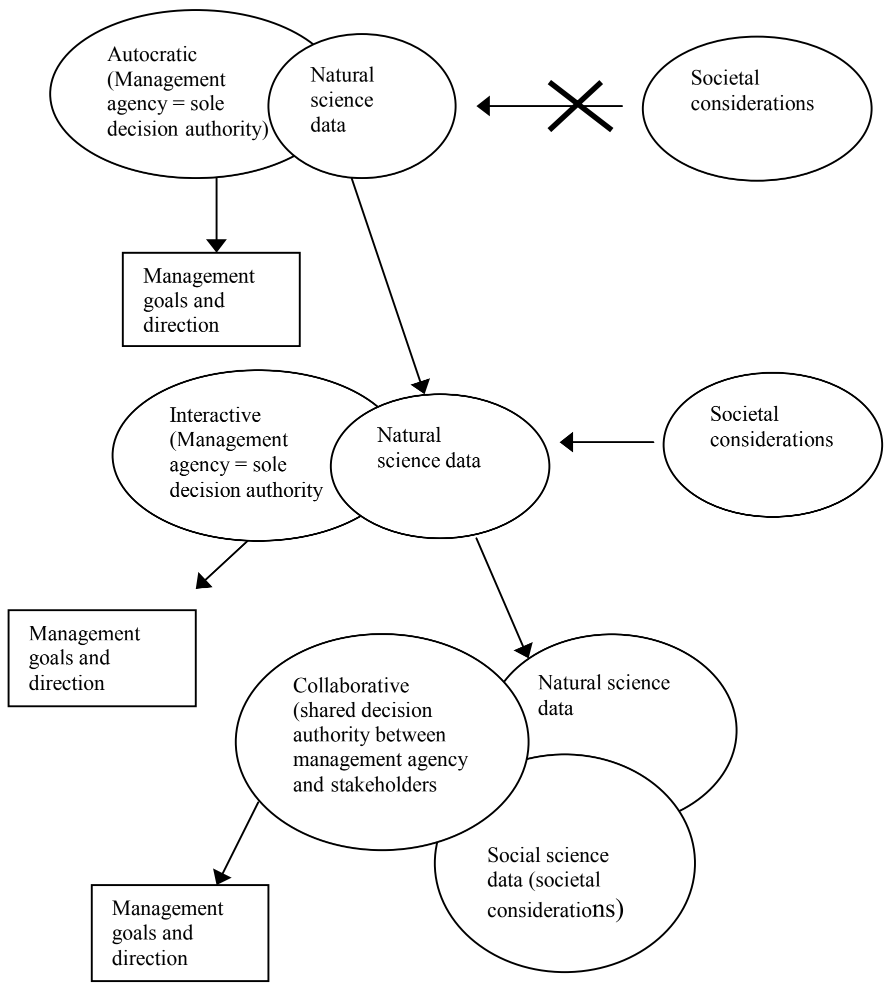

Figure 6: Integration of science and society into decision-making in each of the three renewable resource management paradigms (Mullner *et al.* 2001).

The evolutionary process for the management strategies on Lake Chilwa can be traced from the time when the surrounding ethnic groups settled around Lake Chilwa. These ethnic groups include Lomwe, Yao and Nyanja who migrated to the Chilwa-Phalombe plain from Mozambique and other areas before 1800. The process of the development of management systems for Lake Chilwa can also be defined in terms of both political and socio-economic dimensions. There have been changes in political authority from tribal dominated rule in various places to a British colonial rule early 1900s, which later resulted in the Federation of Rhodesia and Nyasaland in 1950s. Malawi (then Nyasaland) broke away from the Federation of Rhodesia and Nyasaland to independence in 1964. Another change has been from one-party rule to multi-party democratic state instituted in 1994. There has also been a change by shifting from subsistence to cash economy. Figure 7 illustrates an estimated time sequence for the evolution of management systems on Lake Chilwa.

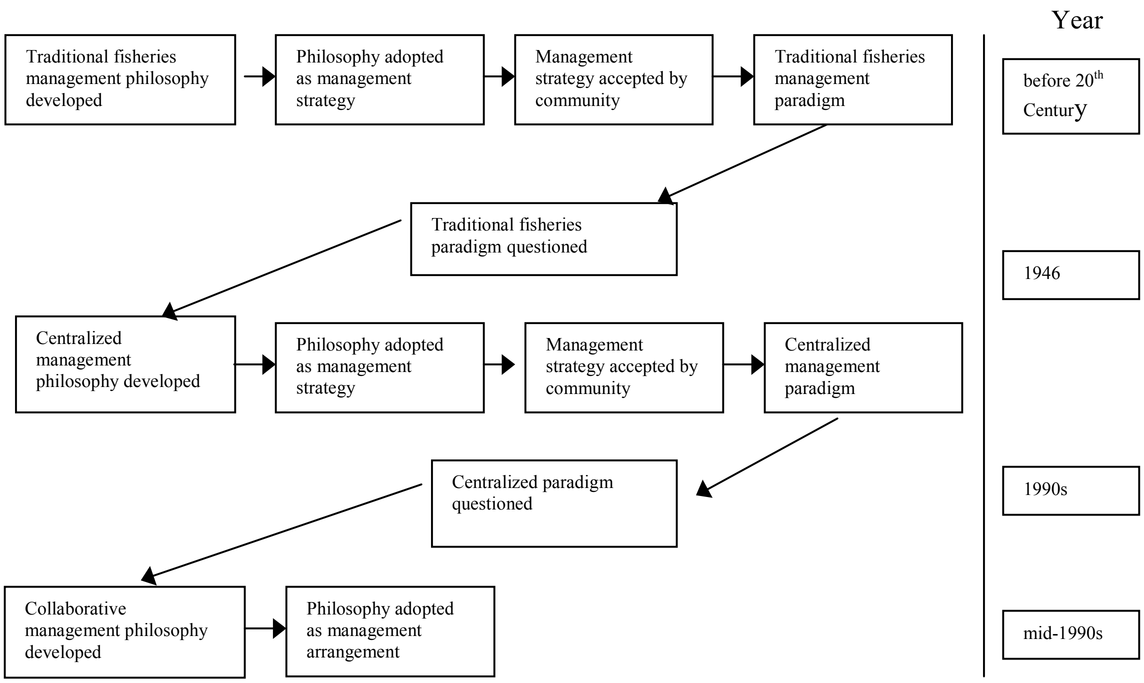

Figure 7: Estimated time for the evolution of the resource management paradigms on Lake Chilwa (adapted from Mullner *et al.* (2001)

The theoretical basis for evolution of fisheries management systems can be explained as follows:

> "The process begins when a management philosophy is espoused by authorities. If the philosophy meets the needs of managers, it may be selected and adopted by them to become a management strategy. Application of an adopted management strategy to the task of renewable resource management provides community the opportunity to consider and ratify the management strategy. If the strategy is accepted by community, it evolves into a management paradigm. When a management strategy is acceptable to managers and society alike and becomes a management

paradigm, substantial discontent and questioning is needed to consider replacing it. However, any management paradigm can be challenged by proponents of a new paradigm. Understanding paradigm evolution provides a basis for understanding the history of renewable natural resource management" (Mullner *et al.* 2001, pp.39-40).

5.1 Traditional fisheries management system before 1900 (pre-colonial era)

Traditional fisheries management of Lake Chilwa was characterised by control of exploitation by the local leaders. The landing beaches had chairpersons who were appointed by the local chief to draw up a time table for seining operations. The local chiefs were mandated by virtue of their authority to control use of their beaches. Social conflicts on the beaches, which could arise due to theft of fishing gear or land disputes, were settled by the chief. However, there were some incentives for the chiefs to be engaged in the control of the beaches. In some parts of water bodies such as Lake Malombe *mawe*[2] was provided to the chief as a way of respect (Hara 2001). The change of authority from the traditional leaders to other systems especially, co-management has brought about conflicts in some cases between the local level institutions and the local leaders (Njaya *et al.* 1999). Table 2 shows major regulations and agreements that were in force during the period of the traditional fisheries management system.

Table 2: Regulations and agreements in the traditional management system

Regulation	Biological rationale	Socio-economic rationale
Seining in turns (according to time table)	Limit effort (implicit)	Equity on the access to the fishing ground
Large meshes (nets made of fibrous plant material) and large spaced traps	To target mature *Oreochromis* spp. and *Barbus* spp.	Large size was culturally accepted for consumption
Fishing was part time	Indirectly protecting spawning season	Farming and fishing were the main activities at subsistence level

It should be noted that during that time population was smaller than at present and fishing was mainly for subsistence use. The main gear used included fish traps and gill nets made of fibrous materials (*chopwa*).

5.2 Centralised system (1946-1995)

The colonial government assumed responsibility with the aim of ensuring efficiency in resource exploitation and utilisation of the resource and hence formulated regulations as shown in Table 3. In 1946, the first Natural Resource Ordinance was proclaimed to conserve and improve natural resources. The premise was that the traditional leaders had no capacity to achieve the goals of sustainable fish production. After independence, the ensuing governments took over the colonial management system largely unchanged.

[2] *Mawe* is a determined amount of fish mostly well selected fish - big in size if it is tilapia or a tin for the smaller fish species given to the local leader by the fishers as a way of respect for using the beach

While licensing was introduced in all water bodies, the increased exploitation of fishery resources remained largely unchecked. The capacity of the Fisheries Department in enforcing fisheries regulations became constrained due to limited budgetary provisions. Weak enforcement was the main reason for increased non-compliance of regulations. However, this has not been the case with Lake Chilwa due to its variable water levels and high productivity.

Table 3: Regulations in the centralized system (pre-1995 recession) (adapted from Njaya and van Zwieten 2000)

Regulation	Biological rationale	Socio-economic rationale
Minimum takeable size of tilapia was set at 100 mm	Protect breeding stock	To fetch a higher price
Headline length for *Matemba* seines should not exceed 300 m	Larger seine nets could damage the juvenile and spawning habitats of commercial species	
Minimum mesh size for gill nets was set at 2¾ inches (69 mm)	Mesh size ensures a minimum size of *Oreochromis shiranus* in the catches, it protects juvenile stocks and ensures that the fish caught has bred at least once	Larger fish fetches higher market prices
Licensing of seines and gill nets	Control of effort	Maximize profits for licensed fishers Revenue for the government
Commercial license fees to be paid by any trawlers.	Control of effort	Maximize profits for licensed fishers Revenue for the government

5.3 Co-management arrangement (post 1995 recession)

Njaya and van Zwieten (2000) indicated that the assumed inefficiencies during the centralized system resulted in a shift to a co-management approach, under the assumption that involvement of resource users in management would bring legitimacy to fishing regulations. Non-compliance would be reduced through more equity in the decision-making process and process transparency; efficiency in terms of reduction in transaction costs and sustainability in terms of stewardship, robustness or resiliency.

The Lake Chilwa co-management programme started in 1995 after the lake dried up. The co-management arrangement has been implemented for over five years. While some of the regulations formulated under the centralized management were maintained, others were changed to reflect the newly introduced co-management approach. Table 4 shows formal and informal regulations (by-laws) currently in force.

Table 4: Regulations in the co-management arrangement (adapted from Njaya and van Zwieten 2000)

Regulation	Biological rationale	Social-economic rationale
Lake Chilwa and Mpoto lagoon should be closed from 1 December to 1 April	Protection of spawning stocks; reduction of fishing effort	To enable fishers to also work on their farms
Riverine fishing is closed from May to September	Protection of spawning stocks	
Nkacha is a prohibited gear	To avoid destroying habitat due to nature of its operations Regulate fishing effort	To avoid competition with the existing beach operated seines
Juvenile fish should be released	To allow juvenile fish to grow and spawn	Larger fish fetches better prices
Poisonous substances from plants like *Syzigium* spp. (*katupe*) should not be used	To avoid indiscriminate catching of fish	Impacts the long term yield of the resource
Fishing should be done during the day only	No biological rationale, reduction of effort possibly as side effect	For easy monitoring of landed fish
Any thief or non-compliant fisherman should be evicted		Control of theft and ensure compliance to regulations
Any fishermen should be registered by a Beach Village Committee[3] (BVC) and pay a fishing licence	To regulate effort	Control movement of fishers and control of theft of gear Revenue for the government and community (proposal)
Traditional leaders and BVCs should be respected		To promote regulation compliance
All fish traders should not market their fish within the waters		To ensure that fish landed is checked by BVCs

Some of the fisheries regulations have no biological basis, but attempt to regulate the behaviour of fishermen. The biological measures are generally based on common sense,

[3] Beach Village Committees are elected members of a group on a beach. Their main duties include formulating and reviewing regulations, enforce regulations, disseminate messages about fisheries. They are supported by their local leaders.

as they appear to be the same as those introduced since the colonial era with some minor adjustments. Since the fishing community has adopted the regulations, they seem to be legitimate (Njaya and van Zwieten 2000).

While a number of regulations presently taken are based on fishers' 'local knowledge', it can be argued that some of them may just be restrictive causing under-exploitation of the resource in 'normal' years. Such an argument is based on the observed capacity of the commercial species of Lake Chilwa to restock the lake in a relatively short time span (Furse *et al.* 1979a). The informal regulations, which have gained high legitimacy among local leaders, could possibly result in the full potential of the lake not being utilized. The changes in the management systems, main tasks and characteristics are summarized in Figure 8.

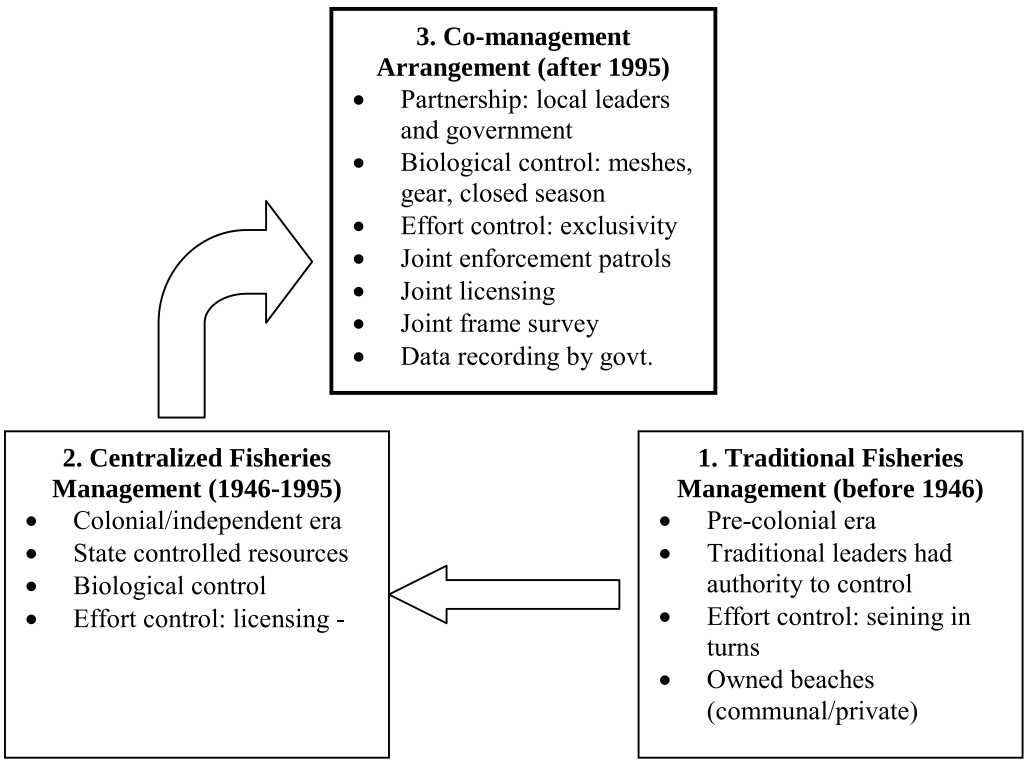

Figure 8: Management systems and their characteristics developed on Lake Chilwa

6. PROPOSED MANAGEMENT STRATEGIES FOR LAKE CHILWA

The question could be on the relative importance of the community actions during innate resilience of the ecosystem. This brings in another management strategy, which is the adaptive system. Adaptive management as defined by Walters (1997) is a structured process of 'learning by doing' that involves more than simply better ecological monitoring and response to unexpected management impacts. Considering the way the co-management arrangement has been introduced, there was no drawn up objective but rather it was a question of responding to a crisis - the recession. The response of the community was positive as the idea of conserving stocks in the surrounding rivers and lagoon seems to have been embedded within the traditional setting of the resource management. Therefore, it is recommended that the change of the management system should be dictated by circumstances depending on water levels.

The review of regulations in the co-management arrangement is necessary for improved utilization of the fisheries resources. Njaya and van Zwieten (2000) noted that most of the current regulations were imposed by the local leaders to reduce effort of *matemba* fishery. The closed season was justified for the first two to three years after the recession of 1995. However, there is a need to review and readjust it possibly by reducing the length of the closed season so that optimum utilization of the resources from the lake can be achieved. All such changes have to be based on scientifically sound strategy advice and for that more research is needed. The adaptive management strategy suggested in this chapter also implies that the closed season will be lengthened if the scientific evidence dictates that.

6.1 Biological and economic measures

6.1.1 Estimated sustainable yield

Bio-economic models are based on the work of Schaefer (1957) Gordon (1954). The major criticism of the traditional model is that it focuses on a single species fisheries and ignores the age or size structure of the population. Despite the inappropriateness of the application of the bio-economic model to highly variable ecosystems such as Lake Chilwa (Njaya and van Zwieten 2000), an attempt was made to estimate the Maximum Sustainable Yield (MSY) for a seine fishery, which mostly lands *matemba* from 1984 to 1987.

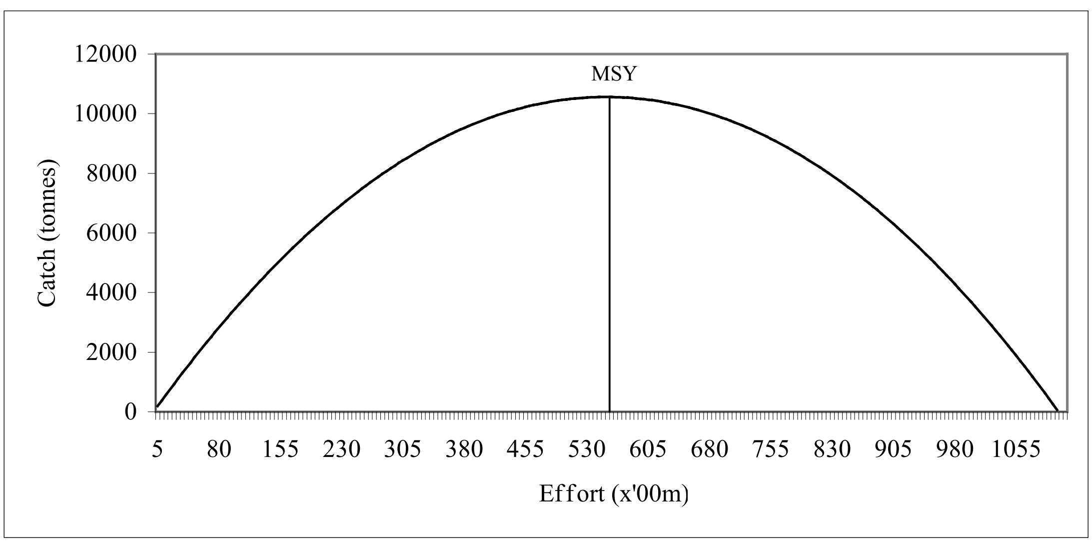

Figure 9: Estimated maximum sustainable yield (MSY) for the *matemba* seine fishery (1984-87)

The rationale for using the model is that even incomplete information is better than no information at all. The fullest care has been taken in interpreting the results from the model. The period from 1984 to 1987 was a period of relatively higher to medium water levels (2.4 m on average). The estimated maximum sustainable yield (MSY) during that period was 10,559.43 tons at an effort of 55,500 m equivalent to 111 seines of 500 m each (Figure 9).

According to frame survey data (Table 1) there has been an increase in the number of seines. The major problem, however, is on how to define effort when considering seine-fishing operations. What is usually considered an increase in effort is in terms of the number of pulls as was done by Njaya and van Zwieten (2000). While this could be true, it may cast some doubts since the length of the seines have now been reduced from a mean of 500 m in 1980s to around 100 m in the 1990s (Figure 10).

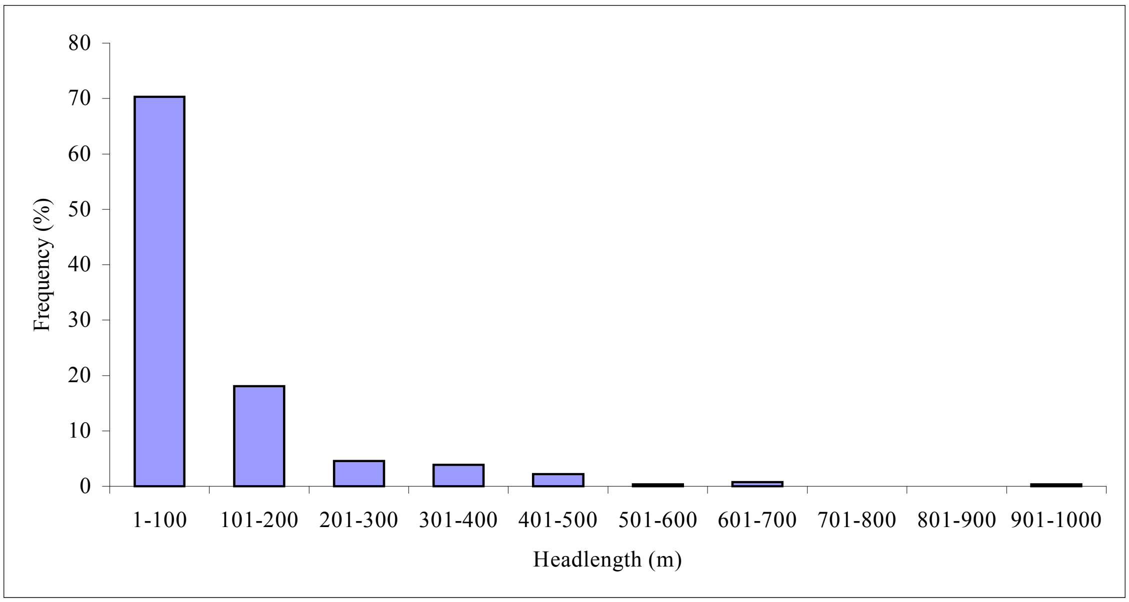

Figure 10: Frequency of headline length (m) of seines (n=735) (Fisheries Department 2000)

Reasons for this reduction may include limited access to capital although compliance to the regulation of 300 m maximum headlength may also be considered a valid reason. Therefore, comparing catch per pull (kg/pull) from seines of different lengths may not provide reliable results. However, this observation calls for research to examine catch rates based on different seine lengths.

The results show that the estimated catch by 422 *matemba* seines (42,200 m) in 1999 was around 3,818 tons. Therefore, based on the MSY, a catch level of around 9,800 tons could be expected in that year assuming the seines are about 100 m each (Figure 10). This shows that the catch level recorded in 1999 was lower than the estimated MSY. There are several reasons that can be attributed to these results. First, there has been a fishing season of 8 months since 1997, as opposed to 12 months during 1984-87, a period during which the MSY was determined. Second, the 8-month fishing season was further reduced by strong *mwera* winds experienced annually between May and August. Third, by 1999 the water level was still lower than 2.4 m, which was the case during the 1984-87 when the MSY was determined. Fourth, there could be some changes in gear interactions which target the same species such as fish traps and lastly, the aquatic vegetation (*Typha*) might not have been fully recovered by 1999.

However, considering the high productivity and great variability of Lake Chilwa, management measures based on the usual sustainable yields calculated from historical averages are not recommended (Njaya and van Zwieten 2000, Sarch and Allison 2000). A report by Kalk *et al.* (1979) states that it takes 3-4 years for the full recovery of Lake Chilwa fishery after a recession. Ratcliffe (1971) noted that productivity of Lake Chilwa was 169 kg/ha/year in 1971, while Kabwazi and Wilson (1996) estimated a figure of 159 kg/ha/year for 1996, which is one of the highest in Africa. Considering that an annual estimated catch of 12,500 tons was recorded in 1999, it agrees with the above observations that the lake is highly productive, as it took about 3 years to record such catch level. However, Kalk *et al.* (1979) indicated that a limit on the minimum mesh size of gill nets in normal years is needed, as it demonstrably protects the breeding stocks of *Oreochromis* species, without seriously affecting the catch of the other species.

In some years, such as 1979 and 1990 catch levels of over 18,000 tons and 14,000 tons respectively have been recorded as caught by seines, which may be above the MSY estimated in this study. This could explain lower catches by seines from 1990 to 1993 (Appendices 1 and 2), although lower water level had a major impact. Application of the MSY model should, however, be treated with caution, as there is need to verify the recovery of the fishery through other biological and socio-economic studies. The MSY does not take into account changing biological and economic processes, which implies that it could be more suitably applied during the mid-1980s when the water level was above 2.4 m than when the water level is lower. However, it provides an estimate of yield when water levels may be substantially high (above 2.4 m). While it may be recommended to determine the biomass growth for *matemba* through research, this may be more challenging because of the high variability of Lake Chilwa.

6.1.2 Estimated maximum economic yield (MEY)

Based on the same economic model and the average beach price of MK14/kg for *Barbus paludinosus* estimated in 1999 (Njaya 2001), the maximum economic yield (MEY) is about US$3.4 million. The maximum rent is estimated at US$2.7 million at an effort level of 49,500 m (99 seines of 500 m each) for the seine fishery. This is the point where the difference between revenue and total cost is greatest. Open access equilibrium is determined at an effort of 98,500 m (Figure 11).

The total cost is a straight line because it has been assumed that the total cost of operating each seine (US$6,693.02) would be the same in 1999, assuming capital costs include procurement of new seines and boats (Appendix 4). However, in reality, after a few years, the capital costs would be changed.

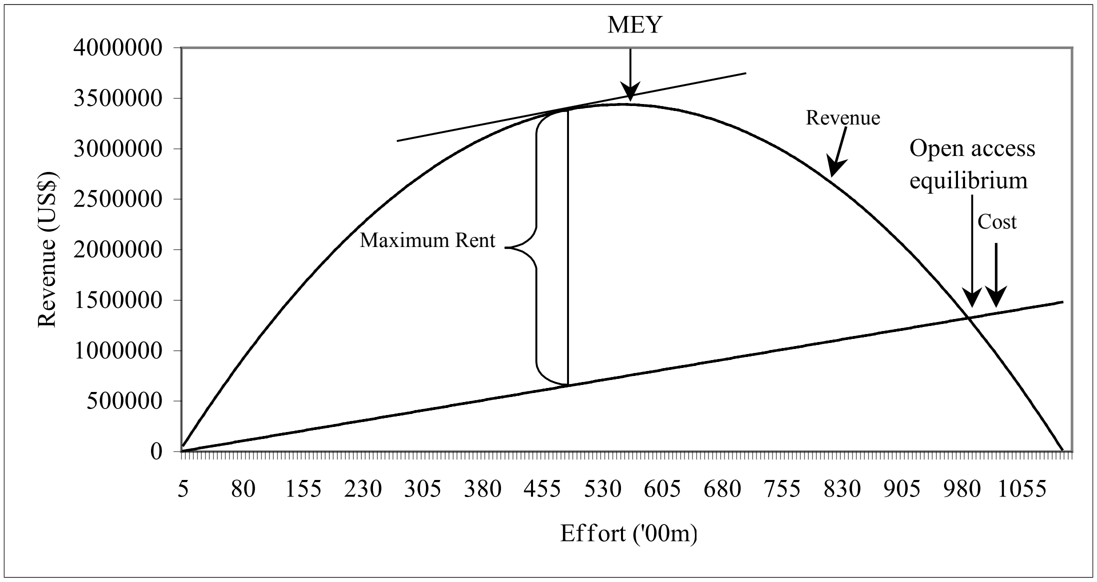

Figure 11: Estimated maximum economic yield (MEY) and rent for the seine fishery in 1999

Schuijt (1999) estimates a total of $8,291,470 as net benefits from fishing in Lake Chilwa. The results are not necessarily contradictory. Differences could be due to different price levels used as in this report prices are based on fresh weight. It excludes price of processed fish, which can also be sold on the beaches to other middlemen. Secondly, there should be differences in costs of seining operation units. Thirdly, this model deals with the seine net fishery only and not all the fisheries. However, a more realistic way to assess the potential revenue given a time frame of 3-4 years or given a water level is by collecting economic data on costs of fishing inputs.

Recommended course of action for the seine fishery

Based on the results obtained in this study, further research is recommended to enhance utilization of matemba. The research should focus on the following areas:

(a) Conduct fishing experiments during closed seasons. Sarch and Allison (2000) recommended that in fisheries where exploitation has little demonstrable impact on fish stocks and productivity is closely linked to climate, it is not useful to limit fishing effort. However, as a precautionary measure, it will be important to monitor any effort changes as more seines may result in operating the fishery at or above the equilibrium level. Consequently, the fishery will not have sufficient profits to keep more crewmembers employed.

(b) Commercial fishing should be tried as a demonstration unit. It was stated by Kalk *et al.* (1979) and Ratcliffe (1971) that the Lake Chilwa fishery can support a commercial fishery sector, but they cautioned that no attempt should be made to remove the aquatic vegetation. The commercial fishing operations should be based on a further research after assessing the biomass and other ecological changes after the 1995 recession.

6.1.3 Biological measures for gill net, and fish trap fisheries

The gill net fishery needs to be closely checked as it mostly targets *makumba* or *chambo* that recovers 4 years after recession as reported by Furse *et al.* (1979a). The 2000 frame survey results (Fisheries Department 2000) indicate that most of the gill nets used are illegal (74%) as they are less than 2¾ inches (69 mm) as shown in Figure 12.

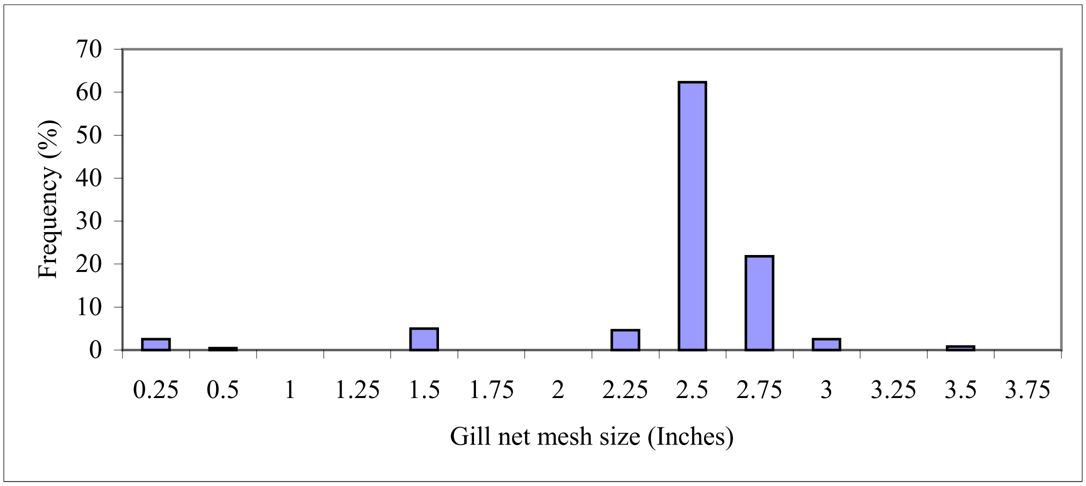

Figure 12: Frequency distribution of gill net mesh sizes (Fisheries Department 2000)

The other passive gears such as long lines and *chomanga* may not have a major impact on the stock levels. However, there is need to check setting of fish traps and weirs on river mouths especially where weirs are constructed across the rivers. This may target spawning of *matemba* migrating from the lake to the rivers or juveniles and adults returning to the lake during the rainy season. This has to be verified with biological research.

Recommended course of action

In general, the following measures are proposed for management of the other fisheries in Lake Chilwa:

(a) Gill net fishery regulations should be enforced, as most of the gill nets have meshes less than 2¾ inches, which means that they target juvenile tilapia. However, Furse *et al.* (1979a) observed that any attempts to protect *Oreochromis shiranus chilwae* stocks merely denies the fishing industry the opportunity to crop the other species whilst they are there to be cropped unless control can be carried out selectively. It was recommended, that while some proposals are valid and laudable for permanent water bodies, in Lake Chilwa the fish should be caught whilst stocks exist. Stocks that can recover in two or three years from virtual annihilation by drought are never likely to be overfished to the point of disappearance and Lake Chilwa itself has its own reservoirs in the swamps which serve as the great conservator of fishes.

(b) Setting of fish traps in rivers should be closely monitored, as it is observed that during the rainy season, *B. paludinosus* swim upstream for spawning and re-enter the fishery during the same period with many juveniles. The closed season should also be reviewed, as it does not match with the spawning period for *B. paludinosus*. This is to enhance its recruitment capacity.

(c) Explore other means of exploiting Lake Chilwa fishery resources. Socio-economic value of the other fisheries species like *mphuta* (*Gnathonemus* spp.) and *nkhalala* (*Alestes imberi*) should be explored to maximize benefit of the fishery. This could be based on the higher catches, which were contributed by the species between 1980 and 1994.

6.2 Institutional measures

Some of the local level institutions like Beach Village Committees can become cooperatives to deal with a number of activities with an aim of distributing benefits to the surrounding community (Figure 13).

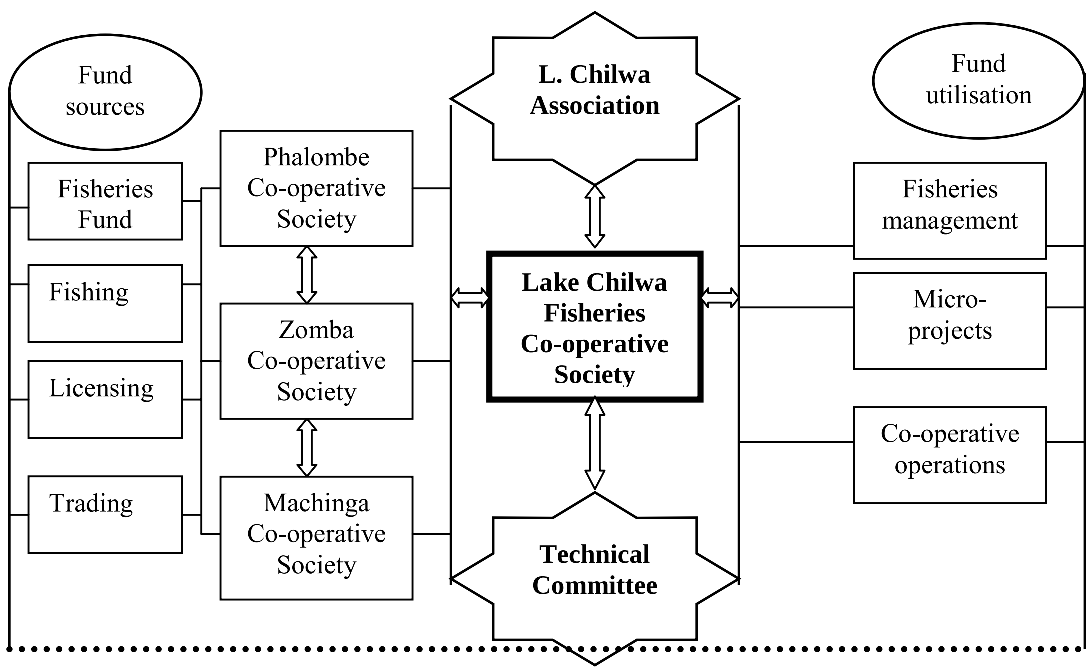

Figure 13: Proposed set up of the Lake Chilwa Co-operative Society

This can be achieved by designing and implementing micro-community-based projects. They can also be involved in fishing, exploring fish marketing opportunities (domestic and export), fish supply, supplying fishing and can provide loans to fishers.

The community level micro-projects can be considered appropriate means to achieve the government's overriding policy of poverty reduction and food security through the increased fish supply, as people will be engaged in fish trading businesses. Projects like feeder roads, water supply and clinics will promote living standards of the rural population. Revenue generated by the district-based cooperative societies (Phalombe, Zomba and Machinga) can be used to fund certain fisheries management activities including research, enforcement activities and message delivery (extension service) which are not adequately conducted due to limited government funds.

The technical committee will provide technical advice on issues related to fishing, environmental management, business and book keeping. They will facilitate some of the development work by conducting needs assessment, preparing project appraisal reports and seek solutions to any emerging problems from the co-operatives.

However, for effective implementation and the general operational efficiency, there is need for capacity building of the local institutions. Appropriate means of training should be done by conducting study tours to places like Lake Kariba where co-operatives have been working for some years.

6.3 Enhancement measures

Promotion of fish culture within the Chilwa basin will ensure supply of fish at both household and national levels especially during the recessions. There is need to utilize small water bodies by stocking fish, which can be managed by private individuals or communities. Cage culture is another area that can be explored to promote supply of tilapia. There are similar projects on Lake Kariba from where some lessons can be drawn. A possible option would be to stock the indigenous *Oreochromis shiranus chilwae* in cages rather than introducing new species which may not cope with the saline conditions. However, this will demand systematic monitoring studies on the environmental factors especially with respect to pollution.

6.4 Environmental management

As an enclosed ecosystem, it is important to consider other environmental issues, which have been outlined in the Lake Chilwa management plan (Environmental Affairs Department 1998). Issues like pollution control, proper farming practices that minimize surface run-off and subsequent silt load into the lake, use of fertilizers on the adjacent rice schemes such as Khanda, Domasi, and Likangala, and a tree plantation campaign should be considered during planning of activities in the Chilwa basin. As noted by Moss (1979), the Chilwa fish species are clearly well adapted to persist in the fluctuating ecosystem, provided the refugium of swamps and stream is maintained. He cautions that more dangerous than overfishing in this resilient system are threats to the swamps through 'reclamation' for agriculture or perhaps as irrigation reservoirs, siltation catchment erosion and accumulation of pesticides.

Some researchers have emphasized the importance of influent rivers and aquatic vegetation for Lake Chilwa and other shallow lakes. Kalk *et al.* (1979) recommended that *Typha* swamps should always be preserved. The fundamental role of rivers and peripheral flood plains and swamps as an inoculum source of plankton, benthos and particularly fish is evident from studies on Lakes Chilwa, Chad and George. The influence of marginal areas of shallow lakes is such that there may be little point in even focusing on management of the open water without management or protection of the surrounding swamps and/or floodplains. Management policies for shallow lakes should extend to as much as the surrounding land as possible (UNEP 1981).

Furse *et al.* (1979b) noted that overfishing may not destroy the fishery but accumulation of toxic chemicals could one day do so. The dangers of the accumulation of fertilizers or of directly toxic substances have been clearly demonstrated in open basin lakes. This danger is far more acute in closed basin lakes, like Lake Chilwa. Lake Chilwa, its fishes and its fishery may have the resilience to overcome the physico-chemical stresses climate places upon it. It must be protected against the untimely ravages of man.

6.5 Transboundary measures

Transboundary issues are not considered in the current management plan. As a shared ecosystem, it is important to have a common management strategy like data collection and policy formulation which would take into consideration needs of the communities from both Malawi and Mozambique.

Figure 14 shows a conceptual set up of a local fisheries management strategy. The emphasis is the level of co-ordination, which is between the surrounding communities in Malawi and Mozambique. The higher authorities should be responsible for formulating policy framework and principles and consolidating such localized common management strategies through treaties or agreements such as the Southern African Development Community (SADC).

The set up recognizes the joint operational framework through the fishing communities from both countries. These communities need to be in groups like Beach Village Committees (BVCs), which are already in place on the Malawian side of Lake Chilwa. These BVCs should have a coordinating body (association). The Malawian and Mozambican associations can arrange to elect a common joint management committee with a mandate of two to three years.

This means that any need for a management plan or issues concerning Lake Chilwa has to be tabled for discussion between the fishing communities from both countries through the joint committee. The role of the local district or provincial administrations and fisheries authorities will provide logistical support and technical solutions to problems regarding the Lake Chilwa ecosystem. This will minimize conflicts, which normally occur during closed seasons.

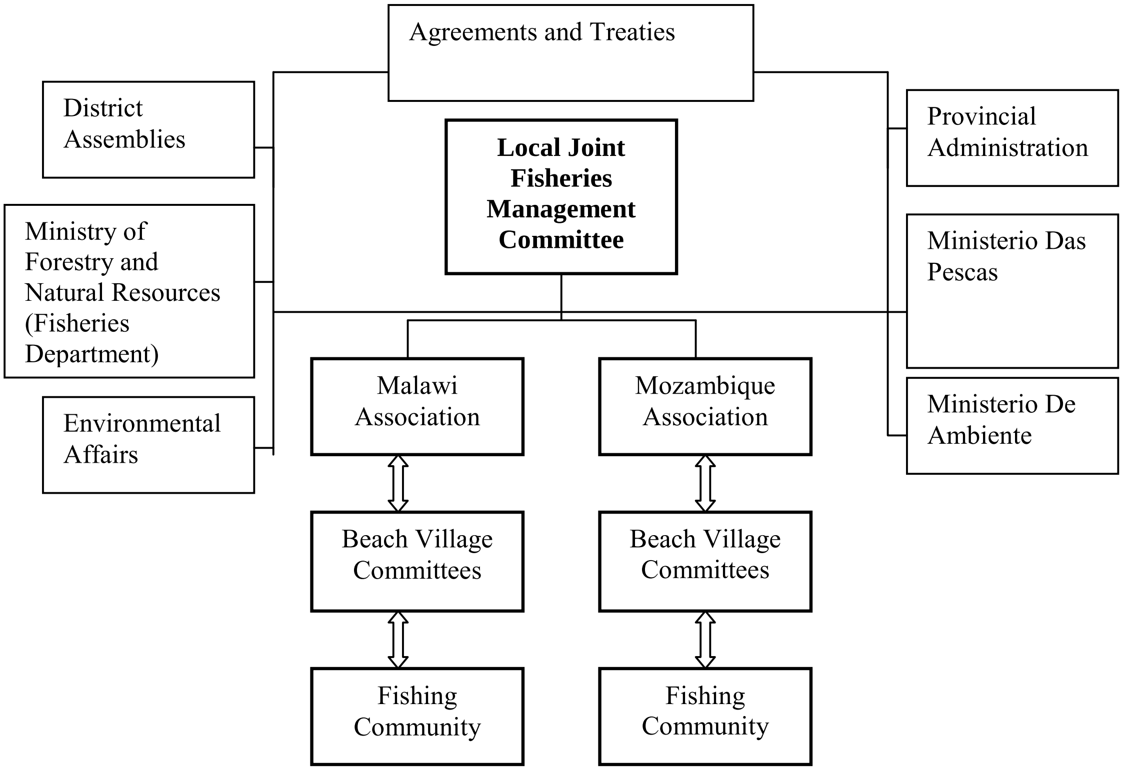

Figure 14: Proposed set up of a local Joint Fisheries Management Committee (Malawi and Mozambique)

6.6 Water regulation measures

Furse *et al.* (1979b) reported that schemes to provide a stable water level are extremely expensive, of unproven efficacy and most unlikely to be implemented. With intervals between recessions of only perhaps five to ten years any imposition of fishing regulations merely denies the local fishers the chance of cropping the fish stocks before the lake itself does so through critical physico-chemical demands and mass mortalities. Some fish species like *Barbus paludinosus* and *Clarias gariepinus* are capable of very rapid recovery in newly inundated conditions.

However, despite such difficulties, suggestions have been provided by various stakeholders. For a sustained water supply into Lake Chilwa, some stakeholders have recommended construction of dams in the catchment area, which can be regulated to minimize floods or recessions (Chavula 2000). These ideas may be difficult to implement, but with water development programmes in the pipeline, these issues can be taken into account. The World Bank, for example, funded dam construction on Likangala River in Zomba. Of particular attention would be the effect of water flow so that the substrate necessary for the spawning of *matemba* stock should not be altered. Kalk *et al.* (1979) warned against any plan for changing the present drainage of rivers as that could damage the ecosystem. This should be done by involving other experts such as fisheries biologists and hydrologists when designing and implementing such projects. With dam constructions, conflicts on water usage for irrigation schemes can also be minimized as volume of water required for each sector (domestic use, farming, aquaculture and the fishery) can be quantified.

6.7 Sustainable livelihoods approach

The concept of 'sustainable rural livelihoods' is increasingly becoming central to the debate about rural development, poverty reduction and environmental management. A livelihood comprises capabilities, assets (including both material and social resources) and activities required for a means of living. A livelihood is sustainable when it can cope with and recover from stresses and shocks, maintain or enhance its capabilities and assets, while not undermining the natural resources base (UNDP 1997).

It is important to consider fishing as well as other income generating activities that provide sources of livelihoods for the community around Lake Chilwa. This should be supported, as the Lake Chilwa fisherfolk are also farmers. Any project that promotes fisheries development should also take into consideration other general issues affecting the community. These may include economic empowerment for investing in other businesses so that during recessions fish traders and fishers can support their families. Sarch and Allison (2000) note that the apparently greater importance of climate relative to fishing, in driving the dynamics of fish stocks in many of Africa's inland waters suggests that effort should be redirected at protecting wetland functions and broader ecosystem integrity and away from trying to manage fish stocks for sustainability. This means that other sources of income generation should be identified and promoted.

7. RECOMMENDATIONS AND CONCLUSION

This project paper has reviewed the past and current management strategies and identified an exploitation level of *matemba* seine within a specified time frame of about three years when water level is about 2 m deep. Based on the variability of Lake Chilwa and the review of the past management strategies, an adaptive fisheries management strategy is recommended for Lake Chilwa. As reported by Furse *et al.* (1979a), fish stocks should be cropped when they exist, especially between recessions. The situation should be different when water level drops due to recessions. At this time, there is need to conserve remnant stocks by implementing some measures like banning seining and use of destructive fishing methods in the adjacent Mpoto Lagoon and influent river systems. The adaptive management strategy will ensure resiliency of the ecosystem to recover after recessions and optimize utilization of the fish stocks when they exist. This has been the case over the previous recession such as in 1968 recession when communities had to develop some management measures for recovery of the collapsed fish stocks after refilling.

While the study has estimated MSY and MEY levels, their applicability can be limited in ecosystems like Lake Chilwa, which is highly variable. Management decisions based solely on bio-economic principles may not be appropriate, although depending on water levels, they may provide yield and revenue estimates.

There is a need to review the current regulations governing exploitation of the fishery especially *matemba*. Based on the previous studies and the biology of *matemba*, it is increasingly becoming theoretical to assume that overfishing could be experienced in Lake Chilwa. The way forward is to carry out experimental fishing studies with *matemba* seines during the rainy season when the seining operations are closed and estimate catch per unit of effort. Results from such studies may recommend reduction of the length of the closed season, which is currently 4 months. It may also be suitable to estimate biomass of the fishery by conducting trawling surveys as those conducted by Ratcliffe (1971). There is need to check setting of the fish traps to avoid targeting spawning stocks of *matemba* when they migrate up or down streams. The closed season for riverine fishing needs to be checked to match with the breeding patterns of *matemba*. The gillnet meshes should be enforced to allow for recovery of *makumba* or *chambo* and this can be reviewed when considered appropriate.

The review of the historical management system of the lake has provided a basis for the recommended measures by focusing on the potential of the community's initiatives for resource recovery. This appears to be within the adaptive management framework although it is not formally recognized by the government authority.

Further studies should be conducted on Lake Chilwa to determine major changes that might have occurred since the last comprehensive study conducted by Kalk *et al.* (1979). In particular, understanding the response of various fisheries to historical lake either by gear type or by species is recommended for subsequent development of suitable predictive models of the lake. With changes to farming systems and increased population pressure, there is a need to examine the morphology of the lake and depth as siltation and other environmental impacts might have induced changes in spawning grounds and other habitats.

The institutional arrangements at the local level need to be consolidated with proper incentives. These may include transforming them into co-operative societies that will ensure equity and efficiency in their operations including management of the fishery. However, capacity building is necessary for effective performance of the institutions.

As a shared ecosystem, a common management strategy should be developed. This will minimize conflicts which emerge between communities from Malawi and Mozambique, especially during closed seasons.

Some environmental threats to the ecosystem need to be considered. Issues like deforestation, chemical fertilizer application with phosphorous and other pollutants from the catchment area around Zomba municipality should be addressed with appropriate policy and legislative framework such the Environmental Policy (Environmental Affairs Department 1998). There is need for compensation to the Chilwa basin population in case of any pollution. The local level institutions should be sensitized in these issues so that they are able to take legal actions where necessary.

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APPENDICES

Appendix 1: Catch trends for Lake Chilwa

Fishing gear	Year	*O. shiranus chilwae*	*Barbus paludinosus*	*Clarias gariepinus*	Other species	Total
Gill net	1980	4294.28	0.00	368.12	16.42	4678.82
	1981	3411.00	0.00	276.39	0.95	3688.34
	1982	1722.34	0.00	457.84	0.00	2180.18
	1983	1333.02	12.27	453.52	33.73	1832.54
	1984	760.48	21.70	330.96	7.87	1121.48
	1985	223.61	23.74	144.95	2.74	395.04
	1986	456.14	4.44	142.31	17.80	620.69
	1987	839.53	238.12	171.69	2.72	1252.06
	1988	1282.94	8.55	333.55	3.19	1628.23
	1989	1346.46	21.92	190.84	10.77	1569.99
	1990	1383.54	0.00	629.76	33.01	2046.31
	1991	992.68	2.76	231.05	4.72	1231.21
	1992	1253.93	54.67	374.13	252.78	1935.51
	1993	546.70	53.97	592.90	38.58	1232.15
	1994	402.04	57.28	405.97	1.75	867.04
	1995	0.57	0.00	217.85	0.00	218.42
	1997	101.06	0.00	53.20	4.12	158.38
	1998	505.67	9.39	240.85	1.09	757.00
	1999	1990.72	0.00	994.13	2.56	2987.41
Long line	1980	0.00	0.00	630.73	0.00	630.73
	1981	4.68	0.00	475.25	0.15	480.08
	1982	7.54	0.00	662.00	21.61	691.15
	1983	1.49	0.00	547.77	60.75	610.01
	1984	12.29	0.00	418.14	0.81	431.24
	1985	2.03	0.00	614.42	2.96	619.41
	1986	25.94	0.00	573.02	8.96	607.92
	1987	7.06	0.00	591.33	12.89	611.28
	1988	25.74	0.00	512.66	13.25	551.65
	1989	9.18	0.00	302.08	22.41	333.67
	1990	67.28	0.00	603.25	9.73	680.26
	1991	60.40	0.00	469.69	232.63	762.72
	1992	12.54	0.00	977.81	28.41	1018.76
	1993	120.50	0.00	1183.14	0.00	1303.64
	1994	0.00	0.00	554.96	0.00	554.96
	1995	0.00	0.00	73.08	0.00	73.08
	1997	0.00	0.00	31.47	0.00	31.47
	1998	1.47	0.00	216.61	0.00	218.08
	1999	0.00	0.00	519.87	0.00	519.87
Seine	1980	501.37	1861.66	128.99	41.00	2533.02
	1981	259.04	837.94	76.13	70.28	1243.39
	1982	1708.98	9009.79	755.74	31.49	11506.00
	1983	1406.19	5966.51	505.51	322.79	8201.00
	1984	838.36	8093.14	672.21	54.19	9657.90
	1985	1173.24	6721.90	826.51	237.66	8959.31
	1986	1620.55	4208.54	463.89	1355.76	7648.74
	1987	546.91	790.23	257.25	1206.77	2801.16
	1988	766.69	1204.34	208.96	1022.37	3202.36

	1989	644.93	1871.73	99.56	541.86	3158.08
	1990	661.92	13329.16	93.53	4012.77	18097.38
	1991	1477.96	1833.41	86.97	1187.93	4586.27
	1992	1609.32	2358.06	397.02	2044.75	6409.15
	1993	689.56	4762.86	687.14	906.87	6760.90
	1994	586.59	5893.40	911.97	559.59	7951.55
	1995	1.00	22.10	975.17	0.00	998.27
	1997	214.49	431.24	98.14	0.00	743.87
	1998	1046.22	1624.83	289.81	5.77	2966.63
	1999	1132.59	2230.35	454.67	0.00	3817.61
Fish trap	1980	927.23	3449.40	91.43	4441.43	8909.49
	1981	628.96	842.78	28.43	2884.56	4384.73
	1982	140.36	633.42	31.46	366.79	1172.03
	1983	1130.80	530.72	1074.79	600.57	3336.88
	1984	199.89	561.64	546.24	157.54	1465.31
	1985	566.52	1380.43	442.12	591.66	2980.73
	1986	1038.21	2121.77	392.84	1287.93	4840.75
	1987	588.55	1591.24	165.80	973.57	3319.16
	1988	398.43	344.79	217.94	352.33	1313.49
	1989	475.09	1103.96	63.51	292.55	1935.11
	1990	495.38	1634.18	63.18	460.55	2653.29
	1991	400.67	67.62	68.08	122.65	659.02
	1992	441.33	69.68	322.83	118.83	952.67
	1993	152.40	554.37	143.93	359.08	1209.78
	1994	24.88	282.87	175.81	234.32	717.88
	1995	4.80	4.37	29.42	0.00	38.59
	1997	9.38	47.70	29.10	15.57	101.75
	1998	69.09	209.33	162.86	27.34	468.62
	1999	472.31	925.35	527.22	9.64	1934.52
Other gear	1980	4.68	16.81	1.55	0.78	23.82
	1980	13.91	19.75	0.63	20.55	54.84
	1980	0.00	8.07	0.00	0.00	8.07
	1982	0.14	7.68	0.00	1.02	8.84
	1982	0.00	8.76	0.00	0.00	8.76
	1983	54.66	234.57	45.00	126.80	461.03
	1983	0.00	5.98	0.00	0.00	5.98
	1984	43.33	174.97	0.00	49.26	267.56
	1985	31.70	17.94	1.18	32.59	83.41
	1985	1.14	0.45	0.00	0.00	1.59
	1986	0.99	0.83	0.00	0.00	1.82
	1987	4.90	0.00	0.00	0.00	4.90
	1989	26.22	0.00	0.00	0.00	26.22
	1990	74.37	0.08	2.83	0.00	77.28
	1991	9.47	0.00	4.40	0.61	14.48
	1991	96.83	0.00	0.20	0.00	97.03
	1992	0.00	0.76	10.93	0.00	93.99
	1993	0.00	10.28	0.08	1.40	18.04
	1994	0.00	0.00	0.00	1.25	1.25
	1994	0.00	11.15	0.00	30.55	63.20
	1997	0.00	0.00	33.45	0.00	33.45
	1998	0.00	0.00	1.24	0.00	1.24
	1998	0.00	0.43	249.50	0.23	250.46
	1999	0.00	0.00	3281.72	0.93	3306.29

Appendix 2: Catch by species

Year	*O. shiranus chilwae*	*B. paludinosus*	*C. gariepinus*	Other species	Total
1976	1883.41	6783.25	4545.21	1903.18	15115.05
1979	7383.09	5735.03	4689.53	6502.36	24310.01
1980	5741.47	5355.69	1221.45	4520.18	16838.79
1981	4303.68	1680.72	856.20	2955.94	9796.54
1982	3579.36	9659.65	1907.04	420.91	15566.96
1983	3926.16	6750.05	2626.59	1144.64	14447.44
1984	1854.35	8934.64	1967.55	269.67	13026.21
1985	1998.24	8145.23	2029.18	867.61	13040.26
1986	3141.83	6335.58	1572.06	2670.45	13719.92
1987	1986.95	2621.17	1186.07	2195.95	7990.14
1988	2473.80	1570.26	1273.11	1391.14	6708.31
1989	2501.88	2997.61	655.99	867.59	7023.07
1990	2682.49	14970.84	1392.55	4516.06	23561.94
1991	3038.01	1942.35	860.39	1548.54	7389.29
1992	3399.42	2527.08	2082.72	2444.77	10453.99
1993	1515.44	5381.48	2607.19	1305.93	10810.04
1994	1035.01	6244.85	2048.71	827.46	10156.03
1995	6.37	26.47	1295.52	0.00	1328.36
1996	Recession				
1997	324.93	478.94	245.36	19.69	1068.92
1998	1622.75	1843.98	1160.87	34.43	4662.03
1999	3619.26	3155.70	5777.61	13.13	12565.70

Appendix 3: Bio-economic analysis of the seine fishery in 1999

CPUE (t/seine/yr)	Effort (E) (Seines)	Yield (CPUE x E)	Revenue (R) (US$)	Total Costs (TC) (US$)	Profit (US$) (R - TC)
189.95	0	0.00	0.00	0.00	0.00
179.61	12	2155.27	701716.47	80316.00	621400.47
169.26	24	4062.29	1322605.40	160632.00	1161973.40
158.92	36	5721.05	1862666.79	240948.00	1621718.79
148.57	48	7131.55	2321900.65	321264.00	2000636.65
138.23	60	8293.80	2700306.98	401580.00	2298726.98
127.89	72	9207.79	2997885.77	481896.00	2515989.77
117.54	84	9873.53	3214637.02	562212.00	2652425.02
107.20	96	10291.01	3350560.74	642528.00	2708032.74
96.85	108	10460.23	3405656.93	722844.00	2682812.93
86.51	120	10381.20	3379925.58	803160.00	2576765.58
76.17	132	10053.91	3273366.70	883476.00	2389890.70
65.82	144	9478.37	3085980.28	963792.00	2122188.28
55.48	156	8654.57	2817766.33	1044108.00	1773658.33
45.13	168	7582.51	2468724.84	1124424.00	1344300.84
34.79	180	6262.20	2038855.81	1204740.00	834115.81
24.45	192	4693.63	1528159.26	1285056.00	243103.26
14.10	204	2876.81	936635.16	1365372.00	-428736.84
3.76	216	811.73	264283.53	1445688.00	-1181404.47

Appendix 4: Costs (US$) of a seining operation on Lake Chilwa in 1999

Item	Amount (US$)
Capital costs	
Seine net, floats and weights	930.23
Planked boat	465.12
Shelter	116.28
Fixed costs	
Depreciation (15% of capital costs)	36.63
Interest (30% pa)	2007.91
Licence	23.26
Operating costs	
Food supplies	116.28
Repair	46.51
Wages (10 operators)	2950.81
Total Costs	6693.02