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# Fisheries Research Unit Research Plan 2000 & 2001

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# CHAPTER 1: Introduction

The National Environmental Policy (2000) states that the objective for fisheries is: "To manage fish resources for sustainable utilisation, reduction and conservation of aquatic biodiversity". To achieve this objective for capture fisheries, harvesting should be based on established sustainable yields of different species/stocks and opportunities to expand existing and/or develop new aquatic resources must be explored (National Environmental Policy 2000).

The Department of Fisheries (DoF) 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. The main role of the Fisheries Research Unit (FRU) is to provide the DoF with such information based on an understanding of the biology, life history and distribution of the target species as well as an understanding of the harvesting fisheries (King 1995). To achieve this, the FRU has adopted a holistic research approach whereby research activities are geared towards the ultimate formulation of a management strategy for Malawi's fisheries.

This document outlines research activities planned for the July 2000-June 2001 financial year. These research activities fall under the five categories shown in the flow diagram, namely gear selectivity, utilisation trends, biological surveys, population dynamics and social and economic research. The research plans presented in this can be classified as either discrete surveys 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 (*viz.* chapter 2); the determination of biological parameters for major target species (*viz.* chapter 3); or rapid stock assessments of small lakes (*viz.* chapter 4); are surveys with outcomes achievable during short-term research programmes (1-5 years). Long term monitoring programmes, such as catch and effort surveys (*viz.* chapter 5) and trawl surveys (*viz.* chapter 6) can only yield management information if they are sustained over long periods (20 years). It should also be noted that 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 programmes can only be ensured if they are budgeted from within the DoF.

The research proposals have been ranked according to importance (Table 1). While some projects are ranked higher than others, it should be noted that all proposals outlined within this document are relevant and necessary for the formulation of a management strategy for Lake Malawi and other fisheries within Malawi.

**Table 1.** Ranking of research proposals within this document. (1= highest priority requiring immediate action for monitoring; 2 = high priority requiring action; 3 = intermediate priority requiring action but can be done *ad hoc*; 4 = low priority can be done if and when funds are available).

| Section | Project Title | Priority |
|---|---|---|
| 2.1 | Kauni Fishery selectivity survey. | 2 |
| 2.2 | Chilimira fishery selectivity. | 2 |
| 2.3 | Gillnet selectivity surveys. | 2 |
| 2.4 | Handline catch assessment and gear selectivity. | 2 |
| 2.5 | Traditional gear selectivity surveys (Northern Lake Malawi) | 2 |
| 2.6 | A preliminary study of the effectiveness of monofilament gillnets in Lake Malawi | 2 |
| 2.7 | Commercial pair trawl selectivity | 3 |
| 2.8 | Trawl net selectivity survey | 3 |
| 3.1 | Aquatic ecology and fisheries of Lake Chikukutu | 4 |
| 3.2 | Lake Malombe assessment programmes | 2 |
| 3.2 | Lake Chiuta assessment programmes | 2 |
| 4.1 | The economics of processing and distribution of small scale fishing in Lake Malawi | 3 |
| 5.1 | Biological management parameters for target species in Lake Malawi | 1 |
| 6.1 | Monitoring of catch and effort in artisenal fisheries | 1 |
| 6.2 | Demersal monitoring surveys | 1 |
| 7.1 | Demersal exploratory surveys | 3 |
| 7.1 | Pelagic exploratory surveys | 3 |
| 8.1 | Limnological Surveys | 3 |

# CHAPTER 2: GEAR SELECTIVITY SURVEYS

## 2.1. Kauni Fishery selectivity survey

### Introduction

Chambo are plankton feeders belonging to the genus *Oreochromis.* They are wide ranging, but show geographic variation and they are overfished (Bulirani *et al.* 1999). Catches of chambo in Lake Malawi peaked at 8-9000 tons in the late 1970s and in the mid-1980s but declined in 1986-87 (Bulirani *et al.* 1999). Catches were stable at 5-6000 tons during 1986-92 but declined to 1800-2800 tons in recent years (Bulirani *et al.* 1999). The bulk of the catch has been taken in the traditional fishery, which use 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 using a technique that is locally known as "kauni" whereby the gear is used at night in conjunction with light attraction (Banda, unpublished). The chilimira that targets chambo is a deviate 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 south-west 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; Banda unpublished). A preliminary report on the fishery in this area showed that over 80% of the chambo caught in the "kauni" fishery are immature thus indicating that this gear may contribute towards growth and recruitment overfishing of chambo (Banda, unpublished) and it has been recommended that there should be a closure of this fishery in area A of Lake Malawi (Bulirani *et al.* 1999). Weyl, 1999).

### Objectives

(1) To assess the size of the "chambo-targeting" kauni fishery and the areas that are fished to target chambo.

(2) To determine the gear specifications and mode of operation of the "chambo-targeting" chilimira net and to determine how the chilimira gear used for chambo fishing differs from the traditional usipa/utaka fishing approach.

(3) To assess the impact of the gear on the chambo and other fish stocks through the assessment of the species and size composition of the catches.

**Methods**
A general survey of the size of the kauni fishery will be conducted in the south eastern and south western arms of Lake Malawi by visiting known landing sites in both areas during the morning when the fishermen are returning from the lake. The gear involved in the kauni fishery will be described and gear dimensions recorded. Other information, such as the area fished, will also be recorded.

Two major landing sites for the "kauni" fishery from both the eastern and western arms of the lake will be sampled once a month for one calendar year. At each landing site boats returning to the site will be sampled and crew members will be interviewed to determine the mode of operation of the gear, gear dimensions including net length and mesh size at the bunt for the gear from which catches are to be sampled will be measured.

The total weight of the catch will then be determined by weighing one sample unit (tin or crate) and counting all sample units landed by the fishing crew. A subsample of the catch will be collected and weighed. The sample will then be sorted to species level and the various species groups will be weighed. Each fish in the subsample will be measured for total length (TL). The length-frequency data from the fish caught by "kauni" fishery will be analysed to determine the mean size at which the fish are caught.

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## 2.2. Chilimira fishery selectivity survey.

**Introduction**
In terms of annual yield, the chilimira fishery is the most important on the lake as utaka are mainly caught by the chilimira net and these fish comprise more than half of the fish yield from Lake Malawi. The chilimira net is an open water seine net used in Lake Malawi. It has a conical appearance and is used at night, mainly to catch usipa, while during the day, the gear is used to target utaka (*Copadichromis* spp). Usipa are short-lived, widely distributed fish with a pelagic larval phase. It is unlikely that they are genetically distinct local stocks and so local overfishing is probably not a conservation problem (Turner, 1994). It is often less appreciated that populations or species of utaka have small ranges within the lake (Turner, 1994). Many of the exploited *Copadichromis* spp. have restricted distributions (Konings, 1990) and may be vulnerable to local overfishing. Systematic sampling of the chilimira gear has not been performed and is urgently required in order to determine the state of the fishery (Turner, 1995).

It should therefore be recognised that a greater understanding of the biology and exploitation pattern of the utaka is required. A study of the chilimira fishery of Lake Malawi National Park estimated that utaka make up 44% of the overall catch of the gear (Smith, 1998). There has been an increase in the participation of chilimira gears in Lake Malawi and yet the extent of the utaka stocks (which are mainly caught by this gear) and their biology remains largely unknown. Consequently there is presently no management system to control the exploitation of these fishes.

Little information is available about the catches of this gear and considering that more than 600 nets presently operate in the south-east arm, it is recommended that the catch composition of these catches is closely monitored (Weyl *et al.* 2000). It has been noted that there are numerous variations in the operational procedure and design of the basic chilimira gear. Unfortunately such variation has not been documented, however due to the fact that gear efficiency and target species are likely to change in gear design and operation, such modifications should be documented. During a survey in the Chiweta-Usisya area in Nkhata Bay and Karonga districts, it was noted that there were some variations in the operational mode and design of some of the Chilimila nets with a lighter 2-ply multifilament net imported from Tanzania being widely used (Weyl *et al.* 2000).

**Objectives**

(1) To assess the impact of the gear on the utaka and other stocks through the assessment of the species composition of the catches.

(2) To define the design of chilimira gear used to catch utaka and its operation.

**Methods**

The same team involved in the kauni fishery assessment (viz. Section 1.1) will also be responsible for sampling daytime chilimira catches on a monthly basis for one calendar year. Experimental design will follow that described for the assessment of the Kauni fishery in Section 1.1.

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## 2.3. Gillnet selectivity surveys.

**Introduction**

The gillnet fishery is one of the most important fisheries in Malawi. It has been in existence on Lake Malawi as early as 1940. Gillnets contribute about 35% of the total landings from Lake Malawi and the main species caught in this fishery are chambo (*Oreochromis* spp.), kampango (*Bagrus meridionalis*), bombe (*Bathyclarias* spp.), cyprinids (*Barbus, Labeo* and *Opsaridium* spp.) and utaka (*Copadichromis* spp.). The number of gillnets has increased tremendously over the years and between 1993 and 1999 there was a three-fold increase in the number of gillnets used in Malawis waters (Weyl *et al.* 2000). In contrast, catches have remained stable indicating a decline in CPUE. This decline in CPUE has been countered by a decrease in mesh size and the 1999 Frame Survey revealed that over 95% of all gill nets used in Mangochi were below the legal minimum mesh size (Weyl, 2000). These illegal meshed nets, locally known as Ngongongo, may be a harvesting strategy by local fishers to tap unexploited cichlid resources other than chambo (Weyl 2000). In addition, many traditional fishers have modified the mode of operation of gillnets.

Traditionally, the gillnet is a passive gear that is set in the water column drifting over night and catching fish which try to make their way through them, getting stuck in the meshes in the process (Witte and Van Densen, 1995). In this situation, the catching capability of gillnets is highly dependent on the activity pattern of the fish and on the specific characteristics of the gear such as mesh size, hanging ratios as well as twine type. In turn, the probability of catching fish with passive gear depends on the probability of encounter and the probability of capture and retention (Hamly and Regier, 1975).

However, in many areas of the lake, a number of fishermen have abandoned the passive method of gillnet fishing. Currently, there are two deviates of the passive fishery, namely Chiombera and Chikwekwesa. Chikwekwesa and Chiombera gillnet fisheries are wide spread although these are commonly practised by fishers in Nkhotakota. The existence of Chikwekwesa fishery was noted as early as 1990's. In Lake Malombe it was referred as encircling gill nets (Tweddle and Bowa 1995). Similarly Chiombera gill nets have been in use in Lake Malombe for a long time. Tweddle described the existence of chiombera fishery in Lake Malombe in 1994. "Driving, involves beating the water with sticks to frighten and drive the fish into the nets (Tweddle *et al.* 1994a). This is exactly what is done in the Chiombera fishery. Most of the gill nets used in Chiombera and Chikwekwesa fisheries are legal, with mesh sizes of 3.5 and 3.75 inches (Banda and Sipawe, 2000).

A third modification to the gillnet exists in the combination of the gillnet with a longline. Presently this innovation is only practised in Karonga district (DFO Karonga, personal communication). In this fishery, baited hooks are placed regularly on the footrope of the gill net so that the system functions both as a regular gillnet as well as a long line.

A comparison of catches and CPUE for the passive and the deviate gill nets shows that deviate gill nets have high catches per unit effort as compared to the passive gill nets (Tweddle *et al.*, 1994a). Therefore, there is a need to carefully study the effects of this mode of gear operation in order to make recommendations for effective management and sustainable utilisation of this fish resource.

## Objectives

(1) To carry out an in-depth study of gill net selectivity in passively set gill nets as well as in the Chiombera and Chikwekwesa fisheries.

(2) To assess the catch per unit effort in the traditional passive gillnets to Chiombera and Chikwekwesa gillnets, i.e. the change in catchability coefficient.

(3) To assess the viability of the use of these modified gillnets in the light of sustainable utilisation of the fish resource.

**Methods**
Gillnet catches will be sampled monthly from the SEA and SWA of Lake Malawi and from Nkhotakota district, the two main important gillnet fishing areas on the lake. In addition, experimental gill netting will be carried out in the areas during the sampling period to supplement data sampled from local fishers. A sampling team consisting of two Fisheries Research Scientists and four Technical assistants will be deployed in the field for the first trip. This trip will last for 12 days. One of the Research Officer and half the technical assistants will be involved in sourcing relevant historical information concerning the fishery through interviews to establish the extent and size of the fishery. This same team will be involved in actual fishing (i.e. experimental gillnetting) with the fishermen to establish the exact operation of the gill nets. The other half of the team will be responsible for intensive collection of data on species composition and length-frequency from the normal gillnets as well as any derivatives present. Thereafter monthly sampling will commence (6 days each month) for a period of one year specifically to determine species and selectivity in the gill net fishery.

Catches of normal passive gillnets verses the derivative gillnets by numbers and weight will be compared using a significance level of 5% ($p=0.05$), to test the hypothesis that:
Modified gillnets will catch more fish than normal passive gillnets.
Species selectivity differs between modified gillnets and normal passive gillnets.

## 2.4. Handline catch assessment and gear selectivity.

**Introduction**
Large gears, such as Chilimila nets, nkacha nets, beach seines and gill nets are adequately assessed by access point surveys were the recorder waits at the fishing beach to be landed at the end of the fishing day. This technique is currently used to assess the catch of Lake Malawi's artisenal fishery. While this approach suffices to assess these large gears, other gears such as handline fishing is not adequately assessed. This is evident when one considers that between 1994 and 1998 only 13 handline catches were assessed during the routine artisenal fishery monitoring system. The reasons for this shortfall may result from the subsistence nature of this fishery where fish are not necessarily landed on beaches. However, this fishery may contribute significantly towards the total harvest of fish from the lake and undoubtedly plays a major role in the provision of food security in lakeshore areas. For example, in Lake Chicamba, Mozambique, the contribution of hook and line fishing to the total fishing mortality ranged between 4 and 25%, and contributed more than 11% to the total catch from the fishery (Weyl 1998[1]).

The 1998 frame survey estimated that there were 349 handline fishers in the southeast arm. The distribution of handlines in the six strata comprising the southeast arm is shown in Table 1. However, this is likely to be an underestimation as participation in this fishery

[1] Weyl, O.L.F. 1998.The dynamics of a subtropical lake fishery in central Mozambique. Ph.D. Thesis, Rhodes University, South Africa. 205pp.

is not constrained by high gear costs and many handline fishers do not consider themselves fishermen, especially if they also own other gears (Weyl *pers. obs.*). In January to May 1999, more than 25 handline fishers were observed in stratum 2.1 on a regular basis.

**Table 1.** Number of handlines in each stratum of the southeast arm of Lake Malawi, according to 1998 frame survey.

| Stratum | Handlines |
|---|---|
| 2.1 | 0 |
| 2.2 | 45 |
| 2.3 | 0 |
| 2.4 | 148 |
| 2.5 | 0 |
| 2.6 | 156 |

For this reason it is proposed that an assessment of this fishery be undertaken as soon as possible.

## Objectives

This handline fishery assessment project will aim to:

1. Provide an estimate total fishing effort for the handline fishery in the southeast arm of Lake Malawi.
2. Estimate catch rate and total catch by the handline fishery and incorporate the annual yield from this fishery into annual estimates.
3. Qualify species composition and catch rate for handline fishing.

## Methodology

The assessment of catch and effort in the handline fishery will be performed using a combination of roving creel surveys and activity counts following guidelines set up by Lester *et al.* (1991[2]). According to Lester *et al.* (1991), with expected activities of 10 or more fishing parties per day a minimum of 20 sampling days should be undertaken per year. The sampling area will comprise the southeast arm of Lake Malawi, which will be stratified into 2 strata one covering the east bank (strata 2.2, 2.4 and 2.5) and the west bank (strata 2.1 and 2.3) (Figure 1). For sampling one of the enforcement boats and/or the NARMAP rubber dinghy will be required. On each sampling day the vessel will travel through the selected stratum starting from a randomised direction and all handline fishers will be counted. Of these fishers at least 10 will be interviewed to determine catch composition and catch per unit effort. CPUE will be determined at species level where possible. When species cannot be identified in the field they will be grouped into categories according to genus and a sub-sample will be procured and analysed in the laboratory. The length frequency of easily distinguished species will be determined during the interview. In addition, samples of small cichlids will also be collected for later identification and length measurements. The provisional random sampling dates for this survey are shown in Table 2.

[2] Lester, N.P., Petzold, M.M & Dunlop, W.I. 1991. Sample size determination in roving creel surveys. Am. Fish. Soc. Symposium, 12: 25-39.

**Table 2.** Provisional randomised sampling days for the east bank and west bank strata for the assessment of the handline fishery in the south east arm of Lake Malawi.

| Month | Sampling day East bank (Strata 2.2, 2.4,2.5) | Sampling day West bank (Strata 2.1, 2.3) |
|---|---|---|
| October | 22 | 23 |
| November | 8 | 7 |
| | 23 | 24 |
| December | 1 | 2 |
| January | 16 | 15 |
| February | 8 | 7 |
| | 26 | 25 |
| March | 1 | 2 |
| | 21 | 20 |
| April | 29 | 30 |
| | 13 | 14 |
| Mai | 20 | 21 |
| June | 2 | 3 |
| | 24 | 23 |
| July | 14 | 13 |
| | 26 | 25 |
| August | 16 | 17 |
| | 7 | 6 |
| September | 9 | 10 |
| | 21 | 20 |

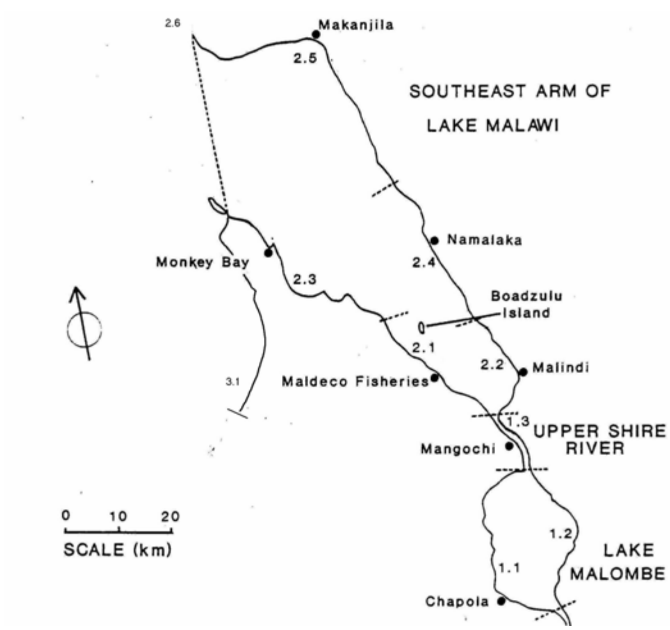


**Figure 1.** Map of the southeast arm of Lake Malawi, showing the strata in which the handline fishery assessment program is to take place.

## 2.5. Traditional gear selectivity surveys (Northern Lake Malawi)

### Introduction

The artisanal fisheries are the most important fisheries sector in Malawi in terms of income, employment, and as a source of food. Approximately 53,000 people are directly engaged in catching fish (Weyl, *et al.*, 2000b), and fish accounts for about 70% of the total dietary animal protein in the country (Bulirani *et al.*, 1999). The artisanal fisheries in Malawi are open access and catch a wide diversity of fishes. They account for more than 90% of the total annual landings (~ 40,000 tonnes) from Lake Malawi while the commercial fishery contribution to the total annual catches from Lake Malawi is around 7% (Bulirani *et al.*, 1999).

Many different gears are employed in the artisanal fishery and the main gear types are beach seines (= chambo and kambuzi seines and mosquito nets), chilimira, fish traps, gillnets, handlines and longlines (Weyl, *et al.*, 2000b). Full descriptions of the gear types are given in Weyl *et al.* (2000b; 2000c). The traditional fisheries are most extensive in the southern part of the lake, namely Salima and Mangochi districts. There has been an increase of about 32% in the total fishing fleet in the last 10 years, while small-mesh sized gears such as chilimira and nkacha have increased by more than 50% between 1990 and 1997 in the southern part of Lake Malawi. Dugout canoes and plankboats, with or without outboard engines, are the main fishing vessels (Weyl, *et al.*, 2000b), while the exploited species are principally chambo, utaka, kampango, bombe and usipa (Bulirani *et al.*, 1999). Fisheries statistics for the area show that the number of fishers has increased steadily (Weyl, *et al.*, 2000b), whereas the total catch has declined (Bulirani *et al.*, 1999). Most indicators point to a combination of growth, recruitment and ecological over fishing as a result of the use of destructive fishing practices such as small mesh nets and excessive increases in effort (Bulirani *et al.*, 1999).

Despite the importance of the artisanal fishery as the main source of fish, little information is available in this sector. In view of the general decline in the catches, as has been experienced recently due to intense fishing pressure, it is necessary to introduce a monitoring programme, which could look at the changes taking place in fish size distribution and species composition both temporally and spatially.

While the southern part of Lake Malawi has received relatively greater attention with regard to traditional fisheries surveys (e.g. FAO, 1976), correspondingly few surveys have been conducted in the central or northern parts of the lake (e.g. Jackson *et al.*, 1963; Tweddle *et al.*, 1995; Weyl *et al.*, 2000a). In order to get a full picture on the status of the traditional fisheries in these parts three districts, i.e. Nkhotakota, Nkhata Bay and Karonga, have been targeted for the traditional gear selectivity sampling programme.

According to the 1999 frame survey (Weyl *et al.*, 2000b) the number of fishers, i.e. gear owners plus crew members, in the target districts were: Nkhotakota – 7,178, Nkhata Bay – 7490, and Karonga – 4,471; these three districts thus account for about 48% of the recorded fishers operating on Lake Malawi. The total counts of the main fishing gear types in the districts are given in Table 1. Nkhotakota recorded the greatest number of beach seines, gillnets and handlines, while Nkhata Bay led in the number of chilimira nets and longlines , and Karonga in fish traps.

**Table 1.** 1999 Frame Survey total counts of main fishing gear types in target districts[a].

| Gear type | District | | |
|---|---|---|---|
| | Nkhotakota | Nkhata Bay | Karonga |
| Beach seines | 278[b] | 39[c] | 109[c] |
| Chilimira | 369 | 726 | 446 |
| Fish traps | 107 | 2 | 140 |
| Gillnets | 9206 | 4600 | 4458 |
| Handlines | 896 | 848 | 267 |
| Longlines | 317 | 321 | 127 |

[a]Adapted from Weyl *et al.* (2000b)
[b]Kambuzi and Mosquito seines only
[c]Chambo, Kambuzi and Mosquito seines

## Objective and Implementation

(1) To determine species selectivity and size selectivity of the main artisanal gears in areas other than the southeast and south-west arms of Lake Malawi.

## Methods

The programme will be conducted twice (2x) a year, and each sampling period will be about 25 days, covering most of Lake Malawi's coastline in Nkhotakota, Nkhata Bay and Karonga districts. The selected minor strata and stratum descriptions in the target districts are presented in Table 2, while the relative occurrences of the main fishing gear types among the minor strata are shown in Table 3. The selection of any particular minor stratum was based on having the greatest possible range of the main gear types, as well as, in some cases, having the largest proportion of any particular gear type within a major stratum.

During each survey, four significant landing sites will be sampled in each stratum and at each landing site six fishing gear types: beach seines, chilimira, fish traps, gillnets, handlines and longlines (Tables 1 & 3) will be sampled per day. On a sampling site, an average of 4 catches will be from beach seines, 8 from chilimira, 2 from fish traps, 10 from gillnets, 3 from handlines and 4 from longlines. All catches from each gear will be identified to species level, and total weight of each species category recorded. Total length of individual fish for each species will also be measured.

A team of four persons: two Fisheries Research Scientists and two Technical Assistants will be deployed in the field to collect the data during each trip. This will ensure that the sampling area, which is vast, will be sampled efficiently in a specified period.

**Table 2.** Selected minor strata and stratum descriptions in target districts. (Data source: Weyl *et al.* 2000b)

| District | Minor stratum | Stratum description |
|---|---|---|
| Nkhotakota | 5.4 | Nkhotakota Central North |
| Nkhata Bay | 6.1 | Tukombo |
| " | 6.6 | Usisya |
| Karonga | 7.3 | Chilumba |
| " | 7.7 | Kaporo |

**Table 3.** Relative occurrence, by percentage, of fishing gear types among minor strata in target districts. (Data source: Weyl *et al.* 2000b)

| | | Gear type | | | | | |
|---|---|---|---|---|---|---|---|
| District | Minor stratum | Beach seines | Chilimira | Fish traps | Gillnets | Handlines | Longlines |
| | | (%) | (%) | (%) | (%) | (%) | (%) |
| Nkhotakota | 5.4 | 26 | 25 | 46 | 47 | 68 | 23 |
| Nkhata Bay | 6.1 | 28 | 12 | 0 | 22 | 7 | 9 |
| " | 6.6 | 8 | 12 | 100 | 16 | 2 | 6 |
| Karonga | 7.3 | 25 | 17 | 0 | 9 | 73 | 92 |
| " | 7.7 | 9 | 11 | 32 | 10 | 6 | 1 |

## 2.6. A preliminary study of the effectiveness of monofilament gillnets in Lake Malawi.

### Introduction

Gill net fishing in Lake Malawi dates back to the early 1940`s. The number of gill nets and gill net fishers was very small then. However, the number of gill nets has increased tremendously over the years. In 1997, there were over 37 987 sets of gill nets in operation in the lake (Frame Survey, 1997). Even though the number of gill nets has grown to this magnitude over the years, not a single one of these is a monofilament gill net. It is also apparent that the catches in the commonly used multifilament gill nets are decreasing so much so that gill net fishing may become uneconomical (FRU gill net selectivity survey, unpublished).

A lot of work has been done elsewhere to compare the effectiveness and the catchabilities of monofilament vs. multifilament gill nets. From all the work done so far, monofilament gill nets are shown to be more effective than multifilament gill nets. Collins (1979) found that the catching power for white fish was increased two-fold with the introduction of monofilament gill nets during the early 1970s. Monofilament gill nets were also shown by experimental net comparisons to be more efficient for pacific salmon *Oncorhynchus* spp. (Larkin 1963, 1964; Washington 1973).

Since monofilament gill nets are shown to give higher catch per unit effort, these nets can be used to replace the common and traditional multifilament gill nets in Lake Malawi. However, it is important that before monofilament gill nets are introduced to the local fishers that preliminary experimental work be done to establish the effects of such an introduction on the fish stocks. This is to be achieved through comparisons of catch compositions between the mono- and the multifilament gill nets. It is also imperative to establish the catchability coefficients of the monofilament verses the multifilament gill nets and to determine the effect of such an introduction on the fish stocks of Lake Malawi. The results from this project will aid in the formulation of advice on the use of multifilament nets on Lake Malawi.

## Objectives.

The aim of this project is to compare the species and size selectivity of monofilament and multifilament gill nets in order to assess the effect of large-scale monofilament net use on Malawi's stocks. The main objectives are:

1. To assess catch per unit effort in multifilament to monofilament gill nets. i.e. differences in catchability coefficient.
2. To assess the feasibility of the use monofilament gillnets in the light of sustainable utilisation of the fish resource.

## Methods

For the experiment, five monofilament nets and five multifilament nets will be required. Each net will be 100 metres long 40 meshes deep and 3.5 inches mesh size. There will be five experimental units. Each experimental unit will consist of two 25-metre panels of monofilament net and two 25-metre panels of multifilament net. In each experimental unit these four 25 metre panels will be joined in a way that a monofilament portion will alternate with a multifilament portion. Cork floats will be placed one metre apart along the headrope and locally made clay weights will also be placed at intervals of one metre along the footrope. Buoys will be placed at each end of the net on the headrope and an anchor will be placed on both ends of the footrope for proper hanging of the nets.

The experiment will be conducted for three months, 10 days per month. All the five experimental units will be set within the vicinity of Monkey Bay for security purposes, but they will be located far from each other so that each net acts independent of the others. All the units will be set after dusk say at 6.00 p.m. and will be hauled at around 6.00 a.m. the following morning. 150 replicates will be made by the end of the 30 days.

Catches from each fleet and from the monofilament panels and the multifilament panels within each fleet will be sorted into species, counted and weighed. Catches of monofilament verses multifilament portions of the gill nets by numbers and weight will be compared using a significance level of 5% ($p=0.05$), to test the hypotheses that:

1. Monofilament gill nets will catch more fish than multifilament gill nets.
2. Size selectivity differs between nets.
3. Species selectivity differs between nets.

## 2.7. Commercial pair trawl selectivity

### Introduction

There are three trawling techniques used on Lake Malawi, namely semi-pelagic trawling, demersal single-boat trawling and demersal pair trawling units. These techniques exploit haplochromine cichlids. Pair trawlers operate in the shallow water, mainly fishing at depths of less than 50 m in the SEA and SWA of Lake Malawi (Turner *et al.* 1995). It has been stated that an entirely different community of species is exploited by pair trawlers than is exploited by the semi-pelagic and demersal stern trawls (Turner, 1995).

Since the inception of the trawl fisheries in 1968, all pair-trawl units operating on Lake Malawi are required to submit complete daily catch (by species group and by weight) and effort records monthly (Tweddle 1994). Between 1971 and 1974, experimental trawls revealed substantial decreases in populations of larger haplochromine cichlids in the southern part of the lake. On the recommendation of FAO, the minimum legal trawl cod-end mesh size was increased from 25 to 38 mm. Pair trawl catch-per-unit effort declined for one year, but thereafter returned to previous levels (Turner *et al.* 1995).

Under the present licensing system, trawl units are allocated to eight fishing areas in Lake Malawi. Present regulations for the pair trawl fishery include a 25-mm minimum mesh size fat the cod-end; a maximum gear size with a 37 m net mouth width; a maximum engine power of 30 Hp; a minimum shore distance for fishing of one nautical mile and minimum depth for fishing 18 m. Closed hours to fishing are from 6pm to 6am (Bulirani *et al.* 1999). Management regulations have however generally been ignored by this sector (Turner, 1994). It was observed that pair trawlers routinely fish within one nautical mile from the shore; mesh sizes have been reduced from the legal minimum size to around 20 mm; nets are double bagged and pulls last 8 hours or more resulting in clogging of meshes (Turner, 1994). High yields have therefore been maintained only by the adoption of progressively more ecologically damaging fishing practices (Turner, 1994).

At present there is no monitoring system established by the Fisheries Department for the pair trawl fishery. Due to the fact that this fishery operates in shallow water where the small scale fishery also operates, it is imperative that research is undertaken to assess fishing effects on the shallow water haplochromine species and determine possible conflict areas with the small-scale fishery.

### Objectives

(1) To assess the species and size composition of the catches of the pair trawl fishery in order to assess the impact of the gear on the fish species.

(2) To establish the collection of data for the pair trawl fishery on a regular basis.

(3) Compare catches of the small-scale fishery with the pair trawl fishery.

**Methods**

The study will be done in Malembo (SWA) and Namiasi (SEA) which are the two popular landing sites for pair trawlers. Sampling will occur for three days each month for a year involving two teams at selected sites in the SEA and SWA of Lake Malawi.

The total weight of the catch will then be determined by weighing one sample unit (crate) and counting all sample units landed by the fishing crew. A subsample of the catch will be collected and weighed. The sample will then be sorted to species level and the various species groups will be weighed. Each fish in the subsample will be measured for total length (TL). The length-frequency data from the fish caught by "kauni" fishery will be analysed in to determine the mean size at which the fish are caught. Specimens of species that form an important part of the catches will be collected for further biological work.

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## 2.8. Trawl net selectivity survey

**Introduction**

The southern end of Lake Malawi has gentle and smooth lakebed that provides extensive demersal trawling areas (Tweddle and Makwinja, 1994). Commercial trawling on Lake Malawi was introduced in 1968 after successful trials of experimental trawling in 1965. Since its introduction, the trawl fishery in this area has expanded rapidly. An initial report on the status of the fishery (Tarbit, 1972) was followed by detailed investigations into the changes taking place as this fishery developed (FAO, 1976, Turner, 1977 a, b; Tweddle and Turner, 1977). The outcome of these investigations were recommendations that restricted the number of licences issued in different geographical areas of the southeast arm of the southern part of the lake.

However, the need to put in place a monitoring system to check the status of the stocks in the area became apparent and the Malawi Government Department of Fisheries in collaboration with the Food and Agriculture Organisation of the United Nations (FAO) carried out experimental trawling from 1971 to 1974. These surveys revealed that there was a substantial decrease in the population of large Haplochromine cichlids in the southern portions of the lake (FAO, 1976). The recommendation from the FAO report was that the minimum legal mesh size for the trawl cod-end be increased from 25 mm to 38mm (Turner *et al.*, 1992). Despite the use of this 38mm cod-end, there was little or no improvement at all in the fishery since experimental trawl surveys conducted from 1989 to 1991 showed that this management measure was not successful (Turner *et al.* 1992). It was discovered that species such as *Lethrinops mylodon* and *Lethrinops macrocanathus* became locally extinct. Turner *et al.* (1992) recommended that no further expansion of the trawl fishery be permitted in the deeper waters north of Boadzulu Island in the southeast arm of Lake Malawi until a study on the feasibility of establishing a refuge for the trawl fishery in that area was done.

However, the activity of large-scale commercial trawlers has been limited to the area immediately north of Boadzulu Island, and little or no activity was observed further north in the South East arm (Banda *et al.* 1996). For this reason, a survey of the area was undertaken using the new research vessel, *R.V. Ndunduma,* to assess the validity of the FAO recommendations (Banda *et al.* 1996). The results of the survey undertaken using *R.V. Ndunduma* showed that exploitation levels over the area as a whole were not be as severe as those implied by the FAO (1993). Biomass figures from the *Ndunduma* survey showed stocks of nearly 5000 tonnes for the areas of B and C in excess of 50 m depth (Banda *et al.* 1996). Banda *et al.* (1996) also pointed out that fishing effort overall was not excessive and that if the heavily fished areas close to Boadzulu Island were rested, stocks could recover and an overall improvement in CPUE and profitability.

Since 1991, the trawl fishery has undergone tremendous increase despite the recommendation against such an expansion. The area is currently exploited by a number of powerful and more efficient stern trawlers that include *M.V. Kandwindwi* (380Hp), *R.V. Ndunduma* (380Hp) and *M.V. Chenga* (190Hp). *R.V. Ndunduma* is a research vessel of the Department of Fisheries that also fishes commercially while the *M.V. Kandwindwi* belongs to Maldeco Fishieries. *M.V. Chenga* is a Vessel belonging to a private individual. The fourth, *M.V. Kampango* (190Hp) has recently been acquired by Maldeco and will start operations shortly. The old fishing fleet's engine power ranged from 90 to 180 horsepowers.
All these trawlers are currently using the 38mm mesh size codend. A preliminary selectivity study on the 38mm cod end conducted in 1999 showed that this mesh is destructive to the dermesal stocks since the rate of clogging in the 38mm cod end is very high as such it does not allow the juveniles to escape (Kanyerere, 1999).

According to Maclennan (1992) a good fishing gear should select the older fish from the population that is being exploited. This means that the capture efficiency of the gear which is usually the proportion of fish encountering the gear that are retained in the catch, should change with age and size of the fish (Maclennan, 1992). It is important to determine the length of the fish at first capture because this will help prescribing the minimum mesh size of the netting. The length at first capture if correctly determined ensures that the yield from the stocks is optimised (Armstrong *et al.*, 1990). In view of this, there is a need to carry out more studies on the selectivity of the 38 mm code-end since only one study has been carried out (Kanyerere, 1999). Surely, the use of a single mesh size for the fishery as a whole is a compromise in this multi-species fishery where some species have little chance of escape through the cod end while others have little chance of being retained.

## Objectives

(1) To determine the impact and feasibility of 38, 50, and the 100 mm cod-end mesh size restrictions on the demersal stocks.

(2) To determine the selectivities of these three mesh sizes on the major target species in the trawl fishery.

(3) To make specific recommendations on the most appropriate mesh sizes for the commercial trawl fishery.

(4) To quantify the effect of clogging on the selectivities of the 38, 50, and 100mm cod ends.

**Methods**

The R.V. Ndunduma, a 17 metre stern trawler with 380 hp engine and a maximum cruising speed of 10 knots will be used in this study. All trawls will be conducted at 3.5 knots pulling the Gulloppur bottom trawl net.

Trawl net selectivity will be determined by the covered cod end method where the cod end of the net to be assessed is covered with a larger and fine net with a stretch mesh size of 6.35mm.

Three different cod ends of 38mm, 50mm, and 100mm mesh sizes will be used in this study.

Experiment will be carried out in three depth strata, 0-50, 51-100, and <101 metres in the southeast arm of Lake Malawi. Two to four trawls will be done in each depth strata using each cod end mesh size. Trawl duration will range from 15 minutes to 60 minutes so that the degree of clogging in relation to trawling time should be investigated.

The total weight of the catch in the cod end and in the cover will be determined after each trawl. A sample of not less than 10% of the catch will be taken and all fish will be identified to species level and all fish will be measured for TL.

The proportion of fish in each 1 cm size class retained by a cod end will be calculated for each species. The probability of capture will be calculated from a plot of the estimated proportions retained against corresponding class midpoints (Sparre *et al.*, 1992). The S-shaped ogive which completely describes the selectivity of the trawl net or part thereof (Mac Lennan, 1992) will be used for the analysis of selectivity data.

# CHAPTER 3: SMALL LAKES STOCK ASSESSMENTS

## 3.1. Aquatic ecology and fisheries of Lake Chikukutu in Nkhotakota

**Introduction:**

Lake Chikukutu is a man made lake in Nkhotakota District. It lies to the west of Nkhotakota Boma, approximately 8-10 km from the Boma along the Nkhotakota-Ntchisi road. It is a small long and narrow lake, approximately 5km long and its width ranges between 0.4 to 1km. The Chamba and the Hoo are the main inflowing rivers while the Kaombe River is the main outlet that drains directly into Lake Malawi. In the early

1970's the lake was a small dam that was built for the irrigation of rice along the Kaombe River.

The potential of Lake Chikukutu fisheries are not known at the moment as no quantitative work has been undertaken. It has been suggested that some fishers migrate to the lake during the closed season for the Chia and Lake Malawi (Banda and Sipawe, 2000). Fisheries research in recent years has primarily focused on Lake Malawi, while small lakes and lagoons have been neglected. The fisheries in these small water bodies is typically artisanal and open access by nature as well as being harvested by multiple gears.

During May 2000, the FRU conducted a rapid appraisal study of the fisheries of the lake. The fisheries were found to be subsistence to small-scale commercial with the main gears being gill nets, beach seines, hand lines, fish traps, and scoop nets. Ten species categories were identified from the samples collected from the lake, of which cichlids constituted 56% of the catch, while cyprinids and clariids contributed 31% and 13% respectively (Banda and Sipawe, 2000). All the species caught during the study are in-shore demersal species that occur in shallow waters of Lake Malawi (Tomasson and Banda, 1998) and most of which are common in other small water bodies in the country (Tweddle, 1983). There is no other information on the ichthyofauna and the artisanal fisheries of Lake Chikukutu.

## Objectives

(1) To establish baseline data on the limnology, aquatic vegetation, fish species composition and abundance and gear utilisation in the lake.

(2) To determine spatial and temporal variability of physical and chemical factors affecting primary production and to determine spatial and temporal variability in primary production.

(3) To determine the abundance, distribution and species composition of macrophytes in the lake.

(4) To determine the species composition distribution and abundance of fish in the lake.

(5) To determine the fishing effort on the lake and to qualify and quantify the fishing gears used on the Lake.

(6) For the main target species, to determine those biological parameters that are pertinent for the management of the fishery.

## Methods

Two teams each consisting of a Fisheries Research Scientist and two Technical Assistants will be involved in this programme. One team will be involved in collection of all fishery related information while the other team will be responsible for studying limnology and aquatic vegetation of the lake.

Since changes in nutrient and phytoplankton dynamics are very rapid, it would have been necessary to sample more frequently, e.g. weekly. But due to logistical and financial constraints, sampling will be done on 10 consecutive days during the first trip. The other trips will take 5 days each month and data collection will continue for one year.

***Fish biology and Stock assessment***

Samples will be collected from local fishermen mainly from beach seines, fish traps, hand lines and scoop nets. Experimental gill netting will also be carried out.

All experimental gill net fleets will be composed of six randomly distributed panels of six-ply multifilament gill netting of stretched mesh sizes of 25,50,70,90,110 and 130mm and hung at a 60% ratio. The gill nets will be set both overnight and during the day at randomly selected sites in the lake.

Each species will be weighed and length of individual fish measured. The fish will then be dissected and sexed, the gonads removed weighed and categorised according to developmental stages. Sagittal otoliths will be removed and stored dry in manila envelopes for subsequent sectioning and age determination in the lab at FRU.

To determine effort, all gears on the lake will be counted during the first visit to the lake. Another gear count will be undertaken after one year. Catch surveys will be conducted during field visits and use the methodology as that employed by gears selectivity studies and the national catch assessment surveys.

***Limnology***

The limnology of the lake will be assessed according to the procedures outlined in Chapter 8.

***Aquatic macrophytes***

The distribution of the different macrophytes in the lake will be assessed from a dinghy. Specimens of the different species of macrophytes will be collected from randomly distributed quadrants that will be made in various areas of the lake. All macrophytes within a quadrant will be cut of or dug up using a knife, grass clippers and trowel for identification.

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## 3.2. Lake Malombe and Lake Chiuta assessment programmes

### Introduction

Fisheries research in recent years has focused primarily on Lake Malawi (29,604 km$^2$), while the smaller lakes, such as Malombe (323 km$^2$), Chilwa (2,037 km$^2$) and Chiuta (max. area = 304 km$^2$) (Ojda 1994), have received little attention. There is no doubt that lakes Malombe, Chilwa and Chiuta contribute significantly towards the wealth, well-being and food security of the communities living within their vicinity (Alimoso *et al.* 1990; Bulirani *et al.*, 1999; FAO, 1993; Pálsson *et al.*, 1999; Seisay *et al.*, 1992; Tweddle *et al.*, 1995; Van Zalinge *et al.*, 1991; Weyl *et al.*, 2000a, Ojda, 1994; Tweddle, 1983). The fish resources in these lakes are typically harvested with multiple gears (Weyl, *et al.*, 2000a). 1998 estimates indicate that the total annual multi-species catch from these three lakes is about 13,000 tonnes (Bulirani *et al.*, 1999). This accounted for just over 26% of Malawi's 1996 total fish production of 49,393 tonnes (Bulirani *et al.*, 1999). The formulation of a management procedure that takes the dynamics nature of these fisheries into account is, therefore, of vital importance for the sustainable management of these resources.

Given budgetary constraints within the Department of Fisheries, management advice must be based on the best possible scientific information that can be obtained within the given constraints of time and budget. It has therefore been decided that management advice be obtained by through the following protocol.

The first priority will be to determine the target species and selectivity of each harvesting gear. The biological parameters pertinent for the application of analytical models will be investigated for each of the target species. Growth and maturity parameters in freshwater fishes are locality specific and the determination of these parameters forms the basis for management in each particular water body. Since the harvesting of a fish stock after the attainment of 50%-maturity reduces the risk of spawning failure, the determination of the size-at-50% maturity will be the first priority. By comparing the size-at-selectivity of each species harvested in each fishery to the age-at-maturity, the sustainability of each gear can be assessed. The subsequent determination of age and growth, using sectioned otoliths, will allow for an increase in resolution of management advice. The determination of fish length-at-age allows for the determination of mortality rates, which together with growth parameters can be used to apply both single species and multi-species per-recruit models in the management of these fisheries.

## Objectives

(1) Formulate management strategies for Lakes Malombe and Chiuta based on a full understanding of the biology of the fish stocks and harvesting fisheries.

## Methods

The methodology for the assessment of Lake Malombe and Chiuta follows the steps in the protocol outlined. However, due to differences in accessibility, the two lakes will be sampled using different strategies. Lake Chiuta will be sampled for 14 consecutive days in three-month intervals while Lake Malombe will be sampled on consecutive 4 days per month.

A bipartite approach will be taken towards the sampling; one team will collect biological data, and the other team will collect data on the fisheries. The biological team will employ an experimental gillnet fleet, seine and fry seine nets to determine species composition, population structure and habitat preferences of the target species. This team will also determine size at maturity as well as spawning periodicity, and age and growth of the target species. The fisheries team will interview fishermen to determine catch rate species selectivity and size selectivity of the target species.

***Experimental gill nets***
All experimental gill-net fleets will be composed of six randomly distributed panels of 6 ply multifilament gill netting with manufacturer quoted stretched mesh sizes of 25, 50, 70, 90, 110 and 130 mm, hung at a 60% ratio. All gill nets will be set both overnight and during the day at a number of randomly selected sampling sites, representative of the main ecological zones of the lake. To determine size composition, catch rate selectivity and population structure, each species component in the gill net catch will be weighed to the nearest gram and each fish measured to the nearest millimetre standard length (SL) and total length (TL).

***Experimental fry seine nets***
Fry seines will be constructed of a 1m deep x 2m long panel of mosquito netting with a mesh size of 1mm. Hauls will be performed in varying marginal areas of the lakes. All fish sampled will be identified and measured for standard length (SL) and total length (TL).

***Biological samples***
Fish samples for biological analysis will be collected from experimental gear or procured from fishermen. These samples will comprise at least 30 mature individuals of each species. Biological assessments will be conducted using the standard procedures listed in Chapter 5.

***Questionnaire surveys***
To ascertain gear use, utilisation patterns, some resource awareness among the fishers, questionnaire surveys, are to be conducted.

***Creel surveys***
Landing site creel surveys, used to obtain catch composition, length frequency, catch per unit effort and total effort data for the subsistence fishery, will be conducted at three major landing sites in each lake. At least five fishermen, per gear type, returning to a landing site on the sampling day are to be interviewed and the gear type, effort and the total weight of each species component in each catch is to be recorded. A sample of not less than 10% of each species component in each catch will be measured to the nearest millimetre TL. Total effort in the fishery will be estimated by the annual frame survey.

# CHAPTER 4: SOCIAL AND ECONOMIC SURVEYS

## 4.1. The economics of processing and distribution of small scale fishing in Lake Malawi- an analysis of profitability.

**Introduction**

There is little information on the marketing structure at village level. Such knowledge is vital for the understanding of the fishery.

**Objective**

To identify the profitability structure of the small-scale fishing sector defined as the aggregated return on capital and labour through the entire process from catch to value adding measures and distribution to the consumer.

***Method:***

The analysis will be empirical within a framework of a basic theoretical model. The purpose of the model is to give some structure to the empirical material and it is kept very simple in order not to make too many assumptions that could restrict the conclusions. The strength of all conclusions will be subject to sensitivity analysis. The model will assume a basic Cobb-Douglas production function with diminishing returns to capital and labour and will include a variable indicating the significance of market imperfections.

It is hypothesised that the economy could consist of $n$ markets, separated by transaction costs. There is one 'inland market' and $n-1$ 'shore markets'. The 'inland market' is characterised by having a large share of the aggregated demand, but no intrinsic suppliers. The market is supplied from the 'shore markets' at the production cost plus a transport cost. This would yield a situation with a high elasticity of demand and a competitive market situation as all 'shore markets' can supply at the same cost. The 'shore markets' are small having a limited demand and hence a lower demand elasticity. The situation is reinforced by a limit to the number of suppliers restricting competition. The producers can supply their local market at production cost, whereas the inland market and the other shore markets can be supplied only with an additional transport cost. This creates a natural oligopoly on the shore markets, predicting a local price, depending on strategic behaviour and other local conditions.

Since there can be only one monopoly profit (supply equalling marginal revenue rather than demand) through the entire vertical processing, the specific pricing policies would determine the distribution of any supernormal returns.

**The empirical approach:**

There will be an emphasis on primary source research through field studies following the product from the fishermen (primary producers) through processing and distribution to the end consumer. This study will be followed up by interviews with market participants.

All results will be compared to existing and relevant research and be subject to an extensive sensitivity analysis. In accordance to the theoretical model two ‘shore markets’, Chembe village and Masaka village, as well as the inland market (Blantyre or Lilongwe) will be included in the study.

## Field research:

The study will follow the production and value adding process from fishing boats to the final consumer. Several studies will be undertaken in order to cover a variety of different fishing situations such as different gears, the scale and classification of the catch and external factors such as the weather conditions and moon phase.

The next phase will be the division of the catch between the capital owners and the boat crew. There will be a test of the assumption of divided markets i.e. a share market going to the beach and in the home village of the fishermen and a second inland market involving transaction costs and the need of preservative measures for the fish. The local market can be studied by following the fishermen and observing the fish markets, the quantities, prices and the relative share of the crew members’ part of the catch *vs.* the gear owners.

An analysis of the inland market will include preservative measures such as drying of the fish. Further studies will include transport, intermediaries, transaction costs and location of demand. This study will likely take place in the Blantyre region, as this is the inland region with a population cluster.

## Interviews:

Each target group will require a separate questionnaire. The questionnaires will be kept as short and concise as possible. The target groups will be the market participants, capital owners, fishing boat crew, transactors and consumers. In total the survey would cover more than 200 interviews.

**Capital owners:** As many as possible, up to 20 in Chembe and Msaka Villages. Questions will be centred mainly on rates of return, opportunity costs, the structure and liquidity of the capital market and the existence or extent of vertical integration in the processing.

**Fishing boat crew:** 30 each in Chembe and Masaka village. The topics would be focussed on their share of the catch, labour market integrity, opportunity costs and the return on effort i.e. skill and time.

**Transactors:** As many as possible up to 20 each in each sector i.e. fish dryers, transporters and intermediary salesmen as well as 20 intermediary salesmen at the end of distribution, presumably Balantyre. Questions would regard rates of return and opportunity costs as well as capital requirements.

**Consumers:** 30 each in Chembe, Masaka village and the Blantyre region. Questions would focus on elasticity of demand, final prices and consumer loyalty.

**Sub-studies**

A sub-study would be required to find common denominators and conversion rates for pricing of fish. Weight and volume of a specific catch alter during the processing and different measurements are used in the transactions. For example: Utaka are sold in 5l buckets by the fishermen, the dried fish is traded in 4l tins and the final product is sold per unit.

**Assistance:**

1. Translator. There is possible local candidate, Mr Patrick M. Phiri whom has a good command of English as well as recommendations from Scuba Shack where he is currently working and he has also assisted in a demographic survey in 1998.
2. Weighing and measuring equipment.
3. Fish and gear identification.
4. Computer and photocopying facilities for questionnaire design, analysis and outputs.

# CHAPTER 5: BIOLOGICAL SURVEYS

## 5.1. Biological management parameters for target species in Lake Malawi

### Introduction

All of the fisheries on Lake Malawi catch a large number of species with different life history characteristics (Turner *et al.* 1995). The majority of the species caught are haplochromine cichlids that are endemic to Lake Malawi. All species of haplochromine cichlids are maternal mouth brooders and many of these cichlids have low fecundities and have restricted distributions within the lake (Turner, 1994). Consequently they may be particularly vulnerable to localised overfishing. Due to the fact that most species have similar economic values, populations of more vulnerable species may decline long before fishing becomes uneconomical (Turner, 1994).

In the artisanal fishery, it has been observed that in areas of high productivity such as the south-east arm of Lake Malawi, there is an increase in the use of small meshed seines; from 13 mm down to mosquito netting (Turner, 1994). Studies on trawling grounds in the south of the lake have shown that fishing has had considerable effects on the populations of many cichlid species (Turner *et al.* 1995). Trawl surveys in this area revealed the elimination or serious decline of large haplochromine cichlid species (Turner, 1995).

Lake Malawi trawl fisheries exploit over 100 species, with a wide range of sizes and presumably ages at maturity (Turner, 1994). For most of the species, including the important commercial ones, little is known of their biology. There have been few published studies of growth and mortality rates in Lake Malawi cichlids (Turner, 1995). Current management of the fishes of this lake depends on the analysis of available catch and effort data and also with some experimental fishing to give an indication of the biomass and condition of the stock (Bulirani *et al.* 1999). However, management based entirely on biomass indices is unsatisfactory as the proper assessment and management of a fishery requires an understanding of the biology, life history and distribution of the target species (King 1995). This has led to a worldwide trend for fisheries management advice to be based on more quantitative methodologies.

### Objectives

**(1)** To determine those biological and population dynamic parameters which are pertinent for the application of analytical fisheries models used for the determination of management recommendations.

## Methods

The basic biological parameters that will be determined are age and growth, diet, fecundity, size at maturity and mortality estimates.

Important commercial species will be collected regularly during demersal and pelagic surveys on the Ndunduma, during experimental gill netting and procured from artisanal fishermen (using chilimira nets). The importance of the species will be determined by their percentage in the catches. To date, *Alticorpus mentale, A. geoffreyii, Buccochromis lepturus, B. nototanea, Diplotaxodon limnothrissa, Copadichromis virginalis, Lethrinops gossei, Otopharynx speciosus, Maravichromis anaphyrmus* and *Trematocranus placodon* have been selected. However, this list is by no means exhaustive and additional species will be added when necessary. Specimens will be collected on a monthly basis for a one-year period. Data on the length frequency for each of the fish species will be collected from the fishing surveys on the Ndunduma and gill net trials. For the collection of the fish specimens, care will be taken to insure that for each species there will be a good representation of both sexes. Once the specimens are collected they will be taken to the lab and stored in the freezer for further biological work.

Each specimen will be weighed to the nearest 0.1g, measured to the nearest mm total length (TL) and standard length (SL), sexed and gonads will be removed and weighed (g). The stage for gonadal development will be assessed. For mature female specimens in the ripe condition, the eggs in the ovaries will be preserved in ethyl alcohol (75%) for fecundity studies. Stomachs of the specimens will also be dissected and they will be preserved in 10% formalin. For each species at least 50 specimens will have their sagittal otoliths removed and stored in dry envelopes for later age determination studies.

For each of the species used for biological studies, reference collections will be made (at least 5 specimens of each species). The fish will be fixed in 10% formalin that will later be washed out after which the specimens will be preserved in ethyl alcohol (75%).

***Reproductive activity***

Temporal patterns in reproductive activity will be assessed on a monthly basis using gonadosomatic index (GSI) and development stages of the gonads.

$$GSI = [\text{Gonad mass (g)} / \text{Eviscerated mass (g)}] \times 100$$

***Size at maturity:***

The mean length at sexual maturity will be determined from a large sample of the species that will be collected during the peak reproductive season. The proportion of sexually mature individuals ($\Psi$) by length (L) will be fitted to a logistic curve.

$$\Psi = 1/\left(1+ e^{-(L - Lm_{50})/\delta}\right)$$

where

$Lm_{50}$ = The mean length-at-50% sexual maturity.

$\delta$ = The width of the logistic ogive.

***Fecundity:***
The number of eggs from mature female specimens will be counted. Comparisons of egg production against length will be made.

***Diet:***
Stomach contents will be examined using a binocular microscope and individual items will be counted and weighed (to the nearest 0.05g).

The stomach contents will be assessed using the index of relative importance (IRI)

$$IRI = (\%N + \%M) \times \%F$$ (Hyslop, 1980)

where:

- %N = The number of individuals in each food category (expressed as a percentage of the total individuals in all food categories).
- %M = The mass of all individuals in each food category (expressed as a percentage of the total mass of all food categories).
- %F = The frequency of occurrence of a particular dietary item (i.e. the number of stomachs containing a certain food item expressed as a % of all stomachs in the sample).

***Age and growth***:
The sagittal otoliths will be burnt (using an ethanol flame of low intensity) until the otolith turns light brown. The otoliths will then be mounted in clear polyester casting resin and will then be sectioned transversely through the nucleus) using a double-bladed diamond edged saw. The sectioned pieces will then be mounted on slides with DPX mountant for the reading of opaque zones (using a dissecting microscope).

The von-Bertalanffy growth model will describe length at age

$$l_a = L_\infty [1-e^{-K(a-a_o)}]$$

where:

- $L_\infty$ = the predicted asymptotic length (referred to as the 'final' or 'maximum' size)

- K = a measure of the rate at which the growth curve approaches the asymptote (the Brody growth co-efficient)

- $a_o$ = a time scaler equivalent to the hypthothetical starting time at which the fish would have been zero-sized if they had always grown according to the above expression.

***Estimation of mortality rates:***

Total mortality rate (Z) will be estimated using catch curve analysis. The catch curve analysis will be applied to length frequency distributions which will be converted to age frequency distributions by means of a normalised age-length key (Butterworth *et al.* 1989).

Natural mortality rate (M) will be estimated by the use of different methods.

1. Pauly's 1980 empirical equation:

$$\ln M = -0.0152 - 0.279 \ln L_\infty + 0.0543 \ln K + 0.463 \ln T$$

where:
$L_\infty$ and K are von Bertalanffy growth parameters and T is the mean annual water surface temperature ($^oC$).

2. The Rikhter and Efanov (1977) equation:

$$M = \frac{1.521}{a_m^{0.72}} - 0.155$$

where:
$a_m$ is the age-at-50% maturity

3. The Gunderson and Dygert (1988) equation:

$$M = 0.03 + 1.68 \times GSI$$

where:

GSI (gonadosomatic index) of ripe female fish is used.

Therefore fishing mortality (F) will be estimated as

$$F = Z - M.$$

Where Z and M are total and natural mortality respectively.

# CHAPTER 6: ROUTINE MONITORING SURVEYS

## 6.1. Monitoring of catch and effort in artisenal fisheries

### Introduction

According to 1999 frame survey data (Weyl *et al.* 2000), 15 000 gear owners and over 35 000 fishing assistants rely on the fish resources for food security and income. The monitoring of the small-scale fisheries is, therefore, of great importance to the fishing community. The data from such monitoring programmes are vital for the assessment of the fishery and the development of management advice for the sustainable utilisation of the fishery. To date estimates of catch and effort for Malawi's fisheries form the basis of management recommendations (Bulirani *et al.* 1999). For this reason, the assessment and improvement of the current fisheries monitoring programme is a high-priority activity of the Department of Fisheries (DoF). Two surveys form the basis of artisanal fisheries monitoring these are Catch assessments and the frame surveys.

***Catch assessments***

Catch statistics have been collected for Malawi's fisheries since the early 1970's (FAO 1993). To date, the DoF uses two separate statistical systems to monitor the artisenal fisheries. These are the Catch assessment survey (CAS) developed by Bazigos (1974) and the Malawi Traditional Fisheries (MTF) system introduced during the FAO Chambo project in 1991. Both systems utilise a stratified sampling procedure. However, while the CAS system relies on a boat based sampling procedure, the MTF system is gear-based (Alimoso *et al.* 1990, FAO 1993). During the initiation of the MTF system as the *modus operandi* for catch and effort estimation in Mangochi District, it was generally acknowledged that this system was superior and should be extended to the rest of the country (FAO 1993, DoF statistical committee meetings 1993-1994[*]).

However, the DoF realised that there were certain deficits with the MTF system. For this reason, the MTF system was re-assessed by the GTZ assisted National Aquatic Resource Management Programme (NARMAP) and recommendations for its improvement were made (Weyl and Manase 1999). These recommendations were accepted by the Department of Fisheries and presently an improved system is being implemented in Mangochi District. This system incorporates the following:

- A gear based and stratified sampling strategy.
- Re-designed datasheets ensuring the collection of vital catch and effort data.
- A new database for the storage, assessment and reporting of artisenal fisheries data that will **be MS-WINDOWS supported and will be** based on existing software packages such as MS-EXCEL and MS-ACCESS and is capable of:
- The inclusion of uncertainty parameters into effort and yield estimates;
- Modification and integration of additional data tables;

[*] DoF 1993a. Minutes of four Statiscal Committee meetings held between 14th October, 1993 and 1st July 1994.

- Hardcopy printouts of data tables, summary tables and graphics from the database;
- Export of data to other Microsoft applications such as MS-WORD and MS-EXCEL.
- Automated-backups;
- Error checking data entries.

A training manual (Weyl *et al.* 2000b) and a new database system (Booth 2000) was developed and Technical staff of the DoF in Mangochi District has received training in sampling procedure, fish identification and communication skills as well as in the use of the new database programme. The new software for the analysis of the data was installed in August 2000 and a testing phase has commenced using Mangochi district as a pilot area. This will allow for an assessment of the application of this system to the rest of the country. It is envisaged that the system will be adopted in other Districts by 2002.

While the assessment of catch and effort data in Mangochi district are on schedule, the assessment data from other districts using the CAS system has had a number of shortfalls. These include, non-submission of results to the Fisheries Research Unit (FRU), and subsequent delays in analysis and reporting of the data. To aid in the assessment of the CAS data, the FRU statistics unit has designed spreadsheet procedures using EXCEL to facilitate rapid analysis in the District Offices. However, these have not been distributed. It is therefore recommended that:

- Outstanding data be collected from the field stations as soon as possible.
- EXCEL spreadsheets be distributed to the District offices as soon as possible and local staff are trained in the use of these spreadsheets.
- All catch statistics from 1989 to 1999 are published as Fisheries Bulletins before year end.

***Frame surveys***

The annual frame survey is a complete census of basic fishery characteristics for the purpose of planning and management. The Department of Fisheries (DoF) usually carries out these frame surveys in August during the dry season when most landing sites are accessible by land. This involves visits to all landing sites along the shore to count fishermen, their gears and fishing craft. In conjunction with sample catch-effort data the frame survey data are used as a basis for estimating total monthly landings and fishing effort for the various traditional fisheries.

The major fishing grounds of Malawi are divided, for statistical purposes into major and minor strata. It must be pointed out that since the 1994 Frame Survey Report the coding for major and minor strata has been revised in the 1999 Frame Survey Report (Weyl *et al.*2000). New stratum numbers and descriptions are provided in Table 1. One or two recorders are assigned the responsibility of the frame survey as well as the collection of other data in each minor stratum. These data are reported to the District Fisheries Office, which has jurisdiction over various minor strata in the District.

**Table 1.** New and old codes, descriptions, administrative district and controlling District Fisheries Office for all minor strata assessed during annual frame surveys in Malawi.

| New Code | Old code | Stratum description | District | Controlling District Fisheries Office |
|---|---|---|---|---|
| Lake Malombe *(Figure 1.1)* | | | | |
| 1.1 | *1.1* | Lake Malombe West | Mangochi | Mangochi |
| 1.2 | *1.2* | Lake Malombe East | Mangochi | Mangochi |
| Upper Shire River *(Figure 1.1)* | | | | |
| 1.3 | *1.3* | Upper Shire River | Mangochi | Mangochi |
| Lake Malawi *(Figure 1.1)* | | | | |
| 2.1 | *2.1* | S. W. Boadzulu Island | Mangochi | Mangochi |
| 2.2 | *2.2* | S. E. Boadzulu Island | Mangochi | Mangochi |
| 2.3 | *2.3* | N. W. Boadzulu Island | Mangochi | Mangochi |
| 2.4 | *2.4* | N. E. Boadzulu Island | Mangochi | Mangochi |
| 2.5 | *2.5* | Makanjila | Mangochi | Mangochi |
| 2.6 | *2.6* | Fort Maguire | Mangochi | Mangochi |
| 3.1 | *3.1* | Malembo | Mangochi | Mangochi |
| 3.2 | *3.2* | Mtakataka | Dedza | Salima |
| 3.3 | *3.3* | Chipoka | Salima | Salima |
| 4.1 | *4.1* | Senga Bay | Salima | Salima |
| 4.2 | *4.2* | Domira Bay | Salima | Salima |
| 5.1 | *5.1* | Nkhotakota South | Nkhotakota | Nkhotakota |
| 5.2 | *5.2* | Chia Lagoon | Nkhotakota | Nkhotakota |
| 5.3 | *5.3* | Nkhotakota Central | Nkhotakota | Nkhotakota |
| 5.4 | *5.4* | Nkhotakota Central North | Nkhotakota | Nkhotakota |
| 5.5 | *5.5* | Nkhotakota North | Nkhotakota | Nkhotakota |
| 6.1 | *6.1* | Tukombo | Nkhata Bay | Nkhata Bay |
| 6.2 | *6.2* | Kande | Nkhata Bay | Nkhata Bay |
| 6.3 | *6.3* | Chintheche | Nkhata Bay | Nkhata Bay |
| 6.4 | *6.4a* | Sanga | Nkhata Bay | Nkhata Bay |
| 6.5 | *6.4b* | Thotho | Nkhata Bay | Nkhata Bay |
| 6.6 | *6.7a* | Usisya | Nkhata Bay | Nkhata Bay |
| 6.7 | *6.7b* | Tcharo | Nkhata Bay | Nkhata Bay |
| 6.8 | *6.8* | Mlowe | Nkhata Bay | Nkhata Bay |
| 7.1 | *7.1* | Chiweta | Karonga | Karonga |
| 7.2 | *7.2* | Chitimba | Karonga | Karonga |
| 7.3 | *7.3* | Chilumba | Karonga | Karonga |
| 7.4 | *7.4* | Nyungwe | Karonga | Karonga |
| 7.5 | *7.5* | Mlare | Karonga | Karonga |
| 7.6 | *7.6* | Karonga Boma | Karonga | Karonga |
| 7.7 | *7.7* | Kaporo | Karonga | Karonga |
| 8.1 | *6.5* | Likoma Island | Nkhata Bay | Likoma |
| 8.2 | *6.6* | Chizumulu Island | Nkhata Bay | Likoma |
| Lake Chilwa *(Figure 1.2)* | | | | |
| 9.1 | *1.1* | Namanja | Zomba | Zomba |
| 9.2 | *1.2* | Mposa | Zomba | Zomba |
| 9.3 | *1.3* | Chinguma | Zomba | Zomba |
| 9.4 | *2.1* | Chisi Island | Zomba | Zomba |
| 9.5 | *2.2* | Kachulu | Zomba | Zomba |
| 9.6 | *2.3a* | Njalo Island | Zomba | Zomba |
| 9.7 | *2.3b* | Mpoto Lagoon | Zomba | Zomba |
| Lake Chiuta *(Figure 1.3)* | | | | |
| 10.1 | *3.1* | Dinji | Zomba | Zomba |
| 10.2 | *3.2* | Saleya | Zomba | Zomba |
| Lower Shire River *(Figure 1.4)* | | | | |
| 11.1 | *1.1* | N. W. Elephant Marsh | Chikwawa | Ngabu |
| 11.2 | *1.2* | N. E. Elephant Marsh | Chikwawa | Ngabu |
| 11.3 | *2.1* | S.W. Elephant Marsh | Chikwawa | Ngabu |
| 11.4 | *2.2* | S.E. Elephant Marsh | Chikwawa | Ngabu |
| 11.5 | *3.1* | Bangula Lagoon | Nsanje | Ngabu |
| 11.6 | *3.2* | River Shire- Nsanje | Nsanje | Ngabu |
| 11.7 | *4.1* | West Ndinde Marsh | Nsanje | Ngabu |
| 11.8 | *4.2* | East Ndinde Marsh | Nsanje | Ngabu |

There are a number of limitations to the data collected during previous frame surveys, these include:

- Current data can only be aggregated to Fisheries Statistical Stratum level and cannot be compared with information collected by other institutions such as the National Statistics Office (NSO).

- There are no maps of the spatial distribution of fishing beaches and villages available. This has lead to a situation where specific areas within a stratum cannot be assessed.

- While beaches within a stratum are listed, there is no indication of the village to which these beaches belong. Extreme cases have been reported in Northern lake Malawi where one village may have 10 beaches.
- While gears are counted, there is little information on the specifications and mesh size and gear length. This has made it impossible to track changes within a given gear type e.g. mesh size and gear length.

- There is no information on how many craft are used in the operation of specific fishing gears.

- There is no data on whether fishers and crew-members are resident within the village were they are assessed or are migrants.

Recommendations for the 2000 Frame survey are:
- NSO codes for the area where the beach occurs should be included in the database for the frame survey.
- NSO maps of Lakeshore districts should be provided during the 2000 Frame survey and field staff should indicate the location of all beaches within a stratum on these maps.
- The village name and Traditional authority (TA) or Sub Chief (SC) of the village where a fishing beach occurs should be indicated on the datasheet.
- Full information on the operational gears should be provided for a significant sample of fishermen.

## Activities

***Catch assessments***
Mangochi District Statistics Office adopts the new database programme and all data for the year 2000 are entered by February 2001.

EXCEL spreadsheets are distributed to district offices by October 2000 and key personell are trained in the use of these spreadsheets for the evaluation of CAS data. FRU statistics staff should collect all compiled data from field stations during the first week of November and ensure that all data is entered into the main database by the end of

November 2000. Data compilation and analysis is to be completed by the end of December 2000.

***Frame Survey***

The basic operating method during the 2000-Frame survey whereby all beaches are visited by fisheries staff are enumerated remains unchanged from previous surveys. While data collection is the responsibility of the District Fisheries Office, supervision will be provided by FRU staff.

All field staff will be issued with NSO maps of the minor stratum that they are to survey. On these maps the location of fishing beaches will have to be filled in and these maps must be returned with the completed data forms.

The summary data form (FRAME SURVEY DATA FORM 1) is similar to the form used in previous surveys but, in addition to the Minor stratum, the name of the village at which the beaches occur has to be filled in as well. The overall Traditional Authority e.g. TA Nankumba or TA Makanjila but NOT the village headman. In areas where boundaries are made by Sub Chiefs (SC) the names of these should be used.

The additional form (FRAME SURVEY DATA FORM 2) should be used to provide accurate information on various gear types. At each beach, the number of fishers that should be sampled at each beach gears to be sampled with this form are:
10 gill net fishers; All fishermen with beach seines i.e. Chambo seine, Kambuzi seine, Mosquito net and Matemba seine; 10 Nkacha nets and 10 Chilimira net fishermen.

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## 6.2. Demersal monitoring surveys

### Introduction

Lake Malawi fisheries are multi-species fishery with over 600 species and are exploited by many small and few large-scale fishermen (Eccles and Trewawas, 1989; Konings, 1995; Turner, 1996). Exploitation of fisheries resources is done using different selective harvesting methods and the choice of gear depends on the target species and investment capacity of the individual fishermen. The fisheries on the lake can be divided into traditional (artisanal) or commercial (industrial) fisheries, depending on their mode of operation. The traditional fisheries are open access and account for over 80% of the total catch (50,000 tonnes) (Banda unpublished). The fishery uses various kinds of gear, and operates around the lake but largely in the in-shore areas. The main gears used are gillnets, seines and, hand and long line (FAO, 1993). The commercial fisheries are mechanised and capital intensive and use mainly trawling and purse-seining (ring net). The commercial vessels account for less than 20% of the total catch and are confined to the southern part of Lake Malawi.

There are two types of trawling being practised on Lake Malawi, research and commercial. The first research trawling was carried out in 1965 by the Fisheries Department, which demonstrated the potential for commercial fishery. In 1969 the department initiated demersal stock assessment surveys following the inception of the commercial trawl fishery and these have been conducted by the Fisheries Research Unit on the demersal fishery resource since then (Tarbit, 1972). The objectives of the surveys were to monitor the effects on the stocks of the then rapidly expanding commercial fisheries in the southern arms of the lake and to explore the potential for trawl fisheries in other parts of the lake (Tarbit, 1972). These surveys have produced some punctuated time series of biomass estimates for the demersal fish stocks and are now regarded as core trawl sampling programmes of the station. The first regular trawling surveys started in the southern part of the lake from 1971 to 1976 under the FAO project, with similar aims (FAO, 1976; Turner, 1977a, b). A number of recommendations, which are still used in the management of the commercial fisheries to this day, were made based on the findings of the surveys and included 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. After the discontinuation of these regular surveys in 1976, changes in the exploited stocks were monitored through catch and effort data from commercial operators until 1988 (Tweddle and Magasa, 1989; Lewis and Tweddle, 1990). During this period the Fisheries Department noted various changes in fishing practices such as the use of illegal mesh sizes and fishing in prohibited inshore areas. The average size of the fish in the catches also appeared to be declining. Consequently, it became evident that there was a need to re-assess the stocks and the regular fishing surveys were started again in 1989 under ODA project using the same boat and methodology as the early ones. These surveys were carried out on a quarterly basis and the project phased out in the early 1994. The major findings were the following; the exploited biomass had declined in the heavily fished areas, some larger cichlid species had declined and the minimum mesh size of 38 mm of the cod end was ineffective (FAO, 1993; Turner *et al.*, 1995). A survey undertaken using the new research vessel, *RV Ndunduma,* to assess the validity of the FAO recommendations indicated that there were little variation in classical indicators of heavy fishing such as number of species per pull, and differences in the average size of some of the species found between the more heavily fished areas and areas where little or no trawling had taken place for several years. Catch rates were found to be lowest in a limited area next to the base of the trawling fleet (Banda *et al.*, 1996).

The quarterly stock assessment surveys continued under ICEIDA project using the new power research vessel that was donated to Fisheries Department by ICEIDA (Banda and Tomasson, 1997). The fishing surveys ran on a quarterly basis from 1989 to 1997 and since then they have been restricted to on-going biannual because of the budget constraints. The findings from the early eight surveys indicated that there was scope for expansion of the demersal fisheries in the deep waters of the southern part of the lake, which has resulted into the development of the deep-water fisheries in the southeast arm of Lake Malawi (Banda and Tomasson, 1997). A recent review of these demersal monitoring surveys indicates that the total average catch per unit effort (CPUE) has been stable since 1995 although the CPUE for individual species such as *Bathyclarias* spp. and *Oreochromis* spp. have declined (Palsson *et al.*, 1999).

Commercial fisheries on Lake Malawi include purse-seining, trawling and light attraction by the use of lift rigs. Purse seining was introduced in 1943 for the exploitation of *Oreochromis spp*. and is confined to relatively shallow parts of the southeast arm. Since 1993 the operation of the units has become erratic because of the sharp decline in the catch per unit effort (Banda and Tomasson, 1997). Lift net rigs using light attraction started on the lake in 1996 for the commercial exploitation of *Engraulicypris sardella* and are currently fishing in the southeast arm at night in the shallow waters (Banda and Tomasson, 1997).

Commercial trawling on Lake Malawi was introduced in 1968 following the 1965 experimental trawl surveys to harvest the demersal fisheries in the southern shallow parts of the lake. The fishery presently involves bottom and mid water trawling using pair and stern trawlers. The pair trawlers are wooden boats; about 8 m long with a 20-40 hp inboard engine and are licensed to fish between 18 and 50 m depth, and not less than one nautical mile from the shoreline. At present there are 16 units licensed to fish on the lake. The number of licenses has remained fairly constant for the past 16 years since the recommendation by FAO (1976).

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 southeast arm. 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 unpublished). 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 extended to deeper water (up to 100 m) by the two new powerful boats (380 hp) (Banda unpublished).

## Objectives

The aim of these surveys is to update the time series of the demersal monitoring survey results on the demersal species and to monitor changes in the exploited areas in terms of total catch in number and weight by species, biomass trends, fish abundance, the size of the potential annual yield yearly and size frequency distributions of the commercial important species.

## Justification

The sustainable management of the commercial fishery is largely based on the findings of the monitoring surveys. The catch composition, fish abundance, standing stock size and potential yield are determined through such surveys and information from these parameters is used as a basis in the formulation of policies for the management and conservation of the demersal fishery resource to attain sustainable development and rational exploitation of the fishery resource. The issuing of commercial fishing licences, for instance, is dependent on the amount of fishing that would produce the maximum amount of fish from each area on a sustainable basis. Because bigger engines increase fishing power and hence effort, the hp is also restricted. More powerful boats would mean that fewer licenses could be allowed. The number of licenses is the most powerful and effective management regulation for the industrial fishery and the number of licenses to be issued each year depends on the status of the fishery as perceived from the monitoring surveys. It follows therefore that fishing surveys need to be carried out every year and maintained as one of the main station research activities in order to manage the commercial fishery sustainable. The biomass estimates can also provide the basis of the introduction of quotas for each boat if a need arises in the near future.

## Methods

Considerable effort has been devoted to assessing the demersal stocks mainly through bottom-trawl surveys (swept area method) in a projectised approach because of financial constraints. Two research vessels of different power were used during these surveys, *RV. Ndunduma* and *RV. Ethelwynn Trewavas*. The former is powered with a 380 hp engine and the mesh size of the cod end is 38-mm stretched mesh while the latter with a 90 hp engine and a cod end mesh size of 24 mm. The nets have a similar selectivity curve for fish at first capture although the *Ndunduma* catches a higher portion of the larger fish.

A total of 97 fixed stations, 54 in the South East Arm and 43 in the South West Arm sampled during each survey in the previous standardised surveys will be adopted in these surveys because it is a continuation of the monitoring surveys. Each survey will be carried out twice a year and its duration is about 18 days. All trawling will be done during daylight hours. Two research vessels, *RV. Ethelwynn Trewavas* and *RV. Ndunduma* will be used in shallow (10-50 m) and deep water (>50 m) respectively. During *RV. Ndunduma* surveys stations will be identified by using the Global Positioning System (GPS), and on the *RV. Ethelwynn Trewavas* by a combination of depth, landmarks and hand set GPS if available. The trawling sped for *RV. Ndunduma* will be 3.7 knots and *RV. Ethelwynn* is about 2.5 knots.

The catch will be split up into small fish, kampango (*Bagrus meridionalis*), bombe (*Bathyclarias* species) and other fish, usually consisting of cyprinids and larger cichlid species as in the previous surveys. A 10-20 kg sub sample will be taken from the small fish and will be sorted into species. The total length of fish of each species for all four groups will be measured and the weight of each category recorded.

The trends in the catch between the early surveys have not been followed properly because two research vessels with different pulling power have been used in these experimental surveys making comparison of the results difficult. Furthermore, the main focus of the surveys is the biomass estimates but virtually nothing is known on factors and mechanisms controlling spatial and temporal shifts in abundance of the demersal fish stocks. Nevertheless, the understanding of the dynamics of the demersal species needs to be greatly improved through improving the existing methods of resource assessment and identifying key life-history stages, and studying the effects of their dynamics on population size. The following studies will be necessary:

Methods of collecting data for stock assessment need to be compared and standardised and research tools inter-calibrated.

Ways need to be found of assessing the demersal stocks using acoustic methods because some species are semi-demersal fish.

Techniques need to be developed for assessing fish occurring in shallow waters or too close to the bottom to be detected by echo sounders.

Factors affecting the availability and accessibility of fish to fish survey need to be investigated.

Survey designs need to be improved.

Large-scale investigations need to be carried out on the identification and distribution of the demersal fish species.

The first task will be to review current methods of biomass estimation and stock assessment for the demersal resource, including data collection techniques, survey methodology and data analysis methods. Where possible these methods will be standardised and/ or intercalibrated.

# CHAPTER 7: EXPLORATORY SURVEYS

## 6.1. Demersal exploratory surveys project proposal

### Introduction

The demersal exploratory surveys that were carried out in the mid 1960's and early 1970's with the aim of assessing the potential of a trawl fishery on Lake Malawi, led to the establishment of the present trawl fishery in the late 1960's and early 1970's in the shallow and relatively deep parts of south east (Tarbit, 1972; FAO, 1976). Subsequent surveys carried out in other parts of the lake such as Domira Bay and Nkhata Bay area in 1970's also resulted in the development of the trawl fishery in the central parts of the lake especially in Domira Bay and Nkhota kota (Tarbit, 1972; Chaika, 1976, Turner 1977). The average catch rate was higher in shallow water than in relatively deep water and was comparable to those of the southern part of the lake. The trawl fishery in these areas was short lived from 1977 to 1981 because the fishery was not sustainable (Tweddle pers. Comm.). On the other hand it seems that the fisheries stopped because of the flooding of the landing places following the rise in the lake level (Seymour pers. Comm.).

The Fisheries Department acquired the powerful multi-purpose vessel, *RV. Ndunduma*, in 1993 that has enabled the department to identify and explore the potential trawling grounds in the deeper virgin waters of Lake Malawi. The surveys in the southern part of the lake, which started in 1994 and were part of the routine monitoring surveys, have led to the establishment of the deeper water fisheries especially in the southeast arm (Banda and Tomasson, 1997; Banda unpublished). Currently, there are four boats fishing in the deep waters (50-150 m) and the other three boats are under construction, which have not been licensed yet. In the same year, two such surveys were carried out on the demersal fish stocks from Domira Bay to Nkhata Bay followed by a detailed one that concentrated around Domira Bay area (Banda and Tomasson, 1994a, Banda and Tomasson, 1994b; Banda and Tomasson, 1996). Potential areas for further development of the fishery were identified and mapped and these have been confirmed by the recent two shallow water surveys carried out between 1997 and 1998, and two deep water survey in 1998 all covering the central and northern waters of Lake Malawi (FRU unpublished; Kanyerere, 1999).

A comparison of the data collected during the monitoring and exploratory surveys indicate that similar information is being gathered only that the former one is standardised i.e. the same stations are sampled each survey for the same length of time (Banda *et al.*, 1999). In view of this, a new demersal survey design has been proposed in central and northern Lake Malawi, which will essentially be used to monitor fish stocks in these areas and provide a scientific basis for the management of fish resources in particular the deep-water fisheries. On the other hand, the surveys may yield relevant results on the status of some water fish stocks, exploited by the artisanal fishery, such as *Oreochromis* spp. and *Bargus meridionalis*.

## Objectives

The objectives of the demersal exploratory surveys are to assess the feasibility of commercial fishing, to map trawlable grounds and to increase the knowledge base of the resource.

## Justification

The fish stocks in the shallow southern part of Lake Malawi are under increased fishing pressure from both the traditional and commercial fisheries, and the use of small meshed nets in both fisheries has increased over the past 20 years (Tweddle *et al.*, 1995; Turner, 1995). The catches of the *Oreochromis*, which once supported both the gillnet and purse seine fisheries has declined from about 9000 tonnes in 1985 to less than 2000 tonnes in 1996 (FAO, 1993; Banda and Hara, 1994) while the overall catch in the same period fluctuated between 20000 and 37000 tonnes with an average of 27000 tonnes (Bulirani *et al.*, 1999).

The four stern trawlers that operate in the southeast arm of the lake heavily exploit the deep-water stocks (Palsson *et al.*, 1999), and this has maintained the same level of demersal production. The expansion of the demersal fishery into the deeper waters has not resulted in increased demersal production because of reduced effort by the pair trawlers, which are old and lack proper maintenance. The results from the regular monitoring surveys indicate that the deep-water trawl fishery is currently fully exploited (Palsson *et al.*, 1999) and there may be no room for further expansion. Consequently the future expansion of the deep trawl fishery should be geared towards the deep water of the south-west arm, central and northern waters of the lake. In view of this, and the fact that there is high demand for animal protein due to increase in population and decline in traditional catches (Bulirani *et al.*, 1999), there is a great need to monitor and explore these virgin deep waters of the lake. The deep waters fishery might reduce fishing pressure from the heavily exploited shallow water stocks by diverting the some of the effort from the shallow water into the deep areas if the current traditional gears could be improved. Currently, the deep waters fish stocks can effectively be exploited by means of trawling because the present traditional gears are unable to catch the deep demersal stocks.

## *Implementation*

*RV. Ndunduma*, a 17.5 m stern trawler, which is powered by a 386 hp Caterpillar engine, will carry out the surveys. It pulls a “Gulltoppur” bottom trawl with a 23 m long head rope. The mesh size of the cod end is 38 mm stretched mesh.

The survey will take place twice a year and will be carried out in the shallow and deep waters of the Central and Northern parts of the lake that have been divided into three main areas. Area 1 starts from Senga Point to Sungu point, area 2 from Sungu Point to Chirombo Point and area 3 from Rukuru to Songwe River. Each area will then further be divided into three depth strata, 0-49m, 50-99m and 100-200m on which the allocation of stations is based and the total number of stations for such a survey is 100 (see the table below)(Banda *et al.*, 1999).

The duration of each survey will be about 20 days and all trawling will be carried out during daytime. The Global Positioning System (GPS) will be used to identify stations during each survey. The trawling sped will be 3.7 knots.

| Area | Depth (m) | Surface area (km$^2$) | Number of stations |
|---|---|---|---|
| 1 | 0-50 | 569 | 19 |
| | 51-100 | 319 | 11 |
| | 101-150 | 468 | 16 |
| 2 | 0-50 | 471 | 16 |
| | 51-100 | 225 | 7 |
| | 101-150 | 365 | 12 |
| 3 | 0-50 | 88 | 3 |
| | 51-100 | 233 | 2 |
| | 101-150 | 50 | 2 |
| | 151-200 | 400 | 13 |
| Grand total | | 3017 | 100 |

The catch will be split up into small fish, kampango (*Bagrus meridionalis*), bombe (*Bathyclarias* species) and other fish, usually consisting of cyprinids and larger cichlid species as in the previous surveys. A 10-20 kg sub sample will be taken from the small fish and will be sorted into species. The total length of fish of each species for all four groups will be measured and the weight of each category recorded.

## 7.2. Pelagic exploratory surveys

### Introduction

The fishes of Lake Malawi are one of the most remarkably diverse and abundant faunal groups in the world. At present, there is thought to be over 600 fish species in the lake in twelve families (Eccles and Trewavas, 1989; Konings, 1995; Turner, 1996). Most of these species are endemic to the lake and the dominant group is the cichlids. The fishes of the lake are recognized according to the habitat type and follow into three communities: the rocky, demersal and pelagic (Ribbink *et al.*, 1983). Most of the research has concentrated on the rocky and demersal communities of the lake (Lewis, 1981; Ribbink, 1991; FAO, 1993; Ribbink and Eccles, 1988; Ribbink *et al.*, 1983) and very little information on the pelagic (FAO, 1982; Thompson *et al.*, 1996). The pelagic community inhabits the offshore pelagic zone, which is unexploited (Allison, 1996; Thompson and Allison, 1997). The offshore pelagic zone is defined as all areas of > 50m depth, or 2 km offshore where the 50 m isobath is close to the shore (Allison, 1996).

Two donor-funded programmes have been carried out on Lake Malawi in connection with the pelagic fisheries (FAO, 1982; Menz, 1995). The first project was executed by FAO between 1979 and 1981 with an aim of trying to estimate the density of pelagic fish in the lake. Much of the studies were done on the usipa because it was assumed that it was the most important truly pelagic fish component of the pelagic ecosystem. Being the first study of its kind on the lake and that was done over a limited period of time, many of the conclusions were preliminary and only provided a baseline for further studies. The UK/SADC project between 1991 and 1994 was a follow up study and repeated some aspects studied in the previous project. The major finding of interest as far as fisheries are concerned is that there is a resource in the offshore waters and the estimated total sustainable yield was about 34,000 tonnes $y^{-1}$ (Thompson and Allison, 1997). However, heavily mechanised vessels such as the RV *Ndunduma* could not viably exploit this but could be exploited by the use of improve traditional gears. Thus the establishment of an offshore fishery would provide a useful additional source of high-protein food and may also alleviate pressure on the fully exploited inshore fish populations that are on the decline (Bulirani *et al.*, 1999).

Currently, the mechanised fishery is exploiting some species that belong to the pelagic community by the mid-water trawling (with bottom-set otter boards) (Turner, 1994,1995). This trawling technique is only carried out by the only private company, Maldeco and has never been monitored since its establishment in 1972 (Turner, 1977). The same company is also expanding its mid-water trawl efforts in the south-west arm of the lake and a new mid water trawler will start operating very shortly. This requires the Fisheries Department to establish a monitoring programmed for this fishery.

**Objective**

The main objectives of the study are to monitor changes in the species composition, size distribution, and catch rates in the exploited areas and to increase the knowledge base of the resource.

**Implementation**

*RV. Ndunduma*, a 17.5 m stern trawler, which is powered by a 386 hp Caterpillar engine, will carry out the surveys with a mid water trawl 40-m headline and a vertical height of 33.5 m from the footrope and 38 mm mesh size cod end. The survey will be done twice a year and the main emphasis will be in the deeper waters of the southern part of the lake and the duration of each survey is about 10 days. Stations will be located in the deeper waters of the southeast arm and west and the number of stations in each sampling site will depend on the size of area. Some stations will be sampled at different depth levels depending on the depth profile. The Global Positioning System (GPS) will be used to identify stations during each survey. The trawling sped will be 2.8 knots.

The catch will be split up into small fish, kampango (*Bagrus meridionalis*), bombe (*Bathyclarias* species) and other fish, usually consisting of cyprinids and larger cichlid species as in the previous surveys. A 50 kg sub sample will be taken from the small fish and will be sorted into species. The total length of fish of each species for all four groups will be measured and the weight of each category recorded.

**Output**

A monitoring programme for the midwater trawl fishery will be established.

# CHAPTER 8: LIMNOLOGICAL SURVEYS

## 8.1. Limnological and Phytoplankton monitoring for the South East Arm of Lake Malawi and Lakes Malombe, Chilwa, Chiuta and Chikukutu.

### Introduction

Fisheries research in the past has mainly been focussed on the major Lake Malawi with little work on the smaller water bodies such as L. Malombe, L. Chilwa, L. Chiuta and L. Chikukutu.

There is however evidence that these lakes also play a major roll in the provision of water and essential and cheap protein through its fisheries (Alimoso, 1990; Bulirani *et al.*, 1999; FAO, 1993; Pálsson *et al.*, 1999; Ojda, 1994; Tweddle, 1983). In the past, low population density, minimal fishing pressure and moderate agricultural practices meant that the lakes could manage themselves. But now they are under transitional change and although there are few overt signs of drastic change, fish catches are declining and some of the fish species are extinct. However this is not a surprise considering the population increase within the watersheds, the increase in fishing pressure and changes in land use.

Experience has shown that human activities can negatively affect the quality of water and many beneficial uses of the lake impaired up to the point of elimination. Major contributions to this could be as a result of eutrophication (a term for excess nutrient enrichment causing overabundant phytoplankton growth), and siltation from run off. The influence of agricultural development, deforestation, biomass burning, and human settlement have been shown to affect water runoff and chemistry (Calder *et al.* 1995) and are important to address nutrient loading studies.

Experience in the Laurentian Great Lakes of North America (Ragotzke 1988; Sweeney 1993) and within Africa (Lake Victoria; 1993) has shown that fisheries and biodiversity in these lakes can be affected seriously by changes in water quality resulting from human activities within the lakes' watersheds. There is therefore no need to relearn the lesson in our water bodies that good water quality is essential to maintenance of healthy, diverse aquatic ecosystems.

History has shown that management response to deleterious impacts on the aquatic ecosystems has been in most cases *ad hoc*. Nutrient abatement programmes are initiated when the water turns green with algae; fisheries are closed after the stocks have declined and fish consumption warnings are issued when the contamination levels have increased. This approach is however not only ideal, but also time and financial resource consuming, as it would require much time to avert the problems.

It is therefore wise and proper that effective management strategies precede problems rather than respond to them. The reason for this is that our diverse endemic fishery is more sensitive to environmental changes than the fish communities found in most temperate areas. Programmes of nutrient removal may restore the quality of the water but can not bring back the fish species which are lost due to the unfavourable environmental conditions.

FAO, 1993 reports that Lake Malombe is polymictic (fully mixed) and nutrients are well recycled and hence extends the productive zone up to the bottom. This could be due to the size of the lake – maximum depth 17m. The maximum depths of the other lakes are however not very different from this. This means that any nutrient, sediment inputs, would result in rapid changes in the water chemistry and plankton composition.

The objective of this programme is to determine the current status and composition of the physical, chemical and biological properties of these smaller water bodies and how these properties will determine their response to human activities.

## Specific objectives

1. To determine the spatio-temporal variability of the physical and chemical factors affecting primary production.

2. To assess spatial and temporal variability in primary production

3. To determine the composition, abundance and species distribution of macrophytes.

## Sampling techniques and methods of analysis

A number of permanent stations within the water bodies will be identified using the hand held GPS (Global Positioning System) where the below parameters will be monitored on a monthly basis

### *Phytoplankton*

Phytoplankton are a sensitive indicator of the physical and chemical changes of lakes and definitely changes in phytoplankton composition accompanies changes in fish community structure since they make up the food web base.

Sampling of phytoplankton will be done using the Van Dorn sampler, which allows for specific depth sampling and the measuring of phytoplankton concentrations will be done in two ways.

1. **Algae counting**. Lugols solution is added to the samples after which they will be stored in a dark place for about two weeks to give ample time for the phytoplankton to settle down. The sample is reduced to 100ml by sucking away the top layer without shacking and then left to settle for another one week. A further reduction to a volume of less than 50ml is done where upon neutral formalin is added to adjust the volume to exactly 50ml (final formol concentration approximately 4%). Counting is done under an inverted microscope (Utermöhl method described by Lund *et al.*1958).

2. **Chlorophyll *a.*** An integrated water sample is filtered using a Whatman GF/F filters and stored in a dark place of temperature approximately $-12^0$C. Avoid prolonged exposure to light as photosynthesis is aided with the presence of light. The filter paper is then ground in acetone and filtered. (Golterman *et al.*, 1978. Analysis is done using a fluorometer, which is equipped to provide an excitation at around 440nm and detect emission at around 600nm. (Talling and Driver, 1963)

***Zooplankton***

Zooplankton are the main trophic link between primary and fish production in the open water ecosystem because they take up phytoplankton as their food while most of the pelagic fish feed on them. The productivity of zooplankton is however related to the nutrient status of the water while their composition is determined by food availability (phytoplankton) on the one hand and predation pressure on the other.

A zooplankton net will be used to sample zooplankton from specific water column and a grab sampler will be used to sample bottom mud for benthic invertebrates. All the samples both from the zooplankton net and the grab sampler will be fixed in formalin. A dissecting microscope will be used to identify the various types of invertebrates contained in the samples.

***Aquatic macrophytes***

The distribution of the different macrophytes in the lakes will be assessed from a dinghy. Specimens of the different species of macrophytes will be collected from randomly distributed quadrants that will be in various areas of the lake. All macrophytes within a quadrant will be cut off or dug up using a knife, grass clippers and towel for identification.

***Lake nutrient***

Nutrient availability in lakes plays a major role in controlling the abundance and composition of phytoplankton community. Increased nutrient input to these lakes will most likely result in a decrease in the volume of oxygenated water and available fish habitat. Growth of algae and composition depends on the type of element available in the water. For example, an N:P ratio of lower than 16:1 would favour the growth of cyanobacteria – nitrogen fixing blue-green algae species while excess Silica would favour the proliferation of diatoms.

Samples will be collected from the same stations as those of phytoplankton and will be analysed on the major nutrients: total phosphorus (TP), soluble reactive silica (SRSi), nitrate ($NO^{3-}$) and ammonium ($NH^{4+}$).

All the samples will be filtered through the GF/F filters and kept frozen in polyethylene bottles except those of silica. Prior to analysis, samples have to be thawed for a period of not less than 12 hours to attain uniform mixing. Total phosphate ($PO_4$-P) is determined using the molybdate method and ammonium nitrogen ($NH_4$-N) using the indophenol blue method. Silicate is also determined using the molybdate method (Stanton 1977). Other parameters to be monitored will be; pH, Conductivity, Dissolved Oxygen, Turbidity (water clarity using the Secchi disk), and Temperature.

**Requirements**

Due to unavailability of proper equipment in our Monkey-bay Limnology Lab., samples will be taken to SADC/GEF premises in Salima for analysis. This exercise will be carried out quarterly for a period of two weeks. While it will be possible to use the equipment at the SADC/GEF labs, chemicals will have to be supplied by the FRU. The required chemicals and equipment listed in the following table.

| Item | Unit | Quantity | Unit cost | Cost (MK) |
|---|---|---|---|---|
| Sample bottles-polyethylene | | | | |
| a) 100ml | Number | 50 | 50.00 | 2500.00 |
| b) 30ml | Number | 100 | 50.00 | 5000.00 |
| 47mm O GF/F filters | Pieces | 1 | 4060.00 | 4060.00 |
| Small plastic petri dishes (90mm) | Pieces | 1 | 3500.00 | 3500.00 |
| Hydrochloric acid | Litres | 5 | 911.00 | 1822.80 |
| Parafilm roll | Roll | 1 | 900.00 | 900.00 |
| Distilled water | Litres | 50 | 50.00 | 2500.00 |
| | | | | **20282.00** |

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