CHANGES IN THE FISHERIES OF LAKE MALAWI, 1976 - 1996: ECOSYSTEM-BASED ANALYSIS

by

EDWARD NSIKU

B. Sc., University of Malawi, 1985
Pg. Dip., University of Humberside (HCHE), 1988
Dip., University of Tromsø, 1991

A THESIS SUBMITTED IN PARTIAL FULFILMENT OF
THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE

in

THE FACULTY OF GRADUATE STUDIES

(Department of Resource Management and Environmental Studies; Fisheries Centre)

We accept this thesis as conforming
to the required standard

THE UNIVERSITY OF BRITISH COLUMBIA

December 1999

In presenting this thesis in partial fulfilment of the requirements for an advanced degree at the University of British Columbia, I agree that the Library shall make it freely available for reference and study. I further agree that permission for extensive copying of this thesis for scholarly purposes may be granted by the head of my department or by his or her representatives. It is understood that copying or publication of this thesis for financial gain shall not be allowed without my written permission.

Department of RESOURCE MANAGEMENT AND ENVIRONMENTAL STUDIES

The University of British Columbia
Vancouver, Canada

Date January 21, 2000

DE-6 (2/88)

ABSTRACT

Lake Malawi is one of the most species-rich freshwater bodies in the world. Conservation of aquatic resources in the lake, however, competes with the need to provide for food and livelihood for a majority of adjacent fishing communities. The lake is therefore impacted by both anthropogenic and environmental factors.

This study looks at the changes in the fisheries of Lake Malawi between 1976 and 1996 using ecosystem-based analyses. Four analyses are carried out. First, the fisheries are evaluated by using a rapid appraisal technique, 'Rapfish', to assess their health status in sustainability terms. Second, a new Ecopath model is constructed to show the trophic structure of the Lake Malawi ecosystem. Third, maximum lengths and trophic levels are analysed to establish the extent of decline in fish size. Finally, alternative policies for exploiting the lake are explored using the Ecosim, which is an ecosystem simulation routine.

Application of the rapid appraisal technique on the species-based fisheries shows that the health status has worsened with time. It shows further that the gear-based fisheries are healthier when the operation level is small rather than large. Twenty-six trophic groups are quantified in the Ecopath model and three of these, lakefly *Chaoborus edulis, Engraulicypris sardella* larvae and predatory zooplankton *Mesocyclops aequatorialis*, form the main pathway through which energy flows from the bottom to top trophic levels in the lake's ecosystem. The trophic structure of Lake Malawi deteriorated over time. Detritus is less important in the lake's energy flow. Maturity of the lake ecosystem is between early and middle stages. Both mean maximum length and trophic level of fish caught in the lake declined with time. However, decline in the latter is masked by the decrease in catches of more herbivorous fish with low trophic levels and an increase in landing of small sized fish with high trophic levels. The traditional sector influences the lake's fisheries and ecosystem more than the commercial sector. A number of species-based fisheries, apart from Chambo *Oreochromis* spp. are exploited at above their maximum sustainable levels.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS

AIDS	Aquired immunodeficiency syndrome (disease)
ALCOM	Aquaculture for Local Communities
CITES	Convention on International Trade in Endangered Species of Wild Flora and Fauna
COV	Coeffient of variability (recruitment)
CPUE	Catch per unit effort
FAD	Fish aggragating (attracting) device
FAO	Food and Agriculture Organization of the United Nations
GDP	Gross Domestic Product
GOM	Government of Malawi
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit (German Technical Agency)
HP	Horse Power
ICEIDA	Icelandic International Development Agency
ICLARM	International Center for Living Aquatic Resources Management
ICZ	Intertropical Convergence Zone
IMF	International Monitary Fund
IUCN	World Conservation Union
MALDECO	Malawi Developmet Company
MDS	Multidimensional scaling
MFD	Malawi Fisheries Department
MK	Malawi Kwacha
NSO	National Statistical Office (Malawi)
ODA	Overseas Development Administration (of UK)
RAPFISH	Rapid appraisal technique for analysis of fisheries sustainability status
SADC	Southern African Development Community
SADCC	Southern African Development Cordination Conference
SPSS	software package for microcomputer data management and analysis (by SPSS Inc.)
UBC	University of British Columbia
UK	United Kingdom
UN	United Nations
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
WWF	World Wide Fund for Nature

ACKNOWLEDGEMENTS

I sincerely thank Professor D. Pauly, my advisor, for the unique way he has guided me and helped bring out this work to its present level. I would also like to thank my committee; Professor T. J. Pitcher, Dr U. R. Sumaila and Professor L. M. Lavkulich (Chair) for the many comments that have helped improve this study. Thanks to Ann Tauz (FC) and Nancy Dick (RMES) for the administrative issues that needed sorting and colleagues at the Fisheries Centre.

My special thanks go to the Director of Fisheries in Malawi, staff and funding agencies of the Malawi Fisheries Development Project for organizational and financial support that enabled me to study at UBC. Finally, I thank Steve Donda, D. D. Bandula and staff of the Malawi Fisheries Department for organizing and sending me data, and to my family and friends for their love and emotional support.

CHAPTER 1:

SETTING THE STAGE: BASIC INFORMATION ON MALAWI HISTORY, FISH AND FISHERIES

1.1 Geographic conditions of Malawi

Malawi is a small landlocked country in eastern central Africa, lying between latitudes 9°20' and 17°10' S, and longitudes 32°40' and 35°50' E (Fig. 1.1). The country is elongated and has a total area of 119,140 square kilometres (GOM 1989) of which 29,000 square kilometres (24 %) consists of water bodies from various drainage systems (Mills 1980; GOM 1989; ICLARM/GTZ 1991; Scholz et al. 1997). It has a north - south axis of 901 km and an east - west extent or width that varies from 80 to 160 km. Malawi is contiguous on the north and north east with Tanzania, on the east, south, and south west with Mozambique and on the west with Zambia (ICLARM/GTZ 1991; GOM/UN 1992; Ngwira et al. 1996).

The physical environment of Malawi is very diverse, due to the tectonic movement that resulted in the formation of the East African Rift Valley. The topography is dominated by the Rift Valley floor, which includes Lake Malawi at an elevation of almost sea level, and high plateaux rising to 3000 m. The relief falls within four main physiographic zones of highlands, plateaux, escarpment and plains, with the last two forming part of the Rift Valley. The strong relief is also responsible for wide ranges in climatic, hydrological and

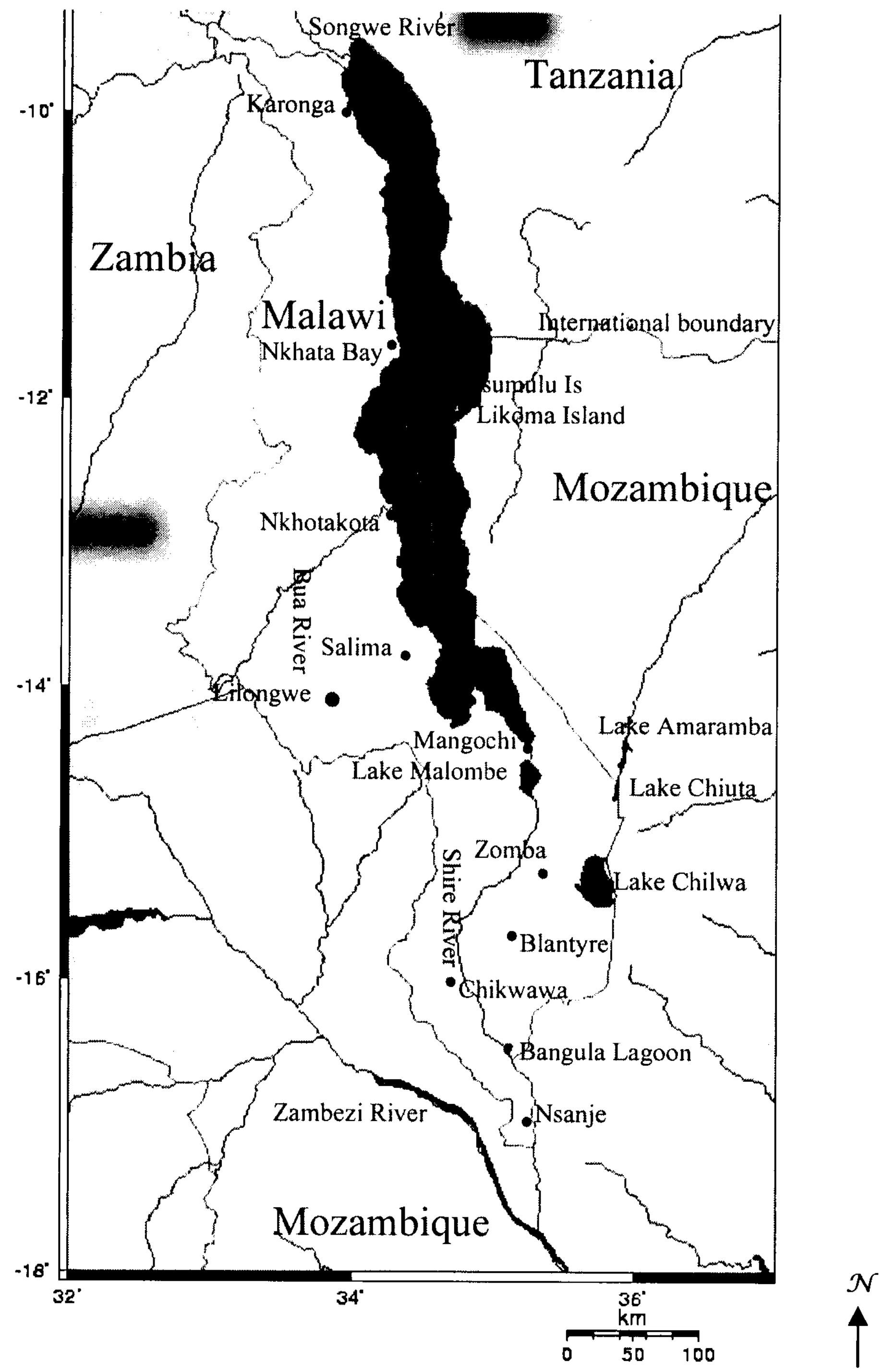


Figure 1.1 Map of Malawi showing the main water bodies, some cities and fishing district towns, and international boundaries (from www.aquarius.geomar.de/omc)

edaphic conditions leading to differences in the distribution of the population. Together with the differences in soil types, this leads to large ranges of agricultural potential. There are three seasons linked to the latitudinal movement of the intertropical convergence zone (ICZ) which is mainly influenced by the southeast trade winds ('mwera')[1] and northeast monsoon ('mpoto') apart from topography, air mass movement and microclimatic impact of Lake Malawi. There is therefore a hot and wet season (November-March/April), a cool and dry season (Mid-April/May-August) and a hot-dry season (August/September-November). In general, total rainfall corresponds to the physiographic regions with ranges of 60-80 cm (plains), 80-105 cm (escarpment), 105-150 cm (highlands) and over 150 cm (plateaux). Temperature varies between 10 and 30°C, but occasionally reaches 40°C in low-lying areas. Air temperatures are to a large extent influenced by altitude rather than latitude. Other factors that also affect temperatures include cold air masses reaching the country from the Mozambican coast of the Indian Ocean, and deep expansive water masses of Lake Malawi which warm up the shore areas during the cool season (GOM 1989; ICLARM/GTZ 1991).

The Lake Malawi catchment area dominates the hydrography of the country. Apart from lakes, streams and seasonal rivers (there are very few perennial ones), lacustrine and potamic marshes, and 'dambo' (small wetlands), which are mainly found in the upper reaches of rivers, are the major areas of the seasonal and rainfall induced surface drainage. The water flow rates in these areas vary from 10 to 44.1 % (ICLARM/GTZ 1991).

---

[1]The vernacular names are in Chichewa, which is one of the two national languages in Malawi (with English being the other and official one in Government business; Mchombo 1997; MBendi 1999).

1.2 Physiography of Lake Malawi

Lake Malawi is the most southerly of the African Rift Valley lakes, shared by Malawi, Mozambique and Tanzania. The lake is about 550 km long and 50-60 km wide giving it a total surface area of 28,800 km^2. The lake has an average depth of 292 m and a maximum point of about 700 m. Its only outlet, Shire River, is responsible for about 20 % of the outflow. The lake has a catchment area of 126,500 km^2 which includes 23 % as the lake itself. The volume of water is 1.26×10^5 km^3, i.e., 7 % of the world's total surface liquid fresh water. The lake is however sensitive to rainfall and evaporation, which is responsible for a major part of water removal, after the river outflow and other uses. Water loss due to evaporation accounts for most of the annual fluctuation of 1.6 m on average; water residency is about 750 years (Heckey and Bunyeni 1992).

1.3 Historical, political and economic profile of Malawi

Malawi has been British Colony since 1891 and received full Independence in 1964 and became a Republic two years later. Until Independence the country was known as Nyasaland (GOM 1999; Nyasanet 1999). At Independence a Prime Minister was the head of the country. An executive president was the head of the country when the Republic status was attained. Under the constitution, a single chamber of Parliament enacts legislation (GOM 1989; GOM/UN 1992). Elected constituency representatives make up the Parliament (GOM 1989). The country is now divided into 192 parliamentary constituencies (Nyasanet 1999; NSO 1999). The representatives are elected every five years by a universal adult citizen suffrage. A single party dominated the political system until 1994 when multiparty democratization was adopted.

The constitution provides for the executive president to appoint Government ministers. It also provides for independence of the Judiciary from the Legislative and Executive arms of Government. The Judiciary has a separate system of Traditional Courts to deal with customary law. Four independent executive organs of Government (Judicial, Police, Public and Local Government Service Commissions) concerned with the appointment of public servants are also specified in the constitution. There are three strands of public administration; consisting of Central Government, Local Government and Traditional Authorities (GOM 1989; GOM/UN 1992). The Central Government consists of the Office of the President, about 20 Ministries, a few separate Departments not in Ministries and a number of Statutory Bodies most of which are concerned with business enterprises of Government. The Local Government is organized as a single tier system with a number of urban and rural councils to provide services to people under the supervision of the Ministry of Local Government. The Traditional Authority system has a hierarchy of village headmen, group village headmen, chiefs, and in some areas Paramount Chiefs. Appointment is normally hereditary but is subject to confirmation by Government. The structure has an important role in the political organization of the country and through its supervision by the District Administration of the Central Government, policies are communicated down to the village level. It complements other Government administrative systems as part of the delivery mechanisms and channels for the development to reach the people.

Malawi has a population of about 11 million[2], which grows at 3.5 % per annum (UNDP 1997). This population growth rate has placed Malawi ahead of other Sub-Saharan African

[2] Government's National Statistical Office will be conducting national population census in 1999 and expects to confirm the population to be between 11 and 12 million (NSO 1999).

countries in average density per square kilometre. The population is projected to reach 12 million next year but its growth rate of 3.5 % in 1997 is expected to be slowed down to 2.1 % by the year 2000 because of the AIDS epidemic (GOM 1989; ICLARM/GTZ 1991; GOM/UN 1992; Nyambose 1997). The majority of the people are young. In 1987, 46 % of the population was under 15 years, 50 % between 15 and 64 years, and 4 % over 64 in age (Ngwira et al. 1996). The distribution of the population is predominantly rural. In 1987 only 11 % of the people lived in urban areas. Urbanization is estimated to grow at the rate of 5-15 % annually (GOM/UN 1992; Ngwira et al. 1996), and 12 % by 1992 (Nyambose 1997, based on World Bank 1994).

Malawi has a narrow economic base. There are limited mineral resources. The economic activity is dominated by agriculture. Agriculture employs 85 % of the population and contributes 40 % of the GDP and 90 % of export revenues (GOM 1989; Nyasanet 1999). There are smallholder and estate sub-sectors of agriculture. The smallholder sub-sector accounts for 70 % of the agricultural production and meets the national requirements for staples when the right amount of rainfall is received during the cropping season. The sub-sector also provides for some of the agricultural raw materials. The staples include maize, beans, sweet potatoes and rice while the raw materials cover cotton and sun and / or fire cured tobacco (GOM 1989).

The estate sub-sector is responsible for the remainder of the agricultural production but contributes over two thirds of exports mainly from tobacco, tea and sugar. Some of the factors that aggravate the problems faced by the economy of Malawi (apart from a lack of exploitable mineral resources) are the high population density in relation to the arable land, and lack of seacoast which entails prohibitive costs in its external trade (GOM/UN 1992). The main imports of Malawi are intermediate materials for industry and transport (plant and machinery), and petroleum products (Nyasanet 1999).

1.4 Fish fauna and fisheries of Malawi

1.4.1 Fish fauna

Malawi is endowed with rich fish diversity, especially in the cichlid flock of Lake Malawi. Although there are as many as seventeen hydrographic basins in the country (ICLARM/GTZ 1991), only three are relevant for fish fauna and distribution of fish species (Kirk 1968): (1) the Lake Malawi catchment, (2) the Lake Chilwa and Chiuta depression, and (3) the Lower Shire Valley. The Lower Shire Valley with extensive marshes and lagoons has similar fish fauna to the Lower Zambezi River system (Tweddle et al. 1979). The presence of extensive falls in the middle course of the Shire River, the only outlet of Lake Malawi, separates it from the other two water resource areas. The Lower Shire Valley area has more families of fish, i.e., twenty compared to eleven in the Lake Malawi system. The number of species from the former only reaches 61 (Tweddle and Willoughby 1979; see Appendix 1.1). The Lake Chilwa and Chiuta drainage system with twenty-two fish species in six families (Kirk 1968; see Appendix 1.2) has a smaller number of both species and families of fish than the others. The Lake Malawi basin is the most important and has the largest number of fish species (Appendix 1.3). It includes Lake Malombe and upper and middle parts of Shire River in the south. It also covers Lake Malawi's six major inlets; Linthipe, Bua and Dwangwa in the central and Rukuru, Songwe and Ruhuru in the northern part of the lake

(Patterson and Kachinjika 1995). Compared to other lakes in the East African Rift Valley, the Malawi system has a very limited number of fish families (Lowe-McConnell 1975). For its size, the system especially Lake Malawi is said to have the world's most species-rich fish fauna and displays some of the most stunning bio-diversity on earth (Barel et al. 1985; McKaye 1985; Pitcher 1994). The wide array of species is due, in part, to the presence of many semi-isolated habitats, including floating islands (Oliver and McKaye 1982). Although Lake Malawi has been said to have limited habitat diversity (Fryer 1959), the ecological zones include stretches of rocky coastline, open sandy beaches, densely vegetated areas including reeded estuaries, swampy and sheltered bays, shallow but open inshore waters, offshore pelagic region, benthic mud surface water region and mudflats, and abyssal zone (Beadle 1974; Lowe-McConnell 1975).

1.4.2 Fisheries

The fish resources of the lakes, rivers and other water bodies in Malawi have been exploited using traditional methods by the lakeshore inhabitants dating back to time immemorial (GOM 1989; Banda and Tomasson 1997). Today, fishing operations employ many types of fishing methods as a result of differences between water bodies and, in some situations, within a water body. Despite the wide variety of fishing methods, which range from traps and weirs, beach and open seine nets to ring and trawl nets in high-tech fishing vessels, fishing operations are categorized into commercial (large scale) and traditional (small scale) fisheries (Ngwira et al. 1996). The use of advanced fishing technology is limited mainly to one private fishing company (MALDECO) and two research vessels belonging to the Government and an external funding agency.

The classification is said to be arbitrary and reflects ownership of the capital assets and organization of the fishery (Ngwira et al. 1996, based on the observations of Cambell and Townsley 1994). The earliest categorization of fisheries (Bertram et al. 1942) into 'European' and 'native' was based on the size of operation, quality of the gear and uses of the catch. Although written records began in 1938, interest in the lake's fish fauna by scientists started when a collection of fish was made and taken back to Britain by John Kirk, a member of Dr Livingstone's party after their arrival at the lake's shores in 1858 (Banda and Tomasson 1997).

A third category of fisheries is the ornamental or aquarium fisheries. The catches are not large, although it is very valuable (Table 1.1) for foreign exchange earnings (ICLARM/GTZ 1991). Commercial fishing started in 1935 when purse seining was introduced to Lake Malawi; however, it was not until 1968 when bottom trawling was adopted, that commercial fisheries developed (GOM 1989). The commercial fisheries, which consists of semi-industrial and industrial operations, use advanced fishing technology including pair trawlers for shallow and mid-waters, and deep-water stern trawlers. In addition, ring nets and 'Usipa rigs' (i.e., lift nets) are utilized. The boats in this category have propulsion power starting from 22HP. Commercial fisheries have been developed only on Lake Malawi.

With the exception of very few boats in the twenty-two fishing units of the commercial fisheries sector on the lake, craft in both traditional and commercial fisheries sectors carry out most of their fishing operations in the pelagic zone. The only difference is that the

Table 1.1 Landing and value of fish in Malawi[a].

Year	Catch (t*10^3)	Mean Beach Price (MK/kg)	Value (MK*10^6)	Export Value: Aquarium Fish (MK*10^3)	Export Value: Other Fish (MK*10^3)
1975	71.00	0.11	7.94	297.00	1060.00
1976	75.00	0.10	7.49	247.00	451.00
1977	68.00	0.10	6.82	244.00	802.00
1978	68.00	0.13	8.80	254.00	512.00
1979	60.00	0.14	8.37	168.00	671.00
1980	66.00	0.10	10.52	249.00	2085.00
1981	51.00	0.16	8.22	243.00	1436.00
1982	58.00	0.16	9.35	185.00	1138.00
1983	65.00	0.20	12.98	134.00	682.00
1984	65.00	0.27	17.65	163.00	87.00
1985	62.00	0.35	20.51	85.00	77.00
1986	73.00	0.38	27.65	449.00	172.00
1987	88.50	0.34	37.13	–	–
1988	78.80	0.64	71.71	–	–
1989	70.81	0.62	77.35	–	–
1990	74.10	0.80	59.28	–	–
1991	63.70	1.02	65.00	–	–
1992	69.50	1.12	82.42	–	–
1993	68.20	1.95	113.63	–	–
1994	59.91	4.99	298.93	–	–
1995	62.50	6.54	408.76	–	–
1996	64.13	7.72	495.06	–	–

Sources: GOM (1989); ICLARM/GTZ (1991); Bland (1996); MFD (1996).
[a]The rate of exchange of Malawi Kwacha (MK) per unit of US$ was 0.87 in 1975; 0.81 in 1980; 1.74 in 1985; 2.79 in 1989; and 15.3 in 1996 (ICLARM/GTZ 1991; National Bank of Malawi 1996; IMF 1998).

former concentrates in the zone less than one nautical mile from the shore while the latter are required by law to go further offshore and in waters of more than eighteen metres in depth (Banda and Tomasson 1997; see Appendix 1.7). Traditional fisheries are by far in the majority. They are characterized by numerous small-scale or subsistence fishing operations. They have for a long time employed nets, traps, hooks and other manual techniques (Table 1.2). Stupefacants or poisons (Appendix 1.4) were also used in some areas.

Table 1.2 Numbers of operating gears in the traditional fisheries in Malawi.

Year	Gill Nets	Long lines	Seine nets	Chilimila nets	Fish Traps	Hand lines	Nkacha nets	Scoop nets	Mosquito nets	Cast nets	Other gears
1985	13952	1923	761	1090	11716	405	152	46	160	543	244
1986	15057	1755	829	1253	16282	382	153	98	86	560	316
1987	17725	1901	873	1286	15516	486	150	61	149	526	273
1988	20341	2129	975	1347	13960	568	157	11	138	595	228
1989	15264	1846	1041	1428	16048	1190	144	43	124	455	272
1990	21035	2458	1152	1443	24607	5348	217	27	140	605	217
1991	17512	2912	1133	1541	21509	2178	237	41	214	343	183
1992	20409	2752	1249	1620	37742	2383	281	44	212	305	163
1993	22111	3014	1588	1632	53394	3280	263	59	65	450	279
1994	23320	3372	1842	1891	38449	5158	309	222	268	678	569
1995	23213	3177	946	2013	49913	12285	344	187	342	242	184

Source: MFD (1996).

Traditional fisheries now mostly use a variety of manufactured fishing gear which include gillnets, beach seines, open seines, long-lines, in addition to the locally made ones such as traps, weirs and fences (ICLARM/GTZ 1991; FAO 1993; Brummett and Noble 1995; Banda and Tomasson 1997; see Appendix 1.5). They contribute between 85 and 95 % (Fig. 1.2) of the total fish catch in the country. The fishing craft include canoes and plank boats. Outboard engines power some of the plank boats. The majority of the fishing craft are dugout canoes. Between 1985 and 1995, dugout canoes accounted for 78 % of all the fishing craft (Table 1.3).

Table 1.3 Numbers of traditional fishing craft in Malawi.

Year	Canoes	Boats	Total	% Canoes
1985	6653	2021	8674	77
1986	7651	2304	9955	77
1987	7698	2318	10016	77
1988	8724	2122	10846	80
1989	8462	2291	10753	79
1990	8971	2303	11274	80
1991	9710	2739	12449	78
1992	9858	2822	12680	78
1993	9112	2613	11725	78
1994	9715	2746	12461	78
1995	10477	2792	13269	79

Source: MFD (1996).

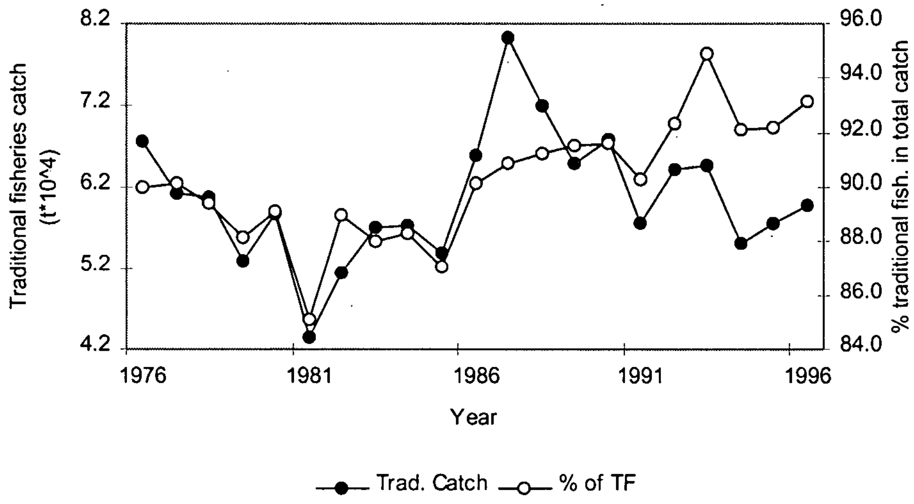


Figure 1.2 Trend of traditional fisheries catch and its contribution to fish landing in Malawi.

The MFD records fish catches in nineteen categories (see Appendix 4.1). These are based on single or group of species, identified species or group of species from some of the specific water bodies in the country, and finally differentiated through size for few of the species. In the traditional fisheries sector, the main species or groups of species that most influence the catch trends are Utaka (*Copadichromis* spp.) and Usipa (*Engraulicypris sardella*) in terms of the component they make to the total landings. The other major contributors are Chambo (*Oreochromis* spp.), Kambuzi (*Protomelas* spp.), Kampango (*Bagrus meridionalis*) and Mlamba (*Clarias* spp.). Many other species are also caught but make up much smaller percentage of the total catch as individual species (FAO 1993; Pitcher 1994; Turner 1996). The major part of the fish products from the capture fisheries is processed before they are marketed.

Fish processing techniques are limited to sun-drying, hot kiln or open fire smoking, applying insecticides (actellic)[3] in combination with sun-drying or smoking, and to a much less extent icing and freezing. It is estimated that 50 % of the catch is sun-dried, 30 % smoked and 10 % is sold either chilled or frozen. The remaining 10 % is consumed fresh (Hara 1993; Scholz et al. 1997). Fish smoking is one of the high fuelwood energy users. Together with other industry fuelwood uses of tea and tobacco drying and brickmaking, fish smoking consumes an estimated 30 % of the 7 million tonnes total fuelwood requirements in Malawi (Scholz et al. 1997). Salting or brining and caning have proved to be unsustainable as business activities mainly because of high costs (SADC[4] 1991). The fish is marketed locally except for a very small proportion of regional trade. However, internal market distribution is skewed towards the urban markets because many roads are in bad condition. Fish is mainly transported on bicycles, public transport, private vehicles, but sometimes or in certain areas head loads or ox-drawn carts are used (ICLARM/GTZ 1991; Hara 1993).

Aquaculture contributes marginally to the total fish landing in Malawi. Aquaculture began as rainbow trout (*Oncorhychus gairdnerii*) stocking programme for sport fishing on the high mountain streams as early as 1906 and black bass (*Micropterus salmoides*) in the 1920s. Pilot programmes to culture local fish species began in 1952 (ICLARM/GTZ 1991). Fish farming continues to be promoted as a complementary activity to capture fisheries in

---

[3] This is a trade name for specified chemical forms containing pyrethrum as a solution or dust product (SADC 1991).

[4] SADC stands for Southern African Development Community and its member countries are Angola, Botswana, Lesotho, Malawi, Mauritius, Mozambique, Namibia, South Africa, Swaziland, Tanzania, Zambia and Zimbabwe.

Malawi. It is very important in the household economy of smallholders. Of the land area estimated at up to 200,000 hectares in Malawi (ALCOM/FAO 1994) as having some potential for fish culture, there are only about 1,000 hectares of fish ponds (ICLARM/GTZ 1991). The fish culture production has a low yield approximated at 200 tonnes per annum for the 1,700 smallholders in the southern region of the country (Scholz et al. 1997) and possibly half as much in each of the other two regions of centre and north. Aquaculture has, however, not made much impact on a large scale even with the involvement of large estates which stock fish in their dams and reservoirs. Among the factors that influence aquaculture performance in Malawi are limited suitable land for expansion in areas where fish farming is currently practiced, erratic rainfall pattern, and limitation in the production potential (Scholz et al. 1997). In addition, impact of sociological and / or cultural factors is a major constraint to aquaculture adoption in Africa (ICLARM/GTZ 1991). However, some studies have reported high production potentials with minimal capital costs (Brummett and Noble 1995). Common aquaculture fish species in Malawi include *Oreochromis shiranus, Oreochromis shiranus chilwae, Tilapia rendalli, Serranochromis robutus* and *Oreochromis karongae.* Common carp (*Cyprinus carpio*) was also widespread in the southern part of the country before it was banned from culture for fear of interfering with the habitats of species-rich Lake Malawi (Brummett and Noble 1995). To a lesser extent species stocked in fishponds include *Barbus trimaculatus, B. paludinosus* and few other cichlid species (Eccles 1975; ICLARM/GTZ 1991; Brummett and Noble 1995). Rainbow trout (*O. gairdnerii*) and black bass (*M. salmoides*) are limited to mountain streams and large dams respectively (B. Rashidi, *pers. comm.*; ICLARM/GTZ 1991). Freshwater giant prawns (*Macrobrachium rosenbergii*) and a number of other cichlid and cyprinid species from Lake Malawi have also been cultured on experimental stations. The former continued to be raised on a very small scale by one of the sugar companies in the country. Interest to farm prawns has also been expressed by other entrepreneurs since 1980s (Mikkola 1996). Fish farming research has been focusing on improving pond productivity through integration with on farm resources for the smallholder and identifying local species as candidates for promotion in aquaculture. In addition general pond ecology and fish farming socio-economic studies have been carried out and have determined biophysical environment, cultural or social and economic potentials for fish farming in Malawi (Brummett and Noble 1995).

The fish resources are important for employment, income and source of protein and food security for the majority of the rural and urban poor. They are also highly valued as educational asset and natural heritage of aesthetic beauty (GOM 1989; ICLARM/GTZ 1991; SADC 1997). Although fish resources in Malawi contribute only 4 % to the GDP, they provide about 70 % of protein intake from animals and 40 % of the total protein intake to a cross section of the communities (ICLARM/GTZ 1991; Munthali 1997). The fisheries sector employs an estimated total of 230,000 people directly and indirectly (GOM 1989; Nyambose 1997). It is further assumed that the industry as a whole supports between 250,000 and 300,000 people when the average household size of 12 people is considered in the calculations (FAO 1993; Scholz et al. 1997). The fisheries sector also acts as a source of foreign exchange income from exports of aquarium or ornamental fish trade. The introduction of nylon nets in the 1940s and 1950s for gillnets and seines, their increased use in the 1960s, and expansion of the mechanized fishery in 1968 improved the fish landings from Lake Malawi and other water bodies. Fish consumption has however dropped from

14.7 kg per person in 1970 to 9.8 kg per person in early 1980s (ICLARM/GTZ 1991), 9.2 kg per person in late 1980s (Thomson and Mullin 1993) and stands at less than 7.0 kg per person from 1990 (Tenthani 1999). The high population growth rate creates a further deficit from the current shortfall of 39 % in fish supply to meet the recommended fish per capita consumption of up to 15 kg nationally (ICLARM/GTZ 1991, based on FAO 1983; SADC 1997; Tenthani 1999). The fish consumption of 15 kg per person per year is also difficult to achieve because of post-harvest losses, which fall within the range of 20-30 % (SADC 1991; see also Appendix 1.6). At the same time, some of the fish species appear to be fully exploited in a few lakes including some parts of Lake Malawi mainly due to a large increase in the craft and gears of artisanal fisheries sector (Banda and Tomasson 1997). The fish price at the beach shows a steady increase over the years. The mean income per fisher in real monetary value is, however, not following the same trend. The increase in the number of fishers and deterioration of the economy as a whole, are considered contributory factors.

1.5 Fisheries management in Malawi

The management of fisheries in the country is carried through the Fisheries Department (FD). The FD was established by an Act of Parliament in 1971 to implement the fisheries policy strategies. The FD has six divisions of (i) research, (ii) extension and development, (iii) training, (iv) fish farming, (v) management and administration, and (vi) the coordination of inland fisheries in the SADC area (MFD 1996; Ngwira et al. 1996). There are seven field offices that carry out activities pertaining to the achievement of the policy strategies. In addition to this, there is the headquarters of the department situated in the capital city, five of the offices are situated along the shores of Lake Malawi while one is in the Lakes Chilwa and Chiuta area and the other in the Lower Shire Valley. Further more, there are five field stations including two with laboratories for national and international initiated research programmes, two for fish farming programmes, the last one being a training institution. The major monitoring tool of the traditional fisheries is through carrying out annual frame surveys and monthly data collection organized in ten management zones. The zones are associated to fisheries of Lower Shire Valley, Lake Chilwa, Lake Chiuta, and Lake Malombe together with Upper Shire. The remaining six zones relate to fisheries of Lake Malawi. For the allocation and management of commercial fisheries, which occur only on Lake Malawi, the lake is also organized in fishing areas. There are nine areas where entry is regulated, at least in principle (ICLARM/GTZ 1991; Tweddle et al. 1994). The tenth zone is mainly inshore, available to traditional fishing operations, and is open access.

The fisheries sectoral policy objectives in Malawi aim to maximize the yield from the fish stocks in the national waters. This includes:

- Improving efficiency of exploitation, processing and marketing; and
- Exploiting all opportunities to expand existing , and develop new aquatic resources.

However, care is taken to protect endemic fish fauna as scientific and educational asset; and because they represent a particularly vulnerable major economic resource (GOM 1989; Ngwira et al. 1996; Scholz et al. 1997).

The sector complements the national development policy which include the objectives of:

- Poverty alleviation - through providing employment and thus financial income. At least 10 % of the national workforce or part of the rural population covering fishworkers (estimated at 230,000) and their families and other dependents (assumed to be as many as 250-300,000 in number) get their livelihood from activities in the sector (GOM/UN 1992; Scholz et al. 1997);

- Reduction of disease or improved health - the sector provides a large percentage (70 %) of the protein intake from animals and 40 % of protein intake from all sources (GOM 1989; ICLARM/GTZ 1991); and
- Income re-distribution - through involvement in both direct and indirect fisheries services.

The strategies that are pursued to achieve the above policy objectives include the following:

- Monitor and, where appropriate, control the exploitation of the fish fauna from national waters on continuing basis, directing and regulating production within safe sustainable yields for each individual fishery, and using the law to safeguard the resource from any other threat;
- Undertake a programme of research to identify and quantify under-utilized fish resources, particularly those in the offshore waters of Lake Malawi;
- Promote inter-territorial co-operation in fisheries matters on all shared waters to minimize resource duplication and obviate any risk of over-exploitation (GOM 1989; Ngwira et al. 1996); and, more recently,
- Promote community/fisher participation in the decision making process for the management of the fisheries and enforcement of the legislation and regulations that are acceptable to all stakeholders.

The fisheries regulations in the existing laws of Malawi are placed under the responsibility of the Fisheries Department. They include: the necessity to obtain a fishing license; closed seasons; prohibited methods of fishing; prohibited fishing gear and dimensions; and minimum size or length of fish (Ngwira et al. 1996; Scholz et al. 1997). The regulations are based on the Fisheries Act in the Laws of Malawi, Cap. 66:05 1974 and amended or supplemented in 1976, 1977, 1979, 1984 and 1996. These are viewed to be adequate measures for the management of fisheries in the country (see Appendix 1.7), if appropriately applied. A few of management measures for example in the Chambo fishery may need review in light of the recent research that showed inconsistency of minimum size, 15 cm versus size of 50 % maturity above 20 cm (FAO 1993; Palsson et al. 1998). However due to various factors including under-funding of enforcement programmes, and centralized management approach by enforcement of regulations through Government institutions, the measures have, in Malawi, been largely ineffective (Scholz et al. 1997). The situation fits many examples of crises in Government-controlled fisheries that prompt some form of stakeholder involvement (Emmerson 1980; Sen and Nielsen 1996; Norman et al. 1998).

Some effort is now being placed on involving the fishing communities in the management of the fisheries. Community participation in fisheries management as with other sectors has to be implemented with a lot of care. There are many factors that impinge on community involvement with the effect of causing initiatives to either succeed or fail. The factors include perception of communities, influence of Government or state, status of the economy -whether it is cash-based or not, technical limitations, shift in economic development orientation and language, assumptions that may be used when implementing community participation, degree of participatory orientation, and leadership (Nsiku 1994).

The factors that determine community participation initiatives have been especially researched and documented for Third World communities (Hulme and Turner 1990; Murphee 1993; Ferguson et al. 1993; Matowanyika et al. 1994; Sengupta 1996). In the case of Malawi, a few areas where community involvement in the management of fisheries has been actively pursued some drawbacks were experienced (Hara 1996; Scholz et al. 1997). There is however a big shift by Government now in encouraging involvement of user communities in management and conservation of natural resources. The Government has amended its legislation pertaining to fisheries in Malawi to recognize the roles and empower the fishing communities in the decision making process (Ngwira et al. 1996; Dobson 1996; Scholz et al. 1997).

1.6 Current issues and concerns in the fisheries sector in Malawi

The concerns in the fisheries sector in Malawi are many. They include resource utilization pressure, environmental degradation, and fish resource degradation. For Lake Malawi, four factors; high population growth, economic value of the lake (including fisheries as employer of last resort), culture of lake-shore inhabitants, and overfishing, were identified to contribute to the lake's environmental degradation (Nyambose 1997).

There is in general pressure to provide for the ever-growing demand for fish. But indiscriminate expansion of the fisheries cannot be the answer (Menz et al. 1995; Banda and

Tomasson 1997). Limited increase in fish catch may be possible when resource management is improved and post-harvest losses are reduced (SADC 1991). Increasing fish production may also be achieved by utilizing land for fish farming efficiently and integrating aquaculture with other farming systems (FAO/ALCOM 1994, based on Kapensky 1993; ICLARM 1994). In addition, utilization of the fish resources may be modestly expanded by including species such as edible clams, which occur in substantial quantities in sheltered sandy beaches along the shores of Lake Malawi (T. Gloerfelt-Tarp *pers. comm.*).

Environmental degradation involved the destruction of fish breeding areas; the accumulation of agro-chemicals within the catchment area of Lake Malawi (particularly along the rivers which are inlets to the lake); river and lake inshore siltation; and decrease in both size and life span of the most common fishing craft in Malawi, canoe (ICLARM/GTZ 1991; Banda and Tomasson 1997; Munthali 1997). Fish nesting areas are destroyed by gears that are dragged on the lake bottom (Banda and Hara 1994). Silt and debris cover up suitable breeding grounds for most of the inshore species. Primary productivity ceases due to sediment plumes causing huge shaded areas as a result fish and other aquatic life are adversely effected in the water system (Tenthani 1999). Excessive deforestation and high human population growth rate, which exerts strong pressure for land, aggravate the problems. Agriculture is practiced even in marginal areas, mountain slopes and riverbanks. The anadromous cyprinid species of Mpasa *Opsaridium microlepis* and Sanjika *Opsaridium micrcephalus* are becoming more vulnerable. Trees suitable for large and long-lasting canoes are no longer available.

Fish resources degradation, especially through overfishing has been reported in a number of cases. Decline in the catches has for a long time been observed in Nchila *Labeo mesops*. Although a very fecund species it has not been able to regenerate to its original stock sizes (Tweddle et al. 1994). Chambo (*Oreochromis* spp.) have also been overfished in Lake Malombe and other areas where they occur with exception of the southeast arm of Lake Malawi. There is thus the danger that a slight increase in effort will have disastrous consequences (FAO 1993). It is possible that other species, which do not contribute significantly to catches and have not been described, can also disappear without being noticed (Munthali 1997). In general there has been a decline in the catch per fisher with the result of increased ill-will or finger pointing between the commercial and artisanal fishers as well as increased flouting of fisheries regulations (Scholz et al. 1997). Changes in composition of catch and fish size have occurred in the southern part of Lake Malawi (Turner 1977a; Tweddle and Magasa 1989; Turner et al. 1995).

1.7 Why model the fisheries of Lake Malawi

Sustainable utilization of renewable natural resources such as fisheries for the benefit of all stakeholders in future requires proper or rational management. The fundamental principal of sustainable fisheries management is the knowledge or understanding of the biology and ecology of fish stocks (Pitcher and Hart 1982). Lake Malawi is the major water body in Malawi and it is important for fish resources (Section 1.4.1), water, transport, recreation, electricity and irrigation (GOM 1989; Nyambose 1997). There have been several research programmes or studies on Lake Malawi (Anon 1988; Tweddle and Mkoko 1989; Tweddle 1991). But studies that related the lake's ecosystem and fish resources have so far not covered all areas (Allison et al. 1995b; Pitcher 1994; Turner 1996). It is now recognized that management of resources especially fisheries must encompass all users or requires mutually agreed system of controls with appropriate forms of enforcement to ensure responsible use and conservation of the resource (Emmerson 1980; FAO 1986; Munthali 1997; Tailor and Alden 1998). There are examples of fisheries failures all over the world (Pitcher and Hart 1982; Sen and Nielsen 1996; Tailor and Alden 1998). The involvement of stakeholders of fisheries is just beginning in Malawi (GOM 1989; Ngwira et al. 1996; Turner 1995; Scholz et al. 1997). It is imperative that there is full understanding of the resources even as the fishing community starts to be involved.

Biological and social considerations are thus required to develop effective management of Lake Malawi's fisheries. The next four chapters cover comparisons of the lake's fisheries by means of 'Rapfish' analysis; construction of the ecosystem trophic model of the lake; analysis of catches and maximum lengths of fish and their trophic levels; and finally exploring alternative policies for exploiting the lake through simulation of biomasses and catches for a period of 20 years. This is done with the aim of strengthening knowledge of the lake's ecosystem and fish resources.

CHAPTER 2:

COMPARISONS OF LAKE MALAWI FISHERIES: A RAPFISH ANALYSIS

2.1 Introduction to Rapfish and objective of the analysis

'Rapfish' is a recently developed rapid appraisal technique that analyzes the health status of fisheries with respect to sustainability (Pitcher et al. 1998a). Rapfish uses information from different disciplines in the form of scores for specific attributes. When the scores are ordinated with multidimensional scaling (MDS), the technique obtains its properties of being objective, replicable, and thus reliable (Pitcher et al. 1998a).

Rapfish is a useful tool in assessment of the problems in a fishery since relatively easily obtainable information is used as opposed to depending on results from complex stock assessment (Pitcher et al. 1998a). Signs of poor health status or serious problems, which may be diagnosed early, enable appropriate or mitigating measures to be carried out in time and possibly save a fishery. The technique considers aspects other than the 'traditional' biological and, to a lesser extent, economic science on which to base the management decisions. At the same time fisheries or 'fisheries management' has always grappled with the problem of expressing human dimension (Jentoft 1998; Pitcher et al. 1998a). Rapfish attempts to accommodate the human component. It avoids subjective weightings by different observers and assigns equal weight to all attributes in the ordination.

The purpose of undertaking a 'Rapfish' analysis is to evaluate the heath status of (i) twelve traditional species-based fisheries for three different years (1985, 1990, & 1995), and (ii) seven gear-based fisheries in Lake Malawi as detailed in Table 2.1. The analysis is then considered in light of the current conditions and information about the lake and its fisheries.

Table 2.1 Lake Malawi fish and fisheries used in the Rapfish analysis, showing abbreviations used in the analysis.

	Species-based Fisheries			**Gear-based Fisheries**	
No.	**Fishery for 1985, 1990 and 1995 years**	**Abbr.**	**No.**	**Fishery**	**Abbr.**
1	Chambo (*Oreochromis* spp.)	Ch	1	Commercial	Com
2	Chilunguni (*Tilapia rendalli* & *Oreochromis shiranus*)	Otil	2	Semi-commercial	Semc
3	Kambuzi (*Protomelas similis* & other haplochromines)	Ka	3	Chambo seine	Cs
4	Utaka (*Copadichromis* spp.)	Ut	4	Kambuzi seine	Ks
5	Chisawasawa (*Lethrinops* spp.)	Chis	5	Gillnet	Gn
6	Kampango (*Bagrus meridionalis*)	Kam	6	Pair trawl	Pt
7	Mlamba (*Clarias* spp.)	Mla	7	Midwater trawl	Mwt
8	Usipa (*Engraulicypris sardella*)	Usi			
9	Nchila (*Labeo mesops*)	Nch			
10	Mpasa (*Opsaridium microlepis*)	Mpa			
11	Sanjika (*Opsaridium microcephalus*)	San			
12	Other species (Bombe *Bathyclarias* spp., Ndunduma *Diplotaxodon* spp. and *Synodontis njassae* as well as many more)	Os			

2.2 Rapfish methodology

Rapfish, which was developed at the Fisheries Centre, University of British Columbia, is designed to allow an objective multidisciplinary evaluation of the status of fisheries, without aiming to replace conventional stock assessment (Pitcher et al. 1998b). The version[5] of Rapfish employed in this study evaluates attributes from five categories; ecological, economic, sociological, technological, and ethical disciplines. The attributes are presented in

[5] The latest version of Rapfish includes a sixth category of FAO 'Code of Conduct' (Pitcher 1999).

Table 2.2. Scores assigned to the attributes are ordinated within the categories through multidimensional scaling (MDS), implemented using SPSS[6] software (Pitcher et al. 1998a). The Rapfish technique as used in this analysis is modified to include ethical attributes (Pitcher and Power in press); and changes made during a 1998/99 course module on Rapid Appraisal Methods for Fisheries offered at the Fisheries Centre, University of British Columbia. An example of the changes is catch per fisher, an attribute in the economical category. It is removed in the Rapfish analysis as it cannot be used to show the health status of a fishery in terms of sustainability one way or the other, i.e., whether the value is low or high.

The scoring specifications for the attributes are used to assign values in respect of each fishery. The application of MDS routine to statistically ordinate attribute scores in the categories or disciplines is described in Pitcher and Preikshot (1999) and Pitcher (1999). Goodness-of-fit in the attribute score ordination is evaluated using stress values. The stress values are considered acceptable when they are below 0.25 (see Appendices 2.2-3). The ordinated scores in the categories may be pooled to obtain a multidisciplinary MDS. Further use of randomly generated fisheries, and maximum and minimum attribute values as 'Good' and 'Bad' fisheries assists in the analysis by providing fixed reference points or 'anchors' (Pitcher and Preikshot 1999; Pitcher et al. 1998a,b). The basic steps in the Rapfish procedure are described in Appendix 2.3.

[6] SPSS is a 'software package for microcomputer data management and analysis' manufactured by SPSS Inc. The version used in this analysis is 7.5.1 of 1996.

Table 2.2 Attributes and scoring procedure in the Rapfish analysis in five disciplines.

	Attribute	Scoring	Good	Bad	Notes
	Ecological				
1	Exploitation status	0; 1; 2; 3	0	3	FAO-like scale: low/under-(0), fully-(1), heavily-(2); over-exploited(3)
2	Recruitment variability	0; 1; 2	0	2	COV : low <40 %(0) ; medium 40-100 %(1); high >100 %(2)
3	Trophic level	Number	high	low	Average trophic level of species in catch
4	Change in trophic level	0;1; 2	0	2	is trophic level of fisheries sector decreasing: no(0), somewhat slowly (1), rapidly (2)
5	Migratory range	0; 1; 2	0	2	# of jurisdictions encountered during migration (includes international waters): 1- 2(0); 3-4(1) >4(2)
6	Range collapse	0; 1; 2	0	2	is there any evidence of geographic range reduction? no(0), a little (1), a lot, rapid (2)
7	Size of fish	0;1; 2	0	2	has average fish size landed changed in past 5 years: no (0), yes, a gradual change(1), yes, a rapid large change (2)
8	Catch before maturity	0; 1; 2	0	2	Percentage caught before maturity : none(0); some (>30 %)(1); lots (>60 %)(2)
9	Discarded by-catch	0; 1; 2	0	2	Percentage of target catch: low 0-10 %(0); medium 10-40 %(1); high >40 %(2)
10	Species caught	0; 1; 2	0	2	Includes species caught as by-catch: low 1-10(0); medium 10-100(1); high >100(2)
11	Primary production	0; 1; 2; 3	3	0	$GCm^{-2}year^{-1}$: low=0-50(0); medium =50-90(1); high=90-150(2); very high >160(3)
	Economic				
1	Price	0; 1; 2; 3; 4; 5	5	0	US$/tonne of landed product for time of data point; <250 (0); 250-900 (1); 900-1500 (2); 1500-3000 (3); 3000-5000(4), >5000 (5)
2	Fisheries in GDP	0; 1; 2	2	0	Importance of fisheries sector in national economy: low(0); medium(1); high(2)
3	GDP/person	US$/capita	high	low	in country , region, etc. of fishery
4	Limited entry	0; 1; 2	2	0	Almost none(0); some(1); most(2), (includes informal limitation)
5	Marketable right	0; 1; 2	2	0	Marketable right/quota/share: none(0); some(1); full ITQ(2)
6	Other income	0; 1; 2; 3	0	3	in the fishery, fishing is mainly: casual (0); part-time (1); seasonal (2); full-time (3)
7	Sector employment	0; 1; 2	0	2	Employment of formal sector of the fishery: <10 %(0); 10-20 %(1); >20 %(2)
8	Ownership	0; 1; 2	0	2	Profit from fishery mainly to: locals(0); mixed(1); foreigners(2)
9	Market	0; 1; 2	0	2	Market is principally: local/national (0); national/regional(1); international(2)
10	Subsidies	0; 1; 2	0	2	are subsidies (including hidden) provided to support the fishery?: no(0); somewhat (1); large subsidies(2)
	Sociological				
1	Socialization of fishing	0; 1; 2	2	0	Fishers work as: individuals(0); families(1); community groups(2)
2	Fishing community growth	0; 1; 2	0	2	Growth over past 10 years (pre-data point): <10 %(0); 10-20 %(1); >20 %(2)
3	Fishing sector	0; 1; 2	0	2	Households fishing in the community: <1/3(0); 1/3-2/3(1); >2/3(2)
4	Environmental knowledge	0; 1; 2	2	0	Level of knowledge about environmental issues and the fishery: below/none(0); same/some(1); lots/above population average(2)
5	Education level	0; 1; 2	2	0	Education level compared to population average: below (0); at par (1); above (2)
6	Conflict status	0; 1; 2	0	2	Level of conflict with other sectors: none(0); some(1); lots(2)
7	Fisher influence	0; 1; 2	2	0	Strength of fisher direct influence on actual fishery regulations: almost none(0); some(1); lots(2)
8	Fishing income	0; 1; 2	2	0	Fishing income as % total family income: <50 % (0); 50-80 % (1); >80 % (2)
9	Kin participation	0;1	1	0	do kin sell family catch and/or process fish: no (0) or yes(1)

Table 2.2 Attributes and scoring procedure in the analysis disciplines (continued).

	Attribute	Scoring	Good	Bad	Notes
	Technological				
1	Trip length	Days	low	high	Average days at sea per fishing trip
2	Landing sites	0; 1; 2	0	2	are landing sites: dispersed(0); somewhat centralized(1); heavily centralized(2)
3	Pre-sale processing	0; 1; 2	2	0	Processing before sale e.g. gutting, filleting: none(0); some(1); lots(2)
4	Use of ice	0; 1; 2; 3	3	0	None(0); some(1); lots/sophisticated (e.g. flash freezing, champagne ice) (2); live tanks(3)
5	Gear	0; 1	0	1	gear is: passive (0); active(1)
6	Selective gear	0; 1; 2	2	0	Device(s) in gear to increase selectivity: few(0); some(1); lots(2)
7	Power gear	0; 1	0	1	is gear power assisted?: no (0); yes(1)
8	FADS	0; 0.5; 1	0	1	Fish aggregation devices - FADS: not used(0); bait is used(0.5); FADS are used a lot(1)
9	SONAR	0; 0.5; 1	0	1	is SONAR used : no(0); sounders are used (0.5); yes(1)
10	Vessel size	0; 1; 2	0	2	Average length of vessels: <8m(0); 8-17m(1); >17m(2)
11	Catching power	0;1; 2; 3	0	3	have fishers changed gear and vessel to increase catching power over past 5 years?: no(0); few(1), somewhat (2); a lot, rapid increase (3)
12	Gear side-effects	0; 1;2	0	2	does use of gear have undesirable side effects (cyanide, dynamite, trawl): no(0); some(1); a lot(2)
	Ethical				
1	Adjacency and reliance	0;1; 2; 3	3	0	Geographical proximity & historical connection: not adjacent/no reliance (0); not adjacent/some Reliance(1); adjacent/some reliance(2), adjacent/strong reliance(3)
2	Alternatives	0; 1; 2	2	0	Alternatives to the fishery within the community: none(0); some(1); lots(2)
3	Equity in entry to fishery	0; 1; 2	2	0	is entry based on traditional/historical access/harvests?: not considered(0); considered (1);traditional indigenous fishery (2)
4	Just management	0;1; 2; 3; 4	4	0	Level of inclusion of fishers in management of fishery: none(0); consultations(1); co-mgmt/gov't leading (2); co-mgmt/community leading (3); co-mgmt with all parties equal (4)
5	Influences -ethical formation	0;1; 2; 3; 4	4	0	Structures which could influence values: strong negative (0); some negative (1), neutral (2); some positive (3); strong positive (4)
6	Mitigation -habitat destruction	0;1; 2; 3; 4	4	0	Attempts to mitigate damage to fish habitat: much damage (0), some damage (1); no ongoing damage or mitigation(2); some mitigation (3); much mitigation (4)
7	Ecosystem -depletion mitigation	0;1; 2; 3; 4	4	0	Attempts to mitigate fisheries-induced ecosystem change: much ongoing(0), some ongoing(1); none ongoing/no mitigation(2); some mitigation(3); much mitigation(4)
8	Illegal fishing	0; 1; 2	0	2	Illegal catching/poaching/transshipments: none(0); some(1); lots(2)
9	Discards/wastes	0; 1; 2	0	2	Discard and waste of fish: none(0); some(1);lots(2)

Sources: Pitcher and Preikshot (1999); Pitcher and Power (in press); Pitcher (1999).

Preliminary scores for each attribute were sent to various experts who are familiar with the fisheries of Lake Malawi for validation (comments on adjusting the scores were only received from Professor T. J. Pitcher at the University of British Columbia). Information used for the scores (Appendix 2.1) was mainly obtained from literature and from the Malawi Fisheries Department. 'Weighing' the scores in some of the attributes against factors such as value or catch of a fishery separates known differences in fisheries that score similar values when based on the scoring procedure in Table 2.2. An example of differentiation of scores is in the economic category attribute of 'fisheries in GDP'. The GDP score is low for the fisheries in Malawi but the catch of each fishery and its beach price are used to obtain the fishery values. Percentage ranks of the fisheries, based on their values, are obtained (Table 2.3) which are then used to calculate each fishery's score for economic attribute 'fisheries in GDP'.

Table 2.3 Rating of the fisheries based on value[7] (fisheries as in Table 2.1).

Year	1985[8]			1990			1995	
Fishery	Value MK'000	%	Fishery	Value MK'000	%	Fishery	Value MK'000	%
All fisheries	11286	100.00		25755	100.00		344213	100.00
Gn[9]	4007	35.50	Ut	9013	35.00	Usi	140342	40.77
Ch	3225	28.58	Ch	4226	16.41	Ut	55173	16.03
Com[10]	2288	20.27	Ka	3058	11.87	Os	31939	9.28
Usi	1873	16.60	Os	2071	8.04	Ch	26078	7.58
Mwt	1662	14.73	Kam	1618	6.28	Kam	22376	6.50
Semc	1569	13.90	Usi	1260	4.89	Ka	13724	3.99
Pt	1299	11.51	Mla	1141	4.43	Mla	12686	3.69
Ut	1208	10.70	Otil	259	1.01	Mch	2698	0.78
Ks	1149	10.18	Mpa	252	0.98	Mpa	2559	0.74
Cs	508	4.50	Chis	246	0.96	San	2363	0.69
Ka	457	4.05	Mch	201	0.78	Otil	1979	0.57
Kam	355	3.15	San	158	0.61	Nch	1258	0.37
Os	263	2.33	Nch	21	0.08	Chis	1111	0.32
Mla	248	2.20						
Mch[11]	111	0.98						
Chis	100	0.89						
Mpa	61	0.54						
Otil	47	0.42						
San	27	0.24						
Nch	8	0.07						

Source for catch and price: MDF (1996); see also Table 4.3.

[7] Value is from catch and beach price. MK is the Malawi currency, Malawian Kwacha. The exchange rates to 1US$ were on average 1.7 in 1985, 3.0 in 1990 and 15.0 in 1995.
[8] Average price for the species in 1986
[9] Mean price for all the species was used for Mcheni and all gear-based fisheries
[10] MALDECO (the only major industrial fishing company) is reported to have had a turnover of MK 1,953,400 in 1985.
[11] Mch stands for Mcheni *Ramphochromis* spp. This species was not used in the analysis as it only began to be recorded separately in Malawi Fisheries Statistics in 1994 and was usually included in the category of Other species (Os).

Other attributes where this technique was used are 'sector employment' and 'market' (in the economic category), and 'fishing community growth' (in the sociological category). In the latter, attribute changes in number of fishers, crafts and gears are used to differentiate the scores assigned to each fishery.

2.3 Results and discussion of the Rapfish analysis

2.3.1 Results

The attribute scores are presented in Appendix 2.1. They are not easy to differentiate among the periods of 1985, 1990 and 1995 in the species-based fisheries. There are however a few attributes with scores that do stand out. Attributes of 'change in trophic level' and 'range collapse' in the ecological category show scores with clear range differences in an increasing order for the 1985, 1990 and 1995. In the economic category scores decrease with time in the 'GDP/person' and 'limited entry'. Scores increase with time in the 'fishing sector' attribute of the sociological category. In the technological category scores change from low to high levels between 1985 and 1990 only for the 'catching power' attribute. Clear score differences also occur in only one attribute in the ethical category. 'Just management' scores decrease with time.

In the gear-based fisheries, scores are not distinct for any particular gear in the ecological category. Scores for the small scale gears stand out in a few attributes in all the categories except for the ecological category. 'Limited entry', 'other income' and 'subsidies' in the economic category have lower scores for the small scale fisheries (Cs, Ks & Gn) than for the large scale fisheries (Com, Semc, Pt & Mwt). Similar cases exist for 'fishing sector', 'fisher influence' and 'fishing income' in the sociological category; and 'landing sites', 'use of ice', and 'power gear' in the technological category. In the ethical category, however, except for 'just management' attribute which has lower scores for the small scale fisheries, the attributes of 'adjacency and reliance', 'equity in entry' and 'influences in ethical formation' have higher scores for the small scale fisheries than the large scale ones (Appendix 2.1).

Table 2.4 presents the ordinated values of attributes in the five categories, as well as a combined multidisciplinary analysis. Note that these scores run from minus 3 standard deviations (sds) to plus 3 sds – as output by MDS. Later, in this analysis, these are replaced by percentage scores expressing the distance along the Bad (0 %) to Good (100 %) axis. Note also that MDS axis 1 lies between 'Bad' and 'Good', as transformation achieved by rotating the raw MDS ordination scores, and hence expresses sustainability. Axis 2 represents differences among the fisheries not related to sustainability. is evaluated using stress values. The stress scores, signifying goodness-of-fit, are below 0.25 which is within the acceptable range in all the categories as well as the interdisciplinary ordination (Table 2.4). The lowest stress score is for the sociological category with a value of 0.13 and the highest is for the technological category at 0.24.

Table 2.4 Ordinated attribute values in dimension 1 (left) and dimension 2 (right) columns for the Lake Malawi fisheries in the five categories and for a combined ordination. The stress value is a goodness-of-fit criterion for MDS: values lower than 0.28 indicate acceptable ordinations. 'Good' and 'Bad' refer to constructed fixed reference point fisheries.

Fishery	Attribute Category											
	Ecological		Economic		Sociolog.		Technolog.		Ethical		Combined	
	1	2	1	2	1	2	1	2	1	2	1	2
Ch85	1.03	1.26	0.33	-1.09	1.24	-0.17	0.49	-1.10	-0.10	0.85	0.97	-0.19
Otil85	1.07	1.19	0.58	0.62	1.42	0.05	0.82	-0.59	0.05	1.06	1.00	-0.32
Ka85	0.51	0.87	0.87	0.02	1.53	0.28	1.24	0.47	-0.25	1.08	1.06	0.06
Ut85	0.47	1.04	0.78	-0.92	1.53	0.28	0.53	-0.03	0.25	0.92	0.90	-0.12
Chis85	0.38	0.70	0.58	0.68	1.42	0.05	0.53	-0.03	0.33	0.56	0.60	-0.27
Kam85	-1.62	0.38	0.68	-0.31	1.35	-0.09	-0.03	-0.95	0.86	1.09	0.86	-0.74
Mla85	-0.71	0.48	0.68	-0.31	1.35	-0.09	0.60	-1.32	0.86	1.09	0.97	-0.61
Usi85	-1.78	0.98	0.86	0.07	1.53	0.28	0.82	0.47	0.47	0.84	1.02	-0.51
Nch85	-0.13	0.98	1.04	0.50	1.45	-0.52	1.56	-0.15	0.68	0.93	1.12	-0.30
Mpa85	-1.69	-0.63	0.82	1.24	1.45	-0.52	0.88	-1.20	1.15	1.14	1.30	-0.92
San85	-1.69	-0.63	0.67	0.84	1.45	-0.52	0.93	-1.05	1.15	1.14	1.18	-0.84
Os85	-1.76	0.75	0.64	-1.11	1.61	-0.30	1.27	-0.14	0.48	0.92	1.26	-0.29
Ch90	1.62	0.41	0.37	-0.98	0.71	0.20	0.60	0.30	-0.80	0.59	0.45	0.71
Otil90	1.40	0.46	0.53	0.33	0.71	0.20	0.77	0.10	-0.80	0.59	0.57	0.25
Ka90	0.78	0.14	0.64	-0.15	0.86	0.33	0.99	0.81	-1.06	0.42	0.52	0.60
Ut90	0.85	0.44	0.92	-0.09	0.86	0.33	0.34	0.65	-0.63	0.42	0.43	0.41
Chis90	0.73	-0.15	0.55	0.39	0.71	0.20	0.34	0.65	-0.63	0.42	0.22	0.33
Kam90	-0.83	-0.44	0.44	-0.33	0.65	0.10	-0.13	-0.37	-0.07	0.98	0.41	-0.07
Mla90	-0.28	-0.28	0.59	-0.38	0.65	0.10	0.60	-0.95	0.30	1.14	0.70	-0.24
Usi90	-1.50	0.50	0.58	-0.14	0.86	0.33	0.61	0.80	-0.63	0.43	0.64	-0.03
Nch90	0.45	-0.71	0.65	0.65	0.77	-0.44	1.46	0.48	-0.28	0.52	0.60	0.52
Mpa90	-1.16	-1.18	0.69	0.79	0.77	-0.44	0.88	-0.61	0.18	0.81	0.87	-0.21
San90	-1.16	-1.18	0.65	0.74	0.77	-0.44	0.88	-0.61	0.18	0.81	0.85	-0.20
Os90	-0.94	-0.12	0.44	-0.33	1.02	-0.22	1.23	0.50	-0.62	0.62	0.65	0.34
Ch95	2.32	-0.32	0.84	-1.07	0.14	0.39	0.61	0.34	-1.27	-0.20	0.29	1.23
Otil95	1.88	-0.17	0.93	0.42	0.14	0.39	0.79	0.33	-1.27	-0.20	0.34	0.84
Ka95	1.29	-0.29	1.20	-0.92	0.28	0.62	0.93	0.81	-1.64	-0.41	0.42	1.20
Ut95	1.35	-0.49	0.89	-0.26	0.28	0.62	0.43	0.80	-0.92	0.11	0.30	0.78
Chis95	1.20	-0.68	0.93	0.42	0.14	0.39	0.43	0.80	-0.79	-0.48	0.06	0.73
Kam95	-1.00	-1.00	0.70	-0.48	0.05	0.19	-0.07	-0.26	-0.28	0.60	0.32	0.12
Mla95	0.04	-0.71	0.90	-0.44	0.05	0.19	0.60	-0.95	0.09	1.10	0.71	-0.05
Usi95	-1.35	-0.53	1.31	0.12	0.28	0.62	0.45	0.83	-1.10	-0.07	0.57	0.51
Nch95	1.05	-1.72	1.06	0.86	0.20	-0.54	1.13	0.58	-0.91	0.69	0.63	1.18
Mpa95	-0.66	-2.38	1.20	1.01	0.20	-0.54	0.70	-0.08	-0.82	0.97	0.99	1.04
San95	-0.66	-2.38	1.02	0.75	0.20	-0.54	0.70	-0.08	-0.82	0.97	0.88	1.03
Os95	-0.66	-0.79	0.69	-0.49	0.49	-0.37	1.24	0.50	-1.15	-0.20	0.39	0.81
Com	0.37	-0.35	-3.65	0.42	-3.50	-0.17	-2.81	1.52	0.73	-2.44	-3.39	-0.17
Semc	0.36	-0.33	-0.45	0.81	-3.10	0.49	-0.32	1.18	-0.71	-1.67	-1.40	0.51
Cs	2.10	0.11	0.74	-0.29	-0.03	1.00	1.13	-0.38	-1.01	0.87	1.06	0.51
Ks	1.65	-0.13	1.11	-0.66	0.47	0.67	1.13	0.55	-2.29	0.58	0.93	1.31
Gn	0.31	1.78	0.92	-0.75	0.33	0.53	0.78	-1.66	1.12	1.66	1.35	-1.09
Pt	0.34	-0.42	-1.20	1.14	-3.16	0.36	-0.75	1.20	-0.22	-1.70	-1.72	0.27
Mwt	0.04	-0.33	-2.80	1.30	-3.36	0.03	-2.81	1.51	0.26	-2.30	-3.09	-0.19
GOOD	-1.96	2.28	-1.22	3.15	-0.72	2.42	0.61	-2.54	2.98	0.39	0.53	-4.25
BAD	1.98	-2.22	-1.16	-2.56	-1.06	-2.67	-2.36	2.72	-2.32	-2.27	-2.83	3.56
Stress	0.22		0.21		0.13		0.24		0.17		0.17	

In the 1985 species-based fisheries, the Chilunguni (Otil) fishery ordinated highest values of 1.07 and 1.19 in dimension one and two respectively for the ecological category. The lowest values are those of Usipa (Usi) *Engraulicypris sardella* fishery in dimension one (-1.78) and *Opsaridium* fisheries of Mpasa (Mpa) and Sanjika (San) in dimension two (-0.63). Nchila (Nch) *Labeo mesops* and Mpasa (Mpa) *Opsaridium microlepis* fisheries have the highest ordinated values of 1.04 and 1.24 in dimensions one and two respectively in the economic category. The lowest values in the category are from Chambo (Ch) *Oreochromis* spp. and Other species (Os) fisheries with values of 0.33 and -1.11 in dimensions one and two respectively. The sociological category has respective highest and lowest values in Other species (Os) and Chambo (Ch) fisheries in dimension one, and Usipa (Usi) and a group of three fisheries (Nchila (Nch), Mpasa (Mpa) and Sanjika (San)) in dimension two. In the technological category, Nchila and Kambuzi (Ka) *Protomelas* spp. fisheries have highest ordinated values in dimensions one and two respectively while respective fisheries of Kampango (Kam) *Bagrus meridionalis* and Mlamba (Mla) *Clarias* spp. have lowest values in dimensions one and two. *Opsaridium* fisheries are, in the ethical category, at the highest position in both dimensions one and two. The Kambuzi (Ka) and Chisawasawa (Chis) *Lethrinops* spp. fisheries are respectively at lowest positions in dimensions one and two. The combined or interdisciplinary ordination registers Mpasa (Mpa) and Kambuzi (Ka) with highest values of 1.30 and 0.06 in dimensions one and two respectively. The lowest values in the respective dimensions are for Chisawasawa (Chis) and Mpasa (Mpa) fisheries.

In the 1990 and 1995 periods, dimension two (expressing differences unrelated to sustainability) of the ecological category has highest and lowest ordinated values taken up by similar fisheries to those in 1985 period as might be expected. The same situation occurs for the highest positions of dimension two in economic category, lowest positions in dimension two and one of sociological and technological categories respectively and finally highest and lowest values in dimensions two and one of the technological category and combined or interdisciplinary ordination respectively. For the comparison of the ordinated values in the 1990 and 1995 periods, fisheries that fell on similar positions in the two periods occur in two categories and the interdisciplinary ordination. Chambo and Usipa fisheries obtain respective highest and lowest values in dimension one while Chilunguni (Otil) and *Opsaridium* fisheries do that in dimension two in the ecological category. In the sociological category, it is the fisheries of Other species (Os) and a group of two (Kampango and Mlamba) at respective highest and lowest positions in dimension one. In dimension two, the two respective positions are for fisheries of groups of two (Kambuzi and Utaka (Ut) *Copadichromis* spp.). and three (Nchila, Mpasa and Sanjika). In the combined or interdisciplinary ordination, Mpasa and Chisawasawa have highest and lowest values respectively in dimension one; and Chambo and Mlamba fisheries have the respective values in dimension two.

In the gear-based fisheries, the Gillnet (Gn) fishery has highest positions in dimension one of the ethical category and interdisciplinary ordination and in dimension two of ecological and ethical categories. The Commercial (Com) fishery has lowest positions in dimension one of economic, sociological and technological categories in addition to the interdisciplinary ordination and in dimension two of sociological and ethical categories. The interdisciplinary ordination of gear-based fisheries also places the Gillnet and Commercial fisheries in highest and lowest positions respectively in dimension one. In dimension two the respective positions are for Kambuzi Seine (Ks) and Gillnet fisheries.

The ordination plots (Fig. 2.1) show ordinated value positions in each category, which are summarized by the interdisciplinary ordination (Fig. 2.1f). The species-based fisheries have overall 'good' results in 1985 followed by 1990 and then 1995 period. The positions are, however, mixed in the economic and sociological categories. In the technological category, most positions for the 1985 fisheries are on the 'bad' side while those of 1990 and 1995 are mixed. The gear-based fisheries have more 'good' positions for the small scale group of Chambo seine (Cs), Kambuzi seine (Ks) and Gillnet (Gn) fisheries, in the combined ordination. They are unlike the large scale group of Commercial (Com) and Semi-commercial (Semc) fisheries or large scale individual gear operation group of Pair trawl (Pt) and Midwater trawl (Mwt) fisheries which have all of their positions on the 'bad' side (Fig. 2.1f). The small scale fisheries' positions are on the 'bad' side In the economic and technological categories. They are all on the 'good' side in the sociological category.

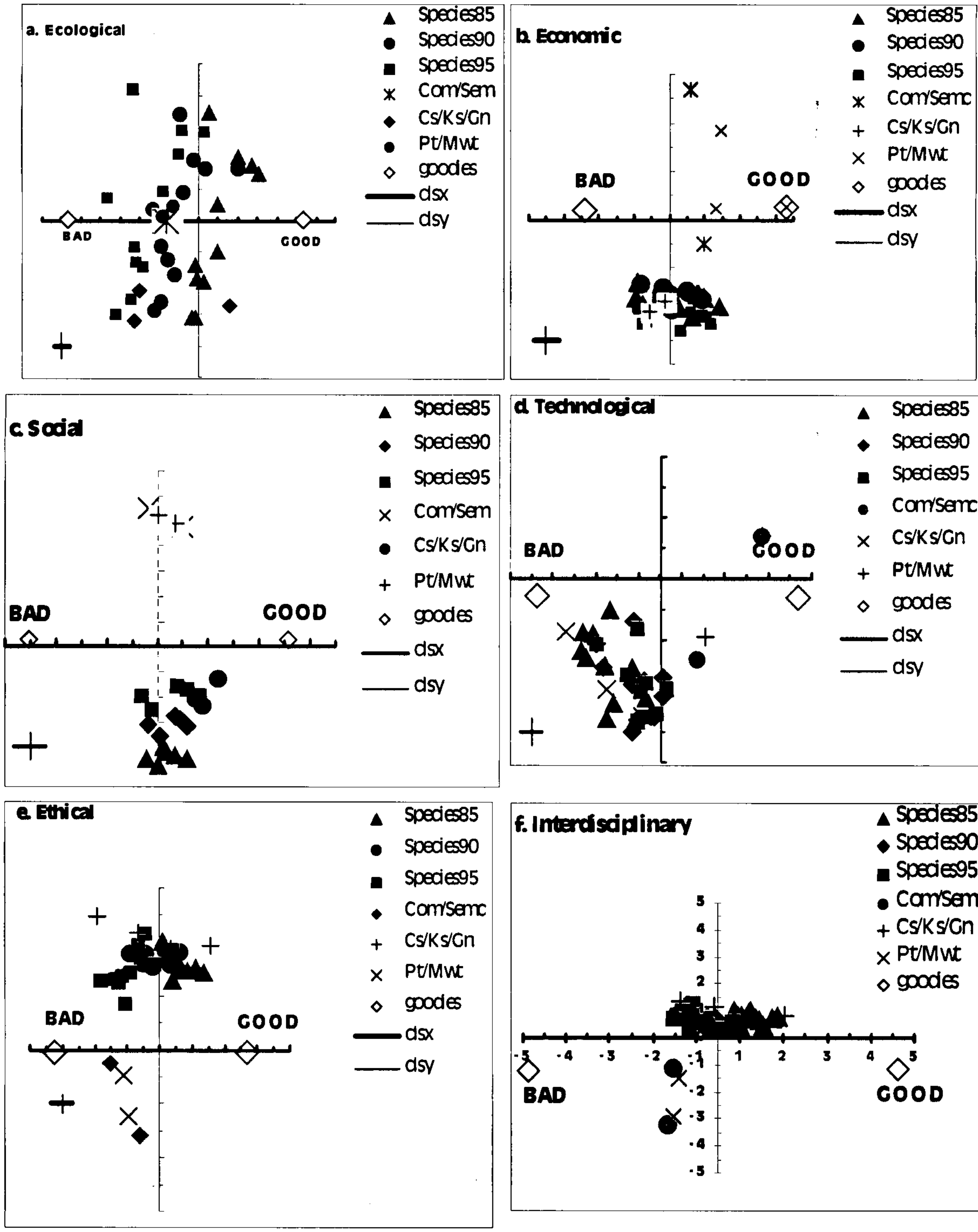


Figure 2.1 Ordination plots of Lake Malawi fisheries in five categories (a-e) and the interdisciplinary ordination (f). The fisheries are grouped into the species-based fisheries of Species85, 90 and 95 for the specified years; and gear-based fisheries split into Com/Semc, Cs/Ks/Gn and Pt/Mwt designating large scale, small scale and trawling operations respectively. Cross at lower left shows approximate confidence limits in the two dimensions, obtained from the constructed reference points using random attribute scores. 'Good' and 'Bad' points show reference points for constructed fisheries with extreme attribute scores, and the raw ordination has been rotated to make this axis, which expresses sustainability, horizontal.

Fishery scores were transformed to percentages along 'Good' and 'Bad' axis. Scores for the five categories and interdisciplinary ordination follows that of ordinated values are in Fig. 2.2.1-6 and Table 2.5. In the ecological category, the 1985 species-based fishery of Usipa (Usi) *Engraulicypris sardella* fishery has the highest score at 81.6 % while Other species (Os) fishery is the lowest at 53 %. The respective top and bottom positions in the other categories are for Mpasa (66.6 %) and Other species (25.4 %) fisheries in economic category. Two fishery groups of threes (Kambuzi, Utaka and Usipa) at 61.2 % and (Mpasa, Nchila and Sanjika) at 45.3 % are also at highest and lowest positions respectively in sociological category while Mpasa (83 %) and Usipa (58.5 %) are in technological category. Group of two (Mpasa and Sanjika) at 77.9 % and Kambuzi fisheries at 56.5 % are in respective top and bottom positions in ethical category. The combined or interdisciplinary percentage values are highest at 67.4 % and lowest at 55.7 % in Mpasa and Kambuzi fisheries respectively.

In 1990, the top and bottom values are for Usipa (72.5 %) and Nchila (35.8 %) in the ecological category, and Mpasa (58.8 %) and Chambo (27.7 %) in the economic category. In the sociological category, similar groups of fisheries as those in 1985 are in the top position with 61.2 % and bottom position with 46.1 %. For the categories of technological and ethical, the respective highest and lowest percentages are scored by fisheries of Mlamba (77.1 %) and a group of two fisheries (Chisawasawa and Utaka) at 51.9 % in the former, and Mlamba (65.3 %) and Kambuzi (39.3 %) fisheries in the latter category.

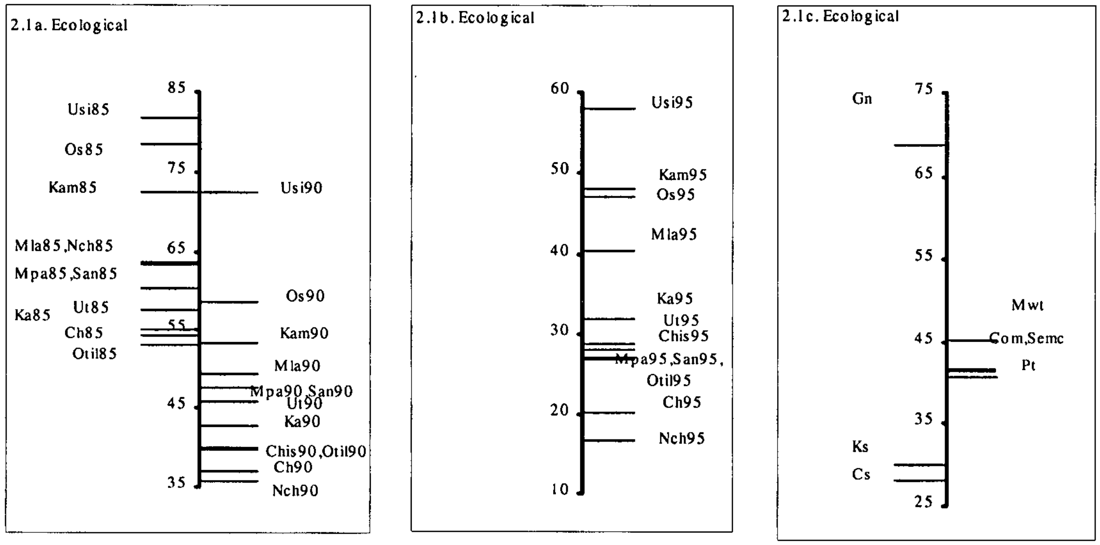


Fig. 2.2.1 Ecological ordination in percentage format: 2.1a 1985 and 1990 species-based fisheries; 2.1b 1995 species-based fisheries; and 2.1c gear-based fisheries.

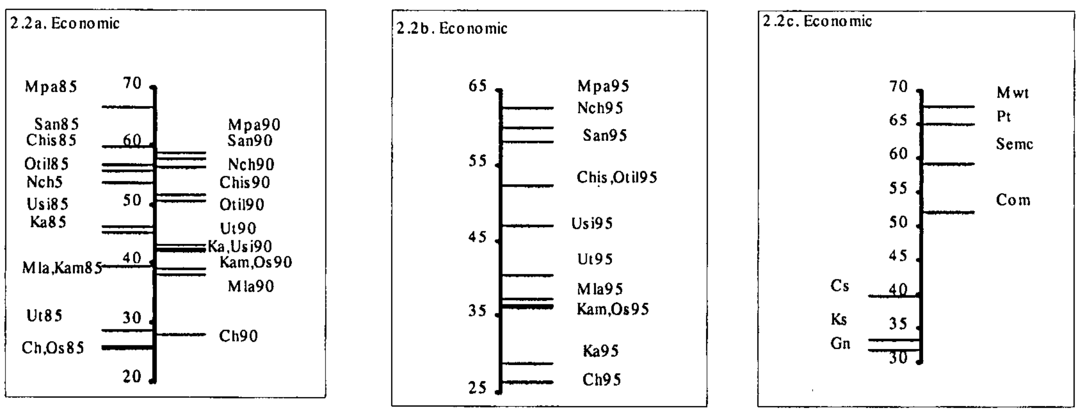


Fig. 2.2.2 Economic ordination in percentage format: 2.2a 1985 and 1990 species-based fisheries; 2.2b 1995 species-based fisheries; and 2.2c gear-based fisheries.

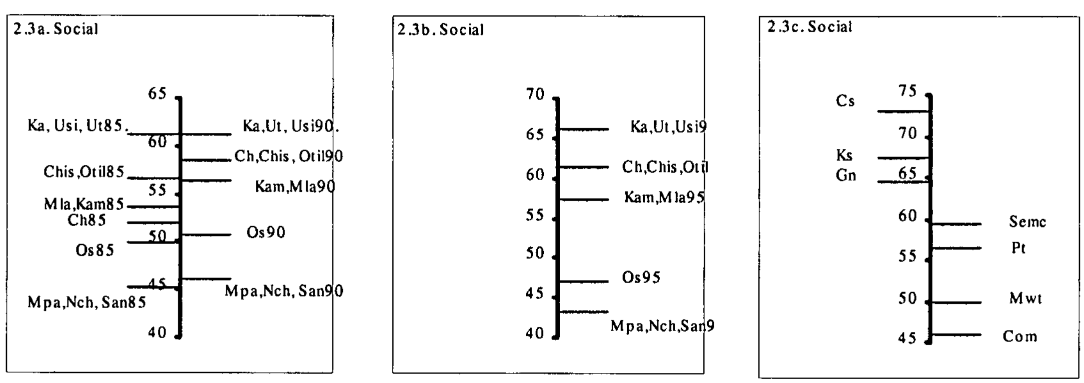


Fig. 2.2.3 Sociological ordination in percentage format: 2.3a 1985 and 1990 species-based fisheries; 2.3b 1995 species-based fisheries; and 2.3c gear-based fisheries.

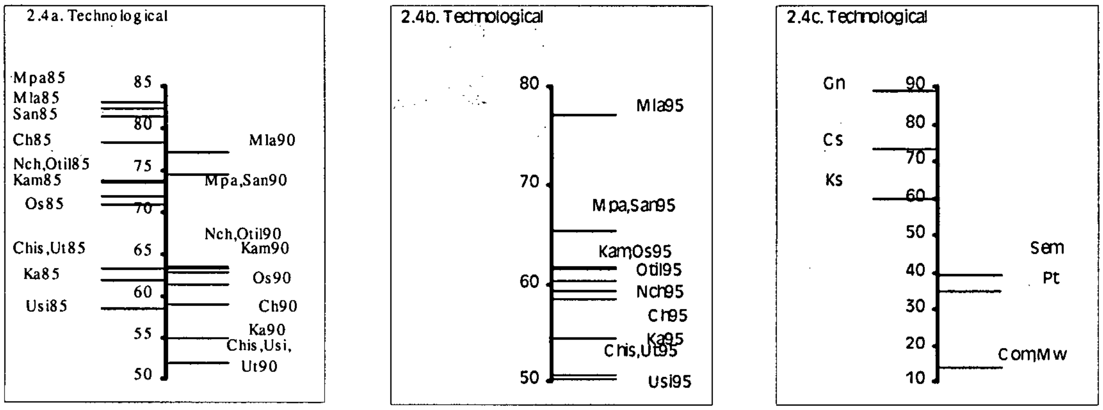


Fig. 2.2.4 Technological ordination in percentage format: 2.4a 1985 and 1990 species-based fisheries; 2.4b 1995 species-based fisheries; and 2.4c gear-based fisheries.

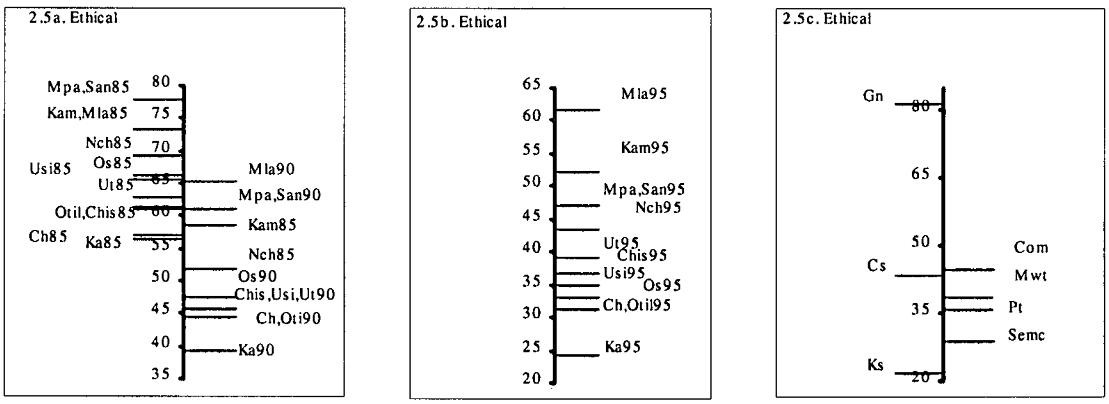


Fig. 2.2.5 Ethical ordination in percentage format: 2.5a 1985 and 1990 species-based fisheries; 2.5b 1995 species-based fisheries; and 2.5c gear-based fisheries.

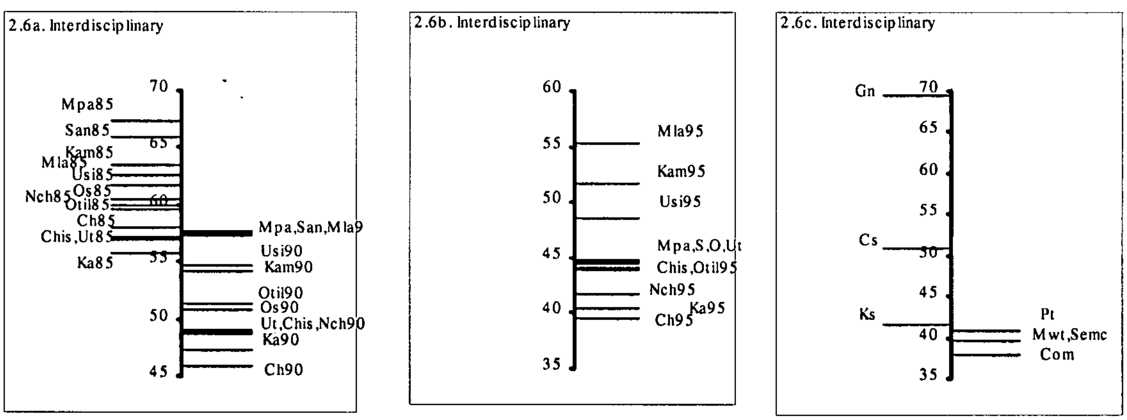


Fig. 2.2.6 Interdisciplinary ordination in percentage format: 2.6a 1985 and 1990 species-based fisheries; 2.6b 1995 species-based fisheries; and 2.6c gear-based fisheries.
***S for Sanjika (San) and O for Other species (Os).**

Table 2.5 Percentage scores along the sustainability axis (MDS axis 1) of the fisheries in each of the disciplinary categories and a combined analysis.

Fishery	Category					
	Ecological	Economic	Sociological	Technological	Ethical	Combined
Ch85	54.2	25.8	52.0	78.4	57.0	58.1
Otil85	53.0	55.7	56.6	73.7	60.9	59.6
Ka85	55.1	45.2	61.2	62.0	56.5	55.7
Ut85	57.6	28.7	61.2	63.3	62.8	56.9
Chis85	54.4	56.7	56.6	63.3	61.2	57.2
Kam85	72.3	39.4	53.6	71.9	73.3	63.5
Mla85	63.5	39.4	53.6	82.3	73.3	62.6
Usi85	81.6	46.1	61.2	58.5	65.5	61.7
Nch85	63.5	53.6	45.3	73.5	69.3	59.9
Mpa85	60.4	66.6	45.3	83.0	77.9	67.4
San85	60.4	59.6	45.3	81.3	77.9	66.0
Os85	78.5	25.4	49.8	71.0	66.2	60.4
Ch90	37.1	27.7	58.5	59.1	44.5	45.8
Otil90	40.1	50.7	58.5	63.4	44.5	51.4
Ka90	42.9	42.2	61.2	55.0	39.3	47.4
Ut90	45.9	43.3	61.2	51.9	45.8	49.1
Chis90	39.8	51.7	58.5	51.9	45.8	49.0
Kam90	53.3	39.1	56.4	62.7	58.5	54.2
Mla90	49.3	38.1	56.4	77.1	65.3	57.3
Usi90	72.5	42.4	61.2	52.0	45.8	54.7
Nch90	35.8	56.3	46.1	63.7	51.8	48.6
Mpa90	47.6	58.8	46.1	74.5	61.0	57.8
San90	47.6	57.9	46.1	74.5	61.0	57.5
Os90	58.6	39.1	50.6	61.4	47.4	50.8
Ch95	20.2	26.2	61.4	58.6	31.4	39.5
Otil95	26.9	52.3	61.4	60.3	41.4	44.0
Ka95	31.9	28.8	66.1	54.5	24.3	40.4
Ut95	28.7	40.4	66.1	50.6	39.1	44.5
Chis95	28.0	52.2	61.4	50.6	36.6	43.9
Kam95	48.2	36.5	57.4	61.7	52.3	51.7
Mla95	40.3	37.2	57.4	77.1	61.8	55.3
Usi95	57.9	47.0	66.1	50.3	35.0	48.6
Nch95	16.6	59.9	43.4	59.4	43.5	41.6
Mpa95	27.0	62.6	43.4	65.4	46.9	44.7
San95	27.0	58.0	43.4	65.4	46.9	44.4
Os95	47.0	36.2	47.2	61.5	33.2	44.5
Com	41.3	52.2	45.9	13.5	44.7	37.9
Semc	41.6	59.0	59.3	38.9	28.8	39.6
Cs	28.0	39.7	73.1	73.3	43.4	50.8
Ks	30.0	33.2	67.4	59.8	21.9	41.6
Gn	68.7	31.7	64.5	88.8	81.5	69.5
Pt	40.7	64.9	56.5	35.1	35.9	40.8
Mwt	45.1	67.5	49.9	13.6	38.8	39.6

Overall, the respective top and bottom percentages in the interdisciplinary ordination are for Mpasa (57.8 %) and Chambo (45.8 %) fisheries. Similarly the respective highest and lowest values for the 1995 period are for Usipa (57.9 %) and Chambo (20.2 %) in ecological category, Mpasa (62.6 %) and Chambo (39.5 %) in economic category, Chisawasawa (61.4 %) and a group of three fisheries (Nchila, Mpasa and Sanjika) at 43.4 % in sociological category, Mlamba (77.1 %) and Usipa (57.9 %) in technological category, and Mlamba (61.8 %) and Kambuzi (24.3 %) in ethical category. Finally Mlamba (55.3 %) and Chambo (39.5 %) fisheries are in the respective top and bottom positions in the interdisciplinary ordination.

The gear-based fisheries have the respective top and bottom percentage values for Gillnet (68.7 %) and Chambo seine (28 %) in ecological category, Midwater trawl (67.5 %) and Gillnet (31.7 %) in economic category, Chambo seine (73.1 %) and Commercial fishery (45.9 %) in sociological category, Gillnet (88.8 %) and Commercial fishery (13.5 %) in technological category, and Gillnet (81.5 %) and Kambuzi seine (21.9 %) in ethical category. The combined or interdisciplinary ordination has highest and lowest values for Gillnet (69.5 %) and Commercial fishery (37.9 %) respectively. In general the percentage ranges and values in the categories and interdisciplinary ordination decrease with time (Table 2.5, Fig. 2.2.1-2.2.6). The small scale gear-based fisheries of Chambo seine (Cs), Kambuzi seine (Ks) and Gillnet (Gn) have higher percentages in interdisciplinary ordination as well as sociological and technological categories. Their percentage values are mixed in the ecological and ethical categories; they are lower than those of large scale fisheries of

Commercial (Com), Semi-commercial (Semc), Pair Trawl (Pt) and Midwater trawl (Mwt) in the economic category.

2.3.2 Discussion

The Rapfish analysis shows that the health status of the species-based fisheries declined between 1985 and 1995. Some of the important factors that could have aggravated the problem would include the increase in the number of fishers (Fig. 2.3) and use of gears that had a higher proportion of immature fish in their landings (FAO 1993; Scholz et al. 1997). Lake Malawi like other water bodies (in Malawi) is also plagued by problems of resource utilization pressure, environmental degradation and fish resource degradation (see also Section 1.6).

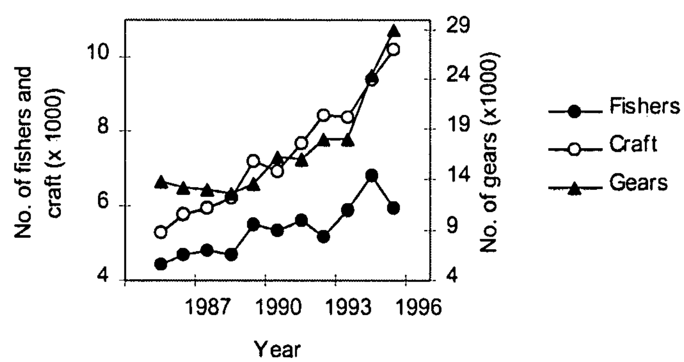


Figure 2.3 Trends of fishers, craft and gears of traditional fisheries in Lake Malawi.

High population growth rate is noted to generate an ever-growing demand for fish (Nyambose 1997). The ecological 'Rapfish' scores reflected this problem. This was particularly shown in the case of the Chambo, *Oreochromis* spp., fishery. The results of decreases in scores, ordinated values and percentages (Appendix 2.1; Tables 2.4 and 2.5;

Fig. 2.2.1a,b and 2.2.6a,b) supported earlier observations. A number of gears are used to catch Chambo and some catch relatively high proportions of juveniles (FAO 1993). Regulations which prohibit catching of immature Chambo have not been effective (Tweddle et al. 1994; Scholz et al. 1997; Stauffer et al. 1997). The Usipa *Engraulicypris sardella* fishery was unique. It had highest percentage sustainability scores in the ecological and sociological categories for the two periods of 1985 and 1990 plus 1995 for the former category even when Utaka *Copadichromis* spp. fishery was leading in catches in the first two periods. The Usipa fishery, again, ordinated with relatively high scores in the combined or interdisciplinary ordination for the three periods. This is thought to be the effect of indirect use of catches in scoring a number of attributes including 'exploitation status' in the ecological category; and 'price', 'GDP' and 'sector employment' in the economic category. Usipa strongly influenced the landings of the artisanal fisheries. It also seemed resilient in spite of perceptible overall decline in sustainability terms for all the fisheries in the lake (Preikshot et al. 1998). This is attributed to the fact that Usipa is a short-lived and highly fecund fish, and its catch trends reflect more the productivity in the lake rather than problems of fishing pressure or being caught before maturity (Skelton et al. 1991; Thompson 1995). Utaka, unlike Usipa, only influenced the sociological category in 1985 and 1990 periods, again only in conjunction with two other species (Usipa and Kambuzi *Protomelas* spp.).

The influence of the economic category seemed strong in 1985 and 1990. The Mpasa *Opsaridium microlepis* fishery was highest in the percentage scores for the economic category as well as the interdisciplinary ordination. In 1995, technological and ethical categories seemed to have most influence. The Mlamba *Clarias* spp. fishery obtained top percentage scores in the two categories and the interdisciplinary ordination. It is clear Mpasa has the highest prices for all the periods, and better scores in 'other income' and 'sector employment' attributes in the economic category. There are however no outstanding scores for Mlamba in 1995 except for obtaining a lowest score (which is on the 'good' side) in the 'effect of gear' attribute of the technological category. In the comparison of percentages that individual fisheries obtain in the five categories and interdisciplinary ordination, highest values are scored in the technological category. Two exceptions include the period of 1995 when the sociological category has just one fishery of highest percentage value more than the technological category. And the other is the economic category in the section of gear-based fisheries, where both the technological and economic categories have the same number of fisheries with highest percentage values. This is because of the influence of the values of 'Good' and 'Bad' in the scores given to the fisheries in the attributes. A close examination of the scores reveals that it is only in the case of technological category where in a little over half of the attributes have scores that are mostly close to the value assigned as 'Good'. While the technological category is prominent in the percentages, it also gets the highest stress score, although this is within the credible range. The high uncertainty as indicated by the stress score is speculated to be due to the fact that the category has the largest number of attributes, which (probably) introduces more errors during the process of ordinating the attribute scores.

The gear-based fisheries, especially the large scale fisheries of Commercial, Semi-commercial, Pair trawl and Midwater trawl, have poor scores in all categories except for the sociological category, in which more than half of the attributes have scores tending to 'Good'. The high sustainability status is also expressed in the interdisciplinary combined category (Fig. 2.1a-f; Table 2.5). The situation seems to emphasize the lowering of the overall potential of the fisheries in the lake (Preikshot et al. 1998) since nylon nets and trawling were introduced and expanded (GOM 1989; ICLARM/GTZ 1991). In addition, other problems as noted in Section 1.4.2, further compound the effect of the gears which are used in most of the fisheries in Lake Malawi. Localized Malthusian over-fishing (Pauly 1994) is shown by an over 800 % increase in the inhabitants of the Chembe lakeshore area in the southern part of the lake compared to earlier in the century (Nyambose 1997, based on the work of Smith 1993). There is at the same time evidence of a decrease in catches in at least some species within the same region (FAO 1993; Stauffer et al. 1997).

From the Rapfish analysis, it would appear that small rather than large fisheries operations are, all things being equal, healthier in sustainability terms. This view, however, needs to be moderated by the type and use of gears in traditional fisheries, some of which are very catch efficient and destructive (Tweddle et al. 1994; Scholz et al. 1997), an aspect that is very well demonstrated in this analysis. For example, the small scale gear-based fisheries of Kambuzi seine and Chambo seine have very low sustainability scores in the ecological, ethical and, even in the economic categories. The use of seines has been shown to destroy fish habitats in Lake Malombe and Upper Shire River (Banda and Hara 1994) and it is certain that the same effect can result in any fishing area. For the gear-based fisheries, the Chambo seine has the lowest score in the ecological category, as a result of a poor score in 'catch before maturity' attribute; a consequence of widespread use of unrecommended mesh sizes (FAO 1993;

Scholz et al. 1997; Stauffer et al. 1997). Further poor attribute scores are assigned in 'exploitation status' leading to the worst score in 'range collapse', as well as scores tending to 'Bad' side in 'species caught' and 'discarded by-catch' attributes. In the case of the Kambuzi seine, it has the lowest score in the ethical category, mainly due to its poor scores in attributes of 'habitat destruction' and 'ecosystem depletion' in addition to 'just management' and 'alternatives'.

CHAPTER 3:

ECOPATH MODELS OF LAKE MALAWI

3.1 Basics of Ecopath modelling

3.1.1 Origins and development of Ecopath

In the ecosystem context, modelling refers to consistent descriptions, emphasizing certain aspects of the system investigated, as required to understand their function (Christensen and Pauly 1992). Interrelationships of various components of a system can be represented in a number of ways including graphs and text. Models may also be in a form of equations with specified parameters (states and rates of the elements included in the model). One type of models, termed simulation models, can also be constructed to represent the interactive behaviour of, at least the major, components of an ecosystem through time. It has for a number of years now been demonstrated that understanding how a given ecosystem functions is achievable by constructing a quantitative model of the interactions between its components (Christensen and Pauly 1992).

The Ecopath model is an approach which analyses trophic interactions within an ecosystem. This approach uses the concept of mass-balance in a steady state or equilibrium. It was first used by Polovina (1984a) for the estimation of biomass and food consumption of various elements (species or group of species) of an aquatic system and subsequently combined with various approaches from theoretical ecology (e.g. Ulanowicz 1986). The Ecopath routine, originally based on the work of Polovina and colleagues (Polovina and Ow 1983; Polovina

1984b & 1985), has been subsequently improved by Christensen and Pauly (1992; 1993) notably by adding elements of theoretical ecology. Therein, functional groups, which may be a group of ecologically or taxonomically related species, a single species, or a single size/age group of a given species, are the ecosystem's components or interacting 'state variables' (Pauly and Christensen 1996; Pauly 1998). The most recent version of Ecopath routine is Ecopath with Ecosim 4 available in an alpha version (see www.ecopath.org).

3.1.2 Ecopath equations

The basic Ecopath system approach models an ecosystem using a set of simultaneous equations (one for each group i in the system), which can be expressed, following Christensen and Pauly (1992); Pauly (1998) as:

Production by (i) - all predation on (i) - nonpredation losses - export of (i) = 0, for all i.

This can also be represented as:

$$P_i - B_i * M2_i - P * (1 - EE_i) - EX_i = 0 \qquad \text{Eq.1)}$$

Where: P_i is the production of (i), B_i is the biomass of (i), $M2_i$ is the predation mortality of (i), P is the production of (i), $(1 - EE_i)$ is the "other mortality" and EX_i is the export of (i).

Equation (1) may be expressed as:

$$B_i * (P/B)_i - \sum_{j=1}^{n} B_j * (Q/B)_j * DC_{ji} - (P/B)_i * B_i * (1-EE_i) - EX_i = 0 \qquad \text{Eq. 2)}$$

or

$$B_i * (P/B)_i * EE_i - \sum_{j=1}^{n} B_j * (Q/B)_j * DC_{ji} - EX_i = 0 \qquad \text{Eq. 3)}$$

Where: P/B_i is the production/biomass ratio, Q/B_i is the consumption/biomass ratio and DC_{ji} is the fraction of prey (i) in the average diet of predator (j).

Based on Eq. 3 for a system with n groups, n linear equations can be given explicit terms,

$$B_1*(P/B)_1*EE_1- B_1*(Q/B)_1*DC_{11}-B_2*(Q/B)_2 * DC_{21} \ldots -B_n*(Q/B)_n*DC_{n1}-EX_1 = 0$$

$$B_2*(P/B)_2*EE_2- B_1*(Q/B)_1*DC_{12}-B_2*(Q/B)_2 * DC_{22} \ldots -B_n*(Q/B)_n*DC_{n2}-EX_2 = 0$$

:

:

$$B_n*(P/B)_n*EE_n- B_1*(Q/B)_1*DC_{1n}-B_2*(Q/B)_2 * DC_{2n} \ldots -B_n*(Q/B)_n*DC_{nn}-EX_n = 0$$

In Ecopath, the generalized inverse method of Mackay (1981) is utilized to solve this system of simultaneous linear equations. The method provides the Ecopath routine with features that make it more versatile than standard inverse methods (Pauly and Christensen 1996; Pauly 1998). Other details on Ecopath can be accessed from http://www.ecopath.org.

3.1.3 Requirements and applications of Ecopath

The general requirements to be met when using the Ecopath routine include that

- only one of the parameters B_i, P/B_i, Q/B_i or EE_i may be unknown for any i. In special cases, Q/B_i may be unknown in addition to one of the parameters;
- exports and a diet composition matrix are always required.

The Ecopath software is useful for quick construction and verification of mass-balance models of ecosystems. The key procedural steps to build a model include:

- identifying area and period for which the model is to be constructed;
- defining the functional groups (trophic boxes);

- entering a diet matrix which defines all trophic linkages by expressing the fraction that each functional group in the model represents in the diet of its consumers;
- entering the food consumption, production/biomass ratio and or biomass, and fisheries catches, if any, for each group box; and
- modifying entries (i.e., third and fourth points above until input is equal to output for each trophic group); and comparing model outputs (network characteristics, estimated trophic levels and other features of each box) with estimates for the same area during another period, or with outputs of the same model type from other, similar areas (Pauly and Christensen 1996).

Examination of ecosystem structure and function can also be achieved with the use of Ecopath routine. It is again a means that enables modelling of impacts to higher trophic level, among very few studies that have looked at effects to high trophic level of ecosystems. Ecopath can therefore be used to explore impacts of exploitation strategies as well as those due to environmental variation (Polovina 1996).

3.2 Brief description of previous Ecopath models of Lake Malawi

3.2.1 Ecological characteristics of Lake Malawi ecosystem

Clear waters of low biological productivity characterize the large part of Lake Malawi (ICLARM/GTZ 1991). The southern part of the lake is shallow and produces a lot of fish food and forms a rich-fishing area. There is a seasonal nutrient distribution. Higher production of phytoplankton is found in the southern and northern ends of the lake than in the centre. This is often reflected in higher fish biomass. In 1992/93 season southern and northern pelagic parts of the lake had higher fish biomass of 0.73-0.80 $t{\cdot}km^{-2}$ than the centre portion with fish biomass of 0.56-0.62 $t{\cdot}km^{-2}$ (Menz et al. 1995). The southeast and southwest arms of the lake, being shallow, support highly productive fisheries for sedentary demersal fish stocks. The deep northern side of the lake accommodates only low intensity fishing (Turner 1996). Inter-annual differences occur in the phytoplankton production in the lake. Studies have shown that the production may vary by a factor of three and this correlates with the fish production and biomass of the fish stocks, particularly the short-lived planktivorous species (Banda and Tomasson 1997). Most species feed on zooplankton when available.

Lake Malawi is permanently stratified (meromictic) beyond 250 metres. The sedimentation of nutrients to this layer limits production of phytoplankton, the base of food chain, and cause the lake to be oligotrophic (Eccles 1962; FAO 1993). However, this classification which is based on chlorophyll *a* concentrations (Wetzel 1975, 1983) does not agree with the primary production which falls in Wetzel (1983)'s production band of 91-365 $gCm^{-2}year^{-1}$ signifying mesotrophy (Patterson and Kachinjika 1995). The annual cycle of stratification is from December to March, and mixing from May to August. During stratification, three zones occur. A combination of three factors; depth, temperature and water currents is usually at play. The first zone is the epilimnion. It extends from the surface of the lake to 125m in depth. The second zone is the metalimnion, the middle layer of the lake's water column. This can be as deep as 230m. The third zone is the hypolimnion. It is anoxic and no mixing ever takes place. The effect of temperature in the water column is marked with the presence of a sudden transition depth range, thermocline, between 40 and 60m in January extending to 100m by May. The thermocline disappears during the cold 'mwera' season. The wind causes strong currents so that interchange of the conditions and other properties in the two upper layers, occurs. Complete nutrient mixing of these two layers may also occur with the result of the lake remaining with mixolimnion and monimolimnion layers. The shallower southern part of the lake may therefore become mixolimninic (FAO 1993). The seasonal wind induced upwelling brings nutrients to the northern parts of the lake. Phytoplankton production also increases in the cooler windy season, June-September, with a peak in July. The oxic-anoxic boundary (between the bottom and middle layers) which occurs at 230 m as well as thermocline becomes wedged and tilted down on the northern end (Fig. 3.1). At the south-end, where it is shallow (less than 50 m) and there is no anoxic zone, the boundary starts at or reaches the bottom of the lake. The euphotic zone, i.e., the part of the water column in which photosynthesis occurs, extends to 70 metres. This is however not affected by mixing in the upper two zones. The temperature drops as depth increases from the lake surface. As a result, the depth or temperature dependent chemical elements including nutrients also vary (Beadle 1974; Eccles 1978; Banda 1989; Patterson and Kachinjika 1995; Patterson et al. 1995).

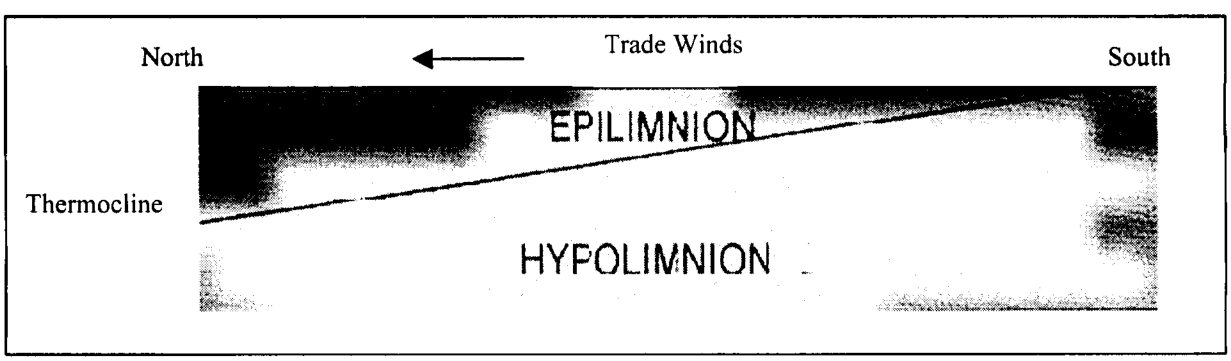


Fig 3.1 Schematic representation of the epilimnetic wedge during the mwera season (after Patterson et al. 1995). The south is very shallow compared with north the oxic-anoxic wedged boundary starts at the bottom of the lake some distance from the south end.

For the fisheries research purposes, three depth categories are recognized: shallow (0-50 m); deep and midwater (51-100 m); and very deep (101-150 m and over). For practical purposes, the pelagic fisheries rarely extend to 50-metre depth and the demersal fisheries are those occurring beyond 50 metres. In Lake Malawi, species composition changes with depth and continuity in distribution of species shows a break around 50 metres. The demersal stern trawler fishery is only permitted below the 50 m depth contour (Banda and Tomasson 1997; see also Appendix 1.7). However, a number of fish species have been reported to occur or adapt to varying depths during their life histories, for example some cichlids in the genus of *Nyassachromis* (Turner 1996). There is also the tendency of certain groups of fish species especially the rock-dwelling cichlids such as *Pseudotropheus* spp. (Mbuna) to occur at different depth zones. This is believed to be a strategy of reducing competition for food (Lowe-McConnell 1987), i.e., food resource partitioning (Yamaoka 1991). Statistical recording of catches by the Malawi Fisheries Department (MFD) does not however differentiate the species by depth.

3.2.2 The pelagic zone of central Lake Malawi: A trophic box model

Degnbol (1993) developed a model of Lake Malawi based on an FAO research programme from 1977 to 1981. Supplementary information, from literature or assumed, included P/B for zooplankton and was based on Banse and Mosher (1980). The model had nine functional groups including five for fish. The number of fish groups was low because the pelagic zone particularly offshore is not rich in species. The ecotrophic efficiency (EE) for three groups (Usipa *Engraulicypris sardella*, haplochromines and phytoplankton) was set at 0.95. The gross food conversion efficiency (GE), which is equal to (P/B)/(Q/B), for *Opsaridium,* *Diplotaxodon* and *Ramphochromis* as top predators was assumed to be 0.1. Two fish species, Usipa *E. sardella* and Utaka (flock of haplochromine cichlids), were the most abundant in the area. Production of fish biomass was conservatively estimated at 5 t·km^{-2}·year^{-1} and 72 % (3.6 t·km^{-2}·year^{-1}) of this was contributed by the two abundant species, Usipa and Utaka. Together with lakefly *Chaoborus edulis*, they were the three main actors in the system's food web. Zooplankton communities were pooled into one group in the model and their predators were lakefly, two cyprinids and two cichlids. Fish catches were assumed to be less than 0.01 t·km^{-2}·year^{-1}.

The major predatory pathway for the system was found to be through zooplankton and *C. edulis* responsible for 98 % of the primary production flow. The larvae stage of the *C. edulis* as a group used in the model was estimated to have a production of close to 50 t·km^{-2}·year^{-1}. Only 12.5 % (6 t·km^{-2}·year^{-1}) was utilized in the system, mainly by *Opsaridium*. The loss of the lakefly *C. edulis* from the pelagic zone system contributed to the low trophic transfer efficiencies at the higher system trophic levels. The *C. edulis* larvae production estimate, though high, appeared justifiable for the pelagic zone where dense clouds of the fly are common. However this could not be quantified for the whole lake. Interpretations that could be made from the model were limited. The causes included knowledge gaps in zooplankton production dynamics, role of detritus and dissolved organic matter, *C. edulis* production and fish mortalities. Lack of size or stage structure in the model parameterization was also noted as important. The model generated a high trophic transfer efficiency for the herbivores and detritivores at 16.9 % which was felt to have been influenced by production of heterotrophs as noted in Lake Tanganyika by Hecky et al. (1981). The pelagic zone of the central part of the lake was estimated to have a total fish biomass of 7 $t \cdot km^{-2}$. The biomass for the fish groups was utilized to also estimate the potential fish yield at a value of 4.5 $t \cdot km^{-2} \cdot year^{-1}$. This was derived from employing the relationship of Pauly (1980) linking growth parameters and instantaneous natural mortality with an assumption that P/B=M, which was averaged for the fish species considered in the model, as well as the formula of Gulland (1971) which estimates maximum yield, Y_{max}, or maximum sustainable yield, MSY, (Gayanilo and Pauly 1997), i.e., Y_{max} or MSY = $0.5 \cdot M \cdot B_o$. The system was considered to rely largely on the production of lakefly *Chaoborus edulis* and its larvae. It was also felt that Usipa, a cyprinid *Engraulicypris sardella,* was a poor predator of zooplankton and it would take a very long time for it to evolve into an effective grazer.

3.2.3 The pelagic ecosystem of Lake Malawi

The next model of Lake Malawi constructed by Allison et al. (1995a), was based on information from the ODA/UK supported research studies from 1990 to 1994 (Menz 1995) whose aims included investigating the trophic basis for fish production in the offshore waters of Lake Malawi (Allison et al. 1995b). The work on the pelagic ecosystem for the lake illustrated the biological effects of the seasonal wind-driven mixing cycle as the main driving force regulating production in the system. The food web of the system's trophic ecology, in a steady state sense, was detailed through annualized biomass, production and consumption estimates for the main functional groups. The biomass, production and consumption were estimates of annual averages. The seasonal cycles in production and biomass of phytoplankton and zooplankton as well as nutrients and other major components of the pelagic system were also examined. The major components of the system included

Usipa *Engraulicypris sardella* and other fish species, lakefly *Chaoborus edulis* and plankton.

Two items were emphasized. The first issue was the fraction of the primary production going into producing lakefly *C. edulis*; which is, then, lost in the system without contributing to fish production. The lakefly is a more effective consumer of zooplankton at low densities than active predatory fish. It is preyed on by many fish and has, in general, a low abundance but can be very concentrated in certain places while moving up in the water column. The second issue was the identification of reasons why the pelagic zone of the lake does not have a productive fishery. This is in comparison to similar fisheries especially Lake Tanganyika, based on the opinions and work of Turner (1982); Hecky (1984); etc. all of which are detailed in Allison et al. (1995b).

A total of fifteen functional groups was used in the model. Nine groups were single species, or groups of fish species. The remaining six trophic groups were for Usipa *E. sardella* larvae, lakefly *C. edulis*, one predatory zooplankton species, herbivorous zooplankton, phytoplankton and detritus. Apart from the consumption over biomass (Q/B) ratio for *Opsaridium* and adult Usipa which were taken from Walczak (1982), all the inputs were derived from the studies in the research programme. Detritus was determined to be an insignificant source of energy to the higher trophic levels. It was also a poor source of organic carbon to the base of the pelagic food web[12]. It was assumed that there were no exports from the system except as flows to detritus, and that there were no imports.

[12] This was based on unpublished data analysis by Hecky and Bootsma of Freshwater Institute, Winnipeg, Canada.

Although the pelagic zone was taken as a closed system, it was noted that there was inshore-offshore interactions related to breeding, growth and feeding of some fish species.

Primary production was estimated at 329.4 $g{\cdot}C{\cdot}m^{-2}{\cdot}year^{-1}$ and 518.3 $g{\cdot}C{\cdot}m^{-2}{\cdot}year^{-1}$ for 1992 and 1993 respectively. This led to increased carbon transfer to consumers in 1993 and signified that biomasses and production rates were controlled by food supply. There was however a corresponding increase in predator population biomass causing decline of prey soon after, suggesting control of biomass by predation. Food supply influenced production while both food supply and predation affected biomass. Because of many year-classes in the fish species no seasonal patterns emerged, except for Usipa, an annual species, which responded to yearly changes. It was observed that inputs had a high degree of internal consistency, which led to suggestion that the model was reasonable. Only two parameters (biomass of adult Usipa and Q/B for its larvae) had to be modified from their original values to balance the model. Lakefly *C. edulis,* carnivorous zooplankton *Mesocyclops aequatorialis aequatorialis* and Usipa *E. sardella* larvae consumed a larger part of the secondary production with a trophic impact of 15-20 % each as opposed to fish mainly Ndunduma cichlid *Diplotaxodon* 'elongate'. The system has a five-stage trophic level and adult fish feed at high trophic levels. *C. edulis, M. a. aequatorialis* and *E. sardella* larvae are an important link to the low and high trophic groups. Although their biomasses are low compared to both their prey and predators, they are very productive.

Overall the unavailability of the lakefly *C. edulis* to fish does not necessarily constitute a loss to the ecosystem as a whole. This is because lakefly is able to concentrate the food resources in the system through forming an extra trophic level. The notion that low fish production of the pelagic zone is attributable to under-utilization of lakefly *C. edulis* (Degnbol 1993 and see above) is however not consistent with the predation pressure observed here. Although lakefly was not fully vulnerable to fish predation at 47 % it was nonetheless significant. The lakefly *Chaoborus edulis* together with herbivorous and carnivorous (*Mesocyclops aequatorialis aequatorialis*) zooplankton and *E. sardella* larvae are categorized in the moderate to heavy predation range. The role of lakefly to the system is quantified. Although a non-predation mortality of greater than 50 % is large, it was in the case of the lakefly attributed to loss at early stages of its life due to starvation. The influence of seasonal lake mixing to its biological productivity could also be linked to fluctuations observed in the landings of Usipa *E. sardella* but its connection through mortality, at the larval stage, which may be caused by predation or food insufficiency (starvation) could not be quantified. There was consistency in the dynamism of the lake system in terms of seasonal changes and food production either by looking at the short-lived (1-year cycle) or long-lived species (seasonal and 2-year cycles). The pelagic zone was determined to be a food-limited system while fish production efficiency in the lake as a whole was similar to any other ecosystem with four or five trophic levels. In the comparison between Lakes Malawi and Tanganyika, the part of carnivorous zooplankton which was thought to be absent in the former is actually occupied by cladocera and *C. edulis* while in the latter it has been two species of atyids. There are therefore no vacant niches in Lake Malawi and ideas on introducing other zooplanktivores to utilize the offshore pelagic zone do not have a strong basis (Allison et al. 1995b; Barel et al. 1985).

3.3 A new Ecopath model of Lake Malawi

3.3.1 Objective of constructing Ecopath model of Lake Malawi

Implementation of appropriate management regimes as well sustainable utilization of Lake Malawi fish resources requires knowledge of both the lake's ecosystem and fish resources (see also Section 1.7). The construction of an Ecopath model would, especially, contribute to understanding the ecosystem of the lake. The ecosystem's structure and function could be examined, and exploration of exploitation strategies and environmental variation impacting the ecosystem could be facilitated (Christensen and Pauly 1992, 1993; Polovina 1996; see also Section 3.1.3). The specific aims of constructing a new Ecopath model of Lake Malawi were to analyse trophic interrelationships in the functional groups (Table 3.1), which include main fish species of catches, in the lake's ecosystem; and assess the trophic structure of the lake's ecosystem.

3.3.2 Names used for the functional groups and fish species in the model

The functional groups especially the fish groups are identified by their names in Chichewa, one of the two national languages in Malawi. The fishing community as well as fisheries managers and researchers in Malawi usually use Chichewa or other vernacular names in reports and other communication. Chichewa was promoted as a national language (besides English) partly soon after independence. In southern central African countries the language is known as Chinyanja (Mchombo 1997). The fish name as given in Chichewa or other vernacular (Table 3.1; Appendices 1.1-1.3) has some bearing on the indigenous technical knowledge of the fishing community on the resources (Berlin 1992).

Table 3.1 Brief summary of the key features of functional groups in Lake Malawi ecosystem.

No.	Name	Details[13]
1	Nkunga	Eel *Anguilla nebulosa* and mastacembelids *Mastacembelus shiranus* and *M.* sp. 'Rosette'.
2	Kampango	Bagrid catfish *Bagrus meridionalis*.
3	Matemba	Represents barbel cyprinids, one alestiid, two cyprinodontids and one anabantid.
4	Utaka	Bottom feeding cichlids in genera *Copadichromis*, *Cyrtocara, Maravichromis* and *Nyassachromis.*
5	Ndunduma	Demersal and off-shore cichlids belonging to genera *Diplotaxodon*, *Palladichromis* and *Placidochromis*.
6	Kambuzi	Cichlids in genera *Protomelas, Hemitaeniochromis Dimidiochromis,* and *Taeniochromis*.
7	Chisawasawa	Mostly bottom feeding cichlids in genera *Lethrinops, Taeniolethrinops* and *Tramitichromis.*
8	Chambo	Refers to three species of tilapiine cichlids in the genus *Oreochromis*; *O. squampinis, O. lidole* and *O. karongae.*
9	Chilunguni	Represents two tilapiines, *Tilapia rendalli* and *Oreochromis shiranus*.
10	Mbuna	Rock-dwelling cichlids popular with tropical fish aquarists and ornamental tropical fish trade. Most species belong to genus *Pseudotropheus*. Other Mbuna genera are *Cyathochromis, Cynotilapia, Genyochromis* and *Melanochromis.*
11	Mcheni	Are offshore, pelagic and demersal occurring tigerfish cichlids in the genus *Ramphochromis.*
12	Bombe	Ten species of clariid catfishes in the genus *Bathyclarias*.
13	Mlamba	Clariid catfishes in the genus *Clarias*. There are four species; *C. gariepinus, C. mellandi, C. mossambicus* and *C. theodorae.*
14	Usipa	Refers to the cyprinid *Engraulicypris sardella.*
15	Usipa larvae	Larvae stage of *Engraulicypris sardella.*
16	Sanjika	Refers to bariliine cyprinid *Opsaridium microcephalus*.

[13] A detailed list of fish species in Lake Malawi is in Appendix 1.3.

Table 3.1 Brief summary of the key features of functional groups in Lake Malawi ecosystem (continued).

No.	Name	Details
17	Mpasa	The bariliine cyprinid *Opsaridium microlepis.*
18	Nchila	Represents two cyprinids, *Labeo mesops and L. cylindricus*. Only *L. mesops* supports a fishery in the lake.
19	Nkholokolo	Refers to squeakers, two small mochokids *Synodontis njassae* and *Chiloglanis neumanni*. The main species, *S. njassae*, is endemic to the lake.
20	Samwamowa	Represents mormyrid species in the genera of *Marcusensis, Mormyrus* and *Petrocephalus.*
21	Nkhungu	The lakefly *Chaoborus edulis* forms key link in energy flow in the lake ecosystem.
22	Nkhono	The group represents gastropod and lamellibranch molluscs.
23	Top predators	This group represents higher animals; fish-eating birds, reptiles (monitor lizards and crocodiles) and otters.
24	Zooplankton	The group has herbivorous and carnivorous zooplankton which include copepods (*Mesocyclops aequatorialis aequatorialis, Tropodiaptomus canningtoni*, and *Thermocyclops neglectus*), cladocerans (*Diaphonosoma excisum* and *Bosmina longrostris*), naupulii, *Diaptomus kraepelini* and *Mesocyclops leuckarti.*
25	Phytoplankton	Includes species in the genera *Aulacoseira, Surirella, Stephanodiscus, Mougeotia, Cymatopleura, Closterium, Synedra, Staurastrum* and others occuring in four phyla of Cyanophyta (blue-green algae), Bacillariophyta (diatoms), Chlorophyta (green algae) and Pyrrophyta (dinoflagellates). The group also represents higher plants.
26	Detritus	Represents organic matter, either dissolved or particulate.

In Chichewa, the fish names in Lake Malawi do not appear to be strongly associated with the morphological structures of natural systems in their groups as a central approach in the development of 'folk generic taxa' (Berlin 1992). In addition the names do not fall in only one of the many name or noun classes, up to eighteen in Werner (1919). The grouping of names or nouns in Chichewa that is currently taught in schools is eight based on Hetherwick (1914). Fish names in Malawi can without critical analysis be allocated to at least five classes. There are however some names that clearly refer to physical characteristics such mouth, size or even habitat. Samwamowa (= doesn't drink beer) referring to *Mormyrus deliciosus* and other species relates to the shapes of the mouths. Nyesi is name for the electric catfish *Malapterurus electricus* based on its generation of some static or chemical electric shocks when touching the skin. 'Mbuna' refers to the rock dwelling *Pseudotropheus* spp. complex in Lake Malawi. 'Mbuna' is a Chitonga name and Chitonga is one of the vernacular languages in Malawi. Chitonga is mostly spoken in three districts with a shore to Lake Malawi, two in northern (Nkhata Bay and Rumphi Districts) and one central (Nkhotakota District) regions of the country (Fig. 1.1). The word 'Mbuna' probably refers to the fact that some members of the species hide in rock crevices or holes. In general, the names in the vernacular languages refer to groups of species as they do not deal with small differences (F. M. Nyirenda *pers. comm.*). Many of the functional groups are therefore defined by Chichewa names or names in other languages in Malawi, reflective of a perception of similarity by local fishers (Smith 1998).

3.3.3 Data sources

3.3.3.1 Basic input information and its sources

The input data were mainly obtained from literature. Many research programmes have been carried out on Lake Malawi (Tweddle 1991). However four studies form the sources on which most of the input data for the present model are adopted. The first research programme that generated applicable information was carried out under the auspices of FAO between 1977 and 1981. An ecosystem model for the pelagic zone of the central part of the lake was developed in 1993 based on this study (Section 3.2.2, Degnbol 1993). The second study was jointly supported by the Malawi Government, UNDP and FAO. It was carried out from 1988 to 19922. It covered taxonomy, biology and growth of Chambo (*Oreochromis* spp.), fishery statistics systems and data as well as stock assessment, description of the fisheries, socio-economics and fish marketing in the Southeast arm of the lake. The research focused on establishing management strategies for the Chambo in the Southeast arm of Lake Malawi, Upper Shire River and Lake Malombe (FAO 1993). The third research programme was funded by the Government of the United Kingdom through its Overseas Development Administration (ODA) and implemented under the auspices of SADC between 1990 and 1994 (Menz 1995). As a result a model of the pelagic ecosystem of the entire lake was constructed. (Section 3.2.3; Allison et al. 1995b). The fourth research programme was undertaken from June 1994 to March 1996 with support from ICEIDA for acquisition of a 17.5 m long and 380 HP engine research vessel in addition to funding part of the operational requirements and technical support. The programme was implemented under the auspices of the Malawi Fisheries Project, which had the NDF and World Bank as financial collaborators (Banda and Tomasson 1997). Additional sources of information included Lowe-McConnell

(1975); Twombly (1983); Louda et al. (1983); Konings (1990); Christensen and Pauly (1993); Ngatunga and Allison (1996); and Turner (1996).

3.3.3.2 Limitation of information and general assumptions

There is limited research information of different periods on many of the species in the lake in order to consider different ecosystem models for the period between 1976 and 1996. Input data for some of the functional groups were not known and were therefore left to be estimated in the new Ecopath Model of Lake Malawi. The two basic research programmes that resulted in construction of previous ecosystem models of the lake have each only considered a distinct ecological zone, not the entire lake. In the new model, the lake as a whole is taken as the ecosystem unit. This is an assumption and is based on ecological characteristics of Lake Malawi (see also Section 3.2.1) and limited coverage of the lake's two previous Ecopath models. It is further based on the fact that the lake has limited habitat diversity for its size (Fryer 1959) as well as nutrient mixing in the 'living' surface and middle layers of the lake. Ecological zones can however be demarcated using geographical features or distance, and depth (Fryer 1959) and these are actually quite varied (see also Section 1.4.1; Lowe-McConnell 1975). A number of other assumptions were also made on some of the parameters used to construct the model.

The biomass estimates of the deep-water catfishes, Kampango *Bagrus meridionalis*, Bombe *Bathyclarias* spp. and Mlamba *Clarias* spp., were based on data in Table 3.2 from Banda et al. (1996); and Banda and Tomasson (1997), at trawl CPUE proportions of 5 % for bagrid and 40 % for clariids and then weighted against their respective overall catches, which are discussed in Chapter 4 (see Tables 4.2-4.3), in the lake. The division of the clariid catfish biomass between Bombe and Mlamba was also arbitrarily set based on the two species' catch proportions as well as analyses of species, gear and CPUE by Tweddle et al. (1994) between 1976 and 1989. The data considered was for traditional fishers who operate gillnets, seines, lines and traps in waters of much less than 50 metres in depth. It is further assumed that there are no significant differences in the clariid biomasses in the different regions of the lake.

Table 3.2 Fish average biomass estimates in the southeast arm (SEA) and southwest arm (SWA) of Lake Malawi; with estimate contributions to CPUE (and thus contributions to catches) of 5 % by bagrids and 40% by clariids in the deep and very deep zones; using a 17.5 m and 380 HP research vessel pulling a 'Gulltoppur' bottom trawl with 23 m long headrope and 38 mm stretched mesh codend.

Fishing Area and	Biomass (tonnes)			Mean Surface	Depth
Depth Category	1971-73+	1991-94+	1994-96	Area (km^2)	(m)
SEA, A Shallow	2900	1290	2510	221	0 - 50
SEA, B Shallow	2310	920	2670	231	0 - 50
SEA, B Deep	2330	1090	1960	233	51 - 100
SEA, C Shallow	1940	1080	2980	256	0 - 50
SEA, C Deep	3100	1900	4320	538	51 - 100
SEA, C Very Deep		890	1720	263	101 - 150
SWA Shallow	3310	1660	3360	406	0 - 50
SWA Deep	2640	2640	3760	608	51 - 100
SWA Very Deep			3460	530	101 - 150
Deep/Very Deep	8070	6520	15220	1203	51 - 150
Total	18530	11470	26740	1320	0 - 150

Source: Banda et al. (1996); Banda and Tomasson (1997).

+The data was obtained using a 14 m and 90 HP research vessel pulling a trawl with 25 mm stretched mesh codend. Comparison of the results with those of the bigger vessel which pulled a larger net at almost twice the speed of the former were reported to have differences with minimal significance.

3.3.4 Model balancing

3.3.4.1 Model area and period

The model area for the functional groups and the input data values are for the lake as a whole. Lake Malawi has a large catchment area containing several inlets and only one outlet responsible for up to 20 % of the outflow (Patterson and Kachinjika 1995). The lake has also been isolated from other water systems long enough to be able to produce its own remarkable fish fauna (Kirk 1959; Beadle 1974). The period represented is between 1976 and 1996. Within this broad period data was collected in two batches, 1977-81 and 1988-96. Most of the information was however obtained from the second period when three research programmes and other smaller studies were carried out.

3.3.4.2 Functional groups and their model input parameters

There are twenty-six functional groups (Table 3.1) and twenty of these are fish groups including one for larvae. The remaining six functional groups comprise of primary producers (phytoplankton), molluscs, apex predators (fish eating avian, reptiles and mammals), zooplankton (both herbivorous and other species), detritus and one group that is important in the food webs or chains of the lake's ecosystem as first level consumer, *Chaoborus edulis* (lakefly). The fish functional groups include species from all the eleven families that occur in the lake. Anguillidae and Mastacembelidae are represented in group one. Bagridae is in group two. Alestiidae is in group three. Cichlidae forms groups four to eleven. Clariidae is in groups twelve and thirteen. Cyprinidae is represented in groups fourteen to seventeen. Some members of the Cyprinidae form part of groups three and eighteen. Cyprinodontidae and Anabantidae are represented in group eighteen. Mochokidae is in group nineteen. Finally Mormyridae is represented in group twenty. Only representative genera and species of the families are mentioned in the following account of how initial parameter set was obtained (see also Table 3.4).

Many other creatures both known and unknown, and not directly placed in any of the above functional groups occur as part and parcel of the lake's ecosystem. Some of the organisms that form the 'import' category in the diet composition (Table 3.3) include freshwater crabs (e.g. *Potamonautes lirraongensis* and *P. orbitospinus*), frogs (e.g. *Xenopus mullereae*), water snakes, leeches, aquatic and other insects (in the families *Coleoptera, Diptera, Lepidoptera*, and *Hymenoptera*), prawn *Caridina nilotica* and many other invertebrates (Beadle 1974; Lowe-McConnell 1975, 987; Konings 1990; Yamaoka 1991; ICLARM/GTZ 1991). Plants are primary producers. Animals such as hippopotamuses may not have a direct impact on the fish but they do feed on land and water plants and therefore impact on the fish, albeit indirectly. For instance their excreta as part of the nutrient received in the lake from the catchment area may induce plankton blooms or stimulate growth of plants and algae (Villee et al. 1989; Solomon et al. 1993) thereby generating food for the higher trophic feeders which include fish (Moss 1980). It is also possible that droppings from large number of animals, for example migratory birds, coupled with natural processes around a lake ecosystem may cause an overload in nutrients or chemicals such as phosphorous, potassium and nitrogen. This affects productivity of an aquatic ecosystem as well as reduces the diversity and abundance of fauna (Moss 1980; Jeffries and Mills 1990).

1. Nkunga

Anguillidae and Mastacembelidae families are represented in this group. *Anguilla nebulosa labiata*, the only representative of Anguillidae and true eel known in the lake, is believed to migrate from the Indian Ocean through the Zambezi and Shire River systems. The indigenous mastacembelids in the group include *Mastacembelus shiranus* and *M.* sp. 'Rosette' (Lowe-McConnell 1975; Konings 1990). *A. nebulosa labiata* feeds on fish and crabs. It pursues *Pseudotropheus* spp. and haplochromines at night in rocky habitats. The mastacembelids feed on insects and other invertebrates. They are also believed to feed on small fishes (Lowe-McConnell 1975; Konings 1990).

Preliminary estimates of P/B, Q/B and EE values of 0.8 $year^{-1}$, 4.0 $year^{-1}$ and 0.94 respectively were adopted from Palomares et al. (1993) based on data estimated for eel, *Anguilla anguilla*, in the Etang de Thau, France. It is most likely that the real P/B, Q/B and EE values for Nkunga in Lake Malawi differ by some magnitude from those of *A. anguilla* considering the differences in environmental as well as geographical conditions between Lake Malawi and Etang de Thau. It is, however for the purposes of this model, assumed that the differences are insignificant.

2. Kampango

This is a single species group of a bagrid catfish endemic to Lake Malawi, *Bagrus meridionalis*. Kampango is piscivore and hunts cichlids in the rocky biotope at night as well as *Engraulicypris sardella* and *Ramphochromis* spp. Its distribution tends to coincide with the availability of the other fish species it preys on (Lowe-McConnell 1975, 1987; Konings

1991). The biomass of the group was estimated at 0.284 t·km^{-2} derived from Banda and Tomasson (1997) for the total biomass of the bottom dwelling fishes from the southern part of the lake. The allocation of biomass fraction for the bagrids was based on the proportion of the trawl CPUE estimated at 5 % (Table 3.2; see also Section 3.3.3.2). The respective estimates for P/B and Q/B values of 0.9 year^{-1} and 5.45 year^{-1} were adopted from Moreau et al. (1993) based on data for *Bagrus docmac* in Lake George, Uganda.

3. Matemba

Four families, Alestiidae, Cyprinodontidae, Anabantidae and Cyprinidae, are included in this group. Matemba mostly refers to small *Barbus* spp. of maximum length in the range of 3 -15 cm. The species in the families have been placed into this functional group mainly because of their small size. There are also some similarities or overlaps in their habitats, with a number of the species occurring in muddy bottoms around the lake's river mouths or swampy areas, and diets, with most species feeding on biocover and sediments on fine sand and mud (Lowe-McConnell 1975; Konings 1990). *Brycinus imberi*, the only alestiid in the lake is a small species found in small shoals in sheltered areas. It feeds on insects, tiny fish and vegetable matter. *Aplocheilichthys johnstoni* and *Nothobranchius orthonatus* which prey on insects, insect larvae and nymphs represent the Cyprinodontidae (killifish or toothed carps) family. Anabantidae family is represented by *Ctenopoma ctenotis*, the only species of the family in the lake. Barbels represent the cyprinids. Up to eleven species of *Barbus,* of different sizes, occur in the lake and adjacent waters (Lowe-McConnell 1975). Diets of *Barbus* cover a wide range of food items including molluscs, fish, adult insects and insect larvae, water beetles, invertebrates, crabs, aufwauchs from rock outcrops and seeds (Lowe-

McConnell 1975; Konings 1990). Some species of *Barbus* do not fit well into the Matemba functional group. These include the large locally popular food fish along the lakeshore, Kadyakolo *B. eurystomus*, predatory Batamba or Litamba *B. litamba* (*rhodesii*) and Ngumbo *B. johnstoni*. The three species attain maximum length of over 40 cm.

The input values for the model were averages from representatives of two families, viz. 11.05 $year^{-1}$ for Q/B and 0.865 for EE. This was based on Walline et al. (1993) who worked on barbels, *B. longicepis* and *B. canis*, in Lake Kinneret, Israel and on *Alestes macrolepidotus* from the Lake Chad System (Palomares et al. 1993). The biomass was set at 0.001 $t{\cdot}km^{-2}$. The biomass value was derived from the early runs of balancing the model when the P/B value of 1.9 $year^{-1}$ from the same sources was used.

4. Utaka

This group is composed of bottom feeding, zooplanktivorous, and shoaling cichlid species in the genus *Copadichromis* and to a lesser extent in *Nyassachromis*. The species are semi-pelagic, although they are mostly thought of as pelagic, and are abundant in upwelling areas around islands or submerged rocky reefs locally termed 'virundu'. *Copadichromis* spp. feed on plankton including both phytoplankton and zooplankton (cladocerans and copepods). They occasionally diet on small fish such as *Engraulicypris sardella*. To a lesser extent, they also utilize chiromonids, chaoborids and algae. *Nyassachromis* spp. feed on zooplankton (copepods), small crustaceans and filamentous diatoms, chiromonid larvae and algal material. (Konings 1990; Turner 1996).

The P/B value of 0.5 $year^{-1}$ was based on that for *Copadichromis quadrimaculatus* in Allison et al. (1995b). The Q/B value of 5.67 $year^{-1}$ was similarly for *C. quadrimaculatus* in Ngatunga et al. (1996) and Allison et al. (1995a). The EE value of 0.475 was a mean from Degnbol (1993) and Allison et al. (1995b).

5. Ndunduma

Ndunduma are fish and zooplankton eaters in deep-water habitats mainly belonging to the genus of *Diplotaxodon* (at least 13 species) while a few species belong to other genera such as *Pallidochromis.* A number of Ndunduma are found in the pelagic zone in the offshore habitats and may take up a place corresponding to that of Utaka (*Copadichromis* spp.). Ndunduma feeds on crustacean zooplankton (*Tropodiaptomus cunningtoni, Mesocyclops aequatorialis aequatorialis, Thermocyclops neglectus* and *Diaphonosoma excisum*, etc.), chaoborid larvae and pupae, and filamentous diatoms or algae (*Aulacoseira*). Some species of *Diplotaxodon* feed on other fish. These encompass *E. sardella* including its larvae and fry, and small cichlid fish such as *Aulonocara* and *Lethrinops* including their larvae and eggs (Konings 1990; Allison et al. 1995a; Turner 1996).

The model input values of 2.49 $t \cdot km^{-2}$ and 0.5 $year^{-1}$ for biomass and P/B respectively were derived from the mean values for *Diplotaxodon* 'bigeye' and *D.* 'elongate' in Allison et al. (1995a). The Q/B value of 5.866 $year^{-1}$ was obtained from a mean of Q/B values for five *Diplotaxodon* spp. (*D. argenteus, D.* 'bigeye', *D. limnothrissa, D. greenwoodi* and *D.* 'holochromis') in Ngatunga et al. (1996).

6. Kambuzi

Kambuzi is one of the large groups of cichlids in the lake. Most of the species belong to the genus of *Protomelas*. One of the common species in this group is *P. similis,* from which the Chichewa name of the group is derived. The Q/B and EE values of 3.9 $year^{-1}$ and 0.95 respectively were adopted from Degnbol (1993). The P/B value of 0.5 $year^{-1}$ was from the 'cichlids' in Allison et al. (1995b). The group's biomass was left to be estimated in the model.

Some Kambuzi species such as *P. similis* are herbivorous and feed on leaves of macrophytes such as *Vallisneria aethiopica*, and on algae. Others for example *P. labridens* feed on snails relying thereby on its enlarged pharyngeal dentition (Turner 1996). *P. pleurotania* feeds on invertebrates in the upper sandy sediment layers. *P. marginatus marginatus* and *P. marginatus vuae* feed on plant material, sponge and invertebrates (Konings 1990; Turner 1996). *P. kirkii* feeds on invertebrates, crustaceans and snails. Yet other Kambuzi e.g. *P. triaenodon* have poor teeth formation. They are here assumed to feed on zooplankton in midwater (Turner 1996).

7. Chisawasawa

This is yet another cichlid group. Its species are demersal feeders mostly found in the genus *Lethrinops*. A few species are from other genera such as *Taeniolethrinops* and *Tramitichromis.* Chisawasawa feed on benthic diatoms; pinnate or unicellular and filamentous *Aulacoseira* (= *Melosira*); benthic calanoid copepods, algae, benthic invertebrates from sand and mud; chironomids and larvae; other benthic arthropods and insect larvae, crustacea or crustacean carcasses and sediments including sand and detritus (Lowe-McConnell 1975; Konings 1990; Turner 1996). P/B, Q/B and EE estimates of 0.5 $year^{-1}$, 5.06 $year^{-1}$ and 0.67 respectively were obtained from Allison et al. (1995b) for this group whose biomass was left to be estimated in model.

8. Chambo

The group represents endemic tilapiine (cichlids) of the genus *Oreochromis* and subgenus *Nyasalapia* (see Appendix 1.7). They are *O. squampinis, O. lidole* and *O. karongae.* The last species has a variant known as *O. saka* (FAO 1993). The diet of Chambo species, in the south of Lake Malawi, is comprised of diatoms, *Aulacoseira, Surirella* and a variety of filamentous green and blue-green algae. The respective percentages of diatoms are 80-81 % and 6-11 % for *O. squampinis*, 79-80 % and 5-13 % for *O. karongae*, and 47-66 % and 11-14 % in addition to 13-29 % of a copepod, *Diaptomus,* for *O. lidole* (Konings 1990; Turner 1996).

The biomass of the group was first derived from the FAO 1988-1992 study whose data yielded a total of 9883 tonnes for the three species. This value was obtained in the southern part of the lake estimated at 2500 km^2 in area or less than 10 % of the lake area. The FAO study area, i.e., the south east arm of Lake Malawi, has high productivity and is the richest fishing area in the lake (Eccles 1962; FAO 1993). The Chambo biomass estimate for the lake as a whole was assumed to be one and a half times its biomass in the southeast arm. However, the biomass estimate did not balance the model when data was inputted into the latest version of Ecopath. The biomass was therefore re-estimated in the model. P/B and

Q/B values of 0.5 $year^{-1}$ and 5.06 $year^{-1}$ respectively have been adopted from Allison et al. (1995b). EE value of 0.81 was a mean from Degnbol (1993) and Allison et al. (1995b).

9. Chilunguni

Chilunguni represent tilapias that are not part of Chambo in Lake Malawi. These are *Tilapia rendalli* and *Oreochromis shiranus*. These tilapias mainly feed on phytoplankton (Konings 1990). *T. rendalli* also feeds on macrophytes. *O. shiranus's* diet comprises macrophytes and detritus as well as benthic and planktonic larvae. Both *O. shiranus* and *T. rendalli* are also well known species for fish farming. In ponds, they can feed on diatoms, other phytoplankton, microcrustaceans, other zooplankton (including rotifers and euglenoids) and detritus apart from prepared feeds. The juveniles are omnivorous while adults (with total length of above 12-15 cm) favour macrophytic plant materials. (van Dam et al. 1993; Brummett and Noble 1995). The Q/B value of 4.48 $year^{-1}$ was averaged from cichlid data in Degnbol (1993) and Allison et al. (1995b). The P/B and EE values of 0.5 $year^{-1}$ and 0.67 respectively were adopted from Allison et al. (1995b) estimated for cichlids other than *Ramphochromis, Diplotaxodon* and *Copadichromis*. The biomass of the group was estimated in the model.

10. Mbuna

Mbuna is a group of rock-dwelling cichlids. It is popular with tropical fish aquarists and ornamental tropical fish trade for they exhibit varied colours. Mbuna consists of a few closely related genera (Lowe-McConnell 1975) with most species in the genus *Pseudotropheus*. Other Mbuna genera include *Cynotilapia, Cyathochromis, Genyochromis,* *Melanochromis* and *Petrotilapia*. Mbuna feed on *E. sardella* larvae, *Chaoborus edulis* and other insects, molluscs, invertebrates, benthic macrophytes and crustaceans, zooplankton, phytoplankton or aufwuch and detritus depending on species type and their geographical zone in the lake (Lowe-McConnell 1975; Konings 1990; Turner 1996).

The P/B, Q/B and EE values of 0.5 $year^{-1}$, 5.06 $year^{-1}$ and 0.67 respectively were based on data for 'other cichlids' in Allison et al. (1995b). The Mbuna functional group may therefore also represent all the cichlids not specifically assigned to any functional group in this model. The biomass of Mbuna was first estimated at 5 $t \cdot km^{-2}$. This was derived from the fish density of 10 per square metre for the group (Lowe-McConnell 1987, based on Ribbink et al. 1983). It was assumed that the average weight in the Mbuna population was 20g per fish, also 10 % of the lake has suitable conditions for *Pseudotropheus* spp. and similar species in the Mbuna functional group. The biomass was then re-estimated in the model.

11. Mcheni

This is a group of zooplanktivorous and piscivorous cichlids ('tigerfishes') belonging to the genus *Ramphochromis* with as many as 20 species. They actively look for food in different habitats and occur offshore in both pelagic and bottom part of the lake with most of them found in deep or mid-waters. Large Mcheni predates mainly on midwater fish species of *Engraulicypris sardella, Diplotaxodon* spp. *and Copadichromis* spp. while small ones feed on zooplankton (Lowe-McConnell 1975; Konings 1990; Allison et al. 1995a).

The biomass and P/B values of 0.285 t·km^{-2} and 0.5 year^{-1} respectively were derived from average values of large *Ramphochromis* spp. *and R. longiceps* in Allison et al. (1995b). The Q/B value of 5.338 year^{-1} was obtained from the mean of four *Ramphochromis* spp. *(R. esox, R. leptosoma, R. longiceps and R. woodi)* in Ngatunga et al. (1996).

12. Bombe

Bombe consists of large clariid catfish *Bathyclarias*[14] spp. endemic to the lake. There are ten species of Bombe viz. *B. euryodon*, *B. filicibarbis*, *B. feveolatus*, *B. gigas*, *B. iles*, *B. longibarbis*, *B. loweae*, *B. nyasensis*, *B. rotundifrons*, and *B. worthingtoni*. Several of the Bombe species are piscivores and prefer rocky and muddy bottoms. However, some Bombe feed on zooplankton through filtering, on small fishes and on insect larvae especially *Chaoboris edulis* (Lowe-McConnell 1975, 1987; Konings 1990).

Bombe biomass was estimated at 1.109 t·km^{-2} (derived as described in 3.3.3.2). The P/B values of 0.9 year^{-1} was adopted from Moreau et al. (1993) based on data for *Bagrus docmac* and *Clarias gariepinus* in Lake George, Uganda. It is here assumed that the maximum ages achieved by *Bathyclarias* are similar to those of the above catfishes. The Q/B value of 3.31 year^{-1} was from Ngatunga et al. (1996).

[14] Jackson believes that some species of the *Bathyclarias* may be misplaced and belong to the genus *Dinotopterus* while Roberts is of the opinion that *Bathyclarias* is not synonymous to *Dinotopterus* but have similar characteristics due to convergent evolution (Lowe-McConnell 1975).

13. Mlamba

Mlamba consists of four species of *Clarias* catfish, *C. gariepinus, C. mellandi, C. mossambicus, and C. theodorae* (Lowe-McConnell 1987; Konings 1990; ICLARM/GTZ 1991). *Clarias* spp. like most clariids, are omnivores. Some species, such as *C. mellandi* and *C. mossambicus,* subsist on snails and similar food items. In Shire River, the only outlet of Lake Malawi, Mlamba feed on fish (22.6 %), plant detritus (22.8 %), humus or soil organic matter (20 %), filamentous algae (9 %), dragonfly nymph (6 %), chiromonid larvae (5 %), fresh plant (4 %), mud (3.6 %), and other materials (2 %) (Willoughby and Tweddle 1978). Other species fed mostly on insects (Konings 1990).

Mlamba biomass was estimated at 1.162 $t \cdot km^{-2}$ (derived as described in 3.3.3.2). The biomass may be over-estimated for the *Clarias* spp. The biomass estimate was based on catch as well as on the assumption that Mlamba is evenly distributed in the lake. However, most species of Mlamba are demersal and occur inshore (ICLARM/GTZ 1991). The catch considered is from traditional fishers, who also fish in the inshore areas. The biomass estimate therefore best reflects the demersal inshore zone rather than the whole lake. The P/B and Q/B values of 0.9 $year^{-1}$ and 5.33 $year^{-1}$ respectively were adopted from Moreau et al. (1993) based on data for *Clarias gariepinus* in Lake George, Uganda.

14. Usipa

The group refers to *Engraulicypris sardella,* a monotypic bariliine cyprinid endemic to Lake Malawi and found in the open waters in large numbers. Usipa is an annual species and suffers a high natural mortality ranging from 0.89 to 0.99 $year^{-1}$ (Anon 1988; Skelton 1991).

Usipa are zooplanktivorous and prey on copepods, *Tropodiaptomus conningtoni* (calanoid), *Mesocyclops a. aequatorialis* and *Thermocyclops neglectus* (cyclopids), *Diaphanisona excisum* (cladoceran), *Bosimina longrostris* as well as nauplii, rotifers and lakefly, *Chaoborus edulis*. The extent of utilization depended on size of Usipa with the adults going for the longer items and juveniles the small ones (Allison et al. 1995a). Usipa annual biomass is influenced by the productivity of the lake, connected through the phytoplankton-Usipa larvae food chain with the result of yearly catch fluctuating by an order of magnitude (Skelton 1991).

Usipa biomass, P/B and Q/B values of 0.56 $t \cdot km^{-2}$, 2.5 $year^{-1}$ and 9.23 $year^{-1}$ respectively were used. The biomass was an average from Degnbol (1993) who estimated 0.9 $t \cdot km^{-2}$ and a mean of 0.22 $t \cdot km^{-2}$ from acoustic surveys in Allison et al. (1995b). The surveys' biomasses were noted to be very variable and the mean of 0.22 $t \cdot km^{-2}$ was allowed to vary in the model constructed after the research programme. The P/B was adopted from Allison et al. (1995b) who calculated the value using the relationship of Pauly (1980) linking growth parameters and instantaneous natural mortality with an assumption that P/B=M. This was probably justifiable considering that the focus area in the study was the pelagic offshore. No fishing occurs there and could reasonably be taken as unexploited system at steady state to meet a prerequisite for equivalence between mortality and ratio of production over biomass (Allison et al. 1995b; Menz 1995). The Q/B value was from Ngatunga et al. (1996).

15. Usipa larvae

This group represents the larvae stage of *Engraulicypris sardella.* The larvae and eggs of *E. sardella* are mostly found in the open waters or pelagic zone throughout the year. Usipa larvae and juveniles are also found inshore, as do the adults. The spatial pattern of the larvae abundance follows that of adults up to a magnitude (Thompson 1995; Allison et al. 1995a). Larvae like plankton are usually plentiful during the cold 'mwera' season between June and August, when water mixing in the lake is greatest (Lowe-McConnell 1987; Thompson 1995). Starvation and predation are the main contributors to its natural mortality. Density-dependent mortality of Usipa larvae is very high when the size is small. Usipa larvae are the only larvae that are pelagic and planktonic among the offshore fish species (Thompson 1995); and are thus food for many predators in the lake. The Usipa larvae form one of the quantitatively important species groups to the lake's pelagic ecosystem (Allison et al. 1995b). Usipa larvae compete with lakefly *Chaoborus edulis* and its larvae. Both feed exclusively (80 %) on a crustacean zooplankton *Tropodiaptomus conningtoni* (Konings 1990; Thompson 1995).

The biomass, P/B and Q/B estimates of 0.13 $t{\cdot}km^{-2}$, 62.0 $year^{-1}$ and 650.0 $year^{-1}$ respectively were adopted from Allison et al. (1995b). These inputs generated a very low gross food conversion efficiency (GE). A GE value of 0.3, a possible range for items similar to Usipa larvae (Christensen and Pauly 1992), was assigned. And the Q/B was left to be estimated in the model.

16. Sanjika

This group consists exclusively of *Opsaridium microcephalus* which functions in many ways like *Opsaridium microlepis*. It is also endemic to the lake and caught in affluent rivers and streams. It is smaller than *O. microlepis*, attaining a maximum length of 30 cm. Sanjika feeds on *E. sardella* and larvae, *C. edulis*, and zooplankton. It is known to pursue *E. sardella* along the shoreline. It is more adapted to lacustrine habitats than *O. microlepis*. Sanjika breeds in rocky shores of the lake that are well supplied with oxygen through wave action (Skelton et al. 1991). When Sanjika migrates upstream to spawn it prefers cooler mountain streams at 300 m or more above sea level (Konings 1990).

Sanjika biomass was estimated at 0.03 $t \cdot km^{-2}$. As for *O. microlepis,* this was derived from the total *Opsaridium* biomass in Allison et al. (1995b) using the two species CPUE proportions from Tweddle et al. (1994). The P/B and Q/B values were 0.6 $year^{-1}$ and 6.21 $year^{-1}$ respectively. P/B was obtained from the mean of two *Opsaridium* spp. values in Degnbol (1993) and Allison et al. (1995b). The Q/B value was empirically derived as reported by Ngatunga et al. (1996), based on a regression model of Jarre et al. (1991):

$$\log_{10}Q/B = 4.885 - 1309.139(1/T) + 0.423 \log_{10}A + 0.285 \log_{10}D - 0.111 \log_{10}W_{\infty} - 0.445 \log_{10}CP$$

Where T = Temperature in Kelvin, A = aspect ratio of caudal fin (=$height^2$/fin surface area), D = depth ratio (standard length/maximum body depth), W_{∞} = maximum live weight (g) in the population, and CP = caudal peduncle depth/maximum body depth.

17. Mpasa

Mpasa consists of *Opsaridium microlepis* a pelagic bariliine cyprinid. With a maximum length reaching in excess of 70 cm and weighing up to 4 kg, Mpasa is the largest African bariliine (Skelton et al. 1991). Like all other bariliines, it is an open water carnivore. It preys mainly on other (smaller) fish, such as *E. sardella* (Konings 1991), *E. sardella* larvae, *C. edulis*, zooplankton (Allison et al. 1995a) with its young feeding on invertebrates such as insects (*Chaoborus*) and crustaceans (Skelton et al. 1991). Mpasa exhibits similar characteristics to salmonids such as feeding less extensively during the breeding season. Selective overfishing of Mpasa at river mouths as well as river habitat degradation and poor water quality are causing the biomass of Mpasa to decline (Skelton et al. 1991).

The biomass of Mpasa was estimated at 0.02 $t \cdot km^{-2}$. This was derived in a similar way to the biomass of Sanjika. The P/B and Q/B values were 0.6 $year^{-1}$ and 4.23 $year^{-1}$ respectively. P/B was derived from mean of values in relation to the two *Opsaridium* spp. occurring in the lake estimated at 0.7 $year^{-1}$ by Degnbol (1993) and at 0.5 $year^{-1}$ by Allison et al. (1995b). The Q/B value was adopted from Ngatunga et al. (1996).

18. Nchila

This group is represented by two labeines belonging to the Cyprinidae family, *Labeo mesops* and *L. cylindricus*. The former species mostly occurs in muddy bottoms around the lake's river mouths or swampy areas. The later occupies sandy bottom areas of the lake (Lowe-McConnell 1975). Competitive exclusion seems to occur between *L. mesops* and *L. cylindricus*. *L. mesops* is a benthic algal grazer; feeding on biocover and sediments on fine sand and mud. *L. cylindricus* is a rock scraper and feeds on diatoms, other small algae and loose material (Lowe-McConnel.1987; Konings 1990).

The biomass of the functional group was assumed to be in the region of 0.01 $t{\cdot}km^{-2}$. Although in early stages of balancing and estimating biomass of the group in the model generated 0 $t{\cdot}km^{-2}$, a fishery for one of the species in the group, *L. mesops,* exists. *L. mesops* fishery used to be the second largest in Lake Malawi but has a mean annual yield of 0.006 $t{\cdot}km^{-2}$ now. This is used in the model for the Nchila group. Also clear streams draining into the lake, and relatively less-populated and less-degraded rivers within the lake's catchment area, which are *L. mesops*'s good spawning areas are available (Eccles 1985). Secondly *Labeo cylindricus* is able to breed in the lake without having to migrate upstream (Lowe-McConnell 1987; Konings 1990). which reduces its vulnerability to fishing by traditional fishers. The P/B and Q/B values of 4.0 $year^{-1}$ and 40.0 $year^{-1}$ respectively were adopted from Palomares et al. (1993) for detritivores (comprising of *Labeo, Citharinus* and *Oistichodus* spp.) from the Lake Chad System.

19. Nkholokolo

This group represents squeakers, small catfishes belonging to Mochokidae family. The main species in this group is *Synodontis njassae* which is endemic to Lake Malawi. It is mostly around rocks hiding in crevices during the day and comes out at night. Nkholokolo is a benthic invertebrate feeder and diets on *Chaoborus edulis,* chironomid larvae, other insects, zooplankton, algae (including vegetative material, *Pistia stratiodes*), crustaceans, other invertebrates and detritus including seeds and pollen. Zooplankton which comprised of

Diaphanosoma excism, Mesocyclops aequatorialis aequatorialis, Thermocyclops neglectus, Tropodiaptomus cunningtoni as well as other species (Konings 1990; Allison et al. 1995a).

The biomass and P/B values of 0.59 t·km^{-2} and 0.5 year^{-1} were from Allison, et al. (1995b). The Q/B value of 8.5 year^{-1} was from Ngatunga et al. (1996). The Q/B was comparable to that estimated for *Synodontis* in Moreau et al. (1993b).

20. Samwamowa

The group represents species in the genera *Marcusensis, Mormyrus* and *Petrocephalus* which usually occur in shallow muddy or swampy areas. There are six species in the lake comprising *Marcusensis discorhynchus, M. macrolepdotus, M. nyasensis, Mormyrus deliciosus, M. longistris and Petrocephalus catostoma.* As a group their food includes insects, larvae of chiromonid and other insects, invertebrates and other fish. Some of the species may also feed on plankton and weeds (Lowe-McConnell 1975; Konings 1990).

The Q/B value of 11.62 year^{-1} was adopted from the mormyrid fishes of Lake Victoria on the Kenyan side (Moreau et al. 1993b). The P/B value of 0.9 year^{-1} was also from Moreau et al. (1993) where it represented mormyrids and *Synodontis* species. The biomass for the Samwamowa functional group in this model was assumed to be 0.001 t·km^{-2}. The group is not recorded separately in the Malawi Fisheries Department (MFD) fisheries statistics and is usually part of the category of 'Others' (Tweddle et al. 1994). It is however present in the category of 'Others' in almost all the MFD records.

21. Nkhungu

The lakefly *Chaoborus edulis* forms a link between the lower and higher trophic level feeders in the pelagic zone of the Lake Malawi ecosystem. It has a short-lived adult phase and a long larvae stage. It was earlier believed that 98 % of the primary production passes through Nkhungu and most that of this energy was then lost as adult *C. edulis* left the lake (Irvine 1995b). However, it was later estimated that as much as 47 % of the energy passing through the lakefly was utilized in the lake system (Allison et al. 1995b). *Chaoborus edulis* is an ambush predator of carnivorous zooplankton which also utilizes zooplankton at low densities (see Section 3.2.3 and Eccles 1985; Allison et al. 1995a). Its diet comprises of zooplankton with the larvae stage feeding more on phytoplankton. The zooplankton includes *Bosinima longistris, Diaphanosoma excism, Mesocyclops aequatorialis aequatorialis, Thermocyclops neglectus, Tropodiaptomus cunningtoni*, unidentified copepods and other food items including small amount of cannibalism. The unidentified copepods probably include *Thermodiaptomus mixtus* and other diaptomid copepods as part of the zooplankton assemblage in the southern part of the lake (Twombly 1983). Nkhungu select their food items for size and large *C. edulis* feed on large food items (Irvine 1995b).

Nkhungu biomass, Q/B and EE values of 1.75 $t{\cdot}km^{-2}$, 69.7 $year^{-1}$ and 0.47 respectively were adopted from Allison et al. (1995b). The P/B value of 38.7 $year^{-1}$ based on the same study was left out and re-estimated in this model as the estimated EE was greater than 1.0 when the value of 38.7 $year^{-1}$ was used.

22. Nkhono

Nkhono covers gastropod and lamellibranch molluscs. There are six families with 19 species (11 endemic) in eight genera including *Balinus, Bellamya, Gabbiella, Lanistes* and *Melanoides* for the gastropods and three families with 12 species (8 endemic) in six genera including *Nauthauma* of lamellibranchs in Lake Malawi (Beadle 1974). Although not known in detail, their role in the food chain is important as they are food source for at least six molluscivore groups of fish in the lake (Louda et al. 1983). The diet of Nkhono has been observed to include benthic macrophytes, phytoplankton and detritus as well as organic matter and bacteria (Louda et al. 1983, 1984).

Nkhono biomass was derived from the mollusc density data in Louda et al. (1983) who report a density distribution range of 2 - 123 m^{-2} for the gastropods in the southern part of the lake. The lower side of the range, i.e., 2 m^{-2} was used in the biomass calculation. The average weight of individual molluscs was assumed to be 10g and the distribution of the molluscs or area they favour was set at a quarter of the lake area. From descriptive accounts, molluscs are abundant and widely distributed in the lake although the number of species is less compared to Lake Tanganyika (Beadle 1974; Fryer 1959 quoting Moore in 1903; Louda et al. 1983; Stauffer et al. 1997). The biomass of Nkhono was therefore conservatively estimated at 5.0 $t \cdot km^{-2}$. The P/B and Q/B values of 2.8 $year^{-1}$ and 5.6 $year^{-1}$ were based on the molluscs of the reef flat ecosystem of Bolinao, Philippines (Aliño et al. 1993).

23. Top predators

This group represents higher animals: avian (reed cormorants, white-breasted cormorants - *Phalacrocorax carbo lucidus*, African fish eagles – *Haliaeetus vocifer*, pied kingfishers – *Alcedinidae* spp., herons – *Ardea* spp., hammerkops – *Scopus umbretta*, egrets – *Egretta* spp. and pelicans – *Pelecanus onocrotalus*); reptiles (monitor lizards and crocodiles - *Crocodylus africanus*); and mammals (spotted-neck and clawless otters) as well as other species which prey on fish (Tweddle 1991; ICLARM/GTZ 1991; WWF 1998). Of the different members in this group, only cormorants have been studied with respect to impact on fisheries in Malawi and their presence including feeding on fish did not have any negative effect on the commercial fisheries in Lake Malawi (Tweddle 1991, based on Campbell 1983; Linn and Campbell 1981 & 1986).

The biomass value of 0.001 $t \cdot km^{-2}$ was assigned based on the numbers of cormorants and crocodiles. There are over 10,000 cormorants in the lake region (Tweddle 1991). The 'harvest' of crocodiles from Lake Malawi is about 200 per year. The CITES[15] limit of crocodile skins that Malawi can trade is 300 per year. In Malawi, quotas allocated to private crocodile hunters and Government total 200 for Lake Malawi and the balance is from other water bodies. Reports on encounters with the crocodiles indicate that they are abundant especially in river mouths and marshy or sheltered areas (ICLARM/GTZ 1991; Tweddle et al. 1994) and thus support the assumption that their biomass is high. In the Lower Shire River, the only outlet of Lake Malawi, there was a very high population of young crocodiles

[15] CITES is the Convention on International Trade in Endangered Species of Wild Flora and Fauna in association with the World Conservation Union (IUCN), United Nations Environment Programme (UNEP), and World Wide Fund for Nature (WWF).

in a survey of 1986 (B. Mphande *pers. comm.*). In the Upper Shire River the number of crocodiles is estimated at more than twice that of hippopotamuses (*Hippopotamus amphibius*) which is about 2,000 for the latter (OLN 1999). For the purposes of the groups' biomass calculation, 450 - 500 crocodiles are assumed to be resident in the Lake Malawi waters on permanent basis. Cormorants and crocodiles are further assumed to have mean weights of 0.5 kg and 50 kg respectively which together provide a value of close to 0.001 $t{\cdot}km^{-2}$. This value is most likely to be an underestimate for the group as other members apart from cormorants and crocodiles also occur in Lake Malawi (ICLARM/GTZ 1991; WWF 1998). With exception of the biomass, the input data for the group were those of fish-eating birds. P/B and Q/B values of 0.25 $year^{-1}$ and 58 $year^{-1}$ respectively were adopted from the fish-eating birds in the Lake George, Uganda (Moreau et al. 1993a).

24. Zooplankton

This group includes both small and large zooplankton. Copepods included *Mesocyclops aequatorialis aequatorialis, Tropodiaptomus canningtoni*, and *Thermocyclops neglectus*. The cladocerans are represented by *Diaphonosoma excisum* and *Bosmina longrostris*. Naupulii are found as well as *Diaptomus kraepelini* and *Mesocyclops leuckarti*. The diet of most species in the group is comprised of phytoplankton and other zooplankton -group cannibalism (Lowe-McConnell 1975; Allison et al. 1995a; Irvine 1995a; Twombly 1983). The respective biomass, P/B and Q/B values of 5.38 $t{\cdot}km^{-2}$, 30.5 $year^{-1}$ and 144.57 $year^{-1}$ were adopted from those of herbivorous and carnivorous zooplankton in Allison et al. (1995b).

25. Phytoplankton

Many species make up this functional group and they include those in the genera of *Aulacoseira, Surirella, Stephanodiscus, Mougeotia, Cymatopleura, Closterium, Synedra* and *Staurastrum* which occur in four phyla (Patterson and Kachinjika 1995; see Table3.1). The functional group is the main producer for the lake system (Thompson et al. 1995). Plants also exist in the lake. These include Lake Malawi val *Vallisneria aethiopica*, hippo grass *Vossia cusidata*, water lily, lake grass bed species *Potamogeton schweinfurthii* and *P. pectinatus*, reed *Phragmites communis*, reed grass *P. mauritianus*, algal vegetative material *Pistia stratiodes* and other macrophytes (Beadle 1974; Lowe-McConnell 1975, 987; Konings 1990; Yamaoka 1991; ICLARM/GTZ 1991). The plants are not quantified. Biomass value of 7.62 t·km^{-2} was a mean from Degnbol (1993) and Allison et al. (1995b). P/B value of 258.4 year^{-1} adopted from Allison et al. (1995.).

26. Detritus

Represents organic matter, either dissolved or particulate.

3.3.4.3 Diet matrix

The diets of the functional groups were quantified basing on the items described under each group in Section 3.3.4.2. The values after editing to balance the model are presented in Table 3.3. In general predation pressure increased from the top to bottom trophic level functional groups.

3.3.4.4 Model modifications

A number of steps were carried out to balance the model. The first step consisted of modifying the diets of Kambuzi, Utaka, Chisawasawa, Mcheni and Usipa to reduce their estimated EE values, which were above unity in early runs of the model. The change in the diet of Kambuzi was reducing its food items of zooplankton by 1.5 % and phytoplankton by 2.5 % as well as increasing import by 4 %. Intake of zooplankton by Utaka was reduced by 4 % while that of phytoplankton was increased by 4.5 %. In the diet of Chisawasawa, phytoplankton and detritus were increased by 1 % and 0.5 % respectively. Consumption of phytoplankton by Mcheni was increased by 1 %. Predation on zooplankton was also reduced in diet of Usipa *Engraulicypris sardella* by 1.5 %, and by 0.5 % in those of Nkholokolo *Synodontis njassae*, Ndunduma *Diplotaxodon* spp., Bombe *Bathyclarias* spp. and Mlamba *Clarias* spp.

In addition to the above changes, predation of Nkhungu *Chaoborus edulis* by Mbuna *Pseudotropheus* spp. was reduced by 5 % in order to reduce the former's gross food conversion efficiency (GE) and production over respiration ratio (P/R) values which were greater than one. The mean trophic level of Lake Malawi system was also changed from 5.0 to 3.8 in the process of reducing predation on zooplankton by increasing grazing of phytoplankton and consumption of detritus by the groups previously feeding mostly on zooplankton.

Table 3.3 Diet Compositions for the model functional groups (values are rounded to two decimal places).

Prey\Predator	Nkunga	Kampango	Matemba	Utaka	Ndunduma	Kambuzi	Chisawasawa	Chambo	Chilunguni	Mbuna	Mcheni	Bombe	Mlamba	Usipa	Usipa larvae	Sanjika	Mpasa	Nchila	Nkholokolo	Samwamowa	Nkhungu	Nkhono	Top predators	Zooplankton
Nkunga	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Kampango	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Matemba	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00
Utaka	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
Ndunduma	0.00	0.09	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.10	0.00
Kambuzi	0.00	0.06	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
Chisawasawa	0.02	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
Chambo	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chilunguni	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mbuna	0.20	0.30	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.20	0.00
Mcheni	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bombe	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00
Mlamba	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Usipa	0.05	0.25	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.28	0.00	0.00	0.00	0.00	0.20	0.20	0.00	0.00	0.05	0.00	0.00	0.00	0.00
Usipa larvae	0.00	0.00	0.01	0.04	0.10	0.00	0.00	0.00	0.00	0.05	0.52	0.05	0.00	0.00	0.00	0.39	0.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sanjika	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mpasa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nchila	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nkholokolo	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00
Samwamowa	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00
Nkhungu	0.00	0.00	0.09	0.22	0.45	0.00	0.05	0.00	0.00	0.07	0.10	0.05	0.03	0.12	0.00	0.30	0.30	0.00	0.59	0.02	0.00	0.00	0.00	0.00
Nkhono	0.05	0.00	0.05	0.02	0.00	0.09	0.10	0.00	0.00	0.01	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.01	0.15	0.01	0.00	0.00	0.18	0.00
Top predators	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00
Zooplankton	0.00	0.00	0.17	0.31	0.13	0.14	0.18	0.08	0.01	0.22	0.05	0.09	0.02	0.57	0.64	0.10	0.09	0.01	0.12	0.15	0.65	0.00	0.00	0.00
Phytoplankton	0.00	0.00	0.05	0.40	0.13	0.63	0.62	0.90	0.86	0.34	0.02	0.00	0.13	0.08	0.35	0.00	0.00	0.51	0.03	0.06	0.25	0.15	0.00	0.80
Detritus	0.00	0.00	0.01	0.02	0.00	0.05	0.01	0.01	0.14	0.05	0.03	0.00	0.46	0.00	0.00	0.00	0.00	0.19	0.01	0.15	0.00	0.20	0.00	0.00
Import	0.67	0.27	0.54	0.02	0.20	0.11	0.05	0.02	0.00	0.27	0.00	0.48	0.02	0.24	0.02	0.02	0.03	0.30	0.11	0.50	0.10	0.65	0.29	0.20
Sum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

The next step related to reducing the respiration/biomass (R/B) ratio of Matemba which was above one. The P/B input value of 1.9 $year^{-1}$ for the group was left unknown to be re-estimated in the model while its biomass value was set at 0.001 $t \cdot km^{-2}$. Thirdly, the biomasses for Utaka (0.38 $t \cdot km^{-2}$) and Chambo (0.343 $t \cdot km^{-2}$), which were originally calculated through field studies, did not balance the model and were therefore allowed to be re-estimated to 1.75 $t \cdot km^{-2}$ and 0.48 $t \cdot km^{-2}$ respectively. Also the phytoplankton biomass value of 9.84 $t \cdot km^{-2}$ from Allison et al. (1995a) was replaced by a mean value of 7.62 $t \cdot km^{-2}$ from those of 5.4 $t \cdot km^{-2}$ (Degnbol 1993) and 9.84 $t \cdot km^{-2}$ (Allison et al. 1995a). Finally, 10 % cannibalism was allowed in the diet of the top predators which consists of 29 % imports and 61 % different fish species to balance the diet composition matrix to 1 for the group. This also increased the group's trophic level from 3.5 to 3.6.

3.3.5 Flowchart and other results

3.3.5.1 Basic estimates and flowchart

The basic estimates of the model are detailed in Table 3.4. The trophic structure of the Lake Malawi ecosystem between 1976 and 1996, i.e., the period when all the research programmes whose results are used in this model were undertaken as detailed in Section 3.2, is graphically summarized in Fig. 3.2. The trophic mode (TM) values in the groups were zero except phytoplankton and detritus signifying the fact that they are consumers. Detritus is utilized by many of the groups although phytoplankton is by far the more important group for the bottom feeding groups. The main users of the secondary production, Nkhungu *Chaoborus edulis* and Usipa larvae have a high number of

Table 3.4 Basic estimate parameters for the Lake Malawi Ecopath model (input parameters are in brackets and dashes mean that data cannot be assigned or is not available; values are rounded to two decimal places).

No.	Group Name	TM	B ($t \cdot km^{-2}$)	P/B ($year^{-1}$)	Q/B ($year^{-1}$)	EE	GE	Catch ($t \cdot km^{-2} \cdot year^{-1}$)	FD ($t \cdot km^{-2} \cdot year^{-1}$)	Net Eff	TL	OI	R ($t \cdot km^{-2} \cdot year^{-1}$)	Assim ($t \cdot km^{-2} \cdot year^{-1}$)	P/R	R/B ($year^{-1}$)
1	Nkunga	0.00	0.00	(0.80)	(4.00)	(0.94)	0.20	–	0.00	0.25	3.50	0.99	0.00	0.00	0.33	2.40
2	Kampango	0.00	(0.28)	(0.90)	(5.45)	0.32	0.17	0.07	0.48	0.21	3.80	0.51	0.98	1.24	0.26	3.46
3	Matemba	0.00	(0.00)	3.35	(11.05)	(0.87)	0.30	–	0.00	0.38	2.50	0.41	0.01	0.01	0.61	5.49
4	Utaka	0.00	1.75	(0.50)	(5.67)	(0.48)	0.09	0.36	2.45	0.11	2.80	0.49	7.07	7.94	0.12	4.04
5	Ndunduma	0.00	(2.49)	(0.50)	(5.87)	(0.73)	0.09	0.01	3.26	0.11	3.30	0.50	10.44	11.69	0.12	4.19
6	Kambuzi	0.00	0.42	(0.50)	(3.90)	(0.95)	0.13	0.08	0.33	0.16	2.20	0.18	1.09	1.29	0.19	2.62
7	Chisawasawa	0.00	0.17	(0.50)	(5.06)	(0.67)	0.10	0.01	0.20	0.12	2.40	0.29	0.61	0.69	0.14	3.55
8	Chambo	0.00	0.48	(0.50)	(5.06)	0.81	0.10	0.15	0.53	0.12	2.10	0.07	1.71	1.95	0.14	3.55
9	Chilunguni	0.00	0.16	(0.50)	(4.48)	0.67	0.11	0.01	0.17	0.14	2.00	0.01	0.50	0.58	0.16	3.08
10	Mbuna	0.00	7.48	(0.50)	(5.06)	0.67	0.10	–	8.81	0.12	2.60	0.45	26.55	30.30	0.14	3.55
11	Mcheni	0.00	(0.29)	(0.50)	(5.39)	0.23	0.09	0.01	0.42	0.12	3.70	0.18	1.09	1.23	0.13	3.81
12	Bombe	0.00	(1.11)	(0.90)	(3.31)	0.07	0.27	0.05	1.66	0.34	3.50	0.79	1.94	2.94	0.52	1.75
13	Mlamba	0.00	(1.16)	(0.90)	(5.33)	0.10	0.17	0.05	2.18	0.21	2.70	0.76	3.91	4.96	0.27	3.36
14	Usipa	0.00	(0.56)	(2.50)	(9.23)	0.77	0.27	0.20	1.36	0.34	3.00	0.31	2.73	4.13	0.51	4.88
15	Usipa larvae	0.00	(0.13)	(62.00)	206.67	(0.89)	(0.30)	–	8.72	0.38	2.70	0.23	13.43	21.49	0.60	103.33
16	Sanjika	0.00	(0.03)	(0.60)	(6.21)	0.23	0.10	0.00	0.05	0.12	3.70	0.07	0.13	0.15	0.14	4.37
17	Mpasa	0.00	(0.02)	(0.60)	(4.23)	0.34	0.14	0.00	0.03	0.18	3.70	0.07	0.06	0.07	0.22	2.78
18	Nchila	0.00	(0.01)	(4.00)	(40.00)	0.15	0.10	0.01	0.11	0.13	2.00	0.08	0.28	0.32	0.14	28.00
19	Nkholokolo	0.00	(0.59)	(0.50)	(8.50)	0.01	0.06	0.00	1.30	0.07	3.40	0.24	3.72	4.01	0.08	6.30
20	Samwamowa	0.00	(0.00)	(1.95)	(11.62)	0.18	0.17	–	0.00	0.21	2.80	0.71	0.01	0.01	0.27	7.35
21	Nkhungu	0.00	(1.75)	19.02	(69.70)	(0.47)	0.27	–	42.04	0.34	2.70	0.21	64.29	97.58	0.52	36.74
22	Nkhono	0.00	(5.00)	0.39	(5.60)	(0.95)	0.07	–	5.70	0.09	2.00	0.15	20.48	22.40	0.09	4.10
23	Top predators[a]	0.00	(0.00)	(0.25)	(58.00)	0.23	0.00	–	0.01	0.01	3.60	0.78	0.05	0.05	0.01	46.15
24	Zooplankton	0.00	(5.38)	(30.50)	(144.57)	0.70	0.21	–	361.22	0.35	2.00	0.03	302.58	466.67	0.54	56.24
25	Phytoplankton	1.00	(7.62)	(258.40)	–	0.27	–	–	1852.43	–	1.00	0.00	0.00	–	–	–
26	Detritus	2.00	0.00	–	–	0.01	–	–	–	–	1.00	0.22	0.00	–	–	–

TM= Trophic Mode, B= Biomass, P/B=Production over biomass, Q/B=Consumption over biomass, EE=Ecotrophic efficiency, GE= Gross food conversion efficiency, FD= Flow to detritus, Net Eff= Net efficiency, TL= Trophic level, OI= Omnivory index, R= Respiration, Assim= Assimilation, P/R= Production over respiration, R/B= Respiration over biomass, TM= Trophic mode. [a]The GE for Top predators is 0.004 and registers zero because of rounding the values to two decimal places.

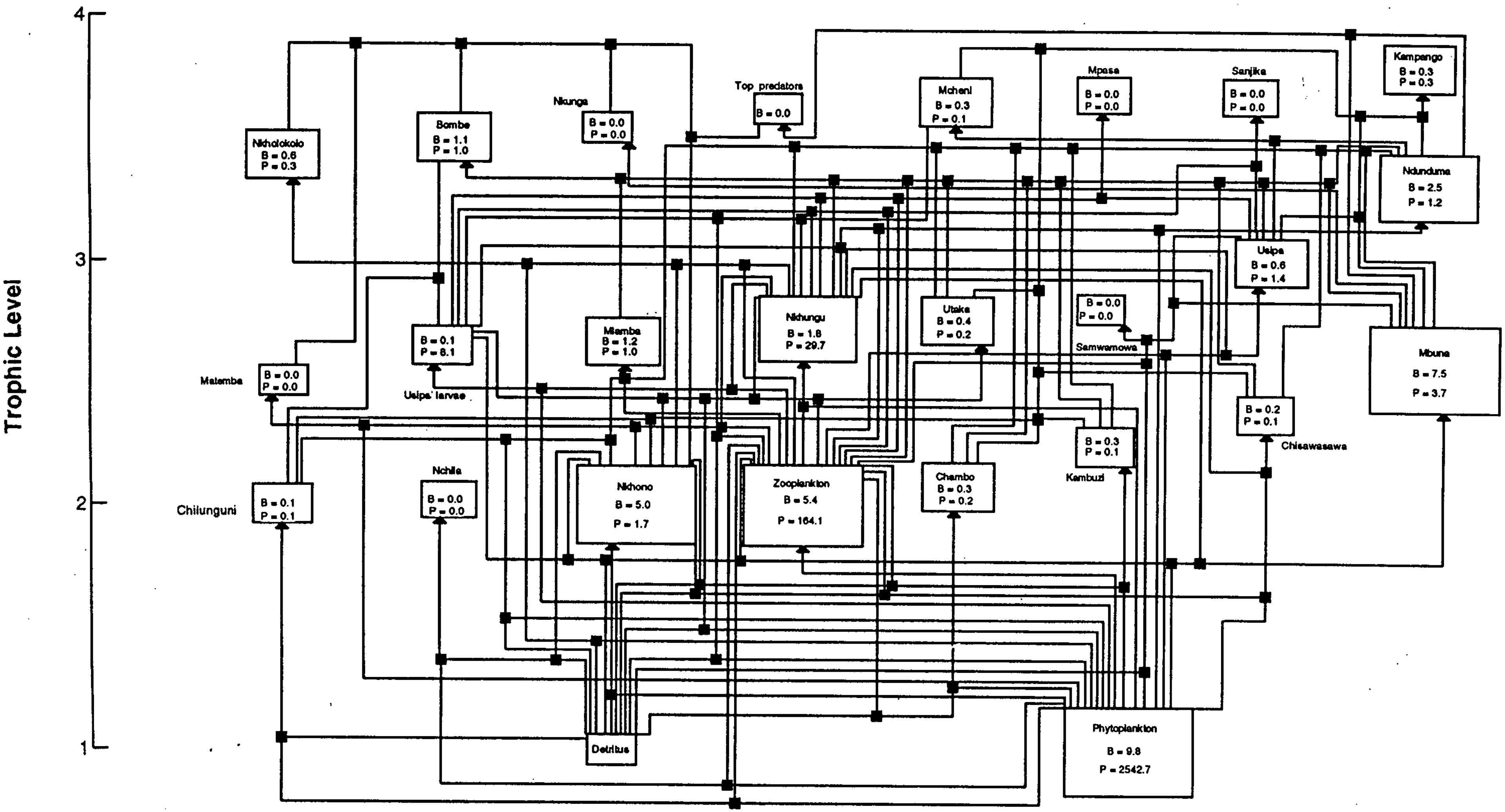


Figure 3.2 Graphic summarization of the Lake Malawi ecosystem trophic structure between 1976 and 1996.

connections to the top trophic groups. The role of the predatory zooplankton, which has a similar function to the last groups (Allison et al. 1995a) is also reflected by many connections to the zooplankton box. The fish groups that are preyed most are Usipa *E. sardella* and Mbuna. The higher a trophic level of fish group is, the fewer are its predators.

3.3.5.2 Model estimated parameters

Biomass, P/B, Q/B and EE values were estimated in seven, three, one and thirteen functional groups respectively. The currently exploited and individual fish groups in the lake have a mean biomass of 0.655 $t \cdot km^{-2}$. The category of 'Others' in the Malawi Fisheries Department statistics which, excluding Mbuna, may include Nkunga, Matemba, Ndunduma, Bombe, Nkholokolo and Samwamowa groups has a mean biomass of 0.475 $t \cdot km^{-2}$.

The ecotrophic efficiency (EE) values estimated in the model, were in the range of 0.1 - 0.8. Three fish groups, Bombe, Mlamba and Nkholokolo had EE values below 0.1. The EE values of the groups were much lower than the values of related species (Table 3.5). It is speculated that this may be a reflection of low predation pressure on the groups in the Lake Malawi system, at least with respect to the input values used in the model. The EE value for phytoplankton (0.27) was also low compared to the estimates in Degnbol (1993) and Allison et al. (1995b) of 0.95 and 0.86 respectively. The present estimate would probably be closer to the real EE for phytoplankton in the lake.

Table 3.5 Ecotrophic Efficiency (EE) values of Bombe *Bathyclarias* spp., Mlamba *Clarias* spp. and Nkholokolo *Synodontis njassae* and related species in Ecopath models of African lake ecosystems.

Lake	Ecotrophic Efficiency (EE)		
	Bombe	Mlamba	Nkholokolo
Malawi	0.07	0.1	0.01
Victoria[1]	0.95[a]	0.95[a]	0.95[b]
Kariba[2]	-	-	0.06[c]
Turkana[3]	-	-	0.03[d]
George[4]	-	0.95[e]	-

Sources: 1) Moreau et al. (1993a); 2) Machena et al. (1993); 3) Kolding (1993); 4) Moreau et al. (1993b)
[a]*Bagrus* and *Clarias*; [b]*Synodontis* and mormyrids; [c]*Synodontis zambezensis*; [d]*S. schall*; [e]*Clarias gariepinus*.

For the other two, the phytoplankton biomass and P/B estimates were thought to be in error for the first model; and the EE value itself was believed to be an overestimate in the second one (Degnbol 1993; Allison et al. 1995b). In addition the present model incorporates, albeit indirectly, the macrophytes, which are quite abundant in some areas of the lake (Konings 1990), in the phytoplankton functional group (see Section 3.3.4.2). The grazing pressure on the group would probably be between low and medium.

The gross food conversion efficiencies (GE) values were estimated in the model except for that of Usipa larvae which was fixed at 0.3. The GE values of twelve groups were in the range of 0.1 - 0.3. Ten groups had GE values between 0.059 and 0.099. Only the Top Predators had a GE value as low as 0.004. High GE values were for Nkhungu, Usipa, Usipa larvae, Bombe and Matemba. Matemba had the highest value of 0.303. Bombe was an odd group in the list as high GE values are usually expected from small and fast growing organisms (Christensen and Pauly 1992).

Flow to detritus was above the value of 10 t·km^{-2}·year^{-1} in five groups. Nkunga's flow to detritus was the lowest at 0.001 t·km^{-2}·year^{-1} while that of Mbuna was highest at 11.0 t·km^{-2}·year^{-1}. In the lower or small organism functional groups, flow sizes were high and their values in decreasing order were phytoplankton (1852.43 t·km^{-2}·year^{-1}), zooplankton (361.22 t·km^{-2}·year^{-1}) and Nkhungu (42.04 t·km^{-2}·year^{-1}). The flows seemed to be dependent on biomasses as well as predation pressure on the groups. The net efficiency was lowest in Top Predators at 0.005 and highest in Matemba at 0.379. In the consumer groups, the omnivory index was highest in Nkunga at 0.988 and lowest in Chilunguni at 0.005. The respiration was lowest in Nkunga and highest in zooplankton with values of 0.002 t·km^{-2}·year^{-1} and 302.582 t·km^{-2}·year^{-1} respectively. Usipa was the group with a respiration over biomass ratio value of above 100 year^{-1}. The respiration over biomass ratio (R/B), which can be any positive value (Christensen and Pauly 1995), is normally expected to fall in the range of between 0 and 100 (Bundy 1998).

3.3.5.3 Summary statistics

The summary statistics of the model are presented in Table 3.7. The lake system fishery has a 'mean trophic level' of 3.8 as a result a flat nutrient flow pyramid was obtained (Fig. 3.3). The fish groups that appeared in the old and present Ecopath models obtained lower trophic levels in the latter model (Table 3.6). The gross efficiency (GE), which signified quantities of discrete trophic flows or the ratio between production and consumption (Christensen and Pauly 1992; Dalsgaard 1999), was low at 0.0004. The GE was, however, comparable to those of other Great African lakes (Table 3.7) as well as that of Java Sea (Buchary 1999).

Table 3.6 Trophic levels of fish groups in the old and present Ecopath models of Lake Malawi.

Fish group	Trophic level		
	1979-81[1]	1990-94[2]	1976-96
Utaka	–	3.3	2.8
Ndunduma[a]	3.3	3.7	3.3
Kambuzi[b]	2.7	–	2.2
Mcheni[c]	3.7	4.3	3.7
Usipa	3.1	3.1	3.0
Usipa larvae	–	3.0	2.7
Sanjika[d]	3.9	–	3.7
Mpasa[d]	3.9	–	3.7
Nkholokolo	–	4.0	3.4
Nkhungu	3.0	3.0	2.7
Zooplankton	2.0	2.0	2.0
Phytoplankton	1.0	1.0	1.0
Detritus	1.0	1.0	1.0

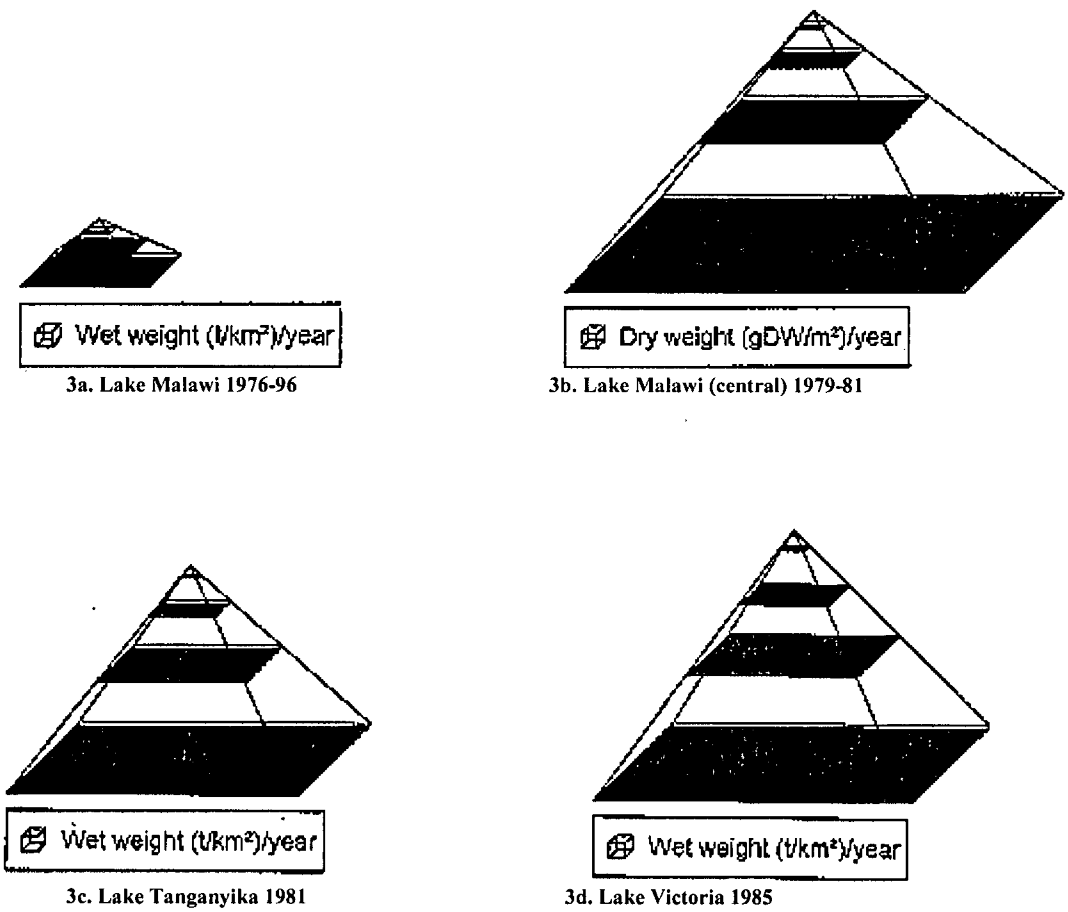
Sources: [1]Degnbol (1993); [2]Allison et al. (1995b). In 1990-94 values for: [a]*Diplotaxodon* is mean of *D.* 'bigeye' and *D.* 'elongate'; [c]*Ramphochromis* is mean of *R. longiceps* and large *Ramphochromis*. In 1979-81: [b]represent haplochromine cichlids; [d]represents mean of the two *Opsaridium* spp.

The biomass over throughput was 0.01 $year^{-1}$ and omnivory index was 0.302. The production over respiration ratio (P/R) is quite high at 5.88 instead of approaching one. It is expected a properly accounted for and mature ecosystem would obtain a P/R close to 1 (Christensen and Pauly 1992). The high P/R value could be attributed to the age of Lake Malawi ecosystem. As an indicator of ecosystem maturity, the P/R would appear to show that the lake is not yet 'mature'. Alternatively, the P/R could have been influenced by the use of input parameters –P/B, Q/B and EE, which were from different ecosystems to that of Lake Malawi for Nkunga, Kampango, Matemba, Bombe, Mlamba, Nchila, Samwamowa, Nkhono and Top predators functional groups (see Section 3.3.4.2). There is the possibility that the differences in some of the values could be significant.

Table 3.7 Ecosystem summary statistics of Lake Malawi and other African Great Lakes (values are rounded to two decimal places).

Parameter	Lake Malawi 1976-96	Lake Malawi (Central)[a] 1979-81	Lake Tanganyika[a] 1981	Lake Victoria[a] 1985
Sum of all consumption ($t \cdot km^{-2} \cdot year^{-1}$)	1037.22	4031.20	1839.76	2515.98
Sum of all exports ($t \cdot km^{-2} \cdot year^{-1}$)	0.00	15607.78	-65.30	-148.85
Sum of all respiratory flows ($t \cdot km^{-2} \cdot year^{-1}$)	460.77	3330.10	1445.27	1991.87
Sum of all flows into detritus ($t \cdot km^{-2} \cdot year^{-1}$)	2296.96	18416.17	0.21	19.68
Total system throughput ($t \cdot km^{-2} \cdot year^{-1}$)	3794.93	41385.24	3219.94	4378.69
Sum of all production ($t \cdot km^{-2}$)	2756.09	2112.76	3295.04	2603.20
Fishery 'mean trophic level'	3.78	3.23	4.46	4.10
Gross efficiency (catch/net p.p.)	0.00	0.06	0.00	0.01
Input total net primary production ($t \cdot km^{-2} \cdot year^{-1}$)	2710.00	1325.00	2876.00	2000.00
Calculated total net primary production ($t \cdot km^{-2} \cdot year^{-1}$)	0.00	1325.02	2880.00	1964.45
Unaccounted primary production ($t \cdot km^{-2} \cdot year^{-1}$)	2710.00	–	–	35.55
Total primary production/total respiration	5.88	0.40	1.99	1.00
Net system production ($t \cdot km^{-2} \cdot year^{-1}$)	2249.23	2005.10	1430.73	8.13
Total primary production/total biomass ($year^{-1}$)	72.49	10.71	92.87	18.89
Total biomass/total throughput ($year^{-1}$)	0.01	0.00	0.01	0.02
Total biomass (excluding detritus) ($t \cdot km^{-2}$)	37.38	123.76	30.97	105.89
Total catches ($t \cdot km^{-2} \cdot year^{-1}$)	1.01	78.32	5.77	16.45
Connectance index	0.25	0.27	0.61	0.46
System omnivory index	0.31	0.06	0.12	0.16

[a]Source: Databases for Ecopath models in Christensen and Pauly (1993).



3a. Lake Malawi 1976-96

3b. Lake Malawi (central) 1979-81

3c. Lake Tanganyika 1981

3d. Lake Victoria 1985

Figure 3.3 Nutrient flow pyramids of Lake Malawi and other African Great Lakes; 3a. Lake Malawi 1976-96, 2b. Lake Malawi, 3c. Lake Tanganyika 1981, and 3d. Lake Victoria 1985; based on databases for Ecopath models in Christensen and Pauly (1993).

3.3.5.4 Mixed trophic impact

The mixed trophic impact is a routine in Ecopath which assesses the effect biomass of a functional group has on the biomass of other functional groups in a system (Christensen and Pauly 1992). For the present Ecopath model of Lake Malawi, the mixed trophic impacts are graphically depicted in Fig. 3.4. The relative impact between the groups can either be positive or negative which are, in Fig. 3.4, represented by upward protruding bars and downward protruding bars respectively. The mixed trophic impact routine could also show the direct and indirect interactions among the functional groups (Christensen and Pauly 1992; Dalsgaard 1999).

Fifteen groups have positive impact on the Lake Malawi ecosystem. Seven groups contribute positively to the fishery in the lake and they include four fish groups; Utaka, Kambuzi, Chambo and Usipa. The lower groups have the greatest impact on the system which is similar to what is observed in other systems (Christensen and Pauly 1993; Opitz 1993). Based on the length of the bars in Fig. 3.4, phytoplankton is the largest contributor while Matemba, Kambuzi and Nkholokolo are at the bottom. Apart from Nkhungu *Chaoborus edulis* and Usipa larvae as primary consumers, important middle trophic level functional groups in the lake are Usipa, Mbuna and to a lesser extent Ndunduma. The tertiary consumers with trophic levels of 3.5 and above which include Nkunga, Kampango, Sanjika, Mpasa, Bombe, Mcheni and top predators do not have any positive impact in the lake.

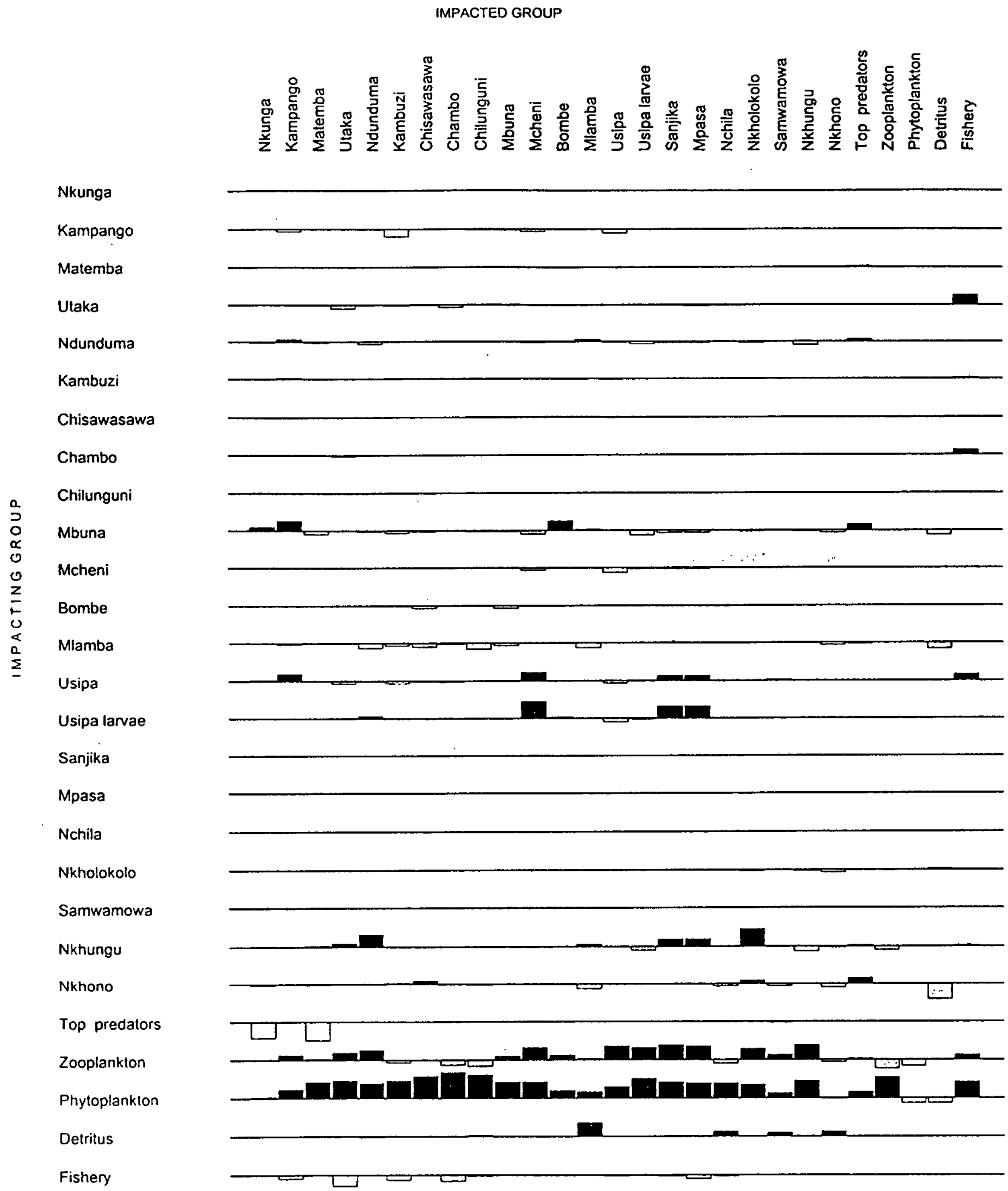


Fig 3.4 Mixed trophic impact of Lake Malawi between 1976 and 1996; effect of biomass in the functional groups and fishery (left) on the biomass of other functional groups (top) is either positive (upward protruding bars) or negative (downward protruding bars).

Although detritus impacts the Lake Malawi ecosystem positively, it is not strong. Detritus was also found to be less important in the lake's energy flow (see also Section 3.2.3; Allison et al. 1995a). Detrital flow is low in the trophic efficiency transfers in the lake system. This provides a clear means to designate the maturity of Lake Malawi ecosystem. Since detrital flow becomes more important in mature systems (Christensen and Pauly 1992; Dalsgaard 1999; Buchary 1999) it can therefore be safely said that Lake Malawi is still between the early and middle stages of its maturity.

The main results of the Lake Malawi model for the 1976-96 period included (i) quantification of 26 trophic boxes; (ii) confirmation of observations in the earlier Lake Malawi Ecopath models (see Sections 3.2.2 and 3.2.3) that the bridge in the energy flow between the bottom and top trophic level groups were three items; lakefly Chaoborus edulis, Usipa *Engraulicypris sardella* larvae and zooplankton, especially the predatory type; (iii) through consideration of the trophic levels in the fish groups which appeared in the old and new Ecopath models of Lake Malawi, the trophic levels were lower in the new model which was regarded to indicated that the trophic structure of the Lake Malawi system was declining (Table 3.6); and (iv) based on the production over respiration ratio, P/R, value and detrital utilization, which are some of the indicators of ecosystem maturity (Christensen and Pauly 1992; Dalsgaard 1999; Buchary 1999), the maturity stage of Lake Malawi is estimated to be between the early and middle stages.

CHAPTER 4:

TRENDS OF CATCHES, FISH MAXIMUM LENGTHS AND MEAN TROPHIC LEVEL IN LAKE MALAWI

4.1 Trends of Catches

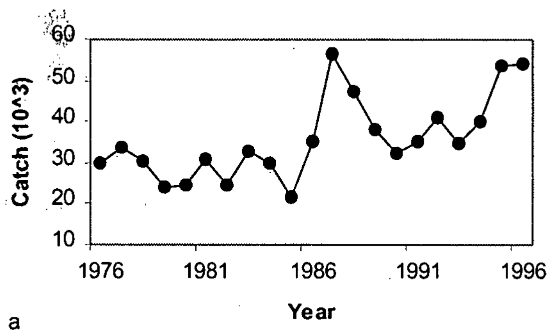
4.1.1 Objectives of the fish length and trophic level analysis

A number of researchers have reported on the changes in composition and size in the groups of fish species that are caught in Lake Malawi (Turner 1977a,b; Tweddle and Magasa 1989; FAO 1993; Banda and Tomasson 1997). In addition, there has been overharvesting of a few species and catch declines in many fisheries (Tweddle et al. 1994; Munthali 1997; Nyambose 1997; Scholz et al. 1997; Stauffer et al. 1997; Chirwa 1998 see also Section 1.4.2) The purpose of undertaking the analysis of the fish maximum lengths and mean trophic levels was to establish the extent of decline in fish size during the 1976-1996 period.

4.1.2 Main fishing areas

Lake Malawi is the only water body in Malawi where both traditional and commercial fisheries take place (Section 1.4.2). Traditional fisheries have been in practice on the lake's shores of for centuries. Commercial fisheries, which refer to the large scale and mechanized fisheries, began in 1938 by two European operators and expanded with the introduction of pair trawling in 1968 (ICLARM/GTZ 1991; Banda and Tomasson 1997). Because of the presence of different habitats or ecological zones (see Section 1.4.1, 3.3.1.2), many species are found in the lake (see Appendix 1.3) and an ornamental fishery also exists mainly targeting the rock-dwelling Mbuna (*Pseudotropheus* spp.). The traditional fisheries sector has the majority fishing operations as there are only twenty-two commercial fishing units, of which four belong to one large-scale fishing company, MALDECO (Banda and Tomasson 1997), and one major aquarium fish trader.

Lake Malawi catch contributes between 40 and 50 % of the total landings in the country. Traditional and commercial fisheries land 85 and 15 % of the lake's catches respectively. Commercial or industrial fisheries are not the only ones that catch fish for trading. The traditional or artisanal fishers also sell part or most of their catch. Traditional fisheries contributed 82.6 % to the lake's total fish catches averaging 35,0000 tonnes per year for 1986-1994 (Banda and Tomasson 1997). The overall maximum catch in the lake has stabilized soon after introduction of the mechanized gears in the late 1960s and early 1970s with a peak in 1987 (Bland 1996; Banda and Tomasson 1997). There are however signs of decline in some areas and species (Pitcher 1994; Banda et al. 1996; Banda and Tomasson 1997). The traditional fisheries catches, from 1976 to 1996, show a fluctuating but increasing trend (Fig. 4.1a). The commercial fisheries catch has downward trend (Fig. 4.1b). Banda and Tomasson (1997) attributed the decline in the commercial fisheries catch to two factors; natural stock fluctuations and the old age of the fishing craft. Until 1994 little or no investment was made into the fisheries.



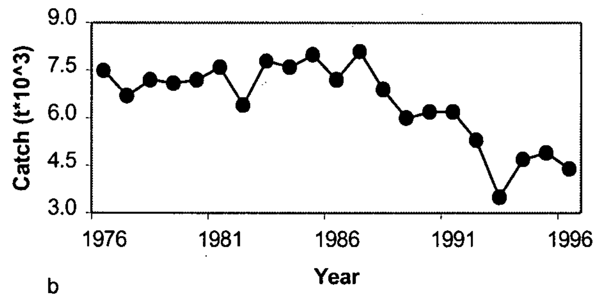


Figure 4.1a Catches of traditional fisheries in Lake Malawi.

Figure 4.1b Commercial fisheries landing in Lake Malawi.

Landings from southern part of Lake Malawi including the system of Lake Malombe, which is connected to the former by Upper Shire River and enables breeding migration of some species to occur (FAO 1993; Palsson et al. 1998), covers less than 10 % of the total area of Lake Malawi but contributed 50.4 % compared to 49.6 % for the centre and north put together for the period 1986-96. The catch from the commercial fisheries, which occurs at the south of the lake, averaged 5000 tonnes per year for 1986-96. The 1976-1990 average is 7800 tonnes per year (Turner 1995). The contribution has also declined in comparison to 1976-1990 period when the south Malawi and Malombe system provided 80 % of the catch while the centre and north did not even reach a quarter of the total catch (Tweddle et al. 1994; Pitcher 1994; Turner 1995). The south - north differences in the catches are a reflection of the limnological conditions. The shallow south has high productivity occurring up to the lakebed. Seasonal wind-induced mixing of nutrients has also a strong influence (Section 3.2.1; FAO 199; Patterson and Kachinjika 1995). Large part of the latter areas has rocky and precipitous coastline. Again half of the mountain ranges reach into the lake at very considerable depths with an almost vertical slope (Beadle 1974; Banda 1989). The productivity is low and more pelagic (Turner 1995).

4.1.3 Catch composition and main species in the catches

Catches are normally composed of many species but they are recorded in thirteen groups in MFD statistics (Appendix 4.1). Twelve of these refer to individual species or group of related species. The last MDF group labeled 'Others' comprises many fish species which may, depending on fishing area, include Nkholokolo (*Synodontis njassae*), Ndunduma (*Diplotaxodon* spp.), Bombe (*Bathyclarias* spp.), Matemba (*Barbus* spp.), Nkunga (*Anguilla nebulosa* and mastacembelids), Samwamowa (mormyrids), Mbuna (*Pseudotropheus* spp.), alestiid, anabantid and cyprinodontids. The first three fish groups on the list are caught in relatively larger quantities than the rest. They are however not caught by the majority of fishers who are artisanal and operate inshore. In Lake Malawi, fish species occur in eleven families and at least sixty-one genera. The major individual or groups of species in the catches (by weight) are Utaka (*Copadichromis* spp.), Usipa (*Engraulicypris sardella*), Chambo (*Oreochromis* spp.), Kambuzi (*Protomelas* spp.), Kampango (*Bagrus meridionalis*) and Mlamba (*Clarias* spp.). Utaka and Usipa are the main fish groups that most influence the catch trends in the lake (Fig 4.2). Declines or increases in landings of principal species do not always coincide.

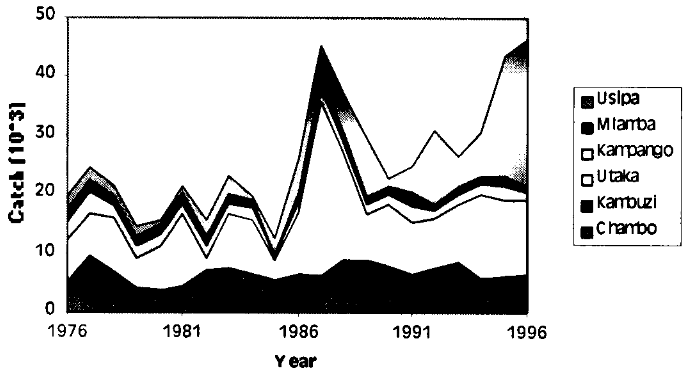


Figure 4.2. Catch trends of main species from traditional fisheries in Lake Malawi.

The landings of the major fish species corresponded to their biomasses (Section 3.3.2.2; Table 3.4) which represented the situation in the lake adequately. The Ndunduma, Mbuna and Nkholokolo groups were exceptions. They have low catches and high biomasses compared to other fish groups that contribute to the fish landings in Lake Malawi. Ndunduma has a catch of 0.005 $t \cdot km^{-2} \cdot year^{-1}$ and a biomass of 2.49 $t \cdot km^{-2}$. Mbuna has catch and biomass of 0 $t \cdot km^{-2} \cdot year^{-1}$ and 9.346 $t \cdot km^{-2}$ respectively. Lastly, Nkholokolo has a catch of 0.001 $t \cdot km^{-2} \cdot year^{-1}$ and a biomass of 0.59 $t \cdot km^{-2}$.

4.2 Catch weighted mean maximum lengths of fish in Lake Malawi

4.2.1 Maximum lengths of main fish groups

Range and mean of maximum lengths (described in Section 4.2.2) in the main fish groups caught in Lake Malawi as well as some aspects, not mentioned in chapter 3, include:

- **Chambo (*Oreochromis* spp).**

Chambo group of species has a maximum length range of 37 - 38 cm and mean maximum length of 37.3 cm. Chambo are the most popular fish in Malawi. Their contribution to total catch is declining rapidly (Fig. 4.3).

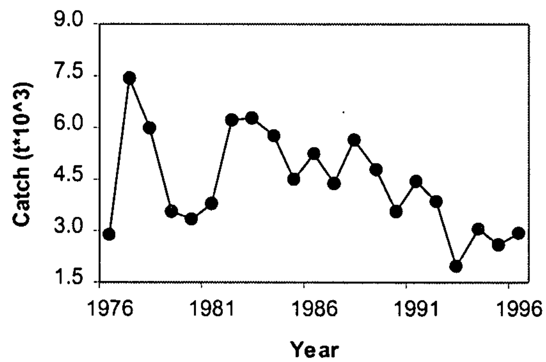


Figure 4.3 Chambo (*Oreochromis* spp.) landings in Lake Malawi.

Chambo catch comprised of only 7.1 % of the landings from Lake Malawi in 1993 although it compared favourably economically (FAO 1993). The larger part of Chambo caught in Lake Malawi is landed by the commercial fisheries; contributing 74.3 % of the catch at 5615 tonnes in 1993. The traditional fishers landed 25.6 %, i.e., 1934 tonnes (Banda and Tomasson 1997). Between 1976 and 1990 the southern part of Lake Malawi produced at least half of the lake's total catch (Turner 1996). Analysis of the catch data from MDF for the years 1988-1990 and 1993-1995 also indicates that 50 % of the Chambo catch came from the south for the period 1988-93. In the 1993-95 period however the south area contribution dropped to 31.25 %. Chambo catch from the south drastically declined in 1993 and 1994 (Table 4.1).

Table 4.1 Chambo catch using beach seines in Lake Malawi and percentage of the Chambo landed from the southern part (in tonnes)

Year(s)	South	Centre	North	Total	% of South
1988	1573	970	150	2693	58.4
1989	2632	1887	240	4759	55.3
1990	2266	1154	161	3581	63.3
1988-90	6471	4011	552	11034	58.7
1993	63	1730	141	1934	3.3
1994	960	1947	132	3039	31.6
1995	1346	1185	82	2613	51.5
1993-95	2369	4862	355	7586	31.2
1988-95	8840	8873	907	18620	47.5

Source: Tweddle et al. 1994; MDF 1996.

- **Chilunguni (*Tilapia rendalli* and *Oreochromis shiranus*)**

Chilunguni group has a maximum length range of 35 - 37 cm and mean maximum length of 36 cm. The species are not abundant in the lake but they are common fish farming species in Malawi. As a group, they contributed an average of 1.2 % to the traditional fisheries catch between 1976 and 1996.

- **Kambuzi (*Protomelas* spp.)**

Kambuzi has a maximum length range of 10.5 - 30 cm and mean maximum length of 20.5 cm. The group is fourth largest contributor to the artisanal catches (Table 4.2).

- **Utaka (*Copadichromis* spp.)**

Utaka are the most abundant group of species in the traditional fisheries landings (Table 4.2). Utaka and other small cichlids, such as Kambuzi and Chisawasawa, are affordable to many people at markets. As a group, Utaka has a maximum length range of 7 - 25 cm and mean maximum length of 15.2 cm.

Table 4.2 Mean catches of main fish groups in the traditional fisheries; 1976-96 (in tonnes)

Parameter	Group														
	Chambo	Chilunguni	Kambuzi	Utaka	Chisawasawa	Kampango	Mcheni	Mlamba	Usipa	Nchila	Mpasa	Sanjika	Ndunduma	Bombe	Nkholokolo
Mean catch (t)	4398	356	2224	10271	179	2005	259	1533	5858	168	112	122	146	1465	37
%	15.1	1.2	7.6	35.3	0.6	6.9	0.9	5.3	20.1	0.6	0.4	0.4	0.5	5.0	0.1
Rank	3	8	4	1	10	5	9	6	2	11	14	13	12	7	15

Source for catches: MDF (1996); see also Table 4.3.

- **Chisawasawa (*Lethrinops* spp.)**

Chisawasawa has a maximum length range of 7 - 35 cm and mean maximum length of 15.7 cm. The group's species are caught in commercial and some artisanal gears and contribute 0.6 % to traditional fisheries (Table 4.2). The most common species is *L. microdon*. It is however becoming less abundant in the southern part of the lake. It contributed 44 % to the cichlid catch in 1983-85 but dropped to 22 % in 1991 and fell further to only 5 % in 1992. The second common species is *L. altus*. It comprises 1 % of commercial fishery catch (in pair and midwater trawls). Other species in the group that are common in the catches are *L. lethrinus*, *L. stridei* and *L. longipinnis*. *L. lethrinus* inhabits river mouth and a little further in the rivers (Turner 1996).

- **Kampango (*Bagrus meridionalis*)**

Kampango contributes to both the traditional (6.9 %, Table 4.2) and commercial fisheries (Banda et al. 1996). Kampango has a maximum length of 100 cm.

- **Mcheni (*Ramphochromis* spp.)**

Mcheni has a maximum length range of 28 - 45 cm and mean maximum length of 37.8 cm. Mcheni was not recorded separately before 1994. Mcheni is not usually caught in pelagic trawls and seines rarely catch the group in the inshore zone. Mcheni is important to both commercial and artisanal fisheries. Although it is caught in very small numbers, it made up 12.4, 8.3 and 15.1 % of the midwater trawl, demersal trawl and pair trawl catches in 1990-91 respectively (Turner 1996). Mcheni is mainly caught in demersal trawls, and sometimes in mid-water trawls. In traditional fisheries, Mcheni contributes an average of 0.9 % to the catches and is taken by handlines, Chilimira beach seines and gillnets.

- **Mlamba (*Clarias* spp.)**

Of the four Mlamba catfishes *C. gariepinus* is the most significant commercially (Willoughby and Tweddle 1978a). In Lake Malawi, Mlamba contributes 5.3 % to the traditional fisheries (Table 4.2). Mlamba has a maximum length range of 22 - 150 cm and mean maximum length of 65.5 cm.

- **Usipa (*Engraulicypris sardella*)**

Usipa is caught in traditional fishers' seines during the inshore migration. Its annual catches fluctuate by a magnitude in the order of 10 (Skelton 1991; Thompson 1995). It has become very important in the traditional fisheries over the years (Fig.4.2) and its average contribution is at 20.1 % (Table 4.2). Catching of Usipa may also be influenced by its sensitivity to noise of some gears like purse seine, as Usipa moves quickly moves down to depth of up to 70 metres when disturbed (Anon 1988). Usipa has a maximum length of 12 cm.

- **Nchila (*Labeo* spp.)**

In traditional fisheries, Nchila is caught in gillnets and seines (Lowe-McConnell 1975). One of the two Nchila species, *Labeo mesops*, now contributes only 0.6 % but used to be the second most important fishery (Tweddle et al. 1994). The two species in the Nchila group have maximum lengths of 35 cm.

Mpasa (*Opsaridium microlepis*)

During the rainy season Mpasa congregate at river mouths to start the spawning migration. This is also the time when Mpasa is found in commercial catches otherwise it is rare to be caught by commercial fisheries (Skelton et al. 1991). It is commonly targeted by traditional fishers and is the most highly priced species. It contributes 0.4 % to traditional fisheries (Table 4.2). Mpasa has a maximum length of 60cm.

- **Sanjika (*Opsaridium microcephalus*)**

Sanjika has a maximum length of 30 cm and contributes 0.4 % to the traditional fisheries.

- **'Others'**

The group of 'others' refers to many species. In some reports the species tend to be noted as cyprinids and mormyrids. The species in the group are not related. Three of the main contributors by weight to the 'others' category are Ndunduma, Bombe and Nkholokolo (Tweddle et al. 1994; FAO 1993; Turner 1996; Banda and Tomasson 1997).

- **Ndunduma (*Diplotaxodon* spp.)**

Ndunduma has a maximum length range of 13 - 35 cm and mean maximum length of 18.2 cm. *D. limnothrissa* is the most abundant in the group and it contributed 700 tonnes in 1990/91, i.e., 53 % of the midwater trawls in the commercial fisheries. Ndunduma forms a minor catch in the traditional fisheries (Table 4.2, Fig. 4.4). *D. argenteus*, *D. greenwoodi* and *Pallidochromis tokolosh* are other species in the group that contribute to the commercial fisheries catch (Turner 1996).

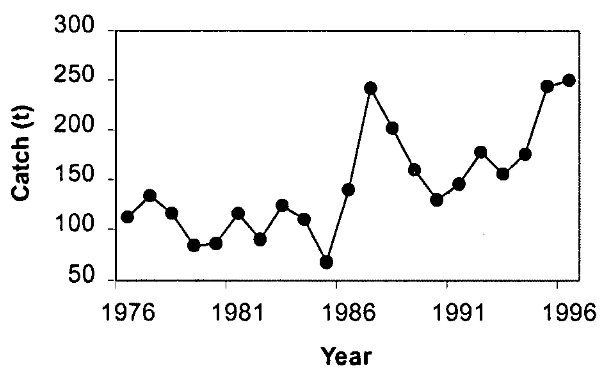


Figure 4.4 Ndunduma (*Diplotaxodon* spp.) landing from the traditional fisheries in Lake Malawi . The group contributes only an average of 0.5 % to the traditional fisheries total catch.

- **Bombe (*Bathyclarias* spp.)**

Bombe together with other two types of catfishes, Kampango (*Bagrus meridionalis*) and Nkholokolo (*S. njassae*), contributed 20 % of catches between 1989 and 1993 (Banda et al. 1996). *B. nyasensis* is the commonest of the Bombe species. It is caught by longlines, floating traps, and gillnets. With gillnets, *B. nyasensis* is trapped down to the limit of dissolved oxygen (Lowe-McConnell 1975, 1987; Konings 1990). Bombe has a maximum length range of 70 - 150 cm and mean maximum length of 88.4 cm.

- **Nkholokolo (mochokids)**

Nkholokolo is mostly caught during its breeding season between October to December. It contributes 0.1 % to the traditional fisheries (Table 4.2). Nkholokolo has a maximum length range of 6 - 20 cm and mean maximum length of 13 cm.

4.2.2 Weighing the lengths by the catches

The fish groups in catch are separated so that each group has its own catch value and a mean maximum length for the species in the group is assigned (Table 4.3). The weighting process to obtain a catch-weighted mean maximum length is achieved through modifying the formula of Pauly et al. (1998) in which mean trophic level, $\overline{TL}$, is obtained by multiplying the catch, Y, by a trophic level of individual species, j, in each year, i, represented:

$$\overline{TL} = \sum_{ij} TL_{ij} Y_{ij} / \sum Y_{ij}$$

or

$$\overline{TL} = \frac{1}{H_j} \sum_{i} TL_{ij} Y_{ij}, \quad H_i = \sum_{i} Y_{ij}.$$

The formula is then changed to:

$$\overline{L}_{\max} = \sum_{ij} L_{\max} Y_{ij} / \sum Y_{ij}$$

or

$$\overline{L}_{max} = \frac{1}{H_j} \sum_i L_{max\,ij} Y_{ij}, \; H_j = \sum_i Y_{ij},$$

where: L_{max} is maximum length;

$\overline{L}_{max}$ is mean maximum length;

i is year;

Y is landing or catch; and

j is individual or group species.

Table 4.3 Catches of main fish groups in the traditional fisheries and their mean maximum lengths (L_{max}) in Lake Malawi.

Fish group	Mean L_{max} (cm)	L_{max} Range (cm)	Catch by year (t) 1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Chambo	37.3	37-38	2911	7424	6017	3567	3345	3829	6235	6297	5772	4479	5253	4363	5668	4760	3581	4464	3856	1934	3038	2613	2942
Chilunguni	36.0	35-37	570	332	474	424	428	370	569	540	426	99	299	204	225	109	275	808	210	304	212	284	305
Kambuzi	20.5	10.5-30	2025	2227	692	443	301	714	1062	1035	758	815	1372	1890	3084	4147	4077	2160	3672	6411	2763	3528	3532
Utaka	15.2	7-25cm	7338	7084	9108	5258	7739	12131	1954	9182	8969	3553	10526	29514	18323	7844	10603	8697	8459	9922	14286	12742	12467
Chisawasawa	15.7	7-35cm	88	90	100	150	100	236	239	138	384	157	130	121	100	53	202	192	357	164	354	155	247
Kampango	100.0	100	3145	3644	2346	1977	1905	1742	2088	1971	2185	555	1635	2211	1862	1576	1703	2752	1353	1832	1660	2572	1383
Mcheni	37.8	28-45	365	331	170	327	298	209	255	151	151	213	144	267	243	242	251	270	305	346	353	443	113
Mlamba	65.5	22-150	1875	1988	1472	1575	1597	1961	1679	1646	1500	413	1677	1772	1920	1394	1312	2224	1075	1312	1225	1574	995
Usipa	12.0	12	2327	1969	1779	1924	724	928	2791	3053	453	2675	5866	5657	6321	9917	1616	4565	12522	5020	7529	20369	25016
Nchila	35.0	35	482	515	197	227	264	104	176	152	130	21	25	35	130	168	22	192	191	140	217	111	32
Mpasa	60.0	60	34	28	31	32	30	34	36	30	61	31	21	245	518	181	145	74	137	164	200	175	149
Sanjika	30.0	30	70	55	61	62	57	65	64	50	107	61	128	219	90	139	97	109	230	346	132	260	168
Ndunduma	18.2	13-35	112	135	117	84	87	116	90	125	111	69	141	242	203	161	130	146	179	157	176	244	250
Bombe	88.4	70-150	1123	1347	1171	844	875	1164	900	1248	1109	687	1412	2422	2030	1611	1300	1460	1793	1570	1762	2436	2501
Nkholokolo	13.0	6-20cm	28	34	29	21	22	29	23	31	28	17	35	61	51	40	32	37	45	39	44	61	63

Source: MDF (1996).

4.2.3 Weighted mean maximum lengths and trophic levels

In the analyses of the maximum lengths and trophic levels for the main fish groups in Lake Malawi, the catches were from the traditional fisheries sector. The commercial fisheries sector catch was not split into individual species or group of species but was largely constant at about 7,000 tonnes until 1989 when it started to decline rapidly (Fig. 4.1b). Catch-weighted mean maximum lengths showed a declining trend although there was fluctuation from year to year (Fig. 4.5). The mean maximum length dropped from 39 cm in 1976 to 23 cm in 1996. This is a typical characteristic of 'fishing down the food web' where, over time, large piscivorous fishes are replaced by planktivorous fishes and smaller invertebrates in the global fisheries landings (Pauly et al. 1998).

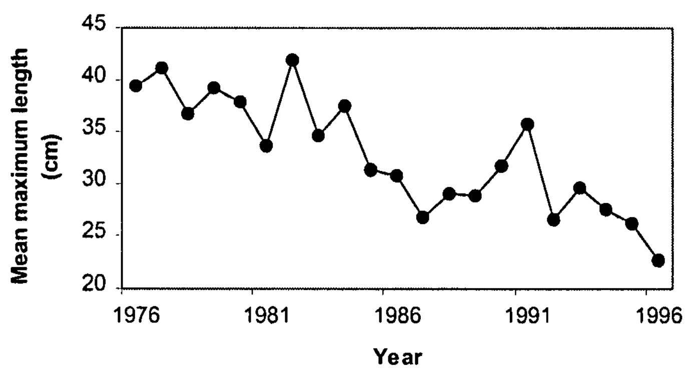


Figure 4.5 Trend of mean maximum length in Lake Malawi fish

The change in length is in line with the concern on shifting from large to small size fish species caught by commercial fisheries in Lake Malawi, attributed to trawling (FAO 1976; Turner et al. 1995; Banda et al. 1996). Turner (1977b) and Tweddle and Magasa (1989) noted decline of large fish species that used to make up higher proportions of demersal trawl fishery catches due to use of small-meshed codends. The changes began when the mechanized fisheries were introduced especially in the heavily fished southern part of the lake (Turner 1977a). However Banda et al. (1996) believe that after the initial changes the composition has stabilized even with instances of localized heavy fishing pressure in the southeast arm of Lake Malawi (fishing areas A and B). It has also been observed that the fisheries management strategy of using large mesh sizes for nets in this area does not profit the fisheries as mature specimens of small sized species are not caught at the expense of large and probably immature ones. Banda and Tomasson (1997) recommended that the mesh size for the nets used in the area should be reduced to be able to exploit most species which have an average maximum lengths of 8 cm. Continuous monitoring should, however, be emphasized in order to detect any shifts in the sizes.

A plot of the mean maximum lengths against total catches further elaborates the change in fish size. The mean maximum length declined as the catch increased (Fig. 4.6).

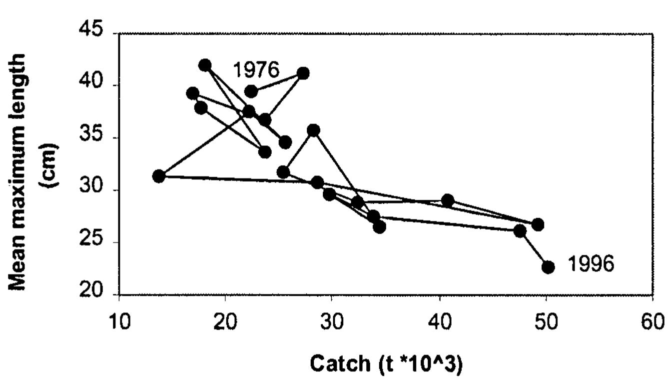


Figure 4.6 Plot of mean maximum length against catch on increasing scale.

Trophic levels decreased between 1976 and 1985 and began to increase from 1986 (Fig. 4.7). The plot of trophic levels against catches (on increased scale) does not show any trend (Fig. 4.8).

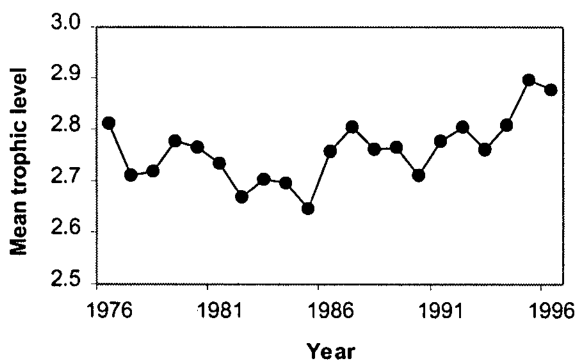


Figure 4.7 Trend in trophic level in Lake Malawi.

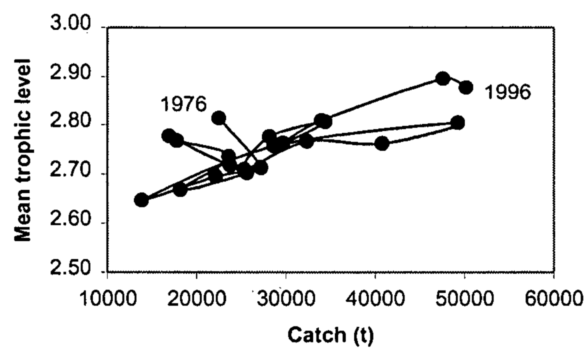


Figure 4.8 Plot of trophic levels against catch on increasing scale.

The decline of trophic level by over 0.1 per decade in the global fisheries as observed by Pauly et al. (1998) was, in the case of Lake Malawi between 1976 and 1996, clear in the first decade. The trophic level changed from 2.81 in 1976 to 2.65 in 1985, i.e., a decrease of 0.16. The second decade showed an opposite trend. The trophic level increased from 2.76 to 2.90 for 1986 and 1995 respectively. Lowest catches and trophic levels were in 1985. The increase in trophic level between 1986 and 1996 is caused by the decline in the catches of large and more herbivorous fish species with low trophic levels, despite increase in traditional fisheries total catches (Fig. 4.1a). Chambo, which has a trophic level of 2.1, is ranked third in the traditional fisheries catches when averaged for the period of 1976-96 (Table 4.2). The contribution of the Chambo in the catches has however been decreasing rapidly. In addition there is a large drop in the landings of Utaka (*Copadichromis* spp.) Utaka, which is small-sized, is a top contributor in the catches from the lake. However, between 1986 and 1996 there was increased contribution of Usipa (*Engraulicypris sardella*) compared to Utaka in the landings (Fig. 4.2). Usipa, although smaller in size, has a higher trophic level (3.0) than Utaka (2.8).

CHAPTER 5:

EXPLORING ALTERNATIVE POLICIES FOR EXPLOITING LAKE MALAWI

5.1 Objectives of the analyses

This chapter explores alternative policies for exploiting the lake through two analyses. The analyses are based on the basic estimates of Lake Malawi Ecopath model (Section 3.3). However, the analyses focus on simulation of strategic management options for the fisheries in the lake using Ecosim (Walters et al. 1997). In the simulation, a mixed control regime is applied (see Walters et al. 1997). In Lake Malawi, the bottom-up control (food supply limitation) has been shown to exist, at least for the pelagic zone, and possibly more than the top-down control (predation) overall (FAO 1993; Allison et al. 1995a). It is however recognized, in the case of cichlids in the lake, that they have a wide range of feeding habits (Yamaoka 1991) and several species, particularly aufwuch feeders, compete for the same food resources. Thus, Yamaoka (1991) contends that resource partitioning in fish feeding behaviour does exist in Lake Malawi cichlids. In addition to stomach content analysis, detailed examination of the species that share same trophic requirements exhibit slight but clear variations in feeding ecology with regard to behaviour, sites and habitat.

The specific objective for the first analysis is to compare management strategies for a period of twenty years focusing on traditional fisheries in Lake Malawi. This sector has majority of fishing operations on the lake (see also Section 4.1.1). Unlike the commercial fisheries sector, access into the traditional fisheries sector is free (FAO 1993). Management of the sector is made difficult due to social and operational factors. Social implications that fisheries management measures may have on fishing communities are first related to their characteristics. Most of the fishing communities in Malawi, as it is the case with other developing countries, have limited alternative income generating opportunities and access to adequate land (FAO 1993; Ngwira et al. 1996). The recent introduction of pluralistic political democracy system of government resulted in change of Government policies. The emphasis is now on reduction or alleviation of poverty. All sectors of government are expected to reflect the shift. In fisheries, socio-economic interests of stakeholders that include traditional fishers have to be blended with the resource conservation objectives (Ngwira et al. 1996). Other social issues that impinge on fisheries management include high population growth rates, poverty connected to the economic value of the lake resources, culture or traditional way of life for the shore communities (Nyambose 1997). Among the issues related to conflicts among the stakeholders and have impact on fisheries management is the allocation of fishing areas between the traditional and commercial fishers (GOM 1989). Resource constraints in terms of personnel, funds and equipment prevent Government to adequately carry out the control measures as outlined in Section 1.5 (GOM 1989; Scholz et al. 1997).

For the traditional fisheries sector, the control measures or regulatory strategies are an indirect way of achieving the same objective as limited entry to control the number of gears or fishing operations in the fishery. Except for the newly legislative recognition of fishing communities' participation in fisheries management, fisheries policy in Malawi has generally been silent on how traditional fishers are to proceed with the long term objective of achieving sustainable resource exploitation (Ngwira et al. 1996). The inshore pelagic zone, which is the main fishing area for the traditional fisheries, seems to have reached maximum exploitation (ICLARM/GTZ 1991; FAO 1993; see also Section 1.4.2). The offshore demersal fish resources of Ndunduma (*Diplotaxodon* spp.), Bombe (*Bathyclarias* spp.), *Synodontis njassae* and to some extent Utaka (*Copadichromis* spp.) as well as the pelagic Usipa (*Engraulicypris sardella*) are however not fully exploitable by traditional fishers. Currently, the limitation is due to unsuitability of craft to safely access the offshore, and gears to fish the demersal species (GOM 1989; Thompson et al. 1995; Banda and Tomasson 1997).

The simulation of the lake's Ecopath model biomasses and catches, in the first analysis, is in relation to specific strategies of:

1. Maintaining the current level of fishing and associated control measures. The maximum level of control is as set in the new legislation for fisheries in the country and associated specific regulations for the lake as found in Appendix 1.3. It is also assumed here that by varying the relative fishing rate in the model simulation, it already translates into the cumulative effect of all control or regulatory measures on the fisheries and is therefore representable by a specific f-factor value in the simulation process. This option (of maintaining the current level of fishing and associated control measures) is assigned an f-factor of 1.00. It also serves as control for the other options;

2. Fishing and associated control measures to have a cumulative relaxation effect of 25 % (i.e., the restrictions are suspended by up to a quarter of the present level) assigned an f-factor of 1.25;

3. Fishing and associated control measures to have a cumulative relaxation effect of 50 % (i.e., the restrictions are suspended by up to a half of the present level) assigned an f-factor of 1.50;

4. Fishing and associated control measures to have a cumulative reduction effect of 25 % (i.e., more restrictions of up to a quarter of the present level are added) assigned an f-factor of 0.75; and

5. Fishing and associated control measures to have a cumulative reduction effect of 50 % (i.e., more restrictions of up to a half of the present level are added) assigned an f-factor of 0.50.

In addition, options of f-factor level 0.00 and 2.00 are included for comparison.

The specific objective of the second analysis is to explore effect of changing fishing rate of only one fishery sector at a time. Between the traditional and commercial fisheries, different levels of f-factor are applied to either one or both fisheries. In the model simulation, ratio of biomass over starting or original model biomass represents change over time to the fisheries. One modification was made in order to carry out the second analysis. The catch, which was based on the traditional fisheries for the Lake Malawi

Ecopath model in the present study (see Section 4.1.1; 4.2.3), was assumed to represent total catch from the lake system. Contributions of traditional and commercial fisheries are assigned for the fish groups which form main fisheries in the lake (Table 5.1) based on Turner (1997a), Tweddle and Magasa (1989), Pitcher (1994), Turner (1995, 1996), Banda et al. (1996), and Banda and Tomasson (1997).

Table 5.1 Catch contributions of the traditional and commercial fleets used in the analysis based on the 1976-96 mean catch of the traditional fisheries in Lake Malawi (dash indicates insignificant amount)

Group	Total Catch		Fleet	
			Traditional	Commercial
	(t)	($t \cdot km^{-2}$)	($t \cdot km^{-2}$)	($t \cdot km^{-2}$)
Chambo	4398	0.15	0.11	0.04
Chilunguni	356	0.01	0.01	–
Kambuzi	2224	0.08	0.08	–
Utaka	10271	0.36	0.26	0.10
Chisawasawa	179	0.01	0.00	0.00
Kampango	2005	0.07	0.05	0.02
Mcheni	259	0.01	0.01	0.00
Mlamba	1533	0.05	0.04	0.01
Usipa	5858	0.20	0.02	0.04
Nchila	168	0.01	0.01	–
Mpasa	112	0.00	0.00	–
Sanjika	122	0.00	0.00	–
Ndunduma	146	0.01	0.00	0.00
Bombe	1465	0.05	0.04	0.01
Nkholokolo	37	0.00	0.00	0.00

Source for catch: MDF (1996).

The rate of change in f-factors applied takes the form of 'simple interest rate' (Budnick 1979) calculated using the formula: $x \cdot r \cdot t$, where x is the starting value, r is the rate of change, and t is the number of years. For this analysis, the rates are detailed in Table 5.2.

Table 5.2 Rates applied in the analysis of effect of changing f-factors in the traditional and commercial fisheries in Lake Malawi (x = 1)

t (years)	r (rate %)		
	0.00	5.00	8.50
0	1.00	1.00	1.00
5	1.00	1.25	1.43
10	1.00	1.50	1.85
15	1.00	1.75	2.28
20	1.00	2.00	2.70

The scenarios simulated in the second analysis include:

1. The f-factor in commercial fisheries grows at the rate of 5 % and remains unchanged in traditional fisheries. The number of fishing operations in the commercial fisheries is estimated to have grown at an average rate of 5 % between 1993 and 1996;

2. The f-factor in traditional fisheries increases at the rate of 8.5 % and is constant in commercial fisheries. Between 1985 and 1996 fishers, gears and craft have increased at a combined average rate of 8.5 % in the traditional fisheries;

3. The f-factor in commercial fisheries decreases at the rate of 5 % while in traditional fisheries it doubles by the end of the simulation period;

4. The f-factor in traditional fisheries goes down at the rate of 8.5 % while in commercial fisheries it doubles by the end of the simulation period;

5. The f-factor in the lake's combined fisheries grows to twice as much by the end of the simulation period; and

6. The f-factor in the lake's combined fisheries decreases to half as much by the end of the simulation period.

5.2 Biomass and catch trends

5.2.1 Introduction to Ecosim

Ecosim is the representation of trophic processes through dynamic equations. The software has a number of useful characteristics which include ability to calculate changes in equilibrium biomasses depending on the fishing mortalities that may be specified; prediction of changes in an ecosystem with respect to fish production over a long time similar to Ecopath but in Ecosim biomasses are varied over time; and prediction of potentials of all biomass pathways. These characteristics enable the software to be used in following policy and ecosystem changes (Walters et al. 1997).

In Ecosim, ability to follow changes over time is achieved through turning the relationships in the ecosystem functional groups (as specified in Pauly and Christensen 1996; Pauly 1998) represented by linear equations in Ecopath into differential equations to capture the variations in biomass and harvesting regimes introduced into a system. The basic formulae for moving from the static mass-balance to dynamic model is as follows:

$$0 = B_i \cdot (P/B_i - F_i \cdot B_i - M_o B_i - \sum_{j=i}^{n} Q_{ij}$$

where B_i is the biomass of (i);

$(P/B)_i$ is the production/biomass ratio of (i);

F_i is the fishing mortality of (i);

M_o is the mortality rate not accounted for in the system,

Q_{ij} is the amount of (i) consumed by (j);

i.e.,

$$dB_i/dt = f(B_i) - M_o \cdot B_i - F_i \cdot B_i - \sum_{j=i}^{n} Q_{ij}(B_i, B_j)$$

where $f(B_i)$ is a function of B_i if (i) is a primary producer;

or $f(B_i) = g_i \sum_{j=1}^{n} c_{ij} \cdot (B_i, B_j)$ if (i) is a consumer; and

g_i is growth efficiency of (i);

$c_{ij}(B_i, B_j)$ is a function used to predict Q_{ij} from B_i and B_j.

The dynamism in the model is achieved when reasonable predictions of $f(B_i)$ and c_{ij} (B_i, B_j) functions are provided so that they are integrated with F_i changing in time. As a result variation in biomass of each (i), as directly affected by:

1. fishing and predation on (i);
2. changes in food available to (i); and indirectly by:
3. fishing or predation on other pools with which (i) interacts, is predicted.

Therefore, Ecosim software is able to include differences in the predation pressures or vulnerabilities associated with specific functional group in the system. And they are rates of biomass transfer between the prey and predator in the assigned values, vulnerability factors (Walters et al. 1997). The dynamic Ecosim approach is applied in the simulation of the Lake Malawi ecosystem. The Ecosim routine, while very useful in prediction of changes in an ecosystem, has some limitations. The major ones relate to strong dependency on mass-balance or equilibrium assumptions of Ecopath, inability to detect or capture food switching in predators and inability to represent smooth and complex size-dependent predation rates that characterize trophic ontogeny in large piscivores (Walters et al. 1997).

The version of Ecosim used in this study is Ecopath with Ecosim Version 4.0 Alpha of August, 1999. The simulation duration was 20 years. Flow control or vulnerability was set at 0.3, i.e., a mixed control regime was used (see also Section 5.1). There was only one juvenile and adult stage linkage; Usipa and its larvae. Fleet was set at combined gears for the first part of the analysis; and then split into traditional fisheries and commercial fisheries for the second one. Other execution or operating settings employed were default and included: integration steps = 100 per year; relaxation parameter = 0.5; discount rate = 5 % per year; equilibrium step size = 0.003; equilibrium maximum fishing rate (relative) = 3; maximum relative P/B = 2; maximum relative feeding time = 2; feeding time factor = 0.5; unexploited predation = 0; and there were no mediation or forcing functions.

5.2.2 Results of biomass and catch simulation

5.2.2.1 Analysis of the fisheries in the lake as single sector

Changes in model simulation of the strategic exploitation options for Lake Malawi are summarized in Table 5.3. The control option with fishing and control measures factor (f-factor) of 1.00 did not vary biomass and catch in the functional groups. The option of f-factor 1.25 reduced catch by 0.12 t·km^{-2}·year^{-1} and biomass of the lake ecosystem by 0.24 t·km^{-2} at the end of twenty years. The option of f-factor 1.50 improved the catch but further worsened the ecosystem biomass. The option of f-factor 0.75 increased the system biomass by 0.36 t·km^{-2} and catch by 0.14 t·km^{-2}·year^{-1}. The greatest catch and biomass for the system are obtained in the strategic exploitation option with f-factor of 0.50. The biomass increased by 0.90 t·km^{-2} and catch went up by 0.34 t·km^{-2}·year^{-1}.

Table 5.3 Summary of Lake Malawi ecosystem biomass and fish catch changes in the model simulation of the strategic exploitation options for the traditional fisheries. Throughout, the starting biomass and catch are 36.89 t·km^{-2} and 1.01 t·km^{-2}·year^{-}1 respectively and increment values are in brackets.

Parameter	f-factor						
	0.00	0.50	0.75	1.00	1.25	1.50	2.00
End biomass (t·km^{-2})	39.93 (-2.14)	37.79 (-0.54)	37.25 (-0.36)	36.89 (-0.24)	36.65 (-0.15)	36.49 (-0.12)	36.37
End catch (t·km^{-2}·year^{-1})	0.00 (+1.35)	1.35 (-0.19)	1.16 (-0.15)	1.01 (-0.12)	0.90 (+0.30)	1.20 (-0.55)	0.65

The ratios of end over starting biomasses (E/S) and similarly those of catches are unity in the control option with f-factor of 1.00. In the rest of the options, there were changes in both biomasses (Table 5.4) and catches (Table 5.5) in all the functional groups. In f-factor 1.25 option, biomasses decreased by over 10 % in five groups; Chambo (24 %), Utaka (16 %), Mpasa (14 %), Kampango (12 %) and Kambuzi (11 %). Biomasses of seven functional groups declined by over 10 % in the f-factor 1.50 option. Chambo was the worst; its biomass dropped by 42 % while Nchila was last with a drop of 12 % (Table 5.4).

Total catch increased by 33 %, 14 % and 19 % in option of f-factor 0.50, 0.75 and 1.50 respectively but it dropped by 12 % in f-factor of 1.25. In individual fish groups high increments in catch for all options are from Kampango, Utaka, Kambuzi, Chambo, Sanjika and Mpasa. Exception is the f-factor 1.50 when mainly the offshore and / or demersal fish groups of Ndunduma, Chisawasawa, Mcheni, Bombe, Mlamba, Usipa and Nkholokolo have high catch increments. Chambo obtains both the highest and lowest percentage changes in catch. Its catch increased by 80 % and dropped by 68 % at f-factor level of 0.50 and 2.00 respectively.

The groups of Usipa larvae, zooplankton and phytoplankton registered unity for the E/S biomass ratio in all the options although there were considerable differences between the end and starting biomass values in options other than the control option. Unity E/S biomass ratios are also obtained in Nkunga, Samwamowa and Nkhungu for f-factor options of 1.25 and 1.50, 1.25, and 0.75 respectively.

Table 5.4 Biomass changes in the Lake Malawi exploitation policy option simulation at different fishing and control measures factors (f-factor) levels; the different gears used in fisheries that occur in the lake are grouped as combined fleet (single sector analysis); there is no change at f-factor level 1.00.

No	Group	Biomass in f-factor levels (t·km^{-2})																		
		1.00	0.00			0.50			0.75			1.25			1.50			2.00		
		Start	End	E/S	% change	End	E/S	% change	End	E/S	% change	End	E/S	% change	End	E/S	% change	End	E/S	% change
1	Nkunga	0.00	0.00	1.03	3.00	0.00	1.01	1.00	0.00	1.00	0.00	0.00	1.00	0.00	0.00	1.00	0.00	0.00	1.00	0.00
2	Kampango	0.28	0.51	1.78	78.00	0.37	1.31	31.00	0.33	1.14	14.00	0.25	0.88	12.00	0.22	0.77	23.00	0.17	0.60	40.00
3	Matemba	0.00	0.00	1.04	4.00	0.00	1.02	2.00	0.00	1.01	1.00	0.00	0.99	1.00	0.00	0.98	2.00	0.00	0.97	3.00
4	Utaka	1.75	3.81	2.18	118.00	2.52	1.44	44.00	2.09	1.20	20.00	1.47	0.84	16.00	1.24	0.71	29.00	0.88	0.50	50.00
5	Ndunduma	2.49	2.26	0.91	9.00	2.38	0.96	4.00	2.44	0.98	2.00	2.54	1.02	2.00	2.60	1.04	4.00	2.71	1.09	9.00
6	Kambuzi	0.42	0.68	1.63	63.00	0.53	1.27	27.00	0.47	1.13	13.00	0.37	0.89	11.00	0.33	0.79	21.00	0.26	0.63	37.00
7	Chisawasawa	0.17	0.18	1.08	8.00	0.18	1.04	4.00	0.17	1.02	2.00	0.17	0.98	2.00	0.16	0.96	4.00	0.16	0.92	8.00
8	Chambo	0.48	1.88	3.89	289.00	0.87	1.80	80.00	0.64	1.32	32.00	0.37	0.76	24.00	0.28	0.58	42.00	0.16	0.32	68.00
9	Chilunguni	0.16	0.20	1.22	22.00	0.18	1.10	10.00	0.17	1.05	5.00	0.16	0.95	5.00	0.15	0.90	10.00	0.13	0.82	18.00
10	Mbuna	7.48	6.89	0.92	8.00	7.20	0.96	4.00	7.34	0.98	2.00	7.63	1.02	2.00	7.77	1.04	4.00	8.05	1.07	7.00
11	Mcheni	0.29	0.30	1.07	7.00	0.29	1.03	3.00	0.29	1.02	2.00	0.28	0.98	2.00	0.28	0.97	3.00	0.27	0.94	6.00
12	Bombe	1.11	1.15	1.04	4.00	1.13	1.02	2.00	1.12	1.01	1.00	1.10	0.99	1.00	1.10	0.99	1.00	1.09	0.98	2.00
13	Mlamba	1.16	1.27	1.09	9.00	1.21	1.04	4.00	1.18	1.02	2.00	1.14	0.98	2.00	1.13	0.97	3.00	1.10	0.94	6.00
14	Usipa	0.56	0.60	1.06	6.00	0.58	1.03	3.00	0.57	1.02	2.00	0.55	0.99	1.00	0.54	0.97	3.00	0.53	0.94	6.00
15	Usipa larvae	0.13	0.13	0.99	1.00	0.13	1.00	0.00	0.13	1.00	0.00	0.13	1.00	0.00	0.13	1.00	0.00	0.13	1.01	1.00
16	Sanjika	0.03	0.05	1.52	48.00	0.04	1.22	22.00	0.03	1.11	11.00	0.03	0.91	9.00	0.03	0.82	18.00	0.02	0.68	32.00
17	Mpasa	0.02	0.04	1.90	10.00	0.03	1.36	36.00	0.02	1.16	16.00	0.02	0.86	14.00	0.02	0.75	25.00	0.01	0.56	44.00
18	Nchila	0.01	0.01	1.31	31.00	0.01	1.14	14.00	0.01	1.07	7.00	0.01	0.94	6.00	0.01	0.88	12.00	0.01	0.77	23.00
19	Nkholokolo	0.59	0.57	0.97	3.00	0.58	0.98	2.00	0.59	0.99	1.00	0.60	1.01	1.00	0.60	1.02	2.00	0.61	1.04	4.00
20	Samwamowa	0.00	0.00	1.03	3.00	0.00	1.01	1.00	0.00	1.01	1.00	0.00	1.00	0.00	0.00	0.99	1.00	0.00	0.99	1.00
21	Nkhungu	1.75	1.72	0.98	2.00	1.73	0.99	1.00	1.74	1.00	0.00	1.76	1.01	1.00	1.77	1.01	1.00	1.79	1.02	2.00
22	Nkhono	5.00	4.71	0.94	6.00	4.86	0.97	3.00	4.93	0.99	1.00	5.07	1.01	1.00	5.15	1.03	3.00	5.30	1.06	6.00
23	Top predators	0.00	0.00	0.95	5.00	0.00	0.97	3.00	0.00	0.98	2.00	0.00	1.02	2.00	0.00	1.03	3.00	0.00	1.07	7.00
24	Zooplankton	5.38	5.37	1.00	0.00	5.37	1.00	0.00	5.38	1.00	0.00	5.38	1.00	0.00	5.39	1.00	0.00	5.39	1.00	0.00
25	Phytoplankton	7.62	7.61	1.00	0.00	7.62	1.00	0.00	7.62	1.00	0.00	7.62	1.00	0.00	7.62	1.00	0.00	7.63	1.00	0.00
	Total	36.89	39.93	1.08	8.00	37.79	1.02	2.00	37.25	1.01	1.00	36.65	0.99	1.00	36.49	0.99	1.00	36.37	0.99	1.00

Table 5.5 Catch changes in the Lake Malawi exploitation policy option simulation at different fishing and control measures factors (f-factor) levels; the different gears used in fisheries that occur in the lake are grouped as combined fleet (single sector analysis); there is no change at f-factor level 1.00. and nil catch at f-factor level 0.00 (dashes mean that data cannot be assigned or is not available).

No	Group	Catch in f-factor levels($t \cdot km^{-2} \cdot year^{-1}$)															
		1.00	0.50			0.75			1.25			1.50			2.00		
		Start	End	E/S	% change	End	E/S	% change	End	E/S	% change	End	E/S	% change	End	E/S	% change
1	Nkunga	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
2	Kampango	0.07	0.09	1.31	31.00	0.08	1.14	14.00	0.06	0.88	12.00	0.08	1.16	16.00	0.04	0.60	40.00
3	Matemba	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
4	Utaka	0.36	0.51	1.44	44.00	0.43	1.20	20.00	0.30	0.84	16.00	0.38	1.06	6.00	0.18	0.50	50.00
5	Ndunduma	0.01	0.01	0.96	4.00	0.01	0.98	2.00	0.01	1.02	2.00	0.01	1.57	57.00	0.01	1.09	9.00
6	Kambuzi	0.08	0.10	1.27	27.00	0.09	1.13	13.00	0.07	0.89	11.00	0.09	1.19	19.00	0.05	0.63	36.00
7	Chisawasawa	0.01	0.01	1.04	4.00	0.01	1.02	2.00	0.01	0.98	2.00	0.01	1.44	44.00	0.01	0.92	8.00
8	Chambo	0.15	0.28	1.80	80.00	0.20	1.32	32.00	0.12	0.76	24.00	0.13	0.87	13.00	0.05	0.32	68.00
9	Chilunguni	0.01	0.01	1.10	10.00	0.01	1.05	5.00	0.01	0.95	5.00	0.02	1.36	36.00	0.01	0.82	18.00
10	Mbuna	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
11	Mcheni	0.01	0.01	1.03	3.00	0.01	1.02	2.00	0.01	0.98	2.00	0.01	1.45	45.00	0.01	0.94	6.00
12	Bombe	0.05	0.05	1.02	2.00	0.05	1.01	1.00	0.05	0.99	1.00	0.08	1.48	48.00	0.05	0.98	2.00
13	Mlamba	0.05	0.06	1.04	4.00	0.05	1.02	2.00	0.05	0.98	2.00	0.08	1.45	45.00	0.05	0.94	6.00
14	Usipa	0.20	0.21	1.03	3.00	0.21	1.02	2.00	0.20	0.99	1.00	0.30	1.46	46.00	0.19	0.94	6.00
15	Usipa larvae	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
16	Sanjika	0.00	0.01	1.22	22.00	0.00	1.11	11.00	0.00	0.91	9.00	0.01	1.23	23.00	0.00	0.68	32.00
17	Mpasa	0.00	0.01	1.36	36.00	0.01	1.16	16.00	0.00	0.86	14.00	0.00	1.12	12.00	0.00	0.56	44.00
18	Nchila	0.01	0.01	1.14	14.00	0.01	1.07	7.00	0.01	0.94	6.00	0.01	1.32	32.00	0.01	0.77	23.00
19	Nkholokolo	0.00	0.00	0.98	2.00	0.00	0.99	1.00	0.00	1.01	1.00	0.00	1.53	53.00	0.00	1.04	4.00
20	Samwamowa	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
21	Nkhungu	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
22	Nkhono	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
23	Top predators	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
24	Zooplankton	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
25	Phytoplankton	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Total	1.01	1.35	1.33	33.00	1.16	1.14	14.00	0.90	0.88	12.00	1.20	1.19	19.00	0.65	0.64	36.00

5.2.2.2 Analysis of the fisheries as traditional and commercial sectors

Table 5.6 summarizes the end catch and ratio of end over starting catch (E/S) at the different f-factor levels. Although the commercial E/S catch ratio differs at the f-factor levels, the end catch is unity at all the f-factors except for the nil f-factor option. The growth rate of 5 % in the f-factor for the commercial fisheries reduced the biomass of Chambo, Utaka and Kampango. Chambo biomass dropped to around 25 % at the end of twenty years (Fig 5.1). Increase of 8.5 % in the f-factor for the traditional fisheries, however, resulted in heavier biomass declines (Fig 5.2). Many more groups were affected; they included Nchila, Kambuzi, Mpasa and Sanjika apart from the above three. A faster biomass decrease was also experienced in the same groups when the f-factor in the lake's combined fisheries doubled by the end of the simulation period. The Chambo fishery crashed and the fisheries of Utaka, Kambuzi, Kampango, Sanjika and Mpasa had biomasses of less than half when twenty years elapsed (Fig 5.5).

Table 5.6 End catch and ratio of end over starting catch in the traditional and commercial sectors in Lake Malawi with respective starting catches are 0.78 t·km^{-2}·year^{-1} and 0.23 t·km^{-2}·year^{-1}. F-factor level of 0.00 has zero values throughout.

Sector/Fleet	f-factor					
	0.50	0.75	1.00	1.25	1.50	2.00
Traditional end catch (t·km^{-2}·year^{-1})	7.62	7.18	7.62	7.62	7.62	7.63
Traditional catch E/S	1.33	1.14	1.00	0.89	1.19	0.65
Commercial end catch (t·km^{-2}·year^{-1})	1.00	1.00	1.00	1.00	1.00	1.00
Commercial catch E/S	0.14	1.16	1.00	0.88	1.16	0.62

In the scenario where the f-factor in commercial fisheries decreases at the rate of 5 % while in traditional fisheries it increases by the end of the simulation period, the biomasses of the above fisheries also went down. The groups gained biomasses when the f-factor in traditional fisheries decreased at the rate of 8.5 % while in commercial fisheries it doubled by the end of the simulation period (Fig 5.4). The highest gain in biomasses for the fisheries was experienced when fisheries in the lake were combined and the f-factor was reduced. Chambo had more than twice its starting biomass (Fig 5.6).

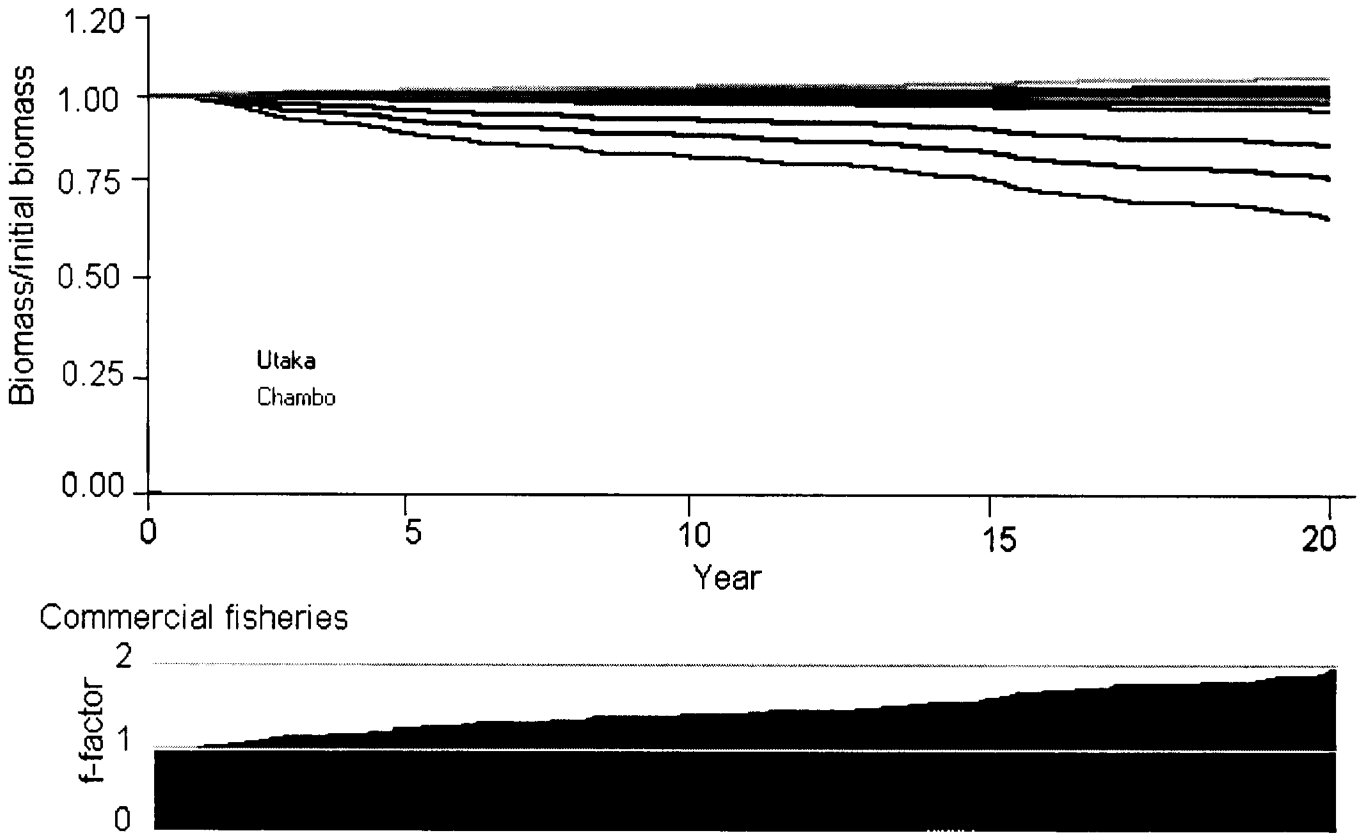


Figure 5.1 Change in the ratio of biomass over initial biomass in Lake Malawi fisheries for increasing f-factor in the commercial fisheries (5 %) with no change in f-factor for the traditional fisheries.

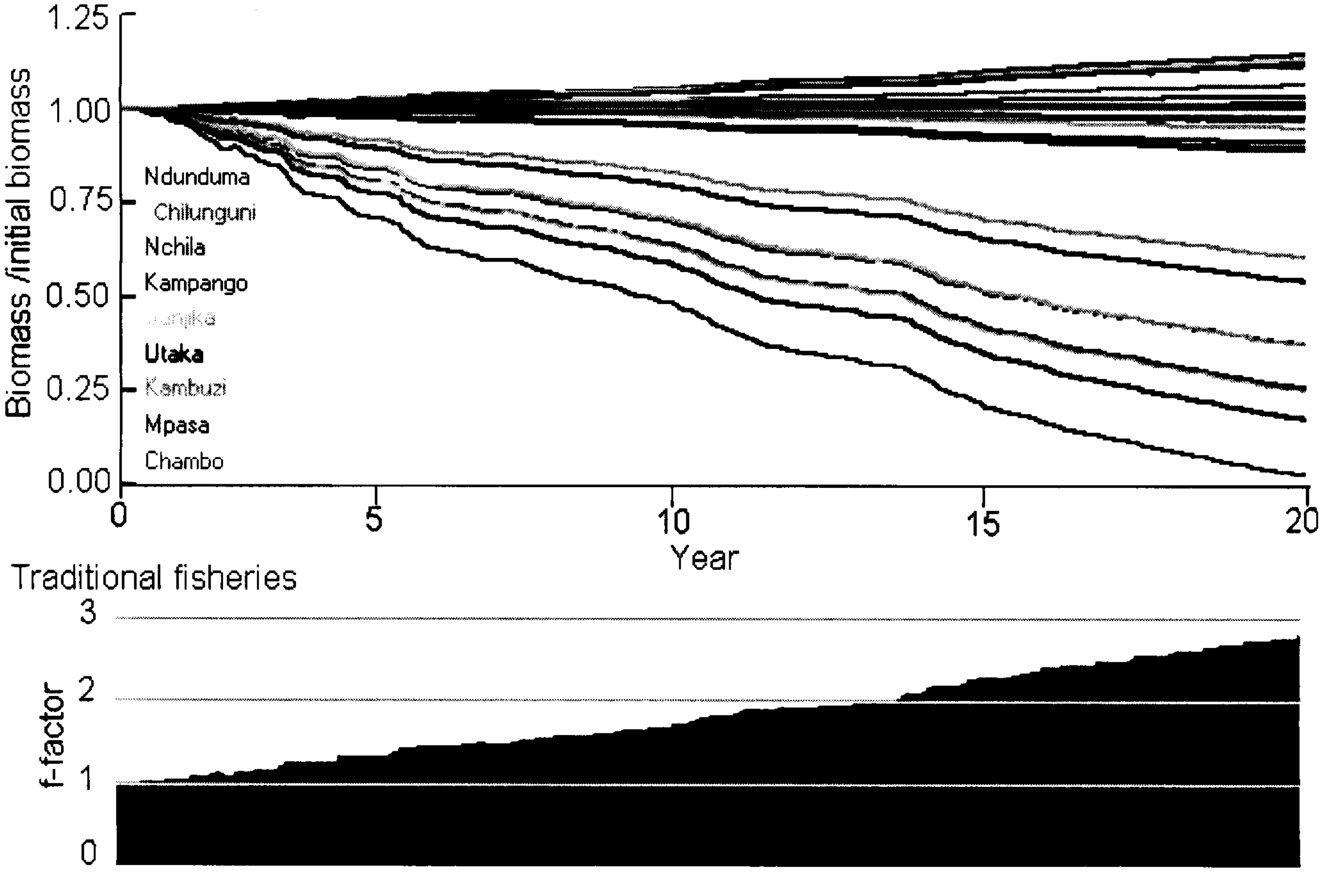


Figure 5.2 Change in the ratio of biomass over initial biomass in Lake Malawi fisheries for increasing f-factor in the traditional fisheries (8.5 %) with no change in f-factor for the commercial fisheries.

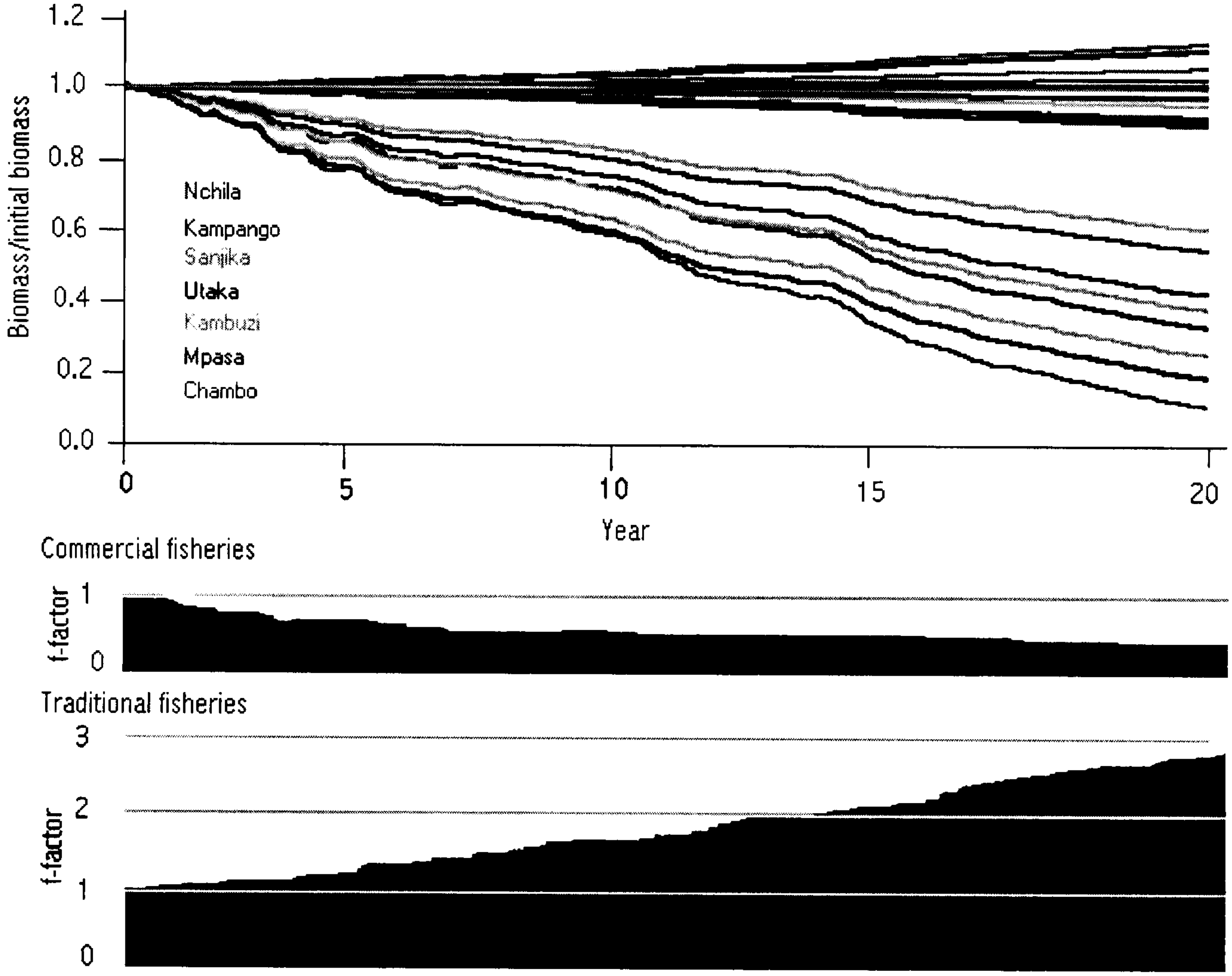


Figure 5.3 Change in the ratio of biomass over initial biomass in Lake Malawi for declining f-factor in the commercial fisheries (5 %) and increasing f-factor in the traditional fisheries (8.5 %).

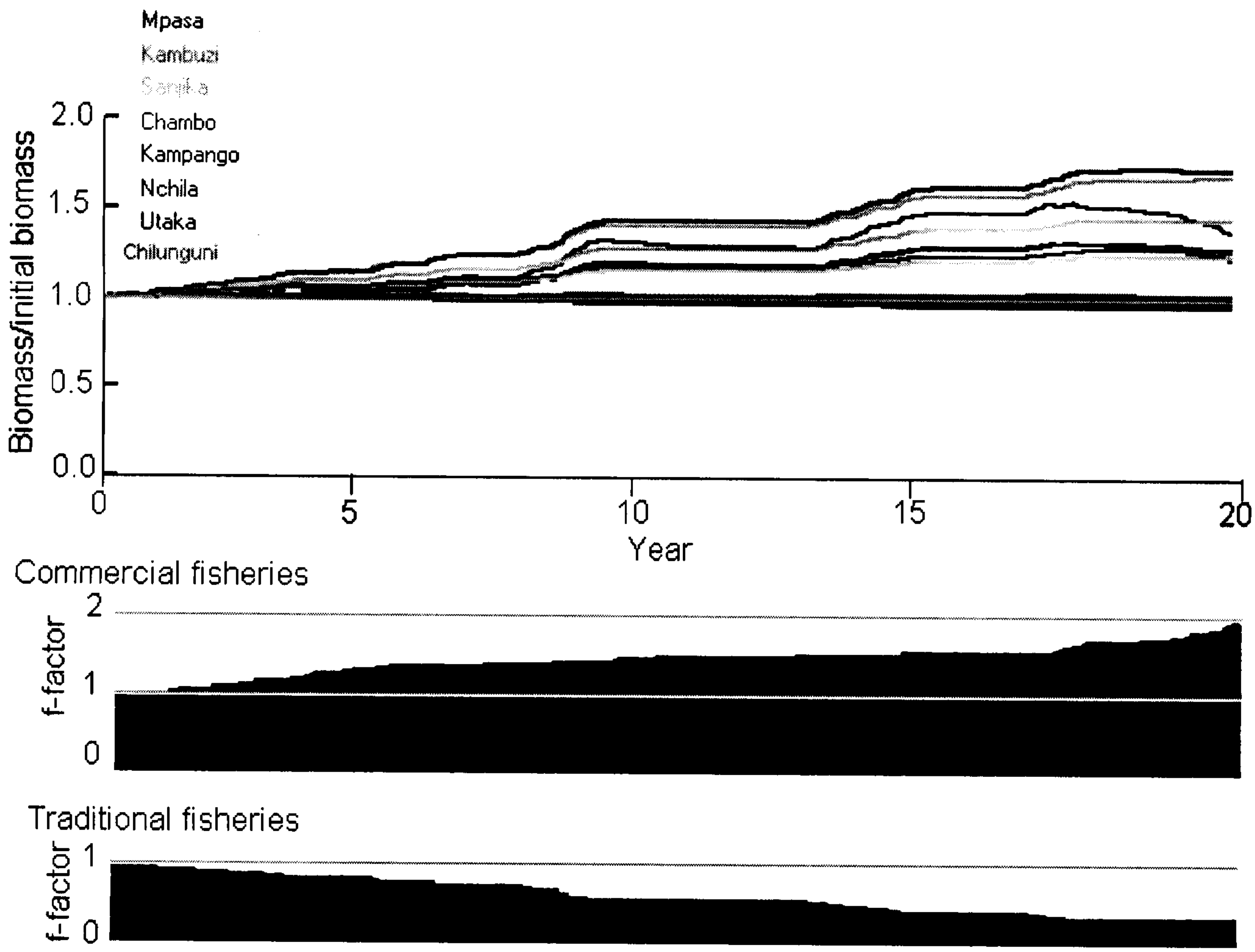


Figure 5.4 Change in the ratio of biomass over initial biomass in Lake Malawi for increasing f-factor in the commercial fisheries (5 %) and declining f-factor in the traditional fisheries (8.5 %).

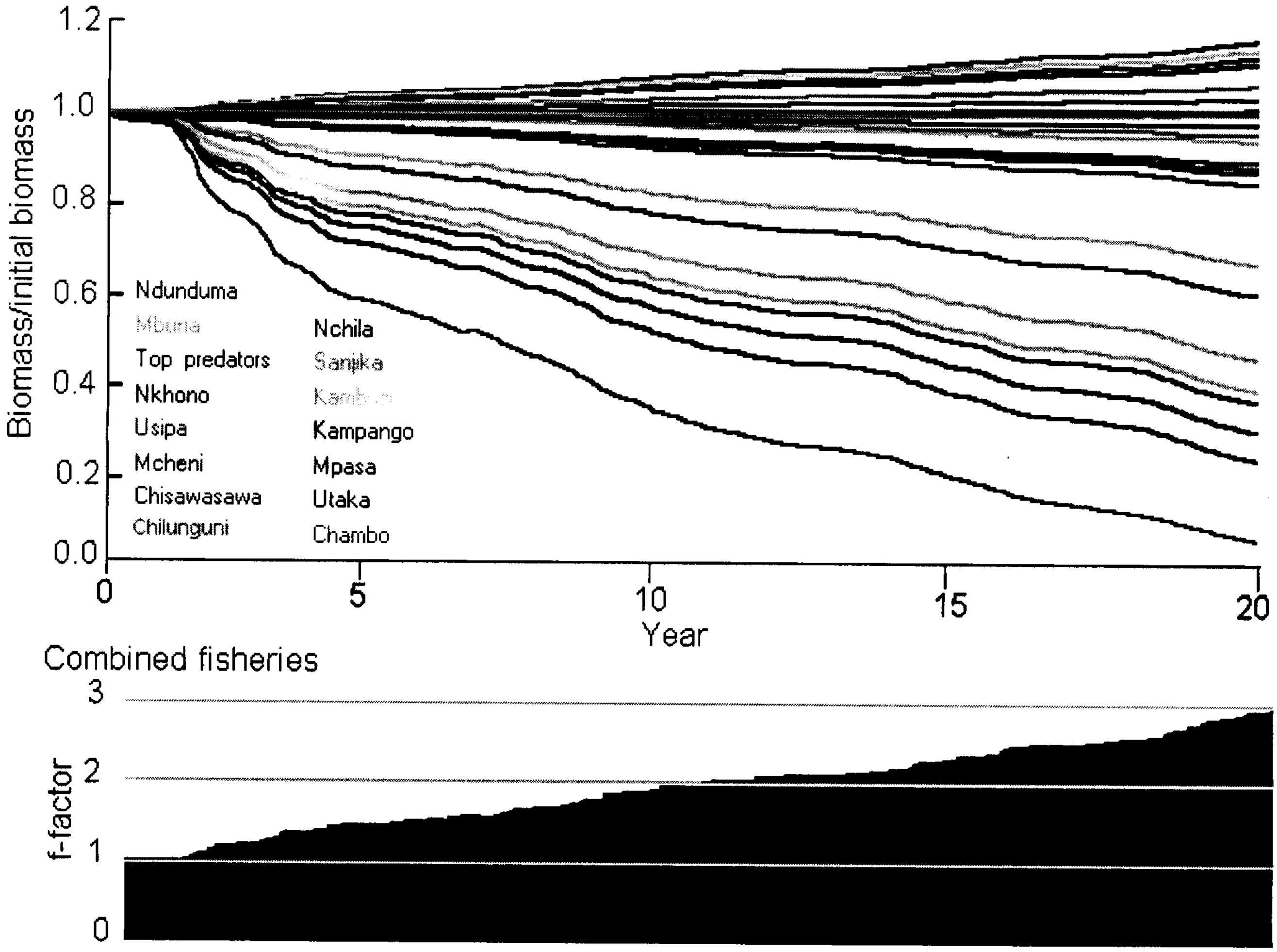


Figure 5.5 Change in the ratio of biomass over initial biomass in Lake Malawi fisheries with increasing f-factor in both the commercial and traditional fisheries.

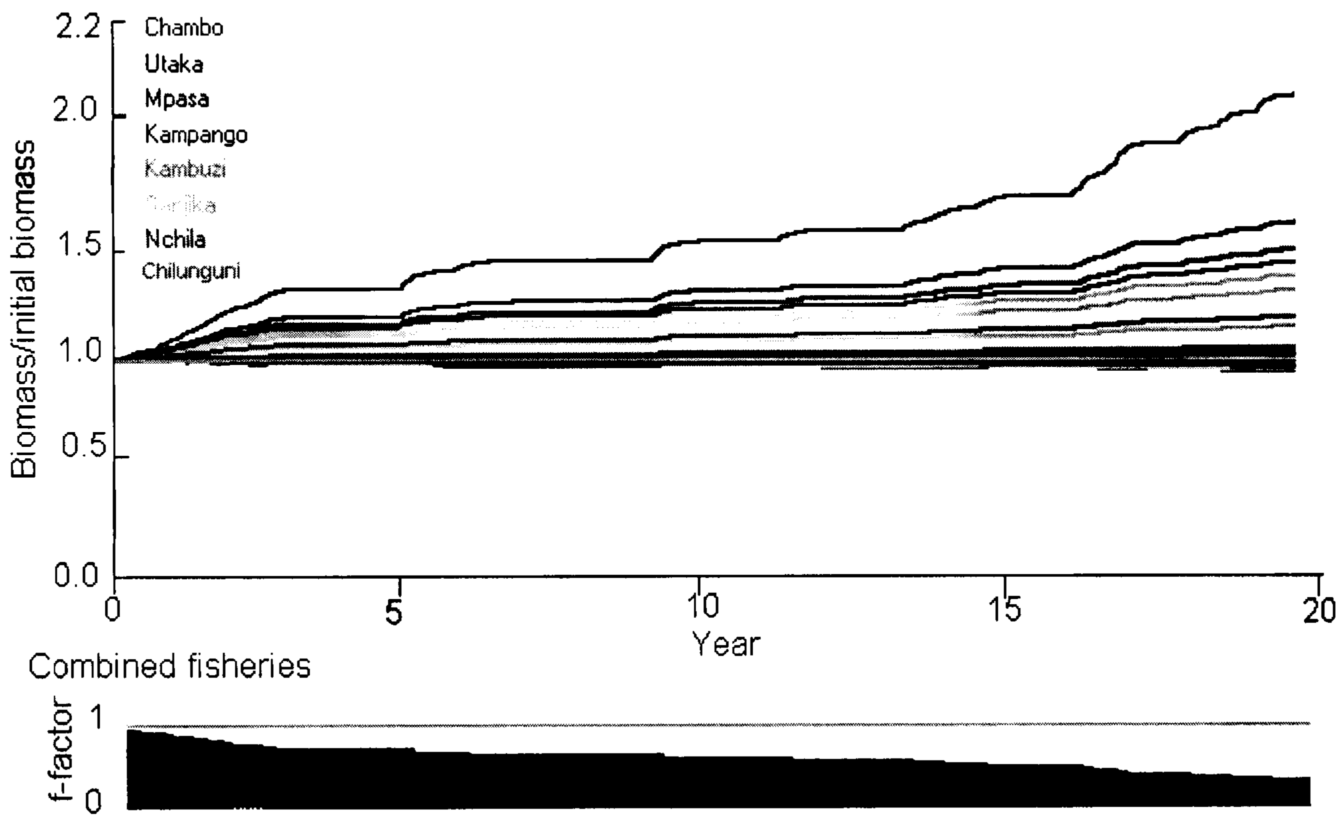


Figure 5.6 Change in the ratio of biomass over initial biomass in Lake Malawi fisheries with decreasing f-factor in both the commercial and traditional fisheries.

Traditional sector has more influence on the fisheries of Lake Malawi than commercial sector. Although increasing f-factor in commercial fisheries can affect the fisheries, particularly Chambo, Utaka and Kampango, its negative effect is mitigated when the f-factor in the traditional fisheries is reduced. The species-based fisheries in the lake appear, in order of their being most vulnerable, to be Chambo, Utaka, Mpasa, Kampango, Kambuzi, Sanjika, Nchila and Chilunguni. The vulnerability of the fisheries in this analysis is in agreement with the analysis of the fisheries as one unit in the last section as well as observations in Sections 1.3.2, 2.4.2, 4.2.3 and 5.1.

To recap, the main results in Chapter 5 were as follow. In the first analysis of simulating the Lake Malawi Ecopath model biomasses and catches, the reduction of the f-factor by half from the present level produced the best biomass and catch returns for the fisheries in the lake. The biomasses and therefore catches increased in the fish groups that formed the main fisheries, while in the fish groups that are not targeted or minimally exploited at present, both biomass and catch dropped. The second analysis, which explored the effect of changing fishing rate of only one fishery sector at a time, emphasized the contribution and therefore influence of the traditional fisheries on fish biomasses. It appears that the quantity of available food resources is one of the important factors in determining fish biomasses in Lake Malawi, after fishing pressure and probably environmental factors (see Section 1.6).

CHAPTER 6:

DISCUSSION

6.1 Comparisons of fisheries

Application of the rapid appraisal technique on the artisanal species-based fisheries showed that the 'health' state of Lake Malawi worsened as the years progressed. It showed further that the gear-based fisheries were healthier when the operation level is small rather than large. These results are in agreement with what was observed in most African lake fisheries that also deteriorated with time (Preikshot et al. 1998). Only Usipa (*Engraulicypris sardella*) fishery appeared sustainable. The life history of Usipa as an annual fish was probably a major cause for that (Allison et al. 1995a). It is very fecund and recovers from poor year classes with recruitment being largely independent of parent stock size (Thompson 1995). It was also possible that the offshore nature of Usipa relieves the fishing pressure from the traditional fishers in the inshore waters although breeding behaviour and food availability partly cause Usipa to be near shore (Allison et al. 1995b).

The Rapfish technique was quite useful in elucidating a number of factors from the combined inter-disciplinary attributes, which were not obvious on their own. The analysis formalized what was currently known about the lake's fisheries conditions as well as concerns on fisheries in general (FAO 1993; Banda and Hara 1994; Nyambose 1997; Stauffer et al. 1997). The technique was also convenient in that results could be improved with additional information in any future analyses. And it would be possible to check against other methods that might be used to evaluate the fisheries. Rapfish combined scores from a number of disciplines and this distinguished it from other methods. Calculating the scores for some attributes using factors such as catch seemed conceptually much more persuasive than relying on scores obtained by using the general scoring guidelines only, in order to show differences in related fisheries. An aspect that might require attention in the broad-based assessment of fisheries using the technique would be to evolve a score validation mechanism by the fisher-folk rather than covering technocrats only.

6.2 Ecopath model

Increasing predation on phytoplankton and detritus lowers the mean trophic level of the Lake Malawi ecosystem. Editing the diets of the main groups which feed on zooplankton and replacing a large part of their consumption on zooplankton by phytoplankton and detritus moved the mean trophic level from 5.0 to 3.8 in the early runs of balancing the model. Inclusion of cannibalism (in-group feeding) in the diets of top predator trophic box shifted its trophic level from 3.5 to 3.6. The main users of secondary production in Lake Malawi, lakefly *Chaoborus edulis* and larvae of *E. sardella* (Usipa) have a higher number of connections to the top trophic groups than other middle level trophic groups, except for zooplankton. The two former groups together with predatory zooplankton *Mesocyclops aequatorialis aequatorialis* form the main pathway or link through which energy flows to top trophic levels in the Lake Malawi ecosystem from the low trophic levels of phytoplankton and herbivorous zooplankton (Allison et al. 1995b). The trophic structure of the lake system seems to decline with time (see Section 3.3.4.3). The species, which appeared in the pelagic zone of central Lake Malawi ecosystem (see Section 3.2.2; Degnbol 1993) or the pelagic zone ecosystem (see Section 3.2.3; Allison et al. 1995b) and the present Lake Malawi Ecopath models, obtained lower trophic levels in the later model (Table 3.6). Although there are differences in the input data such as larger time span and number of functional groups in the new model, most data were from similar sources.

Bombe *Bathyclarias* spp. was among the groups with high gross food conversion efficiency (GE) values in Lake Malawi ecosystem. Unlike Matemba and Usipa which are small (maximum length 3-15 cm, with few exceptions - see also Section 3.3.2.2 (3); Appendix 1.3), Bombe is large (maximum length 70 - 150 cm). Matemba species such as *Barbus paludinosus* and *B. trimaculatus* have been shown, in aquaculture, to be prolific spawners and have a high growth potential (Brummett and Noble 1995). Usipa is also fast growing (Thompson 1995). One of the influencing factors for Bombe's high GE would be fast growth rate. This agreed with preliminary work on raising Bombe in ponds in Malawi (E. Kaunda *pers. comm.*). Other possible reasons could be the fact that the input P/B was from a different species and model with different ecosystem environment as well exploitation rates (see Section 3.3.3.2).

Although detritus impacts the system positively, it is not strong. Detritus is also less important in the lake's energy flow (see Section 3.2.3, Allison et al. 1995b). In terms of ecosystem maturity, detrital flow becomes more important in mature systems

(Christensen and Pauly 1992; Dalsgaard 1999; Buchary 1999). With this analysis, Lake Malawi's maturity is between the early and middle stages.

6.3 Catch, fish mean maximum length and trophic level changes

Up to 80 % of the Lake Malawi catch is taken from only 10 % of its total area in the south (Tweddle et al. 1991; Pitcher 1995; Turner 1995; see Section 4.1.1). The differences in catch between the areas are a reflection of the biophysical and / or limnological conditions. Depth and wind as well as resulting internal water currents are some of the main influencing factors of productivity in the lake (see Section 3.2.1, Beadle 1974; Banda 1989; FAO 1993, Patterson and Kachinjika 1995). Wind-induced mixing of the nutrient-rich deep waters and nutrient-poor surface waters is also fundamental to maintaining the fisheries in the lake (Arnell et al. 1996; WWF 1998). The contribution of the traditional fisheries landings from southern part of the lake declined from 80 to 50.4 % for the period 1986-96 (Section 4.1.1). The average catch from the commercial fisheries was 5000 tonnes per year for 1986-96. The 1976-1990 average was 7800 tonnes per year (Turner 1995). Decrease in the landings of this sector (Fig 4.1b) was due to natural stock fluctuations, old age of the fishing craft and overcapitalization (see Sections 4.1.1; 4.2.3). By 1991 Chambo (*Oreochromis*) fishery, the most lucrative fishery in the country, sharply declined in the southeast arm of the lake, its major fishing area and completely collapsed in the neighbouring Lake Malombe (FAO 1993; MFD 1996). Stauffer et al. (1997) reported of extensive use of gillnets and illegal beach seining, for example lining seines with mosquito netting, since 1985 which has contributed to the decline in biomass of molluscivores from 680 to 373.7 tonnes per annum in the 1970s and 1990s respectively in the southeast arm of Lake Malawi. The decline in the biomass of molluscivores resulted in increased incidence of schistosomiasis infection in some localized areas along the lake. The impact of this on the fisheries could only be related indirectly to increased number of fishers being infected by bilharzia. Other factors that were responsible for dwindling catches, particularly of the food-fish, were of natural or environmental origin (Munthali 1997; see also Section 1.6).

The amount of catch, maximum lengths and trophic levels of the main species in the total catch from Lake Malawi influenced both the mean catch-weighted maximum lengths and trophic levels as they were embedded in the calculation of the last two parameters. Catch-weighted mean maximum length ($\overline{L}_{max}$) and trophic level ($\overline{TL}$) flections – points at which they turn up or down (Figs. 4.5 and 4.7) did not correspond to those of catch for all the years (Fig. 4.1a). Because of weighing the $\overline{L}_{max}$s and $\overline{TL}$s with catches, higher catches did not necessarily result into increased $\overline{L}_{max}$s and $\overline{TL}$s. The trend in mean maximum lengths (Fig. 4.5, 4.6) demonstrated the concept of 'fishing down the food web' (Pauly et al. 1998) very clearly. Large fish species such as Chambo are now being replaced by small ones such as Utaka and Usipa (see also Section 4.2.3). This trend has long been observed in Lake Malawi (FAO 1976; Turner 1977a,b; Tweddle and Magasa 1989; Turner 1995; Banda et al. 1996; Banda and Tomasson 1997). The trophic level increased between 1986 and 1995 due to, again, higher contribution of Usipa (*Engraulicypris sardella*) which has a higher trophic level than Utaka (*Copadichromis* spp.) although the latter has higher landings. Chambo (*Oreochromis* spp.), which has low trophic level and high mean maximum length compared to the two groups above, has declining catches (see also Section 4.2.3).

Biomasses of the groups (Table 3.3) as estimated in the new Lake Malawi Ecopath Model (see Section 3.3), do appear to reflect well the situation in the lake. The catches of the species or groups of species that currently form the main fisheries in the lake are closely related to their biomasses, i.e., the groups that have high biomasses contributed relatively more to the total fish landings in the traditional fisheries sector. Based on comparison of the present catches and estimated biomasses, it seems there may be potential of modest increase in catches of few fish groups, notably Ndunduma (*Diplotaxodon* spp.), Mbuna (*Pseudotropheus* spp.) and Nkholokolo (*Synodontis njassae*). Ndunduma has the second largest biomass of 2.49 $t{\cdot}km^{-2}$. While Ndunduma is an important food fish and its marketing is no problem, the catch stands at a low value of 0.005 $t{\cdot}km^{-2}$. The disparity is caused by the fact that *Diplotaxodon* spp. occur offshore. Although they have been regarded as pelagic species (Thompson et al. 1995), they are one of the large components of the demersal trawl catches (Banda and Tomasson 1997). One of the species of Ndunduma, *D. limnothrissa*, has the most abundant biomass than any other cichlid in the lake, with biomass of 87,000 tonnes (Turner 1996). Traditional fisheries cannot at present effectively exploit Ndunduma due to its offshore occurrence and inappropriateness of craft as well as gear. Since the landing data are based on the traditional fisheries it is possibly underestimated. Commercial fisheries component could not be specifically added due to unavailability of catch trends by species. For the purposes of this analysis it was assumed that the commercial fisheries component would have a minimal effect especially when the landing averaging 6500 tonnes per year for the 1976-96 period was split into species numbering up to 9. Mbuna with biomass estimate of 7.484 $t \cdot km^{-2}$ is the highest for all the fish functional groups. Except for contribution of *Pseudotropheus livingstonii, P. elegans* and may be few other species in the commercial fisheries (Turner 1977a; Tweddle and Magasa 1989; Turner 1996) and utilization as a popular species in tropical ornamental or aquarium trading (Konings 1990), Mbuna is not currently targeted for consumption either in the traditional or commercial fisheries. The species that may form a fishery in the Nkholokolo functional group is *Synodontis njassae.* Its biomass and catch are 0.59 $t \cdot km^{-2}$ and 0.001 $t \cdot km^{-2} \cdot year^{-1}$ respectively. The cause of un-proportionality is similar to Ndunduma's; inability of traditional fishers to effectively catch the species (Banda and Tomasson 1997).

6.4 Policies for exploitation of Lake Malawi

Notwithstanding limitations, the Ecosim software (see also Section 5.1; Walters et al. 1997) can simulate changes in biomasses, given changes in fishing pressure. The properties were useful in the simulation of the Lake Malawi ecosystem for a period of 20 years. With the specification of the fishing mortalities, which was done by setting fishing and control measures factors (f-factors) in the model, Ecosim routine also predicted changes in fish production and potentials of all biomass pathways for the lake ecosystem for the simulation period.

The choice of the model control regime fixed at 0.3 (mixed control, see Section 5.1) seemed plausible based on the studies on Chambo in the southern part of Lake Malawi

(FAO 1993) and the experience of trophic control in the pelagic zone system in the lake (Allison et al. 1995a) and feeding ecology of some of the species (Yamaoka 1991). The FAO Chambo study, after analysing the 1982 -1986 catches, pointed out the possibility of factors other than fishing (or predation) to have influenced the fish biomass and production. Allison et al. (1995a) found higher planktonic biomasses of organisms, comprising of both producers and consumers, in 1993 than 1992 which led to increased carbon transfer in the food chain. This constituted the evidence of their standing biomasses and production rates being controlled by food supply. It was also found that predator control was available through rapid response of predator populations to increases in prey populations (see also Section 3.2.3). Yamaoka (1991) emphasized the food partitioning rather than complete food resource sharing between species which might be assumed to show superabundance of food and thus food supply not to be important in system control (see also Section 5.1).

It was important to focus on the traditional fisheries, in the first analysis of exploring policies for exploiting Lake Malawi using Ecosim, because of the sector's open access nature (see also Sections 1.4, 5.1; ICLARM/GTZ 1991; FAO 1993; Donda 1998) and the difficulty to manage it (Ngwira et al. 1996; Scholz et al. 1997). The strategic exploitation options which are used in the model simulation and that would maintain the integrity of the Lake Malawi ecosystem, at least in terms of total biomass, would have to either maintain the current fishing effort or reduce it (see Section 5.2.2). The fish resources of the lake are said to be fully exploited and expansion of the fish resources is not attainable in the near shore areas (see Section 1.4.2; ICLARM/GTZ 1991; FAO 1993; Menz et al.

1995; Banda and Tomasson 1997). The main recommendations for the development of fisheries in Lake Malawi from the FAO (1993) study are supported by the view of maintaining the lake's integrity. The Chambo stocks were found to be fully exploited while the deep water haplochromine trawl fishery was severely depleted, at least in the southeast arm of the lake. In the present analysis, there was decline in totals of both biomass and catch when the f-factor was above that of the current level, except for total catch at f-factor of 1.5 which increased by 19 %. Chambo as well as Utaka and Chisawasawa, which fall in the respective two categories above, had also decreased biomass and catch when the f-factor was above 1.0, again except for catch at f-factor 1.5. In general it was viewed that expansion of the fisheries would not necessarily result in increased catch. The additional catch obtained at f-factor 1.5 would also not be available to majority of fishers in the lake. The fish groups which contributed most of the 19 % incremental catch were mainly offshore and demersal and inaccessible to the traditional fishing operations.

Fisheries has major impact on the Lake Malawi ecosystem, in addition to other factors (see Sections 1.4, 5.2.2). In the second analysis of exploring policies for exploiting the lake, influence of traditional fisheries which is more than that of commercial fisheries was on biomass and catch of the functional groups. The biomass of fish groups, which do not form fisheries in the lake particularly for Ndunduma, Mbuna, Top predators and Nkhono, have opposing trends to those of species-based fisheries in response to variation in f-factors. The differences could be attributed to the fact that diets of the fish groups in the two categories overlap (see also Sections 3.3.2.2, 3.3.3.1; Table 3.3). The consequence is that food supply increased when f-factor is high as exploited fish groups are depleted. Pressure for food is increased when f-factor is reduced affecting the biomasses of some groups including Ndunduma, Mbuna, Top predators and Nkhono. This scenario seemed to also support the concepts of food partitioning and food supply as a control regime, largely, for the lake's ecosystem (Yamaoka 1991; Allison et al. 1995a).

The variation of f-factors to above and below 1.0 in the simulation options had the effect of reversing outcomes. This was probably due, in part, to vulnerability exchange in the Ecosim routine (Walters et al. 1997) as well as the fact that all other parameters for determining the biomass in the Ecopath model did not vary during simulation. It was unclear why the ratio of end over starting biomass for Usipa larvae, zooplankton and phytoplankton groups was unity when there were some differences between the end and starting biomasses in some of the cases. The same also occurred in Nkhungu at f-factor 0.75. It is assumed that the small size of the organisms in the groups was the determining factor.

The most optimal strategic policy option for exploiting Lake Malawi to benefit both the fisheries and the ecosystem as a whole would seem to be setting the fishing effort to half the current level. In this way the ecosystem status, as it is now, would be maintained. Effort would only be increased for selected offshore and demersal groups of species such as Ndunduma, Bombe and Nkholokolo. It would have been most ideal to develop a 'guarded' fishery for Nkhono but locally it is viewed as not edible. The potential would lie in exploring a market for the product first. Mbuna has the largest biomass among the fish groups in the lake. It would however not be advisable to develop a fishery as the group is also the most diverse in number of species (Ribbink 1991). An established fishery would easily disturb the balance and result in dissemination of some individual species in the Mbuna complex. Based on the first two analyses, some of the fisheries would benefit from a period of closure and / or reduction in fishing effort. The Chambo fishery would especially need urgent attention. Utaka, Kampango and Kambuzi seemed to be fully exploited. This is inspite of the fact that the first two groups are largely demersal and thus limit the fishing pressure from the majority of fishers in the lake. The groups would require either reassessment or some reduction from the current fishing effort.

REFERENCES

Aliño, P.M., L.T. McManus, J.W. McManus, C.L.Nañola, M.D. Fortes, G.C. Trono and G.S. Jacinto. 1993. Initial parameter estimations of a coral reef flat ecosystem in Boliano, Pangasinan, Northwestern Philippines, p. 252-258. *In* V. Christensen and D. Pauly (eds.) Trophic models of aquatic ecosystems. ICLARM Conf. Proc. 26. 390 p.

Allison, E.H., A.B. Thompson, B.P. Ngatunga, and K. Irvine. 1995a. The diet and food consumption rates of the offshore fish, p. 233-278. *In* A. Menz (ed.) The fishery potential and productivity of the pelagic zone of Lake Malawi/Niassa; NRI/ODA. 386 p.

Allison, E.H., G. Patterson, K. Irvine, A.B. Thompson and A. Menz. 1995b. The pelagic ecosystem, p. 351-386. *In* A. Menz (ed.) The fishery potential and productivity of the pelagic zone of Lake Malawi/Niassa, NRI/ODA. 386 p.

Anon. circa 1988. Offshore fishery resources of Lake Malawi/Niassa: A review and bibliography of biological knowledge of Lake Malawi/Niassa. Typescript. 21 p.

Arnell, N., B. Bates, H. Lang, J. J. Mugnuson and P. Mulholland (Editors). 1996. Hydrology and freshwater ecology, p. 325-363. *In* R. T. Watson, M.C. Zinyowera and R. H. Moss (eds.) Climate change 1995; impacts, adaptations and mitigation of climate change: Scientic-technical analysis. Cambridge University Press. New York. 878 p.

Banda, M. C. 1989. A reliable method for the aging of Lake Malawi Chambo, *Oreochromis* spp. M.Sc. thesis UCNW, Bangor. 33 p.

Banda, M. and M. Hara.1994. Habitat degradation caused by seines on the fishery of Lake Malombe and Upper Shire River and its effects. Paper presented at the FAO/CIFA Seminar on Inland Fisheries, Aquaculture and the Environment. Harare, Zimbabwe, 5-7 December, 1994. 12 p.

Banda, M., T. Tomasson and D. Tweddle. 1996. Assessment of the deep water trawl fisheries of the southeast arm of Lake Malawi using exploratory surveys and commercial catch data, p. 53-75. *In* I.G. Cowx (ed.) Stock assessment in inland fisheries. Fishing News Books/Hartnolls Ltd. Cornwall. 513 p.

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

Banse, K and S. Mosher .1980. Adult body mass and annual production/biomass relationships of field populations. Ecol. Monogr. 50:355-379.

Barel, C.D.N., R. Dorit, P.H. Greenwood, G. Fryer, N. Hughes, P.B.N. Jackson, H. Kawanabe, R. H. McConnell, M. Nagishi, A.J. Ribbink, E. Trewavas, F. Witte and K. Yamaoka. 1985. Commentary: Destruction of fisheries in Africa's lakes. Nature 315:19-20.

Beadle, L.C. 1974. The inland waters of tropical Africa: An introduction to tropical limnology, Longman, London. 365 p.

Berlin, B. 1992. Ethnobiological classification: Principles of categorization of plants and animals in traditional societies. Princeton University Press, Princeton. 335 p.

Bertram, C. K. R., H. J. H. Borley and E. Trewavas. 1942. Report on the fish and fisheries of Lake Nyasa. Published on behalf of the Government of Nyasaland [Malawi] by the Crown Agents of the Colonies, London. 181 p.

Bland, S. 1996. Draft discussion document: Statement of fisheries sector development policy - Malawi. Malawi Fisheries Department (unpublished). 23 p.

Bonfil, R., G. Munro, U.R. Sumaila, H. Vattysson, M. Wright, T. Pitcher, D. Preikshot, N. Haggan and D. Pauly (Editors). 1998. Distant water fleets: An ecological, economic and social assessment. Fisheries Centre Research Reports, 1998: Vol. 6, No. 6. 111 p.

Brummett, R.E. and R. Noble. 1995. Aquaculture for African smallholders. Manila, Philippines. ICLARM Tech. Rep. 46. 69 p.

Buchary, E. A. 1999. Evaluating the effect of the 1980 trawl ban in the Java Sea, Indonesia: an ecosystem-based approach. M.Sc. thesis. University of British Columbia, Vancouver, Canada. 134 p.

Budnick, F. S. 1979. Applied mathematics: For business, economics and the social sciences. McGraw-Hill Book Company. New York. 649 p.

Bundy, A. 1997. Assessment and management of multispecies, multigear fisheries: a case study from San Miguel Bay, Philippines. Ph.D. thesis. University of British Columbia, Vancouver, B.C., Canada. 396 p.

Carpenter, S.R, J.F. Kitchell and H.R. Hodgson. 1985. Cascading trophic interactions and lake productivity. BioScience 35(9):634-639.

Chambers, R. 1993. Participatory rural appraisals; past, present and future. Uppsala (Forests, Trees and People) Newsletter No. 15. 16 p.

Campbell, K. I. L. 1983. General biology and feeding ecology of the cormorant, *Phalacrocorax carbo lucidus* (Lichtenstein), on Lake Malawi. Ph.D. thesis, University of Exeter. 337 p.

Campbell, J. and P. Townsley. 1996. Participatory and integrated policy: A framework for small-scale fisheries in sub-Saharan Africa. Integrated Marine Management Ltd, Exeter. 35 p.

Chirwa, W. C. 1998. The Lake Malombe and Upper Shire River fisheries co-management programme: An assessment, p. 61-77. *In* A.K. Norman, J.R. Neilsen and S. Sverdrup-Jensen (eds.) Fisheries co-management in Africa. Fish. Co-mgmt. Res. Project, Res. Rpt. 12. 326 p.

Christensen, V. and D. Pauly. 1992. A guide to Ecopath II software system (version 2.1). ICLARM. Software. 6. 72 p.

Christensen, V. and D. Pauly (Editors). 1993. Trophic models of aquatic ecosystems. ICLARM Conf. Proc. 26, 390 p.

Christensen, V. and D. Pauly. 1996. Ecological modeling for all. Naga, the ICLARM Quarterly 19 (2): 25-26.

Dalsgaard, A.J. 1999. Modelling the trophic transfer of beta radioactivity in the marine food of the Enewetak Atoll, Micronesia. M.Sc. thesis. University of British Columbia, Vancouver, B.C., Canada. 125 p.

Degnbol, P. 1993. The pelagic zone of central Lake Malawi: A trophic box model, p.110-115. *In* V. Christensen and D. Pauly (eds.) Trophic models of aquatic ecosystems. ICLARM Conf. Proc. 26. 390 p.

Dobson, T.A. 1996. Community participation and natural resources legislation in Malawi: A report to the Director of Fisheries on behalf of the Malawi-German Fisheries and Aquaculture Project (MAGFAD). Michigan State University. Michigan. 21 p.

Donda, S. 1998. Malawian experiences with implementation of co-management in inland fisheries, p.73-74. *In* IASCP. Book of abstracts: Crossing boundaries, 7th conference of the International Association for the Study of Common Property hosted by Simon Fraser University at University of British Columbia, Vancouver, Canada. June 10-14, 1998. 304 p.

Earle, M. 1995. Precautionary approach to fisheries, p. 14-16. *In* FAO. Responsible fisheries. Development Education Exchange Papers (DEEP). FAO, Rome. 49 p.

Eccles, D. H. 1962. An internal wave in Lake Nyasa (now Malawi) and its probable significance in the nutrient cycle. Nature 194(4831):832-833.

Eccles, D.H. 1975. Fishes of the African Great Lakes as candidates for introduction into large tropical impoundments. J. Fish. Biol. 7: 401-405.

Emmerson, D. K. 1980. Rethinking artisanal fisheries development: Western concepts, Asian experiences. World Bank, Washington D. C. 97 p.

Everett, J. T. (Editor). 1996. Fisheries, p. 511-537. *In* R. T. Watson, M.C. Zinyowera and R. H. Moss (eds.) Climate change 1995; impacts, adaptations and mitigation of climate change: Scientic-technical analysis. Cambridge University Press. New York. 878 p.

FAO. 1986. Strategy for fisheries management. FAO, Rome, 1986. 26 p.

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

FAO. 1995. Responsible fisheries. Development Education Exchange Papers (DEEP). FAO, Rome. 49 p.

FAO/ALCOM. 1994. Aquaculture into the 21st century in the Southern Africa. ALCOM Report 15. FAO. Harare, Zimbabwe. 48 p.

FAO/SIFR. 1989. Report of the meeting of SIFR working group on critical factors affecting small scale fisheries (Final Draft), 18-22 September 1989. FAO, Rome. 42 p.

Ferguson, A.E., B. Derman and R.M. Mkandawire. 1993. 'The new development rhetoric and Lake Malawi'. Africa (London) 63(1): 1-15.

FishBase. 1998. FishBase 98 CD-ROM. ICLARM, Manila (see also www.fishbase.org).

Fryer, G. 1959. Some aspects of evolution in Lake Nyasa. Evolution 13: 440-451.

Fryer, G. and T.D. Iles. 1972. The cichlid fishes of the Great Lakes of Africa. Oliver & Boyd, Edinburgh. 641 p.

Gayanilo, F.C. and D. Pauly (Editors) FAO-ICLARM stock assessment tools. (FiSAT). Reference Manual. *FAO Computerized Information Series (Fisheries)*. No. 8. Rome, FAO. 1997. 262 p.

Government of Malawi (GOM). 1989. Statement of development policies, 1987-1996. Government Printer, Zomba, Malawi. pp. 1-21, 42-48.

Government of Malawi and United Nations in Malawi. 1992. The situation analysis of poverty in Malawi (Draft). UNICEF. Lilongwe. 202 p.

Government of Malawi (GOM). 1997. Economic report 1997. Ministry of Economic Planning and Development, Government Printer, Zomba, Malawi. 118 p.

Government of Malawi (GOM). 1999. Malawian History: Summary. Ministry of Information and Broadcasting, Lilongwe, Malawi (on www.malawi.net)1 p.

Gulland, J. A. (Editor). 1971. The fish resources of the ocean. FAO. The Whitefriars Press Limited, London. 255 p.

Hara, M. 1993. Fish marketing in Malawi, p. 63-83. *In* E. J. Reynolds (ed.) Marketing and consumption of fish in eastern and southern Africa (selected country studies). FAO Fisheries Tech. Report No. 332.

Hara, M. 1996. Problems of introducing community participation in fisheries management: lessons from Lake Malombe and Upper Shire River (Malawi) Participatory Fisheries Management Programme. Southern African Perspectives No. 59. Centre for Southern African Studies. University of Western Cape. RSA. 28 p.

Hardin, G. 1968. The tragedy of the commons. Science Vol. 162: 1243-248.

Haylor, G.S. 1992. African catfish hatchery manual: Central and northern regions fish farming project, Malawi. Institute of Aquaculture, University of Sterling. 86 p.

Hecky, R.E. and F.W.B. Bugenyi. 1992. Hydrology and chemistry of the African Great Lakes and water quality issues: Problems and solutions. Mitt. Internat. Verein. Limnol. 23: 45-54.

Hetherwick, A. 1914. A practical manual of the Nyanja language. The African Lakes Corporation Ltd, Nyasaland [Malawi] and Northern Rhodesia [Zambia]. 299 p.

Hulme, D. and M.M. Turner. 1990. Sociology and development: Theories, policies and practices. Harveter Wheatsheaf, Hertfordshire. 251 p.

ICLARM/GTZ. 1991. The context of small-scale integrated agriculture-aquaculture in Africa: a case study of Malawi. ICLARM Stud. Rev. 18. 302 p.

ICLARM. 1994. Strategic integrated aquaculture research for SADC smallholder farms: Project proposal. ICLARM Malawi. 16 p.

IMF. 1998. IMF approves third annual ESAF credit for Malawi, Press release No. 98/63. IMF, Washington, D.C. 14 p (see also www.imf.org).

Irvine, K. 1995. Ecology of the lakefly *Chaoborus edulis*, p. 109-140. *In* A . Menz (ed.) The fishery potential and productivity of the pelagic zone of Lake Malawi/Niassa, NRI/ODA. 386 p.

IUCN/UNEP/WWF. 1991. Caring for the earth: A strategy for sustainable living. IUCN/UNEP/WWF, Gland, Switzerland. 228 p.

Jackson, P. B. N. 1961. Ichthyology: The fish of the Middle Zambezi. Published by Manchester University Press for the Trustees of the National Museum of Southern Rhodesia – Kariba Studies. University Press, Cambridge. 36 p.

Jackson, P. B. N.1973. The African Great Lakes: Food source and world treasure. Biol. Conserv. 5(4): 302-304.

Jarre, A., M.L. Palomares, M.L. Soriano, V.C. Sambilay and D. Pauly. 1991. Some new analytical and comparative methods for estimating the food consumption of fish. ICES. Mar. Sci. Symp. 193: 99 - 108.

Jeffries, M. and D. Mills. 1990. Freshwater ecology: Principles and applications. Belhaven Press. London. 285 p.

Jentoft, S. 1998. Social science in fisheries management: A risk assessment, p. 177-184. *In* T. J. Pitcher, P.J.B. Hart and D. Pauly (eds.) Reinventing Fisheries Management. Chapman & Hall, London. 435 p.

Kapensky, J. M. 1993. Fish farming potential in the ALCOM area. A progress report to the technical consultation on the enhancement of small water body fisheries in southern Africa. 3 p.

Kirk, R.G. 1968. The zoogeographical affinities of the fishes of the Chilwa-Chiuta depression in Malawi. Rev. Zool. Bot. Afr., 76(3-4): 295-312.

Kirby, E. S. and E. F. Szczepanik. 1957. Special problems of fisheries in poor countries, p. 83-109. In R. Turvey and J. Wiseman (eds.) The economics of fisheries. International Economic Association Round Table Proceedings held in Rome, September 1956. FAO. Molyneux Offset Ltd., London. 234 p.

Kolding, J. 1993. Trophic interrelationships and community structure at two different periods of Lake Turkana, Kenya: A comparison using Ecopath II box model, p. 116-123. *In* V. Christensen and D. Pauly (eds.) Trophic models of aquatic ecosystems. ICLARM Conf. Proc. 26. 390 p.

Kolding, J. 1994. On the ecology and exploitation of fish in fluctuating tropical freshwater systems. Ph.D. thesis. University of Bergen, Norway. 39 p (plus published papers).

Konings, A. D. 1990. Cichlids and all the other fishes of Lake Malawi. T.F.H. Publications. New Jersey. 495 p.

Linn, I. J. and K. L. I. Campbell. 1986. Cormorants and fisheries: A report on the biology of the white-breasted cormorant (*Phalacrocorax carbo*) as it affects the commercial fisheries of Lake Malawi. University of Exeter, Report to ODA. 51 p.

Louda, S.M. and K.R. McKaye. 1982. Diurnal movements in populations of the prosobranch *Lanistes nyassanus* at Cape Maclear, Lake Malawi, Africa Malacologia 23 (1): 13-21.

Louda, S.M., W.N. Gray, K.R. McKaye and O.J. Mhone. 1983. Distribution of gastropod genera over a vertical depth gradient at Cape Maclear, Lake Malawi. Veliger 25 (4): 387-392.

Louda, S.M., K.R. McKaye, T.D. Kocher and C.J.Stackhouse. 1984. Activity, dispersion, and size of *Lanistes nyassanus* and *L. solidus* (Gastropoda, Ampullariidae) over the depth gradient at Cape Maclear, Lake Malawi, Africa. Veliger 26 (3): 145-152.

Lowe-McConnell. 1975. Fish communities in tropical freshwaters: Their distribution, ecology and evolution. Longman. London. 337 p.

Lowe-McConnell. 1987. Ecological studies in tropical fish communities. Cambridge University Press. Cambridge. 382 p.

Machena, C., J. Kolding and R. A. Sanyanga. 1993. A preliminary assessment of the trophic structure of Lake Kariba, Africa, p. 130-137. *In* V. Christensen and D. Pauly (eds.) Trophic models of aquatic ecosystems. ICLARM Conf. Proc. 26. 390 p.

Malawi Fisheries Department (MFD). 1996. Fisheries statistics (unpublished). 12 p.

Marsh, A. C. and A. J. Ribbink. 1986. Feeding schools among Lake Malawi cichlid fishes. Environ. Biol. Fish. 15: 75-79.

Matowanyika, J.J.Z., J. Jackson, J. Murombedzi and M. Murphee. 1994. Introductory course materials to a six-week course in human and social perspectives in natural resources management: 6 February - 18 March, 1994, Harare, Zimbabwe (9 February 1994). 8 p.

MBendi. 1999. Country profile: Malawi (on MBendi website: www.Mbendi.co.za).

McGoodwin. J.R. 1990. The tragicomedy of the commons, p. 89-96. *In* J.R. McGoodwin. Crisis in the world's fisheries: People, problems, and policies. Stanford University Press. Stanford. 235 p.

Mchombo, S. 1997. Chichewa/Chinyanja: History, ascendancy and politics of language choice [in Malawi]. Department of Linguistics, University of California, Berkeley. 9 p.

McKaye, K.R., R.D. Makwinja, W.W. Menyani and O.J. Mhone. 1985. On the possible introduction of non-indigenous zooplankton feeding fishes into Lake Malawi, Africa. Biol. Conserv. 33 (1985): 289-307.

Menz, A. (Editor).1995. The fishery potential and productivity of the pelagic zone of Lake Malawi/Niassa, NRI/ODA, 386 p.

Mikkola, H. 1996. Alien freshwater crustacean and indigenous mollusc species with aquaculture potential in eastern and southern Africa. Sth. Afr. J. aquat. Sci. 22(1/2): 90-99.

Mills, M.L. 1980. CIFA visit to the Lower Shire Valley, 12th December, 1980. Malawi Fisheries Department Reports (unpublished). 9 p.

Moreau, J., V. Christensen and D. Pauly. 1993. A trophic ecosystem model of Lake George, Uganda, p. 124-129. *In* V. Christensen and D. Pauly (eds.) Trophic models of aquatic ecosystems. ICLARM Conf. Proc. 26. 390 p.

Moreau, J., W. Ligtvoet and M.L.D Palomares. 1993. Trophic relationship in fish community of Lake Victoria, Kenya, with emphasis on the impact of Nile perch (*Lates niloticus*). p. 144-152. *In* V. Christensen and D. Pauly (eds.) Trophic models of aquatic ecosystems. ICLARM Conf. Proc. 26. 390 p.

Moss, B. 1980. Ecology of freshwaters. Halsted Press, Blackwell. 332 p.

Munthali, S.M. 1997. Dwindling food-fish species and fishers' preference: Problems of conserving Lake Malawi's biodiversity. Biodiversity and Conservation 6: 253-261.

Murphree, M.W. 1993. Communities as resource management institutions. IIED (London). SA36: 1-15.

Ngatunga, B. P. and E. H. Allison. 1996. Food consumption /biomass ratios of the pelagic fish community in Lake Malawi/Niassa. Naga, the ICLARM Quarterly19 (4): 36-42.

Ngwira, N., E. Ng'ombe and E. Nsiku. 1996. SADC country reports on the inland fisheries sector: Malawi; for preparation of SADC inland fisheries sector policy and strategy. SADC Inland Fisheries Technical Coordination Unit, Department of Fisheries, Ministry of Natural Resources, Malawi, 64 p. (unpublished).

Norman, A.K., J.R. Neilsen and S. Sverdrup-Jensen (Editors). 1998. Fisheries co-management in Africa. Fish. Co-mgmt. Res. Project, Res. Rpt. 12. 326 p.

Nsiku, E. 1994. Community participation in the Malawi-German Fisheries Development Project (MAGFAD) area. Report for the human and social perspectives in natural resources management course: 6 February - 18 March, 1994. IUCN/University of Zimbabwe (CASS). Harare. 10 p.

National Statistical Office (NSO). 1999. 1999 Population census in Malawi. Press Releases, National Statistical Office, Malawi. April, August 1999.

Nyasanet. 1999. Malawi [electronic] discussion forum; moderated by Malawian volunteers based in USA (on www.crosswinds.net/~nyasanet).

Nyambose, J. 1997. Preserving the future of Lake Malawi. African Technology Forum. MIT 6 p. (see http://web.mit.edu/africantech/www/articles/Lake-Malawi.html).

Oliver, M.K. and K.R. McKaye. 1982. Floating islands: A means of fish dispersal in Lake Malawi, Africa. Copeia 4: 748-754.

O'Riordon, B. 1995. Give a man a fish: Reconciling international trade with food security, p. 17-19. *In* FAO. Responsible fisheries. Development Education Exchange Papers (DEEP). FAO, Rome. 49 p.

Outdoor Life Network (OLN). 1999. Malawi: Documentary (for television broadcast) of 26th December, 1999. OLN, UK.

Palomares, M.L.D, P. Reyes-Marchant, N. Lair, M. Zainure, G. Barnabé, G. Lasserre. 1993a. A trophic model of a Mediterranean lagoon, Etang du Thau, France, p. 224-229. *In* V. Christensen and D. Pauly (eds.) Trophic models of aquatic ecosystems. ICLARM Conf. Proc. 26. 390 p.

Palomares, M.L.D, K. Horton and J. Moreau. 1993b. An Ecopath II model of the Lake Chad system, p. 153-158. *In* V. Christensen and D. Pauly (eds.) Trophic models of aquatic ecosystems. ICLARM Conf. Proc. 26. 390 p.

Palsson, O.K., A. Bulirani and M. Banda. 1998. A review of biology, fisheries and population dynamics of Chambo (*Oreochromis* spp., Cichlidae) in Lakes Malawi and Malombe (MS). 44 p.

Patterson, G. and O. Kachinjika. 1995. Limnology and phytoplankton ecology, p. 1-67. *In* A. Menz (ed.) The fishery potential and productivity of the pelagic zone of Lake Malawi/Niassa, NRI/ODA. 386 p.

Patterson, G., M.J. Wooster and C.B. Sear. 1995. Real-time monitoring of African aquatic resources using remote sensing: with special reference to Lake Malawi. Chatham, UK: Natural Resources Institute. 21 p.

Pauly, D. 1980. On the interrelationships between natural mortality, growth parameters, and mean environmental temperature in 175 fish stocks. J. Cons. int. Explor. Mer 39(2): 175-192.

Pauly, D. 1994. On Malthusian overfishing, p. 112-117. *In* D. Pauly. On the sex of fish and the gender of scientists: A collection of essays in fisheries science. Chapman and Hall, London. 250 p.

Pauly, D. and V. Christensen. 1995. Primary production required to sustain global fisheries. Nature 374: 255-257.

Pauly, D. and V. Christensen (Editors). 1996. Mass-balance models of North-eastern Pacific ecosystems: Proceedings of a workshop held at the Fisheries Centre, UBC, November 6-10, 1995. Fisheries Centre Research Reports, 1996: Vol. 4, No. 1. 131 p.

Pauly, D., V. Christensen, J. Dalsgaard, R. Foroese and F. Torres. 1998. Fishing down marine foodwebs. Science 279: 860-863.

Pauly, D. (Editor). 1998. Use of Ecopath with Ecosim to evaluate strategies for sustainable exploitation of multispecies resources: Proceedings of a workshop held at the Fisheries Centre, UBC, March 25-27, 1998. Fisheries Centre Research Reports, 1998: Vol. 6, No. 2. 49 p.

Pitcher, T.J. and P.J.B. Hart. 1982. Fisheries ecology, Groom Helm, London. 414 p.

Pitcher, T.J. 1994. Results: impact of species changes on fisheries in Lake Malawi, p. 81-84. *In* T.J. Pitcher. The impact of species changes in the African lakes. Report to the Overseas Development Administration, London, UK. 213 p.

Pitcher, T.J. and P.J.B. Hart. 1995. The impact of species changes in African lakes. Chapman and Hall, London. 601 p.

Pitcher, T. J. (Editor). 1996. Reinventing fisheries management. Fisheries Centre Research Reports, 1996: Vol. 4, No. 2. 84 p.

Pitcher, T.J., A. Bundy, D. Preikshot, T. Hutton and D. Pauly. 1998a. Measuring the unmeasurable: a multivariate and interdisciplinary method for rapid appraisal of the health of fisheries, p. 31-54. *In* T.J. Pitcher, D. Pauly and P. Hart (eds.) Reinventing fisheries management. Chapman and Hall, Fish and Fisheries Series.

Pitcher, T.J., S. Mackinson, M. Vasconcellos, L. Nøttestad and D. Preikshot. 1998b. Rapid appraisal of the status of fisheries for small pelagics using multivariate, multidisciplinary ordination. Presented at the fishery stock assessment models for the 21st century, Lowell Wakefield symposium, Anchorage Alaska, October 1997. 25 p.

Pitcher, T.J. and D. Preikshot. 1999. Rapfish: A rapid appraisal technique to evaluate the sustainability status of fisheries. Fisheries Research (in press).

Pitcher, T.J. and M.D. Power. 1999. Fish figures: Quantifying the ethical status of Canadian fisheries, east and west. *In* H. Coward, R. Ommer and T.J. Pitcher (eds.) Just fish: the ethics of Canadian fisheries. Inst. Social. Econ. Res. Press. St. John's, Newfoundland (in press).

Pitcher, T.J. 1999. Rapfish, a rapid appraisal technique for fisheries, and its application to the code of conduct for responsible fisheries (Draft). FAO Fisheries Circular. FAO, Rome. 46 p.

Polovina, J. J. 1993. The first Ecopath, p. vii-viii. *In* V. Christensen and D. Pauly (eds.) Trophic models of aquatic ecosystems. ICLARM Conf. Proc. 26. 390 p.

Polovina, J. J. 1996. Exploring ecosystem responses to environmental variation, p. 86-87. *In* D. Pauly and V. Christensen (eds.) Mass-balance models of North-eastern Pacific ecosystems: Proceedings of a workshop held at the Fisheries Centre, UBC, November 6-10, 1995. Fisheries Centre Research Reports, 1996: Vol. 4, No. 1. 131 p.

Power, M.D. and N. Newlands. 1999. A report on historical, human-induced changes in Newfoundland's fisheries ecosystem. Presented at the 16th Lowell Wakefield symposium: Ecosystem approaches for fisheries management, September 30-October 3, 1998, Anchorage, Alaska, USA. 17 p.

Preikshot. D., E. Nsiku, T.J. Pitcher and D. Pauly.1998. An interdisciplinary evaluation of the status and health of African lake fisheries using rapid appraisal technique. J. Fish. Biol. 53 (Supplement A) :381 - 393.

Reali, P. 1991. Strategy and action programmes for fisheries: Fish for food and development. FAO. Rome, 48 p.

Ribbink, A. J. 1991. Distribution and ecology of the cichlids of the African Great Lakes. p. 36-59. *In* M.H.A. Keenleyside(ed.) Cichlid fishes: Behaviour, ecology and evolution. Chapman & Hall. Fish and Fisheries Series 2.

Regional Inland Fisheries Research Centre (RIFRC). 1997. SADC/GEF, Lake Malawi/Nyasa biodiversity conservation project (Leaflet). RIFRC, Salima, Malawi. 5 p.

Ruddle, K. 1989. Solving the common property dilemma: Village fisheries rights in Japanese coastal waters, p. 168-184. *In* F. Berkes (ed.) Common property resources: Ecology and community-based sustainable development. Belhaven Press. London. 302 p.

SADCC/EEC. 1989. Regional fisheries survey: Country situation reports prepared for SADCC Coordinator for Forestry, Fisheries and Wildlife, Ministry of Forestry and Natural Resources, Malawi, GOPA Consultants, Bad Homburg. Vol. 2. 186 p.

SADC. 1991. Post-harvest fisheries losses in the SADCC region. Workshop Report, Malawi 21-25 October, 1991. ODA/SADCC, Lilongwe, Malawi. 85 p.

SADC. 1993. A natural resources policy analysis manual for the SADC region. SADC Environment and Land Management Sector Coordination Unit, Maseru, Lesotho. 436 p.

SADC. 1997. SADC inland fisheries sector report to the annual summit of Heads of State and Government. IFSTCU, Lilongwe, Malawi. 31 p.

Scholz, U.F., F.J. Njaya, S. Chimatiro, M. Hummel, S. Donda and B.J. Mkoko. 1997. Status and prospects of participatory fisheries management programmes in Malawi: Paper presented at the FAO/ODA expert consultation on inland fisheries enhancements, Dhaka, Bangladesh, 7-11 April, 1997. 12 p.

Sen, S. and J.R. Nielsen. 1996. Fisheries co-management: a comparative analysis. Marine Policy 20 (5): 405-418.

Sengupta, N. 1997. Diversity in participation, p. 75-81. *In* G. Shivakoti, G. Varughese, E. Ostrom, A. Shukla and G. Thapa (eds.) People and participation in sustainable development: Understanding the dynamics of natural resource systems. Proceedings of an international conference held at the Institute of Agriculture and Animal Science, Rampur, Chitwan, Nepal, 17-21 March 1996. Bloomington, Indiana and Rampur, Chitwan. 315 p.

Skelton, P. H., D. Tweddle and P. B. N. Jackson. 1991. Cyprinids of Africa, p. 211-239. *In* I. J. Winfield and J. S. Nelson (eds.) Cyprinid fishes: Systematics, biology and exploitation. Chapman and Hall. Fish and Fisheries Series 3.

Smith, L. 1993. A historical perspective on the fishery of the Chembe enclave village in Lake Malawi National Park, Nyala 17(2): 49-60.

Smith, L. W. 1998. Use of traditional practices and knowledge in monitoring Lake Malawi artisanal fishery. J. Fish. Mgmt. 18: 982-988.

Solomon, E. P., L. R. Berg, D. W. Martin and C. Ville. 1993. Biology. Saunders College Publishing, Fort Worth. 1194 p.

Stauffer, J.R., M.E. Arnegard, M. Cetron, J.J. Sullivan, L.A. Chitsulo, G.F. Turner, S. Chiotha and K.R. McKaye. 1997. Controlling vectors and hosts of parasitic diseases using fishes: A case history of schistosomiasis in Lake Malawi. Bioscience 4(1): 41-49.

Stoneman, J., K. B. Meecham and A. J. Mathotho. 1973. Africa's Great Lakes and their fisheries potential. Biol. Conserv. 5(4):299-301.

Taylor, L. and R. Alden. 1998. Co-management of fisheries in Maine: What does it mean?. Summary report based on J.A. Wilson, J. Acheson and W. Brennan. 1998. Draft Report prepared for the Department of Marine Resources (DRM). DRM, Maine, 8 p.

Tenthani, R. 1999. Water hyacinth threatens aquatic life in Malawi. PanAfrican News Agency (PANA). Internet news article, March 15, 1999. 1 p (www. africanews. org).

Tenthani, R. 1999. Soil erosion threatens lake Malawi's biodiversity. PanAfrican News Agency (PANA). Internet news article, July 26, 1999. 1 p (www.africanews.org).

Tenthani, R. 1999. Malawi fish intake levels below WHO's recommendations. PanAfrican News Agency (PANA). Internet news article, November 23, 1999. 1 p (www.africanews.org).

Thompson, A.B. 1995. Eggs and larvae of *Engraulicypris sardella*, p. 179-199. *In* A. Menz (ed.) The fishery potential and productivity of the pelagic zone of Lake Malawi/Niassa, NRI/ODA. 386 p.

Thompson, A.B., E.H. Allison and B.P. Ngatunga. 1995. Spatial and temporal distribution of fish in the pelagic waters, p. 201-232. *In* A. Menz (ed.) The fishery potential and productivity of the pelagic zone of Lake Malawi/Niassa, NRI/ODA. 386 p.

Thomson, D. and R. Mullin. 1993. SADC marine fisheries: Policy, strategies and programme of work (Report). Instituto Culturale Italiano (ICI), Italy. 97 p.

Twombly, S. 1983. Seasonal and short term fluctuations in zooplankton abundance in tropical Lake Malawi. Limnol. Oceanogr. 28(6): 1214-1224.

Turner, G. F. 1995. Management, conservation and species changes of exploited fish stocks in Lake Malawi, p. 335-395. *In* T.J. Pitcher and P.J.B. Hart (eds.) The impact of species changes in African Lakes. Chapman and Hall. Fish and Fisheries Series 18.

Turner, G. F., D. Tweddle and R. Makwinja. 1995. Changes in demersal cichlid communities as a result of trawling in southern Lake Malawi, p. 397-412. *In* T.J. Pitcher and P.J.B. Hart (eds.) The impact of species changes in African Lakes. Chapman and Hall. Fish and Fisheries Series 18.

Turner, G. F. 1996. Maximization of yields from African lakes, p. 465-481. *In* I.G. Cowx (ed.) Stock assessment in inland fisheries. Fishing News Books/Hartnolls Ltd. Cornwall.

Turner, G. F. 1996. Offshore cichlids of Lake Malawi. Cichlid Press. Lauenau. 240 p.

Turner, J. L. 1977a. Some effects of demersal trawling in Lake Malawi (Lake Nyasa) from 1968 to 1974. J. Fish. Biol. 10: 261-271.

Turner, J. L. 1977b. Changes in the size structure of cichlid populations of Lake Malawi resulting from bottom trawling. J. Fish. Res. Board Can. 34: 232-238.

Tweddle, D. and Turner, J. L. 1977. Age, growth and natural mortality of rates of some cichlid fishes of Lake Malawi. J. Fish. Biol. 10: 385-398.

Tweddle, D., D.S.C. Lewis and N.G. Willoughby. 1979. The nature of the barrier separating the Lake Malawi and Zambezi fish faunas. Ichthylogical Bulletin of the J.L.B. Smith Institute of Ichthyology, Rhodes University, Grahamstown, South Africa 39: 1-9.

Tweddle, D. and N.G. Willoughby. 1979. An annoted checklist of the fish fauna of the River Shire south of the Kapachira Falls, Malawi. Ichthylogical Bulletin of the J.L.B. Smith Institute of Ichthyology, Rhodes University, Grahamstown, South Africa 39: 11-22.

Tweddle, D. and B.J. Mkoko. 1986. A limnological bibliography of Malawi. Rome, FAO, CIFA Occas. Pap. 13. 75 p.

Tweddle, D. and B.J. Mkoko. 1989. A limnological bibliography of Malawi – Supplement 1. Rome, FAO, CIFA Occas. Pap. 13. Suppl. 1.

Tweddle, D. and J. H. Magasa. 1989. Assessment of multispecies cichlid fisheries of the southeast arm of Lake Malawi, Africa. J. Cons. int. Explor. Mer 45:209-222.

Tweddle, D. 1991. Twenty years of fisheries research in Malawi: A review of the Malawi Government Fisheries Department research programmes conducted since 1970. Montfort Press, Limbe, Malawi. Fisheries Bulletin No. 7. 43 p.

Tweddle, D, S.B. Alimoso and G. Sodzapanja. 1994. Analysis of catch and effort data for the fisheries of the Southeast arm of Lake Malawi, 1976-1989 with a discussion on earlier data and inter-relationships with commercial fisheries. Malawi Fisheries Department, Fisheries Bulletin No. 13. 34 p.

Ulanowicz, R. E. 1992. Ecosystem health and trophic flow networks, p. 190-206. *In* R. Costanza, B. G. Norton and B. D. Haskell (eds.) Ecosystem health: New goals for environment management. Island Press, Washington D.C. 304 p.

UNDP. 1997. Human development report 1997. Oxford University Press. New York. 245 p.

van Dam, A.A., F.J.T.K. Chikafumbwa, D.M. Jamu and B.A. Costa-Pierce. 1993. Trophic interactions in a napier grass (*Pennisetum purpureum*)-fed aquaculture pond in Malawi, p. 65-68. *In* V. Christensen and D. Pauly (eds.) Trophic models of aquatic ecosystems. ICLARM Conf. Proc. 26. 390 p.

Ville, C. A., E. P. Solomon, D. W. Martin, L. R. Berg and P.W. Davis. 1989. Biology. Saunders College Publishing, Philadelphia. 1412 p.

Walline, P.D., S. Pisanty, M. Gophen and T. Berman. 1993. The ecosystem of Lake Kinnert, Israel, p. 103-109. *In* V. Christensen and D. Pauly (eds.) Trophic models of aquatic ecosystems. ICLARM Conf. Proc. 26. 390 p.

Walters, C. 1986. Adaptive management of renewable resources. Macmillan Publishing Company, New York. 374 p.

Walters, C., V. Christensen and D. Pauly. 1997. Structuring dynamic models of exploited ecosystems from trophic mass-balance. Reviews in Fish Biology and Fisheries 7: 1139-1172.

Wetzel, R. G. 1975. Limnology. Saunders College Publishing. Philadelphia. 743 p.

Werner, A. 1919. Introductory sketch of the Bantu languages, Kegan Paul, Trench, Trubner & Co. Ltd, London. 346 p.

Willoughby, N.G. and D. Tweddle. 1978. The ecology of the commercially important species in the Shire Valley fishery, Malawi. *In* R.L. Welcomme (ed.) Symposium on river and floodplain fisheries in Africa. Rome. FAO, CIFA Tech. Pap. 5:137-152.

Wilson, J. A., J. M. Acheson, M. Metcalfe and P. Kleban. 1994. Chaos, complexity and community management of fisheries. Marine Policy 18: 291-305.

Winpenny, J.T. 1991. Values for the environment: A guide to economic appraisal. ODI. London. 277 p.

WWF. 1999. Lake Malawi national park, Malawi. International Reports. 1 p (see www.panda.org).

Yamaoka, K. 1991. Feeding relationships, p. 151-172. *In* M.H.A. Keenleyside(ed.) Cichlid fishes: Behaviour, ecology and evolution. Chapman & Hall. Fish and Fisheries Series 2.

APPENDICES

Appendix 1.1 Fish species of the Lower Shire River[16]

Scientific Name	Maximum Length (cm)	English	Chichewa
Amphiliidae			
Amphilius uranoscopus	17	Mountain catfish	–
Anabantidae			
Ctenopoma intermedium	6.2	Blackspot climbing perch	–
Ctenopoma multispine	14	Manyspined ctenopoma	–
Anguillidae			
Anguilla bicolor	65	Shortfin eel	Nkunga
Anguilla bengalensis	160	African mottled eel	Nkunga
Bagridae			
Zaireichthys sp.	2.5	Spotted catlet	–
Carcharhinidae			
Carcharhinnus leucas	260	Zambezi shark	–
Alestiidae*			
Brycinus imberi	19.8	Imberi	Mberi
Brycinus lateralis	14	Alestiid	Tsimbu
Hemigrammopetersius barnardi	4	Barnard's robber	Tsimbu
Hydrocynus vittatus	70	Tigerfish	Mcheni
Micralestes acutidens	9	Silver robber	Tsimbu
Cichlidae			
Astatotilaipa calliptera	13	Eastern happy	Nkakafodya
Pseudocrenilabrus philander	13	Southern mouth brooder	Nkakafodya
Oreochromis mossambicus	35	Mozambique tilapia	Mphende
Oreochromis placidus	35.5	Black tilapia	Mphende
Oreochromis squamipinnis	36	Tilapia	Mphende

*The species were originally placed under Characidae

[16] Based on Tweddle and Willoughby (1979) and updated by using Fishbase (1998).

Scientific Name	Maximum Length (cm)	English	Chichewa
Oreochromis shiranus	39	Shire tilapia	Mphende
Seranochromis robustus	50	Yellowbelly bream	Nkakafodya
Tilapia rendalli	45	Redbreast tilapia	Mphende
Clariidae			
Clarias gariepinus	150	Sharptooth catfish	Mlamba
Clarias mossambicus		Mozambique catfish	Mlamba
Clarias ngamensis	73	Blunttooth catfish	Chikanu
Clarias theodorae	35	Snake catfish	Mlamba
Heterobranchus longifilis	150	Vundu	Vundu
Cyrinidae			
Barbus afrohamiltoni	17.5	Hamilton barb	Matemba
Barbus choeloensis	17.5	Rosefin barb	Matemba
Barbus haasianus	3.2	Sicklefin barb	Matemba
Barbus johnstonii	32	Barb	Matemba
Barbus kerstenii	7.5	Redspot barb	Matemba
Barbus macrotaenia	4	Broadband barb	Matemba
Barbus marequensis	47	Largescale yellowfin	Matemba
Barbus paludinosus	15	Straightfin barb	Matemba
Barbus radiatus	12	Beira barb	Matemba
Barbus trimaculatus	15	Threespot barb	Matemba
Barbus lineomaculatus	8.2	Linespotted barb	Matemba
Barbus toppini	40	East coast barb	Matemba
Barbus viviparus	7	Bowstripe barb	Matemba
Opsaridium zambensis	15	Barred minnow	Tsimbu
Opsaridium ubangensis	12	Minnow	Tsimbu
Labeo altivelis	40	River salmon	Njole
Labeo congoro	41.5	African carp	Tsimbu
Labeo cylindricus	40	Redeye labeo	Nchila
Cyprinodontidae*			
Aplocheilichthys hutereaui	4	Topminnow	–
Aplocheilichthys katangae	5	Striped topminnow	–
Nothobranchius orthonotus	10.6	Spotted killifish	–

*The first two species now placed in Poecillidae while the last one is placed in Aplacheilidae

Scientific Name	Maximum Length (cm)	English	Chichewa
Distichodontidae (Citharinidae)			
Distichodus mossambicus	57	Nkupe	Nkupe
Distichodus schenga	50	Chessa	Nchenka
Gobiidae			
Glossogobius giuris	50	Tank goby	–
Lepidosirenidae (Protopteridae)			
Protopterus annectens brieni	60.1	Lungfish	Dowe
Malapteruridae			
Malapterurus electricus	122	Electric catfish	Nyesi
Mastacembelidae			
Aethiomastacembelus shiranus	34.2*	'Eel'	Nkunga
Megalopidae			
Megalops cyprinoides	150	Oxeye tarpon	–
Mochokidae			
Chiloglanis neumanni	6.5	Neumann's rock catlet	Nkholokolo
Synodontis nebulosus	15	Clouded squeaker	Nkholokolo
Synodontis zambezensis	43	Brown squeaker	Nkholokolo
Mormyridae			
Hippopotamyrus discorhynchus	31	Zambezi parrotfish	Mphuta
Marcusenius macrolepidotus	30	Bulldog	Mphuta
Mormyrops anguilloides	150	Cornish jack	Mphuta
Mormyrus longirostris	75	Eastern bottlenose	Samwamowa
Pristidae			
Pristis microdon	500	Smalltooth sawfish	–
Schilbeidae			
Schilbe mystus	34	Butter catfish	Dande
Eutropius depressirotris	41**	Silver barbel	Dande

*Based on *A. traversi* in the Zaire River Basin.
**Adopted from Jackson (1961).

Appendix 1.2 Fish species of the Lakes Chilwa and Chiuta drainage system[17]

Scientific Name	**Maximum Length (cm)**	**English**	**Chichewa**
Alestiidae			
Alestes imberi	19.8	Imberi	Nkhalala
Cichlidae			
Oreochromis (*Tilapia*) *sparrmanii*	23	Banded tilapia	Makumba
Oreochromis melanopleura[18]	–	Bream	Makumba
Oreochromis shiranus chilwae	16	Chilwa tilapia	Makumba
Haplochromis callipterus	13	Eastern happy	Makumba
Hemihaplochromis (*Pseudocrenilabrus*) *philander*	13	Bream	Makumba
Clariidae			
Clarias mossambicus	150	Catfish	Mlamba
Clarias theodorae	35	Snake catfish	Mlamba
Cyrinidae			
Barbus paludinosus	15	Straightfin barb	Matemba
Barbus radiatus	12	Beira barb	Matemba
Barbus trimaculatus	15	Threespot barb	Matemba
Barbus manicensis	15	Yellow barb	Matemba
Barbus toppini	40	East coast barb	Matemba
Barbus innocens	8	Barb	Matemba
Barbus tangadensis	7.6	Barb	Matemba
Barbus sp.	–	Barb	Matemba
Labeo cylindricus	40	Redeye labeo	Nchila
Labeo sp.	–	Labeo	Nchila
Mormyridae			
Gnathonemus macroleidotus	30	Mormyrid	Mphuta
Petrocephalus catostoma	15	Churchill	Chonjo
Cyphomyrus discorhyncus	31	Mormyrid	Ntchentcheta
Schilbeidae			
Pareutropius (*Eutropiellus*) *longifilis*	10.2	Schilbeid catfish	Dande

[17] Based on Kirk (1968) and updated by using Fishbase (1998).
[18] This species may possibly be *Tilapia zillii* (Redbelly tilapia)

Appendix 1.3 Fish species of the Lake Malawi basin[19]

Scientific Name		Maximum Length (cm)	English	Chichewa
Anabantidae				
Ctnopoma	*ctenotis*	7	Anabantid perch	–
Anguillidae				
Anguilla	*nebulosa*	170	Eel	Nkunga++
Bagridae				
Bagrus	*meridionalis*	100	Bargrid catfish	Kampango+
Alestiidae				
Brycinus	*imberi*	15	Imberi	Nkhalala
Cichlidae				
Alticorpus	Deep	16	Bream	Chisawasawa
Alticorpus	Geoffreyi	20	Bream	Chisawasawa
Alticorpus	*macroleithrum*	18	Bream	Chisawasawa
Alticorpus	*mentale*	25	Bream	Chisawasawa
Alticorpus	*peterdaviesi*	15	Bream	Chisawasawa
Alticorpus	*pectinatum*	16	Bream	Chisawasawa
Alticorpus	*profundicloa*	15	Bream	Chisawasawa
Aristochromis	*christyi*	30	Bream	Chisawasawa
Aristochromis	Deep	–	Bream	Chisawasawa
Aristochromis	Lombardoi	–	Bream	Chisawasawa
Astatotilapia	*calliptera*	13	Bream	Utaka
Astatotilapia	*johnstoni*	–	Bream	Utaka
Astatotilapia	Livingstonii	–	Bream	Utaka
Aulonocara	*auditor*	10	Bream	Chisawasawa*
Aulonocara	*baenschi*	9	Bream	Chisawasawa
Aulonocara	Blue collar	–	Bream	Chisawasawa
Aulonocara	Blue gold sand	13.5	Bream	Chisawasawa
Aulonocara	Blue-orange	11	Bream	Chisawasawa
Aulonocara	Blue orchid	–	Bream	Chisawasawa
Aulonocara	Blue regal	–	Bream	Chisawasawa
Aulonocara	Chitande type Masinje	8.5	Bream	Chisawasawa

[19] Species which are not 'officially' described are listed by their common English or Chichewa name starting with a capital letter after the genus name. The species list in the Lake Malawi basin is based on Lowe-McConnell (1975); Konings (1990); ICLARM/GTZ (1991); Turner (1996); MFD (1996); and updated by using Fishbase (1998). *Also called Kapesa; +Mbuvu; ++Nkhunga in Tumbuka language, spoken in the northern districts of Malawi.

Scientific Name		Maximum Length (cm)	English	Chichewa
Aulonocara	Chitande type Nkhomo	11	Bream	Chisawasawa
Aulonocara	Chitande type north	10	Bream	Chisawasawa
Aulonocara	Copper	15	Bream	Chisawasawa
Aulonocara	Dark stripe	8	Bream	Chisawasawa
Aulonocara	Deep	14	Bream	Chisawasawa
Aulonocara	Deep yellow	9	Bream	Chisawasawa
Aulonocara	*ethelywynnae*	8.5	Bream	Chisawasawa
Aulonocara	Fort Maguire	–	Bream	Chisawasawa
Aulonocara	Gold	15	Bream	Chisawasawa
Aulonocara	Green face	–	Bream	Chisawasawa
Aulonocara	Green metalic	–	Bream	Chisawasawa
Aulonocara	*guentheri*	15	Bream	Chisawasawa
Aulonocara	*hansbaenschi*	10	Malawi peacock	Chisawasawa++
Aulonocara	*hueseri*	9.5	Bream	Chisawasawa
Aulonocara	*jacobfreibergi*	13	Malawi butterfly	Chisawasawa
Aulonocara	Jalo	12	Bream	Chisawasawa*
Aulonocara	Jumbo blue	16	Bream	Chisawasawa+
Aulonocara	Kande brown	8	Bream	Chisawasawa
Aulonocara	*kandeensis*	10	Bream	Chisawasawa
Aulonocara	*korneliae*	10	Bream	Chisawasawa
Aulonocara	Likoma	–	Bream	Chisawasawa
Aulonocara	Long	10	Bream	Chisawasawa
Aulonocara	*macrochir*	15	Bream	Chisawasawa
Aulonocara	Macrochir	18	Bream	Chisawasawa
Aulonocara	*macrocleithrum*	18	Bream	Chisawasawa
Aulonocara	Maleri	9.5	Bream	Chisawasawa**
Aulonocara	*maylandi*	10	Bream	Chisawasawa
Aulonocara	Mbenji	11	Bream	Chisawasawa
Aulonocara	Minutus	7	Bream	Chisawasawa
Aulonocara	New yellow regal	–	Bream	Chisawasawa
Aulonocara	Night	–	Bream	Chisawasawa
Aulonocara	Nkhomo-Benga	–	Bream	Chisawasawa
Aulonocara	Northern	–	Bream	Chisawasawa
Aulonocara	*nyassae*	13	Bream	Chisawasawa
Aulonocara	Orange	9.5	Bream	Chisawasawa
Aulonocara	Pale Usisya	–	Bream	Chisawasawa

Also called *Mgong'u; **Nyamuchecheche; +Chimbwi or Kapesa; ++Mdinyamuboro in Tumbuka language.

Scientific Name		Maximum Length (cm)	English	Chichewa
Aulonocara	Pyramid	12	Bream	Chisawasawa
Aulonocara	Red flush	–	Bream	Chisawasawa
Aulonocara	*rostratum*	20	Bream	Chisawasawa*
Aulonocara	*saulosi*	11.5	Bream	Chisawasawa
Aulonocara	Special	–	Bream	Chisawasawa
Aulonocara	*steveni*	10.5	Bream	Chisawasawa
Aulonocara	Stonemani	7	Bream	Chisawasawa
Aulonocara	*stuartgranti*	12	Bream	Chisawasawa+
Aulonocara	Sulpher head	–	Bream	Chisawasawa
Aulonocara	Sunshine	–	Bream	Chisawasawa
Aulonocara	*trematocephalum*	9	Bream	Chisawasawa
Aulonocara	Trematocranus Masinje	13.5	Bream	Chisawasawa
Aulonocara	Usisya	–	Bream	Chisawasawa
Aulonocara	Walteri	9	Bream	Chisawasawa
Aulonocara	White top	–	Bream	Chisawasawa
Aulonocara	Yellow	8	Bream	Chisawasawa
Aulonocara	Yellow collar	12	Bream	Chisawasawa
Buccochromis	*atritaeniatus*	28	Bream	Dimba++
Buccochromis	*aeterotaenia*	40	Bream	Dimba
Buccochromis	*lepturus*	42	Bream	Dimba
Buccochromis	*nototaenia*	37	Bream	Dimba
Buccochromis	*oculatus*	26	Bream	Dimba
Buccochromis	Oculatus	27	Bream	Dimba
Buccochromis	*rhoadesii*	35	Bream	Dimba
Buccochromis	*spectabilis*	26	Bream	Dimba
Caprichromis	*liemi*	23	Happy	Utaka
Caprichromis	*orthognathus*	25	Happy	Utaka
Champsochromis	*caeruleus*	35	Bream	Ndunduma
Champsochromis	*spilorhynchus*	35	Bream	Ndunduma
Chilotilaia	*euchilus*	25	Bream	Kambuzi
Chilotilaia	*rhoadesii*	30	Bream	Kambuzi++
Copadichromis	*azureus*	16	Happy	Utaka++
Copadichromis	*borleyi*	16	Happy	Mfufuma+++
Copadichromis	Chisumulu blue	17	Happy	Utaka
Copadichromis	*chrysonotus*	16	Happy	Chendemwamba

Also called *Kapesa (especially juvenilles); +Nyamugarara; ++Mgong'u; and +++some silvery=Nyakaluwa in Tumbuka language.

Scientific Name		Maximum Length (cm)	English	Chichewa
Copadichromis	Chrysonotus black	13	Happy	Utaka
Copadichromis	*conophoros (eucinostomus)*	–	Happy	Mdyamphipe
Copadichromis	*cyaneus*	17	Happy	Utaka
Copadichromis	*flavimanus*	13	Happy	Utaka
Copadichromis	*inornatus*	12	Happy	Utaka
Copadichromis	*jacksoni*	23	Happy	Chilibanga
Copadichromis	Likoma blue	17	Happy	Utaka
Copadichromis	*likomae*	17	Happy	Utaka
Copadichromis	*mbenjii*	14	Happy	Utaka
Copadichromis	*mloto*	14	Happy	Utaka
Copadichromis	Mloto Likoma	16	Happy	Utaka
Copadichromis	*nkatae*	14.5	Happy	Utaka
Copadichromis	*pleurostigma*	20	Happy	Utaka
Copadichromis	*pleurostigmoides*	15	Happy	Tudzitayani
Copadichromis	*quadrimaculatus*	23	Happy	Mbarule*
Copadichromis	Three spot eastern	15	Happy	Utaka
Copadichromis	*trimaculatus*	23	Happy	Tudzitayani
Copadichromis	*verduyni*	16	Happy	Utaka
Copadichromis	*virginalis*	17	Happy	Kaduna**
Copadichromis	Virginalis blotch	18	Happy	Kadose
Copadichromis	Yellow fin	16	Happy	Utaka
Copadichromis	Yellow jumbo	25	Happy	Utaka
Corematodus	*shiranus*	20	Happy	Utaka
Corematodus	*taeniatus*	20	Happy	Utaka++
Ctenopharynx	*intermedius*	22	Happy	Saguga
Ctenopharynx	*nitidus*	13	Happy	Saguga
Cyathochromis	*obliquidens*	13	Bream	Mbuna[20]
Cynotilapia	*afra*	8	Bream	Mbuna
Cynotilapia	*axelrodi*	7.5	Bream	Mbuna+
Cynotilapia	Black dorsal	9.5	Bream	Mbuna
Cynotilapia	Black eastern	11	Bream	Mbuna
Cynotilapia	Chinyankwazi	11	Bream	Mbuna
Cynotilapia	Jalo	7.5	Bream	Mbuna
Cynotilapia	Lion	7.5	Bream	Mbuna
Cynotilapia	Mara	8	Bream	Mbuna

[20] The name Mbuna is from Chitonga, one of the many languages spoken in north Malawi. *Also called Chigwombati;**Ambulumatali & juveniles are called Mpekesa.; and +Mdinyamuboro; ++Nyakaluwa (in Tumbuka for +,++).

Scientific Name		**Maximum Length (cm)**	**English**	**Chichewa**
Cynotilapia	Mbamba	12	Bream	Mbuna
Cynotilapia	Ndumbi	–	Bream	Mbuna
Cynotilapia	Taiwan	11.4	Bream	Mbuna
Cynotilapia	Yellow dorasal	8	Bream	Mbuna
Cyrtocara	*moorii*	23	Hump-head	Utaka*
Dimidiochromis	*compressiceps*	23	Eye-biter	Kambuzi+
Dimidiochromis	*dimidiatus*	20	Bream	Kambuzi
Dimidiochromis	*kiwinge*	30	Bream	Binga
Dimidiochromis	*strigatus*	25	Bream	Kambuzi
Diplotaxodon	*argenteus*	18	Silver cichlid	Ndunduma
Diplotaxodon	Deep	20	Silver cichlid	Ndunduma
Diplotaxodon	*ecclesi*	20	Silver cichlid	Ndunduma
Diplotaxodon	*greenwoodi*	25	Silver cichlid	Ndunduma
Diplotaxodon	Intermediate	20	Silver cichlid	Ndunduma
Diplotaxodon	*limnothrissa*	19	Silver cichlid	Ndunduma
Diplotaxodon	Macrops	12	Silver cichlid	Ndunduma
Diplotaxodon	Macrostoma	13	Silver cichlid	Ndunduma
Diplotaxodon	Similis	25	Silver cichlid	Ndunduma
Diplotaxodon	White belly	13	Silver cichlid	Ndunduma
Diplotaxodon	White top	15	Silver cichlid	Ndunduma
Docimodus	*evelynae*	30	Bream	Mbuna
Docimodus	*johnstonii*	30	Bream	Mbuna
Eclectochochromis	*ornatus*	25	Bream	Mbuna
Exochochromis	*anagenys*	30	Bream	Mbuna
Fossorochromis	*rostratus*	35	Bream	Mbuna
Genyochromis	*mento*	13	Bream	Mbuna
Gephyrochromis	*lawsi*	12	Bream	Mbuna
Gephyrochromis	*moorii*	13	Bream	Mbuna
Gephyrochromis	Zebroides	10	Bream	Mbuna
Hemitaeniochromis	Insignis	20	Bream	Kambuzi
Hemitaeniochromis	*spilopterus*	23	Bream	Kambuzi
Hemitaeniochromis	*urotaenia*	22	Bream	Kambuzi
Hemitilapia	*oxyrhynchus*	20	Bream	Mbuna
Iodotropheus	*sprengerae*	11	Bream	Mbuna
Iodotropheus	*stuartgranti*	10	Bream	Mbuna
Labeotropheus	*fuelleborni*	18	Bream	Utaka

*Described as Mbuna-Chiphungu; called +Nyakalukolombe in Tumbuka.

Scientific Name		**Maximum Length (cm)**	**English**	**Chichewa**
Labeotropheus	*trewavasae*	14	Bream	Utaka
Labidochromis	Blue bar	9.5	Bream	Utaka
Labidochromis	*caeruleus*	15	Bream	Utaka
Labidochromis	Chidunga	11	Bream	Utaka
Labidochromis	Chilumba	9	Bream	Utaka
Labidochromis	*chisumulae*	8	Bream	Utaka
Labidochromis	*flavigulus*	8	Bream	Utaka
Labidochromis	*freibergi*	8	Bream	Utaka
Labidochromis	*gigas*	12	Bream	Utaka
Labidochromis	*heterodon*	9	Bream	Utaka
Labidochromis	*ianthinus*	8.5	Bream	Utaka
Labidochromis	*lividus*	8.5	Bream	Utaka
Labidochromis	*maculicauda*	7.5	Bream	Utaka
Labidochromis	Mara	8	Bream	Utaka
Labidochromis	Masinje	7	Bream	Utaka
Labidochromis	*mbenjii*	7.5	Bream	Utaka
Labidochromis	*mylodon*	8	Bream	Utaka
Labidochromis	*pallidus*	8	Bream	Utaka
Labidochromis	*shiranus*	9	Bream	Utaka
Labidochromis	*strigatus*	8	Bream	Utaka
Labidochromis	*textilis*	9	Bream	Utaka
Labidochromis	*vellicans*	9	Bream	Utaka
Labidochromis	Zebra eastern	6	Bream	Utaka
Labidochromis	*zebroides*	8	Bream	Utaka
Lethrinops	*albus*	15	Bream	Chisawasawa
Lethrinops	*altus*	16	Bream	Chisawasawa
Lethrinops	*argenteus*	20	Bream	Chisawasawa
Lethrinops	*auritus*	9	Bream	Chisawasawa
Lethrinops	Big head	10	Bream	Chisawasawa
Lethrinops	Black chin	9.5	Bream	Chisawasawa
Lethrinops	Blue orange	8	Bream	Chisawasawa
Lethrinops	*borealis*	22	Bream	Chisawasawa
Lethrinops	*christyi*	18	Bream	Chisawasawa
Lethrinops	Dark	10	Bream	Chisawasawa
Lethrinops	Deep water albus	15	Bream	Chisawasawa

Scientific Name		Maximum Length (cm)	English	Chichewa
Lethrinops	Deep water altus	10	Bream	Chisawasawa
Lethrinops	Domira blue	10.5	Bream	Chisawasawa
Lethrinops	*furcifer*	19	Bream	Chisawasawa
Lethrinops	Furcifer	20	Bream	Chisawasawa
Lethrinops	*gossei*	16	Bream	Chisawasawa
Lethrinops	Grey	11	Bream	Chisawasawa
Lethrinops	*leptodon*	18	Bream	Chisawasawa
Lethrinops	*lethrinus*	17	Bream	Chisawasawa
Lethrinops	*longimanus*	17	Bream	Chisawasawa
Lethrinops	'Longimanus'	12	Bream	Chisawasawa
Lethrinops	*longipinnis*	21	Bream	Chisawasawa
Lethrinops	Loweae	17	Bream	Chisawasawa
Lethrinops	*lunaris*	16	Bream	Chisawasawa
Lethrinops	*macracanthus*	25	Bream	Chisawasawa
Lethrinops	*macrochir*	14	Bream	Chisawasawa
Lethrinops	*macrophthalmus*	12	Bream	Chisawasawa
Lethrinops	*marginatus*	16	Bream	Chisawasawa
Lethrinops	Matumbae	11	Bream	Chisawasawa
Lethrinops	*micrentodon*	15	Bream	Chisawasawa
Lethrinops	Micrentodon Makokola	13	Bream	Chisawasawa
Lethrinops	*microdon*	15	Bream	Mbaba
Lethrinops	Macrostoma	11	Bream	Mbaba
Lethrinops	*microstoma*	14	Bream	Mbaba
Lethrinops	*mylodon*	25	Bream	Mbaba
Lethrinops	Nyassae	10	Bream	Mbaba
Lethrinops	*oculatus*	16	Bream	Mbaba
Lethrinops	Oliveri	15	Bream	Mbaba
Lethrinops	*parvidens*	16	Bream	Chisawasawa
Lethrinops	Parvidens	18	Bream	Chisawasawa
Lethrinops	Pink head	12	Bream	Chisawasawa
Lethrinops	*polli*	16	Bream	Chisawasawa
Lethrinops	*stridei*	15	Bream	Chisawasawa
Lethrinops	Yellow	7	Bream	Chisawasawa
Lethrinops	Yellow chin	11	Bream	Chisawasawa
Lethrinops	Yellow tail	8	Bream	Chisawasawa

Scientific Name		Maximum Length (cm)	English	Chichewa
Lichnochromis	*acuticeps*	25	Malawi gar	Chisawasawa
Maravichromis	*anaphyrnus*	23	Happy	Utaka*
Maravichromis	*balteatus*	16.4	Happy	Utaka
Maravichromis	*epichorialis*	25	Happy	Utaka
Maravichromis	*guentheri*	20	Happy	Utaka
Maravichromis	*incola*	20	Happy	Utaka
Maravichromis	Kande	20	Happy	Utaka
Maravichromis	*labidodon*	18	Happy	Utaka
Maravichromis	Lateristriga Makanjila	16	Happy	Utaka
Maravichromis	*mola*	17	Happy	Utaka
Maravichromis	*mollis*	17	Happy	Utaka
Maravichromis	*obtusus*	23	Happy	Utaka
Maravichromis	*semipalatus*	18.5	Happy	Utaka
Maravichromis	Silver torpedo	17.5	Happy	Utaka
Maravichromis	*subocularis*	16	Happy	Utaka
Melanochromis	*auratus*	10	Bream	Mbuna
Melanochromis	Black and White Johanni	10	Bream	Mbuna
Melanochromis	Blotch	11	Bream	Mbuna
Melanochromis	Blue	13	Bream	Mbuna
Melanochromis	*brevis*	13	Bream	Mbuna
Melanochromis	Brown	13	Bream	Mbuna
Melanochromis	Chinyamwezi	9	Bream	Mbuna
Melanochromis	*chipokae*	14	Bream	Mbuna
Melanochromis	Chisumulu Johanni	9	Bream	Mbuna
Melanochromis	Dwarf auratus	7	Bream	Mbuna
Melanochromis	*joanjohnsonae*	9	Bream	Mbuna
Melanochromis	*johanni*	8	Bream	Mbuna
Melanochromis	*labrosus*	12	Bream	Mbuna
Melanochromis	Lepidophage	12	Bream	Mbuna
Melanochromis	Maingano	8.5	Bream	Mbuna
Melanochromis	*melanopterus*	12	Bream	Mbuna
Melanochromis	*parallelus*	12	Bream	Mbuna
Melanochromis	*perspicax*	11	Bream	Mbuna
Melanochromis	*simulans*	11	Bream	Mbuna
Melanochromis	Slab	11	Bream	Mbuna
Melanochromis	*vermivorus*	10	Bream	Mbuna

Also called Mgong'u in Tumbuka.

Scientific Name		**Maximum Length (cm)**	**English**	**Chichewa**
Mylochromis	*anaphyrmus*	23	Happy	Utaka
Mylochromis	Balteatus	16	Happy	Utaka
Mylochromis	Chekopae	15	Happy	Utaka
Mylochromis	Deep	18	Happy	Utaka
Mylochromis	Double spot	14	Happy	Utaka
Mylochromis	*ericotaenia*	21	Happy	Utaka
Mylochromis	*formosus*	15	Happy	Utaka
Mylochromis	*gracilis*	25	Happy	Utaka
Mylochromis	*lateristriga*	22	Happy	Utaka
Mylochromis	*melanonotus*	25	Happy	Utaka
Mylochromis	*melanotaenia*	18	Happy	Utaka
Mylochromis	*plagiotaenia*	14	Happy	Utaka
Mylochromis	*sphaerodon*	20	Happy	Utaka
Mylochromis	*spilostichus*	25	Happy	Utaka
Mylochromis	Torpedo	26	Happy	Utaka
Naevochromis	*chryosogaster*	23	Bream	Saguga
Nimbochromis	*fuscotaeniatus*	25	Bream	Mbuna
Nimbochromis	*linni*	30	Bream	Mbuna
Nimbochromis	*livingstonii*	25	Bream	Mbuna
Nimbochromis	*polystigima*	23	Bream	Mbuna
Nimbochromis	*venustus*	22.5	Bream	Mbuna
Nyassachromis	Argyrosoma blue	12	Happy	Utaka
Nyassachromis	*boadzulu*	16	Happy	Utaka
Nyassachromis	*breviceps*	15	Happy	Utaka
Nyassachromis	*eucinostomus*	13	Happy	Utaka
Nyassachromis	Eucinostomus black	12	Happy	Utaka
Nyassachromis	Eucinostomus yellow	10	Happy	Utaka
Nyassachromis	Interruptus	14	Happy	Utaka
Nyassachromis	*leuciscus*	15	Happy	Utaka
Nyassachromis	*microcephalus*	15	Happy	Utaka
Nyassachromis	*nigritaeniatus*	21	Happy	Utaka
Nyassachromis	*prostoma*	14	Happy	Utaka
Nyassachromis	*purpurans*	18	Happy	Utaka
Nyassachromis	*serenus*	21	Happy	Utaka
Oreochromis	*karongae*	38	Tilapia	Chambo[a]

[a]*O. karongae* has a variant known as *O. saka*. In Chichewa, it is called Biriwiri, Langazume, Chidyakoko, Kadyakoko, Lisanga, Masanga, Mamidu and Saka.

Scientific Name		Maximum Length (cm)	English	Chichewa
Oreochromis	*lidole*	37	Tilapia	Chambo
Oreochromis	*squamipinnis*	37	Tilapia	Chambo[b]
Oreochromis	*shiranus*	37	Shire tilapia	Fwilili
Otopharynx	*argyrosoma*	15	Bream	Saguga
Otopharynx	Argyrosoma blue	16	Bream	Saguga
Otopharynx	Argyrosoma red	12.5	Bream	Saguga
Otopharynx	*auromarginatus*	25	Bream	Saguga*
Otopharynx	Auromarginatus stripe	18	Bream	Saguga
Otopharynx	Blue	15	Bream	Saguga
Otopharynx	*brooksi*	15	Bream	Saguga
Otopharynx	Cave	23	Bream	Saguga
Otopharynx	*decorus*	18	Bream	Saguga
Otopharynx	*heterodon*	13	Bream	Saguga
Otopharynx	Heterodon Likoma	20	Bream	Saguga
Otopharynx	Heterodon Nankumba	16	Bream	Saguga
Otopharynx	Kawanga	11	Bream	Saguga
Otopharynx	*lithobates*	16	Bream	Saguga
Otopharynx	*ovatus*	20	Bream	Saguga
Otopharynx	*pictus*	13	Bream	Saguga
Otopharynx	Productus	17.5	Bream	Saguga
Otopharynx	*selenurus*	17.5	Bream	Saguga
Otopharynx	*speciosus*	25	Bream	Saguga
Otopharynx	Spots	12	Bream	Saguga
Otopharynx	*tetraspilus*	16	Bream	Saguga
Otopharynx	*tetrastigma*	14	Bream	Saguga
Otopharynx	*walteri*	16	Bream	Saguga
Otopharynx	Yellow fin Mloto	18	Bream	Saguga
Pallodochromis	*tolokosh*	35	Silver cichlid	Ndunduma
Petrotilapia	Black flank	14	Bream	Mbuna
Petrotilapia	Chitande	15	Bream	Mbuna
Petrotilapia	Fuscous	14	Bream	Mbuna
Petrotilapia	*genalutea*	15	Bream	Mbuna
Petrotilapia	Gold	16	Bream	Mbuna
Petrotilapia	Gold eastern	12	Bream	Mbuna
Petrotilapia	Jalo	12	Bream	Mbuna
Petrotilapia	Likoma barred	20	Bream	Mbuna

[b]It is also called Mkambo, Ching'anga, Ling'ara, Mang'ara, Nchesichesi, Ngwalu and Zeya.
*Also called Mgong'u in Tumbuka.

Scientific Name		Maximum Length (cm)	English	Chichewa
Petrotilapia	Likoma variable	18	Bream	Mbuna
Petrotilapia	Mumbo blue	17	Bream	Mbuna
Petrotilapia	Mumbo yellow	16	Bream	Mbuna
Petrotilapia	*nigra*	14	Bream	Mbuna
Petrotilapia	Orange pelvic	16	Bream	Mbuna
Petrotilapia	Ruarwe	18	Bream	Mbuna
Petrotilapia	Small blue	17	Bream	Mbuna
Petrotilapia	*tridentiger*	17	Bream	Mbuna
Petrotilapia	Yellow chin	17	Bream	Mbuna
Petrotilapia	Yellow ventral	16	Bream	Mbuna
Placidochromis	Acuticeps	15	Bream	Chisawasawa
Placidochromis	Carnivore	9.5	Bream	Chisawasawa
Placidochromis	*electra*	17	Bream	Chisawasawa
Placidochromis	*hennydaviesae*	8.5	Bream	Chisawasawa
Placidochromis	HennydaviesaeII	9	Bream	Chisawasawa
Placidochromis	HennydaviesaeIII	9	Bream	Chisawasawa
Placidochromis	HennydaviesaeIV	11	Bream	Chisawasawa
Placidochromis	HennydaviesaeV	12.5	Bream	Chisawasawa
Placidochromis	HennydaviesaeVI	9	Bream	Chisawasawa
Placidochromis	*johnstoni*	17	Bream	Chisawasawa
Placidochromis	Johnstoni gold	11.5	Bream	Chisawasawa
Placidochromis	Johnstoni solo	9	Bream	Chisawasawa
Placidochromis	Long	12	Bream	Chisawasawa
Placidochromis	*longimanus*	15	Bream	Chisawasawa
Placidochromis	Longimanus Malombe	12.5	Bream	Chisawasawa
Placidochromis	Longimanus Namiasi	12	Bream	Chisawasawa
Placidochromis	Macrognathus	13	Bream	Chisawasawa
Placidochromis	*milomo*	25	Bream	Chisawasawa[+]
Placidochromis	Platyrhynchos	13	Bream	Chisawasawa
Placidochromis	*stonemani*	7	Bream	Chisawasawa
Placidochromis	Subocularis	16	Bream	Chisawasawa
Protomelas	*annectens*	20	Bream	Kambuzi[*]
Protomelas	*fenestratus*	18	Bream	Kambuzi
Protomelas	Insignis Mumbo	25	Bream	Kambuzi
Protomelas	*kirkii*	13	Bream	Mbaba

Also called [*]Mgong'u; [+]Khumbuli in Tumbuka.

Scientific Name		Maximum Length (cm)	English	Chichewa
Protomelas	*labridens*	17	Bream	Kambuzi
Protomelas	*lobochilus*	18	Bream	Kambuzi
Protomelas	*macrodon*	10.5	Bream	Kambuzi
Protomelas	*marginatus*	17	Bream	Kambuzi
Protomelas	Mbenji thick lip	27	Bream	Kambuzi
Protomelas	Paedophange	25	Bream	Kambuzi
Protomelas	*phinochilus*	16	Bream	Kambuzi
Protomelas	*pleurotaenia*	14	Bream	Kambuzi
Protomelas	Red dorsal	8.5	Bream	Kambuzi
Protomelas	*similis*	17	Bream	Kambuzi
Protomelas	*spilonotus*	25	Bream	Kambuzi
Protomelas	Spilonotus Likoma	18	Bream	Kambuzi
Protomelas	Spilopterus blue	17	Bream	Kambuzi
Protomelas	*taeniolatus*	13	Bream	Kambuzi
Protomelas	*triaenodon*	15.5	Bream	Kambuzi
Protomelas	Urotaenia blue	30	Bream	Kambuzi
Protomelas	*virgatus*	15	Bream	Kambuzi
Pseudotropheus	Acei	10	Bream	Mgong'u*
Pseudotropheus	Aggressive blue	9	Bream	Mbuna
Pseudotropheus	Aggressive gray	12	Bream	Mbuna
Pseudotropheus	Aggressive gray head	10	Bream	Mbuna
Pseudotropheus	Aggressive yellow fin	11	Bream	Mbuna
Pseudotropheus	Aggressive zebra	12	Bream	Mbuna
Pseudotropheus	*ater*	11	Bream	Mbuna
Pseudotropheus	*aurora*	11	Bream	Mbuna
Pseudotropheus	*barlowi*	10	Bream	Mbuna
Pseudotropheus	Burrower	7.5	Bream	Mbuna
Pseudotropheus	Chinyankwazi	8.5	Bream	Mbuna
Pseudotropheus	*crabro*	12	Bream	Mbuna
Pseudotropheus	*colbat*	12	Bream	Mbuna
Pseudotropheus	*cyaneas*	9	Bream	Mbuna
Pseudotropheus	Dumpy	7.5	Bream	Mbuna
Pseudotropheus	Dwarf gold	7.5	Bream	Mbuna
Pseudotropheus	*elengas*	16	Bream	Mbuna
Pseudotropheus	*elongatus*	9	Bream	Mbuna

*The name Mgong'u is in Tumbuka language.

Scientific Name		Maximum Length (cm)	English	Chichewa
Pseudotropheus	Elongatus aggressive	13	Bream	Mbuna
Pseudotropheus	Elongatus bar	8	Bream	Mbuna
Pseudotropheus	Elongatus bee	10	Bream	Mbuna
Pseudotropheus	Elongatus Boadzulu	8.5	Bream	Mbuna
Pseudotropheus	Elongatus brown	11	Bream	Mbuna
Pseudotropheus	Elongatus Chailosi	9	Bream	Mbuna
Pseudotropheus	Elongatus Chawere	9	Bream	Mbuna
Pseudotropheus	Elongatus Chisumulu	10	Bream	Mbuna
Pseudotropheus	Elongatus gold bar	10	Bream	Mbuna
Pseudotropheus	Elongatus Likoma	8.5	Bream	Mbuna
Pseudotropheus	Elongatus Masimbwe	11	Bream	Mbuna
Pseudotropheus	Elongatus Mbako	8.5	Bream	Mbuna
Pseudotropheus	Elongatus Mbenji blue	10	Bream	Mbuna
Pseudotropheus	Elongatus Mbenji brown	10	Bream	Mbuna
Pseudotropheus	Elongatus Mpanga	8.5	Bream	Mbuna
Pseudotropheus	Elongatus Namalenje	12	Bream	Mbuna
Pseudotropheus	Elongatus Ndumbi	13	Bream	Mbuna
Pseudotropheus	Elongatus ornatus	11	Bream	Mbuna
Pseudotropheus	Elongatus reef	9.5	Bream	Mbuna
Pseudotropheus	Elongatus Ruarwe	7.5	Bream	Mbuna
Pseudotropheus	Elongatus slab	10	Bream	Mbuna
Pseudotropheus	Elongatus taiwan	11	Bream	Mbuna
Pseudotropheus	Elongatus Usisya	11	Bream	Mbuna
Pseudotropheus	Elongatus yellow tail	9	Bream	Mbuna
Pseudotropheus	*fainzilberi*	12.9	Bream	Mbuna
Pseudotropheus	*flavus*	8.5	Bream	Mbuna
Pseudotropheus	*fuscoides*	12	Bream	Mbuna
Pseudotropheus	*fuscus*	11	Bream	Mbuna
Pseudotropheus	*gracilior*	11	Bream	Mbuna
Pseudotropheus	*greshakei*	10	Bream	Mbuna
Pseudotropheus	*hajomeylandi*	12	Bream	Mbuna
Pseudotropheus	*heteropictus*	10	Bream	Mbuna
Pseudotropheus	Jacksoni	10.5	Bream	Mbuna
Pseudotropheus	Kingsizei	9	Bream	Mbuna
Pseudotropheus	*lanistocola*	8.5	Bream	Mbuna

Scientific Name		Maximum Length (cm)	English	Chichewa
Pseudotropheus	Lime	6.5	Bream	Mbuna
Pseudotropheus	*livingstonii*	14	Bream	Mbuna
Pseudotropheus	Livingstonii Likoma	11	Bream	Mbuna
Pseudotropheus	*lombardoi*	10	Bream	Mbuna
Pseudotropheus	*lucerna*	11	Bream	Mbuna
Pseudotropheus	Lurcena brown	–	Bream	Mbuna
Pseudotropheus	Membe deep	7	Bream	Mbuna
Pseudotropheus	*microstoma*	11	Bream	Mbuna
Pseudotropheus	*minutus*	7.5	Bream	Mbuna
Pseudotropheus	Ndumbi gold	12	Bream	Mbuna
Pseudotropheus	Newsi	8	Bream	Mbuna
Pseudotropheus	Nkhoma lime	7.5	Bream	Mbuna
Pseudotropheus	*novemfasciatus*	11	Bream	Mbuna
Pseudotropheus	Red dorsal	10	Bream	Mbuna
Pseudotropheus	*saulosi*	7	Bream	Mbuna
Pseudotropheus	*socolofi*	7.5	Bream	Mbuna
Pseudotropheus	Thin strip	8	Bream	Mbuna
Pseudotropheus	Tiny	7.5	Bream	Mbuna
Pseudotropheus	*tropheops*	14	Bream	Mbuna
Pseudotropheus	Tropheops aggressive	8.5	Bream	Mbuna
Pseudotropheus	Tropheops black	13	Bream	Mbuna
Pseudotropheus	Tropheops black dorsal	12	Bream	Mbuna
Pseudotropheus	Tropheops Boadzulu	13	Bream	Mbuna
Pseudotropheus	Tropheops broad mouth	12	Bream	Mbuna
Pseudotropheus	Tropheops Chilumba	12	Bream	Mbuna
Pseudotropheus	Tropheops Chinyamwezi	13	Bream	Mbuna
Pseudotropheus	Tropheops Chinyankwazi	12	Bream	Mbuna
Pseudotropheus	Tropheops Chitande Yellow	12	Bream	Mbuna
Pseudotropheus	Tropheops dark	13	Bream	Mbuna
Pseudotropheus	Tropheops deep	10.5	Bream	Mbuna
Pseudotropheus	Tropheops gold	11	Bream	Mbuna
Pseudotropheus	Tropheops gold otter	10	Bream	Mbuna
Pseudotropheus	Tropheops intermediate	11	Bream	Mbuna
Pseudotropheus	Tropheops lilac	11.2	Bream	Mbuna
Pseudotropheus	Tropheops Maleri blue	11	Bream	Mbuna

Scientific Name		Maximum Length (cm)	English	Chichewa
Pseudotropheus	Tropheops Maleri yellow	11.5	Bream	Mbuna
Pseudotropheus	Tropheops mauve	11	Bream	Mbuna
Pseudotropheus	Tropheops Mbenji blue	11.5	Bream	Mbuna
Pseudotropheus	Tropheops Mbenji yellow	11	Bream	Mbuna
Pseudotropheus	Tropheops Membe	13	Bream	Mbuna
Pseudotropheus	Tropheops Mumbo	10	Bream	Mbuna
Pseudotropheus	Tropheops olive	11	Bream	Mbuna
Pseudotropheus	Tropheops red cheek	12	Bream	Mbuna
Pseudotropheus	Tropheops red fin	10	Bream	Mbuna
Pseudotropheus	Tropheops rust	10	Bream	Mbuna
Pseudotropheus	Tropheops taiwan	13	Bream	Mbuna
Pseudotropheus	Tropheops weed	10	Bream	Mbuna
Pseudotropheus	Tropheops yellow chin	13	Bream	Mbuna
Pseudotropheus	Tropheops yellow gullar	12	Bream	Mbuna
Pseudotropheus	*tursiops*	11	Bream	Mbuna
Pseudotropheus	Tursiops Chitande	10	Bream	Mbuna
Pseudotropheus	Tursiops Mbenji	12.5	Bream	Mbuna
Pseudotropheus	Variable	10	Bream	Mbuna
Pseudotropheus	Variable eastern	7.5	Bream	Mbuna
Pseudotropheus	Variable Kande	9	Bream	Mbuna
Pseudotropheus	*williamsi*	13	Bream	Mbuna
Pseudotropheus	Williamsi Makanjila	13*	Bream	Mbuna
Pseudotropheus	Williamsi Maleri	13	Bream	Mbuna
Pseudotropheus	Williamsi Nkudzi	16	Bream	Mbuna
Pseudotropheus	*xanstomachus*	12.5	Bream	Mbuna+
Pseudotropheus	*zebra*	13.5	Bream	Mbuna
Pseudotropheus	Zebra Benga	11	Bream	Mbuna
Pseudotropheus	Zebra bevous	11	Bream	Mbuna
Pseudotropheus	Zebra black dorsal	11	Bream	Mbuna
Pseudotropheus	Zebra blue	9.5	Bream	Mbuna
Pseudotropheus	Zebra Chalo	11	Bream	Mbuna
Pseudotropheus	Zebra Chilumba	13	Bream	Mbuna
Pseudotropheus	Zebra cobalt	11	Bream	Mbuna
Pseudotropheus	Zebra gold	12	Bream	Mbuna
Pseudotropheus	Zebra goldbreast	13	Bream	Mbuna

*Maximum length is over 13 cm. +Called Nyamugarara in Tumbuka.

Scientific Name		Maximum Length (cm)	English	Chichewa
Pseudotropheus	Zebra long pelvic	9	Bream	Mbuna
Pseudotropheus	Zebra Masinje	10	Bream	Mbuna
Pseudotropheus	Zebra Mbenji	12.5	Bream	Mbuna
Pseudotropheus	Zebra Metangula	13*	Bream	Mbuna*
Pseudotropheus	Zebra Mozambique	10	Bream	Mbuna
Pseudotropheus	Zebra patricki	11	Bream	Mbuna
Pseudotropheus	Zebra red dorsal	12	Bream	Mbuna
Pseudotropheus	Zebra Ruarwe	12	Bream	Mbuna
Rhamphochromis	Big mouth	40	Tigerfish	Mcheni[c]
Rhamphochromis	Bigtoothbrown	33	Tigerfish	Mcheni
Rhamphochromis	*brevis*	38	Tigerfish	Mcheni
Rhamphochromis	*esox*	38	Tigerfish	Mcheni
Rhamphochromis	*ferox*	45	Tigerfish	Mcheni
Rhamphochromis	Kolowiko	35	Tigerfish	Mcheni
Rhamphochromis	*leptosoma*	40	Tigerfish	Mcheni
Rhamphochromis	Long finyellow	25	Tigerfish	Mcheni
Rhamphochromis	Long snout	44	Tigerfish	Mcheni
Rhamphochromis	*longiceps*	28	Tigerfish	Mcheni
Rhamphochromis	Longiceps	25	Tigerfish	Mcheni
Rhamphochromis	*lusius*	40	Tigerfish	Mcheni
Rhamphochromis	*macrocephthalmus*	28	Tigerfish	Mcheni
Rhamphochromis	Shire ferox	23.5	Tigerfish	Mcheni
Rhamphochromis	Short-tooth brown	20	Tigerfish	Mcheni
Rhamphochromis	*woodi*	45	Tigerfish	Mcheni
Sciaenochromis	*alhi*	20	Bream	Chisawasawa[+]
Sciaenochromis	*benthicola*	17.5	Bream	Chisawasawa
Sciaenochromis	Blue Kande	15	Bream	Chisawasawa
Sciaenochromis	Deep water	12	Bream	Chisawasawa
Sciaenochromis	*psammophilus*	14	Bream	Chisawasawa
Sciaenochromis	Sand	15	Bream	Chisawasawa
Serranochromis	*robustus*	50	Yellowbelly bream	Tsungwa[d]
Stigmatochromis	Guttutus	16	Bream	Chisawasawa
Stigmatochromis	*modestus*	25	Bream	Chisawasawa
Stigmatochromis	Modestus eastern	15	Bream	Chisawasawa
Stigmatochromis	*pholidophorus*	18	Bream	Chisawasawa

[c]Mcheni is also called Sango; In Chitonga, it is known as Nthamfya. [d]It is also known as Sungwa.*Maximum length is over 13 cm; also called Nyamuchecheche; [+]Mdinyamuboro inTumbuka language.

Scientific Name		**Maximum Length (cm)**	**English**	**Chichewa**
Stigmatochromis	Spilostichus type	20	Bream	Chisawasawa
Stigmatochromis	Tolae	20	Bream	Chisawasawa
Stigmatochromis	*woodi*	30	Bream	Chisawasawa
Taeniochromis	*holotaenia*	20	Bream	Kambuzi[+]
Taeniolethrenops	*cyrtonotus*	11.2	Bream	Chisawasawa
Taeniolethrenops	*furcicauda*	21	Bream	Chisawasawa
Taeniolethrenops	*laticeps*	25	Bream	Chisawasawa
Taeniolethrenops	*praeorbitalis*	30	Bream	Chisawasawa
Tilapia[e]	*rendalli*	35	Redbreast tilapia	Chi(l)unguni
Tramitichromis	*brevis*	16	Bream	Chisawasawa
Tramitichromis	*intermedius*	15	Bream	Chisawasawa
Tramitichromis	*lituris*	18	Bream	Chisawasawa
Tramitichromis	*trilineatus*	14	Bream	Chisawasawa
Tramitichromis	*variabilis*	18	Bream	Chisawasawa
Trematocranus	*brevirostris*	10	Bream	Chisawasawa
Trematocranus	Brevirostris deep	10	Bream	Chisawasawa
Trematocranus	*labifer*	23	Bream	Chisawasawa
Trematocranus	*microstoma*	25	Bream	Chisawasawa
Trematocranus	*placodon*	23	Bream	Chisawasawa
Tyrannochromis	*macrostoma*	35	Bream	Chisawasawa
Tyrannochromis	*maculiceps*	35	Bream	Chisawasawa
Clariidae				
Bathyclarias	*euryodon*	105	Catfish	Bombe[++]
Bathyclarias	*filicibarbis*	79	Catfish	Bombe
Bathyclarias	*foveolatus*	70	Catfish	Chimwanapumba
Bathyclarias	*gigas*	150	Catfish	Bombe
Bathyclarias	*ilesi*	73	Catfish	Bombe
Bathyclarias	*longibarbis*	76	Catfish	Kabwili
Bathyclarias	*loweae*	100[f]	Catfish	Nkhomo[g]
Bathyclarias	*nyasensis*	80	Catfish	Sapuwa
Bathyclarias	*rotundifronds*	70	Catfish	Bombe
Bathyclarias	*worthingtoni*	81	Catfish	Nkopora

[e]*T. rendalli* is sometimes referred to as *Coptodon rendalli*. [+]Sapu; [++]Mbumbu (*Bathyclarias*) in Tumbuka.
[f]Maximum length is over 100 cm.
[g]It is also called Nkoma.

Scientific Name		**Maximum Length (cm)**	**English**	**Chichewa**
Clariidae				
Clarias	*gariepinus*	150	Sharptooth catfish	Mlamba
Clarias	*mellandi*	30	Clarid catfish	Mlamba
Clarias	*mossambicus*	60	Clarid catfish	Mlamba
Clarias	*theodorae*	22	Snake catfish	Mlamba
Cyprinidae[+]				
Barbus	*banguelensis*	8	Barb	Matemba
Barbus	*eurystomus*	50	Barb	Kadyakolo
Barbus	*innocens*	7.5	Barb	Matemba
Barbus	*johnstonii*	60	Barb	Ngumbo[++]
Barbus	*litamba*	44	Barb	Matemba[*]
Barbus	*macrotaenia*	3.6	Barb	Matemba
Barbus	*rhodesii*	31.5	Barb	Batamba
Barbus	*trimaculatus*	8	Threespot barb	Matemba
Engraulicypris	*sardella*	12	Lake sardine	Usipa
Labeo	*cylindricus*	35	African carp	Ningwi[h]
Labeo	*mesops*	35	African carp	Nchila
Opsaridium	*microcephalus*	30	Lake trout	Sanjika[**]
Opsaridium	*microlepis*	60	Lake salmon	Mpasa[***]
Cyprinodontidae				
Aplocheilichthys	*johnstoni*	5	Killifish	–
Nothobranchius	*orthonatus*	9	Spotted killifish	–
Mastacembelidae				
Mastacembelus	Sp. "Rosette"	30	'Eel'	Nkunga
Mastacembelus	*shiranus*	30	'Eel'	Nkunga
Mochokidae				
Synodontis	*njassae*	20	Sqeaker	Nkholokolo
Chiloglanis	*neumanni*	6	Sqeaker	Nkholokolo
Leptoglanis	Sp.	–	Sqeaker	Nkholokolo

[h]Other names for the two labeos are Mbununu and Mtuwa. [+]Small *Barbus* are Nyamere; [++]Mpondo; [*]Nthuwa; [**]Mpherere; and [***]Mphasa in Tumbuka.

Scientific Name		Maximum Length (cm)	English	Chichewa
Mormyridae[+]				
Marcusenius	*discorhynchus*	25	Zambezi parrotfish	Samwamowa
Marcusenius	*macrolepdotus*	30	Bulldog	Samwamowa
Marcusenius	*nyasensis*	30	Mormyrid	Mphuta
Mormyrus	*deliciosus*	100	Cornish jack	Nyanda[i]
Mormyrus	*longirostris*	100	Elephant snoutfish	Chingonti
Petrocephalus	*catostoma*	13	Churchill	Chonjo

[+]Most species are known as Munjolo in Tumbuka. [i]It is also called Njalo.

Appendix 1.4 Stupefacient plant materials used to kill fish in Malawi[j]

Family	Scientific Name	English Common Name	Vernacular Name	Habit	Part used
Araceae	*Culcasia scandens*	n.a.	Mbol(r)o	Perennial climber	Stem
Leguminosae (Caesalpinioideae)	*Swartizia madagascariensis*	Snake bean	Chinyenye Kampangoni Mulundi(u) Cha(i)ronde	Tree/brush	Pods
	Burkea africana	Wild syringa, Rhodesian ash	Mkalati, Kalinguti Kawi(d)zu Kabi(d)zu Muyoka	Tree, gum	Bark
Leguminosae (Mimosoideae)	*Acacia albida*	White/camel thorn Applering acacia	Nsangu, Chitonya Msangumsangu	Tree	Pods, seeds
	Elephantorrhiza goetzei	n.a.	Chiteta, Chamdima Chikundulima, Chamlima	Trees, seeds	Roots

[j]Adopted from ICLARM/GTZ (1991), based on Binns and Logah (1972) and Williamson (1975).

Stupefacient plant materials used to kill fish in Malawi (continued)

Family	Scientific Name	English Common Name	Vernacular Name	Habit	Part used
Leguminosae (Papilionoideae)	*Mundulia sericea*	Corkbush, silverbush	Lusunga, Chiguluka Nandolo	Perennial herb	Whole plant
	Neorautanenia mitis	n.a.	Dema M'memenambuzu	Creeping/climbing shrub	Root
	Tephrosia aequilata	n.a.	Ombwe, Katupe, Kapweso, N(M)tutu	Shrub	n.a.
	Tephrosia vogetti	Fish bean	Mthuthu, Mtetezga	Shrub	Leaves, pods branches
Euphorbiaceae	*Euphorbia tirucalli*	Milkbush	Nkhadze, (M)ngachi	Succulent shrub	Latex, branches
Thymelaeaceae	*Gnidia kraussiana*	Yellowheads	Katupe, Kazinda	Tree/shrub	Bark
Combretaceae	*Combretum fragrans*	n.a.	Kadale, Kasewe	Shrub/sree	n.a.
Guttiferae	*Psorospermum febrifugum*	n.a.	Mdima	Shrub	Roots, bark
Balanitaceae	*Balanites maughamii*	Torchwood	Njuyu, Mpambulu	Tree	Fruit

Appendix 1.5 Local plant materials for construction of traditional fishing gears[j]

Family	Scientific Name	English Common Name	Vernacular Name	Habit	Usage	Part used
Gramineae	*Phragmites mauritianus*	Reed grass	Bango, Matete	Aquatic macrophyte	Fish traps, Fish fences	Stem
	Vossia cuspidata	Hippo grass	(N)duvi, Nsanje (M)sali	Aquatic macrophyte	Fish aggreg-ation device	Sward
Urticaceae	*Pouzolzia hypoleuca*	n.a.	Mulusa Muluza T(h)ingo Lu(i)chopwa Lukayo, Wazi	Shrubby perennial	Nets	Bark fibres
Menispermaceae	*Tinospora caffrara*	n.a.	Lulisi	Shrubby Climber	Ropes	Stem
Polygalaceae	*Seciridaca longendunculata*	Tree violet	Bwazi, Chosi Chiguluka, Njefu, Muluka, Nakabwazi, Mu-uruak	Shrub or tree	Nets	Bark fibres
Anacardiaceae	*Anacardium occidentale*	Chashew nut	Mbibu, Msololikoko Nkoloso	Tree	Net preservative	Seed oil
	Lannea discolor	Livelong	Chiumbu Sidyatungu	Tree	Poles Floats	Timber
Convolvulacaea	*Ipoma pes caprae*	n.a.	Msaula Malandalala	Straggling perennial	Net ropes Fish attract-ant on nets	Stems, Leaves

[j]Adopted from ICLARM/GTZ (1991), based on Binns and Logah (1972) and Williamson (1975).

Appendix 1.6 Calculation of dietary/energy value of fish consumed in the Malawi

Biological requirements of calorific values of food (cvf) substances consumed in Malawi are 80 % (although its known to be as low as 74 % when other cereals - rice, sorghum, and millet and root crops, pulses and bananas are taken into consideration) maize at 2200 daily calorific value and 90 kg per person per year. The total cvf is estimated at 2750. The remaining 20 % which, is equivalent to 550 cvf, is met from protein at 12 % (of livestock, maize and wildlife mainly fish) and fat (of peanuts and animal products including milk) intake (ICLARM/GTZ 1991; GOM/UN 1992). The maize per capita consumption is based on calculation from an average family household of 2 adults and 3 children. The per capita value may also be complicated by a number of other factors as considered in terms of nutritional status of a family. Some of the important examples include ability of providing own maize requirements, and intra-household supply. The calculations would also need to take into account losses, which can be very high. Field production processes of maize account for up to 18 % of the losses. Maize flour processing, which is practiced by the majority population, alone contributes to losses in the range of 30-40 % (GOM/UN 1992).

Fish contributes substantially to the calorific values that are met through protein intake comprising 12 % of the total energy intake. Dietary protein of animal origin make up 15 % of total protein component. Fish then provides 70 % of the protein intake from animals and 40 % of all the protein intake (GOM 1989; ICLARM/GTZ 1991). Of the total cvf fish make up about 600. Using figures from Reali (1991) of 18.6 % average weight of protein in fish and the nutritional intake contribution of fish at 600 cvf translates to a consumption of about 12 kg per person per year. In order to ensure that this amount is made available while the fish post-harvest losses of 20-30 % (SADC 1991) are accounted for, fish consumption of 15 kg per person per year is recommended (SADC 1997; Tenthani 1999).

Appendix 1.7 Fishing/fisheries regulations in Malawi, 1996-97.

Area	Operation	Restriction	Minimum	Maximum
Lake Malawi (Large-scale)	Midwater trawl (Chambo)	Mesh size	100 mm	-
		Net mouth width	-	110 m
		Closed areas	Area A From shore to 1852 m (1 nm)	-
		Closed season	No restriction	-
		Number of licences	-	One
	Midwater trawl (Utaka/Ndunduma)	Mesh size	38 mm	-
		Net mouth width	-	110 m
		Closed areas	Area A From shore to 1852 m (1 nm)	-
		Closed Season	No restriction	-
		Number of licences	-	One
	Shallow water trawl (up to 50 m)	Mesh size	38 mm	-
		Net mouth width	-	37 m
		Power	-	30 HP per boat of a pair trawler
		Closed areas	From shore to 1852 m (1 nm) Not less than 18 m	-
		Closed season	Area specified	-
		Number of licences	Area A	4

Area	Operation	Restriction	Minimum	Maximum
			Area B and C	3
			Area D and E	7
			Area G and H	3
			Area N	1
	Deep water trawl (more than 50 m)	Mesh size	38 mm	-
		Net mouth width	-	37 m
		Closed areas	From shore to 1852 m (1 nm) Not less than 50 m	-
		Closed season	No restriction	-
		Number of licences	Area A	None
			Area B and C	3
			Areas D-H	3
	Purse seine/ring net	Mesh Size	100 mm	-
		Net mouth width	-	650 m
		Closed areas	From shore to 1852 m (1 nm) Not less than 18 m	-
		Closed season	1 Nov - 31 Dec	-
		Number of licences	Area B-H	2
	Usipa lift net (rig)	Mesh size	No restriction	-
		Net mouth width	-	No restriction
		Closed areas	No restriction	-
		Closed season	No restriction	-
		Number of licences	Area B,C,E,G and H	5

Area	Operation	Restriction	Minimum	Maximum
Lake Malawi (Small-scale)	Chilimila	Mesh size	No restriction	-
		Headline length	-	No restriction
		Net depth	-	No restriction
		Closed areas	No restriction	-
		Closed season	Area A 1 Nov - 31 Dec	-
		Number of licences		No restriction
	Gillnet (Southeast Arm) (south of Lat. 14° 30' S)	Mesh size	95 mm	-
		Headline length	-	No restriction
		Net depth	-	No restriction
		Closed areas	No restriction	-
		Closed season	During day	-
		Number of licences	-	No restriction
	Gillnet (south of Lat. 12° 15' S)	Mesh size	90 mm	-
		Headline length	-	No restriction
		Net depth	-	No restriction
		Closed areas	No restriction	-
		Closed season	-	-
		Number of licences	-	No restriction
	Gillnet (north of Lat. 12° 15' S)	Mesh size	No restriction	-
		Headline length	-	No restriction
		Net depth	-	No restriction
		Closed areas	No restriction	-
		Closed season	-	-
		Number of licences	-	No restriction

Area	Operation	Restriction	Minimum	Maximum
	Chambo beach seine	Mesh size	90 mm	-
		Headline length	-	1000 m
		Net depth	-	18 m
		Closed areas	No restriction	-
		Closed season	1 Nov - 31 Dec	-
		Number of licences	-	No restriction
	Kambuzi beach seine	Mesh size	25 mm	-
		Headline length	-	150 m
		Net depth	-	10 m
		Closed areas	No restriction	-
		Closed season	1 Nov - 31 Dec	-
		Prohibited	Area A, E and D	-
		Number of licences	-	No restriction
	Usipa beach seine	Mesh size	No restriction	-
		Headline length	-	100 m
		Net depth	-	6 m
		Fishing time	No restriction	-
		Closed areas	No restriction	-
		Closed season	No restriction	-
		Number of licences	-	No restriction
	Long line	-	No restriction	-
	Hand line	-	No restriction	-
	Trap	-	No restriction	-

Area	Operation	Restriction	Minimum	Maximum
	Scoop net	-	No restriction	-
	Cast net	-	No restriction	-
Lake Malombe[21]	Nkacha net	Mesh size	19 mm	-
		Headline length	-	250 m
		Net depth	-	-
		Closed areas	-	-
		Closed season	1 Oct - 31 Dec	-
		Number of licences	-	(Limited)
	Kambuzi beach seine	Mesh size	19 mm	-
		Headline length	-	500 m
		Net depth	-	-
		Fishing time	6 am - 6 pm	-
		Closed areas	-	-
		Closed season	1 Oct - 31 Dec	-
		Number of licences	-	(Limited)
	Chambo beach seine	Mesh size	90 mm	-
		Headline length	-	1000 m
		Net depth	-	-
		Closed areas	-	-
		Closed season	1 Nov - 31 Dec	-
		Number of licences	-	No restriction

[21] Limitation of number of licences in certain gears is starting under the community participatory management programme being promoted with external financial support from the German Government (Scholz et al. 1997).

Area	Operation	Restriction	Minimum	Maximum
	Gillnet	Mesh size	95 mm	-
		Headline length	-	No restriction
		Net depth	-	4.5 m
		Closed areas	-	-
		Closed season	No restriction	-
		Number of licences	-	No restriction
	Long line	-	No restriction	-
	Hand line	-	No restriction	-
	Trap	-	No restriction	-
	Cast net	-	No restriction	-
	Kauni (Light attraction fishery)	-	-	Prohibited
Upper Shire River	Nkacha net	Prohibited gear	-	-
	Kambuzi beach seine	Prohibited gear	-	-
	Chambo beach seine	Prohibited gear	-	-
	Gillnet	Mesh size	95 mm	-
		Headline length	-	No restriction
		Net depth	-	3 m
		Closed areas	-	-
		Closed season	No restriction	-
		Number of licences	-	(Limited)

Area	Operation	Restriction	Minimum	Maximum
	Long line	-	No restriction	-
	Hand line	-	No restriction	-
	Trap	-	No restriction	-
	Cast net	-	No restriction	-
Lake Chilwa	Trawl	Mesh size	No restriction	-
		Net mouth width	-	25 m
		Net depth	-	No restriction
		Closed areas	No restriction	-
		Closed season	No restriction	-
		Number of licences	-	Nil (1996/97)
	Beach seine	Mesh size	No restriction	-
		Headline length	-	300 m
		Net depth	-	5 m
		Closed areas	No restriction	-
		Closed season	No restriction	-
		Number of licences	-	(Limited)
	Nkacha net	Prohibited gear		
	Gillnet	Mesh size	70 mm	-
		Headline length	-	No restriction
		Net depth	-	3 m
		Closed areas	No restriction	-
		Closed season	No restriction	-
		Number of licences	-	(Limited)

Area	Operation	Restriction	Minimum	Maximum
	Long line	-	No restriction	-
	Hand line	-	No restriction	-
	Trap	-	No restriction	-
	Cast net	-	No restriction	-
Lake Chiuta	Beach seine	Mesh size	64 m	-
		Headline length	-	250 m
		Net depth	-	5 m
		Closed areas	No restriction	-
		Closed season	No restriction	-
		Number of licences	(Limited & suspended for 1996/97)	-
	Nkacha net	Prohibited gear	-	-
	Gillnet	Mesh size	64 mm	-
		Headline length	-	No restriction
		Net depth	-	No restriction
		Closed areas	No restriction	-
		Closed season	No restriction	-
		Number of licences	-	No restriction
	Trap	-	No restriction	-
	Cast net	-	No restriction	-

Area	Operation	Restriction	Minimum	Maximum
Lower Shire	Beach seine	Mesh size	No restriction	-
		Headline length	-	200 m
		Net depth	-	15 m
		Closed areas	No restriction	-
		Closed season	No restriction	-
		Number of licences	-	No restriction
	Gillnet	Mesh size	51 mm	-
		Headline length	-	No restriction
		Net depth	-	3 m
		Closed areas	No restriction	-
		Closed season	No restriction	-
		Number of licences	-	No restriction
	Long line	-	No restriction	-
	Hand Line	-	No restriction	-
	Trap and fence	-	No restriction	-
	Cast Net	-	No restriction	-
Rivers and dams	Long line	-	No restriction	-
	Hand line	-	No restriction	-
	Beach seine	Prohibited		

Area	Operation	Restriction	Minimum	Maximum
River mouth	Seine net	Prohibited		
	Weir	-	Gap (third of river width)	-
Other restrictions				
	Fish poisons	Prohibited	-	-
	Dynamite	Prohibited	-	-
	Electrical fishing	Prohibited	-	-
	Water hyacinth (introduction onto water bodies, etc.)	Prohibited	-	-
Species size restrictions				
	All species of Chambo (genus *Oreochromis*, sub-genus *Nyasalapia*)	-	150 mm fork length (to be increased)	-
	Other tilapia (*Tilapia* spp. And genus *Oreochromis*, subgenus *Nyasalapia*)	-	100 mm fork length (to be increased)	-
	Mpasa (*Opsaridium microlepis*)	-	300 mm fork length	-
Aquaculture	Fish farms over 2 ha	-	Aquaculture permit	-
	Fish for export	-	Aquaculture permit	-
	Other fish farms	-	No restriction	-
	Movement of live fish	-	Prohibited	-
	Species restrictions	-	Carp and exotics	-
Aquarium trade		Number of licences	-	Three

Appendix 2.1 Attribute Scores for Rapfish analysis of Lake Malawi fisheries.

Fishery	ECOLOGICAL	exploitation status	recruitment variability	trophic level	change in trophic level	migratory range	range collapse	size of fish	catch < maturity	discarded bycatch	species caught	primary production
Ch85	1	1.0	0.0	2.1	1.0	0.3	1.0	1.5	1.0	1.2	1.5	3.0
Otil85	2	1.0	1.0	2.0	1.0	0.3	0.0	1.5	1.0	1.0	1.5	3.0
Ka85	3	1.0	0.5	2.2	1.0	0.4	0.0	1.5	1.0	1.1	1.5	2.8
Ut85	4	0.8	1.0	2.8	1.0	0.5	0.0	1.5	1.0	1.4	1.5	2.8
Chis85	5	1.0	1.0	2.4	1.0	0.5	0.0	1.5	1.0	1.0	1.5	2.8
Kam85	6	1.0	0.0	3.8	1.0	0.5	0.0	1.0	0.8	0.1	1.3	2.5
Mla85	7	1.0	1.0	2.7	1.0	0.5	0.0	1.0	0.8	0.1	1.3	2.8
Usi85	8	0.5	0.0	3.0	1.0	0.5	0.0	1.0	0.0	0.2	1.4	2.5
Nch85	9	2.0	1.0	2.0	1.0	0.2	0.8	1.0	0.5	0.0	1.2	2.8
Mpa85	10	1.5	1.0	3.7	1.0	0.8	0.8	1.0	0.5	0.0	1.2	2.5
San85	11	1.5	1.0	3.7	1.0	0.8	0.8	1.0	0.5	0.0	1.2	2.5
Os85	12	0.8	1.0	3.2	1.0	0.3	0.0	1.0	0.0	0.1	1.1	2.5
Ch90	13	2.0	0.0	2.1	1.5	0.3	1.5	1.8	1.0	1.2	1.5	3.0
Otil90	14	1.5	1.0	2.0	1.5	0.3	0.5	1.8	1.0	1.0	1.5	3.0
Ka90	15	1.5	0.5	2.2	1.5	0.4	0.5	1.8	1.0	1.1	1.5	2.8
Ut90	16	1.0	1.0	2.8	1.5	0.5	0.0	1.8	1.0	1.4	1.5	2.8
Chis90	17	1.5	1.0	2.4	1.5	0.5	0.3	1.8	1.0	1.0	1.5	2.8
Kam90	18	1.5	0.0	3.8	1.5	0.5	0.0	1.8	1.0	0.1	1.3	2.5
Mla90	19	1.5	1.0	2.7	1.5	0.5	0.0	1.0	1.0	0.1	1.3	2.8
Usi90	20	1.0	0.0	3.0	1.5	0.5	0.0	1.0	0.0	0.2	1.4	2.5
Nch90	21	2.3	1.0	2.0	1.5	0.2	1.0	1.0	0.8	0.0	1.2	2.8
Mpa90	22	2.0	1.0	3.7	1.5	0.8	1.0	1.0	0.8	0.0	1.2	2.5
San90	23	2.0	1.0	3.7	1.5	0.8	1.0	1.0	0.8	0.0	1.2	2.5
Os90	24	1.0	1.0	3.2	1.5	0.3	0.3	1.0	1.0	0.1	1.1	2.5
Ch95	25	2.5	0.0	2.1	2.0	0.3	2.0	2.0	1.1	1.2	1.5	3.0
Otil95	26	2.0	1.0	2.0	2.0	0.3	1.0	2.0	1.1	1.0	1.5	3.0
Ka95	27	1.8	0.5	2.2	2.0	0.4	1.0	2.0	1.1	1.1	1.5	2.8
Ut95	28	1.8	1.0	2.8	2.0	0.5	0.3	2.0	1.1	1.4	1.5	2.8
Chis95	29	2.0	1.0	2.4	2.0	0.5	0.5	2.0	1.1	1.0	1.5	2.8
Kam95	30	1.8	0.0	3.8	2.0	0.5	0.3	1.0	1.0	0.1	1.3	2.5
Mla95	31	1.8	1.0	2.7	2.0	0.5	0.3	1.0	1.0	0.1	1.3	2.8
Usi95	32	1.5	0.0	3.0	2.0	0.5	0.3	1.0	0.0	0.2	1.4	2.5
Nch95	33	2.8	1.0	2.0	2.0	0.2	1.0	1.0	1.0	0.0	1.2	2.8
Mpa95	34	2.5	1.0	3.7	2.0	0.8	1.5	1.0	1.0	0.0	1.2	2.5
San95	35	2.5	1.0	3.7	2.0	0.8	1.5	1.0	1.0	0.0	1.2	2.5
Os95	36	1.5	1.0	3.2	2.0	0.3	0.3	1.0	1.0	0.1	1.1	2.5
Com	37	1.5	0.7	2.9	2.0	0.5	0.5	1.7	1.0	0.7	1.4	2.8
Semc	38	1.8	0.4	2.8	2.0	0.5	0.8	1.5	1.0	0.6	1.3	2.9
Cs	39	1.7	0.0	2.1	2.0	0.3	1.5	2.0	1.1	1.3	1.5	3.0
Ks	40	1.5	0.5	2.2	2.0	0.4	1.0	2.0	1.3	1.3	1.5	2.9
Gn	41	1.0	0.7	2.7	2.0	0.4	0.9	1.3	0.0	1.2	0.3	3.0
Pt	42	1.8	0.4	2.6	2.0	0.5	0.9	1.5	1.0	0.1	1.3	2.9
Mwt	43	0.9	0.8	3.0	2.0	0.5	0.3	1.5	1.0	0.0	1.5	2.8

Fishery	ECONOMIC	price US$/tonne	fisheries in GDP	GDP/person	limited entry	marketable right	other income	sector employment	ownership	market	subsidies
Ch85	1	1.4	0.2	155.0	0.5	0.0	3.0	1.2	0.0	0.8	0.0
Otil85	2	1.3	0.0	155.0	0.5	0.0	3.0	1.1	0.0	0.0	0.0
Ka85	3	1.3	0.0	155.0	0.5	0.0	3.0	1.2	0.0	0.0	0.0
Ut85	4	0.2	0.1	155.0	0.5	0.0	3.0	1.2	0.0	0.0	0.0
Chis85	5	1.4	0.0	155.0	0.5	0.0	3.0	1.1	0.0	0.0	0.0
Kam85	6	1.4	0.0	155.0	0.5	0.0	3.0	1.2	0.0	0.3	0.0
Mla85	7	1.4	0.0	155.0	0.5	0.0	3.0	1.2	0.0	0.3	0.0
Usi85	8	1.4	0.0	155.0	0.5	0.0	2.0	1.2	0.0	0.3	0.0
Nch85	9	0.2	0.0	155.0	0.5	0.0	2.0	1.1	0.0	0.1	0.0
Mpa85	10	2.1	0.0	155.0	0.5	0.0	2.0	1.1	0.0	0.0	0.0
San85	11	1.3	0.0	155.0	0.5	0.0	2.0	1.1	0.0	0.0	0.0
Os85	12	0.2	0.0	155.0	0.5	0.0	3.0	1.2	0.0	0.3	0.0
Ch90	13	1.4	0.2	140.0	0.3	0.0	3.0	1.2	0.0	0.8	0.0
Otil90	14	1.3	0.0	140.0	0.3	0.0	3.0	1.1	0.0	0.0	0.0
Ka90	15	1.3	0.1	140.0	0.3	0.0	3.0	1.2	0.0	0.0	0.0
Ut90	16	1.3	0.4	140.0	0.3	0.0	3.0	1.2	0.0	0.0	0.0
Chis90	17	1.4	0.0	140.0	0.3	0.0	3.0	1.1	0.0	0.0	0.0
Kam90	18	1.3	0.1	140.0	0.3	0.0	3.0	1.2	0.0	0.3	0.0
Mla90	19	1.3	0.0	140.0	0.3	0.0	3.0	1.2	0.0	0.3	0.0
Usi90	20	1.3	0.1	140.0	0.3	0.0	2.0	1.2	0.0	0.3	0.0
Nch90	21	1.3	0.0	140.0	0.3	0.0	2.0	1.1	0.0	0.0	0.0
Mpa90	22	1.6	0.0	140.0	0.3	0.0	2.0	1.1	0.0	0.0	0.0
San90	23	1.5	0.0	140.0	0.3	0.0	2.0	1.1	0.0	0.0	0.0
Os90	24	1.3	0.1	140.0	0.3	0.0	3.0	1.2	0.0	0.3	0.0
Ch95	25	1.7	0.1	132.0	0.0	0.0	3.0	1.2	0.0	0.8	0.0
Otil95	26	1.5	0.0	132.0	0.0	0.0	3.0	1.1	0.0	0.0	0.0
Ka95	27	0.2	0.0	132.0	0.0	0.0	3.0	1.2	0.0	0.0	0.0
Ut95	28	1.3	0.2	132.0	0.0	0.0	3.0	1.2	0.0	0.0	0.0
Chis95	29	1.5	0.0	132.0	0.0	0.0	3.0	1.1	0.0	0.0	0.0
Kam95	30	1.5	0.1	132.0	0.0	0.0	3.0	1.2	0.0	0.3	0.0
Mla95	31	1.6	0.0	132.0	0.0	0.0	3.0	1.2	0.0	0.3	0.0
Usi95	32	1.5	0.4	132.0	0.0	0.0	2.0	1.2	0.0	0.3	0.0
Nch95	33	1.8	0.0	132.0	0.0	0.0	2.0	1.1	0.0	0.0	0.0
Mpa95	34	2.1	0.0	132.0	0.0	0.0	2.0	1.1	0.0	0.0	0.0
San95	35	1.6	0.0	132.0	0.0	0.0	2.0	1.1	0.0	0.0	0.0
Os95	36	1.4	0.1	132.0	0.0	0.0	3.0	1.2	0.0	0.3	0.0
Com	37	1.5	0.2	132.0	2.0	0.1	3.0	1.0	0.5	0.8	1.0
Semc	38	1.5	0.1	132.0	2.0	0.0	3.0	1.1	0.0	0.3	0.3
Cs	39	1.4	0.1	132.0	0.3	0.0	2.0	1.2	0.0	0.5	0.0
Ks	40	0.2	0.1	132.0	0.3	0.0	2.0	1.2	0.0	0.0	0.0
Gn	41	1.4	0.4	132.0	0.3	0.0	2.0	1.2	0.0	0.5	0.0
Pt	42	1.5	0.1	132.0	2.0	0.1	3.0	1.1	0.0	0.3	0.5
Mwt	43	1.5	0.2	132.0	2.0	0.1	3.0	1.0	0.3	0.3	1.0

Fishery	SOCIOLOGICAL	socialization of fishing	fishing community growth	fishing sector	environmental knowledge	education level	conflict status	fisher influence	fishing income	kin participation
Ch85	1	1.5	0.8	1.5	0.3	0.8	1.0	0.0	1.6	1.0
Otil85	2	1.5	0.8	1.3	0.3	0.8	1.0	0.0	1.6	1.0
Ka85	3	1.8	0.8	1.3	0.3	0.8	1.0	0.0	1.6	1.0
Ut85	4	1.8	0.8	1.3	0.3	0.8	1.0	0.0	1.6	1.0
Chis85	5	1.5	0.8	1.3	0.3	0.8	1.0	0.0	1.6	1.0
Kam85	6	1.3	0.8	1.3	0.3	0.8	1.0	0.0	1.6	1.0
Mla85	7	1.3	0.8	1.3	0.3	0.8	1.0	0.0	1.6	1.0
Usi85	8	1.8	0.8	1.3	0.3	0.8	1.0	0.0	1.6	1.0
Nch85	9	1.3	0.8	1.3	0.3	0.8	1.0	0.0	1.0	0.8
Mpa85	10	1.3	0.8	1.3	0.3	0.8	1.0	0.0	1.0	0.8
San85	11	1.3	0.8	1.3	0.3	0.8	1.0	0.0	1.0	0.8
Os85	12	1.5	0.8	1.3	0.3	0.8	1.0	0.0	1.0	1.0
Ch90	13	1.5	1.0	1.5	1.0	1.0	1.0	0.0	1.6	1.0
Otil90	14	1.5	1.0	1.5	1.0	1.0	1.0	0.0	1.6	1.0
Ka90	15	1.8	1.0	1.5	1.0	1.0	1.0	0.0	1.6	1.0
Ut90	16	1.8	1.0	1.5	1.0	1.0	1.0	0.0	1.6	1.0
Chis90	17	1.5	1.0	1.5	1.0	1.0	1.0	0.0	1.6	1.0
Kam90	18	1.3	1.0	1.5	1.0	1.0	1.0	0.0	1.6	1.0
Mla90	19	1.3	1.0	1.5	1.0	1.0	1.0	0.0	1.6	1.0
Usi90	20	1.8	1.0	1.5	1.0	1.0	1.0	0.0	1.6	1.0
Nch90	21	1.3	1.0	1.5	1.0	1.0	1.0	0.0	1.0	0.8
Mpa90	22	1.3	1.0	1.5	1.0	1.0	1.0	0.0	1.0	0.8
San90	23	1.3	1.0	1.5	1.0	1.0	1.0	0.0	1.0	0.8
Os90	24	1.5	1.0	1.5	1.0	1.0	1.0	0.0	1.0	1.0
Ch95	25	1.5	2.0	1.7	1.0	1.0	1.0	0.5	1.6	1.0
Otil95	26	1.5	2.0	1.7	1.0	1.0	1.0	0.5	1.6	1.0
Ka95	27	1.8	2.0	1.7	1.0	1.0	1.0	0.5	1.6	1.0
Ut95	28	1.8	2.0	1.7	1.0	1.0	1.0	0.5	1.6	1.0
Chis95	29	1.5	2.0	1.7	1.0	1.0	1.0	0.5	1.6	1.0
Kam95	30	1.3	2.0	1.7	1.0	1.0	1.0	0.5	1.6	1.0
Mla95	31	1.3	2.0	1.7	1.0	1.0	1.0	0.5	1.6	1.0
Usi95	32	1.8	2.0	1.7	1.0	1.0	1.0	0.5	1.6	1.0
Nch95	33	1.3	2.0	1.7	1.0	1.0	1.0	0.5	1.0	0.8
Mpa95	34	1.3	2.0	1.7	1.0	1.0	1.0	0.5	1.0	0.8
San95	35	1.3	2.0	1.7	1.0	1.0	1.0	0.5	1.0	0.8
Os95	36	1.5	2.0	1.7	1.0	1.0	1.0	0.5	1.0	1.0
Com	37	0.0	2.0	2.0	2.0	2.0	2.0	1.0	2.0	0.0
Semc	38	1.0	2.0	2.0	2.0	2.0	2.0	1.0	2.0	0.0
Cs	39	1.5	2.0	1.3	1.0	1.0	2.0	0.5	1.6	1.0
Ks	40	1.5	2.0	1.3	1.0	1.0	1.0	0.5	1.6	1.0
Gn	41	1.3	2.0	1.3	1.0	1.0	1.0	0.5	1.6	0.9
Pt	42	0.8	2.0	2.0	2.0	2.0	2.0	1.0	2.0	0.0
Mwt	43	0.3	2.0	2.0	2.0	2.0	2.0	1.0	2.0	0.0

Fishery	TECHNOLOGICAL	trip length	landing sites	pre-sale processing	use of ice	gear	selective gear	power gear	FADS	Sonar	Vessel Size	catching power	effects of gear
Ch85	1	1.0	0.8	0.8	0.5	0.5	0.7	0.5	0.3	0.0	0.0	1.0	0.3
Otil85	2	1.0	0.3	0.5	0.5	0.5	0.5	0.3	0.0	0.0	0.0	1.0	0.5
Ka85	3	1.0	0.5	0.5	0.5	1.0	0.3	0.3	0.0	0.0	0.0	1.0	1.0
Ut85	4	1.3	0.5	0.5	0.5	1.0	0.6	0.8	0.0	0.0	0.0	1.0	0.5
Chis85	5	1.3	0.5	0.5	0.5	1.0	0.6	0.8	0.0	0.0	0.0	1.0	0.5
Kam85	6	1.3	0.8	0.8	0.8	0.5	0.7	0.5	0.5	0.0	0.0	1.0	0.5
Mla85	7	1.3	0.0	0.5	0.8	0.3	0.7	0.3	0.5	0.0	0.0	1.0	0.3
Usi85	8	1.3	0.5	0.5	0.5	1.0	0.3	0.3	0.3	0.0	0.0	1.0	1.0
Nch85	9	1.3	0.8	0.0	0.0	0.3	0.5	0.0	0.0	0.0	0.0	1.0	1.0
Mpa85	10	1.3	0.8	0.4	0.0	0.0	0.5	0.0	0.0	0.0	0.0	1.0	0.3
San85	11	1.3	0.8	0.4	0.0	0.0	0.5	0.0	0.0	0.0	0.0	1.0	0.5
Os85	12	1.0	0.0	0.5	0.3	1.0	0.5	0.3	0.0	0.0	0.0	1.0	0.8
Ch90	13	1.0	0.8	0.8	0.8	0.8	0.7	0.5	0.3	0.0	0.0	2.0	0.8
Otil90	14	1.0	0.3	0.5	0.8	0.8	0.5	0.3	0.0	0.0	0.0	2.0	0.8
Ka90	15	1.0	0.5	0.5	0.8	1.0	0.3	0.3	0.0	0.0	0.0	2.0	1.0
Ut90	16	1.3	0.5	0.5	0.8	1.0	0.6	0.8	0.0	0.0	0.0	2.0	0.8
Chis90	17	1.3	0.5	0.5	0.8	1.0	0.6	0.8	0.0	0.0	0.0	2.0	0.8
Kam90	18	1.3	0.8	0.8	1.0	0.8	0.7	0.5	0.5	0.0	0.0	2.0	0.5
Mla90	19	1.3	0.0	0.5	0.8	0.5	0.7	0.3	0.5	0.0	0.0	2.0	0.3
Usi90	20	1.3	0.5	0.5	0.5	1.0	0.3	0.3	0.3	0.0	0.0	2.0	1.0
Nch90	21	1.3	0.8	0.0	0.0	0.3	0.5	0.0	0.0	0.0	0.0	2.0	1.0
Mpa90	22	1.3	0.8	0.4	0.0	0.0	0.5	0.0	0.0	0.0	0.0	2.0	0.5
San90	23	1.3	0.8	0.4	0.0	0.0	0.5	0.0	0.0	0.0	0.0	2.0	0.5
Os90	24	1.0	0.0	0.5	0.5	1.0	0.5	0.3	0.0	0.0	0.0	2.0	1.0
Ch95	25	1.0	0.8	0.8	1.0	0.8	0.7	0.5	0.3	0.0	0.0	2.0	0.9
Otil95	26	1.0	0.3	0.5	1.0	0.8	0.5	0.3	0.0	0.0	0.0	2.0	1.0
Ka95	27	1.0	0.5	0.5	1.0	1.0	0.3	0.3	0.0	0.0	0.0	2.0	1.0
Ut95	28	1.3	0.5	0.5	1.0	1.0	0.6	0.8	0.0	0.0	0.0	2.0	1.0
Chis95	29	1.3	0.5	0.5	1.0	1.0	0.6	0.8	0.0	0.0	0.0	2.0	1.0
Kam95	30	1.3	0.8	0.8	1.0	0.9	0.7	0.5	0.5	0.0	0.0	2.0	0.5
Mla95	31	1.3	0.0	0.5	0.8	0.5	0.7	0.3	0.5	0.0	0.0	2.0	0.3
Usi95	32	1.3	0.8	0.5	0.5	1.0	0.3	0.3	0.3	0.0	0.0	2.0	1.0
Nch95	33	1.3	0.8	0.0	0.3	0.5	0.5	0.0	0.0	0.0	0.0	2.0	1.0
Mpa95	34	1.3	0.8	0.4	0.3	0.3	0.5	0.0	0.0	0.0	0.0	2.0	0.8
San95	35	1.3	0.8	0.4	0.3	0.3	0.5	0.0	0.0	0.0	0.0	2.0	0.8
Os95	36	1.0	0.0	0.5	0.5	1.0	0.5	0.3	0.0	0.0	0.0	2.0	1.0
Com	37	1.5	2.0	1.0	2.0	1.0	0.7	1.0	0.0	1.0	2.0	2.0	0.8
Semc	38	1.5	1.0	0.5	1.0	1.0	0.6	1.0	0.0	0.0	1.0	2.0	1.0
Cs	39	1.0	0.5	0.5	0.5	1.0	0.7	0.0	0.3	0.0	0.3	1.0	0.9
Ks	40	1.0	0.5	0.5	0.5	1.0	0.3	0.3	0.0	0.0	0.3	1.0	1.0
Gn	41	1.3	0.3	0.5	0.5	0.0	0.7	0.0	0.0	0.0	0.0	1.0	0.0
Pt	42	1.5	1.0	0.5	1.5	1.0	0.6	1.0	0.0	0.5	1.0	2.0	1.0
Mwt	43	1.8	2.0	1.0	1.8	1.0	0.6	1.0	0.0	1.0	1.5	2.0	0.8

Fishery	ETHICAL	Adjacency & Reliance	Alternatives	Equity in Entry	Just Management	Influences in Ethical Formation	Mitigation of Habitat Destruction	Mitigation of Ecosystem Depletion	Illegal Fishing	Discards and wastes
Ch85	1	3.0	0.1	0.3	0.0	3.0	2.0	0.8	0.8	0.0
Otil85	2	3.0	0.1	1.0	0.0	3.0	2.0	0.8	0.8	0.0
Ka85	3	3.0	0.1	1.0	0.0	3.0	2.0	0.5	0.8	0.1
Ut85	4	3.0	0.1	1.0	0.0	3.0	2.0	1.0	0.8	0.1
Chis85	5	2.0	0.1	1.0	0.0	3.0	2.0	1.0	0.8	0.1
Kam85	6	3.0	0.3	1.0	0.0	3.0	2.0	1.0	0.3	0.0
Mla85	7	3.0	0.3	1.0	0.0	3.0	2.0	1.0	0.3	0.0
Usi85	8	3.0	0.3	1.0	0.0	3.0	2.0	1.0	0.8	0.1
Nch85	9	3.0	0.5	1.0	0.0	3.0	2.0	1.0	0.8	0.0
Mpa85	10	3.0	0.8	1.0	0.0	3.0	2.0	1.0	0.8	0.0
San85	11	3.0	0.8	1.0	0.0	3.0	2.0	1.0	0.8	0.0
Os85	12	3.0	0.3	1.0	0.0	3.0	2.0	1.0	0.8	0.0
Ch90	13	3.0	0.0	0.0	0.0	3.0	1.0	0.8	1.0	0.0
Otil90	14	3.0	0.0	0.0	0.0	3.0	1.0	0.8	1.0	0.0
Ka90	15	3.0	0.0	0.0	0.0	3.0	1.0	0.5	1.0	0.1
Ut90	16	3.0	0.0	0.0	0.0	3.0	1.0	1.0	1.0	0.1
Chis90	17	3.0	0.0	0.0	0.0	3.0	1.0	1.0	1.0	0.1
Kam90	18	3.0	0.0	0.0	0.0	3.0	1.5	1.0	0.3	0.0
Mla90	19	3.0	0.0	1.0	0.0	3.0	1.5	1.0	0.3	0.0
Usi90	20	3.0	0.0	0.0	0.0	3.0	1.0	1.0	1.0	0.1
Nch90	21	3.0	0.3	0.0	0.0	3.0	1.0	1.0	1.0	0.0
Mpa90	22	3.0	0.5	1.0	0.0	3.0	1.0	1.0	1.0	0.0
San90	23	3.0	0.5	1.0	0.0	3.0	1.0	1.0	1.0	0.0
Os90	24	3.0	0.0	0.0	0.0	3.0	1.0	1.0	1.0	0.0
Ch95	25	2.0	0.0	0.0	0.3	3.0	0.3	0.8	1.3	0.0
Otil95	26	2.0	0.0	0.0	0.3	3.0	0.3	0.8	1.3	0.0
Ka95	27	2.0	0.0	0.0	0.3	3.0	0.0	0.5	1.3	0.1
Ut95	28	3.0	0.0	0.0	0.5	3.0	0.8	1.0	1.3	0.1
Chis95	29	2.0	0.0	0.0	0.5	3.0	0.8	1.0	1.3	0.1
Kam95	30	2.5	0.0	0.0	0.0	3.0	1.0	1.0	0.3	0.0
Mla95	31	3.0	0.0	1.0	0.0	3.0	1.0	1.0	0.3	0.0
Usi95	32	2.0	0.0	0.0	0.0	3.0	0.5	1.0	1.3	0.1
Nch95	33	3.0	0.0	0.0	0.0	3.0	1.0	1.0	1.3	0.0
Mpa95	34	3.0	0.0	1.0	0.0	3.0	0.5	1.0	1.3	0.0
San95	35	3.0	0.0	1.0	0.0	3.0	0.5	1.0	1.3	0.0
Os95	36	2.0	0.0	0.0	0.3	3.0	0.3	1.0	1.3	0.0
Com	37	1.0	0.5	0.0	1.0	2.0	1.0	0.8	0.3	0.0
Semc	38	2.0	0.0	0.0	1.0	2.0	1.0	0.8	1.0	0.0
Cs	39	3.0	0.0	1.0	0.0	3.0	0.5	0.5	1.0	0.0
Ks	40	3.0	0.0	1.0	0.0	3.0	0.0	0.3	1.0	0.3
Gn	41	3.0	0.0	1.0	0.0	3.0	2.0	2.0	0.8	0.0
Pt	42	2.0	0.3	0.0	1.0	2.0	1.0	0.8	1.0	0.0
Mwt	43	1.0	0.3	0.0	1.0	2.0	1.0	0.8	0.5	0.0

Appendix 2.2 Rapid appraisal technique (Rapfish)[22] development.

The technique

Rapfish is rapid appraisal technique designed to allow an objective multidisciplinary evaluation, but it not intended to replace conventional stock assessment for setting quotas etc. Rapfish accommodates human dimension intertwined with the gear, vessels, markets, biological and economic sustainability, management, allocation and rebuilding of depleted stocks (giving fisheries its truly multidisciplinary face). It is becoming abundantly clear that fisheries management is as much about managing human behavior as about fish ecology (Jentoft 1998).

Definition of fisheries

The method is flexible about the scope of fisheries included in the analysis. Ordination can be of a set of fisheries, or trajectory in time of a single fishery or both. Snapshots of a fishery in time may be taken at regular intervals (one, five-years, etc.) or at points when major shifts are known to have occurred. Points which plot very close together, or even fall at identical locations on the ordination, will not disrupt the analysis.

An actual scope of a fishery chosen may be all of the fisheries in a country or lake compared en masse with those of other countries and lakes, or comparison of fisheries based on two different species using the same gear type and on the same vessel.

Attributes and data

Work using Rapfish so far has ordinated fisheries in four disciplinary areas that are critical to long term viability of a fishery, including some of the parameters:

- Ecological (fish population and environment)
- Technological (gear and fishing characteristics)
- Economic (micro and macro economic factors)
- Sociological (social and anthropological factors)

In the present case, ethical attributes (covering judicial and fairness factors) are included.

Within each ordination, a set of 8-12 attributes is defined. Attribute numbers are designed to maximize discriminating power in the ordination technique, where a rule of thumb is to have three times as many fisheries as attribute used to ordinate them (Stalans 1995). Criteria for choosing attributes are that they are easily and objectively scored, and that extreme values are easily ascribed to 'good' and 'bad' in relation to sustainability, and that scores are available for all the fisheries and time periods in the analysis.

Fixed reference points

To provide ordination with fixed reference points, status is assessed relative to the best and worst possible fisheries that may be constructed from the set of attributes for each discipline. Choosing extreme scores for each attribute simulates two

[22] Edited excerpt from Pitcher and Preikshot (1999).

hypothetical fisheries, 'good' and 'bad'. Note that 'good' and 'bad' are evaluated in terms of the sustainability of the fishery within the discipline. If the scores cannot be easily assigned to an attribute then the attribute itself may not be useful for the Rapfish analysis. The 'good' and 'bad' fisheries are generally plotted on the final ordination, and their positions are used to rotate the plot and calculate percentage changes.

Random reference points

In addition, twenty random sets of attribute scores ('random' fisheries) are simulated for each discipline. Values are chosen at random from the score range for each attribute and 'entered' as fisheries in the ordination. The objective here is to show if status evaluations are meaningful, since any fishery locations that lie inside the 'random' area could have arisen by chance. More than twenty random points might be chosen to improve statistical rigor, but there are limits because most ordination methods allow only about 100 data points to be included.

After pilot work, in which the random fisheries ordination positions were shown to be normally distributed about zero (Pitcher et al. 1998b), individual random fisheries have been replaced by the mean and 95 % confidence limits. These are usually represented as crossed lines on the final ordination plot. Further more, by convention the ordination plot is recentred to the zero of the random points.

Combined interdisciplinary ordination

Two ordination scores from each analysis, making a total of ten scores given five (in this study) disciplinary analyses may be used as input data for a combined inter-disciplinary ordination. This effectively provides an unweighted evaluation of sustainability status among disciplines.

Whether this evaluation is useful for decision making depends on the view of the user. For example, fisheries that score highly in status on the ecological area, may score poorly in economic terms. The combined ordination will tend to average out these differences.

Ordination method

Currently the non-parametric multidimensional scaling, MDS (Kruskal and Wish 1978; Schiffman et al. 1981; Stalans 1995), an ordination technique that can produce unbiased distance 'maps' of relative location (Clarke 1993) is used. These maps may be rotated and shifted linearly with minimal disruption (Clarke and Warwick 1997).

A squared Euclidean distance matrix with attribute scores normalized using z-values is employed because it has been shown to produce least disruption monotonicity. MDS for ratio data in two dimensions is carried for all the fishery points including the 'good', 'bad', and 20 'random' fisheries. The SPSS statistical package (SPSS 1996) and the PREMER package (Carr 1997) are used. Goodness-of-fit is evaluated using stress values (values below 0.25 are considered acceptable by Clarke and Warwick 1997).

Rotation and display of results

Conventionally, it is expected that a fall in quality or status to be represented graphically as a line falling from top left to bottom right. Accordingly, after ordination, a convention to rotate plots (to a least squares criterion) so that 'good' appears at top left (azimuth 315 degrees, relative to straight up as zero) and 'bad' at the lower right (azimuth 135 degrees) is adopted. The MDS ordination technique allows this rotation because it does not bias the relative map position of the points.

In pilot work, all cases of 'good' and 'bad' points fell close to a straight line through the plot origin, and so, given the monotonicity described as a validation below, it is justified to interpret this as an axis of sustainability. Hence by rotating the plot using least squares until 'good' and 'bad' lie at positions nearest to 90 and 270 degrees, status position along this axis can be shown. Changes in status of a fishery with time, comparisons of status among fisheries, can then be represented as percentage of the extent of the axis from 'good' to 'bad'. At the same time, changes normal to axis (and normal to the top/bottom right axis of original plot) represent changes in fishery status that are not reflected in sustainability.

Ordination axes: attribute-loading estimation

To examine which attributes most influenced an ordination, the plots are rotated using least squares until 'good' and 'bad' lies at 90 and 270 degrees, as described above. The x-axis is then taken as the dependent variable in a multiple regression with the normalized attributes as the independent variables. Regression coefficients that are significant show relationships of the original attributes to the sustainability axis. Because of the non-parametric nature of the MDS technique, these relationships hold only for an individual ordination and do not transfer to other analyses. An alternative method is to use multiple regression (e.g. in the canonical correlation package of Statistica; Statsoft 1996). Such analysis allows the interpretation of the meaning of derived axes from the attributes most highly correlated with them (Stalans 1995). High negative correlations imply that when a particular attribute score was for any fishery, it was likely to score high on an ordination axis. It is important to remember, though, that the correlations may not be interpreted singly, for they determine the MDS axes jointly (James and McCulloch 1990).

Ordination clustering

Cluster analysis of the ordinated points can be used to group the ordinated fisheries in a mathematically objective fashion. A useful technique here is to promote 'clumpness' using the complete Euclidean distance rule (e.g. using the CA package of the Statistica package; Statsoft 1996), which creates groups by identifying each member's furthest neighbours. The first four or five readily identifiable groups may be chosen as convenient, since there are no clearly accepted rules for defining what constitutes a mathematical 'group' in such investigations (Cooper and Weekes 1983). Tools such as amalgamation schedules (in CA package of the Statistica package; Statsoft 1996) may be used to judge the amount of variation explained by creating more groups. If such plot shows little new variation being explained by adding extra groups then the linkage distance is essentially the same (Statsoft 1995).

Appendix 2.3 Procedural steps[23] in Rapfish.

1. Attributes of fisheries are scored for each discipline. If more than one person provided the scores, consistency among partners in scoring is checked. Minimum and maximum values for each attribute are saved.
2. 'GOOD' and 'BAD' fisheries are constructed from extremes of attribute scores as criterion of sustainability.
3. Twenty 'UGLY' fisheries are constructed with random selection of attribute scores for each discipline. Excel random number generator is used for this.
4. Fisheries in attribute space for each discipline are ordinated with MDS. Z-score attribute are normalized and Euclidean distance squared is used as the distance matrix with interval data option. Stress score of <0.25 is considered credible.
5. To recentre the ordination plot, mean of ordination scores for the random fisheries are subtracted. Median +/- 95 % tiles of randoms are saved.
6. There is a convention of rotating ordination plot to 315/135 azimuth for 'GOOD' and 'BAD' fisheries. Each set of fishery points, fishery trajectories, 'GOOD' and 'BAD' locations and randoms as a cross are plotted.
7. To express each point as a percentage of 'bad' to 'good' distance, they are rotated to 0/180.
8. In a combined interdisciplinary MDS, each pair of disciplinary ordination scores is used.

[23] These were developed by Professor T. J. Pitcher for a 1998/99 course module on Rapid Appraisal Methods for Fisheries offered at the Fisheries Centre, University of British Columbia.

Appendix 4.1 Malawi Fisheries Department fish catch statistics, 1986-1996 (in tonnes and recorded by area and by species[k]).

Area	Year	Species																	
		Chambo	Chilunguni	Kasawala	Mbaba	Mphende	Kambuzi	Utaka	Chisawasa.	Matemba	Chikanu	Kampango	Mcheni	Mlamba	Usipa	Nchila	Mpasa	Sanjika	Makumba	Other species
Lower Shire	1985	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	1986	0	0	0	0	4178	0	0	0	0	1095	0	0	1909	0	0	0	0	0	1128
	1987	0	0	0	0	3879	0	0	0	0	830	0	0	1468	0	0	0	0	0	879
	1988	0	0	0	0	4044	0	0	0	0	1073	0	0	1910	0	0	0	0	0	1142
	1989	0	0	0	0	4250	0	0	0	0	1068	0	0	2876	0	0	0	0	0	2751
	1990	0	0	0	0	3442	0	0	0	0	666	0	0	1654	0	0	0	0	0	1270
	1991	0	0	0	0	3483	0	0	0	0	920	0	0	3597	0	0	0	0	0	1048
	1992	0	0	0	0	950	0	0	0	0	416	0	0	1221	0	0	0	0	0	371
	1993	0	0	0	0	1111	0	0	0	0	463	0	0	998	0	0	0	0	0	321
	1994	0	0	0	0	618	0	0	0	0	266	0	0	656	0	0	0	0	0	214
	1995	0	0	0	0	536	0	0	0	0	303	0	0	799	0	0	0	0	0	263
	1996	0	0	0	0	465	0	0	0	0	136	0	0	792	0	0	0	0	0	455
L. Chilwa/ Chiuta	1985	0	0	0	0	0	0	0	0	8306	0	0	0	2036	0	0	0	0	2060	860
	1986	0	0	0	0	0	0	0	0	6417	0	0	0	1616	0	0	0	0	3577	2857
	1987	0	0	0	0	0	0	0	0	1672	0	0	0	1264	0	0	0	0	4289	771
	1988	0	0	0	0	0	0	0	0	1596	0	0	0	1407	0	0	0	0	3890	1519
	1989	0	0	0	0	0	0	0	0	9373	0	0	0	874	0	0	0	0	3365	661
	1990	0	0	0	0	0	0	0	0	15456	0	0	0	1535	0	0	0	0	4263	1476
	1991	0	0	0	0	0	0	0	0	2195	0	0	0	994	0	0	0	0	400	1858
	1992	0	0	0	0	0	0	0	0	3661	0	0	0	2904	0	0	0	0	6417	5197
	1993	0	0	0	0	0	0	0	0	6121	0	0	0	2957	0	0	0	0	2725	2709
	1994	0	0	0	0	0	0	0	0	6639	0	0	0	2492	0	0	0	0	2510	1738
	1995	0	0	0	0	0	0	0	0	38	0	0	0	1480	0	0	0	0	252	650
	1996	0	0	0	0	0	0	0	0	4	0	0	0	1087	0	0	0	0	838	1651

[k]The species names include Juvenile *Oreochromis* (Kasawala), *Protomelas kirkii* and other species (Mbaba), *Oreochromis shiranus* (Mphende), *Clarias ngamensis* (Chikanu), *Ramphochromis* spp. (Mcheni) in addition to those in Table 2.1 (see also appendices 1.1, 1.2 and 1.3).

Area	Year	Chambo	Chilunguni	Kasawala	Mbaba	Mphende	Kambuzi	Utaka	Chisawasa.	Matemba	Chikanu	Kampango	Mcheni	Mlamba	Usipa	Nchila	Mpasa	Sanjika	Makumba	Other species
L. Malombe	1985	5296	34	0	0	0	2475	0	0	0	0	159	0	122	57	39	0	0	0	334
	1986	5292	45	0	0	0	6753	207	0	0	0	270	0	276	127	47	0	0	0	420
	1987	2366	127	0	0	0	7400	2246	2	0	0	178	0	238	12	74	0	0	0	370
	1988	2046	178	0	0	0	6405	506	1	0	0	121	0	117	86	200	0	0	0	498
	1989	1460	229	0	0	0	3669	541	2	0	0	219	0	195	38	65	0	0	0	618
	1990	1561	242	0	0	0	7893	715	0	0	0	580	0	239	410	53	0	0	0	969
	1991	566	113	0	0	0	5192	835	2	0	0	430	0	366	50	223	0	0	0	702
	1992	590	149	0	0	0	5739	407	0	0	0	92	0	145	44	23	0	0	0	843
	1993	65	114	0	621	0	5273	14	0	0	0	72	0	124	16	12	0	0	0	331
	1994	86	55	0	427	0	3517	0	0	0	0	49	0	99	16	1	0	0	0	582
	1995	110	45	0	508	0	3214	0	0	0	0	75	0	92	19	0	0	0	0	500
	1996	134	28	0	588	0	2911	0	0	0	0	100	0	84	21	6	0	0	0	419
L. Malawi South (Mangochi)	1985	4194	96	0	0	0	653	1258	5	0	0	262	0	199	1820	11	0	0	0	87
	1986	3190	59	0	0	0	452	890	4	0	0	592	0	751	4412	7	0	0	0	233
	1987	2126	45	0	0	0	621	5127	68	0	0	496	0	332	2363	18	0	0	0	196
	1988	1573	13	0	0	0	1021	2144	54	0	0	154	0	397	1615	17	0	0	0	69
	1989	2632	60	0	0	0	2823	1297	0	0	0	177	0	281	6698	117	0	0	0	429
	1990	2266	43	0	0	0	2782	2237	57	0	0	160	0	353	589	5	0	0	0	828
	1991	2793	432	0	0	0	1269	1782	46	0	0	518	0	646	3042	137	0	0	0	748
	1992	2474	50	0	0	0	2601	3282	208	0	0	410	0	285	7686	23	0	0	0	664
	1993	63	114	0	0	0	5273	14		0	0	72	0	124	10	12	0	0	0	1023
	1994	960	5	0	0	0	1623	3983		0	0	113	0	52	1995	6	0	0	0	527
	1995	1346	14	0	0	0	1894	4014		0	0	107	0	84	7934	7	0	0	0	508
	1996	1732	23	0	0	0	2164	4048		0	0	101	0	115	13873	8	0	0	0	489

Species

Area	Year	Species																		
		Chambo	Chilunguni	Kasawala	Mbaba	Mphende	Kambuzi	Utaka	Chisawasa.	Matemba	Chikanu	Kampango	Mcheni	Mlamba	Usipa	Nchila	Mpasa	Sanjika	Makumba	Other species
L. Malawi	1985	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Central 1	1986	1306	166	0	0	0	795	1699	15	0	0	668	0	562	262	8	20	83	0	405
(Salima)	1987	888	75	0	0	0	824	4939	0	0	0	894	0	732	413	9	218	93	0	509
	1988	3090	115	0	0	0	1454	7585	0	0	0	1102	0	733	1441	6	483	25	0	579
	1989	1197	17	0	0	0	875	2765	0	0	0	803	0	397	598	0	70	4	0	448
	1990	398	13	0	0	0	286	2382	0	0	0	838	0	292	300	1	72	3	0	225
	1991	1147	116	0	0	0	411	1056	0	0	0	1647	0	829	1083	27	23	0	0	677
	1992	260	34	0	0	0	379	1541	0	0	0	252	0	127	1288	16	14	7	0	357
	1993	297	17	0	0	0	159	1817	0	0	0	696	0	255	908	6	38	3	0	468
	1994	339	8	0	0	0	227	1595	0	0	0	393	0	189	171	4	57	5	0	648
	1995	664	1	0	0	0	913	1427	0	0	0	1635	0	530	1746	4	76	2	0	1194
	1996	611	7	0	0	0	774	2212	0	0	0	692	0	275	2887		110	10	0	620
L. Malawi	1985	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Central 2	1986	546	71	0	0	0	53	5381	5	0	0	181	0	197	322	2	0	26	0	272
(Nkhotakota)	1987	1129	61	0	0	0	404	16600	0	0	0	376	0	422	1641	1	12	77	0	781
	1988	855	95	0	0	0	569	6087	0	0	0	276	0	448	2332	3	21	40	0	896
	1989	690	31	0	0	0	365	1665	1	0	0	191	0	272	640	45	88	44	0	383
	1990	756	218	0	0	0	807	2323	1	0	0	161	0	349	236	3	43	31	0	423
	1991	338	255	0	0	0	369	3069	0	0	0	217	0	306	186	16	17	56	0	548
	1992	1015	126	0	0	0	587	1747	5	0	0	299	0	388	768	34	73	159	0	885
	1993	1433	157	0	0	0	935	6441	8	0	0	623	0	520	1456	101	94	233	0	1255
	1994	1607	154	0	0	0	843	7144	14	0	0	751	0	542	810	153	101	54	0	1051
	1995	521	223	0	0	0	557	5249	5	0	0	445	0	636	3663	72	49	103	0	1438
	1996	500	252	0	0	0	492	3495	24	0	0	182	0	131	3125	23	6	31	0	367

Area	Year	Chambo	Chilunguni	Kasawala	Mbaba	Mphende	Kambuzi	Utaka	Chisawasa.	Matemba	Chikanu	Kampango	Mcheni	Mlamba	Usipa	Nchila	Mpasa	Sanjika	Makumba	Other species
L. Malawi	1985	87	0	0	0	0	125	1815	56	0	0	202	0	141	722	8	0	0	0	157
North 1	1986	94	1	0	0	0	46	2093	58	0	0	115	0	133	795	5	0	5	0	139
(NkhataBay)	1987	71	21	0	0	0	16	2567	38	0	0	327	0	229	979	5	0	9	0	229
	1988	116	0	0	0	0	30	2213	31	0	0	257	0	299	281	102	3	19	0	254
	1989	178	0	0	0	0	58	1442	29	0	0	286	0	377	1919	3	2	68	0	255
	1990	86	0	0	0	0	134	2997	52	0	0	395	0	263	447	11	12	38	0	312
	1991	83	5	0	0	0	17	2032	103	0	0	244	0	355	223	7	3	35	0	371
	1992	33	0	0	0	0	11	1195	55	0	0	270	0	239	2009	114	18	33	0	1306
	1993	59	4	0	0	0	12	1214	31	0	0	353	0	358	1549	20	17	55	0	610
	1994	33	26	0	0	0	6	896	119	0	0	283	353	355	4152	53	12	31	0	871
	1995	28	36	0	0	0	26	959	63	0	0	265	443	259	5557	26	11	70	0	418
	1996	57	20	0	0	0	7	1311	118	0	0	294	113	425	4307	0	9	36	0	893
L. Malawi	1985	198	3	0	0	0	37	480	96	0	0	91	0	73	133	2	0	0	0	130
North 2	1986	117	2	0	0	0	26	463	48	0	0	79	0	34	75	3	1	14	0	118
(Karonga)	1987	149	2	0	0	0	25	281	15	0	0	118	0	57	261	2	15	40	0	230
	1988	34	2	0	0	0	10	294	15	0	0	73	0	43	652	2	11	6	0	317
	1989	63	1	0	0	0	26	675	23	0	0	119	0	67	62	3	21	23	0	182
	1990	75	1	0	0	0	68	664	92	0	0	149	0	55	44	2	18	25	0	325
	1991	103	0	0	0	0	94	758	43	0	0	126	0	88	31	5	31	18	0	353
	1992	74	0	0	0	0	94	694	89	0	0	122	0	36	771	4	32	31	0	291
	1993	82	12	0	0	0	32	436	125	0	0	88	0	55	1097	1	15	55	0	142
	1994	99	19	0	0	0	64	668	221	0	0	120	0	87	401	1	30	42	0	176
	1995	54	10	0	0	0	138	1093	87	0	0	120	0	65	1469	2	39	85	0	337
	1996	42	3	0	0	0	95	1401	105	0	0	114	0	49	824	1	24	91	0	295