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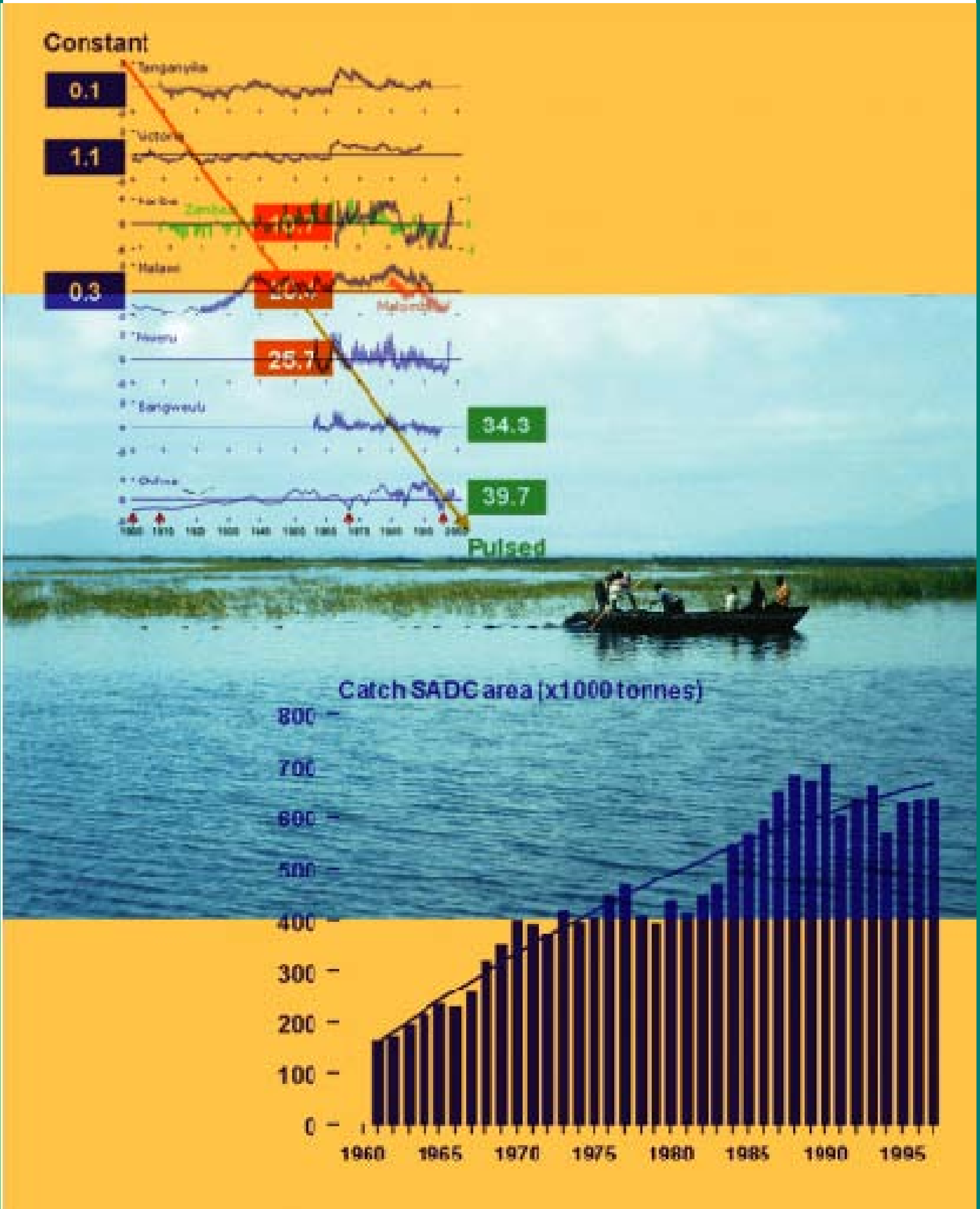
426/2

Management, co-management or no management?

Major dilemmas in southern African freshwater fisheries
2. Case studies



Cover photograph: Lake Chilwa, Paul van Zwieten, Wageningen University, the Netherlands. The set-up is by van A tot Z.

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Edited by
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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome, 2003

PREPARATION OF THIS DOCUMENT

The present report is the main result of a four-year research project on freshwater fisheries development in the Southern African Development Community (SADC) area funded by the Norwegian Research Council. It has involved a number of African and European researchers who have delivered written contributions. The report is divided into a synthesis part and ten case studies covering five important freshwater bodies in the Democratic Republic of Congo, Malawi, Zambia and Zimbabwe. Due to practical and financial constraints, it was unfortunately not possible to include all participants in the development of the synthesis but we hope that we have been able to reflect all the major findings which emerged from the case studies. The names of the editors appear in alphabetical order.

ACKNOWLEDGEMENTS

First of all we wish to thank the Norwegian Research Council as the main funding source; they have shown great interest in our work and have been very supportive. The fisheries authorities in Malawi, Zambia and Zimbabwe have provided very useful assistance by giving us access to all sorts of data and we thank them sincerely. We also wish to thank the Development Planning Service, Fisheries Policy and Planning Division of the Fisheries Department of FAO, for a close and very fruitful collaboration which has included several workshops and seminars and a six months stay as visiting scientist. We also thank the Norwegian Agency for International Development (NORAD) for financial support to the dissemination of results.

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ABSTRACT

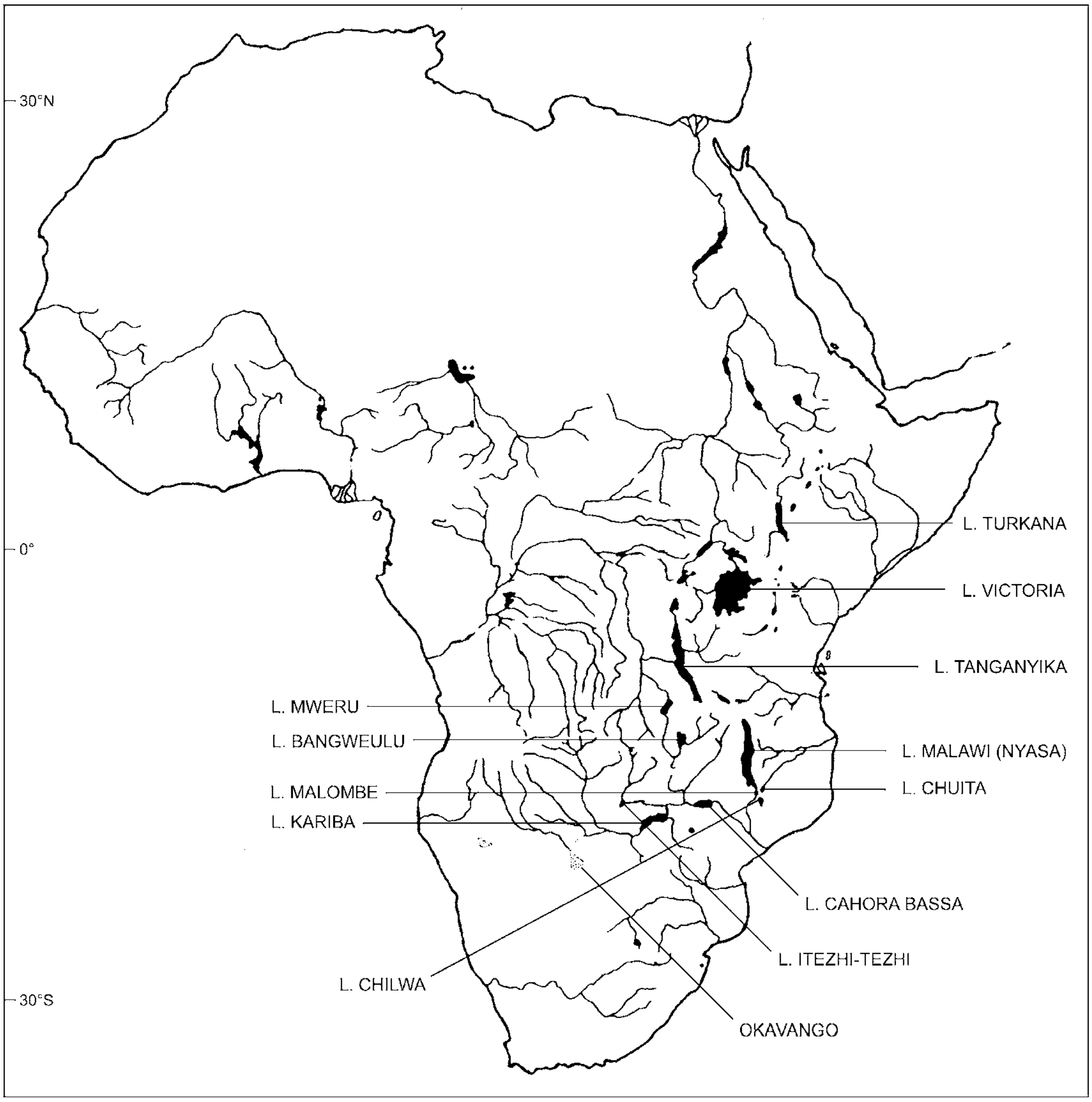
This report contains ten case studies which serve as background for a synthesis report published in FAO Fisheries Technical Paper 426/1. They have been conducted in five medium sized lakes in the Democratic Republic of Congo, Malawi, Zambia and Zimbabwe. Five of the case studies focus on biological and environmental effects while the remaining five are concerned with historical and sociological analysis. In different ways all the case studies focus on some of the following three features, relevant for the management of freshwater fisheries in the South Africa Development Community (SADC) region:

– How has fishing effort developed in these lakes over the last 50 years?
Despite a considerable increase in the total fishing effort in the region, the report demonstrates great variation in effort dynamics both in time and place. Most papers distinguish between changes related to the number of people and changes in technology and investment patterns and show that most of the increases in effort have been population-driven. Only in the case of Lake Malombe have changes in effort mainly been investment-driven.

– What causes the changes in fishing effort?
The sociological papers show that the level of mobility among fishermen – into as well as out of the fisheries sector – is considerable and this mobility is strongly influenced by economic features external to the sector (such as changes in the Copperbelt economy for Lakes Mweru and Kariba or that of the South African mines for Lake Malombe). Changes in the number of fishermen also depend on the effectiveness of the local access regulating mechanisms found to exist in all the lakes. The moderate prevalence of investment-driven changes in these fisheries is analysed with reference to deficiencies in infrastructure, credit support and complex and often unclear social relations prevailing at the local level. When occurring, investment-driven increases are generally induced by access to external financial sources. Finally, one paper compares fisheries regulations in Zambia and Zimbabwe and shows how regulations in both countries – rather than being based on data from the fisheries development – seem to reflect certain historical concerns which have been important for the states with regard to fish.

– How do fishing effort and environmental factors compare in their effects on the regeneration of fish stocks?
The biological papers show that in the five lakes studied, environmental drivers are often more significant than fishing effort in explaining changes in fish production and the strong environmental influence is not only restricted to cases where environmental variability is very high (e.g. Lake Chilwa). Total yields in the multispecies and multigear fisheries are surprisingly stable over a large range of effort levels, but changes in species and size composition are considerable. So, in these fisheries with small-scale operations there is limited danger in increased diversification of fishing patterns and they are close to an overall unselective and ecologically sound fishing pattern, highly adaptive to changing conditions. The only case where fishing effort can be said arguably to have led to reduction in catches is on Lake Malombe and there it is found that increased gear efficiency is the probable cause for reduced fish stocks.

Map of study area



Map of Africa with the five study areas indicated on the left. Freshwater systems in Africa where the authors have additional research experience are indicated on the right. (Drawn by Elin Holm).

CONTENTS

MWERU-LUAPULA IS AN OPEN EXIT FISHERY WHERE A HIGHLY DYNAMIC POPULATION OF FISHERMEN MAKES USE OF A RESILIENT RESOURCE BASE

P.A.M. van Zwieten, P.C. Goudswaard and C.K. Kapasa

1. INTRODUCTION

"Mwelu mukata mukandanshe" – "the wide waters that the locust cannot cross" is the full name of Lake Mweru, the lake situated on the border of Northern-Zambia and the Democratic Republic of Congo in the Luapula valley. Its fish provides the basis for food, employment and income for the estimated 400 000 people that live there. Lake Mweru and the Luapula River with its floodplains, swamps and lagoons have a long history of fishing in connection with cassava farming as main economic and subsistence activities (Aarnink, 1997). Since the beginning of last century, fishing has been, and still is, closely linked by trade to the towns of the Copperbelt and the diamond mines in Zambia and Congo (Musambachime, 1981; Gordon, 2000). Around 1944, after the decimation of the crocodile population instigated by the Belgian colonial authorities, the river and lake area became fully accessible for fishing activities (Musambachime, 1987). It facilitated the development of a fishing pattern, mainly conducted by European fishermen that caused the decline and virtual destruction of a once important fishery on the cyprinid *Labeo altivelis*.[1] At its height in the 1940s this species contributed 40–60 percent of the commercial catch, but was fished down within four years during its spawning migrations upstream the Luapula river to less than three percent of the total catch, never to recover again (Kimpe, 1964; Gordon, 2003). With the increase in population in the valley, roughly following the demographic rate of increase in both Zambia and the Congo, fishing pressure increased as well. Between 1965 and 1970 total catches and catch rates of the cichlid *Oreochromis mweruensis*[2], declined severely, which led to concern about the sustainability of the fishery on this now most important stock (Aarnink, 1999a; Aarnink, 1999b). Two decades later, despite an enormous increase in fishing effort by any measure, it returned as one of the most important stocks in the fishery and allowed two new fish freezing factories to thrive in the 1990s. *Oreochromis* and other cichlids remained the mainstay of the fishery to this day, roughly taking 60–70 percent of the long-term average catch of 8 300 tonnes that the Zambian part of the fishery has produced since 1955 (Figure 1).

Nevertheless, fishing patterns did change over this period. Large traps and cotton gillnets, still used in the 1950s, were replaced by multifilament nylon gillnets. In 30 years the dominant mesh size decreased from 102 mm to 63 mm stretched mesh and active methods in combination with gillnets became prevalent. Diversification of methods take place continually, the latest addition being the development of Fish Aggregating Devices (Kapasa, 1998) targeting the hitherto underexploited pelagic stocks of *Alestes macrophthalmus*. The largest new development in fishing patterns, however, took place in the early 1970s, when the fishery on a small pelagic freshwater herring *Microthrissa moeruensis* started its rapid development to become, in terms of production, the most important fishery of Zambia. The light fishery on "chisense" is now estimated to produce 25 000–45 000 tonnes per year (Zwieten *et al.*, 1996), far exceeding the production of all previous and present fisheries of Mweru-Luapula.

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1 See Appendix for local and English names.
2 Formerly known as a subspecies of *Oreochromis macrochir* but elevated to the status of species (Schwanck, 1994).

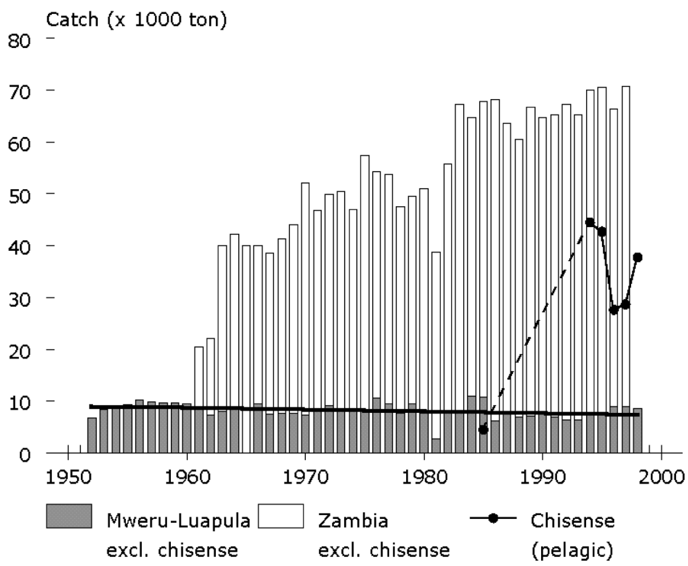

FIGURE 1. *Zambian catch from Lake Mweru and the total catch of Zambia, in both cases excluding the catch of the pelagic fishery on Microthrissa moeruensis ("chisense"). The monitored ("demersal") catch of Lake Mweru decreases slightly over 45 years. The long-term mean catch is 8 350 tonnes. The pelagic light fishery is not monitored regularly: estimates are based on daily logbooks of 21 fishermen (Zwieten et al., 1996) except for the 1985 estimate that is taken from Scullion, 1985.*

This short account of the developments in the Mweru-Luapula fisheries already reveals the difficulty to put into perspective legitimate concerns about the effects of the fast increasing fishing effort over the past 50 years. The total production of the demersal trap and gillnet fisheries has remained relatively stable over a long period of time, whereas total fish production of the lake has increased tremendously since the onset of the pelagic light fishery (Figure 1). One species effectively has disappeared from the fishery, other stocks have declined or exhibited tremendous fluctuations even with increased effort, and despite being an intensively fished lake for at least a century (Musambachime, 1981; Gordon, 2000) some stocks are known to have been subject to very low exploitation rates until very recently. Though, the fish community and with that the ecology of the lake has changed, as will be shown later, many stocks prove to be surprisingly resilient to today's high exploitation levels. Mweru-Luapula is a productive system but with highly fluctuating stock levels of important species. Directional changes have taken place in the contribution and size of species in the catch as well that could reflect changes in the fish community. Fishermen have reacted to changes in stocks by adapting their fishing pattern.[1] How can such adaptive changes in effort be characterized and what can be said about the effects of increased effort in a system like Mweru-Luapula? These are complex issues that cannot be treated here exhaustively. In the following overview we will intend to describe the complexity and how changes can be interpreted and possibly quantified.

Lake Mweru is an allotrophic riverine lake (Kolding, 1994) meaning that production is to a significant extent dependent on nutrient pulses brought in with the floods. In such a system susceptibility to increased fishing effort is thought to be low, recovery potential rapid and yield potential high but variable. Our observations on Lake Mweru suggest a differing impact of increased and changing fishing effort on the recovery potential of different species after periods of low water levels. After a description of the lake and surroundings we will describe the developments in fishing effort based on statistical frame surveys of the fishery and then characterize these changes. The picture that emerges is that access to and utilization of the fish resources is highly dynamic involving many people that enter and exit the fishery within short time spans, next to a large resident fishing and farming community. Next we will discuss the selectivity of the various fishing methods employed in the fishery. Though the fishery is based

[1] A fishing pattern is a fishing method including its spatio-temporal allocation, scale of operation and labour input. This to a large extent determines the selection of species (see Jul-Larsen *et al.*, 2003).

on three gear categories – gillnets, traps and liftnets – many different fishing patterns are employed with these gears that target the fish community in different ways. These patterns combined possibly create an overall, more or less unselective, fishing pattern. In the last paragraph we will describe the changes in stocks from a system perspective with the aid of biomass-size distributions of the demersal stocks constructed from experimental fishing surveys with gillnets, and relate this to dynamic pulses in productivity as a result of changes in water levels. In the discussion we will address the central question of all biological case studies of this research: what is the effect of increased fishing effort on the stocks in these pulsed systems? How clear are such effects, or in other words, how are the effects of fishing effort obscured by the variability in stocks due to changes in productivity? Ultimately this will have to lead to answers on what monitoring data need to be collected and whether present data collections through fishery dependent and independent surveys provide the information needed to recognize in time and conclusively the magnitude of changes taking place through changes in effort.

FIGURE 2. *Map of the Mweru-Luapula fishery indicating the main trading center (Kashikishi), the district administrative center (Nchelenge) and islands, lagoons and rivers. The four areas, strata I to IV, are statistical areas of the Catch and Effort Data Recording System (CEDRS) of Zambia, roughly coinciding with the main ecological areas of the fishery. The northern border of stratum I is formed by the Lunchinda River. The border between Zambia and the Democratic Republic of Congo follows the main course of the Luapula River. The broken line gives and approximate indication of the border. From the Mambilima falls to the Luvua River is approximately 230 km as the crow flies.*

2. MATERIALS AND METHODS

2.1 Data: origin and treatment

Effort data are based on two frame surveys: one conducted in 1992 (Aarnink, Kapasa and Zwieten, 1993; Zwieten, Aarnik and Kapasa, 1995; Zwieten *et al.*, 1996) and a second one in 1997 (Goudswaard, 1999). Data from earlier surveys conducted between 1955 and 1986 presented here are discussed and referenced in Zwieten, 1995. All surveys only covered the Zambian part of the Mweru-Luapula fishery, which encompasses around 51 percent of the lake and river area. Little is known about developments in fishing effort on the Congolese side of the lake, but there are indications from local Congolese fisheries authorities that the level of effort in terms of numbers of fishermen and boats is the same or even higher compared to Zambia (Anon., 1996; Goudswaard, 1999). Both frame surveys in the 1990's were not limited to counting of fishermen, boats and fishing activity needed for an estimate of total catch, as part of the Zambian Catch and Effort Data Recording System (CEDRS) (Bazigos, 1974; Bazigos, 1975a, 1975b). They were designed as well to give additional information on gears, spatial and temporal activity patterns, migration within and outside the lake area and demographic patterns in the fishery: age distribution, ethnic origin, ownership of boats and gear, etc. The surveys distinguished between fishermen who are the owners of boats and gears and assistants (crew). The frame-survey of 1997 contained questions regarding the most important occupation before investing in fishing gear and the year the fisherman started (i.e. owning his own gear). From these data we can infer what economic sectors fishermen came from before taking up fishing, and how long they have been fishing. Subsequently, the proportion of the total number of fishermen entering into the fishery in a certain year could be derived from this. By assessing these numbers against the net increase in numbers between 1992 and 1997, we obtained an indication of the number of fishermen moving in and out of the fishery. In the surveys further questions were asked on the birthplace and the home village of the fisherman. From this information indications on both migration into the fishery and migration within the fishery could be deduced.

Catch data were obtained from the Department of Fisheries, Statistical Section in Chilanga, and are calculated from data obtained through the CEDRS (Bazigos, Grant and Williams, 1975a) of Lake Mweru. This CEDRS is designed as a boat based stratified random sampling system. The Mweru-Luapula fishery is divided into four major strata (Figure 2) each of which is subdivided into four minor strata. In each minor stratum three landing sites are chosen at random and sampled for three consecutive days each, according to a strict protocol. This procedure, called Catch Assessment Survey (CAS), is repeated between one to three times each year depending on the funds available. Average catch per boat is then calculated by major stratum. These figures are subsequently multiplied by the total effort expressed as number of boats and by the activity levels, both obtained through the Frame Survey, and added to obtain a total catch for the lake. In case a CAS is only carried out once in a year or in case of missing strata, the total catch figure of that year usually is weighed with data from the previous year. Though the CAS contains information on separate species or species groups, these data are not analysed. Furthermore, it would be possible to derive the error structure of the data sampled from individual boats, but this analysis is not done as well. This shows that the data are underutilized, with only limited evaluation with regard to their quality (Zwieten, Njaya and Weyh, 2003). However, the error in the total catch estimate is deemed to be around 15-20 percent (Lupikisha, pers. com.).

Water level data were obtained from the Department of Hydrology, Lusaka and our own measurements, both taken from the gauge at Nchelenge. Missing years could be interpolated by a correlation with data from Lake Bangweulu and from rainfall data. The latter two data sets were obtained from the Department of Hydrology in Lusaka.

Experimental gillnet surveys and the construction of biomass-size distributions

Experimental surveys with a fleet of multifilament gillnets ranging from 25 mm to 178 mm stretched mesh with 13 mm increments were carried out by the Department of Fisheries from 1970 to 1972, 1982 to 1985 and from 1993 to 1999. Sampling sites during the latter two periods were identical while during the first period the number of sampling sites was both larger and overlapping with later surveys. All fish or subsamples of fish in case high numbers were caught were measured as standard length (SL)[1], and weighed and sexed. The data set was digitized in PASGEAR[2] (Kolding 1999). Numbers of fish were corrected for the amount of effort of each net as 100 m^2 of gillnet of a mesh size set during three years at all sampling sites. Numbers of fish caught were further corrected for the selectivity of the fleet of gillnets and for the proportional difference in number of settings at the sampling stations in the three periods. Selectivity curves were estimated with the aid of the selectivity module in PASGEAR that implements methods of estimation based on Millar, 1992; Millar and Holst, 1997 and Millar and Fryer, 1999.

Biomass-size distributions were constructed as follows. Length-frequencies of 1 cm classes were made with the corrected numbers of all species and for each length class the relative biomass per species was calculated. All weights by length class were subsequently added. The resultant biomass-size distributions thus are in fact catch rates of 100 m^2 of gillnets of all fish caught by one centimetre length class, hence are an index of the actual biomass by length class. As the methods of sampling and sampling sites have not changed over the three periods examined, the distributions can be compared directly with each other. Changes in the distribution thus reflect changes in the fish community that are independent of the fishery and as viewed through the selective window of experimental gillnets.

Changes in the aggregated biomass-size distribution were assessed in two ways. Aggregated biomass per 1 cm length-class was ^{10}log-transformed. A regression of biomass over length from 14 cm onwards was made per period and the significance of the difference in slope and intercept of these regressions were examined by stepwise examining the reduction in variability of the different terms of the following model:

$$^{10}\text{Log}\,(B)_{ij} = \mu_{ij} * Fj + \beta_i * L(D_{:j})$$

in which,

μ_{ij} = overall mean

B = biomass = CpUE per length class

F_j = factor by which the intercepts of the three regression lines are determined

L = length

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[1] Standard Length is a measure of the length of the fish, more or less excluding the tail fin (for an exact definition see Bagenal (1978)).

[2] PASGEAR is a database package with a number of descriptive data analysis tools developed for artisanal and experimental fisheries with PASsive GEARs, i.e. gillnets, hooks, traps etc. ©Jeppe Kolding, Dep. of Fisheries and Marine Biology, University of Bergen, Norway. E-mail: jeppe.kolding@ifm.uib.no

$D_{.j}$ = decade from 1970-1972, 1982-1985, 1994-1997

Both length and biomass axes were centred by subtracting the mean before submitting the model.

Next, splines with λ constrained to explain at least 90 percent of the variability in the aggregated and ^{10}log-transformed biomass-size distributions were drawn. The shape of the expected values of biomass over length given by the spline for the three periods was interpreted.

3. MWERU-LUAPULA: PHYSIOGRAPHY, PRODUCTION AND PRODUCTIVITY

The Mweru-Luapula fishery is situated in an area that is a clearly defined geographical unit, also recognized by the people of the region who refer to it as the “Luapula valley”. The Luapula river has its origin in Lake Bangweulu, from where a broad (a few hundred metres wide) swamp-like river system flows southward. Where the river hits the plateau it turns to the west and forms the border with the Democratic Republic of Congo (DRC). A steep waterfall, the Mambatuta falls, forms the beginning of a narrower river that meanders to the north to the place where it descends into a series of rapids called the Mambilima falls. This is where the lush and densely populated Luapula valley with its mango trees, cassava fields and the Mweru-

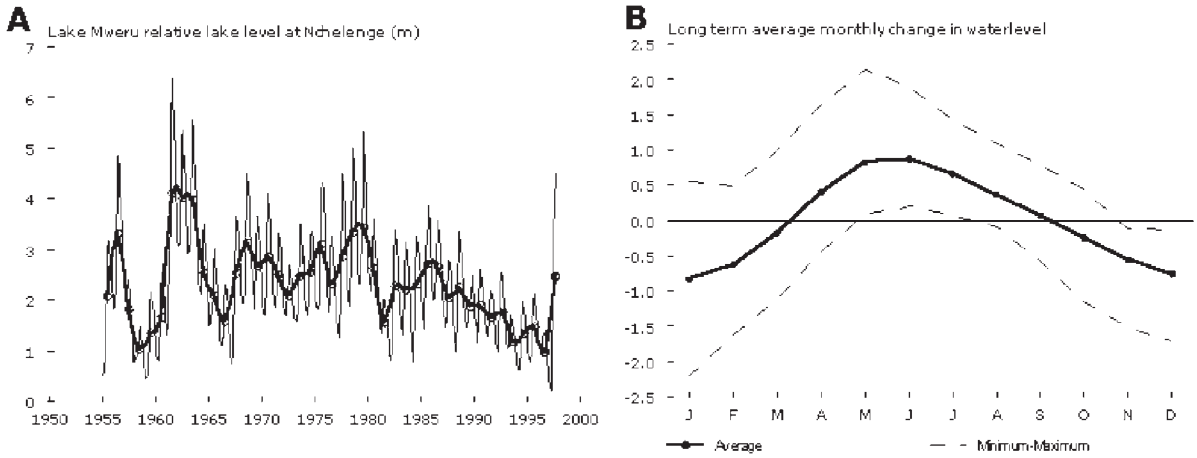

FIGURE 3. ***A***. *Annual average water level (thick line) and mean monthly water level (thin line) of Lake Mweru from 1955 to 1998.* ***B***. *Long term average and minimum and maximum relative change in monthly water levels as a factor of the annual average water level.*

Luapula fishery starts. From that point onwards the river broadens into a vast system of floodplains, marshes and permanent lagoons for about 150 km before it flows into Lake Mweru. The lake itself is about 115 km long and 45 km wide. Around the river mouth, the swamp-lake edge and to the Northeast of Kilwa Island, the lake is about 2 m deep. It gradually deepens to 10–14 m in the northern part of the lake. The deepest part of the lake is a narrow trough with a maximum depth of 24 m close to and along the northeastern shore (Bos, 1995). The lake discharges at its northernmost tip in the Luvua River that is part of the Lualaba River system. In the southern half of the lake the shores are formed by beaches, and dambo’s (vlei), while the northern half, where the Kundelungu plateau meets the lake on both sides, is formed by relatively steep hills and escarpments interspersed with small beaches that serve as landing places for boats. A 45 km sandy beach forms the north edge of the lake. An almost continuous string of villages from the Mambilima falls in the south along the 300 km shoreline of the river and the lake, usually not exceeding a few hundred metres width, runs to the border with the Democratic Republic of Congo near the Luvua River in the north.

Mean annual lake levels range over three metres, while highest minimum and maximum levels recorded at the gauge in Nchelenge in the south of the lake range 6.2 m (Figure 3A). Seasonal lows are reached in January while maximum levels are usually attained in May, with a long-term intra-annual fluctuation of 1.7 m. However, while the size of the seasonal fluctuation is highly variable and ranges almost 2.7 m the timing of the seasonal pulse usually is much less variable, with a shift of one month at the most (Figure 3B). Average water levels exhibited a slight decreasing trend over time, explaining nine percent of the variability. No correlation between water level (de-trended average, minimum, maximum or annual change in mean water level and amplitude) and Zambian demersal catch was found at any meaningful lag.

The proportion of the demersal catch to the Zambian freshwater fisheries output has decreased from up to 40 percent in the 1960s via 20 to 30 percent in the 1970s to around 10 percent since then. However, with the pelagic catch included Mweru contributes around 40 percent of the total catch of Zambia (Figure 1)! The total catch as reflected in the monitoring statistics of the Zambian fishermen of Mweru shows a slightly decreasing trend of 0.3 percent per year over the period of 45 years (r2=0.12, p=0.02). It has a long-term annual average of 8 350 tonnes (Figure 1). Including the DRC the total demersal fishery is estimated from 12 500 (Kimpe, 1964) to 22 000 tonnes per annum. The productivity of the lake based on the “demersal” catch is estimated at 20–36 kg/ha; including the pelagic fishery productivity is 67–108 kg/ha[1].

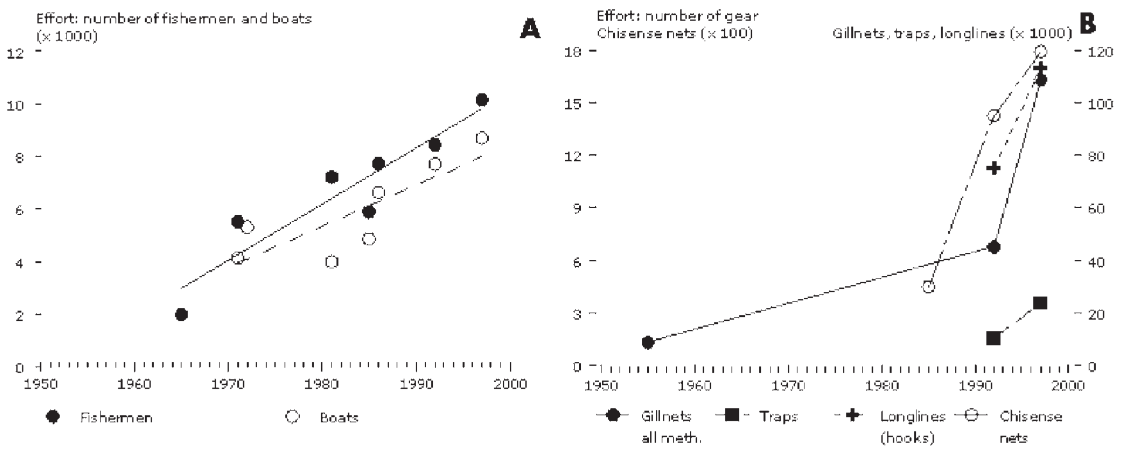

FIGURE 4. *Development in fishing effort expressed as **A**. number of fishermen (=male gear owners), boats (plank boats and dugout canoes) and **B.** gears: chisense nets, gillnets, traps and long lines (number of hooks). ‘Gillnets’ include all methods such as beach-seining, drift netting, driving (“kutumpula”) and various kinds of open-water seining. Similarly three types of chisense nets and at least five types of traps are included in the numbers.*

1 Productivity is calculated over the area covered by the lake (4 650 km^2) ánd the permanent swamps (1 500 km^2). The area of floodplain (900 km^2) is not taken into account.

4. EFFORT DEVELOPMENT IN MWERU-LUAPULA, AN OPEN-EXIT FISHERY

Fishing mortality in small-scale fisheries is notoriously difficult to quantify. In many situations it is still reasonably feasible to obtain quantitative counts of fishing effort as numbers of boats and fishermen, which in fact are the net result of investment and access. It is already much more difficult – and expensive – to obtain information on gear, gear sizes and gear usage and ultimately the selection of species that are targeted within a particular fishing pattern. In a management context where it could be deemed necessary to regulate fishing effort, ultimately it will be necessary obtain information about the spatial and temporal aspects of fishing patterns i.e. where fishing is actually done, with what gear and how, and who is actually fishing. In this section we will first discuss the trends in numbers of fishermen and fishing gear of Mweru-Luapula, and we will indicate that these figures are the net result of a highly dynamic migration in and out of the fishery. After that we will discuss the distribution of fishing activities in space and time and their relation with agriculture.

4.1 Net result: increased effort by all measures

Based on frame-surveys a linear increase in numbers of gear-owners of 2.1 percent per year since 1965 took place, resulting in an increase from 2 000 to 10 152 male fishermen between 1965 and 1997.[1] Over the same period the number of boats increased by 1.6 percent per year. Canoes and plank boats are generally not motorized and are driven by paddle or sail: whereas the early seventies saw an increase in the use of outboard engines, these became relatively rare in the last few decades of the twentieth century. All numbers of gears increased significantly over the periods examined. The number of gillnets even increased exponentially since earlier estimates. This is related to the influx of cheap Korean nets in the local markets that serve the fishery and were not available prior to 1992 (pers. obs. van Zwieten). The availability of cheap gillnets has as effect that entry into the fishery hardly will be impeded by the necessary investments.

Comparatively high investments in lights and gear are needed to enter the pelagic fishery on chisense. The fishery started on a limited scale in the early seventies (Gordon, 2003), but apparently it took off only in the second half of the 1980s. This long inception period could be caused by a multitude of factors, including learning the methods of fishing and preservation[2], creation of markets and the investments needed. In the early 1980s the fishery was supported by development aid (Scullion, 1985), the success of which may have inspired many fishermen to enter the fishery as well. We will see that while most chisense fishermen have a background in fisheries, a considerable proportion comes from outside the fishery.

4.2 Migration into and out of the fishery

During the 1997 frame survey around 60 percent of the fishermen indicated that their previous occupation was either in fisheries or in agriculture. The remaining 40 percent of fishermen had highly diverse occupations before they started fishing (Table 1). One should note that most

[1] In 1992 and 1997 also female gear-owners were counted, respectively 862 and 1 895 but not so in earlier surveys.

[2] See e.g. Benneker, C., (1996) and Benneker, C., (1995) for a description of this learning process in the emerging pelagic fishermen on *Mesobola* sp. in Lake Bangweulu.

fishermen do not have one job, or do not necessarily completely exchange their job for a life as a fisherman, but will spread their risks in income over various activities. In particular fishing and agriculture will be shown to be interchangeable, but also many occupations categorized as artisan, business, trade and housewife can be readily exchanged or could be held simultaneously with fishing activities. Nevertheless, many occupations mentioned under the categories civil servants (GRZ) and general worker but also school attendance can hardly be combined with fishing activities. Retirements – after 20 years of service in Zambia –, redundancies in the civil service and limited availability of jobs in other sectors than fishing and farming cause entry of people into the fishery.

TABLE 1. *Main occupation of fishermen before they became gear-owners in 11 categories. In brackets is the number of times an occupation was mentioned. GRZ = civil servant of the Government Republic of Zambia. Several occupations mentioned in this category can also be found in other categories, but were specified by the acronym GRZ. TAZARA = Tanzania-Zambia Railways, LCU = Luapula Co-operative Union, ZESCO = state electricity company, ZCBC =state retail co-operative; UBZ = state bus company; Chani = fish freezing factory in Nchelenge.*

Category	Occupation before fishing
Agriculture	Agriculture (27), farmer (3831), hunter (2), poacher
Fisheries	Fish hand (3143), fish worker (71), Tanganyika fishermen
School	School (1053), student (4)
Trade	Basket seller, fish trader (56), marketer (4), merchandising (10), meat trader, selling (7), selling beer (4),selling clothes, trader (475), trading rice, transporter (2)
Housewife	Housewife (620)
GRZ (=Civil servant of the Government Republic of Zambia)	Accountant (2), administrator, agricultural assistant, banana plantation worker, bank (4), buildings, bus driver (2), carpenter, chief retainer (2), community development officer, company, cook (6), council worker, (20) councillor, court clerk (3), court messenger, doctor (4), driver (70), engineer (2) fire brigade, fitter (2), forestry (2) guard (2), health (20), LCU, manager (2), medical officer , messenger (6), operator (2), pensioner (2), police (18), pontoon, post (4), printer (2), prison warden, prisoner, railway (5), red cross (2), revenue, roads department (3), rubber plantation, security (2), statistics department, storekeeper (9), sweeper, tax collector, TAZARA (2), teacher (102), tsetse control (2), typist, UBZ, watchman (9) water affairs (6) worker (98), ZCBC, ZESCO (2)
Business	Accountant (3), baker (5), beer brewing (18), bread baking, business (375), film shower, grocery (2), manager, mill operator (2), petrol dealer (1), photographer (3), printer, sausage maker, shop keeper (16), shop owner (5), treasurer
General worker	Bakery worker, bar keeper (5), care taker, casual labour (3), Chani worker (2), cleaner, Coca-Cola company, company worker (7), cook (5), factory worker (2) general worker (138), grass cutter (2), Greek cook, house boy (5), house servant (7), lorry boy (6), lorry mate (7), operator, pensioner, piece worker (64), private company worker, secretary, security, servant, shop hand (8), stone breaker, storekeeper (4), tea picker, theatre, training, watchman (5) worker (75)
Mines	Miner (315)
Artisan	Basket maker (7), blacksmith (7), boat-builder (2), boiler, brick-burner, bricklayer (83), brick-maker (3), builder (6), bicycle repair (5), carpenter (121), charcoal burner (55), contractor (3), drum maker, electrician (8), engineer (2), fish-basket weaver, fitter (2), key maker, machine operator, mat maker (10), mechanic (16), metal welding, painter (6), photographer (3), plumber (10), radio repairs (6), sawyer (31), shoe repair (2), tailor (35), watch repair, weaving (2), welder (4), woodcarving
Miscel-laneous	African doctor (17), dependant (2), from home (2), soldier (41), herbalist (3), loafer (189), pastor (2), radio operator, smuggling, staying, unknown (750)

TABLE 2. *Proportion of fishermen that are not born in a fishing community of the Mweru-Luapula fishery by occupation before fishing. Shaded cells indicate proportions higher than the total average (21 percent for all fishermen; 26 percent for chisense fishermen). GRZ = Government Republic of Zambia (civil service).*

Category of fishermen	Fisheries	House -wife	School	General work	Agri-culture	Busi-ness	Artisan	Mines	GRZ	Trade	Miscell-aneous
All	15	17	21	21	22	28	28	31	34	35	18
Chisense	21	-	23	25	30	29	26	47	38	30	31

A first indication of migration into the fishery is that one-fifth of all fishermen, and more than a quarter of the chisense fishermen are not born in fishing communities of the Mweru-Luapula area (Tables 2 and 4). In particular for fishermen with a background as miner, civil servant or trader this is not the case. Only a relatively small proportion of fishermen with a background in fisheries and as housewife have their origins outside the fishery (Table 2).

Nearly half of the all fishermen that answered the question (app. 4 800), said to have started fishing (i.e. owning gear) in the last five years during or preceding the survey in 1997. The net increase of number of fishermen between the two surveys in 1992 and 1997 is 2 750 fishermen or an increase of 23 percent over five years. Surprisingly, this must mean that around 25 percent of the number of fishermen counted in 1997 must have left the fishery over this same period. Furthermore, adding-up the total number of fishermen that said to have started in and before 1992 (app. 6 000), and comparing this figure with the total number of fishermen counted in the frame survey of 1992 (app. 9 300), would mean that 35 percent of the fishermen counted in 1992 have stopped in the next five years. Equally, 21 percent of the chisense fishermen stopped between the two surveys, and 26 percent of those who started before 1992 stopped as well.

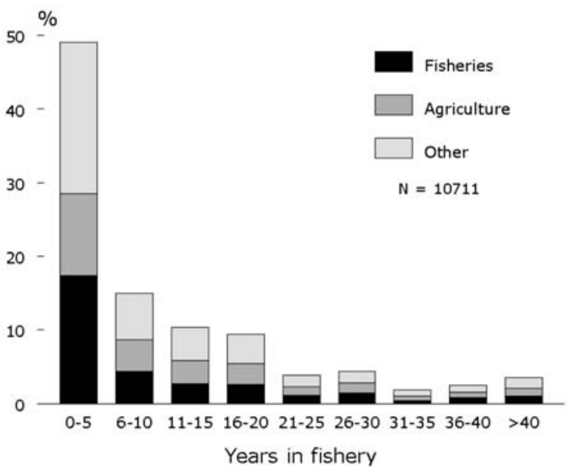

FIGURE 5. *Relative frequency distributions of the total number of fishermen by number of years in the fishery: 1-5 = fishermen started fishing between one and five years ago i.e. between 1993 and 1997.*

These figures cannot be taken at face value: as already mentioned fisheries and agriculture are highly interchangeable and multiple occupations are common. Thus many people will over time be occupied in fisheries to varying degrees. In many cases it is likely that an absolute starting date of fishing as answered in the questionnaire will not necessarily reflect an actual first entry from outside the fishery. Nevertheless, a quarter to one third of the fishermen exiting the fishery is not insignificant, and we must conclude that exiting or temporarily leaving the fishery is a common phenomenon. This means that the population of fishermen fishing at any moment is highly dynamic: besides to a permanent core of fishermen and farmers who are part time fishermen, a large impermanent and fast changing population of temporary fishermen exists. Though an absolute increase in total number of fishermen over time (two percent per year over the long run and 21 percent (<2 percent per year) between 1992 and 1997) has taken place, many people try their luck at fishing or fish for a short time before moving on to other occupations.

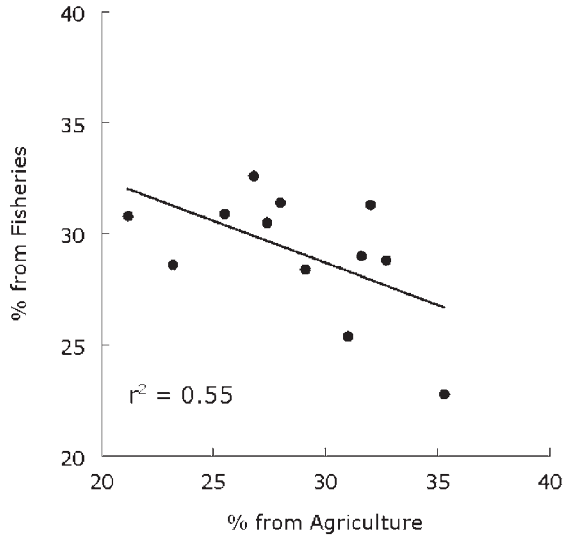

FIGURE 6. *Proportion of total number of fishermen that were occupied in fisheries before owning their own gear against the proportion of those fishermen mentioning agriculture as their preceding occupation for each interval of five years between 1937 and 1997 that was mentioned as starting year as fishermen (=gear owner).*

Agriculture and fisheries both account for around 30 percent of the total number of people entering the fishery, with agriculture becoming relatively more important in the last 5 to 10 years, probably because of the drought during the beginning the 1990s. The proportion of people from both sectors for each five-year period between 1937 and 1997 shows an inverse relation, indicating that their numbers are interchangeable for at least a large section of the fishing population (Figure 6). Of the remaining 40 percent of entrants in each year school-leavers always form between eight and ten percent, increasing somewhat over time (Table 3). The proportion of influx of general workers, artisans and, most especially, miners decreased over time: in total these three comprised 22 percent of the influx between 1940 and 1955, dropping to ten percent from 1980 onwards. The proportion of housewives and men and women with trading and business backgrounds increased over the same two periods from an average of 5.5 percent to 13.1 percent. Fishermen with backgrounds in the civil service (GRZ) always formed around four to five percent of the influx: entering the fishery can be either after retirement or retrenchment. From this figure alone it cannot be concluded that the retrenchments of low-ranking jobs in the civil service in the 1990s has resulted in an increased influx in the fisheries. However, the age distribution of GRZ workers is bi-modal and includes a large proportion of relatively young people, this could mean that recent influx is related to retrenchments instead of retirements. Lastly, 68 percent of the women start from agriculture or as housewife with an additional 12 percent from school, while 61 percent of the men have an agriculture or fisheries background.

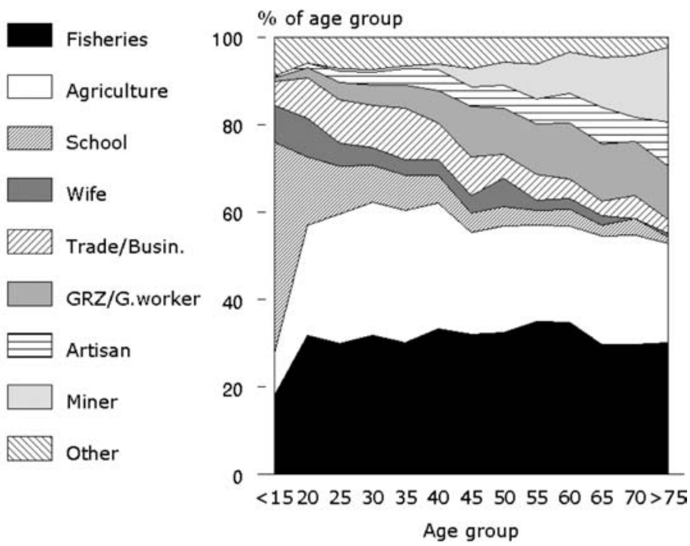

FIGURE 7. *Proportion of fishermen categorized in occupation before becoming a fishermen (=gear owner) by age-group*

The average age of all fishermen is 38 years. The mean age of fishermen from most occupational backgrounds is not significantly different from this, except for female school-leavers who are on average 19 years old, while general workers, GRZ-workers and artisans are on average 44 to 45 years old. Fishermen with a background in mining are on average 54, indicating that at present little influx of younger people from redundancies in the mines of the Copperbelt takes place! The highest proportion of fishers between 10 to 20 years old is school-leaver. The mode of the distribution for housewives and business people is around 20 years old, and for traders around 35 years old. From 20 years of age onwards about 25–30 percent of the fishermen are always people with a background in agriculture and around 30 percent always have a background in fisheries. The proportion of people with these backgrounds is lower towards older age groups. In contrast those with a background in the GRZ, as general worker, miner and artisan background form a larger proportion of the older age groups (Figure 7).

TABLE 3. *Proportion of entrants in the fishery by category of occupations in three periods of 15 years. Shaded cells indicate the highest proportion of a category over the three periods. GRZ = Government Republic of Zambia (i.e. civil servant)*

Period	Agri-culture	Fishery	School	Trade	Business	House-Wife	GRZ	Artisan	General Worker	Mines	Miscellaneous
1940 – 1955	28.4%	28.9%	6.7%	1.9%	1.6%	2.0%	4.5%	6.0%	6.9%	7.9%	5.3%
1960 – 1975	28.2%	30.6%	8.4%	3.7%	2.0%	2.5%	4.8%	4.7%	4.4%	5.2%	5.5%
1980 – 1995	29.4%	28.2%	9.5%	5.1%	4.1%	3.9%	3.9%	3.8%	3.1%	2.8%	6.4%

4.3 Distribution and migration within the fishery

Two main characteristics of small-scale fisheries are that fishing effort is unevenly distributed over the fishery in space as well as over the year, while fishing patterns are both highly diverse and labour intensive. The total number of fishermen of Mweru-Luapula is about equally divided between the river area and the lake (Table 4). Their spatial distribution is skewed in the north, in the south of the lake and halfway up-river, near the two main lagoons and Mwansabombwe, the old capital of the Lunda's and residence of senior chief Mwata Kazembe (Figure 8, top). These areas more or less coincide with the three main fisheries: the chisense light-fishery, gillnets and traps. The total number of fishing days per kilometre coastline is less unevenly distributed along the lake than the spatial distribution of gillnets and chisense gear, mainly as a result of the lower activity of chisense fishermen in the north during the stormy months of June and July. Along the river total fishing days per kilometre decreases considerably towards the south where the floodplains are at their narrowest. The proportion of non-resident fishermen, i.e. those fishermen that during the survey were found fishing and residing along the lake outside their home village, highlight the main fishing areas. Both in the north and the south of the lake and along the river area most non-resident fishermen are found living in temporary shelters on the beaches, on the banks along the river or on the islands in the swamps. In the south of the lake most non-resident fishermen are found on the islands near the river mouth near the area officially closed for fishing.

TABLE 4. *Entrants in the fishery by previous occupation (frame survey 1997) and place of birth as a proportion for all fishermen (last column) and as a proportion of the number of fishermen in a fishing area (see Figure 1 for the boundaries of the strata 1 to 4) and in the pelagic light fishery on chisense. Shaded cells by stratum indicate the highest proportion by occupation before fishing in that row. Shaded cells in the two last columns indicate highest proportion in the column. The last row gives the proportion of the total number of fishermen by area and fishery.*

Stratum / **Occupation before fishing**	**North Lake (1)**	**South Lake (2)**	**Islands/ Lake edge (3)**	**River (4)**	**Chisense fishermen**	**Total of all fishermen**
Agriculture	21%	21%	31%	39%	17%	**31%**
Fisheries	41%	33%	27%	18%	39%	**26%**
Other	38%	46%	42%	43%	44%	**42%**
Other of which:						
School	15%	16%	16%	25%	20%	**20%**
Trade	23%	19%	10%	3%	23%	**11%**
Wife	0%	1%	12%	20%	1%	**12%**
GRZ	9%	10%	11%	6%	14%	**8%**
Business	7%	15%	9%	5%	14%	**8%**
General Worker	6%	8%	7%	7%	8%	**7%**
Mines	12%	7%	6%	7%	7%	**7%**
Artisan	4%	10%	8%	7%	10%	**7%**
Miscellaneous	23%	14%	20%	20%	3%	**19%**
Not born in the fishery	**23.9%**	**28%**	**17.3%**	**20%**	**26%**	**21%**
Proportion of all fishermen	**14%**	**17%**	**25%**	**45%**	**12%**	**100% = 12293**

Fishing gears are highly unequally distributed over the fishery (Figure 8, middle). While most fishermen are found in the productive southern part of the lake near the main market of Kashikishi, they have on average a low number of gillnets. This could indicate a link between influx in the fishery and trade. Most gillnets are found further north along the coast, in the long established fishing villages near productive areas around the mouths of smaller rivers discharging into the lake. Here fishermen have on average ten gillnets per person with a large proportion owning up to 40–50 gillnets. In the remaining areas the average number of gillnets per fisherman is much lower and even as low as one per fisherman in the river area (Zwieten, Aarnink and Kapasa, 1995).

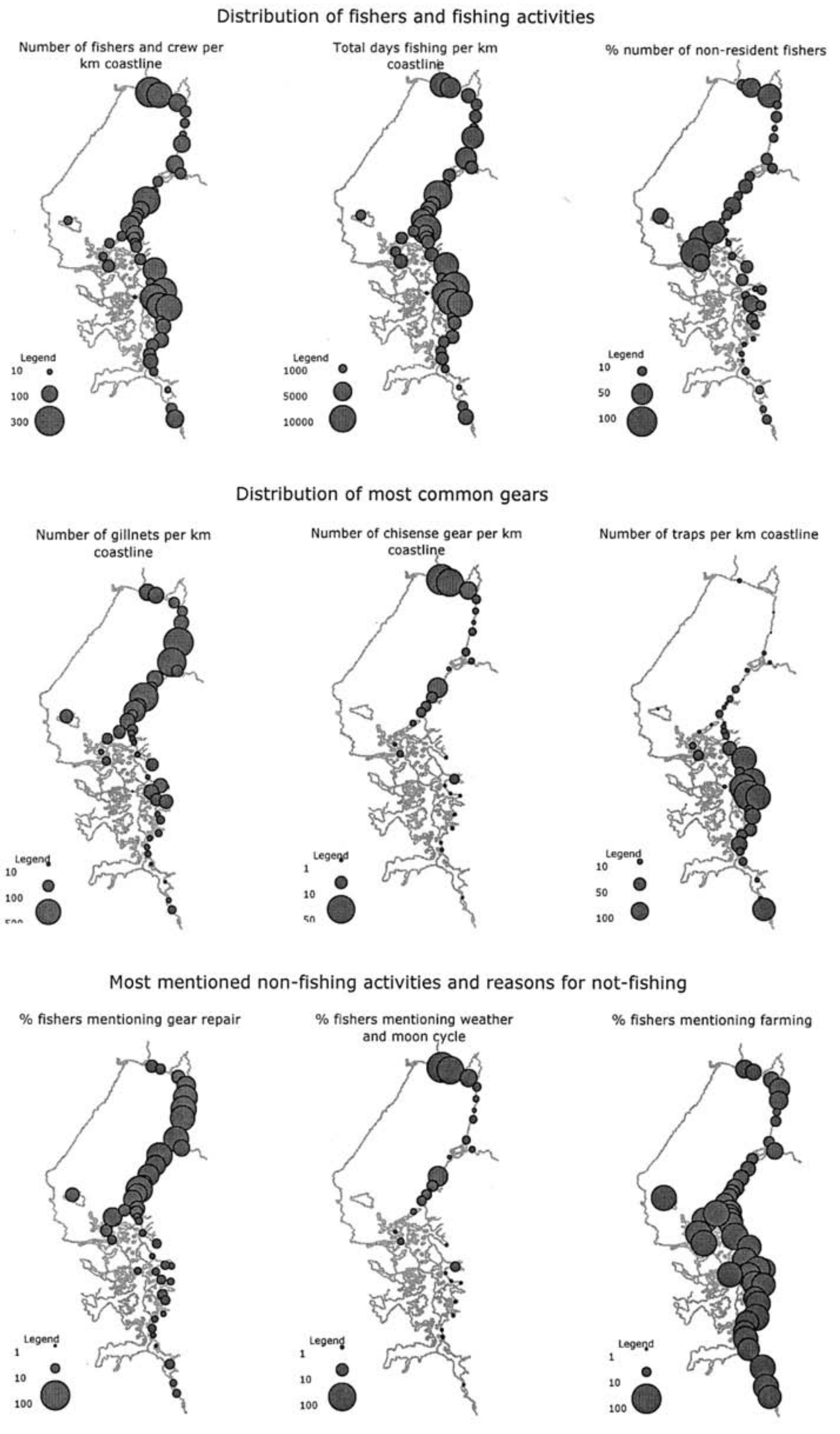

FIGURE 8. *Distribution of fishermen, gear and fishing activities per kilometre of coastline (frame survey 1992). Each bubble represents a fishing community. Top: number of fishermen and crew are added; fishing days=average activity level by community multiplied by the number of fishermen; non-residents are fishermen encountered outside their home-village. Middle: distribution of gillnets, chisense nets and traps. Bottom: proportion of the number of times of all activities mentioned during the survey. Fishermen could mention more than one activity.*

Chisense fishing is almost completely limited to the north of the lake, where many resident traders from the Democratic Republic of Congo buy up and store the dried chisense before transporting the produce to Lubumbashi. Some chisense fishing activity is found in the south of the lake near the main markets. The distribution of non-fishing activities along the lake is very much related to these two main fisheries: repair of gillnets and unfavourable conditions of weather and moon when chisense fishing stops (Figure 8, bottom). The trap fishery is almost completely confined to the river area, with a lowered activity around November and December when water levels increase (Zwieten, Aarnink and Kapasa, 1995). Farming activities are important in all areas along the lake, but in particular in along the river. Here fishermen fish between 30 to 120 days per year and are most of the year farmers. Fishermen from the long established gillnet fishing areas fish between 150 and 220 days.

The frame survey of 1997 confirmed that agriculture is of less importance in the lake area compared to the river: less than 20 percent of the people mentioned fisheries as occupational background, and almost 40 percent mentioned agriculture (Table 4). Historically, the Ba Shila or “real fishermen” (Gordon, 2000) live in the north of the fishery and still the highest proportion of fishermen with a background in fisheries is found here. At the main trading centre in the south of the Lake Area (Figure 1; Table 4) and in the north at the beaches where most chisense is landed and traded with Congolese traders, fishermen with a background other than agriculture, fisheries or school are found. In both cases trading and “business” backgrounds are prevailing and 28 percent are not born in the fishery. A relative higher proportion of ex-miners are found in the north of the lake. Most chisense fishermen have a background in fisheries and other occupations, of which trade and “business” are the most important (37 percent) followed by ex-civil servants and artisans. Ex-miners are much less important in the chisense fishery than often is reported (e.g. Gordon, 2003), though they may have been important as initial investors during the early start of the fisheries in the 1970s and 1980s. Almost all fishers with a background as housewife are to be found in the river area. These are mostly women fishing with baskets during the dry period after the harvest season (Zwieten, Aarnink and Kapasa, 1995). Only a very low number of female gear owners are found in the lake area.

4.4 Conclusions on fishing effort

Fishing effort in Mweru-Luapula is increasing by any measure, and in particular the gillnet and chisense fisheries have grown tremendously since the early 1990s. Fishing is done by a core of around 60 percent of farmers and fishermen who are bound to the area through agriculture and fisheries. The remaining population of fishermen has a highly diverse occupational background, and is likely to move in and out of the fishery as income opportunities from other sectors change. Entry to the fishery for these people thus does not appear to be a last resort but is at the most a temporary resort, as many appear to leave the fishery as fisherman again.

Furthermore we can conclude that:

(1) The originally strong connection between the mines and the fishery became weaker in recent times

(2) There is a strong link between agriculture and fisheries. Droughts in agriculture probably increase the influx in the fishery and *vice versa*. The link is strongest in the river area, where the fishery operates at a very small scale, often on a subsistence level, with low investment gears such as traps and one or a few gillnets.

(3) There is an increasing importance in the connection between trade and fishery, and in particular in the pelagic light fishery where relatively high initial investments and payments for operational costs are needed to start and maintain an operation. Near trade centres many appear to try their luck with the gillnet fisheries as well.
(4) An increasing proportion of school-leavers enter the fishery, indicating the limited availability of jobs in other sectors.

5. SELECTIVITY OF GEARS USED IN THE FISHERY

Both in spatial and temporal patterns of operation and by design, all fishing gears and methods are selective. Each fish species has different catchabilities due to species-specific behaviour and habitat preferences. Furthermore behaviour and habitat preferences change over the different life stages that are susceptible to fishing, changing catchability. In a fully developed fishery as Mweru-Luapula a mixture of gears is used to harvest different parts of the fish community. In recent years a large database has been collected through participation of local fishermen in scientific fisheries data collection on most of the gears encountered in the fishery (van Zwieten, Goudswaard and Kapasa unpublished data; for methods see: Kolding, Ticheler and Chanda, 1996; Ticheler, Kolding and Chanda, 1998). Based on an initial examination of this huge database and personal observation of the authors, Table 5 is constructed. The table emphasizes species selectivity of the methods, with some spatial information on the selectivity as a result of the fishing pattern and the total effort in number of gear owners.

As described in the previous paragraph, the three dominant fishing gears in the Mweru-Luapula fishery are gillnets, traps and a type of scoopnet used in the light fishery. The largest output of the fishery is *Microthrissa moeruensis* (chisense) caught by a limited set of gear types. The dominant gear-type in the initial stages of this fishery – boat seines – required two boats and a crew of seven or eight. Boat seines have been replaced almost completely by the operationally simpler ‘Japan net’ or Chapani. A scoop method requiring one boat with a crew of four that is cheaper both in terms of investment and operational costs and maintenance. The fishery has an important bycatch of the fish predators *Serranochromis* and *Alestes*. Many different gears and methods mainly based on gillnets target the endemic *Oreochromis mweruensis*, the second most important species of the fishery. Fishing patterns based on these different fishing methods – stationary, chasing by beating on the water (“kutumpula”) and seining methods (“chibata”; “sikide”) sometimes in conjunction with chasing – are easily interchangeable, and fishermen often switch between them. The two *Serranochromis* species and *Tylochromis mylodon*, mainly targeted through gillnets each dominate in different parts of the lake and swamps. Fish traps are dominant in the riverine and swamp area and mainly target clariid catfishes, but specialized trap methods target a large variety of other species. Next to these three dominant fisheries a large variety of specialized methods each target different species or groups of species.

The high diversity of methods used could be complementary to each other in exploiting different parts of the fish community. This diversity in fishing patterns can be considered as adaptations to the large diversity of species in the fishery. Characteristic of the specialization is that all gears require relatively low-investments (traps, hooks and lines, etc.) or, if requiring more investment as in case of gillnets, the gears can be used in a large variety of fishing patterns, thus making them highly adaptable to changing circumstances. All these gears also do not last long, a few years at the most, before they need to be replaced, again contributing

TABLE 5. *Fishing patterns of the Lake Mweru-Luapula fishery as gleaned from fishing effort (numbers of fishermen using a method), spatial patterns (area) and categorical selectivity (target and bycatch of species) by gear type and method*

[1] Most active methods are illegal. Reported effort through framesurveys for these methods is probably an underestimate; [2] Mapira = gillnetting at mid-water depths; [3] Kutumpula = chasing [1]

Fishery		Method (A = Active P = Passive)[1]	Fishers	Area	Target species (T) - Important bycatch (B) – Other bycatch(O)
Gillnet	P	Stationary (Malalika)	4764	1. Swamps 2. Lake South 3. Lake Middle 4. Lake North	1. large variety of species (T) 2. *Oreochromis mweruensis* (T) 3. *Serranochromis* spp.(T) 4.*Tylochromis mylodon* (T); All areas: *Clarias* or the other cichlids mentioned (B); many other species (O)
		Driftnetting (Kusenswa)	114		*Hydrocynus vittatus*; *Alestes macrophthalmus* (T) cichlids, *Clarias* spp. (B) Large *Barbus* and a variety of other species (O)
		With Fish Aggregating Device (Tusela)	At least 53		Small *A. macrophthalmus* (95% of catch)
		Stationary midwater (Mapira)[2]	150	Midwater lake	*Opsaridium zambezense*; small *A. macrophthalmus*
Gillnet	A	Chasing (Kutumpula)[3]	1668	Whole fishery	*O. mweruensis* (T) Serr. spp. (B) many other species e.g. *Hydrocynus*, *Barbus* etc.(O)
		Beach seining (Chosa; Mukwau)[4]	Total seine methods:	Shores lake,river	*O. mweruensis* (T) *Tylochromis* juveniles (B) many mormyrid species and *Alestes* (O)
		Open water seining (Sikide); "Purse seining" (Chibata)	1193	Shallow parts lakes	*T. mylodon* (T) *O. mweruensis* and many other species (B)
Light fishery on small pelagics	A	Scoopnet (Japan; chapani)[5]	1557	Pelagic lake	*Microthrissa moeruensis* (T) juvenile *Alestes* and small Cyprinidae (B)
		Boat seine (Scullion net)	82	Pelagic lake	*M. moeruensis* (T); *Serr. macrocephalus* (B); *A. macrophthalmus* (B)
		Lift net (Tanganyika style)	5	Pelagic lake	*Microthrissa moeruensis*
		Scoopnet (Mutobi)	12	Pelagic lake	*Microthrissa moeruensis*
		Beach seine (Mukwau; Chosa)	73	River	*Microthrissa moeruensis*
		Chasing	App. 200	Shore lake	*Microthrissa moeruensis*
Line and longline	P	Angling (Indobani/Kuloba)	368	Luapula mouth	*Hydrocynus vittatus* (T) (bait: pieces of *Alestes* or *Serranochormis*)
		Longline (Kabamba; Ngui; Ngoshi): two types (1) large hooks (6,8,10); bait: fish; overnight (2) small hooks (12,14,16); bait: worms, mussel, snail; overnight	50	Predominantly in northern areas of lake	(1) Large *Chrysichthys sharpii*[6], *Clarias* sp. (T) *Heterobranchus boulengeri* *Serranochromis* spp. (B) (2) *C. sharpii*, *Clarias gariepinus*; *C. ngamensis* (T) *Auchenoglanis occidentalis* (B)
Weirs	P	Weirs and barrages (Ubwamba)	App. 40-50	Swamps	Almost exclusively Clarias gariepinus
Traps and baskets	A	Baskets (Intende; Ulwanga)	App. 800	Shores	Small and juvenile cichlids (e.g. *Pseudocrenilabus philander*); small *Barbus* spp.
	P	Traps (Umono)	>2063	Swamps	Two main types: 1. (Dominant) *Clarias theodorae*; *C. buthupogon* (T) *Ctenopoma* sp. (B) *C. ngamensis*; *C. gariepinus*; *H. boulengeri*; *Serranochromis* sp. 2. *O. mweruensis* (T); *Tilapia rendalli* and clariids (B)
		Large traps	10	Open Lake	Large mormyridae (T)
		Drainage traps	3	Swamp	Clariid, Ctenopoma and small *Barbus* spec.
Cast net	A	Castnet	38	Lakeshore, swamp	*Tilapia rendalli* (T). *T. sparmanni* (T); *Serranochromis* sp. (B) *Pseudocrenilabrus philander*

[1]Most active methods are illegal. Reported effort through framesurveys for these methods is probably an undersestimate; [2] Mapira = gillnetting at mid-water depths; [3] Kutumpula = chasing fish into the net by beating on the water with a knobbed stick;[4] Seining = three types of seining are used. The number of fishermen refers to all methods; [5] Chisense gears = all are light fisheries except chasing. Japan = a net hung in between two loose bamboo poles sticking from the side of the canoe, is lowered under the light and hauled inside by at least 2-4 people pulling ropes and poles. A boat seine is operated from two boats by 7-8 persons; method comparable to purse seine but the net is closed at the bottom only at hauling onto the canoe; Mutobi = handheld scoopnet operated by one person; Chasing = two women walking at kneedepth in the water who haul a piece of netting or cloth in between; [6]Previously *Chrisichthys mabusi* (Rich, 1986).

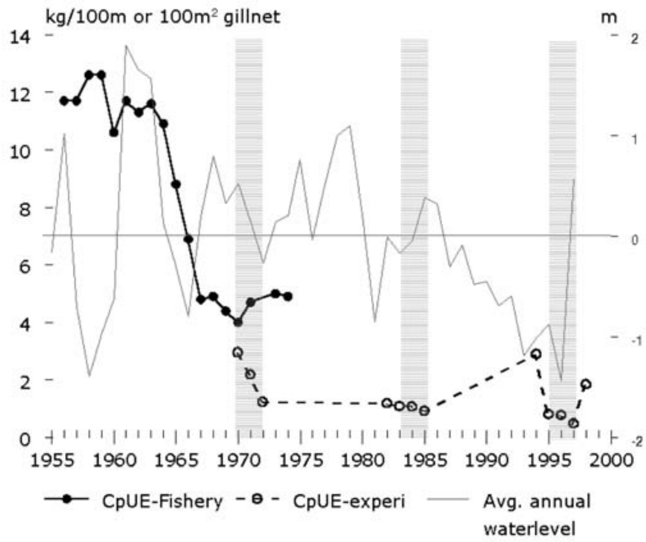

FIGURE 9. *Development of catch rates in the fishery and in experimental surveys with gillnets of dominant mesh sizes in the fishery (76–102 mm in 1970s and 63–76 mm in 1980s and 1990s). Catch rates from the fishery are standardized to 100 kg/m gillnet; catch rates from experimental gear = kg/100 m*^{2}. Water *level is shown as annual deviations of the long term mean. Grey bars indicate years over which biomass-size distributions are calculated (see text)*

to the high adaptability to changing circumstances. The only fishery that requires larger investments, the pelagic light fishery, has converged after initial years of experimentation on a low cost method, both in terms of capital and organization of labour. In the following paragraph we will discuss the result of both this adaptability and the huge increase in effort in particular of the gillnet based fishery.

6. CHANGES IN THE FISH COMMUNITY OF LAKE MWERU IN RELATION WITH EFFORT AND WATER LEVEL

By comparing catch rates in experimental surveys with fleets of gillnets with a range of mesh sizes conducted over three periods between 1970 and 1999 in the lake, changes by species and on a fish community level can be observed[1]. The indicators we will use are changes in species composition of the experimental catch, changes in size and catch rate by species and changes in the size-structures of the fish community based on biomass-size distributions. By relating these changes to fluctuations in lake level and to what is known about effort development in the fishery we can deduce the effects changing and increasing fishing effort would have on the fish community of lake Mweru. Over the period from 1970 to 1999 examined here, effort on the lake has been and still is dominated by gillnets. Mesh sizes used in the fishery have decreased from 76 to 102 mm in the 1970s, via 63–76 mm in the 1980s to mainly 63 mm in the 1990s (Zwieten and Kapasa, 1995, 1996; Goudswaard, 1999).

Gillnets only last for a few years and a whole fishery can shift rapidly from one dominant mesh size to another in response to changes in size structure and biomass of the commercially important species in a fish community. Catch rates in the fishery have dropped from 10 to 12 kg per standardized net before 1964 to around 4 to 5 kg from 1967 onwards (Figure 9), decreasing further since to about one to two kilos now. The vast drop over three years after 1964 coincided with a massive increase in effort both through an increase in synthetic gillnets that became accessible to fishers after independence, an increase in number of fishers and a

[1] Long time series of catch rates from the fishery by species group based on the Catch Assessment Surveys (CAS) could have been constructed, to allow comparative analysis with other case studies (Zwieten and Njaya, 2003; Zwieten, 2003). This would have yielded insights in the potential to detect changes in the fishery with the regular monitoring system. However, since 1974 catch rates are as yet not available in a format allowing such analysis. This also means that no relation between time series of catch rates in the fishery and changes in water level can be made directly.

drop in water levels during a dry spell lasting five years. Increases and drops in catch rates of the fleet of experimental gillnets – i.e. with a range of mesh sizes between 25 and 178 mm stretched mesh other than in the fishery where only a few mesh sizes are used – are generally lower than catch rates from the fishery[1]. They do not appear to follow variations in water levels closely (Figure 8). Changes in aggregated catches and catch rates do not reveal the underlying changes in species composition targeted by the fishery, while total number of species caught in the experimental surveys did not change between the three decades as well: 46 in the 1970s, via 38 to 48 in the 1990s. However, Shannon's diversity index (H'), which includes information on relative abundance, indicated that a change in diversity had taken place over the 30 year period examined. The index decreased from 2.37$\pm$ 0.07 (mean and confidence interval) via 1.21 $\pm$ 0.12 to 1.49 $\pm$ 0.14 in the three periods examined from 1970 to 1996. Thus in experimental catches the number of species did not change, whereas the relative abundance of species did.

These changes are reflected both on a species and on community level. We will discuss these first before trying to relate them to effects of changes in effort and productivity. The biomass-size distributions over the three periods in subsequent decades (Figure 10) contain in a highly aggregated form a wealth of information. The aggregations are over:

- time: three years per decade;
- space: nine sampling sites distributed over the whole lake,
- and category: twelve species and species groups aggregated over catches of in total 78 species, that are simultaneously represented as broadly defined trophic groups as well.

The following can be noted immediately from the graphs:

1. A decreased contribution to the total biomass of large sized individuals of different species from the 1970s to the 1990s, in particular the larger bagrid and clariid catfishes and large Mormyridae, and the large piscivore *Hydrocynus vittatus.*
2. An enormous variability in biomass of the small sized species and specimens, in particular *Alestes macrophthalmus*,
3. A shift in importance of species: an increase in biomass and size of the cichlids *Serranochromis macrocephalus* (dark blue), of *Tylochromis mylodon* (green), and in particular of *Oreochromis mweruensis* (red) and decreased contribution of Mochokidae and Schilbeidae.

6.1 Changes on a species level

Changes in the mean length and mean weight in the catch of the nine most important species in the in the fishery (Figure 11) reveal that:

1. All species decreased in average length comparing the two years 1971 and 1996, except *Schilbe mystus*, but with no consistent pattern over all species at intermediate years. Species that obtain larger sizes, decreased >20 percent in average length. This includes *Alestes macrophthalmus* that can grow up to 50 cm, but has a low mean size because of high abundance of small individuals. Similarly large Mormyridae, other large Clariidae and the bagrid *Auchenoglanis occidentalis* (not shown) have decreased in average length by similar proportions. Of the remaining species shown in Figure 11, a few exhibited a consistent decrease in length over time. But in almost all cases including that of the piscivore *Hydrocynus*, variability in mean length between years was either high, did not

[1] See e.g. Figure 13, for catch rates of groups of mesh sizes as used in the fishery.

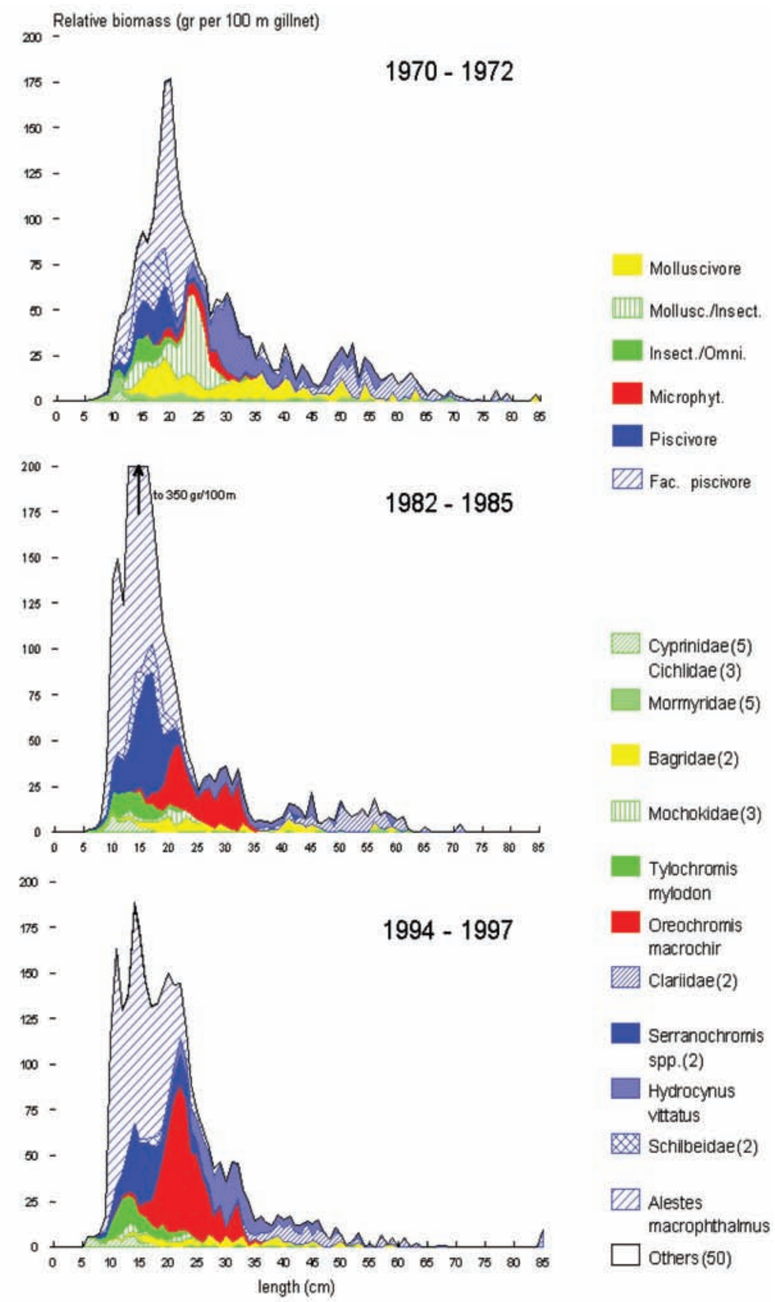

FIGURE 10. *Biomass-size distributions of Lake Mweru over three periods. Stacked areas in the graph indicate species (groups), colours indicate broad trophic categories. Biomass is expressed as standardized average catch per unit of effort of 100 m2 of gillnet by 1 cm length class in the catch over the periods indicated and over all sites sampled during that period. Catch rates were corrected for net selectivity and amount of effort per sampling site. In brackets are the numbers of species combined in that particular group. See text for further explanation.*

change significantly after an initial drop, or even increased again. In particular the cichlid species *Tylochromis* and *Serranochromis*, targets of most of the fisheries, did not change much and in case of *Oreochromis* mean length even increased again between 1994 and 1996.

2. All species declined in mean weight in the catch, except *Oreochromis mweruensis* for which the mean weight in the catch increased consistently over the period examined! The mean weight of the other two cichlids fluctuated (*Tylochromis*) or increased (*Serranochromis*) since the initial drop of between 50 and 80 percent. The mean weight in the catch of the two piscivores *Hydrocynus* and *Alestes*, fluctuated greatly. That of the other species consistently decreased from 1971 onwards.

Apart from species that grow to large sizes, there is no consistent unidirectional pattern in both indicators mean length and mean weight as would be predicted from the unidirectional increase in fishing pressure after 1971 (e.g. Welcomme, 1999). Large individuals of some species have been hit hard, but with differing results with regard to their biomass. Mean

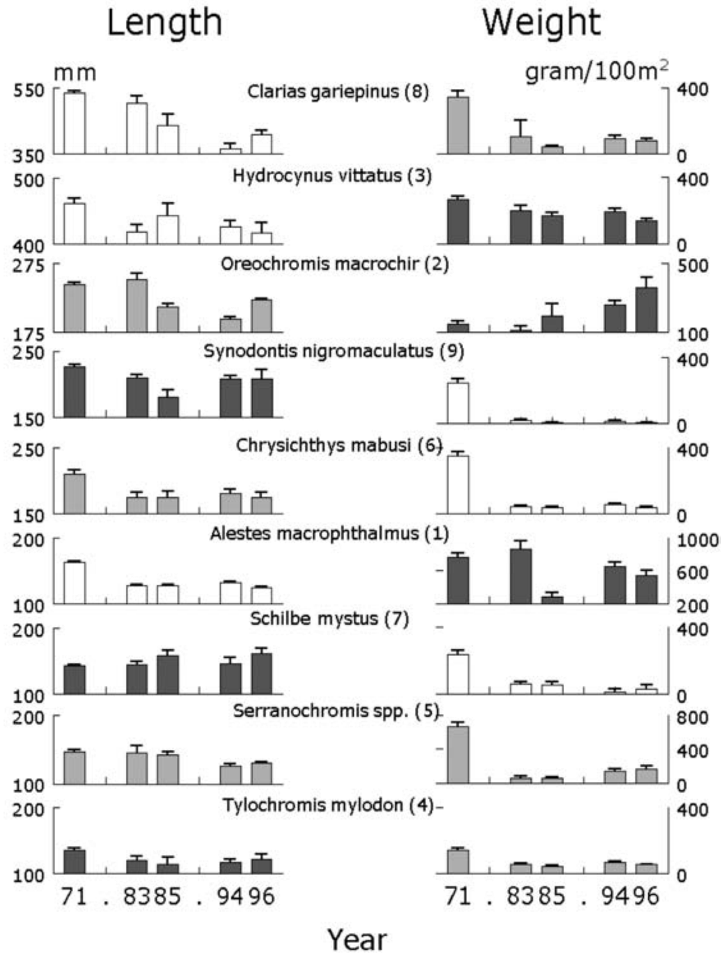

FIGURE 11. *Mean length and weight in the catch per 100 m^2 net of fleets of experimental gillnets of the nine most important species in Lake Mweru from 1971 to 1996 (order of importance in brackets according to the percent Index of Relative Importance (Kolding, 1999). From top to bottom species are ordered by largest mean length measured in the catch between 1971 and 1996. Error bars are 95 percent confidence limits.*
Length*: all y-axis have a range of. 100 mm. White bars:>20 percent decrease in mean length between 1971 and 1996; grey bars: 10–20 percent decrease; black bars <10 percent decrease to increase.* ***Weight****: all y-axis are scaled at 400 mm except for Alestes and Serranochromis. White bars: between 1971 and 1996 >80 percent decrease in mean weight >80 percent; grey bars: 50-80 percent; black bars <50 percent increase.*

lengths of smaller species either vary much or have even increased, again with considerable differences in abundance.

6.2 Predation, fishing and productivity changes

Three important interactions with and within a fish community are to be considered to understand the mechanisms behind the observed changes in biomass-size structure (Figure 12). For our purpose we will leave aside competition, other biotic interactions and spatial considerations:

1. *Predation*: fish predators prey on smaller species and are thus length selective. In the absence of other sources of pressure an increased predation will lead to a decrease in biomass at smaller sizes. Over time this will result in an increased mortality of larger predators and in a decrease in biomass of larger sized specimen of species preyed upon, resulting in a decrease in biomass at larger length categories. A decreased mortality of smaller sizes will follow, and the cycle can start again. In other words, a decrease in biomass of larger individuals theoretically can come about through predation alone.
2. *Fishing effort*: the effect of length selective fishing effort, in Lake Mweru predominantly through gillnets, in principle does not differ from the effects of predation. The point here is that a decrease in biomass of larger sized individuals theoretically can occur without fishing effort being directed at these large specimens.

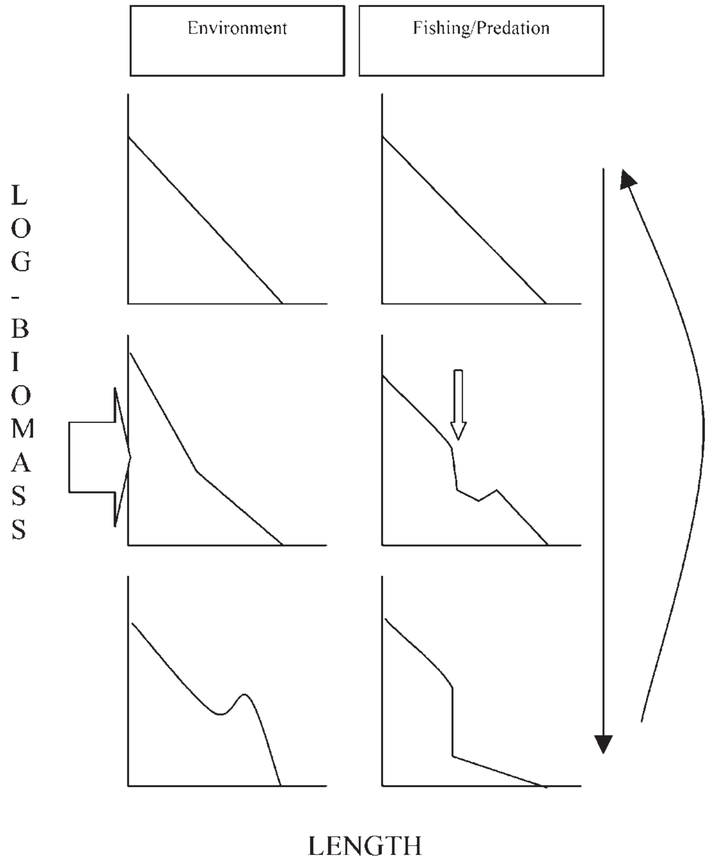

FIGURE 12. *Effect of change in productivity (environment) and length selective fishing pressure or fish predation on the biomass-size structure of a fish community. The biomass-size structures discussed further, are combinations of these processes. Black downward arrow indicates the direction of time; the return arrow indicates a return to the initial state, when the pressure, indicated by the open arrows in the middle panels, ceases. Top: initial state of the length-biomass structure. Left panels: an increase in productivity (large open arrow) causes an initial increase in biomass of small fish that shows over time as a travelling wave over the biomass size spectrum (bottom). Fishing or predation (small open arrow) act at specific sizes of fish, resulting in the theoretical form of the biomass-size spectrum shown in the right panels.*

3. *Productivity changes*: an increase in productivity will lead to an increased recruitment of small sized individuals. A travelling wave of increased production – a good year-class – will move over the length distribution leading, in time, to a higher biomass at larger sizes (Figure 12, left panel).

Predation/fishery rates are the dominant within-community structuring process, and growth of individuals a second order process (Pope, Shepherd and Webb, 1994). The largest sized specimens of fish encountered in the experimental surveys of Lake Mweru are at least six years old. This gives an indication of the time lag over which an increase in productivity would be visible in a biomass-size distribution.

We will now discuss the results of these three interactions as can be gleaned from the biomass-size distributions:

1. *Predation*: five of the nine species mentioned in Figure 11 are partial or ubiquitous fish predators, all preying on *Microthrissa moeruensis* (“chisense”) at least at smaller sizes. This species is short-lived (6-12 months), reaches a maximum size of 5 cm Standard Length (SL) and feeds on zooplankton and insect larvae. Like all small freshwater clupeids, large fluctuations in its standing stock are governed by changes in water level and associated nutrient influx (Zwieten *et al*., 1996). Smaller piscivorous *Alestes*, *Serranochromis* and the Schilbeidae are caught as bycatch in the chisense light fishery. *Serranochromis* also forms an important part of the present gillnet fishery (Figure 12). While the larger piscivores *Hydrocynus* and *Alestes*, both fast swimming animals, can escape the pelagic light fishery, they are caught by the gillnet fishery at intermediate sizes (Figures 11 and 12). Large specimen of *Hydrocynus* and *Clarias* prey on small

cichlids as well. As a result of the decrease in biomass of most fish predators (Figure 11) predation pressure on smaller sizes will be reduced.

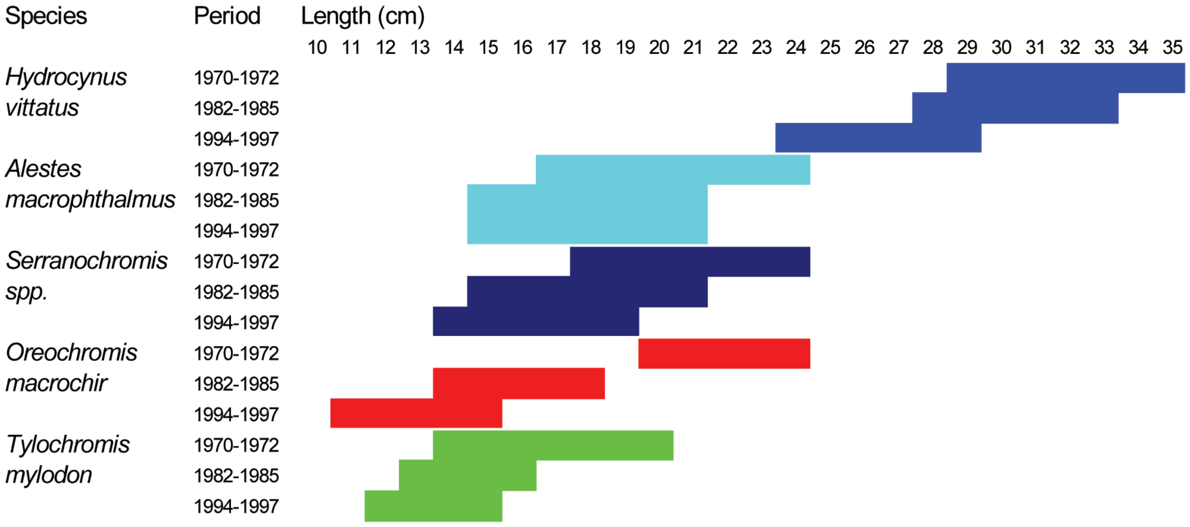

FIGURE 13. *Length selectivity of dominant mesh sizes in the fishery with stationary gillnets of Lake Mweru for the five commercially most important target species. Mesh size changes from 102 mm in the 1970s via 76 mm in the 1980s to 63 mm in the 1990s. The top three species are all piscivores. Active methods with gillnets (seines, water beating) will change the size structure to larger specimens.*

2. *Fishing*: the decrease in mesh size of the dominant gillnets in the fishery, as a result of decreased catch rates (Figure 12), changed fishing pressure to smaller length ranges and different species (Figures 11 and 12). From Figure 11 it can be inferred that the length of species in the commercial catch goes down, as a function of the dominantmesh size in the fishery. Length-selective pressure thus has changed to smaller sizes. Larger individuals of species can escape this fishery. This could be an explanation why larger *Oreochromis mweruensis*, mostly caught in nets of 102 mm and higher, increases in biomass despite increased effort: large *Oreochromis* escapes the present stationary gillnet fishery with 63 mm nets.[1] However, this does not explain yet why the biomass of *Oreochromis* has increased in the first place, so that a larger stock of older year-classes could survive?
3. *Change in productivity*: peaks in recruitment need to occur occasionally to be able to trigger a situation where length-selective mortality incurred by the fishery (F = a proportion of the fishable biomass) will not lead to the subsequent early disappearance of a particular year class. Erratic recruitment with occasional extreme peaks will be an adaptive life history characteristics of a species, that will over time lead to a shift in the size structure not only of the individual species but also of the fish community. Large slow growing species with generally low recruitment levels will eventually disappear from a fishery even if they are fished with passive length-selective fishing methods. In other words: large specimens of such species do not necessarily have to be fished out

[1] A considerable proportion of the catch of Oreochromis in Lake Mweru is made by shore based seines, fishing in the shallower areas where larger sized bream will build its nests. However, given the size of the swept area of Mweru seines, even if the complete accessible coast of Lake Mweru would be covered by this activity, this would still represent only around 10-15 percent of the area that could be utilized by bream for breeding.

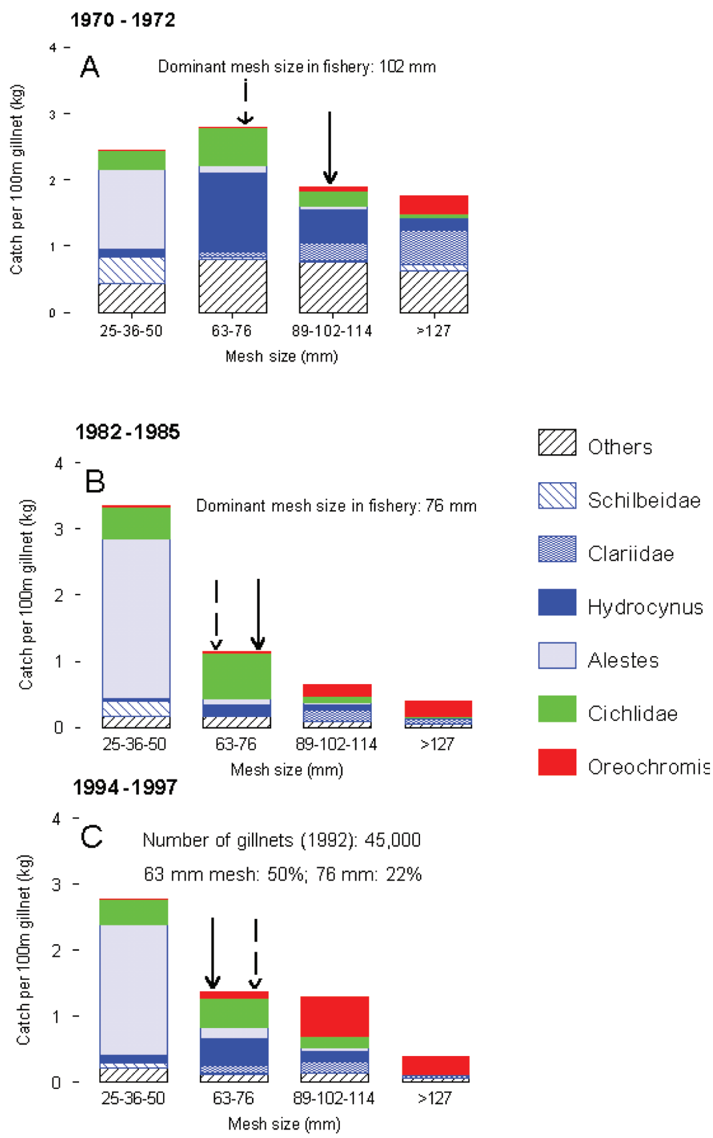

FIGURE 14. *Catch rate composition of experimental gillnets in groups of four mesh sizes in three periods from 1970 to 1996. Shown are the six most important species in the catch and a rest group containing all other species. Solid and broken arrows indicate the first and the second dominant mesh size in the catch respectively. Blue in stacked bars represents fish predators.*

themselves, their biomass will decrease through natural causes, not being supplemented by younger year-classes. In contrast, small fast-growing short-lived species, with highly fluctuating recruitment levels triggered by external drivers will always show extreme variability in catches and catch rates, independent of the size of the fishing mortality: they appear and die faster than the fishery can fish them out. But, and this is the point to be made, also larger species that have slower growth rates, and irregular recruitment – that is occasional extreme peaks – will show a high variability. In the case of pulsed systems like Mweru and *Oreochromis mweruensis* changing water levels triggers these peaks. This will result in considerable change in size structure within a few years after such events, despite high selective fishing pressure, as the fishery does not adapt as fast as the size-structure changes. For instance, two years after the high water levels in 1998, catches of 25 cm (? two year old), *Oreochromis* were so high that the two fish freezing factories stopped buying fish in fishing camps as their freezing capacity was too low to handle the enormous supply. A large increase in biomass of *Oreochromis* of 25 cm had occurred due to the recruitment peak in 1998 (van Zwieten, pers. obs.).

6.3 Changes on a system level

Based on the three mechanisms that explain the overall changes in biomass-size structure of the Mweru fish community, we will now look at changes on a system level. A biomass-size curve of a fish community is exponentially descending over size: there is a larger biomass of small fish than large fish. Variations in the shape of this curve indicate systematic changes in the size-structure of a community that can be related to variables such as changes in lake-productivity and human impacts (Cyr, Downing and Peters, 1997). The first question is whether there is a systematic change in the overall distribution of length classes over biomass. Regression lines through a log-transformed biomass-size curve[1] differ in slope and intercept with the biomass-axis, which differences can be interpreted as follows:

1. same slope but decreasing intercept means a decrease in overall productivity: this seems to have happened between the periods 1970/72 and 1982/85. Note that this means lower biomasses of smaller as well as larger sized fish.
2. increasing slope and increasing intercept means a shift of the biomass of a fish community towards smaller species and specimens (Rice and Gislason, 1996). This seems to have happened between 1972/85 and 1993/96.

Two questions are relevant for a decision on the significance of these observed differences. First, disregarding the distribution of the residuals around the regression lines, are the observed slopes and intercepts at all significantly different from each other? Second, it will be immediately clear from the graph (Figure 15) that the residuals are not randomly distributed around the regression lines, but are considerably auto-correlated, which has an influence on the values of both slope and intercept. What information does this curved shape of the distribution of the biomass-size structure of the community contain? Changes in the shape of the distribution are of interest, in the light of the above outlined model on changes in size structure on a species level (Figure 12). The first question will be answered by stepwise examining a series of regression models through which slopes and intercepts can be compared. The second question will be answered more tentatively by comparing the shapes of splines drawn through the three biomass-size distributions constrained such to explain at least 90 percent of the variation in the length-biomass distribution, and relate these splines both to changes in fishing and lake level fluctuations.

First: are the changes in slope and intercept as noted significant, in other words, are the perceived differences in intercept of 1990s > 1970s > 1980s and in the slope of 1990s > 1970s = 1980s? Slope and intercept of a regression line are strongly correlated, which means that they cannot be independently examined for significance between different regression lines. By examining the reduction in variability in regression models in which either slope or intercept are fixed, and compare these with the overall reduction of variability in the full model the significance of changes in intercept and slope can be established (Table 6). The amount of variability explained by the differences between slopes ($r^2 = 0.02$) and intercepts ($r^2 = 0.03$) in the full model is very small. The full model (the last line in Table 6) gives the result that the intercepts are significantly different only between 1990s and 1970s, while all slopes are significantly different from each other, with 1990s having both the highest slope and intercept. In the full model, the slopes of the 1970s and 1980s closely resemble each other, but separate

[1] The aggregated level of Figure 15 is Figure 10 with a 10log-transformed biomass-axis.

slope analysis reveals that there is no difference between the three slopes. Co-variance analysis shows that only the intercepts of 1990s and 1970s are significantly different from each other, with higher intercept in the 1990s. The intercepts of the 1980s and 1970s are not significantly different from each other. From this analysis we can conclude that while a change in productivity between the 1970s and 1980s cannot be shown, the change in size distribution between the 1990s and 1970s is significant. This indicates that in the last two decades a qualitative change in length distribution of the whole fish community has taken place. But it is also clear from this analysis that the observed differences in overall size structure are not dramatic, when taking into account the large time window (>20 years) and the massive increase in fishing effort that has taken place over this period.

TABLE 6. *Regression models to compare the significance of sources of variation explaining the total variation in the biomass over size. Both biomass and size were centred around the mean (mean L=49.5, mean B=1.27). L=length (size); B=^{10}log(CpUE) (=biomass); D=decade, respectively top=1970-72; middle= 1982-85; bottom=1994-97; N_{obs}=number of obsevations corrected for the mean. SSQ = sum of squares; Df = degrees of freedom of the explanatory variable (source); significance levels are indicated by asterisks: * = p<0.05, ** = p<0.01 , *** = p<0.001, n.s. = not significant*

Regression model	N_{obs}	Total SSQ	Source	Df source	Explained SSQ	p	Slope	Intercept
Overall slope B ~ L	163	56.59	L	1	41.40	***	-0.029 ***	-0.227
Separate slopes B ~ L(D)	163		L	3	41.76	***	-0.029 *** -0.026 *** -0.033 ***	-0.227
Separate slopes compared to overall slope B ~ L + L(D)	163		L L(D)	1 2	41.40 0.36	*** n.s.	-0.033**** n.s. n.s. --	-0.227
Separate intercepts B ~ L + D	163		L D	1 2	41.40 1.71	*** ***	-0.030	-0.315*** 0.209***- 0.075 n.s. --
Full model: separate slopes and intercepts compared to overall slope and intercept (see figure 13) B ~ L + D + L*D	163		L D L*D	1 2 2	41.40 1.71 0.86	*** *** **	-0.037*** 0.010** 0.008* --	-0.386*** 0.292*** 0.080 n.s. --

Second: what information can be inferred from changes in the shape of the biomass-size distribution? A clear dip in the length structure around 44 cm can be observed in the 1970s, decreasing to 36 cm in the 1980s. The dip disappears again in the 1990s. By then the descending curve is smoothed both through an increase in smaller size categories compared to 10 and 20 years before, and the disappearance of the peak in biomass around 51 cm (1970s) and 54 cm (1980s). In other words, it seems that between the first two decades a broadening of size selective mortality has occurred towards smaller fish, causing the plateau between 36 and 54 cm. Both 1970s and 1980s distributions were preceded by high water levels in 1968 and 1979 respectively or between 2–5 and 3–6 years before the periods over which the size distributions are calculated. Since 1986 up to 1998 water levels consistently decreased (Figure 9). The dominant fishing pressure was directed to fish species of up to 35 cm, shifting to smaller sizes over time (grey bar in Figure 15; Figure 13). Larger sized fish will be caught by active methods and by non-size selective processes such as entangling, which could have quite an effect taken over a whole fishery. However, these observations could also indicate that larger sized fish disappeared in the 1990s because of reduced pulses of productivity over a significant period of time. Increased biomass of smaller sizes in the 1990s could then occur both because of decreased predation pressure and fishing.

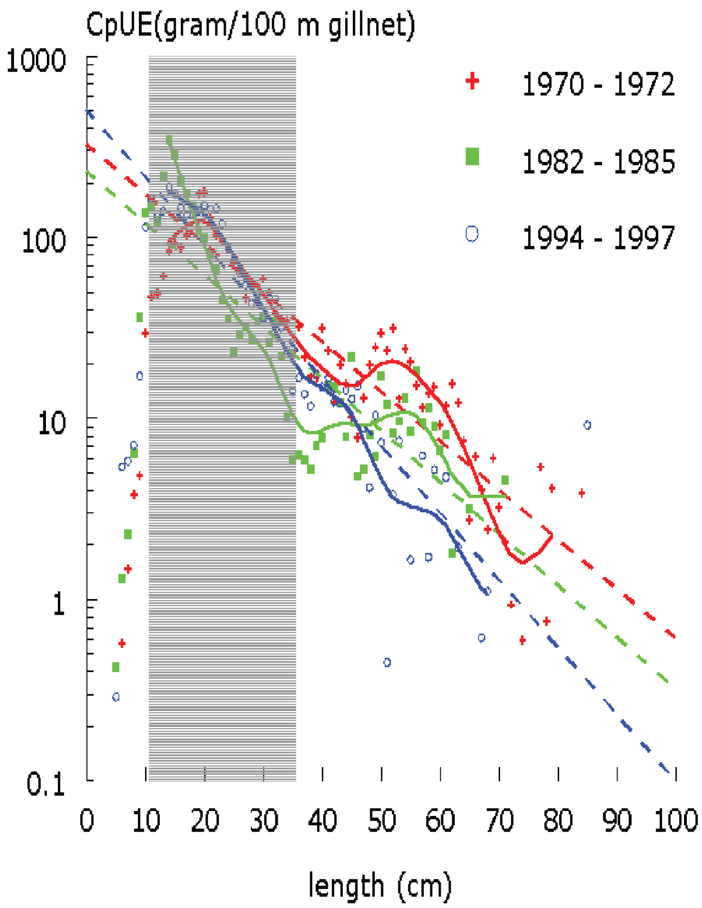

FIGURE 15 *Biomass-size distribution with linear regression lines and spline by period. Splines were constrained at lambda =100 explaining 91-92 percent of the variation. Linear regression was done from lengths ≥14cm. The parameters from the linear regressions for respectively the 1970s, 1980s and 1990s are as follows (^{10}log-transformed values): intercept=2.52, 2.37 and 2.71; slope=-0.027, -0.029, -0.037; r^2=0.83, 0.68, 0.78. All slopes and intercepts were significant at $p< 0.001$, but see text for further explanation. Grey bar indicates selectivity of the gillnet fishery over the whole period between 1971 and 1997 of species of commercial importance.*

As the conceptual model in Figure 12 indicates, a dip in the biomass-size structure followed by a peak at larger sizes could come about both through previous periods of higher productivity and because of size-selective fishing pressure. Size selective mortality through fishing did shift to the smaller species that have a higher turnover and hence are more resilient to this pressure. But it cannot be decided from just these observations alone which of the three processes are dominant in determining the particular shapes of the biomass size curve in each period. However, it will be clear from these tentative remarks that, while fishing will have an effect on size structure and species composition of fish community, fishing alone does not determine it in this system where large recruitment peaks occur as a result of irregular large (to extreme large) flood pulses.

7. CONCLUSIONS

All fish communities harbour species or segments of populations that are resilient to fishing to different degrees. For Mweru-Luapula these can be categorized as (Coulter, unpublished; see also Chapter 5 in Jul-Larsen *et al*., 2003):

1. *Susceptible to fishing* were the spawning runs of the *Labeo altivelis* (Mpumbu), a species that has disappeared from the fishery[1]. Equally susceptible are large, old, specimen of long-lived species such as all catfish species (*Clarias* spp., and the bagrids *Auchenoglanis occidentalis* and *Chrysichthys sharpiii*) and the predatory tigerfish *Hydrocynus vittatus*.
2. *Resilient to fishing* are the tilapias – the mainstay of many African fisheries as well as Mweru – notably the detritus feeder *Oreochromis mweruensis* (Pale). Stocks of *O. mweruensis* appeared to be depleted in the 1970s, but returned, resulting in huge catches of two year old sized fish two years after the high increase in water levels in 1998; The predators *Serranochromis* spp. and the mollusc and insect eater *Tylochromis mylodon* are relatively resilient to fishing as well.
3. *Highly resilient to fishing* are the species with high population turnover rates: *Microthrissa moeruensis* (chisense) with a P/B ratio[2] of around 5 (Zwieten *et al.*, 1996), and small *Alestes macrophthalmus*. *A. macrophthalmus* can grow to large sizes, but matures already at small sizes. The standing stock of these species varies tremendously as can be seen in Figure 10.

As of 1997 the fish community of lake Mweru has shifted towards smaller sizes, in particular with the onset of the pelagic light fishery, that now dominate the catch. In fact now that the more resilient part of the fishery is being exploited, total production has increased tremendously and as a result also varies more (Figure 1). Fishing therefore has become more uncertain for the individual fisher, and the total outcome will be more susceptible to boom and bust periods. Whereas the average size of fish landed by the fishery becomes smaller, due to the size selection of the dominant mesh sizes used, it is less clear what happens with the length of individual species in the stocks. If, that is, part of the available (larger) sizes of the fish population is released from fishing pressure, as result of the interplay between size selective fishing mortality and recruitment variability. Considering the large period examined over which a dramatic increase in fishing effort has taken place, average length of fish caught has not changed very fast. Average length thus is only a good indicator of change caused by fishing effort for larger species with generally slow growth rates. In other words, for the mainstay of the fishery of lake Mweru, the cichlids, and smaller target species, length does not seem to be a good and timely indicator of change (contrary to Welcomme, 1999).

Based on this analysis it can be concluded that smaller mesh sizes could be less harmful and more productive for a multispecies fishery such as that in lake Mweru. The danger that small mesh sizes will lead to growth over-fishing is diminished, as a result of pulses in floods that lead to very strong year classes of which a considerable proportion still can outgrow the size-selective fishery. However, extended periods of low pulses such as between 1986 to 1998 may then be particularly dangerous in affecting this type of resilience. With the recent high water levels an increase in biomass of larger sized specimen, also of the predators *Hydrocynus* and *Alestes,* can be expected.

[1] Though not from the ecosystem (Goudswaard, pers. obs.).

[2] P/B ratio = ratio of annual Production over instantaneaous Biomass. In this case the production is the total annual catch of the fishery on Microthrissa moeruensis, and the biomass is estimated through acoustic methods at a specific moment in time (hence instantaneous). The ratio is thus a measure of the speed of biomass regeneration (see Chapter 5 and Appendix in the Synthesis Report, FAO Fisheries Technical Paper 426/1).

Lake Mweru has a multigear fishery whereby the dominant part of the catch of gillnets and traps is formed by species feeding on low trophic levels such as the microphytovore and detrivore *Oreochromis mweruensis* (around 20 percent of weight of the gillnet catch), while at present the largest catch comes from the zooplankton feeder *Microthrissa moeruensis*. Intermediate levels such as the molluscivore *Tylochromis mylodon* (6 percent of the weight in gillnet catch), the omnivore *Clarias gariepinus* (10 percent) and the predatory species such as *Hydrocynus vittatus* (22 percent) and *Serranochromis* spp. (10 percent) still form a substantial part of the catch. Theoretically a fishery that utilizes available stocks at all trophic levels in proportion to their biomass turnover could be a resilient fishery not affecting the structure of the fish community (Jul-Larsen *et al*., 2003). As changes in the fishing methods will be slower than changes in the stocks and as effort keeps on increasing, it will depend on the flood pulse driven dynamics whether a longer term pressure, in particular on the more vulnerable parts of the fish community, will result in structural changes in the ecosystem. The fishery of Lake Chilwa (Zwieten and Njaya, 2003) presents a case where catastrophic natural events leads to a simplified fish community that can withstand very high fishing mortalities, while changes in total catch reflect recruitment variability. After the tremendous increase in effort in the 1980s and 1990s, the gillnet fishery in Mweru, now with a few dominant mesh sizes, selectively fishes out fish between 10 and 20 cm, while the pelagic fishery targets even smaller sizes. Structural changes in the fish community have taken place as a result of the increase in effort, and fishing patterns have moved in a direction comparable to Lake Chilwa. At present Mweru-Luapula can be described as an open exit fishery where a highly dynamic population of fishers makes use of a variable but resilient resource base.

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Appendix

LIST OF SPECIES OF LAKE MWERU MENTIONED IN THE TEXT WITH LOCAL AND ENGLISH NAMES

Family	Species	Local name (Bemba)	English name
Cichlidae	*Oreochromis mweruensis*	Pale	Green headed bream
	Tilapia rendalli	Chituku	Red breasted bream
	Serranochromis macrocephalus	Makobo	
	Serranochromis stappersii	Makobo/Impanda matete	
	Tylochromis mylodon	Ntembwa	
Mormyridae	*Mormyrops longirostris*	Kafutwe	Elephantfish
	Mormyrus anguilloides	Mulobe	
	Marcusenius monteiri	Lusa	
	Marcusenius macrolepidotus	Lububu	
Alestidae	*Hydrocynus vittatus*	Imanda	Tiger fish
	Alestes macrophthalmus	Misebele	Torpedo robber
Cyprinidae	*Opsaridium zambezense*	Mutande	Carp like fishes
	Labeo altivelis	Mpumbu	Luapula salmon
Schilbeidae	*Schilbe mystus*	Lupata	African butterfish
	Schilbe banguelensis	Ibanga	
Clariidae	*Heterobranchus boulengeri*	Katondwa	Catfishes
	Clarias gariepinus	Muta	
	Clarias theodorae	Milonge	
	Clarias buthupogon	Milonge	
	Clarias ngamensis	Akabukula	
Mochokidae	*Synodontis species*	Bongwe	Sqeakers
Bagridae	*Chrysichthys sharpii*	Imonde	Bagrid catfishes
	Auchenoglanis occidentalis	Mbowa	
Clupeidae	*Microthrissa moeruensis*	Chisense	Freshwater herring

THE BANGWEULU SWAMPS – A BALANCED SMALL-SCALE MULTISPECIES FISHERY

J. Kolding, H. Ticheler and B. Chanda

This study is dedicated to the memory of Ben Chanda who suddenly passed away while we were working on it. Ben Chanda worked for the African Wildlife Foundation and before that for the Fisheries Department of Zambia.

1. INTRODUCTION

The fishery of the Bangweulu swamps, in Luapula Province, Northern Zambia (Figure 1), is an artisanal small-scale multi-gear, multispecies fishery. Eighty-three species representing 13 taxonomic families have been recorded from the area (Evans, 1978) most of which are caught and utilized. The general impression with the local administration is that the fish stocks are heavily fished. Presently fish stocks are considered threatened by high fishing pressure from both the large numbers of permanent residents in the swamps as well as from the seasonally migrating fishermen coming from surrounding areas. Already for a long time fears have been expressed that the fishery of the Bangweulu system has undergone alarming changes indicated by a decrease in the mean size of fish caught and a general decline in catch per unit effort (Evans, 1978). Total yields however, although fluctuating, show an increasing trend. Fishermen are believed to contribute to these changes by an intensified utilization of small meshed gillnets, seining, weirs, as well as “kutumpula fishing” – a technique which drives the fish into surrounding gillnets by beating into the water (Mortimer, 1965). There is a need for evaluating these changes in the fishery and to establish whether they are indications of possible overfishing, inappropriate (and illegal) fishing practices, or natural factors.

This case study will present and discuss the main results from a length-based stock assessment survey carried out in 1994-1995 (Kolding, Ticheler and Chanda, 1996a, 1996b). The survey was made to establish growth parameters, gear selectivity, individual exploitation rates, and overall exploitation pattern in the multispecies swamp fishery. We conclude that the observed changes are not alarming. On the contrary: we find that the fishery is remarkably adaptable to the natural circumstances; that the exploitation is heavy, but with no evidence of gross overexploitation in general, at the most on some of the larger species; and that the current exploitation pattern is to a large degree unselective and thus in principle ecosystem conserving.

2. BACKGROUND INFORMATION

The Bangweulu perennial swamp (Figure 1) can be characterized as a vast, shallow, oligotrophic, seasonally fluctuating, but predictable aquatic system. The main inflow is via the Chambeshi River that enters the swamps from the east. The surplus water leaves the Bangweulu swamps in its southwestern part through the Luapula River, which later enters the Lake Mweru further north and subsequently connects with the Congo River system. Strong seasonal water level fluctuations with relatively low inter-annual variations (Figure 2) create annual changes in habitat availability (areas of inundation), pathwayas of fish dispersal and pulses of food availability.

The general low level of total dissolved solids in the water, resulting in low conductivity, rank the Bangweulu amongst the most dilute water bodies in Africa (Welcomme, 1972) with very low concentrations of phytoplankton (Table 1). The swamps are dominated by heavy stands of papyrus (*Cyperus papyrus*) along channels and permanent water bodies, fringed by a zone of *Eleocharis* sp. and *Nymphea* sp. *Phragmitus pungens* (reed) and *Eleocharis dulcis* is found on sandy shores of channels. Various sedges, spearworts, wild rice and hippo grass (*Vosia* sp.) are found on firmer ground. The dense emersed vegetation filters nutrients out of the in-flowing Chambeshi waters, especially papyrus, which is able to fix large amounts of nutrients.

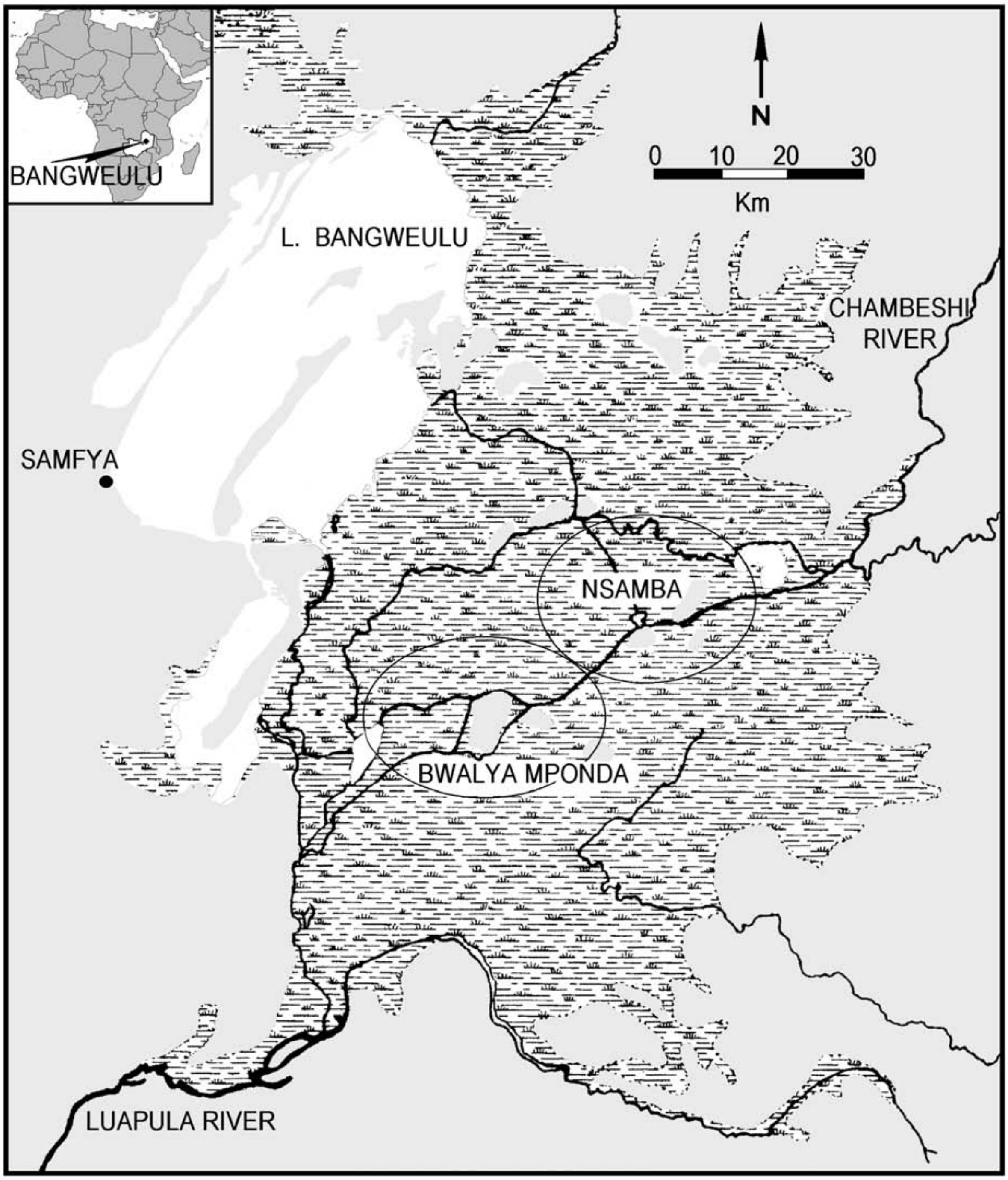


FIGURE 1. *Map of Lake Bangweulu and the perennial swamps with indication of the two sampling areas at Nsamba and Bwalya Mponda. The fisheries research station is located at Samfya. (Map drawn by Elin Holm).*

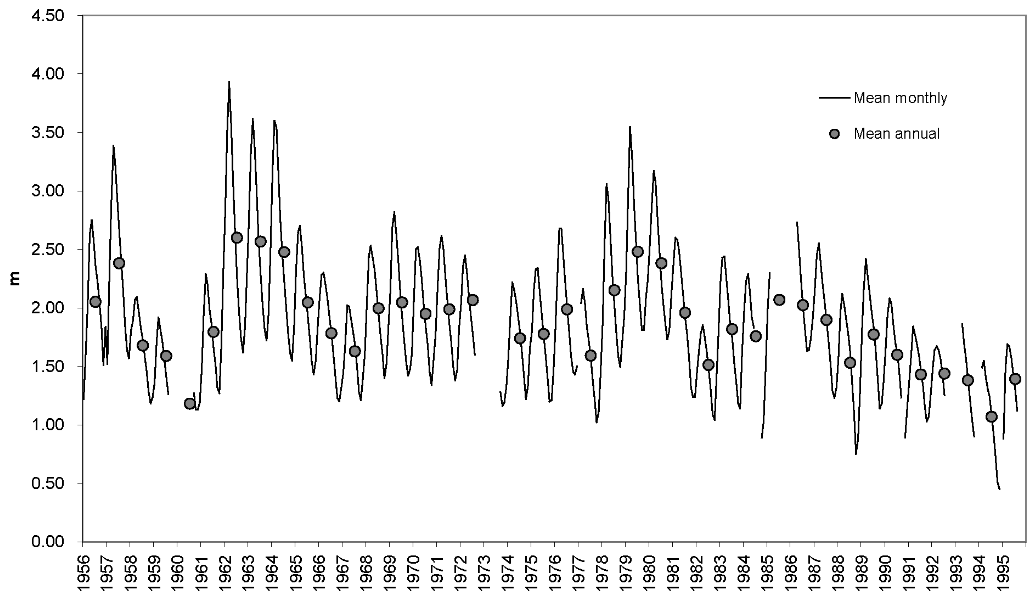


FIGURE 2. *Mean monthly and mean annual water levels of Bangweulu (recorded at Samfya). Mean annual maximum level (March) is 2.46 m (SD 0.60). Mean annual minimum level (October) is1.36 m (SD 0.31).*

TABLE 1. *Selected geographic, limnological and physicochemical data of the Bangweulu system.*

Data	Value	Source
location	10°15' - 12°30' S 29°30' - 30'30°5"E	Bossche and Bernacsek 1990
permanent swamp area (km^2)	5170	Toews 1977
total lake surface area (km^2)	2735	Toews 1977
floodplain area (km^2)	7101	Toews 1977
catchment area (km^2)	109469	Toews 1977
water depth swamps (m)	1 to 2	own data
mean annual water level fluctuation (m)	1.2	Dept. of Water Affairs
minimum water level as percentage of maximum	46 %	
Conductivity (mS m^{-1})	26.5 to 34.3	Bos and Ticheler 1996
pH	6.3 to 6.9	Toews 1977
O_2 %	40-100	Bos and Ticheler 1996
total alkalinity (mg l^{-1})	0.31 to 0.46	Bos and Ticheler 1996
Transparency (m)	0.6 to 1.7	Bos and Ticheler 1996
Total dissolved solids (mg l^{-1})	41.0 to 89.0	own data
Water Temperature (°C)	18.3 to 27.3	Toews 1977
Chlorophyll-*a* (microgram l^{-1})	below detection level of 5 µg l^{-1}	Bos and Ticheler 1996

Fishery research has been carried out intermittently in the Bangweulu lake and swamps since the late 1930s (Ricardo, 1938; Bertram and Trant, 1991), but little has been published in scientific papers or reports (Toews, 1977; Evans, 1978; Toews and Griffith, 1979). Since the late 1970s research has been limited, particularly in the swamp area. In decreasing order of data available the following information on the fisheries existed before the survey:

1) Yield: Fluctuates with a slightly increasing trend. Reported annual yield (mean ±SD) since 1952 is 11, 366 ± 2, 370 tonnes (Figure. 3) (Bazigos, Grant and Williams, 1975; Evans, 1978; Lupikisha, Musuka and Mung'omba, *et al.* 1992, Dept. Fisheries, Zambia).

2) Effort: Frame surveys from 1965, 1971, 1973, 1975 (additional frame survey) 1992 and 1996 (additional frame survey) indicate no trends in fishing effort (Table 2). This is remarkable as in various African fisheries the numbers of fishermen follow at least the demographic growth in a country (van Zwieten, pers. comm.). The lack of demographic growth probably has to be attributed to the harsh living conditions in the swamps and the limited amount of islands to settle on.

3) Growth: Reported for two species: *Tylochromis bangwelensis* and *Hydrocynus vittatus* (Griffith, 1975, 1977), based on scale readings

4) Mortalities, biomass and production: No reliable information available.

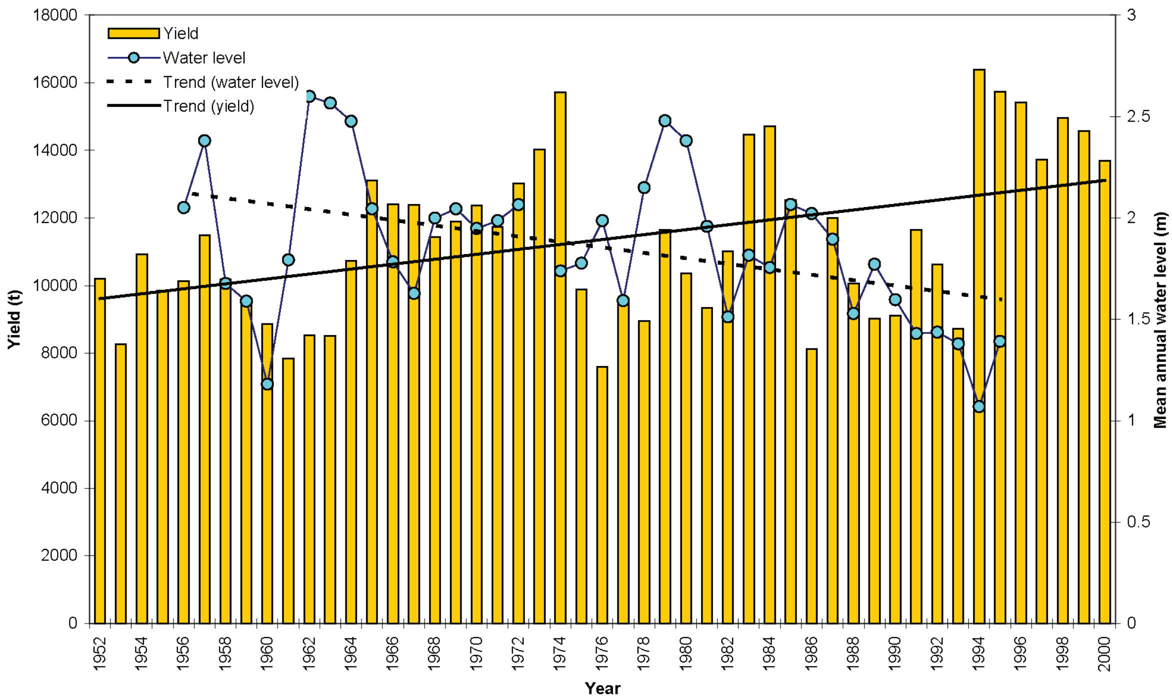


FIGURE 3. *Reported annual yields from the Bangweulu fishery (1952-2000) together with the mean annual water levels (1956-–95). Both trend lines are significantly different from 0 at the 95 percent confidence level. There is no statistical correlation between the annual yield and water level data.*

TABLE 2. *Recorded effort in the Bangweulu fishery*.

Year	No. fishermen	No. actively involved	No. canoes	Source
1965	5 015		6 437	Anon., 1965
1971	5 193	13 878	5 475	Inoue, 1971
1973			8 739	Bazigos, Grant and Williams, 1975
1976		7 696	4 500	Evans, 1978
1992	4 800	10 240	5 900	Ticheler and Chanda, 1993

3. MANAGEMENT REGULATIONS

Fisheries management by the Department of Fisheries in Zambia is primarily focused on effort regulation. A number of nation wide fisheries regulations have been gazetted and one of the duties of the Department is to enforce them.

Regulations currently in place are:
- a closed fishing season from the first of December to the first of March. It is not allowed to fish in this period and transport of fish is prohibited as well.
- mesh size restrictions. In the Bangweulu fishery mesh sizes smaller than 51 mm (2 in") stretched mesh are prohibited.
- fishing gear and method restrictions. All forms of active fishing are prohibited, this includes the popular kutumpula fishing and seine netting. Although not explicitly mentioned in the fisheries act, fishing weirs are generally regarded as illegal gears as well.
- industrial fishing is not allowed in the Bangweulu fishery.

Furthermore Bangweulu is declared an open access fishery. This means that everybody with a fishing licence and legal fishing gear is free to enter the fishery.

In practice however, these regulations are hardly followed by the fishers who disagree with most of them. Fishermen claim that catches of most of the small species as *Tilapia sparmanii*, *Barbus paludinosus*, *Petrocphalus catastoma* and others, are not economically viable if the regulations were to be followed (Chanda, 1998). On the other hand the Department has neither the means nor the manpower to enforce the regulations other than through sporadic patrols. Only during the closed season the transport of fish from the Bangweulu fishery to the outlet markets is controlled to some extent, and with that possibly the levels of fishing effort during that period.

4. METHODS

4.1 Data collection

Fisheries statistics used for estimating annual fish production, species composition, effort, etc., in inland African fisheries are collected by research officers and assistants from governmental research institutes. The methods are usually quite similar and originate from proposals from the FAO in the 1970's. The techniques used are mainly experimental gillnet surveys (GNS) for biological parameters and fishery independent data, frame surveys (FS) for inventories of all fish production factors, and catch and effort surveys (CAS) for sampled daily catch and effort data. The collection of CAS data typically follows a stratified simple random design, where intensity of sampling depends on available manpower and economical resources. The precision, accuracy, usefulness, and cost-efficiency of these methods have sometimes been questioned (Orach-Meza, 1991) and reliable landing statistics is a notorious problem in many African inland fisheries. However, few other sampling alternatives have been developed or tried out.

In Lake Bangweulu the Department of Fisheries (DoF) has employed for many years the above mentioned data collection methods and sampling design. Multi-mesh experimental gillnet surveys, operated by DoF, were used for biological data collection in the open waters since 1971 and CAS survey rounds were done to collect catch-effort data. However, the sample frequency varied strongly over the years depending on availability of funds. The amount of fish of different species caught in the GNS was inadequate to allow for a realistic assessment of the fish stocks in the swamps. In addition, the structure and composition of the artisanal catches was not reflected in the data collected and the time series of catch and effort data from the CAS surveys was too short and contained too little contrast to allow for meaningful analysis.

It was therefore decided to carry out an independent length-based stock assessment of the most important stocks. To obtain sufficient data within a limited period, a number of full-time professional fishers living in the swamps were selected and engaged to carry out part of the sampling, in parallel with the already established monthly experimental GNS by the DoF. Each fisher would receive a basic fee per month for measuring and recording all his catches by species, length, mesh size and sampling area. Some would utilize their own gear (in order to get a representative picture of the fishing pattern) and some would be issued with experimental gillnets (in order to establish growth and mortality parameters). All the fish caught would belong to the fisher and he would be free to fish where and when he wanted, as long as he recorded the catches. This approach of engaging local fishermen in scientific fisheries data collection is to our knowledge new and had never been tried out before (Ticheler, Kolding and Chanda, 1998).

Two main sampling areas in the central swamps were identified: Bwalya Mponda and Nsamba (Figure 1). In these areas all common swamp habitats were well represented, and it was assumed that the status of the stocks in these areas would represent the situation in most parts of the swamps. In each area five fishermen were engaged in the sampling. Three of these were issued with a standard fleet of experimental gillnets (mesh sizes spanning from 25 mm to 140 mm with 12.5 mm increments, i.e. altogether 10 mesh panels), which they should employ concomitantly with their own nets or methods (e.g. gillnets, seines, or “kutumpula”). They were free to choose when they set the experimental nets as long as they were utilizsed on a frequent regular basis. The two remaining fishermen were chosen among those who used kutumpula or seines. A detailed description and discussion of the “Fishermen Data Collection Method” (FDC) is given in Ticheler, Kolding and Chanda (1998).

Data from the 13 most abundant and commercially important species were selected and analysed with respect to gear selectivity, growth rates, spawning frequency, mortality rates, and present and long-term yield assessment. The yield analysis has concentrated on gillnets, kutumpula nets and seines, which are the most important fishing gear in the perennial swamps. Weirs, in connection with small meshed (3–10 mm) fish traps, are another important fishing method, which are mainly (90 percent) found in the seasonal floodplains. For logistical reasons weirs could therefore not be included in this study (Ticheler, Kolding and Chanda, 1998). A separate detailed analysis of the weir fishery, which catch a broader size range and higher proportion of smaller specimens than all the other gears, is given in Chanda (1998).

The standard experimental gillnets (25 to 140 mm) used by DoF were not representative for length groups smaller than 10–12 cm TL for any of the examined species, and they were also not representative for the artisanal catch composition. In order to estimate growth and mortality parameters for most of the smaller species, which are important in the Bangweulu swamps, the sampling design was extended by supplying five of the fishermen with small-meshed experimental monofilament gillnets (the Swedish Lundgren survey types) alongside the experimental standard gillnets.

4.2 Length-frequency data

Nearly one million single fish measurements from various gears were recorded and computerizsed covering a period of two years from July 1994 to July 1996 (Table 3).

TABLE 3. *The number of individual fish records and fish species collected in different fishing gears between July 1994 and July 1996 (except the Lundgren nets, which covers the period June 1995 to July 1996). Local fishermen collected all data except DoF experimental gillnets.*

Gear/method	No. of records	No. of species
DoF experimental gillnets	16 528	37
Experimental gillnets	264 589	37
Lundgren nets	102 602	36
Artisanal gillnets	233 717	34
Seine fishery	290 736	34
Kutumpula fishery	37 810	21
	945 982	

4.3 Frame survey data

TABLE 4. *Total number of fishing gears by type and mesh size for the Bangweulu swamps and the overall fishing effort used in calculating catch volumes by length group and gear type. Data from frame survey 1992, kutumpula survey 1996. Data from the weir fishery (Chanda, 1998) are included for comparison but not used in this study.*

	Total number by gear type			
Mesh size (mm)	Gillnets	Kutumpula nets	Seines*	Weir traps
3				3 869
4				8 358
6				2 322
8				387
10				
25	534	17	53	
38	6 719	68	178	
50	4 233	135	49	
63	1 260	643		
76	554	74		
89	136	-		
102	-	-		
114	-			
127‡	255			
140	-			
Total	13 691	937	280	15 477
Effort	80	100	160	

*mesh size of the bag.
‡The number of 127 mm gillnets has probably more to do with availability of these nets on the market than with specific preference by fishers for these meshes.
†Effort in number of gear settings per year. For gillnets it is 160*0.5 to adjust for catchability (see methods of analysis).

Data from the Frame Survey of 1992 (Ticheler and Chanda, 1993) and an additional kutumpula survey in 1996 has served as input for the calculation of total annual catch volumes by species, by gear category (artisanal gillnets, kutumpula nets and seines) and by length group (Table 4). During the traditional frame survey no difference was made between stationary gillnets and “kutumpula”. However, due to clear difference in the species composition in the kutumpula and stationary gillnet catches (Kolding, 1995; Tables 6 and 7), an additional kutumpula survey was carried out in the swamps where the proportion of all gillnets which is actually being used for kutumpula fishing was obtained (Table 4).

4.4 Methods of analysis

All recorded data were stored in PASGEAR (Kolding, 1996). Most of the calculations, tables and figures were performed using a combination of PASGEAR (ver: 15.10.96) and FiSAT (ver: 1.01, Gayanilo, Sparre and Pauly, 1996; Gayanilo and Pauly 1997). The general approach was based on classical length-structured stock assessment methodology with long-term steady state forecasting (e.g. Sparre and Venema, 1998) using the following steps:

1) Estimation of basic vital parameters (growth and natural mortality) from the experimental gillnet data. For all species the ELEFAN I module implemented in FiSAT was used to calculate parameters for the von Bertalanffy growth function (VBGF) (Gayanilo, Sparre and Pauly, 1988). Total mortality (Z) was calculated from a linearized length-converted catch-curve analysis and natural mortality (M) was calculated from Pauly's (1980) empirical formula with an input Temperature (T) of 23.5 degrees centigrade (estimated mean annual water temperature in the Bangweulu system (Evans, 1978).
2) The growth and natural mortality parameters were used to estimate fishing mortality by length group and overall population sizes from length-based cohort analysis (Jones and van Zalinge, 1981; Jones, 1984; Lassen and Medley, 2001) on the artisanal fishery.
3) Finally a yield analysis and long-term predictions were performed using a length based Thompson and Bell model (Thompson and Bell, 1934). This model combines features of Beverton and Holt's Yield per Recruit model with those of VPA, which it inverts. The basic assumptions are based on a steady state system so that all input parameters, except fishing mortalities, are constants and do not change with fishing effort. Growth parameters, natural mortality, population sizes (recruitment), and fishing mortality by length group estimated in the earlier steps were used as inputs. The Thompson and Bell model was applied for each species in the gillnet, kutumpula, and seine fishery separately (single-species, single gear), as well as on the combined fishery with pooled catches (multi-species and multigear).

The conditions for the validity of this approach are:

1) that the selectivity of the gears used for experimental fishing is such that the derivation of vital parameters is valid, i.e. that the sampled data do represent the population structures, and
2) that it is possible to derive overall catch volumes of the artisanal fishery and that overall length composition data for the artisanal fishery is available.

4.5 Selectivity

The first of these conditions was tested by gillnet selectivity analysis of the experimental catches. Selectivity is a quantitative expression of the probability of capture of a certain size of fish in a certain size of mesh. Indirect methods (i.e. based on catch data alone without *a priori* knowledge on the underlying distribution) for estimating this probability, as in this study, are all based on the assumption that all the fish have the same probability of encountering the gear. This may be a dubious assumption as the smaller fish (specimens or species) normally have a smaller action range than larger fish. This uncertainty, however, is not possible to quantify without independent information on the population sizes and composition. A further assumption of the indirect methods is that all mesh sizes have the same efficiency at their individual "peak length-class", although with the same reasoning as with the previous sassumption, there are indications that the relative fishing efficiency rises with mesh size. Finally, it is a matter of choice which statistical model is used to represent the selection curves for species that also have some degree of entanglement. The statistical models and the method are described in Millar and Holst (1997) and Millar and Fryer (1999) and are implemented in PASGEAR.

4.6 Derivations of overall catch volumes by length groups

The selected fishermen participating in the data collection were encouraged to use their own gillnets. However, it turned out that the participants only used mesh sizes 25, 38, 50 and 102 mm. Therefore their data did not cover the full range of mesh sizes found in the artisanal fishery (Table 4). The overall artisanal catch volume in all gillnets broken down by length groups for Jones' length-based cohort analysis was therefore calculated from the following assumptions: Mean average catch per unit effort ($CPUE_i$) of each mesh $size_i$ per species in the experimental nets were calculated. Overall annual catch per species was calculated from:

$$Total\ catch = \sum (CPUE_i \cdot \#nets\ of\ \ mesh\ size_i \cdot total\ effort)$$

where total number of $nets_i$ and total effort in days fishing were obtained from the frame survey in 1992 and the additional kutumpula survey in 1996. Overall catches of each species per length $group_j$ were calculated as proportions from total catch (see Kolding,Ticheler and Chanda, 1996b for details). A comparison of CPUE in experimental and artisanal gillnets included in the sampling programme revealed that the artisanal nets were less effective then experimental nets, probably due to the general state of the nets, their smaller size, and their age. Based on the overall average differences an estimated conversion factor of 0.5 for CPUE from the experimental to a "general" artisanal net was therefore applied (Kolding, Ticheler and Chanda, 1996b). No conversion factors were applied for seines or kutumpula nets as the data originated from the gear used in these methods.

4.7 Fishing effort and fishing pattern

The estimated total annual fishing effort in number of days fishing for stationary gillnets and seines was based on data on seasonal and weekly fishing activities from the Frame survey (Ticheler and Chanda, 1993). In Bangweulu catch rates fluctuate seasonally and are inversely correlated with water levels (Figure 4). During the high water period (January to June) the fish will tend to disperse into the floodplains for feeding and breeding, while the densities in the perennial swamp will increase during the low water period (July to December). Such inverse relationship between water levels and catch rates is a general trend found in floodplain fisheries. The peak season (more than 50 percent of fisherman actually fishing) for the whole fishery is from May to November. For the different areas small differences were recorded. On the islands the peak season starts in April and in the swamps it continues up to December. Farming is concentrated (with more than 50 percent of fishermen farming) in the months December to March, except for the swamps where farming is mainly done from January to April. The frame-survey revealed that on average fishermen fish for six months a year (ie. 26 weeks), and during that period for approximately for 6.2 days per week (i.e. 160 days per year per fisher). The effort employed in kutumpula fishing differs from the stationary gillnet fishing. A popular Bemba saying amongst the Unga fishers in the swamps is "*ngawatemwa ukusakila kuti wafilwa ukupela umukashi obe ifumo*", which literally means "a kutumpula fisher will fail to make his wife pregnant". This is because kutumpula fishing is much harder compared to stationary gillnet fishing and this is also the reason why people say kutumpula is done less often as compared to stationary gillnet fishing. Although it is not exactly known, this study estimated kutumpula effort at 4.0 days per week in the fishing season, i.e. 100 days per year.

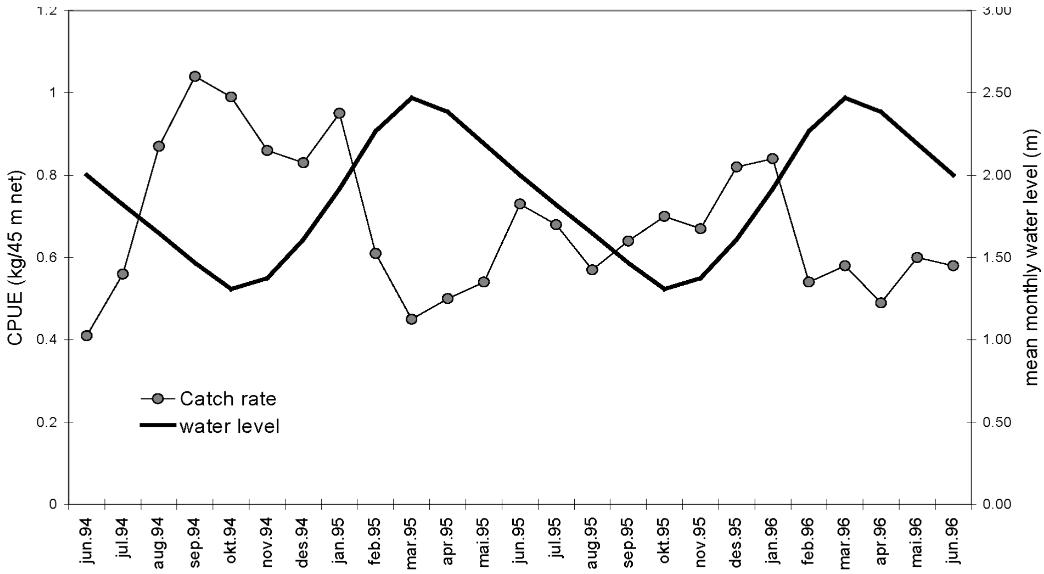


FIGURE 4. *Mean monthly catch rate of all species (kg/45 m net set) in the experimental nets from June 1994 to June 1996 plotted with mean annual water level fluctuations (from the period 1955-1995). The fluctuations are significantly inversely correlated (r = – 0.65).*

The fishery is highly dominated by small meshed nets: all the weir traps and 50 percent of the other gears are less than the legal limit of 51 mm stretched (Table 4, Ticheler and Chanda, 1993; Chanda, 1998). During the 1996 "Kutumpula" survey 809 kutumpula fishers were interviewed and information on the use of 8 105 nets used in the swamps was collected. This is approximately 50 percent of the total number of fishermen covered during the 1992 frame survey. The total number of kutumpula nets is small compared to the total number of stationary gillnets in the swamps (6.8 percent), but for the most commonly used mesh in kutumpula fishing (63 mm), these nets account for one third of all gillnets (Table 4). Kutumpula nets in general have larger mesh sizes than the nets used in stationary gillnet fishing.

4.8 Fish species selection for detailed analysis

Thirteen species were selected for a more detailed analysis of growth, mortality and yield. The first eight were well represented in the experimental gillnets. These were *Marcusenius macrolepidotus*, *Hydrocynus vittatus*, *Clarias gariepinus*, *Oreochromis macrochir*, *Tilapia rendalli*, *Serranochromis angusticeps*, *Serranochromis robustus* and *Serranochromis mellandi*. The last five were small species chosen from the Lundgren nets: *Barbus paludinosis*, *Barbus trimaculatus*, *Petrocephalus catostoma*, *Schilbe mystus* and *Tilapia sparrmanii*. The main criteria for selecting these 13 fish species for a detailed analysis were a) their importance in the artisanal fishery, either by weight or number, and b) the possibility of deriving growth parameters from the data available. The selected species, however, together represent a large variation in biology, distribution and sizes of the species found in the fishery and the first eight alone contribute nearly 75 percent of the total yield (Figure 5 and Table 12).

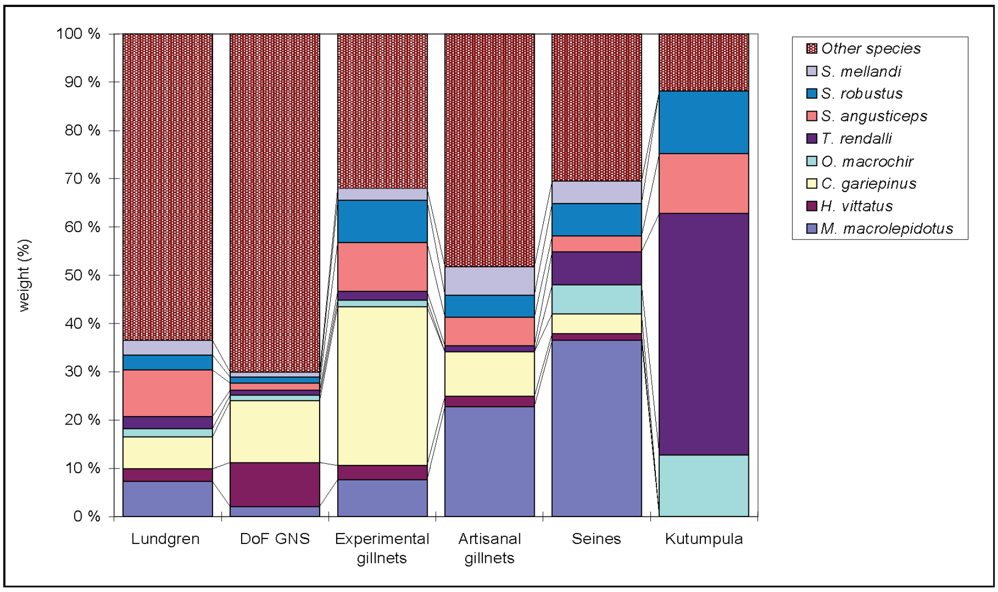
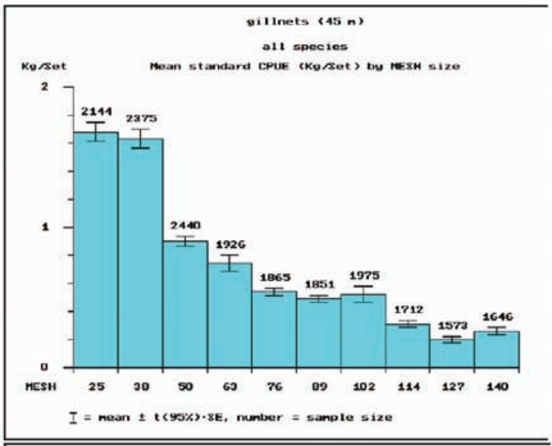
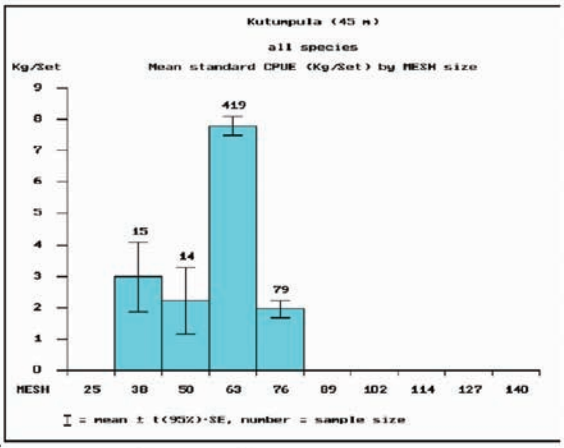


FIGURE 5. *The contribution, weight percentage, of the first eight selected species in the experimental gillnets to the total catch in the different fishing gears.*

RESULTS

Figures 6a to 6c show the mean catch per unit effort in the different mesh sizes by the three gears sampled in this study. Although a few mesh sizes are missing in the kutumpula and seine samples, it is noticeable how close the CPUE pattern by mesh size follows the frequency distributions of the mesh sizes in the fishery (Table 4). Also the relative abundance of the three gear types in the fishery (Table 4) is in close inverse accordance with the overall catch rates of each type (Figure 6 and Table 12).





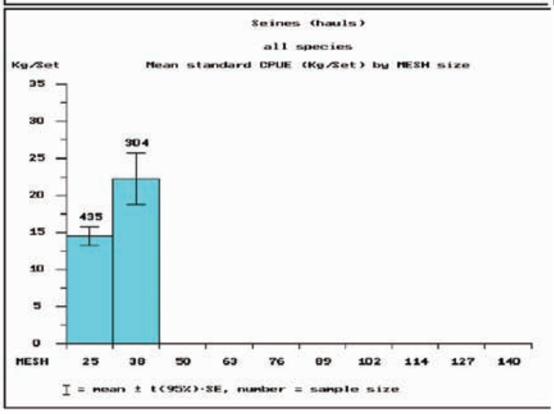


FIGURE 6

A. $Cpue_{(kg)}$ in different mesh sizes for experimental gillnets operated by local fishermen

B. $Cpue_{(kg)}$ in different mesh sizes for kutumpula nets operated by local fishermen

C. $Cpue_{(kg)}$ in different mesh sizes for seine nets operated by local fishermen

5.1 Catch composition in different gears

A distinct difference in catch composition can be observed between the sampling gears (Tables 6 and 7). Furthermore, catches from the GNS by DoF differ to a large extent from the catches realizsed by fishermen using the same gear (experimental gillnets). For example, in the GNS the most important species is *Alestes macrophthalmus*, both by number as well as by weight, while in the fishers experimental nets this species contributes only marginally (<11 percent by number and one percent by weight) to the catch. This can be attributed to different ways of setting the nets. While the DoF surveys primarily set the nets in the open water patches (a.o to reduce the amount of work in cleaning the nets from weeds), fishermen set the nets closer to the banks to target specific species and to improve their catch rates. The results show that the GNS catches in the swamps are not representative for the species composition in the artisanal gears.

TABLE 6. *Relative catch composition, percent number, for the different sampling gears used in this study. Data collected from July 1994 to July 1996, FDC broken down by method. Species contributing with less than 1 percent to the total catch are grouped in "other species".*

Number of settings	GNS		FDC			Lundgren
	Experimental		Artisanal	Kutumpula	Seines	
	1 694	18 037	1 473	527	739	12 076
Alestes macrophthalmus G.	19.7					2.8
Schilbe mystus L.	14.6	12.1	10.9		1.3	21.4
Barbus aff. unitaeniatus G.	10.6	1.9			1.3	5.3
Barbus paludinosis P.	9.3	4.1	10.3			8.0
Petrocephalus catostoma D.	7.9	18.8	24.0		8.2	17.3
Tilapia sparrmanii S.	5.8	19.1	24.1	4.5	5.6	7.1
Marcusenius macrolepidotus P.	4.1	13.8	17.1		48.2	4.1
Hydrocynus vittatus C.	3.5					
Serranochromis mellandi B.	2.3	3.5	4.3	2.4	6.7	1.2
Tylochromis bangwelensis R.	1.9			7.2	1.1	
Hippopotamyrus discorhynchus P.	1.8	1.4	1.8		13.5	1.7
Auchenoglanis occidentalis V.	1.7					
Clarias gariepinus B.	1.2	4.5				
Barbus trimaculatus P.		5.5				12.9
Serranochromis angusticeps B.		4.9	2.3	12.6	1.9	1.4
Synodontis nigromaculatus B.		1.7				1.0
Serranochromis robustus B.		1.6		9.6		
Ctenopoma multispinis P.		1.3				
Tilapia rendalli B.				48.4	3.0	1.0
Oreochromis macrochir B.				10.8	2.1	
Serranochromis macrocephalus B.				3.2		
Marcusenius monteiri G.					2.9	
Other species	15,6	5.8	5.2	1.3	4.2	14.8
Number of species contributing >1%	13	14	8	8	12	13

TABLE 7. *Relative catch composition, percent weight, for the different sampling gears used in this study. Data collected from July 1994 to July 1996, FDC broken down by method. Species contributing with less then one percent to the total catch are grouped in "other species".*

Number of settings	GNS		FDC			Lundgren
	Experimental		Artisanal	Kutumpula	Seines	
	1 694	18 037	1 473	527	739	12 076
Alestes macrophthalmus G.	18.4	1.0				2.6
Auchenoglanis occidentalis V.	14.4	7.5	1.4			3.5
Clarias gariepinus B.	12.8	32.9	9.2		4.1	6.6
Hydrocynus vittatus C.	9.1	3.0	2.1		1.4	2.6
Clarias ngamensis C.	6.5					
Schilbe mystus L.	3.7		3.8	7.1		18.3
Marcusenius macrolepidotus P.	2.1	7.6	22.8		36.5	7.3
Clarias buthopogon S.	2.0	1.9	1.6			1.8
Tylochromis bangwelensis R.	2.0			5.0	1.3	
Chrysichthys sharpii B.	1.9					
Tilapia sparrmanii S.	1.8	6.7	19.4		2.6	7.8
Barbus paludinosis P.	1.7			3.8		3.3
Barbus aff. unitaeniatus G.	1.6					3.3
Serranochromis angusticeps B.	1.5	10.2	5.9	12.4	3.2	9.7
Serranochromis robustus B.	1.2	8.7	4.6	13.0	6.8	3.1
Oreochromis macrochir B.	1.2	1.3		12.8	6.0	1.7
Serranochromis mellandi B.	1.0	2.5	5.9		4.6	3.1
Petrocephalus catostoma D.	1.0	2.4	6.1		1.4	7.0
Tilapia rendalli B.	1.0	1.8	1.3	50.0	6.9	2.5
Mormyrops deliciosus L.		1.1	3.2		10.3	
Synodontis nigromaculatus B.		1.0	2.1			1.7
Serranochromis macrocephalus B.				3.8		
Hippopotamyrus discorhynchus P.					4.5	1.1
Mormyrus longirostris P.					4.0	
Marcusenius monteiri G.					2.2	
Other species	15,1	6.6	3.5	3.0	4.2	13.0
Number of species contributing >1%	19	15	14	8	15	18

The number of species caught also differs by method. GNS and Lundgren nets show the highest species diversity with 19 and 18 different species contributing more than one percent by weight to the total catch. The fishermen using experimental nets, their own nets, and seines have respectively 15, 14 and 15 different species in their catch, and kutumpula target only eight main species. Thus, the three artisanal methods: gillnets, kutumpula and seines, are targeting different parts of the fish community in the swamps. Gillnets are mainly catching smaller species such as *M. macrolepidotus* and *T. sparmanii*, Kutumpula is highly selective on cichlids (96.3 percent by number and 92.0 percent by weight), particularly *T. rendalli* which is well known for its ability of evading stationary gillnets (e.g. Kenmuir, 1984), and the seines are mainly directed at the Mormyridae (59.3 percent by number and 58.9 percent by weight).

5.2 Estimates of vital parameters and long-term yield predictions

Table 8 gives a summary of estimated vital parameters for the selected species. Total mortality Z from the catch curve analysis and natural mortality M from Pauly's formula were used to calculate F and E. The table also includes the length-weight coefficients *a* and *b* used for estimating weights (e.g. weight infinity). For some of the larger species (*H. vittatus*, *C. gariepinus*, *O. macrochir*, *T. rendalli* and *S. robustus*), 2 cm length class intervals were used because FiSAT can only handle up to 50 length groups at a time. A detailed presentation of the derivation of vital parameters and long term yield predictions for the individual selected species in this study are presented in Kolding, Ticheler and Chanda (1996a, 1966b).

For only one of the selected species in the Bangweulu fishery, *Hydrocynus vittatus*, reliable growth parameters have been obtained previously from scale readings (Griffith, 1975). These were used to fit a comparative growth curve on the length-frequencies for *H. vittatus* in this study. The results showed that the two separate estimates produced nearly identical growth curves in the length interval observed, although Griffith had derived an L_∞ that was 20 cm larger. Separate growth parameters for M. macrolepidotus were estimated for experimental gillnet data as well as for data obtained from Lundgren nets. Again the results were comparable over most of the length range, although the Lundgren data yielded a rather low estimate of L_∞.
It was therefore decided to continue with the set of estimates obtained from the experimental gillnet data.

For two species the estimates for M were bigger than for Z. This indicates that fishing mortalities for these species were extremely low and consequently the exploitation rates close to zero. The reason that estimates for M can be bigger than Z estimates (when F is very small) should be attributed to noise in the data and because M and Z are independent estimates (Section 2.2.6) from different methods.

TABLE 8. *Summary of growth, mortality and length-weight parameters for selected species from length frequency analysis.* L_∞, W_∞, and K *are the parameters for the von Bertalanffy growth equation.* φ' *is the growth performance index (Munro and Pauly, 1983),* Z *and* CI_{Z1} *is the estimated total annual mortality and the 95 percent confidence intervals.* M *is the natural annual mortality,* F *is the annual fishing mortality,* E *is the exploitation rate* (F/Z), a *and* b *are the coefficients for the length-weight regressions.*

Species (length interval)	L_∞ (cm)	W_∞(g)	K	φ'	R_n	Z	CI_{Z1}	M	F	E	a	b
M. macrolepidotus	25.5	179.4	1.11	6.58	0.148	3.73	1.95-1.66	1.86	1.87	0.51	0.012	2 968
H. vittatus (2cm)	58.0	3 268.3	0.53	7.49	0.120	2.55	2.76-2.35	0.90	1.65	0.65	0.008	3 182
H. vittatus (2cm)*	78.0	8 389.5	0.34	7.63	0.127	2.76	3.01-2.50	0.62	2.13	0.77	0.008	3 182
C. gariepinus (2cm)	67.5	2 290.4	0.51	7.75	0.089	1.40	1.50-1.30	0.85	0.55	0.40	0.008	2 983
O. macrochir (2cm)	31.6	687.3	1.00	6.90	0.181	2.74	3.65-1.83	1.62	1.12	0.41	0.015	3 108
T. rendalli (2cm)	35.5	760.1	0.85	6.98	0.134	2.72	3.37-2.07	1.41	1.31	0.48	0.033	2 814
S. angusticeps	36.5	661.9	0.65	6.76	0.107	1.81	1.95-1.66	1.18	0.63	0.35	0.009	3 115
S. robustus (2cm)	57.0	2 898.6	0.51	7.41	0.110	1.76	1.99-1.53	0.89	0.87	0.49	0.008	3 166
S. mellandi†	26.0	267.8	0.78	6.27	0.151	2.12‡		1.44	0.68	0.32	0.014	3 026
Parameter values below were estimated data obtained with experimental, monofilament Lundgren nets												
B. paludinosis	11.45	16.8	1.40	5.21	0.218	2.58	3.22-1.93	2.69		M>Z	0.025	2 671
B. trimaculatus	10.53	13.5	1.40	5.04	0.306	2.37	5.89-1.16	2.57		M>Z	0.025♣	2 671♣
M. macrolepidotus	21.9	114.2	0.85	6.01	0.125	2.53	2.86-2.20	1.62	0.91	0.36	0.012	2 968
P. catostoma	9.2	8.9	1.46	4.82	0.745	3.06	4.83-1.28	2.75	0.31	0.01	0.036	2 483
S. mystus	15.0	34.9	1.29	5.67	0.193	2.51	2.79-2.23	2.36	0.15	0.06	0.005	3 268
T. sparrmanii	13.95	47.4	1.35	5.57	0.179	2.97	3.88-2.04	2.48	0.49	0.16	0.027	2 835

*second Z estimate for *H. vittatus* based on growth parameters from Griffith (1975).
†Growth parameters for S. *mellandi* were obtained from Kolding, Ticheler and Chanda (1996a).
‡ Z from the empirical relationship: $Z = 13.49*W_\infty exp(-0.33)$ (Marshall, 1993).
♣values from *B. paludinosis*.

Table 9 (sorted by the size of the species) gives a summary of the long term Thompson and Bell yield predictions for the various species by the three important fishing metods (artisanal stationary gillnets, kutumpula and seines).

TABLE 9. *Summary of Thompson and Bell long term yield predictions by species and catch method (single species- single gear), sorted by descending order of the size of the species (L_∞). LM is the observed modal length of the catch. L50 percent catch is the length at which 50 percent or more of the catch is smaller than or equal to this length. F-mean is the mean fishing mortality and E-mean is the mean exploitation rate (the latter two were obtained from the cohort analysis), values of E-mean higher then 0.5. are indicated in bold. The effort-factor is the fraction at which the current fishing pressure should be altered to achieve the long term theoretical Maximum Sustainable Yield (MSY, whereby 1= present effort; >1 is under - and <1 is overexploitation). The column MSY-Yield gives the absolute changes between Present Yield and long term MSY if the effort factor was applied. The last column ranks the species-gear combinations on present yield contributing more than 10 tonnes per year with the three largest are highlighted.*

Species	Gear type	LM (cm)	L50% Catch	L_∞- L50%	E mean	F mean	effort factor	Present Yield	MSY (tonnes)	MSY-Yield	Rank yield
C. gariepinus	seines	37	37	30.5	0.257	0.295	1.8	26.4	26.6	0.2	16
	gillnets	23	24	43.5	**0.505**	0.869	0.8	134.6	138.9	4.3	5
	kutumpula	27	28	39.5	**0.720**	2.189	0.6	6.9	7.4	0.5	
H. vittatus	gillnets	17	17	41.0	**0.616**	1.442	0.8	17.7	18.4	0.7	22
	seines	15	15	43.0	**0.680**	1.197	0.4	8.6	11.5	2.9	
S. robustus	seines	17	28	29.0	0.278	0.342	1.0	33.3	32.9	-0.4	14
	kutumpula	22	22	35.0	**0.588**	1.270	0.6	112.3	119.4	7.1	8
	gillnets	17	17	40.0	**0.625**	1.481	0.4	30.0	39.5	9.5	15
S. angusticeps	kutumpula	20	21	15.5	0.327	0.573	1.2	112.6	110.9	-1.7	7
	seines	17	17	19.5	0.358	0.659	1.6	23.9	24.7	0.8	19
	gillnets	16	16	20.5	0.364	0.675	1.0	112.7	112.2	-0.5	6
T. rendalli	**kutumpula**	18	19	16.5	0.357	0.784	1.2	423.1	429.2	6.1	**2**
	gillnets	15	15	20.5	0.401	0.942	1.0	8.0	8.0	0.0	
	seines	14	15	20.5	0.428	1.057	0.8	56.3	57.4	1.1	11
O. macrochir	seines	16	16	15.6	0.269	0.269	2.2	49.3	54.2	4.9	13
	gillnets	15	15	16.6	0.336	0.818	1.2	3.5	3.6	0.1	
	kutumpula	20	19	12.6	0.377	0.979	1.8	109.1	110.8	1.7	9
S. mellandi	gillnets	12	13	13.0	0.397	0.949	0.8	77.9	77.4	-0.5	10
	kutumpula	14	14	12.0	0.410	1.000	1.4	18.8	18.5	-0.3	21
	seines	12	12	14.0	0.437	1.117	0.6	26.2	26.6	0.4	17
M. macrolepidotus	kutumpula	18	18	7.5	0.066	0.131	>4	11.0	undef		24
	gillnets	14	14	11.5	0.333	0.931	1.6	259.0	272.1	13.1	4
	seines	14	14	11.5	0.419	1.344	1.0	456.5	450.7	-5.8	**1**
S. mystus	gillnets	14	13	2.0	0.028	0.067	>4	54.7	undef		12
	seines	11	11	4.0	0.076	0.195	>4	3.3	undef		
T. sparrmanii	**gillnets**	10	10	4.0	0.038	0.099	>4	263.1	undef		**3**
	seines	10	10	4.0	0.044	0.114	>4	23.0	undef		20
	kutumpula	10	10	4.0	0.052	0.135	>4	25.6	undef		18
B. paludinosis	seines	10	10	1.5	0.006	0.017	>4	0.8	undef		
	gillnets	9	9	2.5	0.013	0.036	>4	3.2	undef		
B. trimaculatus	seines	10	10	0.5	0.004	0.010	>4	0.9	undef		
	gillnets	9	9	1.5	0.009	0.023	>4	3.5	undef		
P. catastoma	seines	8	8	1.2	0.003	0.010	>4	15.4	undef		23
	gillnets	8	8	1.2	0.004	0.010	>4	9.4	undef		
							Total	2520.6		44.2	

Table 9 shows that in terms of present yield in the Bangweulu swamps, the three dominant species are:

- the small *Marcusenius macrolepidotus* (which is caught in the large quantity of some 700 tonnes per year in both seines and small meshed gillnets),
- the medium sized *Tilapia rendalli* (420 tonnes in kutumpula), and
- the small *Tilapia sparmanii* making up around 260 tonnes in the gillnets.

Each of the three different gears occupies one of the first three ranks according to yield. The next five ranks, yielding between 135 to 100 tonnes per year, consist of the large *Clarias gariepinus* (gillnets) and the three relatively large cichlids *Serranochromis angusticeps, S. robustus* and *Oreochromis macrochir* (gillnets and kutumpula). The seventh and eighth species in terms of yield are the smaller cichlid *Serranochromis mellandi* and the catfish *Schilbe mystus*. These eight species together make up the 22 highest-ranking yields for the three gears. Only after these species-gear combinations other species, such as the Tigerfish *Hydrocynus vittatus* and the small mormyrid *Petrocephalus catostoma*, are listed. The overall picture is a cichlid dominated fishery, with the exception of *C. gariepinus* and *M. macrolepidotus,* where the catches are rather evenly distributed over the three fishing methods.

The largest species in the system (*C. gariepinus, H. vittatus* and *S. robustus*) have the highest exploitation rates. (Table 9). In fact, there is a clear positive trend between the exploitation rate and size. For all the smaller species (*Schilbe mystus, Tilapia sparmanii*, etc.) the exploitation levels are so small and the natural mortality so high that MSY is undefined within the range of the simulated effort-factor: according to this simulation MSY can be estimated within up to four times the present level of fishing effort.

The bigger the fish are the longer they are subject to exploitation. This is illustrated by correlating the size range of exploitation, which is the difference between Length infinity (L_∞) and the length at which more than 50 percent of the catch of a particular species is obtained (Table 9), with the mean exploitation rate (Figure 7).

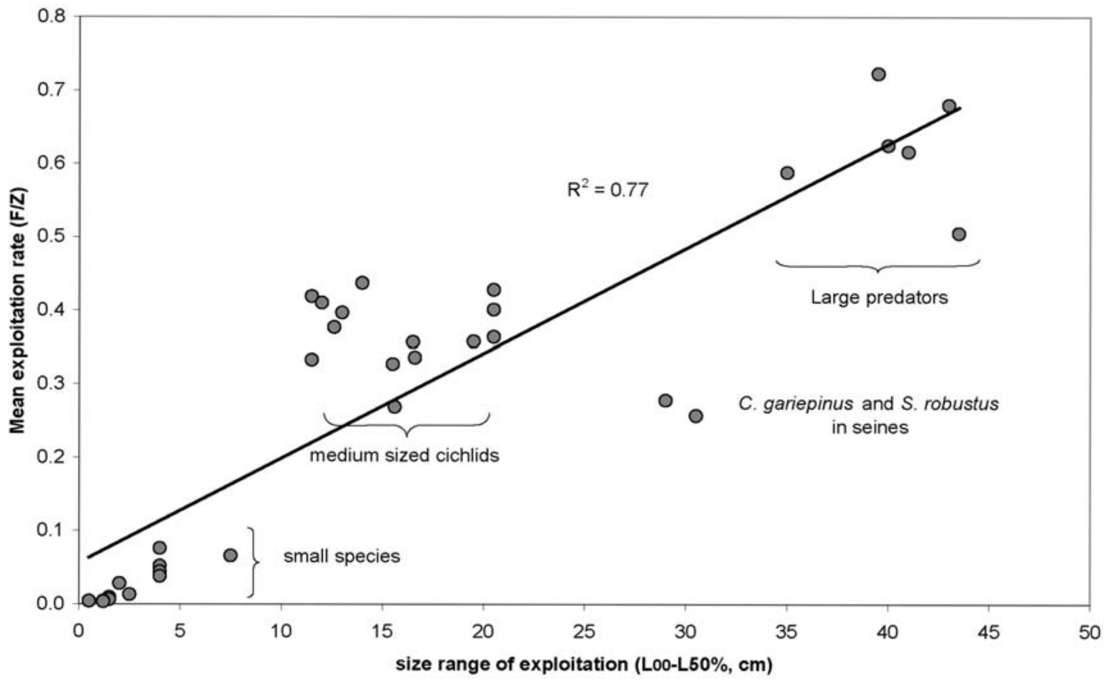


FIGURE 7. *Scatter diagram of E-mean estimates versus "size range of exploitation" (L∞ - L50% catch). Based on data from Table 9.*

Exploitation rates are clearly clustered in three separate groups consisting respectively of large predators, medium sized cichlids and all the small species. The two outliers are *C. gariepinus* and *S. robustus*, caught in the seine nets. All small species are very lightly exploited (E< 0.1), the medium sized species seem fully exploited (0.3<E<0.5), whereas the largest species are over-exploited in terms of the long-term steady-state MSY (E>0.5) (Table 9). This trend is independent of gear category. All three gears are again sharing the three top positions in terms of exploitation levels: kutumpula for *C. gariepinus*, seines for *H. vittatus*, and gillnets for *S. robustus*. Interesting to note, is that even if effort were to be adjusted to the recommended exploitation levels for each gear category (Table 9), the overall long term improvement in yields would only be about 44 tonnes per year, which is less than two percent of the present yield.

TABLE 10. *Summary of Thompson and Bell long term Yield predictions by species (all gears combined), by gear (all species combined) and for all species and all gears combined (multi-species, multigear analysis). To be able to interpret the results of this analysis only the eight species which had defined MSY's within the range of simulated effort levels in the single-species, single-gear analysis were included, that is those with exploitation levels higher than 0.1. The top panel shows the results of each of the eight species based on all three gears combined, i.e. the overall "optimal" exploitation level (effort-factor) of these species compared to the present level with the present combination of gears. Also shown are the cohort analysis results (E-mean and F-mean) on the combined catches of each species in all gears. The middle panel presents the effort-factor estimates of each of the three gears based on all the eight species combined. The bottom panel presents the overall effort-factor, Present Yield and estimated MSY of the all the eight species in all three gears. Z=total mortality. Diff. % = percentage difference between the present estimated yield and the estimated MSY.*

Species/gear Combination	Yield (tonnes)	E-mean	F-mean	Z (F/E)	effort factor	MSY (tonnes)	Diff %
All gears by species							
M. macrolepidotus	726.5	0.355	1.021	2.876	1.6	743.7	2.4
T. rendalli	487.4	0.214	0.383	1.790	2.0	519.3	6.5
S. angusticeps	249.2	0.307	0.522	1.700	1.2	247.1	-0.8
S. robustus	175.6	0.484	0.834	1.723	0.4	198.3	12.0
C. gariepinus	167.9	0.480	0.786	1.638	0.8	171.7	2.3
O. macrochir	161.9	0.228	0.478	2.096	2.0	173.6	7.2
S. mellandi	122.9	0.163	0.483	2.960	>3.0	>165.8	>34.9
H. vittatus	26.3	0.633	1.553	2.453	0.6	30.1	15.3
All species by gear							
Kutumpula	793.8				1.0	796.1	0.3
Seines	680.5				>3.0	>754.8	>10.9
Gillnets	643.4				1.2	661.6	2.8
All species							
All gears	2117.7				1.3	2158.9	1.9

Only the three largest species (*Clarias gariepinus*, *Hydrocynus vittatus* and *Serranochromis robustus*) are biologically "overexploited" in terms of individual maximum yields in the combination of the three gears (Table 10). A reduction in fishing effort could therefore theoretically increase (marginally) the total yield for these species. However, optimizing the yield for *H. vittatus* by 15 percent with a reduction in effort of 40 percent will have no major effect on the total catch since the contribution of this species is limited to 25-30 tonnes per year. *S. robustus* catches could be optimized by 12 percent, but the fishing effort should then be reduced with 60 percent, and this would in turn cause a serious reduction in the catches of smaller species. By contrast, the remaining five species can all be submitted to a higher fishing pressure to increase yields, but again the effect would be rather small: an overall increase of effort of 30 percent, as suggested in the all gears, all species combination, would theoretically only improve the yields with around 2 percent. The overall conclusion from this analysis is that the yield obtained with the present combination of gears and effort is remarkably close to the potential long term MSY under steady state conditions.

5.3 Biomass-size distribution

Based on the cohort analysis of the catches in the experimental gillnets (considered the least selective of the gears studied) a relative biomass-size structure of the main species caught in the Bangweulu swamp can be constructed (Figure 8). The small insectivorous and herbivorous species and individuals with a mode of 9-10 cm dominate the fish community and the biomass is characterized by a steep decline up to a size of around 30 cm. Although the large predators (*C. gariepinus*, *H. vittatus* and *S. robostus*) are the most heavily exploited (Table 10) these species are relatively abundant beyond 30 cm and cause the steep decline to taper off from this size. This could indicate that the larger sized specimen are relatively undisturbed by the present fishery, once grown in size beyond the selectivity range of the present exploitation pattern of the fishery.

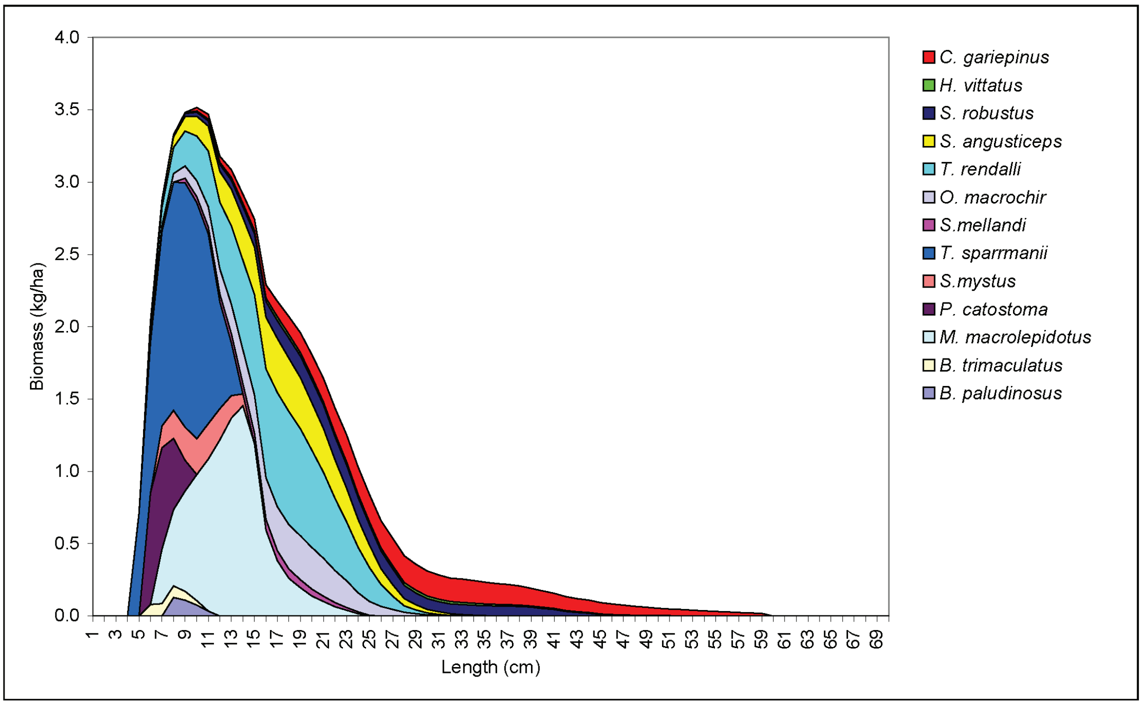


FIGURE 8. *Relative biomass (kg/ha) versus size (cm) of the 13 most common species in the Bangweulu swamps from cohort analysis on the experimental gillnet catches.*

The biomass-size distribution in the Bangweulu swamps would explain the high frequency of small mesh sizes found in the Bangweulu fishery (Table 4). 90 percent of the gillnet catches in numbers are taken in mesh sizes smaller than 50 mm (Figure 9). These catches consist mainly of *T. sparmanni* and *M. macrolepidotus*, which are low to moderately exploited (Table 9).

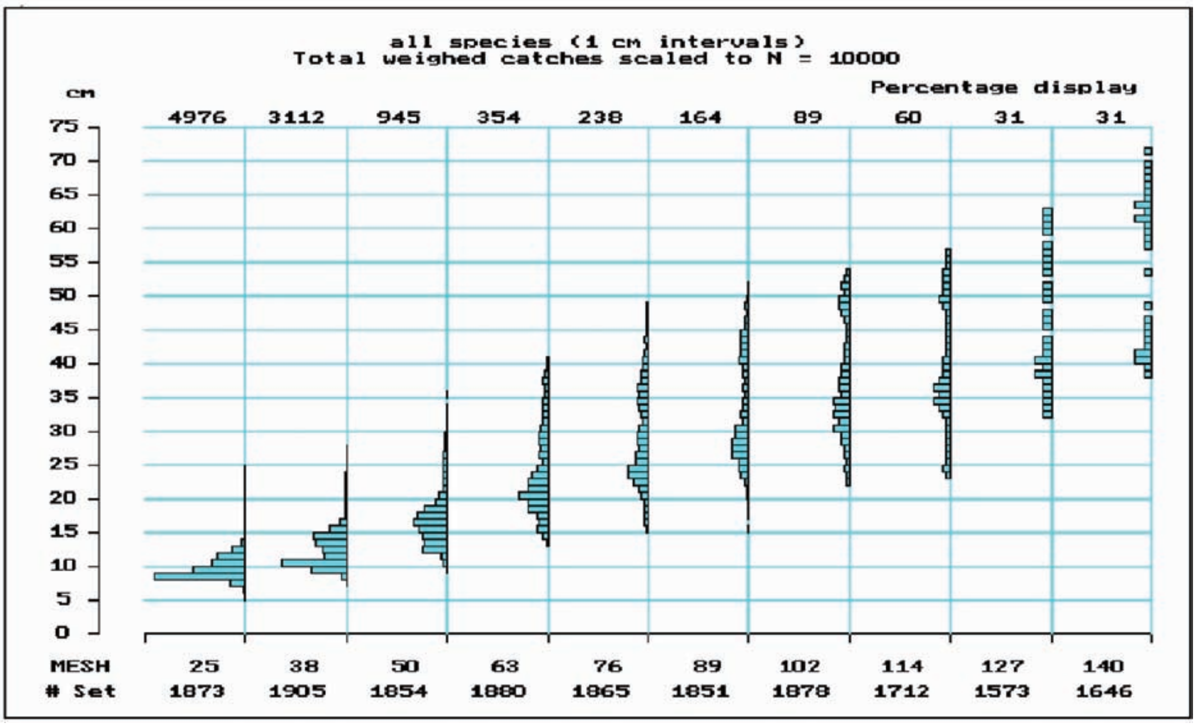


FIGURE 9. *Length frequency distributions and relative number of fish caught (on top, fraction of 10 000) of all species caught in the different mesh sizes of gillnets in Bangweulu swamps.*

5.4 Overall yield estimates

Table 11 gives the contribution to the total yield for the three fishing methods studied. CPUE from data collected by fishermen (by method and mesh size) and Frame Survey figures on total numbers of fishing gear (by type and mesh size) were used to estimate yields. Total annual yield for the swamps in the gillnets, kutumpula and seines is estimated at an average of 2 828 tonnes per year for the period July 1994 to July 1996.

TABLE 11. *Yield estimates (tonnes/year) for the Bangweulu swamps for the period July 1994 to July 1996 in the three gears studied, and the relative contribution of the eight species included in Thompson and Bell long term yield predictions to the total yield.*

Period	Gillnets (tonnes/yr)	Kutumpula (tonnes/yr)	Seines (tonnes/yr)	Total Yield (tonnes/yr)
1-7-94 1-7-95	1 277.0	793.9	1 046.4	3 117.3
1-7-95 1-7-96	984.1	930.1	685.1	2 599.3
Weighted mean $Yield_{yr}$ all species	946.2	902.6	979.1	2 827.9
Weighted mean $Yield_{yr}$ 8 species	643.4	793.8	680.5	2 117.7
Yield of 8 species as % of total yield	68.0	87.9	69.5	74.9
(kg/net/setting)	0.86	9.63	21.85	

In an independent survey on the weirs (Chanda, 1998) this fishery was estimated to produce 6 260 tonnes in 1997, of which *C. gariepinus* alone contributed more than 2 000 tonnes. This means that the weir fishery produced more than twice the amount of the three other main methods combined. The weir fishery, which is the main method in the seasonal floodplains, is catching a broader size range and a larger proportion of small specimens, and is therefore the least selective of the main fishing methods in Bangweulu (Chanda, 1998; Table 4). In terms of species this fishery mainly targets *Clarias gariepinus* (35 percent), *Tilapia rendalli* (12 percent), *Serranochromis angusticeps* (11 percent), *Marcusenius macrolepidotus* (11 percent), and *Serranochromis mellandi* (9 percent) by weight respectively (Chanda, 1998). None of these species are overexploited according to this study (Table 10). For all four gears together, the swamps and floodplains are thus producing around 9 000 tonnes of fish per year, or about 59 percent of the whole Bangweulu fishery (Figure 3). This estimate is in close accordance to Bazigos, Grant and Williams (1975) who estimated that in 1973–1974 an average of 54 percent of the total yield for the Bangweulu fishery is produced by the swamps. Table 11 also indicates that the contribution of the eight selected species used in the Thompson and Bell long-term yield prediction accounted for 75 percent of the total yield of the three gear types studied. Thus the majority of the exploited stocks is taken into consideration. Though catch rates for the three methods in this analysis differ by a factor 10 to 25 (Table 11), the outcome of the daily catch of an individual fisherman appears to be remarkably similar for the three methods when considering the actual daily effort. A gillnet fisher usually owns 8 to 10 gillnets and he operates them on his own. This results in a catch rate between 6.9 and 8.6 kg for a gillnet fisher per day. Kutumpula fishers often team-up with colleagues to be able to enclose a larger area, but each of them uses his own net. This results in a catch rate of 9.6 kg per day for a Kutumpula fisher. Seine fishers have to employ three to four assistants to operate the seine. Usually the catch is shared between the owner and his assistants, resulting in a catch of between 4.4 and 5.5 kg per fisher. These are of course rough estimates and considerable differences will exist between fishers due to differences in quality of the fishing gear (state of maintenance) and the skills of fishermen.

5.5 Catch rates in Bangweulu compared with other African fisheries.

A comparison of catch rates from different other water bodies in Africa (Table 12) shows that in general the catch rates in Bangweulu are low in terms of weight, but high in terms of numbers compared to the other systems. It should be noted that the data from Lake Kariba are from an unfished locality (Zimbabwean side) and from an intensely fished area (Zambian side) (see also Kolding, Musando and Songore this volume, 2003). The CPUE by weight in the experimental multi-filament gillnets in Bangweulu is higher than in Lake Kariba (Zambian side) which is a heavily fished system, but lower than the heavily fished Lake Mweru and the unfished Zimbabwean side of Lake Kariba. The CPUE by number, however, is among the highest of all the other systems and correspondingly the mean weight of the fish, 30 g in the multi-filament nets, is the lowest. This demonstrates the small average size of the fish in Lake Bangweulu as already seen from the biomass-size distribution (Figure 8). Differences in mean size may not be directly comparable between a swamp and an open lake ecosystem. The Okavango Delta, however, should in many ways be an ecosystem comparable with the Bangweulu swamps and here the catch rates in the Lundgren nets are among the highest of the different systems. In contrast to Bangweulu, the Okavango Delta is very lightly exploited (Mosepele, 2000) and this could be a reason for the higher catch rates and higher mean weight. On the other hand, the Okavango River in Namibia is generally highly exploited, and here the catch rates are slightly lower than in the Bangweulu swamps, although the mean weights are higher (Table 12).

TABLE 12. *Comparison of catch rates (mean ±SE) for different water bodies in Africa using similar experimental, monofilament (Lundgren) gillnets (42 x 1.5 m) and standardiszed multi-filament experimental gillnets (45 x 2 m). Sources: Lutembwe, Mukungwa and Kang'ombe (Fjälling and Fürst, 1991). Kariba, Zimbabwian side (=unfished) (Karenge, 1992 and Sanyanga, 1996), Kariba, Zambian side (= fished) (Musando 1996), Lake Ziway (Gelchu 1999), Okavango Delta, Botswana (Mosepele 2000 and Mmopelwa unpublished), Khashm El-Girba (Salih 1994), Mweru-Luapula (van Zwieten and Kapasa, 1996), Okavango River, Namibia (Hay et al., 2000). As the CPUE is obtained with similar standardiszed gillnets (same twine, mesh sizes and gear area), the values are comparable as indices of the fish abundance in the different systems.*

Water body	CPUE (kg/set)	CPUE (no/set)	Mean weight(g)	Mesh sizes (mm)	No. of settings	Net type
Lundgren nets:						
Bangweulu swamps	1.54 ±0.03	118.07 ± 2.27	13.04	13 - 150	869	mono filament
" "	1.36 ±0.08	69.36 ± 5.67	19.60	20 - 150	869	" "
Lutembwe river, Zambia	4.26 ±0.38	-		13 - 150	23	" "
Mukungwa, Zambia	2.35 ±0.44	-		13 - 150	13	" "
Kang'ombe, Zambia	2.02 ±0.38	-		13 - 150	10	" "
Kariba, Zimbabwe	4.20 ±0.30	149.10 ± 7.75	28.17	13 - 150	161	" "
" "	3.72 ±0.29	41.16 ± 2.16	90.38	20 - 150	161	" "
Okavango Delta, Botswana	4.59 ±0.80	82.98 ±10.96	55.31	13 - 150	82	" "
" "	4.36 ±0.78	68.86 ± 8.52	63.32	20 - 150	82	" "
Lake Ziway, Ethiopia	2.47 ±0.22	74.39 ± 4.03	33.20	20 - 160	32	" "
Khashm El Girba, Sudan	2.96 ±0.18	65.48 ± 4.21	45.20	20 - 150	86	" "
Standard experimental gillnets:						
Bangweulu swamps	1.43 ±0.02	48.21 ± 1.03	29.66	25 - 140	18 037	multi filament
Mweru, Zambia	2.94 ±0.12	44.13 ± 2.82	66.62	25 - 140	1 648	" "
Kariba, Zambia	0.57 ±0.03	6.72 ± 0.84	84.82	25 - 140	1 656	" "
Kariba, Zimbabwe	4.60 ±0.11	15.54 ±0.56	296.01	25 - 140	1 169	" "
Okavango Delta, Botswana	7.68 ±0.46	134.30 ±16.4	57.19	22 - 150	406	" "
Okavango River, Namibia	1.44 ±0.08	27.95 ±1.53	51.52	22 - 150	1 076	" "

6. DISCUSSION AND CONCLUSIONS

The underlying assumption in this analysis of a long-term, steady state MSY in the Bangweulu swamps is a strong oversimplification. History shows that all fish populations fluctuate over time, with or without fishing. Nevertheless, almost all fisheries models used for assessing the stocks and evaluation of management options are from necessity built on the simplifying assumption of constant parameters and long-term equilibrium conditions. Only fishing effort and fishing pattern, the parameters we can control, are allowed to vary. The yield analysis presented in this study is only a "snapshot" of the conditions in the Bangweulu swamps during the two years under study. Long time series over decades of reliable catch and effort statistics and environmental parameters are needed to disclose the inherent dynamics of the system. Though not all gears are studied, the coverage of species and methods is assumed to give an impression of the result of the overall exploitation pattern in the fishery. Weirs and traps, the most important other gears in the floodplain fishery exploit the same set of species and sizes as studied here and are the least selective (Chanda, 1998).

As a snapshot, however, this study does provide some insight in the present exploitation pattern of the fish stocks in the swamps. A first conclusion is the seemingly remarkable adaptability of fishermen to fully harvest the various populations in a multi-species fishery. The present fishing in the swamps is dominated by a combination of gillnets, kutumpula and seines. Although fished with unequal intensity and number of units, and mainly targeting different species, each of these fishing methods contribute about the same amount to the total yield (Tables 10 and 11). In addition, the return rate per individual fisher from each method is surprisingly even and the distribution of fishing gears and mesh-sizes in the area seems well balanced to match the catch rates of each gear (Table 4 and Figure 5). The combination and relative proportion of gears, methods, and mesh sizes are on an aggregated level seemingly finely tuned, and result in a maximized yield at a multispecies level.

How to balance the appropriate fishing pattern in a complex multispecies fishery is still a hypothetical issue in most of the world's fisheries and, will probably always be. All fishing gears and methods are inherently selective by their design and operation, and different fish species have very different catchabilities due to their habitat preferences and individual behaviour. Therefore, in a mixed multispecies fishery, such as Bangweulu swamps, also a mixture of gears should be utilized to harvest different parts of the community (Misund, Kolding and Fréon, 2002). In this study, long term yields for the artisanal gillnets, kutumpula, and seine fishery were examined under conditions of an unchanged fishing pattern (i.e. proportion of gears and mesh sizes) but with a varying effort. Judging from the perspective of each individual fishing gear (Table 10, middle part) both the gillnet- and the kutumpula fishery seem to be close to the "optimal" level (effort-factor =1), whereas the seine fishery can be increased with a factor of more than three. When analysing each gear in isolation, however, the result for one gear does not account for the effects of the other two and thus simulates a single gear fishery. The general trend when all gears are combined (total fishing mortality) is that the present yield from the combination of fishing gears is very close to the calculated potential yield (MSY) (Table 10). Calculated MSY is reached at a factor 1.3 of the present fishing effort. However, very flat-topped yield curves due to high natural mortalities (Table 8) indicate that increased effort will have little consequences for the overall yield (less than 2 percent gain, Table 10). On the other hand, increased effort will disproportionately decrease the daily return (= catch rates) of the individual fisherman. Judging from the multispecies, multigear analysis of the eight most important species, the present fishing pattern and intensity in the swamps is very close to the calculated biological optimum in terms of maximizing the output. All three main fishing methods examined in this study exploit to a large extent a specific and separate part of the fish community (Table 7). In doing so, these methods complement each other and reflect the diversity in the fish community.

The estimated exploitation rates (E) of the various species examined (Table 10 and Figure 7) fall into three clusters: high, medium and low depending on the size of the species – which again is largely a function of their trophic level. The upper theoretical limit for a sustainable harvest commonly is set at an E=0.5, and for some of the larger predatory species, this value was exceeded in individual gears (Table 9). However, looking at the species in all three gears combined (Table 10), the estimated exploitation rates of the species with a determined MSY within the simulated range of effort range between 0.16 to 0.63 with a mean of 0.36. The upper limit of 0.5 is only surpassed by *Hydrocynus vittatus* with a value of 0.63. This species yields comparatively little (1%) to the total catch in the overall combination of gears (Table 10). The general trend is that fishing mortalities are below or close to the theoretical maximum for large and medium sized fish species, but that they are negligible for most small sized fish species (Table 9, Figure 7). Overall, the larger predatory species seem to be exploited at rates close to

MSY, while the exploitation of the smaller species is decreasing with size. The medium sized fish species – mainly cichlids – contribute the largest proportion to the total yield. Small fish species are mostly under-exploited. Most of the small species contribute relatively little to the total yield (with the exception of *T. sparrmanii* in stationary gillnets), although they are important in terms of the numbers in which they are caught (Table 9).

The fishery is characterized by generally small mesh sizes (mode at 38 mm) (Table 4). This causes the fishing mortality to rise sharply on most species from around 14-16 cm TL (Table 9, Figure 8). The general impression that exists of a decreased mean size in the fishery during the recent years is not therefore surprising considering such a large output of small specimens in the fishery. The question remains, however, if the fishing pattern has changed towards smaller mesh sizes. Unfortunately no historical data on mesh size distribution exist. Still, there is little doubt that the high fishing intensities in Bangweulu has influenced the stock sizes and that the observed decrease in mean size therefore may be true. The market, however, does not seem to differentiate on fish size: almost everything sells at the same price per unit weight. As the small mesh sizes indeed catch significantly "more" fish by numbers (Figures 5 and 9), the incentives of changing the fishing pattern to larger mesh sizes might therefore not exist at present. In addition, a number of important, but small, species (*T. sparrmanii, P. catostoma, S. mystus*, barbus species, etc.) are probably best exploited by the current fishing pattern of small meshed gillnets. In any case, the high number of small fish in the Bangweulu fishery is not an indication of overfishing as the yields have not declined and all the small species are only lightly exploited (Figure 7 and Table 9). The rationale of changing the fishing pattern is therefore also redundant from a biological point of view. On the contrary, increased use of larger meshed nets would only lead to an even higher fishing pressure on the larger species.

The combination of fishing methods and mesh sizes in the Bangweulu swamps harvest all species and all size classes from around 10 cm and upwards, creating an almost unselective fishing pattern. Still, mean exploitation levels increase with fish size due to the increase in exploitation range with size. Theoretically, a non-selective harvesting pattern is ecosystem conserving (Kolding, 1994,: Misund, Kolding and Fréon, 2002;, Jul-Larsen *et al*., 2003). All species are preyed upon at various rates during their lifespan, and for teleosts the highest mortality is usually during the early life history phase (Bailey and Houde, 1989; Caddy, 1991; Hutching, 2002). Thus in principle, the "utopian" but optimal exploitation pattern, by which a community structure – that is the relative abundance proportions of the populations -– could be maintained, is fishing each population in proportion to the rate of the natural mortality (M) it is subjected to (Caddy and Sharp, 1986; Kolding, 1994). If maximum yield is an additional objective, then the exploitation level should increase with trophic level: E = 0.5 for top predators and less for lower trophic levels, where $E=0.5-(M_2/Z)$ depending on the predation mortality (M_2) (Kolding, 1993, 1994). Although predation mortalities are not known, this is actually the fishing pattern that seems to exist in Bangweulu (Figure 7). As all fishing gears are more or less species and/or size selective, such non-selective exploitation patterns can only be achieved by employing a multitude of gears simultaneously. As demonstrated in this case study, multigear, multispecies artisanal floodplain fisheries that employ a very high gear diversity, often seem to be producing an overall species-, abundance-, and size composition that closely matches the ambient ecosystem structure (MRAG, 1994; Claridge, Sorangkhoun and Baird, 1997, Chanda, 1998;, Hoggarth *et al*., 1999a, 1999b). On the ecosystem level such an exploitation pattern could be considered unselective across the species diversity range. Many floodplain fisheries, particularly in Asia, seem to have persisted (albeit with natural fluctuations) with a very high and diverse fishing effort for as long as our observations can tell (Misund, Kolding and Fréon, 2002).

Putting all the above-mentioned aspects together, the impression surfaces that in the Bangweulu swamp fishery a well balanced way to exploit the stocks in all their diversity, using a variety of fishing methods, has evolved. The combination of gears and effort has created an exploitation pattern that appears to have maximized yield from the community without causing deep structural changes. Two of the fishing methods used – seines and kutumpula – are technically illegal but without these methods less than one third of the present and potential yield would be realizsed (Table 10). Actually, without these methods two of the most important species in terms of yields (*M. macrolepidotus* and particularly *T. rendalli*) would hardly be exploited (Table 9). The stocks do not seem to be overfished in a biological sense but there may be little room for expansion under the present overall fishing pattern (Table 10). On the other hand, there is no evidence of any significant changes in fishing effort over the past 30 years (Table 2). Furthermore, from a journey in the late 1930's Bertram and Trant (1991) write "every dry spot in the swamps is inhabited and fishermen crowd together on tiny patches of floating papyrus beds". This descriptive record gives the impression that the fishing effort in the swamps has remained pretty constant for the past 70 years. It is therefore doubtful whether overfishing has ever been a problem in the Bangweulu swamps. The people of the Bangweulu swamps have always been fishing and they have had plenty of time to develop a fishing pattern that would suit the local conditions. From a biological point of view, effort or gear regulations do not seem to be a key issue at present and the catch per unit effort would, in terms of an economic break-even, probably be a regulating factor by itself (Beverton, 1990; Kolding, 1994). From an economic point of view, however, the fishery in the Bangweulu remains a marginal activity in which there is little room for expansion. If the number of fishermen would increase, it will become more and more difficult for individual fishermen to make a living out of it.

This study is a snapshot and should not be seen in isolation, as the Bangweulu swamps are not a more or less independent ecological entity. The swamps are part of a larger complex with a number of major lakes (Lake Bangweulu, Lake Walilupe, Lake Chifunabuli, Lake Kampolombo) and the Chambeshi and Luapula as major rivers. Both on a biological level and on the level of human interventions, many interactions between the different areas take place. There are water and nutrient flows between the swamps and major lakes and rivers, fish migrations take place, fishermen have a pattern of seasonal migrations between the different areas, etc. Therefore this study of the Bangweulu swamps, which can serve as a bench mark in future stock monitoring and assessments, should be followed by a study on the fish stocks in the open waters. As was the case for the swamps, hardly anything is known about the status, the exploitation patterns and the potential of the open water fishery at present. It is recommended that a full stock assessment through a similar set up with involvement of local fishermen in data collection is carried out for the open water fishery.

6.1 Conclusions

Simple data collected by local fishermen in combination with data on the size and structure of the fishery (obtained from Frame Surveys) can be used to estimate total annual yield and assess the fishing pattern. Our results give the impression that the fishers in the Bangweulu swamps have adapted their methods remarkably to fully harvest the various fish stocks and sizes. The combination and relative proportion of gears, methods, and mesh sizes seems to be finely tuned to maximize output without over-exploiting the stocks. In the Bangweulu swamps a well balanced exploitation pattern appears to have evolved in which a variety of fishing methods are being used and the fish resources are exploited in all its diversity. The fishing pattern has most likely evolved over time from trial and error based on individual catch rates. Individual return rates, rather than biological overfishing, might therefore be the most important regulating factor of the future fishery.

With the findings presented here it becomes apparent that the nation wide fisheries regulations, laid down in the Fisheries Act, do not suit the specific conditions prevailing in the Bangweulu swamp fishery. To be able to effectively exploit the diversity of species in the swamps, a variety of fishing gears are required, using small and medium meshed nets. Methods now used to exploit the different species, kutumpula and seines are prohibited and so is the most commonly used mesh size (38 mm stretched mesh). Further analysis is needed to investigate the impact of mesh size regulations, but at the present stage we feel it safe to conclude that kutumpula and seines are not detrimental to the fishery. On the contrary, these methods are harvesting parts of the fish community that otherwise would have remained untapped. The results show the importance to actually investigate the specific selectivity and impact of different fishing methods before making uniform regulations on their use. Many fisheries regulations still in force can be traced back to the colonial administration from the first half of the previous century (Malasha, this volume 2003) and have often proved to be fairly ineffective (Chanda, 1998). Striking a balance between enforcement of management regulations, and leaving room for fishers who are simply trying to survive is not easy. Therefore, the Department of Fisheries should, with the present adoption of the concept of co-management, consider directing all its management efforts towards monitoring and improving the working relation with the fishing community to be able to give advice based on sound scientific investigations.

The Fisheries Act of Zambia should be revised to leave room for differentiation between the various fisheries in the country. In this way specific regulations, adapted to the prevailing conditions in each individual fishery can be designed. For the Bangweulu swamps, kutumpula and seine netting should be legalized and until further analysis is done on the effect of the smallest mesh sizes the Department should tolerate these methods. Instead it should concentrate its efforts on developing and implementing the co-management concept in the fishery acknowledging that the local fishermen in this fishery to a large extent know what they are doing.

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INSHORE FISHERIES AND FISH POPULATION CHANGES IN LAKE KARIBA

J. Kolding, B. Musando and N. Songore

1. INTRODUCTION

Since the creation in 1958 of Lake Kariba, situated on the Zambezi River and shared between Zambia and Zimbabwe, substantial changes in both its fisheries and in the fish communities have been observed. Although probably one of the best studied fresh water systems in Africa (Karenge and Kolding, 1995a), the sustainable exploitation levels of its fish communities are still largely unknown (Anon., 1992; Kolding, 1994). Fear of overfishing, or at least indications of fully exploited resources, has repeatedly been expressed (Marshall, 1981; Marshall, Junor and Langerman, 1982; Kenmuir, 1982; Marshall 1985, Machena and Mabaye, 1987; Marshall and Langermann, 1988; Moyo, 1990; Scholz, 1993; Sanyanga, Machena and Kautsky, 1995; Sanyanga, 1995; Machena and Kwaramba, 1997), whereas other studies have contested these views (NORAD, 1985; Ramberg *et al.*, 1987; Marshall, 1992; Machena, Kolding and Sanyanga, 1993; Kolding, 1994; Karenge and Kolding, 1995a). Most of the attempts to calculate sustainable yields (Marshall, Junor and Langerman, 1982; Marshall, 1985; Moyo, 1986, 1990) are from classic fisheries stock assessment models based on catch and effort variables, with the underlying basic assumption of ecological stability and constant regenerative capacity. Most of the results from these analyses have proven of dubious value (see Box 5.2 in Volume I).

Lake Kariba is not a stable system as most other small or medium sized lakes in Africa. Karenge and Kolding (1995b) showed that the environment, in terms of the changing hydrological regime, explains a large proportion of the variability in catch rates (CPUE). They concluded that Lake Kariba was an allothropic riverine lake where productivity was largely driven by the nutrient pulses carried by the annual floods. The question is therefore how much of the observed changes can be attributed to fishing activities and how much is due to natural environmental fluctuations. Another important management issue, particularly on the Zambian side, is the high fishing pressure and changing fishing pattern in terms of increased use of small mesh sizes and customary use of illegal fishing methods such as drive fishing (Kutumpula). It is widely believed that such uncontrolled development is a potential sign of overfishing and poses a threat to the biodiversity (FAO, 1992; Lowe-McConnell, 1994; Pitcher, 1995). On the other hand, in highly variable systems, susceptibility to increased fishing effort is thought to be low, while resilience is high and recovery potential is rapid.

Lake Kariba is a man-made grand-scale ecological laboratory with a unique chance to observe and monitor the intricate pathways of natural succession under exploitation, and a relatively good catch and effort monitoring scheme has been in place since its creation. In addition, the inshore fisheries of Zambia and Zimbabwe have evolved differently and have been subject to different types of management regimes (see Bourdillon, Cheater and Murphree, 1984; Malasha, 2003; Jul-Larsen, 2003 and Overå, 2003 for a detailed historical account and analysis). Since the overall fishing effort, catch rates and fishing patterns on the two sides of the lake are very different due to different management and enforcement, a comparative study may shed some light on the impact that these different fisheries have on each side of the same ecosystem.

After a brief description of the physical and biological environment, and the different management regulations in place, we will use the long-term time series of commercial and experimental catch rates available to describe and discuss the observed development and changes on both sides of the lake. From this comparison we will evaluate the impact of fishing on the fish stocks relative to their natural succession and fluctuations in the environment.

There are two distinct fisheries in Lake Kariba: the low cost, non-mechanized, multispecies, inshore artisanal fishery, and the highly mechanized, capital intensive, semi-industrial single-species offshore fishery on the introduced pelagic clupeid Kapenta (*Limnothrissa miodon*). The biological, technical, and socio-economic interactions between these two fisheries are so small (Karenge and Kolding, 1995a; Bourdillon, Cheater and Murphree, 1985) that the fisheries must be treated separately. As the particular problems of the industrial Kapenta fishery are not the main focus of this study, it will be described and analysed only cursorily.

2. BACKGROUND INFORMATION

2.1 The environment

Lake Kariba (277 km long; 5 364 km^2; 160 km^3; 29 m mean depth and 120 m max. depth) is located on the Zambezi River between latitudes 16° 28' to 18° 04'S and longitudes 26° 42' to 29° 03'E. It was the largest man-made reservoir in the world at the time of construction. Today it is the second largest reservoir in Africa by volume. The catchment area covers 663 817 km^2 extending over parts of Angola, Zambia, Namibia, Botswana and Zimbabwe. The dam wall (128 x 580 m) was completed in 1960 and the filling phase lasted from December 1958 to September 1963 when the water reached the mean operation level at 485 m above mean sea level. The lake is naturally divided into five basins (Figure 1) and is almost equally shared by the two riparian countries Zambia and Zimbabwe with 45 percent and 55 percent respectively. The impact of the artisanal inshore fishery on the two sides of the lake can be considered not to affect each other because of the deep channel in between the two shores along most of the lake.

Lake levels fluctuate annually from one to five metres (mean = 2.9 m) as a function of inflowing floods between December and June and continuous drawdown through the turbines and, before 1981, spillage through the sluice gates. Since 1982 the lake levels have declined due to a series of droughts and the lowest levels recorded was in December 1992 and January 1997 at 476 m (Figure 2). Since 1997 the lake levels have risen rapidly, and in April 2000 the sluice gates were opened again for the first time in 19 years.

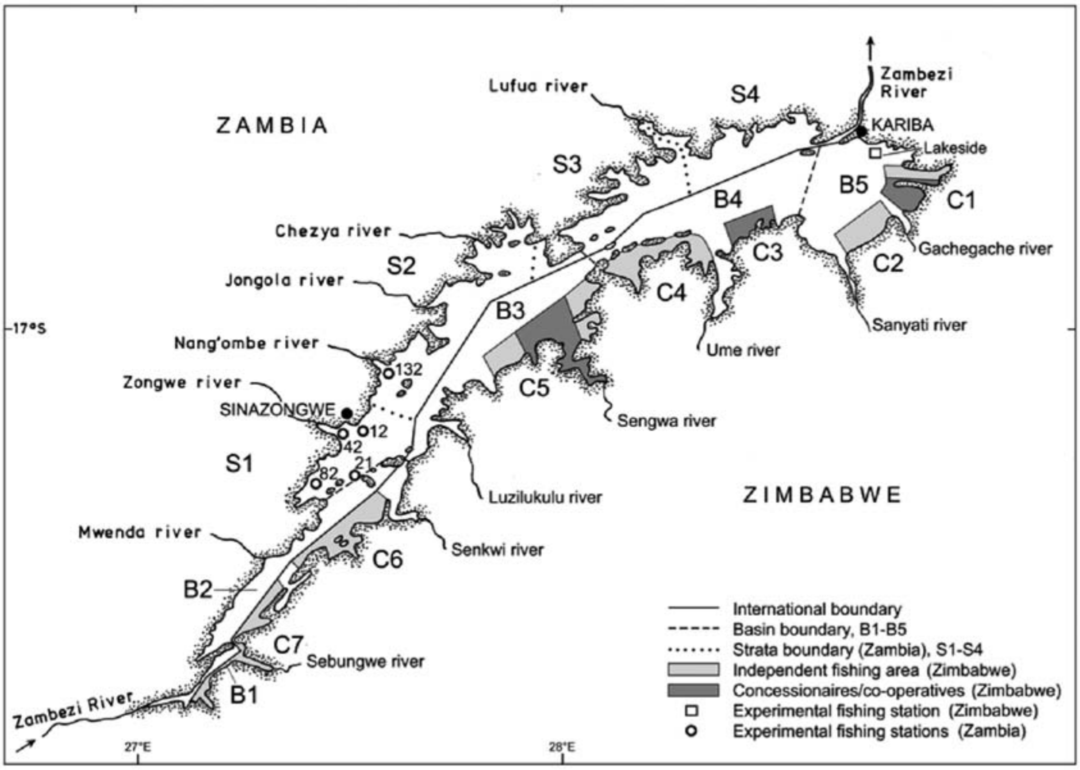

FIGURE 1. *Map of Lake Kariba showing the five natural basins (B1..B5), the designated inshore fishing grounds on the Zimbabwean side (C1..C7), the sampling strata in Zambia (S1..S4), the selected experimental fishing stations in Zambia around Sinazongwe (open circles), and the experimental fishing station (Lakeside) in Zimbabwe near Kariba town (open square).*

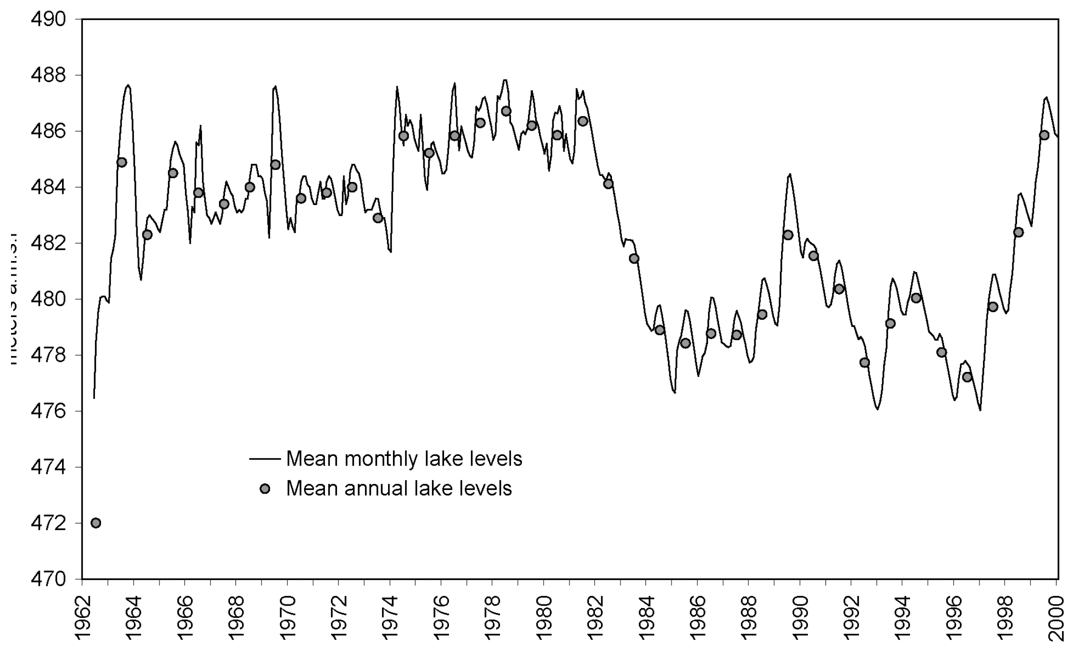

FIGURE 2. *Mean monthly and mean annual lake levels (m a.m.s.l.) in Lake Kariba from 1962 to 2000. Between 1981 and 2000 no surplus spillage through the dam wall floodgates have been performed.*

The limnological and various biological characteristics of Lake Kariba are well described elsewhere (see e.g. Coche, 1968; Balon and Coche, 1974; Marshall, Junor and Langerman, 1982; Marshall, 1984; Machena, 1988 and Moreau, 1997 for comprehensive reviews). The most salient features are a warm (mean surface temperature of 26°), oligotrophic, monomictic lake with overturn occurring in June–July. Stratification begins around September with a thermocline around 15 m depth which gradually moves down to around 35 m at the time of the turnover. The oxygen concentration in the hypolimnion declines steadily during the stratification period and often reaches a stage of deoxygenation. The volume to inflow (c. 50-70 km^3 per year) ratio is low giving a mean water retention time of only 2.6 years. The Zambezi River provides about 80 percent of the inflow and there is a natural gradient in the lake ecosystem from east to west. Basin 1 and 2 have more riverine characteristics gradually attaining a more lacustrine environment to Basin 5 near the dam wall.

The waters from the Zambezi River are very clear and low in plant nutrients. Phytoplankton blooms occur just after turnover and locally at the onset of floods from tributaries, but most of the year primary production may be very low. Zooplankton abundance shows variation in response to phytoplankton biomass (Begg, 1976; Marshall, 1997). Initially after filling, the lake was eutrophic due to the vast amount of dissolved nutrients through inundation of vegetation and land. From 1963 the lake became slightly alkaline with a marked decrease in phosphate and nitrates (Thornton, 1980). During the early eutrophic years the floating fern, *Salvinia molesta*, colonized large areas of the lake and retained vast amounts of plant nutrients (Mitchell, 1973). From the 1970s it has gradually decreased and been replaced by increasing amounts of rooted macrophytes down to a depth of around 10 m (Machena, 1989).

2.2 The fish fauna

The natural limnological gradient in the lake is also reflected in the fish communities which are dominated by potamodromous species in the east (cyprinidae and distichodontidae) and by more sedentary cichlids in the western basins (Begg, 1974). The fish community and biology of the fish species is well described in a number of reviews and research works (Balon and Coche, 1974; Mitchell, 1976a; Marshall, Junor and Langerman, 1982; Kenmuir, 1984; Marshall, 1984; Karenge, 1992; Machena, Kolding and Sanyanga, 1993, Musando, 1996; Karenge and Kolding, 1995a). Several of these discuss the observed biological succession in detail and only a brief update will follow. Most notable is that the number of fish species in Lake Kariba seems to be steadily increasing.

Jubb (1967) listed 55 species occurring in the Middle and Lower Zambezi River system, that is the portion of the drainage system from below the Victoria Falls to the mouth of the Zambezi River into the Indian ocean. In a pre-impoundment gillnet survey (Jackson 1961b), 28 fish species were caught in the Zambezi river at the location of the new lake (but very small mesh sizes were not used). Shortly after filling in 1964, Harding (1966) reported 33 species. In the early 1970s, Balon (1974a) recorded 39 species, later updated to 43 species by Marshall (1984). Since then five more species, the garpike *Hepsetus odoe* (Sanyanga and Feresu, 1994), the tilapias *Tilapia sparmanii* and *Oreochromis niloticus*, the chiselmouth *Varicorhinus nasutus*, and the largemouth bass *Micropterus salmoides* (Karenge and Kolding, 1995b; Anon., 1995) have been caught in the lake by the Lake Kariba Fisheries Research Institute. Bell-Cross and Minshull (1988) list 62 species in Lake Kariba area, defined by the Victoria Falls upriver and all south bank tributaries. Several of these have not been recorded in the lake itself.

2.3 Invasions, introductions and disappearances

The presence of non-introduced Upper Zambezi fish (i.e. above the Victoria Falls) in Lake Kariba a decade after creation, such as the cichlids *Sargochromis giardi*, *Sargochromis carlottae*, *Oreochromis andersonii*, and *Pseudocrenilabrus philander*, the mormyrid *Marcusenius macrolepidotus*, the cyprinid *Labeo cylindricus*, the schilbeid *Schilbe intermedius (mystus)*, and the small barbs *Barbus poechii*, *B. paludinosus* and *B. unitaeniatus*, caused some scientific debate when Balon (1974c) suggested that they survived the drop down the mighty Victoria Falls (e.g. Jubb, 1976a, 1976b, 1977). There are, however, indications that the so called "upper Zambezi invaders" may also have been present in the middle Zambezi before inundation but were missed in the sampling programs. They may also have been accidentally introduced or could have reached the lake through the Victoria Falls power station overflow (Jubb, 1976a; Kenmuir, 1984; Bell-Cross and Minshull, 1988). Whatever the origin, it seems that the new lacustrine environment give these species enhanced conditions to become established.

Presently 50 different fish species have been observed in the lake, five of which are introduced (Songore and Kolding, 2003). However, seven species have been reported just once (*Leptoglanis rotundiceps, Serranochromis angusticeps, Hepsetus odoe, Barbus radiatus, Labeo lunatus, Varicorhinus nasutus*, and the introduced *Micropterus salmoides*). Thus it can be is questioned whether they are stray specimens or have established viable populations in the lake. Two of the introduced species, *Tilapia rendalli* and *Serranochromis robustus*, may as well have invaded the lake naturally (e.g. Kenmuir, 1984). In fact *T. rendalli* was already caught by Jackson (1961b) during the pre-impoundment survey. Thus only three truly exotic species have established in the lake. One is the cichlid *Oreochromis macrochir*, which was stocked into the lake in 1959–62 from Chilanga, Zambia. It was never caught during Balon's (1974a, 1974b) intensive sampling programme and was believed extinct, but started appearing in the Lakeside sampling programme in 1974. It has since then been caught every year in the experimental surveys at Lakeside but only in very small numbers (on average about ten specimens per year out of 5–10 000 total sampled). In the Zambian experimental gillnet surveys it has been recorded only three times: in 1985, 1992 and 1996. The other true exotic is the small pelagic clupeid *Limnothrissa miodon* introduced from Lake Tanganyika in 1967–1969 (Bell-Cross and Bell-Cross, 1971). This introduction is a well-known success story (see section below) and there are no indications that this by far largest single stock in the lake with an annual total production rate around 125-150 000 tonnes, has had adverse effect on the other species (Marshall, 1991; Karenge and Kolding, 1995b). The third true exotic is the Nile tilapia (*Oreochromis niloticus*) which since 1993 has been caught in ever increasing quantities in gillnets by Lake kariba Fisheries Research Institute (LKFRI). This species was never introduced deliberately but is cultured at several farms along the lakeshore, which drain directly into the lake.

Some species have disappeared or have become rare (Kenmiur, 1984). The rheophilic species, *Chiloglanis neumanii*, *Opsaridium zambezense* (and possibly also *Leptoglanis rotundiceps*) are now confined to the tributaries or the two more lotic western basins (Balon, 1974a,1974b). Species diversity could be greater in the eastern effluent part of the lake than is assumed today (Begg, 1974), as Balon (1974a, 1974b) recorded 39 species in the Zinazongwe area (Basin 3) in a poisoning sampling programme. In a similar study in the Sanyati basin (Basin 5) only 27 species were recorded (Mitchell, 1976a). It was feared that the potamodromous mottled eel, *Anguilla bengalensis*, eventually would disappear from the lake, since the elvers coming up from the sea would not be able to mount the 128 m dam wall (Jubb, 1967). Marshall, Junor and Langerma (1982) considered the situation even more problematic with the construction of the formidable Cahora Bassa dam wall (160 m high) about 400 km down-river. However, some elvers still seem able to do so, although in low numbers, and eels have been recorded in the lake at all times (Marshall, Junor and Langerman, 1982). For instance, two mottled eel of around 60 cm TL were captured in March 1993 near the dam wall. If these have not ascended the two dam walls on their way up the Zambezi river, they were by then more than 30 years old (Anon., 1993).

2.4 Management and regulations:

The lake was primarily constructed to generate hydro-electricity but additional expectations were also derived from different estimates of the potential fish yields. Before inundation, an area of some 950 km^2 (about 18 percent of the lake area) was bush cleared at various places within the 20 m contour in order to establish inshore fishing grounds. Between 1959 and 1962, 26 tonnes of cichlid fingerlings (*Tilapia rendalli* and *Oreochromis macrochir*) were stocked into the lake to boost the fishery (Coche, 1971). From the very beginning the essential issue in the management of the fishery was the question “Who was to fish”? On this question the Zambian and Zimbabwean[1] authorities fundamentally disagreed, which eventually led to divergent policies that still mark the fisheries in the two countries today (Bourdillion, Cheater and Murphree, 1985). In Zimbabwe the authorities divided the shorelines into 14 areas, separated in spheres of white and black interest. Along the “Native Area” shoreline, black fishers, who were encouraged to become “professionals”, would exploit the inshore fishery. Therefore the 26 camps in which they were located were strictly for fishing: permanent settlement and shoreline agriculture were prohibited. The native areas were shared with white-owned concessionaires, who in addition to their own fishing concession areas, would also purchase the fish from the black fishers. The area demarcations and concessions allocated for fishing were changed in 1972 into eight larger areas and again in 1976 into the present seven areas (Figure 1), (Marshall, Junor and Langerman, 1982; Karenge and Games, 1995), mainly to conserve the stocks and to meet the demands for more recreational waters from the burgeoning tourist industry. Whilst the total area available for inshore fishing was reduced by these changes, the area allocated to local fishers was increased slightly. At present about 470 km^2 (63 percent) of the fishable water on the Zimbawean side is available to the inshore fishery (Marshall, Junor and Langerman, 1982) and the number of fishing villages has grown to about 40.

From the very beginning, the Zambian authorities took a different view. The interest of the local population was paramount and there was no racially based segmentation. The whole Zambian shoreline was designated as “Native trust land” and could not be utilized without consent of the local people. Furthermore, the Zambian authorities initiated infrastructure and institutions for developing the fishery. A large resettlement compensation was paid to the Gwembe Rural Council, mainly used for development of the fishery. In addition, a Fisheries Training Centre was build in Sinazongwe with harbour, boat building, and ice plant facilities. Up to 1994 there were about 270 fishing villages on the Zambian shoreline, but these were amalgamated into 67 villages in 1995 (Jul-Larsen, 2003). In Zimbabwe, preparations for the

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[1] Before 1964 called Northern and Southern Rhodesia under the Central African Federation of Rhodesia and Nyasaland.

initial fishery were much more modest and little money was allocated for the fishery development. Since its beginning until today any kind of economic investment in the inshore fishery in Zimbabwe has been virtually absent (Marshall, Junor and Langerman, 1982; Bourdillon, Cheater and Murphree, 1985), in contrast with a relatively strong management regime and enforcement capacity.

In Zimbabwe the inshore fishery is controlled by the State through the Department of National Parks and Wildlife Management (DNPWM) who limits access, closes areas to fishing and restricts fishing gear methods. A permit system is in place whereby the DNPWM informs the two riparian local authorities, the Nyaminyami (west) and Binga (east) District Councils (separated by the Sengwe river in Basin 3), of the limits placed on the number of fishing permits that may be issued for the particular year. The Councils then issue these fishing permits to the individual fishers or fishing co-operatives. The distribution of permits per individual fisher can differ according to local authorities. For example for the greater part of the 1980s individual fishers in Binga were allocated 2.5 nets each whilst fishers in Nyaminyami were allowed five nets each. Fishing permits for fishers operation off state lands are issued directly from DNPWM. According to officially set limits there should be a maximum of 2 530 nets on the Zimbabwian side of the lake belonging to 771 fishers, independent fishers and cooperative members inclusive. It is however difficult to establish how these effort limits were arrived at since it proved impossible to obtain documentation on the method used (Songore, 2000). The official limit, however, has never been reviewed and the actual recorded number of nets and fishers, although fluctuating, for most of the time has been below these values (Figure 4).

The fishing patterns are very simple because only one type of gear (gillnets) are used throughout the whole Zimbabwean inshore fishery. Fishing is not permitted using nets with less than a four-inch (102 mm stretched) mesh size. In addition explosives, chemicals, poisons, intoxicating substances, scoop nets, jigging and fish driving may not be used to catch fish. Fishing is also not permitted along parts of the shoreline (about 20 percent, Figure 1) belonging to the DNPWM, notably all the Chete Safari Area, most of the Matusadona National Park and parts of the Charara Safari Area. Other restrictions are in place for river mouths, large population centres, harbours, and river estuaries. Fish net manufacturing is not permitted for persons who do not hold a valid manufacturer and dealer’s license and fishing nets can only be sold to holders of valid fishing permits.

Two institutions dealing with the fishery resort under the DNPWM: The Lake Kariba Fisheries Research Institute conducts research and collects data on the fish stocks, the fishers and their catches, while the management branch of the DNPWM is tasked with policing the fishery.

In Zambia access to the fishery is free in principle and fishers can fish anywhere. When the lake was created the management regulations were similar to the other fisheries in the country, but these were seen as interim to be revised after obtaining further information (Malasha, 2003). Initially, therefore, the legal minimum mesh size was set to four inches and a closed season was to be observed from 16 December to 16 March. In 1962 the Department of Game and Fisheries in Northern Rhodesia tried to abolish the mesh size regulation based on the results of experimental fishing. However, the authorities in Southern Rhodesia rejected this on the grounds that the Lake Kariba Fisheries Research Institute had not yet conducted sufficient experiments to support this move. From the independence of Zambia in 1964 to 1986 no mesh restrictions for gillnet existed and beach seines were allowed. After 1986 the minimum mesh size for gillnets was set at three inches (76 mm) and beach seining was prohibited. In practice, however, there has been little enforcement due to lack of resources (Musando, 1996). Also the kutumpula method (fish driving) is very popular among fishers although it is officially banned by the Fisheries Act (Scholz, 1993).

3. MATERIALS AND METHODS

3.1 Data: origin and treatment

Fish yield data collection in both Zambia and Zimbabwe has been in operation since the fishery started in 1961 (Zambia) and 1962 (Zimbabwe). In addition both the Lake Kariba Research Unit (LKRU) in Sinazongwe (Zambia) and the Lake Kariba Fisheries Research Institute (LKFRI) in Kariba town (Zimbabwe) (Figure 1) have carried out extensive monitoring with experimental gillnets. Very little data, however, are available from Zambia in the period 1974–1980 when the fishery was officially closed due to the Zimbabwean civil war.

Hydrological data were obtained from the Zambezi River Authority (ZRA) as daily lake level recordings, which were averaged on a monthly and annual basis (Figure 2).

3.2 Inshore fishery, Zimbabwe

Fisheries catch and effort data collection has been in operation since the fishery started in 1962 on the Zimbabwean side. Until 1992 a data collection system referred to as Catch Assessment System (CAS) was in place. From 1993 the CEDRS system, unified with Zambia, was introduced as one of the activities under the Zambian-Zimbawean SADC Fisheries Project. Artisanal fishing on the Zimbabwean shores of the lake is conducted in seven fishing areas (C1 to C7, Figure 1). A description of these fishing areas and changes that they underwent during the history of the fishery is given in Marshall, Junor and Langerman (1982) and Karenge and Games (1995). A compilation and partial analysis of the catch-effort data on the Lake Kariba artisanal fishery in Zimbabwe is given in Songore (2000). Methods of data collection differed according to how fishing activities were organized. Operators of concessions (fishing areas C1, C3 and part of C5) were required to submit monthly returns of their daily catches, effort, and sales. The annual catch of this group was worked out from the returns. Data from the remaining fishing areas operated by the local communities were collected through an enumeration programme. Staff from LKFRI carried out enumeration in two fishing areas (C2 and C4) while staff from the Binga District Administrator's office enumerated catches from the three other areas (part of C5, C6 and C7).

Prior to the intensification of the liberation war in Zimbabwe, data were collected from generally all the fishing areas. Later, during the period 1975–1979, when the war escalated, data collection operations were disrupted with some of the sampling areas being abandoned due to closure of fishing villages. This mostly affected data collection in fishing areas that were fished by local communities. The concessionaires continued sending in their catch, effort and sales returns undisrupted. Attempts to normalize data collection again were made in 1980 when the war ended. However, due to inadequate manpower and financial constraints, it was not possible for LKFRI to cover all the landing sites using its own resources. Hence the Binga District continued for some time to collect data from landing sites under their jurisdiction. But, data from these areas (C5 to C7) were sent in irregularly. From 1973 to 1984 total yield was estimated from mean monthly catch from all villages (where catches from villages not enumerated were estimated) through multiplication by 12 months and adding the reported catches from the concessionaires. From 1985 some of the concessionaires were transformed into cooperatives, and during the period 1985–1992 enumeration activities were scaled down to ten fishing villages which were all in the areas C2 and C4. Therefore yield estimates for the whole lake were based on extrapolation of data collected from C2 and C4.

A critical analysis of the sampling strategy and a number of recommendations were made by Sanyanga, Lupikisha and Thorsteinson (1991). This led to the introduction in 1993 of the CEDRS in order to unify the data collection systems of Zambia and Zimbabwe. As it was found impossible to sample either all villages or the total landings for any particular village for the whole year, ten representative villages were to be enumerated for ten days every month on each side of the lake. The sampled catch was to be raised to an estimate of the total catch by multiplying by the ratio between total number of days sampled and days in the year and the ratio between the number of fishers in the villages sampled and the total number of fishers. CEDRS only operated well for a short period, but broke down due to diminishing human resources. Enumerators who retired, resigned or died were never replaced. Furthermore, very few of the proposed strategies for improving were implemented. Hence the quality of data collected continued to be questionable in terms of representing the whole fishery (Songore, 2000).

Total yield estimates from 1985 to present have been calculated using the following formula:

$$\hat{Y} = \frac{sampled\ catch}{sampled\ \#\ fishers \cdot days} \cdot total\ \#\ days^{(1)} \cdot total\ \#\ fishers^{(2)} + reported\ cooperative\ catches$$

(1) total # days = 365 until 1993, thereafter = 360.

(2) from 1985 to 1992 total # fishers used in the calculation was constant (= 765), from 1993 the total # fishers was obtained from Frame surveys, keeping the number constant in between each survey.

3.3 Inshore fishery, Zambia

Scholz (1993) gives a detailed account of various sampling designs used and an analysis of the data from 1961–1990. Aggregated data from his thesis are used for the period 1961–1980. Data from 1980 to 1999 are based on a compilation and partial analysis of the catch-effort data on the Lake Kariba artisanal fishery in Zambia by Musando (2000). Two different systems of collecting catch-effort data have been used. From 1980 to 1993 the so-called CAS (Catch Assessment Surveys) was used, a two stage stratified random sampling system to estimate catch rates (*Cpue*) supplemented by a framesurvey to count total effort (f) and activity level (A), based on which total catch (C) could be estimated (). During three survey days at randomly selected sampling units (PSUs), fishers met at their landing sites were asked to report on catch, mesh sizes and number of nets set. Settings with no catch are said to have been reported as well. The catch was identified by fish family and weighed in kilos. The “CEDRS” (Catch and Effort Data Recording System) was introduced during 1993; in order to unify the data recording system with the Zimbabwean side of the lake. The CEDRS programme was designed to carry out the survey for ten days per month per stratum (Figure 1), in ten selected fishing villages, as well as record catch rate by species name other than the family name.

Unfortunately the execution of the sampling programme for both the CAS/CEDRS designs has been highly irregular due to budget shortcomings and lack of staff (Scholz, 1993, Musando, 2000). Moreover, it appears that the total estimated effort is made as a simple summation of strata sampled, irrespective on the number of strata actually sampled. In this way, the “effort” thus becomes a function of number of strata and on the number of times each strata has been sampled during a year (Musando, 2000).

3.4 Frame surveys on Lake Kariba

Lake wide frame surveys on Lake Kariba were initiated in 1990 under the auspices of the Zambia/Zimbabwe SADC Fisheries Project (ZZSFP) and repeated in 1993. Additional frame surveys have been conducted in 1995 and 1999 on the Zambian side and in 1998 and 2000 on the Zimbabwean side.

3.5 Experimental data

Since 1960 LKFRI in Zimbabwe has conducted an experimental gillnet fishery at Lakeside station close to Kariba town in the Sanyati basin (Basin 5, Figure 1). Here commercial fishing was only permitted between 1962 and 1972 (Kenmuir, 1984) and limited fishing took place from 1977 to 1980, but this probably had little effect on the fish stocks (Marshall, 1984). Experimental fishing during the early years was somewhat sporadic with few settings (Kenmuir, 1984). However, from 1970 to 1975 settings were done twice a month and since 1976 sampling has been done weekly, except for 1981 when no fishing took place (Karenge, 1992; Karenge and Kolding, 1995a). The sampling design has remained constant over the whole period and consists of multifilament nets in multimesh fleets with 12 panels ranging from 38 mm to 178 mm stretched mesh sizes with 12.5 mm increments. The fleet, 550 m in total length, was set overnight perpendicular to the shore with the smaller meshes inshore. Each individual fish caught was recorded for species, mesh size, weight, length, sex and maturity stage. All experimental gillnet data from 1969 to 1999 have been digitized into PASGEAR (Kolding, 2001) which now contains more than 185 000 individual fish records from 39 species and represents more than 14 000 panel settings. A detailed analysis of this data set up to 1992 is given in Karenge (1992) and Karenge and Kolding (1995a).

In Zambia, the Lake Kariba Research Unit (LKRU) under DoF, based in the former Fishery Training Centre in Sinazongwe, has carried out an experimental fishing with multimesh gillnets since 1980. Under this programme, every month three experimental localities (stations) were sampled for three consecutive days. Multifilament nets were in use during 1980 to May 1984 and also from 1992 to 1995, whereas monofilament nets were used between June 1984 to part of 1992 and 1993. Both gear types were set at a hanging ratio of 0.5. A fleet of nets with stretched mesh sizes ranging from 25 mm to 178 mm with 12.5 mm increments, were set. A detailed description and analysis of these data up to 1995 is given in Musando (1996). All experimental gillnet data from 1980 to 1999 have been digitized into PASGEAR. The database now contains more than 118 000 individual fish records from 36 species and represents more than 13 000 panel settings. Unfortunately, the choice in stations sampled during this programme has shifted repeatedly, the gillnet fleets were not always complete due to difficulties in replacing worn out nets while the sampling programme occasionally was not carried out because of fuel-shortages, net thefts and bad weather. For the present analysis, due to the irregular sampling design, only the most used sampling stations in close proximity to

Sinazongwe (Charlets Island (st.12), Samaria Island (st.21), Zongwe estuary (st.42), Ngoma (st.82), and Nang'ombe (st.132)), have been included (Figure 1). From 1994 to 1995 only Charlets Island and Zongwe estuary were sampled. From 1996 to 1999 only Zongwe estuary remained in the sampling programme. Furthermore, only the mesh sizes in the range 50 mm stretched to 152 mm stretched have been included as only this part of the fleet was more or less complete (except for 1989 when only mesh sizes from 89 mm to 152 mm were used).

Catch per unit effort (C/f) in the both the Zambian and Zimbabwean experimental fishery is expressed as catch (kilo wet weight or number of fish) per standard gear unit per setting. The standard gear unit of each mesh size is one panel of 45 m (50 yards) long.

3.6 Multiple regression of hydrology and fishing effort on catch rates

Multiple regressions were performed with mean annual total catch rates (CPUE) as dependent variable, and hydrological indices and effort as independent variables. From the monthly or annual mean lake levels five differently time-lagged indices for the hydrological dynamics in Lake Kariba were tested following (Karenge and Kolding, 1995b):

The absolute mean annual lake levels (m a.s.l.).

The annual amplitude (m), i.e. the difference between the lowest and highest recorded level within one year.

Delta ($\triangle$) lake levels (m), defined as the difference between the mean annual lake levels of one year and the immediately preceding year. This will permit the estimation of the effect in change of lake level of one year on the catch rate the succeeding year.

A combination of 2) and 3) by adding the two figures ($\triangle$ lake level + amplitude), thus taking into account the combined effect of two consecutive years.

The $\triangle_y + \triangle_{y-1}$ (m), which is the sum of the delta lake levels of one and the preceding year, thus giving the combined effect of three consecutive years.

Fishing effort was expressed as total annual number of nets or fishers (inshore fisheries) or total annual boat nights (Kapenta fishery).

Using cross-correlations, where all variables were made orthogonal by subtracting the mean from the original series, it was established whether there was a lag-phase between detrended annual mean water levels and detrended annual mean catch rates, and which of the hydrological variables was more informative. The rise in lake level normally terminates in May-June every year, whereas the lowest lake levels normally are found in late December–early January. The annual fishery statistics are the average of the whole year, but with generally higher catches in the latter part of the year during low lake levels (Marshall, 1988; Karenge, 1992).

The multiple regressions were always of the form:

$$CPUE_i = \mu_i + effort_i + hydrological\ index_{lag(x)} + effort \bullet hydrological\ index_{lag(x)} + \varepsilon_i$$

Where,

$CPUE_i$	= time series of annual mean catch rates
μ_i	= overal mean
$effort_i$	= total number of nets, fishers, or boat nights for $year_i$
hydrological $index_{lag(x)}$	= one of the 5 hydrological indices at lag(x), x = 0 – 5
effort·hydrological $index_{lag(x)}$	= interaction of effort and hydrological index at lag(x)
ε_i	= residual error

In all cases non-significant explanatory variables were removed from the model using stepwise regression. The interaction effect is interpreted as reflecting possible changes in catch rate either as a result of changes in efficiency or of usage of gears in relation to water levels. In case of confounded effects between effort and hydrological variables (i.e. when both variables were significant alone, but one or the other fell out in the combined model) interaction was always high and cannot be interpreted. All statistical analyses were carried out using Statistica (StatSoft ®).

4. RESULTS AND DISCUSSION

4.1 Development of the Kapenta fishery

From a pre-impoundment study, Jackson (1961) predicted that the pelagic habitat of Lake Kariba would remain non-colonized since the species present in the Zambezi river had evolved in a riverine habitat and would therefore only inhabit the shallow littoral zones. Coke (1968) and Mitchell (1978) later confirmed this. Following Jackson's recommendation Kapenta, *Limnothrissa miodon*, (a small pelagic clupeid, which in Kariba reaches a size of around five centimetres) was introduced by the Zambian government into Lake Kariba between 1967 and 1969 from Lake Tanganyika (Bell-Cross and Bell-Cross; 1971, Junor and Begg, 1971). The introduction was a success and, although the colonial Rhodesian Government was not informed about the introduction, the researchers at the Lake Kariba Fisheries Institute observed the widespread presence already in 1969. Commercial Kapenta fishing, or the offshore fishery, began in July 1973 in Zimbabwe with a single purse-seiner. But effort grew rapidly (Figure 3) and from 1976 this fishery changed to using lift nets from pontoons at night with light attraction, which considerably increased the catch rates. From 1978 the fishery started to expand along the Zimbabwean shoreline to six different bases, and in 1981, after the termination of the civil war in Zimbabwe, this fishery started in Zambia (Overå, 2003). The predominantly white-owned, capital intensive Kapenta fishery has now developed into a million dollar industry, with between 20 and 30 000 t landed annually, economically vastly outstripping the inshore fishery, and with theoretical potential for further expansions (Anon., 1992; Machena, Kolding and Sanyanga, 1993; Marshall, 1992, 1993; Kolding, 1994). The Kapenta fishery alone, through its profitability, is according to Bourdillon, Cheater and Murphree (1985) directly responsible for most of the infrastructural development that has occurred on the Zimbabwean shoreline. Cheater (1985) gives a detailed account of the development of this fishery in Zimbabwe until the mid 1980s. From the early 1990s no new licenses were issued in Zimbabwe and the effort development seemed also to stabilize in Zambia around this time (Figure 3) with a corresponding stabilization in catch rates of 150-200 kg per rig per night in both countries. From 1998 there has been a decrease in the reported Zimbabwean effort.

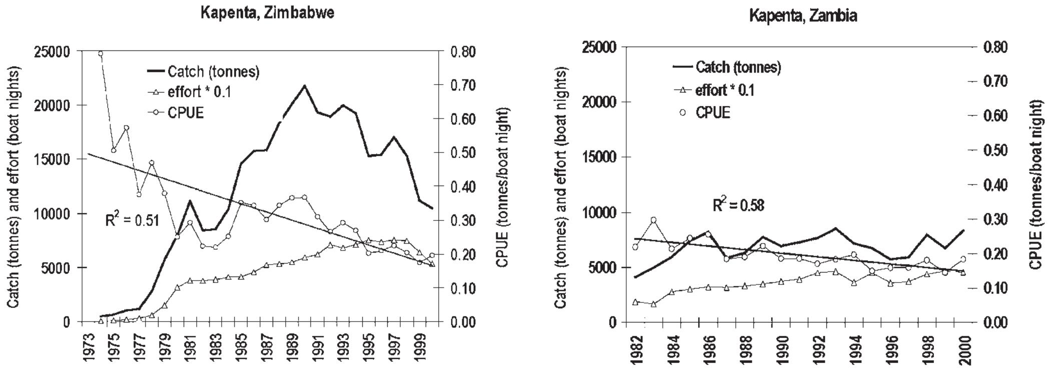


FIGURE 3. *Development in the offshore Kapenta fishery in Zimbabwe (1974-2000) and Zambia (1982-2000). CPUE in tonnes/boat night. Note effort values have been multiplied by 0.1 for scaling reasons. Source: Zambia-Zimbabwe Fisheries Joint Annual Statistical reports.*

4.2 Development in inshore fisheries

Commercial gillnet fishing started on the Zambian shore in 1958 immediately after the impoundment had begun, and from 1962 on the Zimbabwean side because the authorities wanted the filling and stocking complete before a fishery was initiated (Minshull, 1973; Bourdillon, Cheater and Murphree, 1985). Initially, the catches were very high due to the eutrophic state of the lake from the fresh inundation and the rapid colonization of opportunistic riverine detritus feeding species such as mudfish (labeo's) and distichodontids. In 1962 the catches started to decline in Zambia, followed by Zimbabwe four years later (Minshull, 1973). This initial boom and bust of the catches was reflected in the fishing effort. By 1962 about 2,500 fishers were operating on the Zambian side producing around 3 000 tonnes of fish, whereas by 1967 the number of fishers had decreased to less than 500 (Scudder, 1967; Jul-Larsen, 2003; Overå, 2003), (Figure 6). Similarly, on the Zimbabwean side the number of fishers peaked at just over 1 000 in 1966, subsequently declining to less than 500 in 1971 (Minshull, 1973) (Figure 4).

The number of fishers in Zimbabwe increased again during the 1980s with a subsequent decline during the 1990s to same low level as the 1970s (Figure 4). The number of nets per fisher in Zimbabwe, however, has remained relatively stable around an average value of 4 ± 1.5 SD (Figure 4) with no significant development over time.

The overall decline in effort since the early 1990s (Figure 4) has taken place in all fishing areas, with the exception of fishing area C4 (Songore, 2000). For the fishing areas C1 and C3, which were once operated by white concessionaires, the effort has declined most, almost linearly since 1973. This can be attributed to a gradual exodus from fishing due to declining returns on investment (Marshall, 1984). Catch per unit of effort, however, has generally increased in all the fishing areas (Songore, 2000) also reflected by the overall rate (Figure 5).

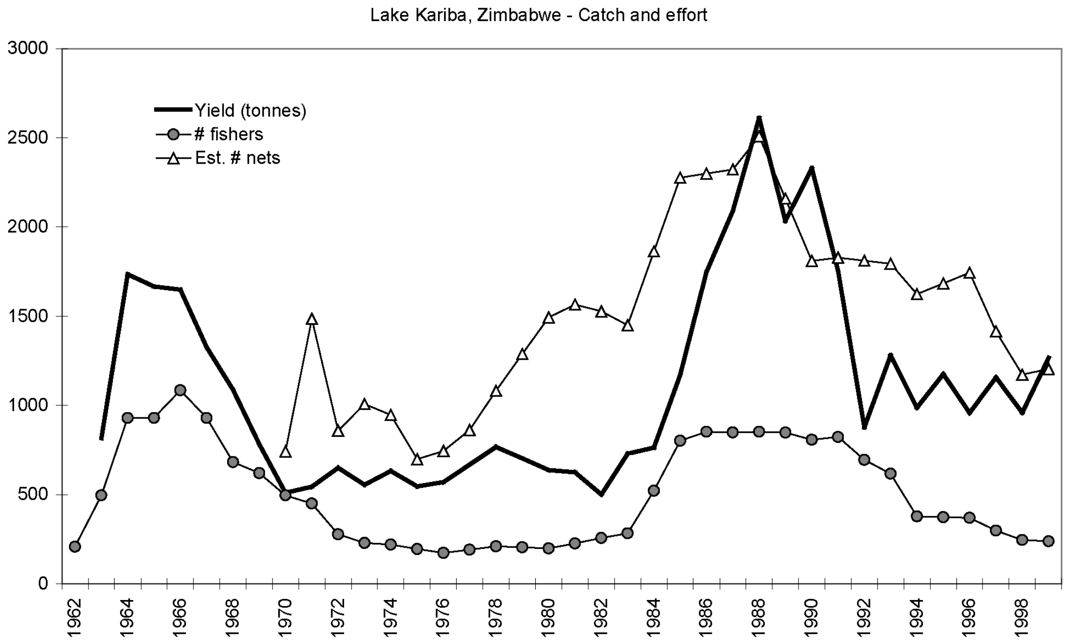


FIGURE 4. *Estimated total annual effort (numbers of fishers and nets) and reported annual yield (tonnes) from the Zimbabwean inshore fishery between 1962 to 1999. Source: Songore (2000).*

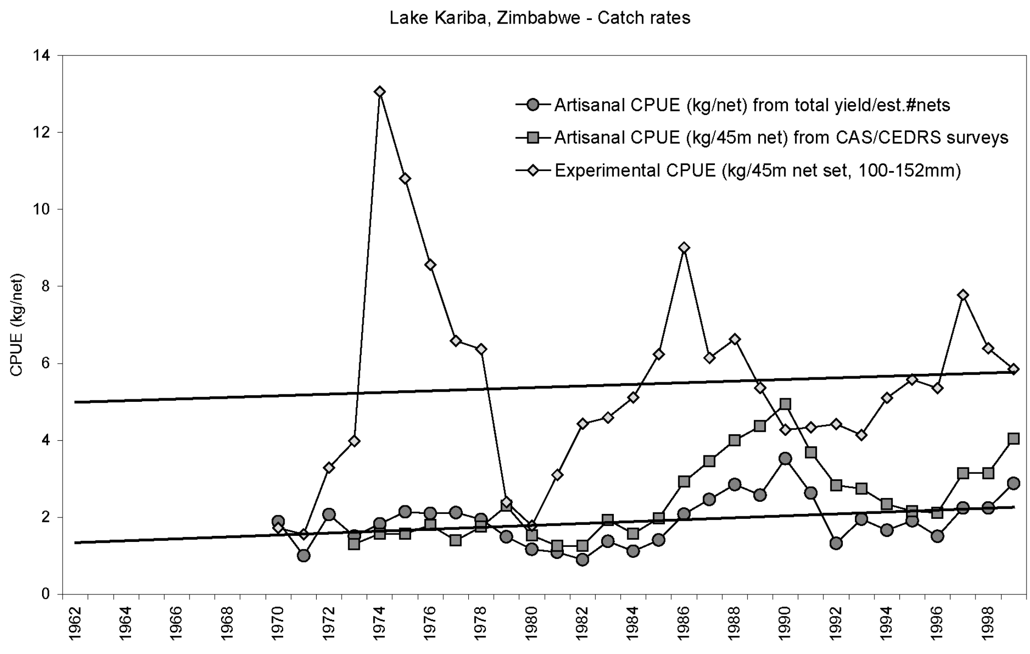


FIGURE 5. *Development in catch rates (kg/45 m net) of the Zinbabwean inshore fishery. Straight lines are linear regression on the experimental catch rates and the artisanal catch rates (kg/net) between 1980 and 1999. The trends (slopes) are not statistically significantly different from 0 (Experimental: Slope = 0.02, SE = 0.06; Artisanal: Slope = 0.02, SE = 0.01), but indicate a slight increase over time. The artisanal catch rates are on average one third of the experimental.*

Both the artisanal and experimental catch rates in the Zimbawean inshore fishery show the same overall trend since 1970 (Figure 5). Since the Lakeside station is in an unfished area, this indicates that the overall development in the inshore biomass appears to be independent of the change in fishing effort. It also indicates that the efficiency of the fishers (catchability coefficient) has not changed much over time which does not sustain the general notion that the fishers are increasingly under-reporting the number of nets used (e.g. Sanyanga, Lupikisha and Thorsteinson, 1991). Mean annual fishing effort (Figure 4) consistently has been operating below the maximum legal limit of 2 530 nets. This may be due to fishers being unable to secure fishing gear or some fishers being passive, keeping their licenses so as to utilize them in times of hardships. Fishers have always indicated that it is very difficult to acquire fishing gear (Songore, 2000). The average catch rates in the fished areas, however, are generally only one third of the experimental catch rates: this difference could be attributed to fishing.

The number of fishers in Zambia increased from around 1 000 during the 1980s reaching almost the level from the heyday in 1962, but has subsequently declined to around 1 200 fishers in the latest frame survey in 1999 (Figure 6).[1] The fluctuations in the number of Zambian fishers largely follows those in Zimbabwe (Figure 4) although initially the latter had a four year time lag due to a later start of the fishery. Since 1980 the ratio between the Zimbabwean and Zambian number of fishers has been remarkably stable with a mean of 0.3±0.1 SD. The average number of nets per fisherman in Zambia, however, has almost linearly increased during the whole period from around two in the early 1960s to around ten in the late 1990s (Figure 6). This means that the actual effort, although fluctuating in concert with the numbers of fishers, has increased much more rapidly and is today almost five times higher than at beginning of the fishery.

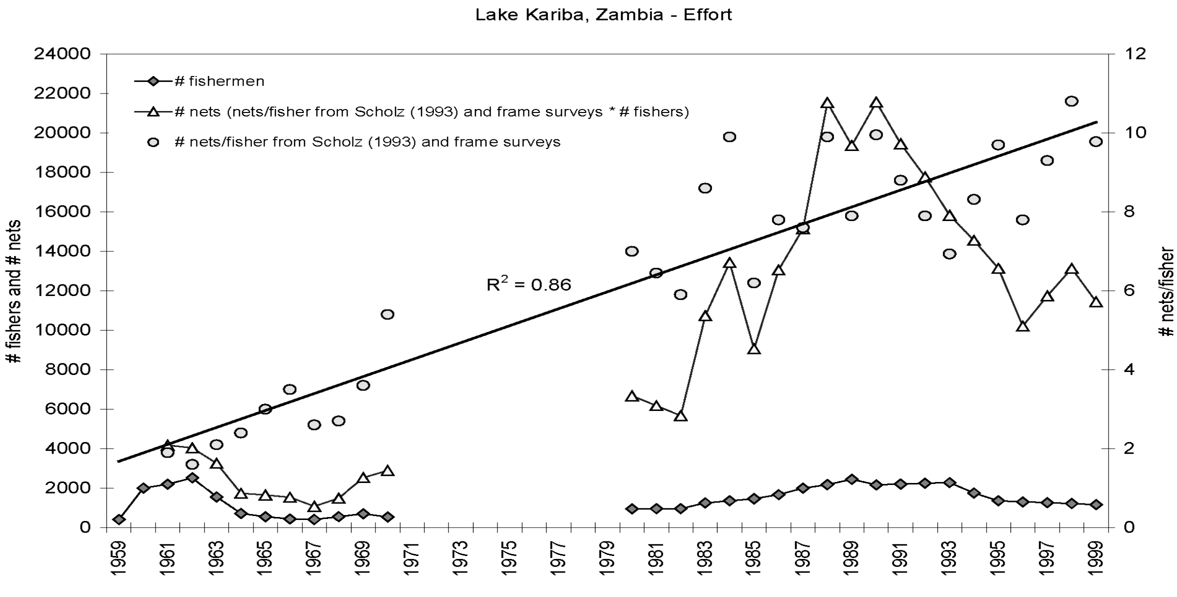


FIGURE 6. *Estimated effort development in the Zambia inshore fisheries. Number of nets are calculated from nets/fisher·#fishers. Straight line is a linear regression on the nets/fishers. Sources: Number of fishers: 1959-61 from Scudder (1967); 1962-89 from Scholz (1993); 1990, 1993, 1995, 1999 from Frame Surveys; 1981, 1991-92, 1994-95, 1996-98 interpolated. Nets per fisherman: 1961-89 from Scholz (1993); 1990, 1993, 1995, 1999 from Frame Surveys; 1996, 1999 from Jul-Larsen (2003); 1981, 1991-92, 1994, 1997 interpolated.*

[1] No effort data are available between 1971 and 1979 but from 1980, after the Zimbabwean civil war, the fishery re-opened and data collection resumed.

Between 1980 and 1999 the reported yield from the Department of Fisheries statistics (Figure 7) is almost identical (only 1.4 times higher) to the estimated yield on the Zimbabwean side (Figure 4) despite the much higher effort in Zambia – on average three times more fishers and eight times more nets – and with approximately the same catch rates from 1980 onwards according to the CAS/CEDRS statistics (Figures 5 and 8).

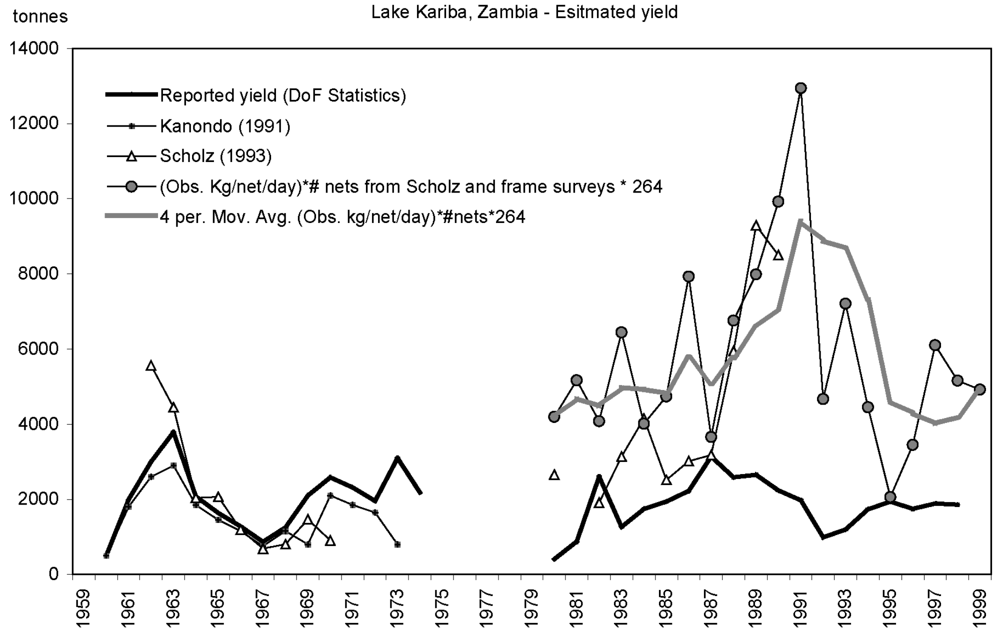


FIGURE 7. *Estimated yield in the Zambia inshore fisheries from various sources and from this study (1980–1999, solid circles and four year moving average).*

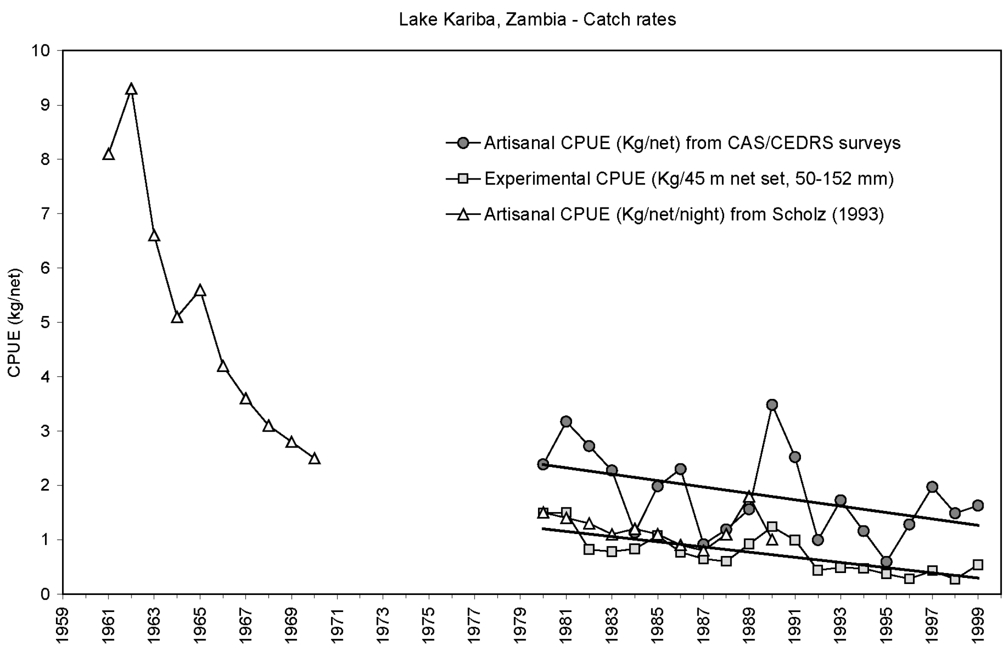


FIGURE 8. *Development in catch rates (kg/45 m net) of the Zambian inshore fishery. Straight lines are linear regression on the experimental catch rates and the artisanal catch rates (from CAS/CEDRS surveys) between 1980 and 1999. The trends (slopes) are not statistically significantly different ((Experimental: Slope = -0.05, SE = 0.01; Artisanal: Slope = -0.06, SE = 0.03), but the artisanal catch rates are on average 2.5 times higher than the experimental.*

These data strongly suggests that the reported Zambian yield is seriously underestimated, as was concluded by Scholz (1993) and Scholz, Mudenda and Moller (1997) as well. By using Scholz's (1993) figures of average active fishing days per fisher of 264 per year times the observed catch per net per day from CAS/CEDRS (Musando, 2000), and the estimated number of nets, a re-calculated estimate of the annual yields in the Zambian inshore fishery has been made (Figure 7). For the period 1980–1999 these recalculated yield estimates are on average three times higher than the reported yield.

After the initial boom in the Zambian fishery a strong decrease in the catch rates between 1962 and 1970 occurred (Figure 8). From 1980 to 1999 the trend continued to decline, although at a much lower rate. The experimental and artisanal catch rates follow the same trend, but in contrast to the Zimbabwean side, the enumerated artisanal catch rates are on average 2.5 times higher than the experimental (Sinazongwe area) for the same range of mesh sizes. This difference could be attributed to the different experience and ways of setting the nets between fishers and research personnel. A similar much lower catch rate of the research personnel compared with the full-time fishers was observed in Bangweulu (Kolding, Ticheler and Chanda, 1996, 2003).

4.3 Seasonal and geographical differences

Catch rates in winter (May–October) are significantly lower than in summer (November–April), both in the experimental and artisanal fisheries. Furthermore, the mean monthly catch rates is strongly correlated with the mean monthly rainfall (r = 0.92). (Figure 9).

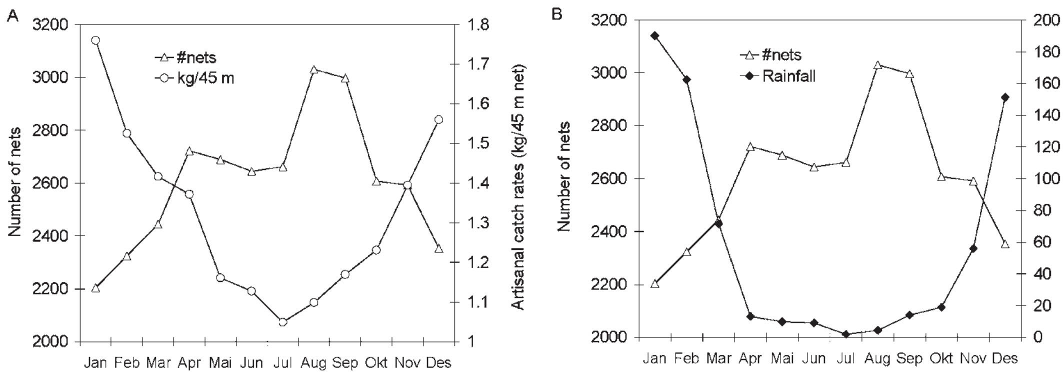


FIGURE 9. *The negative relationship between A: mean monthly effort (number of nets) and mean monthly catch rates (kg/45 m net), and B: mean monthly effort (number of nets) and mean monthly rainfall (mm) in the Zimbabwean inshore fishery*

Effort for the whole Zimbabwean side of the lake fluctuates during the year with low values in January, a stabilization during April to July and a rise to a peak in August after which it starts declining until December. Catch rates display a negative relation with effort (Figure 9A). This pattern can be interpreted in two ways. The first explanation is that the fishers increase their effort during the cold season when catch per unit of effort decreases. However, the alternative explanation is that the overall effort is low during the warm agricultural season which starts in October when land preparation and planting starts and extends to April when harvesting is completed. The second argument supports the "two home condition" (Songore, Moyo and Mugwagwa, 2000) of the fishers, characteristic for the inshore Zimbabwean fishery where permanent settlement and shoreline agriculture is prohibited. The "two home condition" and seasonally fluctuating effort clearly indicates that the original intentions of making the Zimbabwean inshore fishers "professionals" has never succeeded and that fishing is for many only one of several activities.

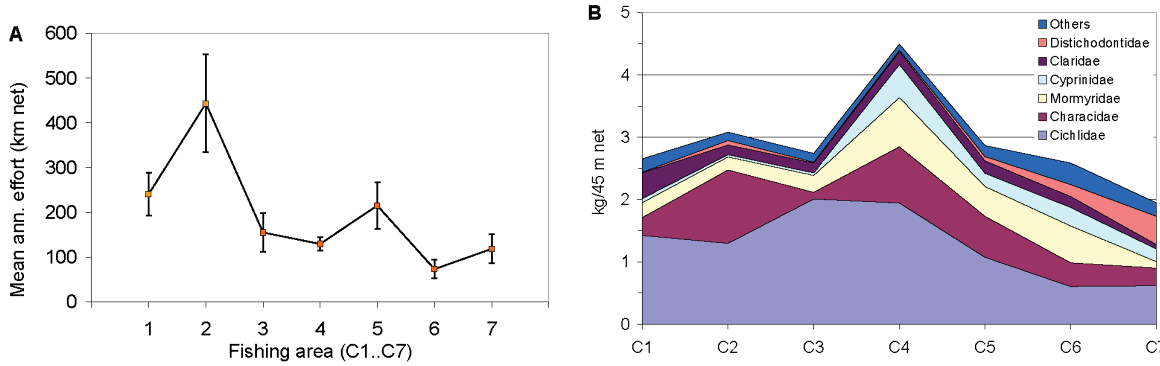


FIGURE 10. *A: Mean annual effort (km net) with 2·SE error bars, and B: mean annual catch per unit effort (kg/45 m net) by major families in fishing areas C1..C7 in the Zimbabean inshore fishery for the period 1980 to 1999.*

The mean annual effort and the mean annual catch rates are not uniform along the east-west gradient of the lake (Figure 10). Fishing area C2 between the Gachegache and Sanyati rivers has in general had the highest average effort, but also the highest variation. Otherwise there is a general decline in effort from the lacustrine eastern basin to the more riverine west of the lake. However, the average catch rates in each fishing area (Figure 10B) shows no apparent relation with the overall effort. This indicates that the effort distribution is more a result of vicinity to markets and the better infrastructure in Basin 5, and that catch rates and effort are largely independent. The catch composition, however, reflects the natural gradient in the lake ecosystem where cichlids are dominant in Basins 4 and 5 whereas large cyprinids and distichodontids become increasingly important towards Basin 1 concomitant with overall lower catch rates. The characids, dominated by tigerfish (*Hydrocynus vittatus*) are more uniformly distributed, but with higher catch rates in fishing areas associated with larger tributaries into the lake, such as the Sanyati river (C2) and the Bumi river (C4).

4.4 Changes in fishing pattern and species composition

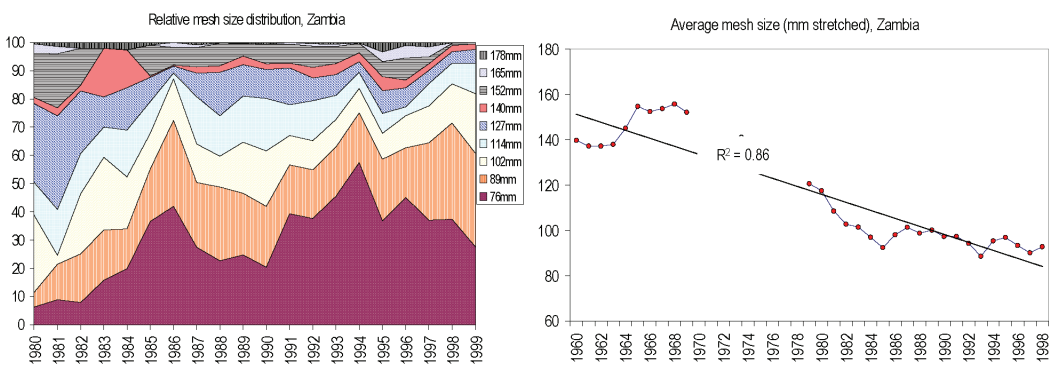


FIGURE 11. *Changes in recorded mesh size distribution in the Zambian inshore fishery. A: relative distribution of mesh sizes from 1980 to 1999, and B: average mesh size from 1961 to 1999. 1961-1970 data from Scholz (1993), 1980-1999 data from Musando (2000).*

During the first decade of the Zambian fishery the average mesh-size ranged between 140-152 mm (Scholz, 1993, Figure 11). From 1980, when monitoring resumed, to 1999 the average mesh-size in the inshore fishery decreased from 120 mm to 90 mm (Figure 11). In addition to a significant decrease in the mesh sizes used, the Zambian inshore fishers are reported to extensively use fish driving techniques (Kutumpula) to catch bream (Scholz, 1993; Malasha, 2003). In Zimbabwe most fishers initially used 150-175 mm mesh until around 1970. As the catches of the large migrating fish (labeo's and distochodontids), remnants from the first inundation period, decreased, the use of smaller mesh sizes increased gradually and by 1978 about 60 percent of the nets were in the range 112–125 mm (Marshall, Junor and Langerman, 1982). In the frame surveys of 1993, 1998 and 2000, the average mesh sizes were 128, 115 and 118 mm respectively (Songore, 2000). In general there has been no significant changes in the fishing pattern of inshore Zimbabwean fishery since the 1970s.

In the inshore fishery about ten species make up more than 90 percent of the catches and of these only three (the cichlids *Oreochromis mortimeri* and *Tilapia rendalli* and the characid tigerfish *Hydrocynus vittatus*) contribute more than 50 percent (Figure 12).

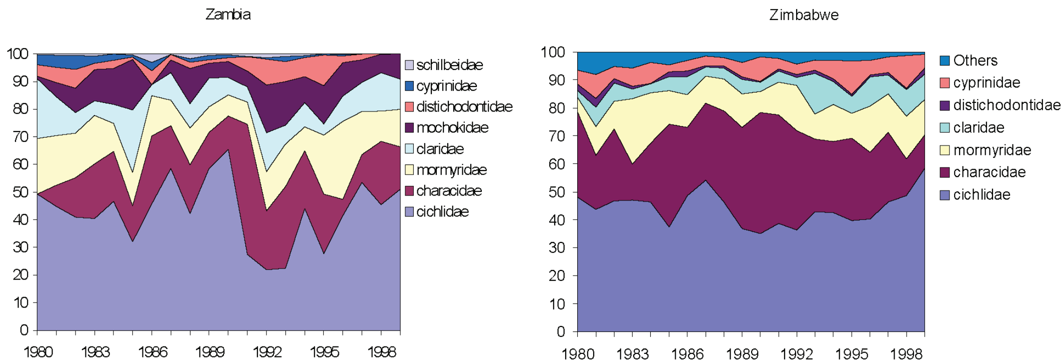


FIGURE 12. *Relative catch composition (% weight) in the inshore fishery between 1980 to 1999 by major families in Zambia and Zimbabwe based on CAS/CEDRS. Sources: Musando (2000) and Songore (2000).*

The changing fishing pattern on the Zambian side is not reflected in the overall species composition of the catches, neither are there any major differences in the overall catch composition between the two countries, which are both dominated by cichlids (Figure 12). In the Zambian inshore fishery relatively less tigerfish and more distichodontids are caught compared to the Zimbabwean side. This difference, however, can be explained from the distribution of the fishers where the majority on the Zambian side is in the western part of the lake, while in Zimbabwe the majority is in the eastern part. For both countries the relative species composition has changed remarkably little since 1980.

A comparison of mean weights and catch rates of the commercially important fish species from two fished areas and the non-fished Lakeside experimental fishing area (Table 1) showed no systematic differences although the overall experimental catch rates are about three times higher than the overall artisanal catch rates (Figure 8).

TABLE 1. *Comparison between mean weight (grams) and mean CPUE (kg/45 m net) for the most important species in the Zimbabwean fishing areas C2 and C4 and the experimental fishing station at lakeside (=LS, mesh sizes 102 to 173 mm) for the period 1980 to 1999. C2 and C4 were chosen because they represent the areas with high and moderate fishing intensity, and because they are the fishing areas enumerated by the same LKFRI staff that is conducting the experimental fishing at lakeside. Below each variable are given the other sites only if these are significantly different at p<0.05).*

	C2		C4		LAKESIDE (LS)	
SPECIES	Mean Weight	CPUE	Mean Weight	CPUE	Mean Weight	CPUE
Hydrocynus vittatus	1460 **C4, LS**	0.95 **C4, LS**	1284 **C2, LS**	0.37 **C2, LS**	993 **C2, C4**	0.36 **C2, C4**
Oreochromis mortimeri	640 **C4**	0.36	532 **C2, LS**	0.33	620 **C4**	0.50
Serranochromis codringtoni	419	0.05 **LS**	384 **LS**	0.10 **LS**	471 **C4**	1.40 **C2, C4**
Tilapia rendalli	543	0.18	533	0.27 **LS**	537	0.14 **C4**
Clarius gariepinus	956 **C4, LS**	0.09 **LS**	1129 **C2**	0.05 **LS**	1190 **C2, C4**	0.46 **C2, C4**
Momyrus longirostris	1801 **C4**	0.09 **LS**	1474 **C2, LS**	0.23 **LS**	1756 **C4**	1.31 **C2, C4**

For two of the species (*H. vittatus* and *T. rendalli*) the catch rates were actually higher in the fished areas than in the non-fished area and for tigerfish also the mean weight was higher in the fished areas. For tigerfish the higher catch rates and mean weights can be explained by location of fishing area C2 and C4 in vicinity to larger tributaries where this species migrate upstream to spawn. For the redbreast tilapia (*T. rendalli*) the higher catch rates could be explained from the use of fish driving as this species is notorious for evading stationary gillnets (Kenmuir, 1984; Karenge and Kolding, 1995a). However, the overall non-systematic difference between the fished and the non-fished areas do not indicate that the observed differences are due to fishing.

4.5 Development of catch rates in the experimental fishing nets

The development of catch rates in the experimental fishing nets on the Zimbabwean side (the unfished Lakeside station) and the Zambian side (Sinazongwe area) show clear differences (Figure 13). In 1980 when the Zambian fishery reopened after the closure due to the war, catch rates on the two sides were almost similar. After this first year, however, the two time series rapidly separated with an increasing trend at Lakeside and a decreasing trend in Zambia. The trends in the two countries are similar to the trends in the inshore fisheries respectively (Figures. 5 and 8). However, the average experimental catch rate in Zambia is about seven times lower compared to Lakeside from the mid 1980s.

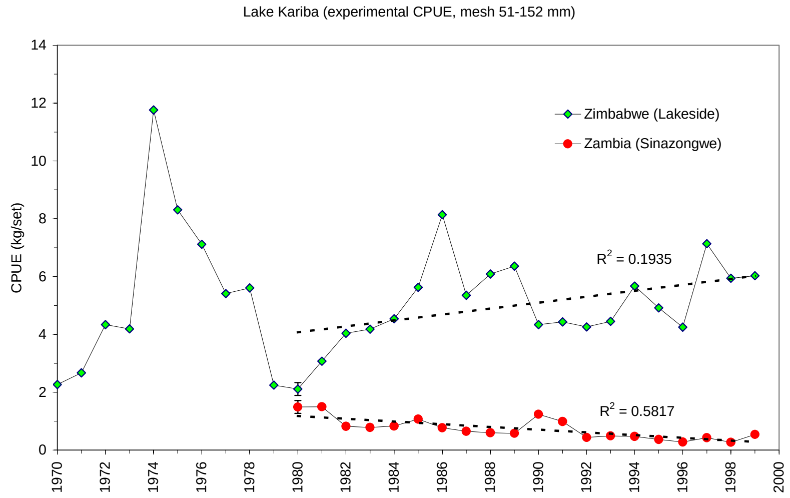


FIGURE 13. *Mean catch rates (kg/set) in the experimental fishery (mesh size range 52-152 mm) on the Zimbawean and the Zambian side of Lake Kariba. 95 percent confidence intervals are indicated for 1980 when the Zambian inshore fishery reopened and the trend lines (both significantly different from 0) represent the period 1980 to 1999.*

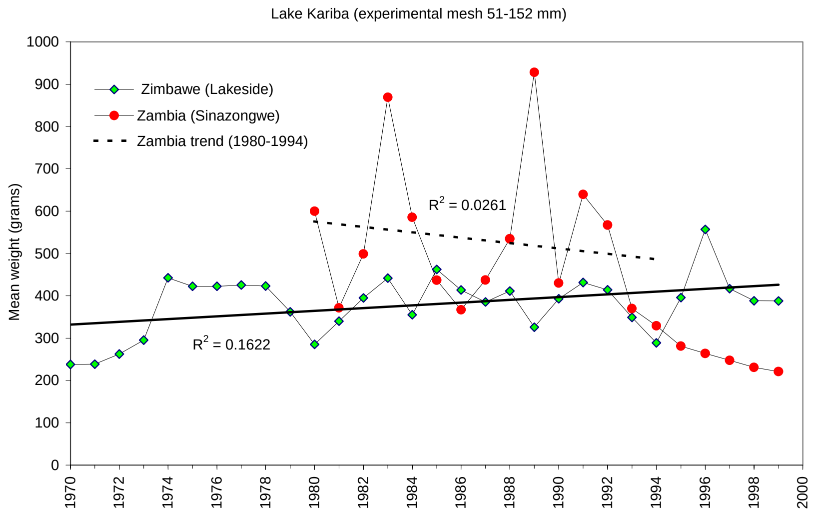


FIGURE 14. *Development in the mean weight of individual fish in the experimental gillnets on the Zimbawean and the Zambian side of Lake Kariba. The trend line for Zimbabwe (1970-1999) is significantly different from 0, whereas the trend line for Zambia (1980-1994) is not significantly different from 0.*

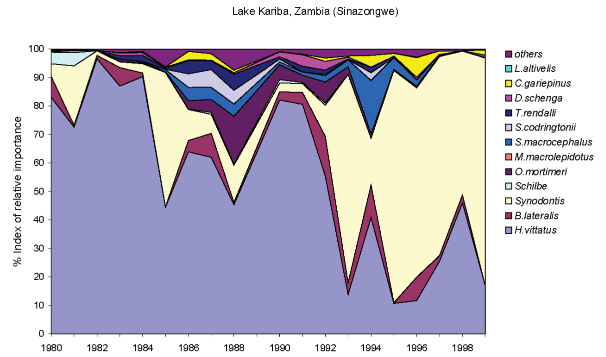
Although the development in the mean weights of the experimental catches (Figure 14) show the same trends as catch rates (increasing in Zimbabwe and decreasing in Zambia), the actual values were higher in Zambia until 1994 when the sampling areas were limited to around the Zongwe estuary (Figure 1). The higher mean weight in the Zambian experimental gillnets can be attributed to the much higher proportion of tigerfish and distichodontids than the Lakeside data dominated by cichlids. Similarly the strong decrease in the Zambian mean weight after 1994 is due to the predominance of squeakers (*Synodontis zambezensis*) in the Zongwe esturay (Figure 15) which means that the experimental gillnet data series in Zambia is not mutually representative before and after 1994.

4.6 Catch composition and species changes in the experimental gillnets.

Most of the published research on the changes and development of the fish populations in Lake Kariba has been from the Zimbabwean side of the lake (Donelly, 1970, 1971; Kenmuir, 1984; Marshall, 1984; Jackson, 1986; Karenge, 1992; Karenge and Kolding, 1995a, 1995b; Sanyanga, 1996). Comparatively little has been published from the Zambian side of the lake, particularly since the study of Balon and Coche (1974). Recently, however, Scholz (1993) and Musando (1996) did analyses on the long-term development of the inshore fish populations in the Zambian waters of the lake.

In contrast to the artisanal catch compositions which show a remarkable stability in the species composition and are dominated by cichlids on both sides of the lake (Figure 12), the relative species composition in the experimental gillnets show a systematic successive development over time (Figure 15). This would indicate that the experimental catches are not representative of the fishery, and that the selectivity (or fishing pattern) is not comparable although gillnets are the main fishing gears used. The Bangweulu case study (Kolding, Ticheler and Chanda, 1996, 2003) also showed that the experimental catches were not representative for the fishery, mainly due to different methods, and even for the same methods (gillnets) different ways of setting the nets. The divergence between the observed succession in the experimental nets and the catch composition in the fishery strongly indicates that the fishers are not passively harvesting the resources, but actively use the different methods and experience available to select and target particular species. In Zambia, for example, the high prevalence of cichlids in the artisanal catches, in contrast to the dominance of tigerfish in the experimental nets (Figure 15), and the large proportion of *Tilapia rendalli* on the Zimbabwean side, both supports the notion of a widespread use of fish driving (Kutumpula) as also observed by Scholz (1993) and Malasha (2003).

Most of the observed changes in relative species composition of the experimental catches can be attributed to the natural species succession that Lake Kariba has undergone since its creation as a new pristine environment (Karenge, 1992; Karenge and Kolding, 1995a; Musando, 1996). Shortly after filling, the large potamodromuos cyprinids *Labeo congoro*, and *L. altivelis*, and characins *Distichodus shenga* and *D. mossambicus*, were abundant in the lake and sustained for a large part the initial boom in the inshore fishery. After a few years they declined, particularly in Basins 3-5, and cichlids gradually became more important (Marshall, Junor and Langerman, 1982).



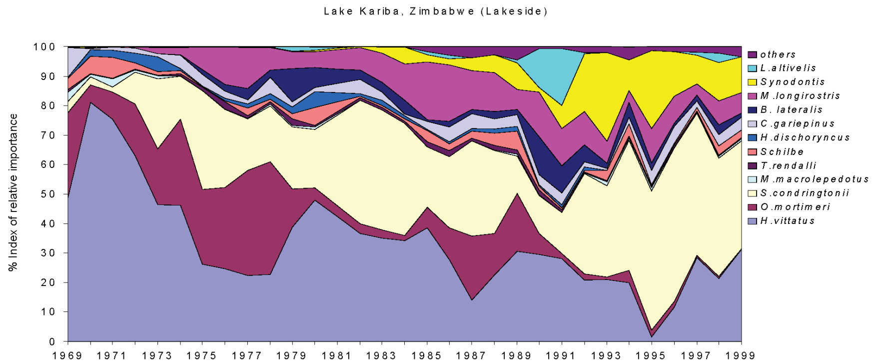


FIGURE 15. *Relative species changes in the experimental surveys represented by Index of Relative Importance (Karenge and Kolding, 1995a). Above Zambia from the Sinazongwe area (Basin 3) and below Zimbabwe from the Lakeside experimental station (Basin 5). From 1994 sampling stations in Zambia were reduced to only cover the Zongwe estuary which are not fully representative for the main lake (see also Figure 16).*

The successive development in species diversity, and particularly the relative evenness, seems more pronounced at Lakeside in the most lacustrine part of the lake (Basin 5) than in the Sinazongwe area (Basin 3). During the 1970s the relative abundance of *Hydrocynus vittatus* gradually declined after which it stabilized (Karenge and Kolding 1995a). Among the cichilids, *Serranochromis condringtonii*, which was not common in the lake in the early years (Kenmuir, 1984), has gradually replaced the Kariba bream (*Oreochromis mortimeri)* in Basin 5. *Oreochromis macrochir*, which had been reported to have disappeared completely shortly after stocking (Balon, 1974a) has been caught in low, though regular, numbers since 1975. This period was also marked by the gradual decline of *Marcusenius macropidotus* and *Hippopotamyrus discorhynchus* but with a substantial increase of the larger mormyrid species *Mormyrus longirostris*. From around 1980 the squeaker *Synodontis zambezensis* gradually became important in the inshore system, while the "Upper Zambezi invader" *Serranchromis macrocephalus* appeared in the lake and increased in abundance.

The tigerfish (*Hydrocynus vitattus*), due to its important recreational value as an angling fish, has always attracted particular attention in the management regulations of Lake Kariba. Its relative decline (Figure 15) has been subject to repeated concern. This species is considered particularly vulnerable to fishing with small mesh sizes (Kenmuir, 1973; Marshall, Junor and Langerman, 1982; Langerman, 1984; Scholz, 1993). Sanyanga (1995) even considered it presently endangered in Lake Kariba and recommended to give it conservation status. However, taking into account that the Lakeside catch data are from an unfished part of the lake and that the Zambian experimental catches are from an area with a continuously increasing level of fishing effort with decreasing mesh sizes, it is a paradox that the mean Index of Relative Importance for 1980-1994 for tigerfish in Zambia was 57 percent while at Lakeside it was only 26 percent. (Figure 15). Thus, while tigerfish has decreased in absolute abundance on the Zambian side since 1980, this decrease is proportionally following the same trend as all the other species in the inshore fishery (Figures 8 and 13). From the available data it is difficult to support the notion that tigerfish is particularly vulnerable to fishing with small mesh sizes, neither that it is an endangered species in the Kariba ecosystem. Karenge and Kolding (1995b) found that the relative lake level changes were the most important factor for the abundance of tigerfish. Lake Kariba experienced a serious drought between 1982 and 1998, with a subsequent rapid rise to full capacity in 2000 (Figure 2). It is expected therefore that the catch rates will increase from 1999 which has been confirmed during 2001 (Patrick Ngalande, pers. comm).

4.7 Diversity

The appearance of new species and the increasing abundance of other species (like *L. altivelis* and *S. zambezensis*, which were common in the Zambezi River before inundation) have resulted in steadily increased fish species diversity (Figure 16).

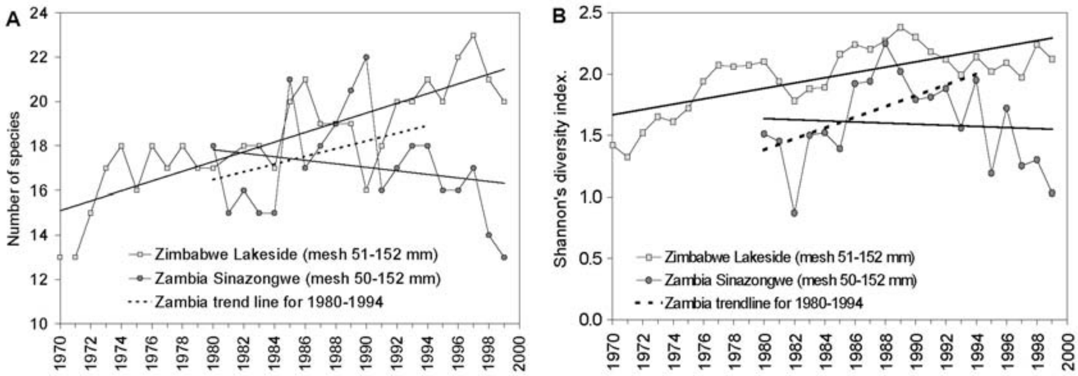


FIGURE 16. *Development in species diversity in the Kariba experimental gillnets (mesh sizes 50-152 mm) represented by **A**: annual mean number of species caught and **B**: Shannons's diversity index (H'). Continuos trendlines are for the whole period of observations (1970-1999 and 1980-1999 in Zimbabwe and Zambia respectively). Broken trendlines are from the period 1980-1994 in Zambia. The broken trendlines for Zambia (**A**: Slope = 0.21, SE = 0.15; **B**: Slope = 0.05, SE = 0.020) and the trendlines for Zimbabwe (**A**: Slope = 0.22, SE = 0.03; **B**: Slope = 0.02, SE = 0.004) are statistically not significantly different at 95 percent confidence intervals.*

An overall increase over time in the both the number of species caught and the Shannons diversity index can be observed at Lakeside, whereas around Sinazongwe an increase in the 1980s was followed by a decrease after 1993 (Figure 16). The decrease in Zambia, however, is believed a sampling artefact because from 1994 only the stations within the Zongwe estuary were sampled which due to the habitat has an overall lower diversity. The total number of species caught over the period 1980-1994 is 32 in Zambia and 29 in Zimbabwe in the experimental fleet of 50-152 mm mesh sizes. The average Shannon diversity index, however, is significantly different between the two countries due to a higher relative evenness among the species at Lakeside in Basin 5 (Table 2, Figure 15).

Comparing the period 1980-1994 in Zambia with the whole period in Zimbawe the successive development in species diversity (slopes) is not significantly different on the two sides of the lake (Figure 16). The lower mean values in the Zambian experimental catches can be explained from the different habitats in Basins 3 and 5 and the overall composition gradient along the lake.

	mesh range	# fleet settings	# species	H'	J'
Zambia	51-152	869	32	1.90±0.04	0.57±0.02
Zimbabwe	50-152	592	29	2.29±0.03	0.69±0.02

TABLE 2. *Comparison of the species diversity in the Zambian and Zimbabwean inshore gillnet catches between 1980 and 1994. Shannons diversity index (H') and evenness index (J') with confidence limits of 2·SE from bootstrapping.*

4.8 Biomass-size distribution

The difference in the mean experimental catch rates between Zimbabwe and Zambia (Figure 13) is reflected in the overall biomass-size distribution of the two areas (Figure 17).

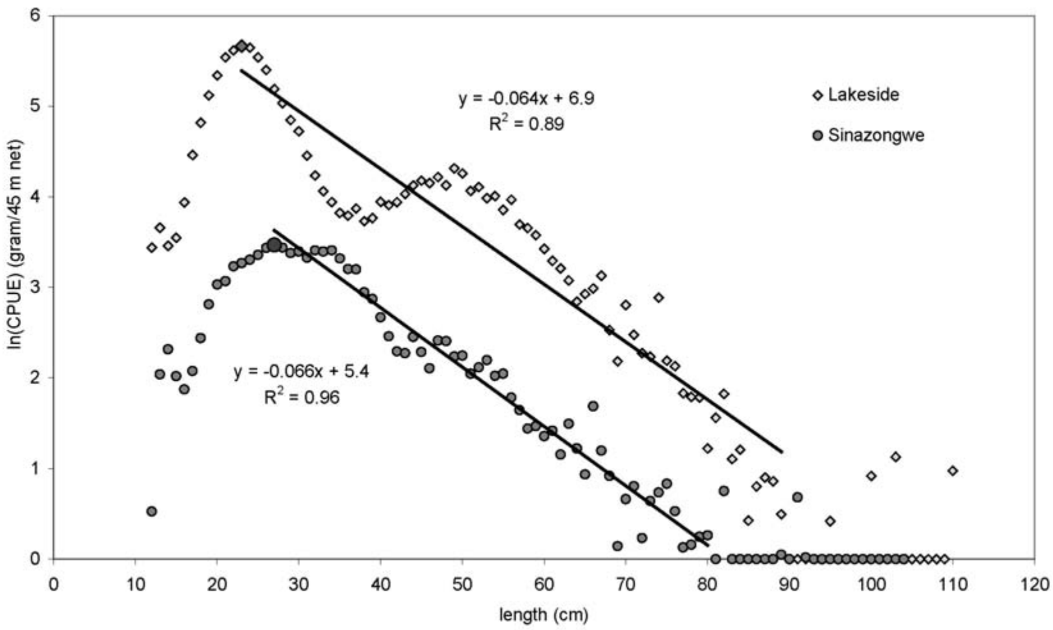


FIGURE 17. *Relative biomass-size distribution with linear regression from Zimbabwe (Lakeside) and Zambia (Sinazongwe) experimental fisheries during the period 1980-1994 for all fish caught in mesh sizes 50-152 mm. Linear regressions on ln-transformed standardized mean catch rates (gram/45 m net set) were made from length range 23-89 cm (Zimbabwe) and 25-78 cm (Zambia) (from the highest value to first 0-observation). The SE of the slopes are 0.0028 and 0.0019 for Zimbabwe and Zambia respectively which means the slopes are not significantly different at 95 percent confidence level.*

Although the means of the biomass-size distributions (intercepts) are significantly different it is interesting to note that the slopes are not. This indicates that although the absolute stock abundance is clearly different between the unfished and fished areas, the overall community size structure is relatively the same. Comparing the biomass-size distributions with the relative inshore catch composition (Figure 12) and the development in species diversity (Figures. 15 and 16), it appears that the much higher fishing intensity in Zambia with smaller mesh sizes only are affecting the overall biomass of the stocks, whereas the community structure and composition seems not affected. There are no indications that the present fishing level and fishing pattern in the Zambian inshore fishery show any potential threat to the biodiversity of the lake. As the overall yields have not declined (Figure 7), the lower catch rates are not a sign of overfishing in a biological sense, but simply a sign of fishing. Furthermore, by decreasing the mesh sizes, and thereby increasingly exploiting the smaller species/sizes in the biomass-size spectrum, the Zambian fishers are not only able to largely maintain their individual returns (CPUE) despite overall increasing effort, but also maintain the same relative size spectrum in the community which ecologically speaking only makes sense (see Jul-Larsen *et al.* 2003, Chapter 5).

4.9 The relative impact of the environment

Both experimental, inshore, and offshore catch per unit of effort (CPUE) fluctuated synchronously with mean annual lake level fluctuations with a remarkably high correlation (Karenge and Kolding, 1995b). The question is therefore how much of the observed variation can be attributed to fishing and how much to the changing environmental conditions.

TABLE 3. *The relative effect of hydrological changes and effort on catch rates in the Kariba fisheries. The statistical regression model used is: Annual mean catch rate*$_{ijk}$ *= overall mean + effort*$_i$ *+ lag(hydrological variable*$_j$*) + effort*$_i$$\cdot$*lag(hydrological variable*$_j$*) + residual variation*$_{ijk}$*. Only significant effects are retained in the model and shown here as positive (+) or negative (-) effects. In some instances the hydrological variables and effort were confounded meaning that both parameters were significant alone, but in the total model one or the other became non-significant depending on the order they were entered into the model. In such situations it is not possible to quantify the relative effect of both parameters simultaneously. N= number of years in the model.*

Dependent variable: Annual mean catch rate		Independent variables								
		Hydrology				Effort			Interaction	
System / Variable	N	Lag	Variable	Sign	%	Variable	Sign	%	Sign	%
Zimbabwe										
Artisanal CPUE (Kg/net)	27	0+1	△Lake levels	+ (**)	29	# Fishers	- (**)	44	Ns	
Artisanal CPUE (Kg/net)	27	0	△Lake levels	+ (**)	19	# Nets	- (**)	26	Ns	
Exp. CPUE (kg/net)	29	0	Amplitude	+ (**)	39	# Fishers	Ns		Ns	
Exp. CPUE (kg/net)	29	0	Amplitude	+ (**)	39	# Nets	Ns		Ns	
Kapenta CPUE(t/night)	26	0	Lake levels	Confounded		Boats	Confounded		- (**)	56
Zambia										
Artisanal CPUE (Kg/net)	20	0	Lake levels	+ (**)	32	# Fishers	Ns		Ns	
Artisanal CPUE (Kg/net)	20	0	Lake levels	+ (**)	32	# Nets	- (*)	9	- (*)	8
Exp. CPUE (kg/net)	20	0	Lake levels	+ (**)	31	# Fishers	Ns		Ns	
Exp. CPUE (kg/net)	20	0	Lake levels	+ (**)	34	# Nets	- (**)	23	- (*)	11
Kapenta CPUE(t/night)	18	0	Lake levels	Confounded		Boats	Confounded		- (**)	60

The results of the multiple regression analyses between the various time series of catch rates, effort, and hydrological variables (Table 3) indicate that the lake level fluctuations have a significant effect on the overall stock sizes in both the unfished area, the inshore, and the offshore Kapenta. The fishing effort had no effect on the experimental catch rates in the unfished Lakeside area, which supports the notion that a closed area could act as a sanctuary. The fishing effort however had significant effect in all the exploited areas. In the Zimbabwe inshore fishery both the number of fishers and the number of nets were significant, reflecting the relatively constant number of nets per fisherman over time in this fishery. In the inshore Zambian fishery, however, only the number of nets were significant, reflecting the ever increased number of nets per fisherman (Figure 6) in this fishery.

Most interestingly, however, fishing effort had a higher relative effect in the lightly fished inshore Zimbabwean inshore fishery (44 percent and 26 percent for the number of fishers and number of nets respectively) compared to the higher exploited Zambian inshore fishery (9 percent for the number of nets). Conversely the environment had a higher effect in the inshore Zambian fishery than the inshore Zimbabwean fishery. Everything else being equal, this seems to indicate that as the fishing effort increases and the stock levels are reduced, the annual catch rates become more and more dependent on the changing environmental conditions. In other words, in an unstable environment with a high exploitation level, the fishery will develop more and more into a boom and bust fishery with the changing environmental conditions (see Figure 5.8, Volume 1). This situation would explain the much more variable annual catch rates and relative species composition in the Zambian inshore fishery compared to the less exploited Zimbabwean side (Figures 8 and 12).

5. CONCLUSIONS

The inshore fisheries on the Zimbabwean and Zambian side of Lake Kariba have ever since the creation of the lake undergone different management regimes. The Zimbabwean side is, compared to the Zambian, much more regulated and enforced resulting in a fishing pressure and fishing pattern which has not changed much over time and where the fish stocks are only moderately exploited. In contrast, the Zambian inshore fishery, with virtually no enforcement of regulations, has experienced a much higher fishing intensity and a changed fishing pattern towards increasingly smaller mesh sizes resulting in a higher exploitation level and reduced stock sizes. In both countries effort has been fluctuating over time. However, in Zimbabwe the effort in general has shown a decreasing trend while CPUE has increased, whereas in Zambia effort generally has increased with a corresponding decreasing trend in CPUE. The overall fishing effort, in terms of number of nets, is about seven times higher in Zambia than in Zimbabwe, while the average experimental catch rates are seven times lower. However, the artisanal catch rates are not very different on both sides of the lake (1.8 and 2.8 kg/net in Zambia and Zimbabwe respectively). This would indicate the Zambian fishers somehow are able to maintain the catch efficiency by decreasing the mesh sizes (Figure 11) and, probably through increased use of fish driving.

Nevertheless, there are no indications of biological overexploitation in the Zambian inshore fishery in terms of reduced total yields or changed fish communities. This leads to the conclusion that the Zimbabwean inshore fishery is underutilized.

Lake Kariba, as a man-made artificial environment, is slowly but constantly changing in terms of biological species succession indicating that it has not yet reached its final maturity stage 40 years after its creation. Both sides of the lake appear to undergo the same trends in diversity development, irrespective of fishing pressure and fishing pattern. The slopes of the biomass-size distributions are equal on both sides of the lake, although with significantly different intercepts. This indicates that the relatively high fishing pressure on the Zambian side does not have any negative impact on the community structure, only that the stock sizes are reduced presumably due to fishing.

The seasonal inputs of nutrients (through the river and through inundation of shores) into the system has a significant effect on the regenerative capacity of the stocks, indicating that Lake Kariba is a naturally fluctuating environment where effort limitations has limited effects on the conservation of stock size levels. In such a system the notion of sustainable long-term yields becomes very difficult to define. Furthermore, there are indications that with increased fishing pressure the relative effect of the environmental changes become relatively more important than the fishing mortality resulting in an increased variability of the catch rates but reflecting the high degree of resilience in the ecosystem. In such a situation, the fishery must adapt to the natural fluctuations by taking advantage of the good flood years, and, by a diversified economy, be able to survive the lean periods. Management regulations such as limited entry and restricted mesh sizes as in Zimbabwe would result in a higher stability for the individual fisherman, but on the other hand in a severe underutilization of the potential yields.

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ENVIRONMENTAL VARIABILITY, EFFORT DEVELOPMENT AND THE REGENERATIVE CAPACITY OF THE FISH STOCKS IN LAKE CHILWA, MALAWI

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1. INTRODUCTION

In between recessions[1], Lake Chilwa is one of the most productive freshwater lakes in Malawi with a fishery production of between 80 and 160 kg/ha resulting in a long-term annual average catch of around 15 000 metric tonnes. The lake has an important bearing on the nutrition of Malawians, in particular within the nearby districts of Zomba, Phalombe and Machinga. The contribution of its fishery to the total fish catch of Malawi ranges between 16 percent and 43 percent, with an average of 22 percent (Figure 1A). Lake Chilwa is shallow, not exceeding 6m depths at peak levels. It has an open water area of around 678 km^2 surrounded by about 600 km^2 of *Typha* swamps, 390 km^2 of marshes and 580 km^2 of inundated floodplain. Early commentators already noted that fish yields were not constant and seemed to depend on lake-water levels (Hickling, 1942; Lowe, 1952; Furse *et al*., 1979). In good years, the annual catch can approach up to 25 000 metric tonnes, but drops below 10 000 tonnes are not uncommon. Lake Chilwa has shown large fluctuations in catch and effort since 1845, with periods where fishing stopped completely when the Lake dried up (Nicholson, 1998; McCracken, 1987). In addition to seasonal cycles of about 0.8–1.0 m, water levels fluctuated annually around 2–3 m which sometimes led to complete desiccation of the lake. For instance, during and after the 1995 recession, fishing operations were suspended on Lake Chilwa for two years (Figure 1B). Shortly after refilling and stabilization of water levels fishing resumed. Complete recessions have been recorded for about six times (Table 1). Spectral analysis of a time-series of water levels from 1949 to 1976 indicated a periodicity of very low water levels of around six years, explaining around 30 percent of the total variance in lake levels (Lancaster, 1979).

Year	High	Low	Very Low (dry)
1859	Livingstone		
1860	O'Neill, 1884		
1870	Buchanan, 1893		
1879			Buchanan, 1893
1880		O'Neill 1884	
1888	Drummond, 1902		
1900			Chipeta, 1972; Duff 1906
1913-		------------- Chipeta, 1972	--------------
1920-		------------- Garson & Campbell-Smith, 1958	
Late	Burgess (pers.comm)		
1943		Chipeta, 1972	
1949		Chipeta, 1972	
1960-		Kalk, 1979	
1967-			Kalk, 1979
1973		Kalk, 1979	
1976	Kalk, 1979 (highest)		
1994-5			Njaya, 1996

Source : Kalk, McLachlan and Howard-Williams (1979) see references there; Njaya (1996).

[1] The word recession in this text refers to periods with low to very low lake water levels.

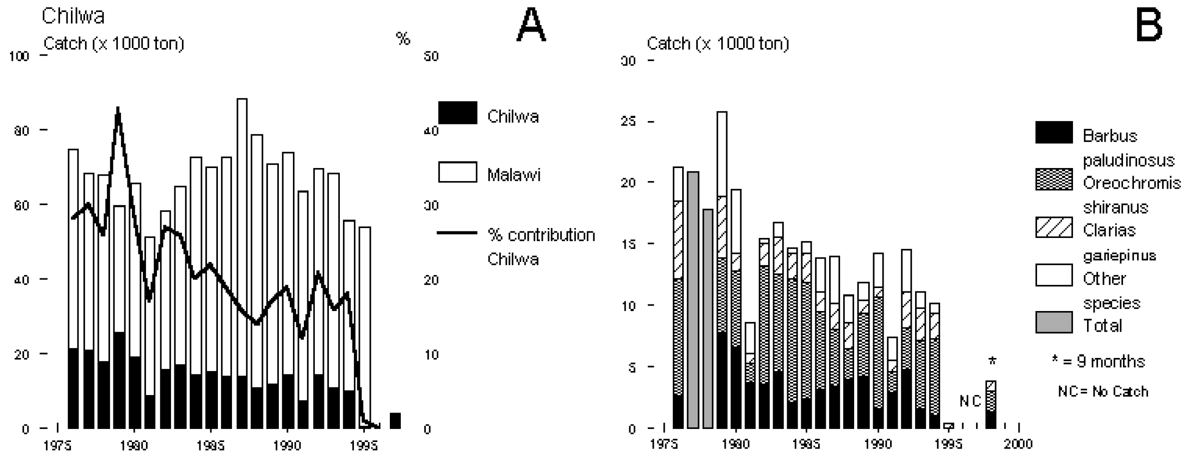

FIGURE 1 ***A***. *Total catch from Lake Chilwa as a proportion of the total catch of Malawi.* ***B***. *Total catch of Lake Chilwa broken down by species and species groups. In 1976 and 1977 no breakdown to species is available. In 1996 and 1997 the lake dried up completely. For 1998 only nine months of data are available.*

How do fish populations react to the recurrent recessions of the lake? The dominant commercial fish species are the endemic *Oreochromis shiranus chilwae* (Makumba), and the ubiquitous *Barbus paludinosus* (Matemba) and *Clarius gariepinus* (Mlamba): typical representatives of the three species groups that survive in highly dynamic systems (Leveque, 1995, 1997). Kalk (1979) gave an account of the fate of the three species in a comprehensive study on the biological effects of recessions before and after the 1968 major recession. Between 1965 and 1968, as the lake dried up, *Oreochromis* catches declined severely, *Barbus* catches initially increased but dropped in the last year and *Clarias* fishing only stopped in 1968, the year of complete drought. During a recession, remnants of the fish stocks find refuge in the mouths of larger inflowing rivers and in deeper lagoons, where water remains. These stocks appear to serve as a nucleus for a natural restocking of the lake after refilling: *Clarias* populations, as reflected in the catches, recovered in two years, *Barbus* in three years and *Oreochromius* after four to five years.

As fish stocks in Chilwa have exhibited an enormous regenerative capacity shown time and again after lake level recessions, the value of MSY estimates based on steady state assumptions of environmental stability can be questioned. The annual variation the lake ecosystem exhibits in fish production, points to a fisheries management approach primarily directed to the protection of remnant stocks during periods of recession and immediately after refilling of the lake, while populations are rebuilding. Therefore the issue of what sustainable levels of fishing effort are is relevant only to the period in between recessions. In the literature on Lake Chilwa different points of view exist on this matter. Furse (in: Kalk 1979, p.228) asserts that detrimental effects due to fishing when water-levels are high seem unlikely because: “stocks that can recover in two to three years from virtual annihilation by drought are never likely to be overfished to the point of disappearance”. He recommended maximizing catches in between recessions. On the other hand, in the same book, Kalk (1979, p.422) contends that a limit on the minimum mesh size of gillnets in normal years is needed. This “demonstrably protected the breeding stocks of *Oreochromis* species, without seriously affecting the catch of “other” species”, thus implying that fishing could have a detrimental effect on fish production levels of Lake Chilwa.

Since 1976 Malawi has a well established Catch and Effort Data Recording System (CEDRS) to monitor this fishery. Data collections as carried out in practice sometimes have been criticized severely to the extent that the information obtained was considered not useful to answer questions on the efficiency of the fishery and predict future developments through formal stock assessment methods. Attempts to determine maximum sustainable levels of production and associated effort levels have failed (Tweddle, Alimoso and Sodzabanja, 1994), and the unsatisfactory notion exists that the system could be overexploited while effort levels keep on increasing without being able to point out what would or could be sustainable levels of efficiency. Nevertheless, data are still being collected, mainly for the purpose of establishing total catch and effort levels. In this paper we will show that, despite their apparent deficiencies, this may be a severe under utilization of the information contained in the data collected that are still useful for management purposes.

Information that could be derived from the time series of catch and effort is not limited to formal stock-assessment methods. An analysis of trends and variability in catches and catch-rates, can produce empirical relationship, which can be used to predict – not necessarily when something happens but what happens if something changes. This will lead to knowledge of what can be perceived on the basis of which expectations can be formulated. The only long-term time series of catch and effort data of Lake Chilwa collected in a systematic way is through the CEDRS. Our present study aims to address, with the present Malawian catch and effort data, the possibility of detecting changes in fish stocks as a result of changes in fishing activity (effort) under the typical cycles of recession and subsequent refilling of Lake Chilwa. The emphasis is on the usage of catch and effort data as they exist in Malawi and the information contained in them to answer questions on effects of natural changes and changes in fishing effort. We will examine the potential to draw conclusions on observed trends in catch-rates – which are considered as an index of fish-stock levels – and relate these to trends in effort and water levels. In this report we will not examine the sources of error and bias that are present in the data collected through the existing CEDRS.[1] For this we refer to Weyl *et al.* (1999), who makes a number of recommendations for improving data collection and handling.

2. OBJECTIVES OF THE STUDY AND RESEARCH STRATEGY

The possibility to detect time trends in fish stocks through catch-rate data and to evaluate the effectiveness of fisheries management on that basis depends both on the strength of the time trend and the variance around it (Peterman, 1990; Pet-Soede *et al*. 1999; Densen, 2001; Zwieten, Njaya and Weil, 2003). Ultimately, the capacity to detect a trend is determined by the statistical power of the information examined, which in turn depends entirely on the variance of the data, given the number of observations and statistical decision levels. Aggregation of independent observations belonging to the same distribution lowers the number of observations but at the same time reduces the variation around a possible trend as well. The time series of estimated monthly catch-rates from CEDRS surveys of Chilwa by major stratum represent the lowest level

[1] Problems outlined by Alimoso (1988), Stamatopoulos (1990) and Weyl *et al.* (1999) are:

a. The CEDRS does not take into account gear distribution and the way the gears are operated. Consequently, significant fishing activities may take place without being recorded: relatively rare gears which make large catches e.g. Matemba seines in Lake Chilwa, may result in severe under or overestimation of daily catches.

b. The use of raising factors in view of actual fishing operations: e.g. some methods use two boats and since the raising factor is based on the ratio of the number of fishing craft in the minor stratum to that of the sampled fishing beach during the sampling exercise catches are overestimated.

c. CAS data forms are complex, leading to recording errors. The manual transfers of data from form to form and the manual calculations, which follow, have been shown to be responsible for significant errors in the accepted statistics.

of data aggregation for this lake that in Malawi is used in reports on the status of the fishery. The capacity of the Malawian fisheries authorities to perceive trends and relate these to changes in the fishery is given with these time series of catch and effort data (Zwieten *et al.*, 2003).

2.1 Structure of the paper

After a description of data collected and methods of analysis we will:

(1) Examine trends and variability (between years, seasonal) in the catch-rates of Lake Chilwa;
(2) Examine changes in water levels and relate these to changes in catch-rates;
(3) Examine trends in fishing effort and relate them to trends in catch-rates taking into account the effect on catch-rates due to changes in water levels;

Data used to examine trends and variability are monthly average catch-rates by species (or species groups) and gear, fishing effort by gear and daily water levels from 1976 to 1998. The analysis will lead to conclusions on the possibility to detect trends and relate these to changes – natural or fishing effort – observed. Thereafter we will shortly address the present fisheries management set up of Lake Chilwa, and discuss whether the present CEDRS and the type of conclusions that can be drawn from it will address the information needs. We will

(4) Discuss present management strategies before, during and after recessions;
(5) Discuss the required information in relation to management of catch and fishing effort; and finally
(6) Ascertain whether the present CEDRS and monitoring of water levels fulfils the requirements related to the management of the fisheries resources in the lake

2.2 Research strategy

A short explanation on the research strategy contained in points 1–3 is needed:

(1) Examine trends and variability in the catch-rates and fishing effort of Lake Chilwa;
Catch-rate – i.e. the catch per time unit and per unit of fishing effort (C/f) – is an important indicator both for the average income of fisherman and the abundance of stocks. As an indicator of abundance a constant efficiency in the fishing methods over time and constant average fish behavior is assumed. Though the assumption of constant efficiency is problematic, the idea is that if a number of different fishing methods employed in more or less the same way over the period examined give similar trend information, the signal is clear. Trend here is loosely understood as a long-term change in the mean levels of the catch-rates (Chatfield, 1996) and the basic question is whether the catch-rate has gone up, remained stable or has gone down over the period over which there are data. For that reason it is sufficient to define trend as a linear regression over time. Obviously it is the downward trend that is most interesting, as this is the main management concern: how do catch-rates develop with increasing fishing effort given the natural variation of the lake system.

The next question is whether such a trend can be perceived within a time window that is useful in a management context. In other words: how variable are the catch-rates around the trend, and in what way does this variation obscure the general trend so that it may not be detectable within time windows of decision making and evaluation given a management framework.

Variability can be attributed to predictable variation, e.g. seasonality, and temporally unpredictable variation, which we will call basic uncertainty (Zwieten *et al*, 2002). Quantifying these attributions will give a first indication of the possibility to perceive a trend.

The development of catch-rates under increasing fishing effort in a system like Chilwa is unlikely to be linear, and fluctuations as a result of strong environmental signals may take place. These fluctuations will be seen as reversals in the direction of long-term trends, and will show as non-random residuals around a linear trend that we will call long-term persistence. The effect of "favorable" or "unfavorable" environmental conditions caused by variation in average water levels could induce persistence in stock biomass of longer lived species. A first approach to examine whether such reversals in trends take place, and obtain an indication how a linear description of a trend diverts from more complex descriptions, is by fitting more complex regression models to the data. We follow the method as outlined by Fiorentini, Caddy and Leiva (1997). They examined a large number of time series catches of different species in the Mediterranean Sea by fitting a simple polynomial regression model to the data. Based on the shape of the resulting fit they decided whether a trend in catches could be described as increasing, stable or declining – including dome shaped fits – with varying speed. Periods of natural increase or decrease in abundance or availability of the resource, followed by a reversal will result in a dome shaped trend, which could be a result either from over-fishing or a change in environment. The peak or trough gives an indication of the period in which a reversal of catch-rates took place, and can be used as a starting point for further analysis of possible events leading to such reversals. Thus, the extra information obtained compared to a linear description of trend is an indication at what stage of development a stock is – increasing, decreasing, collapsed or recovering –, the speed with which this takes place, and, most importantly, the timing of possible reversals.

The relationship of trend and variability can be understood as a signal-to-noise ratio. An analysis of this ratio gives an indication of the time frame needed for trends to be detected, which is in fact an analysis of statistical power. To answer the question on trend perception in statistical terms, we examine the change in the slope of a linear trend over time in relation to the variation around the slope. We can investigate how this *trend-to-noise* ratio changes over time by stepwise increasing the number of data in the analysis. We take two approaches:

(1) Every month more data are added, and this will affect the *trend-to-noise* ratio. We are interested in changes in strength (slope) of trends and timing of reversals in the direction of a trend: when is a negative/positive trend first seen in a long-term perspective?
(2) Questions of effectiveness of regulative management measures often need to be answered in a short time frame. Whether or not a regulation, or measure, intended to change the usage of a natural resource is working, should usually be answered within a framework of around 3–5 years. By investigating trend-to-noise ratio's over five year steps, we will obtain a feeling for the strength of short-term trends and the timeframe over which reversals of trends can be seen.

Finally, we will examine the effect of multi-annual environmental variation, on the possibility to perceive trends caused by the fishery, or, in other words: which driver, fishing or environment has the strongest effect on the variability observed.

(2) Examine changes in water levels and relate these to changes in catch-rates
Sorting out empirically correlations of time series of processes that have only one realization, such as the processes underlying the relation between catch-rates, fishing and water level in

lake Chilwa, is fraught with difficulties (Bakun, 1996). Time series of continuous processes, be it catch-rates or water levels, contain considerable auto-correlation or persistence. Persistence is simply the correlation of the present observation of a parameter with previous observations in time, i.e. yesterday's water level or fish-biomass will to a large extent determine today's level or biomass. This has as consequence that when two auto-correlated time series are cross-correlated, significant but uninformative correlations will always be found. To answer the question whether a fish population, as indexed by catch-rates, collapses due to fishing effort or due to natural variation – where water level is used as a proxy environmental indicator – is typically a situation where auto-correlated time series are involved. One way to address this problem is to correlate the time-series of water level and catch-rates after removing long term and seasonal trends. This will remove most of the auto-correlation, while both series will then be reduced to series revealing possible "anomalies" – i.e. variations deviating from trend and seasonality – that can be subsequently correlated with each other. This could result in statistically significant, and possibly meaningful, correlations of fluctuations in water level explaining fluctuations in catch-rates. This analysis leads to information on:

- The amount of variation in the annual catch-rate series that can be explained by "anomalous" (i.e. non-average) changes in water level, and the possibility to perceive such a signal in the catch-rate data.
- The lag in time (years) over which changes in water level are reflected in changes in catch-rates of fish and hence the regenerative speed of fish production.

Water level is considered an environmental driver, which through a complex of natural processes regulates fish stocks (Junk, 1989; Karenge and Kolding, 1995; Kolding, 1994; Leveque and Quensiere, 1988; Furse *et al*., 1979). This is of course obvious for the years of complete recession - where there is no water there is no fish. But the question is whether changes in water levels have a predictive value for the periods when the lake is filled, and how well observed fluctuations in catch-rates can be explained by such changes.

(3) Examine trends in fishing effort and relate them to trends in catch-rates taking into account the effect of changes in water levels

Further problems arise when attempting to assess multiple causes, in this case distinguishing between the simultaneous effect on catch-rates both of changes in fishing effort and of changes in water levels. In a multiple-gear fishery it is generally not possible to give a single definition of fishing effort, and it is difficult to standardize the fishing effort of different gears. Furthermore the different gears used often target the same stocks of species either in the same or at different stages of their life cycles, leading to so-called technical-interactions, i.e. the outcome of one fishery will affect the outcome of the other. Both problems in defining fishing effort and interactions are important reasons why standard stock-assessments could fail in these situations.

The problem of technical interactions adds another level of difficulty in the statistical approach to explain the relative effects of changing environment and fishing effort. However, if it appears that effort development is mainly due to simple addition of numbers of gears and people – more of the same – then selectivity and technical interactions can be assumed "constant". This means that a multiple regression of fishing effort by gear type and water levels on catch-rates by gear – using the time lags found in the correlations of the de-trended time series of water levels versus catch-rates – could make sense. But selectivity and technical interactions cannot not be considered "constant" if shifts in fishing patterns have taken place – due to changes in technology or changes in spatial allocation of effort – as a reaction of fishermen to changes in stocks. A multiple regression of fishing effort by gear type on catch-rates by gear will be impossible, or at least difficult, to interpret. We will see that the condition of constant selectivity and technical interaction is generally met in the case of Chilwa (but not in Malombe: see Zwieten *et al*., 2003). Therefore, before analysing the combined effect of fishing effort and water levels an analysis of changes in fishing effort is needed:

a. Effort defined as the number of active fisherman and boats disregarding types of fisheries will give an indication of the demographic changes in fishing effort.
b. Effort analysed by gear will indicate possible shifts in fishing patterns. Such shifts can then be examined on changes in available biomass (indicated by changing catch-rates).

Another difficulty in assessing multiple causes is when trends in the explanatory variables (i.e. effort and water level) are confounded. Confounding will take place if no reversals in trends have taken place in both of two explanatory variables. As an example we discuss three possible situations of trends in the annual data:

a. <u>Both water levels and effort levels are increasing.</u>
In this case it cannot be decided directly if a possible downward trend in catch-rates can be attributed to either variable. An analysis where both variables follow the same trend stands a high possibility that either one or both explanatory variables will not be significant. However, a correlation analysis of deviations obtained by de-trending water levels and de-trending catch-rates may indicate a positive correlation between water level and catch-rates, possibly with a certain time lag. From this it can be inferred that fluctuations ("rates of change") in water levels have a positive effect on changes in catch-rates ("growth rates"). In principle the same could be done with de-trended effort levels, though this requires a high reliability in total effort data. If this relation is negative, it could be inferred that the decline in catch-rates could be attributed to the increase in effort, but delayed by increasing water levels.
b. <u>Water levels are decreasing while fishing effort is increasing and catch-rates are decreasing</u>. In this case the time series are entirely confounded and it will be difficult to distinguish cause and effect. Correlation of de-trended series will give an indication of effects but again no decision on size of each effect (proportion of total variation explained) can be reached.
c. <u>Water levels are fluctuating while fishing effort is increasing</u>
Here downward trend in catch-rates will be attributed to fishing effort, and it can be decided how much of the variation around the trend can be attributed to a changing environment.

From this discussion it will be clear that no decision on effects of effort and environment can be reached if there is no contrast in at least one of these two parameters over time, while the other parameter remains either stable or is continuously changing in the same direction. For example, if fishing effort is continuously increasing only a significant increase and subsequent decrease in water levels or vice-versa can provide for the necessary contrast and the effects of both parameters for changes in stocks can be determined.

3. METHODOLOGY

3.1 Data collection

The statistical Catch and Effort Data Recording System (CEDRS) of the Lake Chilwa fisheries has been developed according to the methods described by Bazigos (1972) and has been implemented by Walker (1974). It is based on the method of stratified random sampling. An estimate of total catches (C) is reached through sampling the catch-rates by boat stratified by gear type. The catch-rates (C/f) are raised to total catch by an estimate of total effort by gear (f) obtained through a Frame Survey. Lake Chilwa is stratified into two major strata coinciding with major ecological areas, which are subdivided into five minor strata. Each minor stratum has several beaches on which fish is landed. After the annual frame survey, a number of beaches are randomly selected to record landed catch during so-called Catch Assessment Surveys (CAS). Field-staff spend each month four consecutive days on a beach collecting data according to their monthly CAS itinerary. In total 16 days are spent for fish recording in every month.

During the first day the number and types of boats, fishermen, and type and sizes of fishing gears are counted. In the following three days, all boats leaving for fishing are recorded. Boats landing on a particular beach are recorded and randomly sampled to obtain the fresh weight of the catch by species. The name of the fisherman, amount of fish caught (in kilos), number, size and usage of fishing gear, estimated beach prices and destination of the fish are recorded on the same form. Units of effort are recorded for all seines as number of pulls or hauls; for gillnets it is the number of gillnets of 91 m (100 yards) set. For fish traps the unit of effort is number set and for long lines 100 hooks.

Our analysis of the Lake Chilwa catch and effort data was carried out on four dominant gears although the CEDRS includes in total eight gears. The four gears are fish traps, gillnets, longlines and *Matemba* seine. A *Matemba* seine is used either as a beach-seine or is set in shallow open lake areas. It has a length of around 50-300 m, no restriction on mesh sizes, and is operated by five to six persons. Each of these gears represents more than 20 percent of the data and all four in total approximately 92 percent of the data set. Recently, a new important fishery with hooks was included in the CEDRS called *nchomanga*. Weyl *et al.* (1999) described this as a passive gear used in densely vegetated areas where it is difficult to find enough space for a long line. A large hook (size 1-3/0) is attached to a length of line onto which a float is attached. This float has enough buoyancy so as not to be submerged by the hooked fish. Alternatively the line is attached to a short length of bamboo which is wedged into reeds or mud to anchor the hook and line. *Nchomanga* are normally set overnight and baited with small dead fish. Since these data were available for only two years, they were excluded from this study.

Monthly catch per unit effort (CPUE) is estimated as follows (Alimoso Seisay and Zalinge, 1990, FAO 1993): at the end of each survey, all sampled catch-rates are added to obtain a total sampled catch by minor stratum. Similarly, all sampled effort data by gear are added to get a total monthly sampled effort (f) by gear by minor stratum. An estimate of the monthly CPUE by gear is then obtained by through C/f.

The ratio GA, which is termed “gear activity indicator”, is estimated by dividing the total number of gears that were found to be fishing at the time of sampling by the total number known to exist at the landing sites. Total monthly fishing effort, f in the major stratum is estimated by:

$$f = D * GA * M \quad (1)$$

where M is the total number of fishing gear units in the major stratum that were counted during a frame survey and D is the number of fishing days in a month The estimated total monthly catch, Y, for a particular gear in the major stratum is:

$$Y = CPUE \times f \quad (2)$$

Monthly catch and effort data from the Catch Assessment Survey (CAS) for the traditional fisheries sector were obtained from Monkey Bay Fisheries Research Unit and Kachulu Fisheries Office in Zomba in April 1999. The frame survey data were obtained from the Mangochi Fisheries Office and Monkey Bay Research Unit. Water level data, measured daily at the gauge situated near Kachulu, were obtained through the Water Department in Lilongwe.

3.2 Analysis of variance of catch-rates: Differences between years and between months

As processes affecting fish stocks can generally be said to have a multiplicative character, all our analysis are done on ^{10}log-transformed catch-rates: linear trends are thus descriptions of the speed with which these multiplicative processes take place. All analyses were done on mean monthly catch-rate data (CPUE) aggregated over the whole lake. Total CPUE and CPUE by species (group) of four gears fish traps, gillnets, longlines, *Matemba* seine over a period from 1976 to 1998 were subjected to an Analysis of Variance (ANOVA) with year and month as class variables. This analysis leads to an assessment of the total amount of variation that can be explained by differences between years and between months. The statistical model describing this analysis is:

$$G(m)_{ijh} = \mu_{ijh} + year_i + month_j + \varepsilon ij_h \quad (3)$$

Where:

$G(m)_{ijh}$	=	timeseries of ^{10}log transformed mean monthly catch-rates
μ	=	overall mean
Year	=	effect of i^{th} year (1976 - 1998)
Month	=	effect of j^{th} month (1 - 12)
ε_{ijh}	=	residual error

3.3 Trend analysis in catch-rates

Trends were analysed with the following polynomial regression model.

$$G(m) = a + b*year + c*year*year + \varepsilon_t \quad (4)$$

Where:

G(m)	=	time series of ^{10}log transformed mean monthly catch-rates
a	=	intercept
year	=	represents the linear regression term
year*year	=	represents the quadratic term
ε_t	=	residual error

To examine whether catch-rates went up, down or remained the same the quadratic part (year*year) of the model was removed and the linear regression was fitted to the monthly data.

Only significant parts of the model were retained, which resulted in four possible models:

1) no regression (when both linear and quadratic terms were non-significant)
2) a **linear** regression model if only the linear term was significant.
3) a **quadratic** regression model if only the quadratic term was significant
4) a **polynomial** regression model if both terms were significant. In this case it was also evaluated how much the quadratic and linear terms each contributed to the explanation of the total variance.

If this amount was very small for the quadratic term, a linear model was chosen
The averages (μ), standard deviations (s) are back-transformed from log-scale to obtain (geometric) means and a factor F around the (geometric) mean. This is done and interpreted as follows:

- 10^{μ} = 10 to the power of the mean of the log transformed data = geometric mean (GM)
- 10^{2*s} = 10 to the power 2 x standard deviation This factor (=F) means that that 1 in 20 observations fall outside the range given by F*GM and GM/F.

3.4 Seasonality in catch-rates

Differences between months detected with an Analysis of Variance in (1) give an indication of seasonality. A more formal deterministic description of seasonality could then be made by fitting an appropriate model to the data, and examine the amount of variation explained to judge the strength of the seasonal signal (Zwieten *et al.*, 2002; Densen, 2001). However, as will be seen later, little seasonal effects could be detected in the monthly catch-rate data and this line of inquiry was not continued. As the observed variation between months in the data therefore is not predictable it becomes part of the basic uncertainty in the data.

3.5 Basic uncertainty in catch-rates

The total amount of variation explained through the year effect in the statistical model (3) expresses differences between years. This includes both short-term annual variation and trends and long-term trends (long-term = over the whole series examined). Annual variation, including short-term trends, and seasonality obscure the long-term trend. The total amount of residual variation after removing a long-term trend and seasonality can be deemed basic uncertainty**.** This part of the total variance that cannot be explained by analysis of trends and seasonality consists of process error (i.e. natural variation), measurement error and observation error. If no variability can be explained by trend and seasonality then the total variation is basic uncertainty.

3.6 Trend-to-noise: power analysis

The slope parameter b in the linear regression (2) divided by the standard deviation(s) of the residuals of the linear regression, is the trend-to-noise ratio. How the trend-to-noise ratio affects the number of years (n) over which a trend may be perceived with a power (1-?), given probabilities for the statistical decision levels of a type I error ? and a type II error ? can be derived as follows (Zwieten *et al.*, 2002; Densen, 2001).

An estimate of the variance of the slope estimate b is:

$$s_b^2 = \frac{s^2}{\Sigma(t-\bar{t})^2} = \frac{s^2}{s_t^2} * \frac{1}{n} \qquad (5)$$

where s^2 is an estimate of the variance in the residuals around the regression line, t is the independent variable time and n is the number of observations. If catch-rate estimates are taken at regular intervals in time (or space), s_t^2 ca n be rewritten as (Gerodette, 1987):

$$s_t^2 = \frac{(n-1)(n+1)}{12} \qquad (6)$$

The power of a test is the probability that a decision rule will lead to the conclusion that an alternative hypothesis H_a : $\beta_0 \neq \varphi$ is true, i.e. that a trend or deviation from a trend will be detected in the cases of $\varphi=0$ or some specified value. The test statistic for b is $t^* = (b-\varphi)/s_b$. This probability (P) is given by:

$$P\{|t^*| > t_{(1-\alpha/2;n-2)} | \delta\} \qquad (7)$$

where δ is a measure of non-centrality, or how far the true value β_0 of b is from H_0: $\beta_0 = \varphi$:

$$\delta = \frac{|\beta - \varphi|}{s_b} \qquad (8)$$

To reduce the statistical errors to the specified levels of ? and ? = 0.05 or 0.1 as used here, with the zero hypothesis of no trend (H_0 : $\beta_0 = \varphi = 0$) the following inequality should hold:

$$t^* = \left|\frac{b}{s_b}\right| \geq t_{\alpha/2} + t_\beta \qquad (9)$$

for a two tailed test. Substituting (5) and (6) into (9) gives:

$$\left|\frac{b}{s}\right| \sqrt{\frac{n(n-1)(n+1)}{12}} \geq (t_{\alpha/2} + t_\beta) \qquad (10)$$

In the presence of auto-correlation the variance the residuals is underestimated by a factor $1/(1-r^2)$, where r is an estimate of the auto-correlation coefficient ρ (Neter *et al.*, 1985; Gerodette, 1987). We studied the effect of serial correlation at lag 1 on trend perception by including this factor in equation 7, leading to:

$$\left|\frac{b}{s}\right| \sqrt{\frac{n(n-1)(n+1)(1-r^2)}{12}} \geq (t_{\alpha/2} + t_\beta) \qquad (11)$$

where:

b	=	trend parameter (slope) in the linear regression
n	=	the number of observations
$t_{\alpha/2}$, t_{β}	=	the test statistic or decision rule of a *t*-distribution, where α is the specified probability of making a type I error (a trend is rejected where in fact there is a trend) and β the specified probability of making a type II error (a trend is accepted where in fact there is none). In our case $\alpha=\beta=0.1$ or both errors are set at the 10 percent level.
s	=	the standard deviation of the residuals

This formula is solved for n (the number of months of data collected) with given trend and variance. From the formula it can be inferred that the variance in a series exhibiting auto-correlation will be reduced, which could result in a conclusion of a trend where in fact there is no trend.

3.7 Analysis of water levels related to catch-rates

^{10}Log-transformed annual average catch-rate series were de-trended by subtracting the linear trend from the series through linear regression. There was no need to de-trend the water level series as there was no long-term trend present in the time series and the seasonal signal in monthly variation was low. The resulting residuals of the catch-rates were subsequently cross-correlated with annual mean, minimum and maximum water levels. Cross-correlation is done by shifting the two series with steps of one year against each other and calculate correlations at each successive lag. As the two series were 20 years with a maximum of 18 data up to five lags could be investigated. This, however, is sufficient as the regenerative response (recruitment processes) of the species under investigation to environmental changes is fast – for *Barbus* probably even within a year (see earlier and Kalk, McLachlan and Howard-Williams, 1979). Subsequently, the lags with highest correlation coefficients were investigated through regression analysis. The amount of variability explained by the regression analysis is an indication of the magnitude of the effect of changing water level that can be seen in the time series. A similar analysis was done on monthly catch-rates correlated with monthly water levels, both after de-trending. This analysis did not yield more information than the previous analysis and is therefore not presented.

3.8 Multiple regression of water levels and fishing effort on catch-rates

Multiple regressions were performed with ^{10}log-transformend total catch-rates by gear, or catch-rates by species(group) by gear, as dependent variable. Fishing effort as total number of gears and annual mean, maximum or minimum water levels – the latter with or without a lag phase from the cross-correlation analysis – were the explanatory variables. Both water levels and fishing effort each are made orthogonal by subtracting the mean from the original series. In the previous analysis it was established whether there was a lag-phase between de-trended annual mean water levels and annual mean catch-rates, and which of minimum, maximum or mean water levels was more informative. Missing values for numbers of gear, as taken from frame surveys, were interpolated by linear regression. Lag(1) means that previous years water level is compared with this years catch-rate.

The multiple regressions were always of the form:

$$G(m)_t = \mu + \text{effort}_t + \text{water level}_{t\text{-lag}(x)} + \text{effort}_t{*}\text{water level}_{t\text{-lag}(x)} + \varepsilon_t \quad (12)$$

Where:

$G(m)_t$	=	time series of annual mean $^{10}\log$(CPUE) by gear (1979-1998)
μ	=	overal mean
effort_t	=	total number of gear
$\text{water level}_{t\text{-lag}(x)}$	=	water level at lag(x) where x = 0 – 5
$\text{effort}_t{*}\text{water levelt}_{t\text{-lag}(x)}$	=	interaction of effort and water level at lag(x)
ε_t	=	residual error

In all cases non-significant explanatory variables were removed from the model. The interaction effect is interpreted as reflecting possible changes in catch-rate as a result of changes in efficiency or of usage of gears in relation to water levels. Such changes could be a result of spatial effects of accessibility of species to gears and the effectiveness of gears (e.g. concentration of fish with receding water levels). All ANOVA and regressions are carried out with the General Linear Models procedure (SAS Institute Inc., 1993). Cross-correlations are carried out with the ARIMA procedure (SAS Institute Inc., 1989).

3.9 Analysis of effort data

All effort data were compiled by major strata, and graphically displayed with regression lines to display trends. Total effort data of Lake Chilwa are considered unreliable, in particular concerning fishing operations conducted by migrant fishermen in the swamp area of lake who live in temporary shelters (*Zimbowera*). These fishermen are not recorded. Fish landed on beaches from these operations is mostly in dried form ready for marketing. The swamp areas are difficult to access. However, as all annual frame surveys are conducted in a similar fashion, the effort data can be considered indicative for relative changes taking place.

4. RESULTS

4.1 Analysis of catch-rates

The time series analysed included one low water recession period with no fishery from 1996–1997. This recession occurred 33 years after the previous major recession in 1968, which was extensively documented in Kalk, McLachlan and Howard-Williams (1979). Another minor recession occurred in 1973–74. No catch-rate data are available for the years 1976 and 1977. The results of the analysis of variance and subsequent trend analysis are summarized in Table 2 and Figures 2 to 6.

4.2 Variability in catch-rates is extreme and possibly administratively induced

The variability in catch-rates, expressed as coefficient-of-variation (CV = standard deviation/mean) of the original (non-transformed) data, was extremely high. For instance catch-rates in gillnets, the series with lowest variance (variance = $^{10}\log(s^2)$ = 0.14), the coefficient of variation can be estimated through CV= $\sqrt{(10^{2.303*variance}-1)}$ at 1.04. For other fisheries, daily catch variability (i.e. basic uncertainty as variability with trend and seasonality removed) expressed by CV ranges from 0.1 to 0.5 for trawlers to >1 in sport fisheries and some marine light fisheries. Therefore the aggregated monthly CV in the Chilwa data was about as high as the daily variability that individual sport fishermen experience (Densen, 2001). Individual gillnet fishermen experience a much lower day to day variability in catch-rates, with CV's of around 0.5 to 0.8 (Densen, 2001). The extreme variability in the Chilwa data was even more surprising taking into consideration that the catch-rate series represented aggregations over strata, fishermen and month: the effect of aggregation is that variability is reduced. A dis-aggregation over month and fishermen to daily catch-rates would result in a coefficient-of-variation that is outside the experience even of fisheries exhibiting high daily variability, for example whale fishing (Densen, 2001), sport fishing on pikeperch (CV =1.2, van Densen, 2001), and the Bagan light fishery on small marine pelagics in Ambon, Indonesia (CV =2.4, Oostenbrugge, 2001). The variability in the Chilwa data is definitely outside the range of any gillnet or seine net fishery known from inland fisheries.

Apart from possible effects of trend and seasonality, discussed later, the extreme variability probably is caused by the method of raising the daily catch and effort data to arrive at the estimates of monthly catch and catch-rate. Conversion factors are used to arrive at estimated total catches per standard gear by stratum. After that the effort and estimated catch figures collected during the month are each added to obtain a total catch and total effort. The monthly catch-rate (CPUE) used in our analysis is calculated from these data. This summation procedure induces variability that is not present in the original data collected at the beach. Apart from that, the procedure makes it impossible to detect outliers and typing errors. In other words, much of the variability encountered in the Chilwa time series – and by extension the time series from other fisheries as the same system is used throughout Malawi – is "administratively induced error". However, as the procedure has been maintained over the years, and there is no reason to believe that the administratively induced error changes over time (i.e. it can be considered random), it is still possible to proceed with our intended analyses of trends and their alleged causes. The enormous variability in the data has important consequences for the detection of trends and the analysis of causation: trends and fluctuations will be lost in "noise", most of which unfortunately is administratively induced.

4.3 All gears except traps are selective

The variation in total catch-rates was lowest in gillnets with a factor[1] (F) around the geometric mean of F= 5.6 followed by traps (F = 9.4), seines (F = 16.9) and longlines (F = 20.3) (Table 2, Figure 2). On a species level lowest variation is seen in *Oreochromis shiranus* (F = 7.6) and *Clarias gariepinus* (F=6.5) in gillnet catch-rates. For most other species-and gear combinations the variation is around a factor 20 or higher. Aggregation of catch over species thus leads to a reduction in variation. However, only in traps does the aggregation of various

1 A factor F=5.6 means that 95 percent of the data fall within the range of 5.6 times the (geometric) mean and the mean divided by 5.6.

species to total catches lead to a significant reduction in variation. This indicates that it is the only truly “multispecies” gear in its target: all species are caught in more or less the same amounts over the same period of time. The main target for gillnets is *O. shiranus*, for a seine is *Barbus paludinosus* and to a lesser extent *O. shiranus*, while longlines target *C. gariepinus*. Other non-target species only reduce the variance in total catches slightly. In the case of longlines this reduction of F is just three percent.

4.4 Annual variability is high

Annual variability in catch-rates was high, and significant inter-annual differences explained much of the total variance (Table 2, Figures 2 and 3). As a result the unexplained factor around the mean was lowered by 50 – 75 percent in 14 out of 20 cases. In the remaining six cases, which were all non-target species for the various gears, no variation at all could be explained by temporal analysis, and catch-rate data of these species-gear combinations on the aggregated level of the lake by month indicated pure chance.

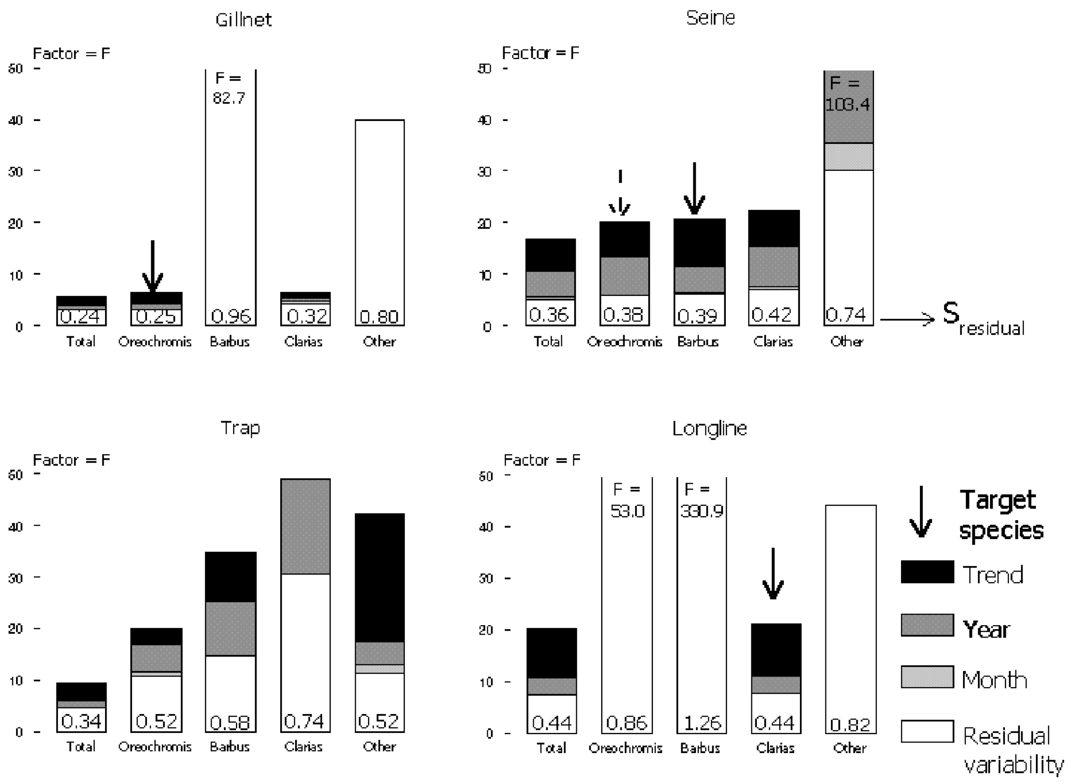

FIGURE 2. *The amount of variability expressed as factor around the geometric mean explained by trends (as linear regression), annual, monthly and residual variation. The residual variation is also expressed as standard deviation (s) at the bottom of each column. The arrow indicates the target species of a gear. Basic uncertainty (see text) is the variability remaining when trend and seasonality are subtracted from the total variation.*

TABLE 2. *Results of Analysis of Variance and regression analysis on monthly catch-rates of Lake Chilwa by gear and species groups as contained in the CEDRS of Malawi (see text for further explanation)*

Total catches	*Fishtrap*						*Gillnets*					
	Model	**df**	**MSE**	**Factor**	**r2**	**p**	**Model**	**Df**	**MSE**	**Factor**	**r2**	**P**
Total variance		207	0.238	9.4				212	0.139	5.6		
After Year	*Year*	189	0.117	4.8	0.55	***	*Year*	194	0.060	3.1	0.61	***
Trend	*Linear*	206	0.164	6.2	0.31	***	*Linear*	211	0.090	3.9	0.36	***
	Polynomial	205	0.160	6.3	0.33	***	*Polynomial*	210	0.086	3.9	0.39	***
	(quadratic term takes 5.8% of total explained variance)						(quadratic term takes 7.5% of total explainedvariance)					
	Longline						***Matemba seine***					
Total variance		210	0.427	20.3				207	0.377	16.9		
After Year	*Year*	192	0.193	7.6	0.59	***	*Year*	189	0.141	5.6	0.66	***
After Month	-	-	-	-	-	**ns**	*Year + Month*	178	0.127	5.2	0.71	***
Trend	*Linear*	209	0.279	10.9	0.35	***	*Linear*	206	0.274	10.6	0.27	***
	Polynomial	208	0.271	11.0	0.37	***	*Polynomial*	205	0.224	8.8	0.41	***
	(quadratic term explains 5.8% of total explained variance)						(quadratic term takes 33% of total explainedvariance)					
Oreochromis	***Fishtrap***						***Gillnets***					
Total variance		194	0.410	19.1				208	0.193	7.6		
After Year	*Year*	177	0.287	11.8	0.36	***	*Year*	190	0.063	3.2	0.70	***
After Month	*Year + Month*	166	0.269	10.9	0.43	*	-	-	-	-	-	**Ns**
Trend	*Linear*	193	0.377	16.0	0.08	***	*Linear*	207	0.136	5.3	0.30	***
	Polynomial	192	0.323	13.7	0.22	***	*Polynomial*	206	0.121	5.0	0.34	***
	(quadratic term explains 62% of total explained variance)						(quadratic term explains 42% of total explained variance)					
	Longline						***Matemba seine***					
Total variance		42	0.743	53.0				204	0.423	20.0		
After Year	-	-	-	-	-	**ns**	*Year*	186	0.147	5.9	0.68	***
Trend	-	-	-	-	-	**ns**	*Linear*	203	0.329	13.3	0.23	***
							Polynomial	202	0.261	10.5	0.39	***
							(quadratic term explains 42% of total explained variance)					
Barbus	***Fishtrap***						***Gillnets***					
Total variance		204	0.594	34.8				59	0.919	82.7		
After Year	*Year*	187	0.338	14.6	0.48	***	-	-	-	-	-	**Ns**
Trend	*Linear*	203	0.513	25.4	0.14	***	-	-	-	-	-	**Ns**
	Longline						***Matemba seine***					
Total variance		19	1.587	330.9				204	0.432	20.6		
After Year	-	-	-	-	-	**ns**	*Year*	186	0.165	6.5	0.65	***
After Month	-	-	-	-	-	**ns**		175	0.155	6.1	0.69	*
Trend	-	-	-	-	-	**ns**	*Linear*	203	0.292	11.5	0.33	***
							Polynomial	202	0.260	10.5	0.40	***
							(quadratic term explains 19% of total explained variance)					
Clarias	***Fishtrap***						***Gillnets***					
Total variance		181	0.714	49.0				212	0.164	6.5		
After Year	*Year*	163	0.551	30.5	0.31	***	*Year*	194	0.116	4.8	0.36	***
After Month	-	-	-	-	-	**ns**	*Year + Month*	183	0.102	4.3	0.46	***
Trend	-	-	-	-	-	**ns**	*Linear*	211	0.140	5.4	0.15	***
	Longline						***Matemba seine***					
Total variance		210	0.437	21.0				207	0.454	22.2		
After Year	*Year*	192	0.200	7.8	0.58	***	*Year*	189	0.193	7.6	0.61	***
After Month	-	-	-	-	-	**ns**	*Year + Month*	178	0.175	6.9	0.67	**
Trend	*Linear*	209	0.282	11.0	0.36	***	*Linear*	206	0.360	15.3	0.20	***
	Polynomial	208	0.277	11.3	0.53	***	*Polynomial*	205	0.350	15.2	0.24	***
	(quadratic term explains 4% of total explained variance)						(quadratic term explains 16% of total explained variance)					
Other spp.	***Fishtrap***						***Gillnets***					
Total variance		193	0.662	42.4				36	0.640	39.8		
After Year	*Year*	176	0.312	13.1	0.57	***	-	-	-	-	-	**Ns**
After Month	*Year + Month*	165	0.280	11.4	0.64	**	-	-	-	-	-	**Ns**
Trend	*Linear*	192	0.400	17.4	0.40	***	-	-	-	-	-	**Ns**
	Longline						***Matemba seine***					
Total variance		28	0.676	44.1				141	1.015	103.4		
After Year	-	-	-	-	-	**ns**	*Year*	124	0.600	35.4	0.48	***
After Month	-	-	-	-	-	**ns**	*Year + Month*	113	0.548	30.2	0.57	*
Trend	-	-	-	-	-	**ns**	*Linear*	-	-	-	-	**Ns**
							Quadratic	140	0.790	59.9	0.23	***

Significance level is indicated by asterixes: * p<=0.05, ** p<=0.01, ***p<=0.001

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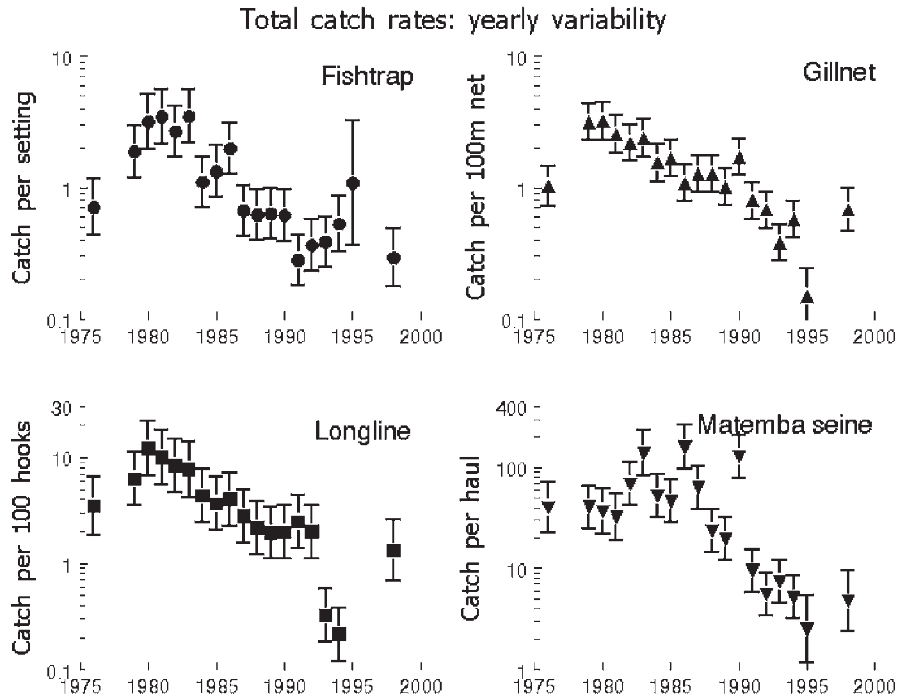

FIGURE 3. *Annual variation in total catch-rates by gear. Vertical bars represent 95 percent confidence limits. Note* ^{10}*log scale on vertical axes.*

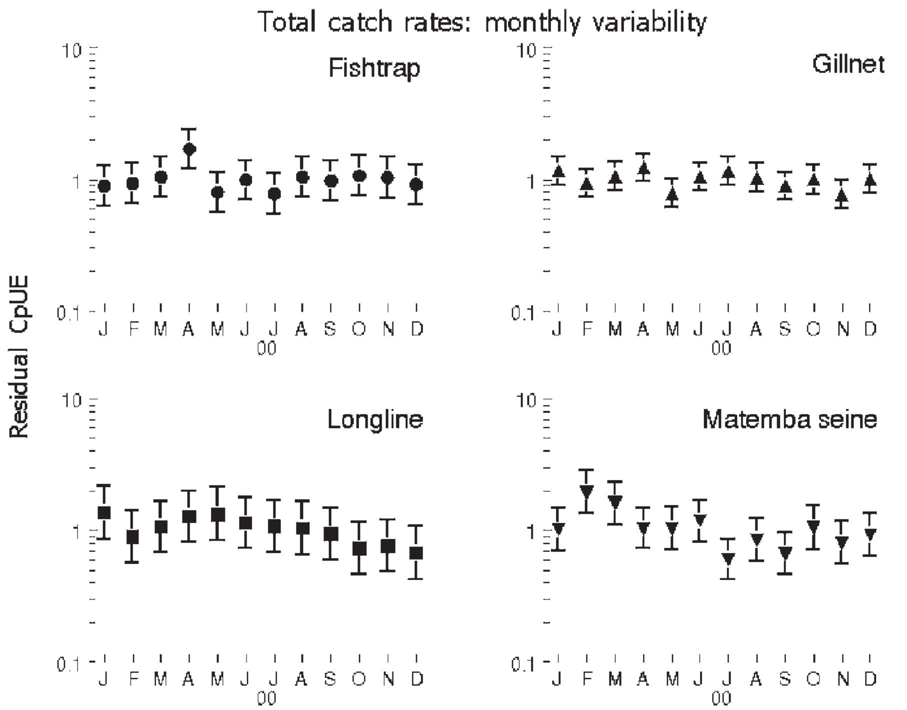

FIGURE 4. *Monthly variation in total catch-rates by gear. Vertical bars represent 95 percent confidence limits. The scale on vertical axes represents a multiplication factor of the of the* ^{10}*log annual mean catch-rates.*

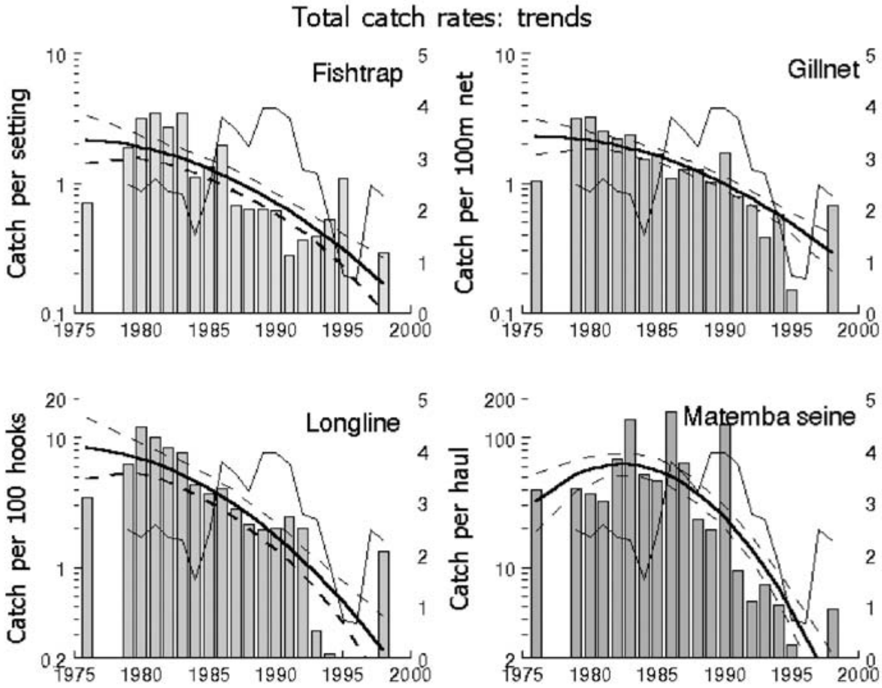

FIGURE 5. *Annual variation (bars) and polynomial trends (thick line) in geometric mean annual total catch-rates by gear in lake Chilwa. Trends are shown with 95 percent confidence limits (broken lines). The thin line is the relative mean annual water level of the lake.*

4.5 No seasonality is present

Generally, no seasonality was observed in the catch-rate data, as no significant differences between months were found in 14 out of 20 series. This indicates that the catch-rate data do not contain a clear seasonal signal for most species(groups) examined (Table 2, Figure 4). Significant differences between months were found in six cases: of *Oreochromis* and of "Other" species caught in fish traps; of *Clarias* caught in *Matemba* seines and in gillnets; of "Other" species caught in *Matemba* seines; and in *Matemba* seines on the aggregated level of total catches. The clearest seasonal signal was seen in traps where 11% of the total variation in catch-rates is explained by the significant differences between months. Overall catch-rates of *Oreochromis* are higher from January to April during rising water levels (Figure 10), however only May, July and December had significantly lower catch-rates compared to the months February to April. "Other" species had significantly lower catch-rates in December and January, the season with lowest water levels, compared to the remaining year. But only 7% of the total variation was explained by this difference. *Clarias* catch-rates of Gillnets and *Matemba* seines were slightly elevated during the low water period in December and January, which explained 10% and 6% of the total variation. Differences between monthly catches of "Other" species in *Matemba* seines explained only six percent of the total variation, and were caused by lowered catch in December compared to the period between March to June and October. On an aggregated level by gear only *Matemba* seines showed monthly differences: February was slightly elevated compared to much of the period from June to December, but the signal was weak as it explained merely 5 percent of the total variation.

4.6 All observed trends are declining

All but six out of 20 time-series revealed a substantial downward trend in average catch-rates ranging in speed from a factor 4 in *Clarias* catch-rates of gillnets to a dramatic factor 120 in catch-rates of "Other" species in fish traps (Table 2, Figures 5 and 6). Polynomial trends

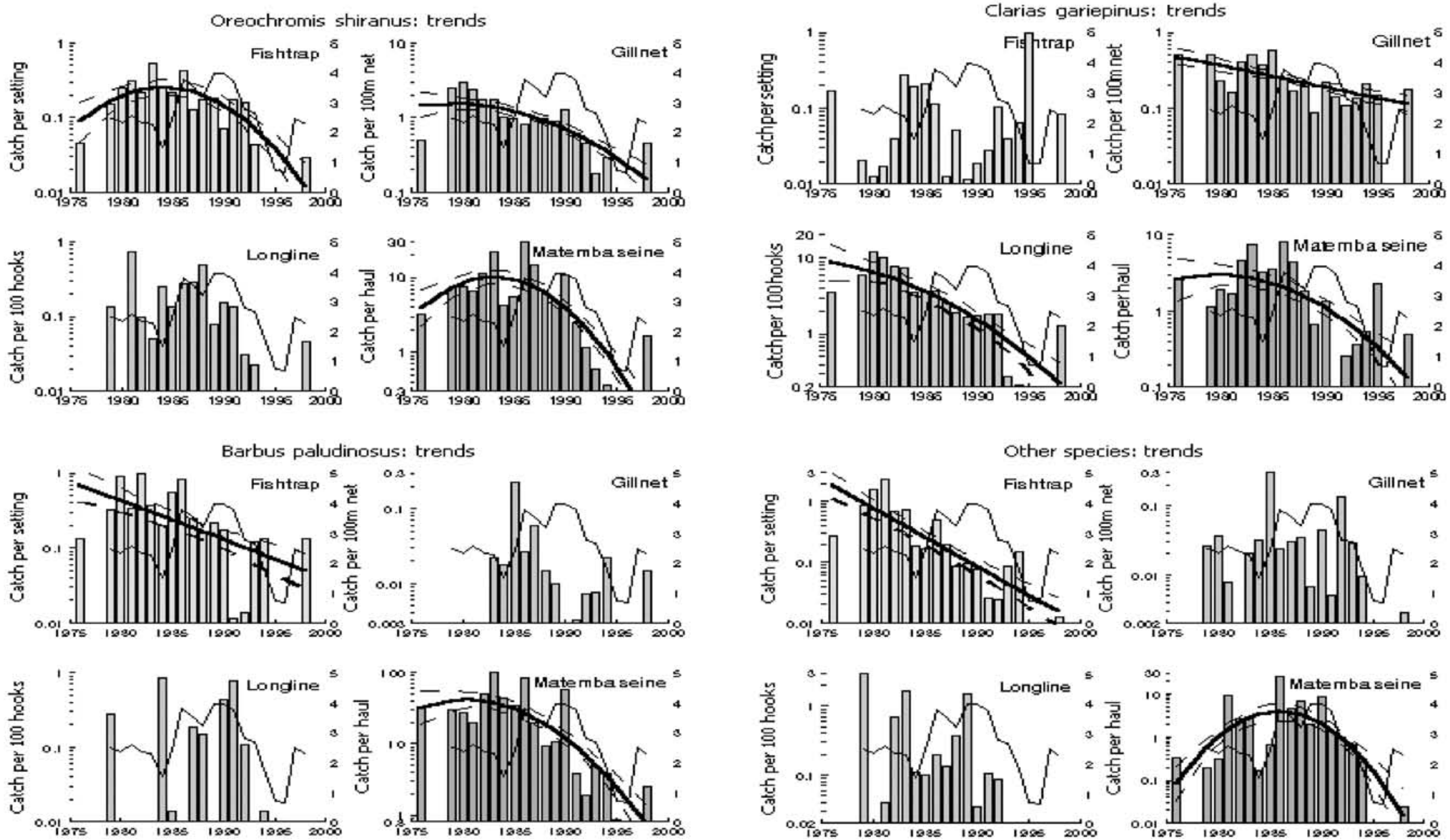

FIGURE 6. *Annual variation (bars) and polynomial trends (thick line) in geometric mean annual catch-rates by species and by gear in lake Chilwa. Trends are shown with 95 percent confidence limits (broke lines). The thin line is the relative mean annual water level of the lake.*

indicated that all of the downward trend legs of the curves commenced before 1986 and most even before 1982. Trends were linear or concave downward in ten series. The quadratic term of only two of the seven concave downward series contributed more than 10 percent to the total variation explained by the trend, indicating that the linear downward component was dominant in all cases. Four series had a dome shaped trend, but with just a slight upward slope and a strong downward slope after the peak. Three of the peaks within these four series were in 1982 (total catches in *Matemba* seine), 1983 and 1984 (*Oreochromis* catches in fish traps and *Matemba* seine). "Other" species caught in *Matemba* seines peaked in 1986 and this was the only series without a linear component. Thus most of the downward trends could be sufficiently explained by the linear component and the remaining analysis will be done using linear trends.

The trend component in the variation is strong: 44 percent to 88 percent of the observed annual variation was explained by the downward trends (Table 2, Figure 2). Both for fish traps – except in case of *Barbus* – gillnets and longlines more than 60 percent of the annual variation was explained by trends. The highest amount of total variation explained by a linear trend was in "Other" species caught by fish traps (40 percent). Linear trends in total catch-rates explained between 27 percent (seines) and 36 percent (gillnets) of the variation.

4.7 Basic uncertainty is high

Unexplained variation is the amount of variation that remains after all significant year and month effects (trends) are subtracted from the monthly catch-rate time-series. The unexplained variation is lowest in gillnets (F=3.1), followed by fish traps (F=4.8), seines (F=5.2) and Longlines (F=7.6). Except in traps, the unexplained variation is about the same or somewhat higher for the separate target species of the various gears compared to the total

TABLE 3. *Trend, trend-to-noise ratio and number of months data needed to detect the observed trends with and without autocorrelation (persistence).*

Species	Gear	df	Trend B	Standard deviation S	Trend/ noise B/s	N (months)	Auto-correlation coefficient r	N (months)
Total	Gillnet	211	-0.04	0.30	0.13	19	0.45	21
	Longline	209	-0.07	0.53	0.13	20	0.40	21
	Seine	206	-0.06	0.57	0.10	24	0.58	27
	Trap	206	-0.05	0.41	0.12	21	0.36	22
Oreochromis	Gillnet	207	-0.04	0.37	0.12	23	0.57	26
	Longline		n.s.					
	Seine	203	-0.06	0.57	0.10	24	0.61	28
	Trap	193	-0.05	0.72	0.07	31	0.41	33
Barbus	Gillnet		n.s.					
	Longline		n.s.					
	Seine	203	-0.07	0.54	0.13	20	0.52	29
	Trap	203	-0.03	0.62	0.06	35	0.42	38
Clarias	Gillnet	211	-0.03	0.37	0.08	29	0.25	30
	Longline	209	-0.07	0.53	0.13	20	0.37	21
	Seine	206	-0.06	0.60	0.09	25	0.55	29
	Trap		n.s.					
Other	Gillnet		n.s.					
	Longline		n.s.					
	Seine		n.s.					
	Trap	192	-0.09	0.63	0.15	18	0.36	19

catch-rates (Table 2, Figure 2). The basic uncertainty, or the uncertainty remaining after removing the trend, is a factor F=4 for gillnets and F=6.5 for traps. Basic uncertainty in catch-rates of seines and longlines is excessively high (F=11), indicating strong interannual variation.

4.8 Trend-to-noise: the capacity to detect trends

All linear downward trends were detectable as statistically significant between 19 and 24 months for the total catch-rates of the four gears (Table 3, Figure 7). Persistence (= non-random residuals) had little effect: it increased the number of data points needed to detect the observed trends with two to three months (Figure 7). *Trend-to-noise* ratio was highest in "Other" species in traps, and lowest in *Barbus* caught by traps. The effect of persistence in the species(groups) was an increase in the data points needed, but all observed trends were detectable from 21 to 38 months of data.

A long-term negative trend for total catch-rates in gillnets and longlines became statistically significant in 1987 (Figure 8a), in both cases around seven years after the peak in catch-rates was reached (Figure 5). The negative trend in fish traps was significant in 1988, or around five years after the peak. *Matemba* seines gave a different signal: the negative trend was significant in 1992 or around two, six and nine years after peaks observed in average annual catch-rates and about nine years after the estimated peak in catch-rates through polynomial regression (Figure 5). Reversals in trends seen in all catch-rate time-series took about three to four years during which only the decision of no long-term trend could be made. For example, this was the case from 1984 to 1986 in gillnets (Figure 8a).

Short-term trends, taken over five years, are obviously much more erratic (Figure 8b), but nevertheless gave fairly consistent signals over time. For instance a strong positive trend (b/s = 0.88) seen in 1980 after three years (plus two missing years) of gillnet data, reversed into a fairly

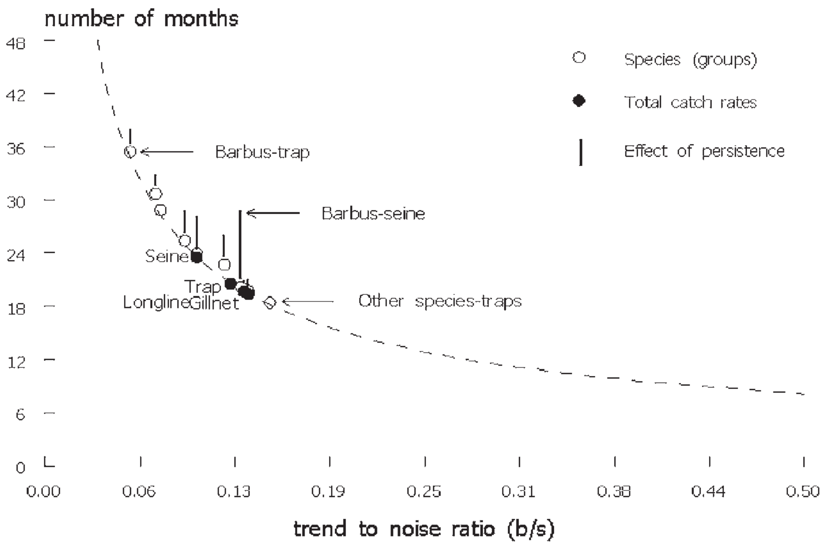

FIGURE 7. *The relation of the trend-to-noise ratio to the number of months of data needed to detect a trend in total catch-rates and catch-rates by species/gear combinations of including the effect of autocorrelation (persistence)*

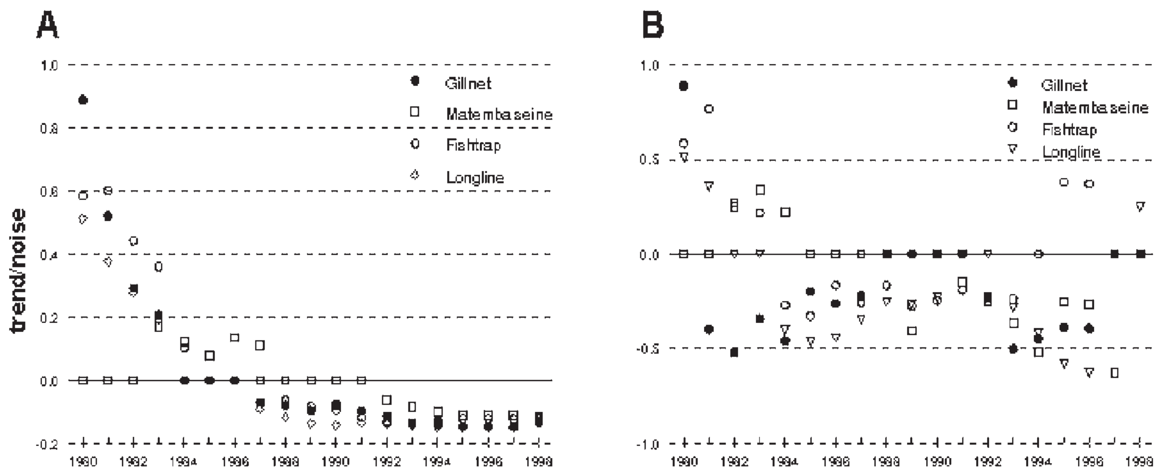

FIGURE 8 A. *Development of the trend-to-noise ratio from five years of catch-rate data in 1980 onwards with successive addition by year of monthly catch-rate data for gillnets, Matemba seines, fish traps and longlines. 1980 is the trend-to-noise over 1976 to 1980; 1981 is b/s of 1977 – 1981 etc.* ***B.*** *Development of trend-to-noise over five year moving periods, each indicated by the last year*

strong negative trend (b/s = -0.40) in 1981. From 1981 to 1988 the short-term trends remained negative, though becoming less strong. Between 1988 and 1991 no short-term trends were seen. During this period of higher water levels, catch-rates levelled out (Figure 5 and Figure 9A). After that short-term trends became significant and negative again. This picture is confused by the behaviour of short-term trends in other gears. Fish traps and longlines did not exhibit negative short-term trends until after 1983 and Matemba seines not even before 1989. Short-term trends in fish traps remained negative until 1995 the year before the lake dried up, while all other short-term trends remained negative until the end of the series in 1998. Furthermore, reversals in short-term trends take place more often in these gears and result in relatively high absolute values of the trend-to-noise ratio.

4.9 Water levels, fishing effort and catch-rates: immediate effect of changes in water level on catch-rates

Average annual water levels increased significantly from 1986 to 1991 compared to the periods before and after. Water levels dropped from 1992 onwards to the drought of 1995 and 1996 when the lake was largely dry. After that the average water level increased to pre-1986 levels (Figure 9). This means that during the period over which we have data on catch-rates (1979–1998) a significant fluctuation in water levels took place providing the necessary contrast to detect the effect of increased effort with changing water levels. In all cases except catch-rates of “Other” species in *Matemba* seines, which peaked in 1986, catch-rates peaked before the onset of the higher water levels. This can be clearly seen in Figures 5 and 6.

Changing water levels have, in all but one case, an “immediate” effect on annual average catch-rates: fluctuations in water levels are reflected in the same or the following year in the catch-rate levels (Table 4). De-trended annual catch-rates in gillnets positively correlated best

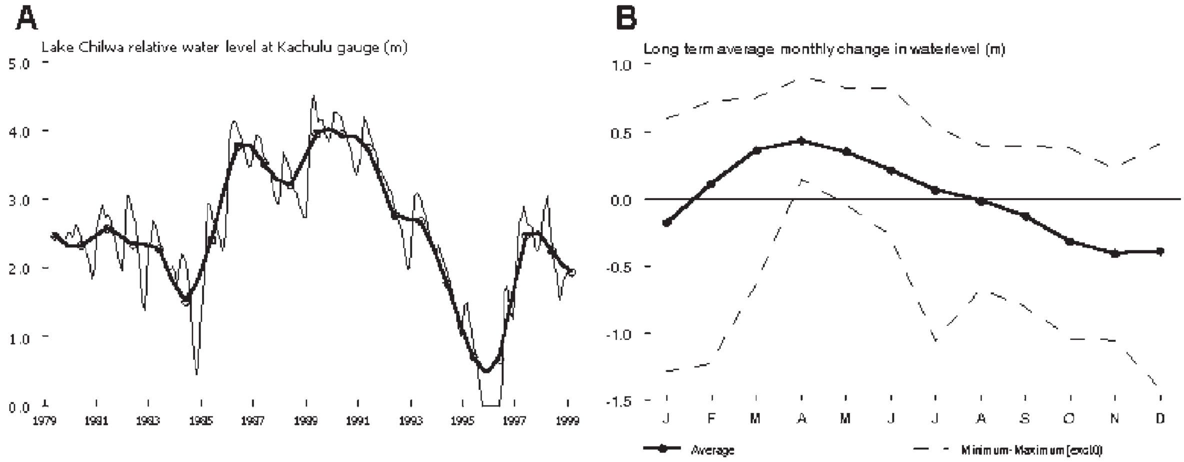

FIGURE 9. ***A***. *Annual average water level (thick line) and mean monthly water levels (thin line) in Lake Chilwa from 1979 onwards.* ***B.*** *Long term average monthly water levels and minimum (excluding periods of recession) and maximum water levels measured by month*

with either mean or maximum average lake levels and significant lags varied between zero years for *O. shiranus* in gillnets and seine nets, to four years for *C. gariepinus* in seine nets. In contrast, regressions between catch-rates by species or gear and water levels with lags higher than one year were not significant, except for total catch-rates in seines. The correlations indicating long-term effects of water levels on catch-rates (i.e. inducing generations of strong and weak year classes of longer lived species) are thus rather weak signals in the variation in catch-rates as observed through the CEDRS data.

TABLE 4. *Cross-correlation between residuals of de-trended annual average catch-rates ("anomalies") and annual mean, minimum and maximum water levels in Lake Chilwa. Analysis is done on total catch-rates by gear and the main target species (groups) of the various gears. Trend is a linear regression on annual average catch-rates. Regressions of anomalies on water levels are done on lags with the highest significant correlation. N=number of observations, r^2 = proportion of explained variation, b = trend parameter. Significance values are denoted by asterixes: * p<0.05, ** p<0.01, *** p<0.001*

Gear	Catch	Trend					Cross correlations						Regression on lags with highest correlation	
							Mean water level		Minimum\ water level		Maximum water level			
		N	r^2	s	b	p	Lag	Corr	Lag	Corr	Lag	Corr	r^2	p
Gillnet	Total	18	0.61	0.23	-0.057	***	1	**0.58**	1	0.57	1	0.52	0.23	*
	Oreochromis	18	0.35	0.79	-0.100	***	0	0.56	0	0.38	0	**0.58**	0.36	**
	Clarias	18	0.38	0.22	-0.031	***	4	0.44			4	**0.45**	n.s.	
Seine	Total	18	0.45	0.51	-0.081	**	3	**0.57**	3	0.53	3	0.54	0.22	**
	Total						0	0.55	0	0.51	0	**0.58**	0.36	**
	Oreochromis	18	0.44	0.64	-0.098	**	1	**0.7**	1	0.66	1	0.67	0.36	**
	Oreochromis						0	0.72	0	0.68	0	**0.78**	0.63	***
	Barbus	18	0.46	0.61	-0.098	**	0	0.52			0	**0.55**	0.32	*
	Clarias	18	0.41	0.42	-0.060	**	4	**0.88**	4	0.88	4	0.88		n.s.
	Clarias						3	0.81	3	0.75	3	0.82		
Longline	Total	18	0.61	0.35	-0.077	***	0	0.51	0	0.48	0	**0.54**		n.s
	Clarias	18	0.62	0.34	-0.077	***	0	0.48	0	0.44	0	**0.51**	0.28	*
Fish trap	Total	17	0.80	0.18	-0.065	***	4	0.68	4	0.65	4	**0.69**		n.s.
	Barbus	17	0.48	0.40	-0.068	**	4	**0.79**	4	0.73	4	0.75		n.s.
	Barbus						3	0.6	3	0.57	3	**0.6**		n.s.
	"Other"	17	0.86	0.23	-0.101	***								

Where an effect of water level on catch-rate could be detected, it explained 10 percent to 40 percent of the total variation in annual average catch-rates. Approximately 23 percent of the residual catch-rates of gillnets (amounting to approximately 14 percent of the total annual variation) and 36 percent of the residual catch-rates of *O. shiranus* in seines (= 22 percent of total variation) were explained by the mean water level of previous years. In all other cases, the highest significant regressions between the residual catch-rates were found with "this year's" maximum water levels, which in case of *O. shiranus* in *Matemba* seines amounted to 63 percent of the residual variation (= 40 percent of total variation) explained. Residuals in total catch-rates in *Matemba* seines were explained for 22 percent by the average water level of one year earlier (≈10 percent of the total variation).

4.10 Effort increases fast and is population driven

All indicators of fishing effort increased significantly over the period examined: i.e. number of gear owners, assistants, boats and gears. Trends in numbers of gear owners, assistants, boats, gillnets and longlines indicate a three-fold increase while, traps and *Matemba* seines increased five fold (Figure 10). In the 1980s the number of fishing operators – gear owners and ancillary workers – in Lake Chilwa ranged from 2 060 to 3 403 while the range was from 3 955 to 9 466 in 1998, just two years after refilling of the lake (Table 5). This latter figure represents the highest number of fishermen and assistants ever registered on Lake Chilwa. Apparently many new fishermen entered the fishery after the recession, mainly in the west and north. This increase could be attributed to return migration from South Africa due to phasing out of the working contracts in the mines. We assume that many of the returning migrants took up fishing, as the Phalombe plain does not receive much rain making agriculture around the upland area an unattractive option.

All gears, both the low-investment (traps, longlines and handlines) as well as high-investment gears such as *Matemba* seines, continuously increase in units over the years. However, as the ratio of gear owners to assistants as well as number of boats and gears per owner exhibit a steady decrease over the period from 1983 to 1998 it is likely that low investment gears (traps, longlines, and *nchomanga*) become relatively more popular (Figure 11).

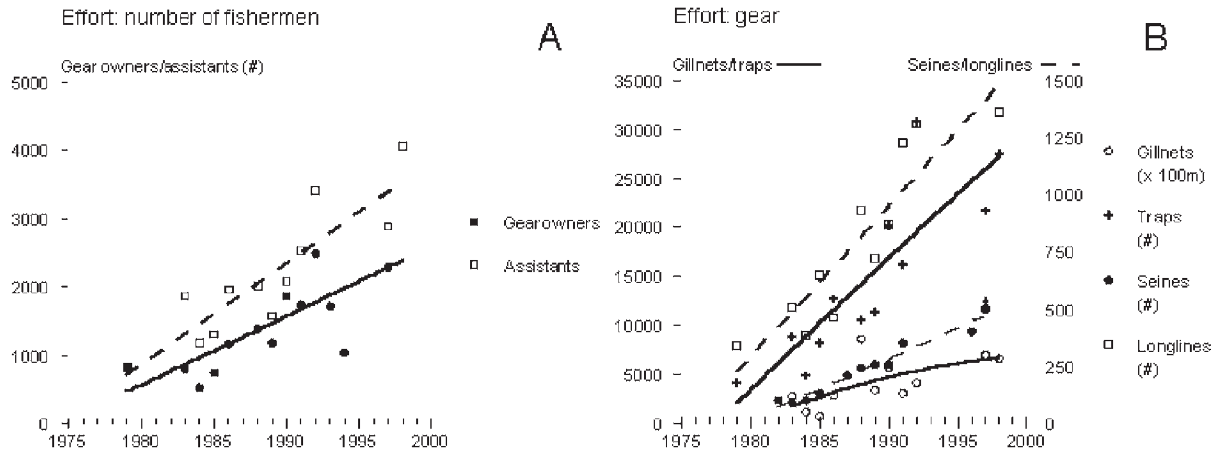

FIGURE 10. *Development in effort expressed as number of gear owners, number of assistants and number of boats in Lake Chilwa. The bold line is the regression of the total numbers over time. The thin regression line refers to the numbers of stratum 1 and the broken line is the regression of numbers of stratum 2 over time.*

Most fishing effort is suspended during recession periods. Many fishermen, especially those operating *Matemba* seines and gillnets, stop fishing or migrate to other water bodies, though such migrations recently have encountered resistance from resident fishermen (Njaya, pers. obs.). Other fishermen migrate to pools of water remaining in the inflowing rivers. Fishermen operating fish traps sometimes set their traps in rivers, often in conjunction with weirs.

4.11 Increased effort negatively affects catch-rates despite high regenerative capacity

We concluded in the previous section that a significant part of the variation in catch-rates is immediately explained by absolute water levels. This implies that catch-rates should increase with higher water levels and vice versa. However, between 1984 and 1991, with elevated water levels, no positive short term-trends were observed though trends became less strongly negative over time or indicated stable levels (Figure 8b). Long-term trends reveal a stabilization in catch-rates between 1984 and 1987 for gillnets, fish traps and longlines and between 1988 and 1991 for Matemba seines (Figure 8a). This would imply that the expected downward trend observed in catch-rates is delayed by increase in production during high water levels. After 1992, during the years before the recession, increased effort and decreasing water levels push stocks in the same direction, as a result of which the decrease in catch-rates will probably accelerate compared to a situation with low effort levels. However, closer examination of the trends versus catch-rates (Figures 5 and 6) show an increase for species (groups) caught in fish traps and for *Clarias gariepinus* caught in Matemba seines in the two to three years before the complete recession, thus confounding the explanations on the general trend.

Multiple regression of water levels and catch-rates confirms these observations: in all cases fishing effort had a significant negative effect on catch-rates. In gillnets 26–40 percent of the variation in annual catch-rates was explained by the number of gillnets for both *Oreochromis* and *Clarias*; in seines this amounted to 52–56 percent for all three species; longline effort explained 57 percent of the variation in annual catch-rates in *Clarias.* In traps the highest significant effect was found with *Clarias* (47 percent), while effort explained only 16 percent in *Oreochromis* catch-rates (Table 6). Water level was positively related to annual catch-rates, but explained much less than fishing effort (7–29 percent). In all gears, except longlines,

TABLE 5. *Number of fishermen, ancillary workers and craft operating in Lake Chilwa (1984-98)*

Year	Fishermen	Assistants	Total	Boats	Boats	Dugout
1984	527	1186	1783	8	71	1289
1985	750	1312	2062	13	75	1180
1986	1167	1962	3129	15	112	1802
1987	No frame survey					
1988	1363	2020	3383	10	146	1683
1989	1185	1597	2782	11	116	1373
1990	1874	2081	3955	4	229	1801
1991	2319	2546	4865	24	268	2045
1992	2496	3412	5908	5	329	1883
1993	1718	3958	5676	27	440	1201
1994	1043	5043	6096	0	507	1190
1995	No frame survey due to recession					
1996	No frame survey due to recession					
1997						
1998	5396	4070	9466	4	582	4090

Source : Fisheries Department Frame Survey (1984-98)

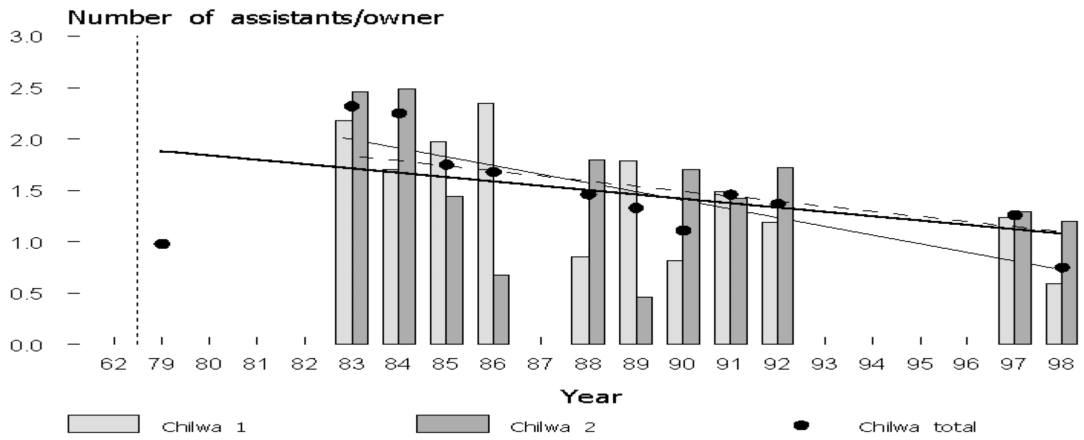

FIGURE 11. *Ratio of number of assistants and gear owners. The bold line is the regression of the total numbers over time. The thin regression line refers to the numbers of stratum 1 and the broken line is the regression of numbers of stratum 2 over time.*

Oreochromis catch-rates were affected most by water levels (20–29 percent). *Clarias* catch-rates were only significantly influenced in seines (15 percent) and longlines (7 percent), but not in gillnets and traps. *Barbus* catch-rates were only influenced by water level in seines (13 percent), but otherwise the regression model could not explain variation in catch-rates of *Barbus*.

4.12 Efficiency of gears (catchability) increases with decreasing water levels

The interaction of water level and gears was significant and positively related to catch-rates, except with seines. The lowest number of gears, counted at the beginning of the time series, as well as the highest number of gears at the end of the series coincided with low water levels, while highest water levels around 1990 are associated with a period of increasing fishing effort with all gears. The drop in water level towards the recession in 1996 and 1997 is thus associated with the highest numbers of gears counted in the time series of fishing effort. Theoretically increased fishing effort would be associated with decreased catch-rates. However, the high proportion of variation explained by the interaction term indicates that the situation is more complex. During receding waters, with a likely subsequent concentration of the fish, some of the gears catch a number of species more efficiently thus maintaining relatively high catch-rates despite increasing effort. This is the case with *Oreochromis* caught with gillnets (30 percent of variation explained by interaction term) and traps (21 percent), and with *Clarias* caught in gillnets (29 percent), traps (26 percent), longlines (18 percent) and to a lesser extent seines (7 percent). This sustains the notion of a crowding effect of these two species during receding water levels. It is particularly clear in the case of *Clarias* where relatively high catch-rates are encountered during very low water levels (Figure 6). There are indications that *Clarias* become more "active" under extreme low water levels in an attempt to find their way out of the desiccating areas changing their catchability.

That the interaction effect does not play the same role in the case of Matemba seines may not be surprising. Seines are active gears used either from the shore, or from boats in and around submerged vegetation, in relatively shallow areas. They are used both with receding or increasing lake levels in the areas where concentrations of smaller species and juveniles of larger species are found. Changes in recruitment levels will therefore affect catch-rates more than crowding effects, which is indicated by the high explanatory value of the water level in the statistical model where seining effort is the explanatory variable. In comparison, longlines show the reverse situation: in this case recruitment variation is much less important (7 percent of variation explained by the effect of water level) compared to the interaction effect (18 percent). Of all gears, the increase in effort of seines and longline explains the highest proportion of variation in their respective catch-rates, indicating a comparatively strong effect on stocks.

TABLE 6. *Proportion of variation in annual catch-rates explained by the multiple regression model with lake water leve l(mean, minimum or maximum), with or without a lag phase of 1 year, fishing effort (number of gear) and their interaction as explanatory variables. Sign indicates the direction of the effect in the model. Left of the vertical line are the statistics of the multiple regression model. Analysis is done on total catch-rates by gear and the main target species (groups) of the various gears. Only regression models explaining the highest amount of variation are shown. Df= degrees of freedom, SS = sum of squares, % = r^2 = proportion of explained variation, sign denotes the direction of the effect in the statistical model. Significance values are denoted by asterixes: * p<0.05, ** p<0.01, *** p<0.001*

Gear	Species	Water level	Model (A)							Statistics of model (B)				
				Water level		Gear		Interaction			Total error	Residual error	Total error explained by model	
			Lag	Sign	%	Sign	%	Sign	%	Df	SS	SS	%	P
Gillnet	Total	Mean	1			-	38	+	38	16	2.53	0.60	76	***
	Oreochrom	Max	0	+	20	-	26	+	30	17	15.11	3.67	76	***
	Clarias	Max	0			-	40	+	29	17	5.01	1.57	69	***
Seine	Total	Max	0	+	16	-	54			17	7.58	2.27	70	***
	Oreochrom	Max	0	+	29	-	52			17	11.54	2.08	82	***
	Clarias	Max	0	+	15	-	56	+	9	17	5.01	1.02	80	***
	Barbus	Max	0	+	13	-	55			17	10.89	3.43	68	***
Longlin	Total	Max	0	+	9	-	57	+	20	17	5.04	0.76	85	***
	Clarias	Max	0	+	7	-	57	+	18	17	5.01	1.01	82	***
Trap	Total	Max	0	+	9	-	49	+	24	17	5.04	0.91	82	***
	Total	Min	0	+	17	-	43	+	13	17	5.04	1.34	74	***
	Oreochrom	Max	0	+	29	-	16	+	21	17	3.56	1.19	67	**
	Clarias	Max	0			-	47	+	26	17	5.01	1.36	73	***
	Clarias	Min	0			-	47	+	14	17	5.01	1.94	61	***

5. CONCLUSIONS AND DISCUSSION

Let us return to the question posed in the introduction on how the data collected through the Malawian CEDRS on Lake Chilwa could be utilized to gain information on the status of the fishery, and following the answer to that summarize our conclusions.

5.1 On the data collected

The catch-rate data contain an enormous variability that, to a large extent, we believe to be mostly administratively induced as caused by the method of raising the daily catch and effort data to arrive at the estimates of monthly catch and catch-rate. As a result, for instance, seasonality is hardly detectable. Seasonality is expected to be clearly visible in the data in a system with highly seasonal changes in productivity. Despite the high variability, it is still possible to significantly detect trends in the various catch-rates series within two to three years of monthly aggregated data. The time windows, over which short- and long-term trends in total catch-rates could be detected, are generally between two and three years of data, and occasionally lower than that. Taking into account that the average duration between periods of recession is six years, and that 30 percent of the variation in water levels is accounted for by these cycles, this is rather a long time-frame to evaluate the effects of any management measure that aims at improving catch-rates. The speed of change in fish stocks in Lake Chilwa appears to be much faster than can be detected through the present CEDRS.

5.2 On the effects of fluctuating water levels and increased effort

- The tremendous increase in fishing effort is largely an increase in numbers of gear and labor and not of changed technology. With highly contrasting lake levels, this makes an analysis of the combined effects of effort and changing productivity as a result of changing water levels possible.
- The effect that changing water levels have on stock levels is large: it can be detected despite the high administratively induced "background noise". Although the effect of water levels seems to be immediate, only a small proportion of the annual variation is explained by it. Two reasons can be given for this:

  (1) The amount of error in the data collection and subsequent handling obscures this effect. This error could be considered as random noise during all the series, as sources of bias and error are the same[1].

  (2) The general trend of decreasing catch-rates is caused by the tremendous increase in effort. Changes in water levels either obscure this general trend if conditions are favorable as was the case between 1986 and 1991, or effects of lowered levels in concentrating fish disguise the effects of increased effort initially during receding water. Eventually the drops in catch-rates speed up during the continued decrease in water levels.

- Changing water levels are reflected in an "immediate" effect on catch-rates in the various gears employed, which means that the effect is on the stock abundance. The time lag in the correlation between water levels and catch-rates is generally short (0-1 year) and long-term effects caused by strong or weak cohorts (year classes) of fish over several years, are not detected – except possibly with *Clarias*. Since most of the variation is accounted for within the "first year" this indicates that the fishing pattern is aimed at small short-lived, or young fish. However, despite the high effort, this fishing pattern does not seem to influence the regenerative capacity of the stock, as this seems to be more a function of water levels. In other words, when the environmental conditions are favorable (strong water influx) the recruitment of new fish could be independent of the fishing pressure, at least within the present range of observations. That the recruitment appears much more dependent on favorable environmental conditions, than on the actual parent stock sizes, is also manifested by the rapid rebuilding of the stocks that is observed after each major lake level recession. The Lake Chilwa fish stocks appear to be adapted to withstand high natural depletions, and are therefore also able to sustain high exploitation rates.

[1] That the effect of water levels on catch-rates can still be seen indicates that the assumption that "administratively induced error" is a random effect may be correct.

- Delayed effects on catch-rates through "dilution" and "concentration" of fish as a result of changes in volumes of water and behavioral change in fish movements, result in changing efficiency of gears. Both effects may be typical for the situation in Chilwa and caused by both the small mesh sizes of the gears employed and the areas fished. Much of the fish caught are small sized (0+ or 1 year old), and an important part of the effort is employed along the shore or in reed beds. The maximum size of *Barbus paludinosus* is only 12 cm while *Oreochromis shiranus* (maximum size 25 cm) reaches maturity already at 12–15 cm (Furse, 1979). The fishery thus is adapted to catching small sizes. This means that as the fishery maximizes on harvesting the production of juveniles or small species before they are subjected to high natural mortalities, yields will also be highly variable due to changing water levels. The amount of variation explained at the aggregated level of years confirms this.

What does this mean for using the information gathered through the CEDRS? Our analysis has concentrated mainly on total catch-rates by gear, with an occasional excursion to individual species (groups). Long-term trends in total catch-rates for all gears all point in the same downward direction. As variation in aggregated total catch-rates by gear is lower than for the individual species, it will be more difficult to detect both long and short-term trends by species (groups), even on the aggregated level of the whole lake. Using the information gathered at lower levels of aggregation – for example at the level of main strata representing ecological areas, at village/beach level or at the level of individual fishermen or by species(group) – will be non-informative within a small time window but may be informative in a large time window. At present, different gears are generally targeting different species(groups), which means that gear specific trends can serve as an indicator for their respective targets species. As some gears – e.g. fish traps – are also fairly habitat specific, such trends will also provide information on changes in those habitats. In a first approximation, short-term trends by gear could be related to existing knowledge – both local-knowledge and scientific knowledge (e.g. Kalk, McLachlan and Howard-Williams, 1979) – of the effects of changing water levels related to the species and area specificity of the gear.

The immediate effect of changing water levels can be illustrated without resorting to sophisticated statistical methods. Peaks in total catch-rates and catch-rates of *O. shiranus*, *Barbus paludinosus*, *Clarias gariepinus* and "Other" species in *Matemba* seines all coincide with the significant increase in water levels in the same year (Figures 5 and 6). This would indicate that relative change in water level is probably a better indicator for changes in catch-rates (≈ stocks), than absolute lake-levels, also indicated by the fact that maximum water levels usually score better than mean or minimum water levels. Also in Kariba annual change in lake levels, reflecting the amount of new inundated land every year (= new nutrients) scored better than mean annual lake levels (Kolding, 1994; Karenge and Kolding, 1995).

By eliminating much of the perceived "administratively induced" variance the information contained in the data collected through the Malawian CEDRS could be made much more sensitive over the short-term to changes both in effort and in productivity. Then the present analysis could be easily extended at a lower aggregated level (by area and by species-gear combination). Furthermore, at a higher aggregated level, overall effects of management measures could be detected more quickly, even with the observed high variation in catch-rates caused by changing water levels. This could make the CEDRS a much better instrument to evaluate the biological effects of (co-) management measures in such an adaptive environment.

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EFFORT DEVELOPMENT AND THE COLLAPSE OF THE FISHERIES OF LAKE MALOMBE: DOES ENVIRONMENTAL VARIABILITY MATTER?

P.A.M. van Zwieten, F. Njaya and O. Weyl

1. INTRODUCTION

1.1 The collapse of a fishery

Lake Malombe is sometimes considered as a foreboding of what could happen with an African fishery if the growth of fishing effort remains unchecked (Coulter, pers. com.): around 1990 an important fishery on a group of tilapiine fish species called "Chambo" collapsed as a result of overfishing (FAO, 1993; Bulirani *et al.,* 1999; Palsson, Bulirani and Banda, 1999). Annual catches of the three species that form the Chambo complex *Oreochromis lidole*, *O. squamipinnis* and *O. karongae*, dropped from 9 300 tonnes in 1982 to a mere 50 – 200 tonnes from 1993 onwards. Subsequently the *Oreochromis* fishery was almost completely replaced by a fishery on a complex of haplochromine cichlids – Kambuzi, the output of which fluctuated heavily, reached levels of around 9 500 tonnes in 1987 and 1990 but dropped to a level of around 2 800 tonnes four years later and has not recovered since[1] (Figure 1).

Presently, the exploitation of Lake Malombe is dominated by two artisanal fisheries: a gillnet fishery and a purse-seine type of fishery, locally known as Nkacha. Gillnets are used as stationary nets and as open water seines; they are on average 750 m long with varying mesh sizes. More important - and more contested as will be discussed later – are the Nkacha nets: the open water purse seines are operated from two planked boats by seven crewmembers using it in day and night shifts. The nets are around 150 m long with a mesh size of 14 mm[2]. Before the collapse of the *Oreochromis* fishery two other gear types were important as well, both beach seines. Large Chambo seines with a headline length ranging from 50 m up to 1 800 m (mean around 800 m) and a depth of 5–20 m required the labour of 10 to 30 people to operate. Kambuzi seines were nets around 200 m in length (range 50–700 m), with a depth of 2–12 m, a mesh size of 15 mm and required 6 to 20 people to operate. These expensive large seines were sometimes operated in pairs or in combination with a larger Chambo seine, where the second net was pulled around the first to catch fish escaping from it, a fishing method called Chalira. The large Chambo seines disappeared shortly after the collapse of the *Oreochromis* fishery, while most small meshed Kambuzi seines presently have been converted into purse seines. In 1993 the proportion of illegal gears used in the Malombe fishery – i.e. gears outside proscribed size and mesh size regulations – was between 40 percent and 75 percent for these four methods (FAO, 1993; Hara and Jul-Larsen, 2003).

FAO (1993) presented evidence that high fishing effort was the cause of the decline in *Oreochromis* catches since 1981 and the report warned of a possible collapse of the haplochromine fishery as well. For *Oreochromis* spp., an MSY of 6 000 tonnes per year was calculated, which was reached from 1984 until 1989, at the estimated effort levels.

[1] Observations in 2003 indicate that a large part, possibly up to one third, of the catch of the Nkacha purse-seine fishery on Kambuzi now consists of snails (M. Banda, pers. rem.; P.A.M.van Zwieten, pers.obs).

[2] Though mesh size may be as small as 6 mm (Weyl, pers.obs).

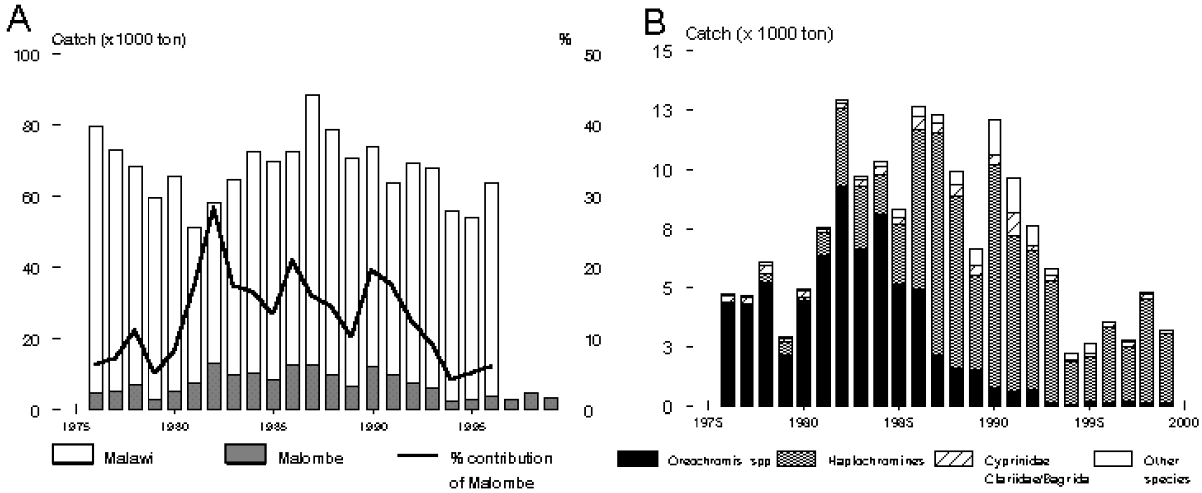

FIGURE 1 ***A***. *Total catch from Lake Malombe as a proportion of the total catch of Malawi.* ***B.*** *Total catch of Lake Malombe broken down by species and species groups.*

Nevertheless, a sharp decline in catch occurred, with effort decreasing further in 1990 and 1991 while neither catches nor CPUE improved. The possibility of recruitment overfishing caused by excessive fishing of the parent stock, was ruled out, as effort levels exploiting the parent stock were low compared to the years between 1976 and 1983, when catch levels were maintained. FAO concluded that excessive fishing of the 0+ and 1 year juveniles by small meshed beach seines and purse seines was responsible for the collapse: 70 percent of all *Oreochromis* spp. caught were taken by these gears. Small meshed beach seines also were thought to harm *Oreochromis* spp. during breeding and brooding periods, as these seines were dragged through habitat utilized by *Oreochromis*, destroying extensive under-water weed beds (Tweddle, Alimoso, and Sodzabanja, 1994). *Oreochromis* spp. that escaped was subsequently fished further away from the shore by gillnets: fishing mortality peaked at both sizes of around 10 cm (0+ and 1+ year of age) and 25 cm and larger (3+ year of age). This is a typical case of technical interaction between different fisheries: small meshed nets, in particular Kambuzi seines and Nkacha nets exploit the juvenile stages in the inshore area, while larger meshed gillnets nets exploit the three year and older fish. In short: the *Oreochromis* stocks were thought to have collapsed by a combination both of excessive fishing of the juvenile stock followed by a high but in itself not unsustainable fishing pressure on the parent stock. The collapse possibly was accelerated by destruction of *Oreochromis* nursery habitat, though the evidence is scant.

In addition all models suggested that haplochromine – Kambuzi – stocks were overexploited by the purse-seine fishery. Nevertheless the Kambuzi fishery remained profitable. Therefore a complete collapse of the Malombe fishery was not outside the realm of the possible: the future of the Malombe fishery was bleak. Recommendations to overcome the situation included: limit access through licensing; limit numbers of gears to present levels; forbid fine meshed beach seines and stimulate conversion of them into purse seines; gear and mesh size regulations for all gears (e.g. the purse seines should have headline length of 150 m and a minimum mesh of 25 mm); no closed season. Continued monitoring was considered of the utmost importance[1]. Since then much work has gone into an attempt to regulate fishing effort through co-management arrangements (Donda, 2000).

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[1] See Banda et al. (2002) for developments on proposed management strategies from a biological point of view.

1.2 Lake Malombe: production, productivity and physical environment

Lake Malombe had a very high fishery production of between 60–320 kg/ha (average 193 kg/ha) that lead to a long-term annual average fish yield of around 7 500 metric tonnes. The fishery contributed around 15 percent to the total fish catch of Malawi during the 1980s with a peak of 22 percent in 1982, but levels dropped to between 5–10 percent in late 1990s (Figure 1). The 390 km^2 lake is shallow, twice as long as wide, and lies in the outflow of Lake Malawi through the Upper Shire River. The average depth is 5–7 m[1] with a maximum of around 17 m. Except for areas of submerged vegetation and Typha swamps found around the in and outflow of the Shire River, it is a fairly featureless open water body. Small-scale fishing only started in the 1960s after the destruction of a large crocodile population (Tarbit, 1972; Tweddle, Alimoso and Sodzabanja, 1994). Dense weed beds, reported on already in the 1940s, and lakeshore reeds were cleared in the 1970s and 1980s to facilitate seining. Currently few weed beds occur in the lake (Weyl pers. obs.). The lake is fully mixed, is fairly turbid with an average visibility of 2.4 m[2].

Rainfall and runoff are believed to contribute significantly to the productivity of the lake, which is much higher than that of the South East arm of Lake Malawi, where the Shire River originates (FAO, 1993). Average annual water levels measured in the Upper Shire at Mangochi, 6 km from its entrance into Lake Malombe have decreased by around 3.5 m over the period from 1978 to 1999 (Figure 2). During most of the decade of 1990s the area received little rainfall that resulted in a complete recession of Lake Chilwa further south in Malawi (Zwieten and Njaya, 2003). If rainfall and runoff are important for the productivity levels of Lake Malombe, then increased fishing effort and declining productivity must have at least acted in conjunction. However, possibly as a result of the overwhelming evidence for overfishing, the possibility of changing productivity of the stocks and the lake as a result of decreasing water levels, increased runoff and sedimentation due to deforestation around the lake (mentioned in discussions with older fishermen as a cause of decreased productivity of *Oreochromis*) or habitat destruction received limited attention in the discussion on the causes of fluctuations and decline in fish stocks. Habitat destruction and the effect of changes in rainfall and runoff were hinted at as causal factors, but never investigated. This is important when evaluating the success of management measures directed to limiting fishing effort: if these factors contributed to lowered productivity or even to structural changes in the pathways of biological production of the lake, expected effects of management measures may take place at a slower rate, may not be as large as expected or will not take place at all.

In this paper we will not address these issues on the level of biological processes. Here we will discuss whether fisheries authorities have the capacity to timely detect important changes and trends based on available monitoring information on catch rates, effort developments and changes in environmental drivers – those indicated by water levels: can changes and trends in fish stocks can be perceived timely and causes of change and variability in catch rates be interpreted meaningfully with the information systems available? Three questions arise:

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[1] Van den Bossche and Bernascek (1990) give an average depth of 4 m. But Figure 2 it can be inferred that average annual water levels over a 20-year period ranged over 3.5 m. A dam in the lower Shire River regulates the minimum water level.

[2] Compare with the South East-arm of Lake Malawi: visibility 7.8 m; Lake Malawi, 12.5 m (Secchi disc readings).

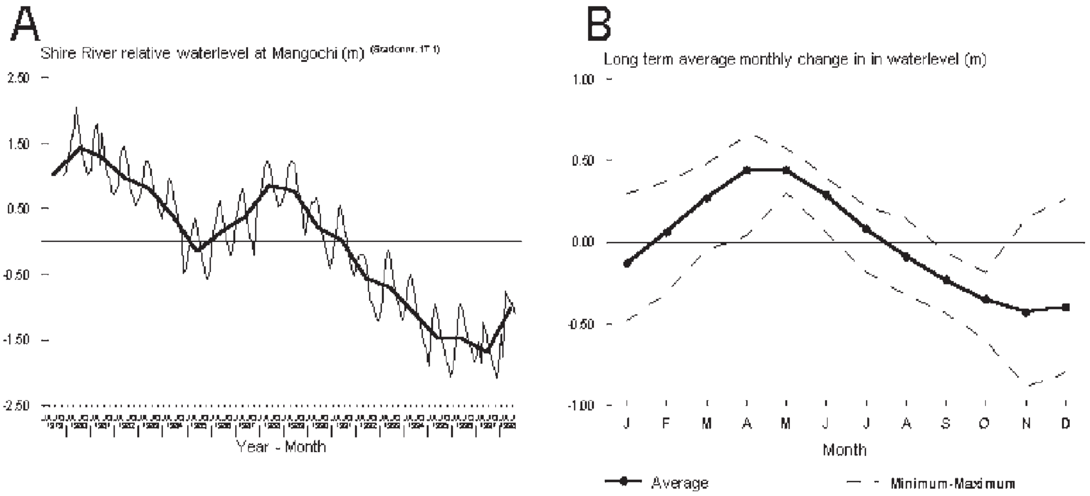

FIGURE 2. ***A***. *Annual average (thick line) and mean monthly (thin line) water levels in the Upper Shire River at Mangochi* ***B.*** *Long term average monthly water levels and highest and lowest recorded monthly water levels.*

- is there evidence for possible changes in productivity of Lake Malombe as a result of environmentally driven factors?
- is it possible to detect the combined effects of productivity changes and increased effort through the existing catch and effort and water level monitoring systems in Malawi?
- what consequences do the answers to these questions have for the resource management of Lake Malombe?

2. RESEARCH STRATEGY: DATA, INFORMATION AND EVALUATION

2.1 Data- poor yes, but not data-less

Many African fresh water fisheries can be considered as data-poor (Mahon, 1997; Johannes, 1998): management decisions have to be made based on little information on drivers of, pressures on and states of fish stocks. Nevertheless, often long-term series of catch and effort monitoring are available, obtained through Catch and Effort Data Recording Systems (CEDRS) mostly developed in the seventies and eighties. The maintenance of a CEDRS is difficult due to the high costs involved, both in the data collections themselves as well as in maintaining the institutional set-up and the knowledge base. As a result, data collected are often considered too poor to be utilized in formal stock-assessments, while the information from assessment results is often qutance, the value of single figure estimates of long-term sustainable yields (e.g. MSY) based on steady state assumptions of environmental stability is questionable when large changes in productivity of fish resources occur, as a result of environmental drivers such as seasonal, annual and longer-term fluctuations in water level. This has as a number of consequences:

- It becomes difficult to unequivocally attribute changes in the state of fish stocks to fishing effort.
- Choosing a fixed optimum level of fishing effort in order to maximize efficiency becomes at best an approximation for a range of acceptable effort levels around a range of long term yield estimates. Banda *et al.* (2002) take this approach.
- Evaluating the effectiveness of measures regulating fishing effort will be problematical as effects of fishing and environment are confounded. This complicates any effort to establish causation.

The perceived inaccuracies of monitoring data collected, as well as frustrations over the applicability of standard fishery science, have lead to a severe under utilization of the quantitative and qualitative information present in the catch and effort time series collected. Despite that, data continue to be collected and in quite a number of cases it is now possible to re-construct sometimes long time series of catch and effort (e.g. Zwieten *et al.,* 2002). Much can be gained from maximising the use of existing information and knowledge on the performance of a fishery by evaluating trends and variability in catch and effort time series.

In addition effects of naturally changing or fluctuating environments on fish production should be taken into account to assess the effect of changing fishing effort. In floodplain environments the evidence of environmentally driven fish production is overwhelming (e.g. Lae, 1995; Junk, 1996; Hoggarth *et al.,* 1999a), but in recent accounts attention is drawn to the regulation of fish stocks in small and medium sized lakes by changes in productivity through fluctuating water levels (Kariba: Karenge and Kolding, 1995; Turkana, Kolding, 1992; Chilwa Kalk, McLachlan and Howard-Williams, 1979; Zwieten and Njaya, 2003 and other lakes Lévêque and Quensière, 1988; Talling and Lemoalle, 1998) or even in large lakes as Lake Tanganyika through other, not yet fully understood long-term environmentally driven processes (e.g. Spigel and Coulter, 1996; Zwieten and Njaya, 2003; Sarvala *et al.,* 1999). Changes and fluctuations in environmental drivers as water levels can be important indicators for changes in stocks in an adaptive management context, as water levels are easily measurable, with often long times-series of data present.

Compared to surrounding countries, the Malawian information base for fisheries management is well established. Past monitoring of stocks and of some environmental parameters has yielded useful information that is available. Also specialized studies on all important fisheries in Malawi has provided biological information on a species level useful for stock-assessments (e.g. Kalk, McLachlan and Howard-Williams, 1979; FAO, 1993; Tweddle, 1995; Palsson, Bulirani and Banda, 1999, Jambo and Hecht, 2001, Banda *et al.,* 2002).

2.2 Evaluation of effectiveness of fisheries resource management in highly fluctuating environments

The evaluation of the effectiveness of fisheries resource management is largely dependent on the possibility to perceive changes in indicators for stock abundance and relate these to measures taken. Time trends in fish stocks as reflected in time series of catch rates are the basis for such evaluations. The possibility of measuring success of resource management actions within the appropriate time window depends both on the strength of effect over time and the variance around it (Peterman, 1990; Pet Soede *et al.,* 1999; Densen, 2001; Zwieten *et al.,* 2002). In this paper we will:

- *Examine trends and variability (inter-annual and seasonal variability by gear-species combinations) in the catch rates of Lake Malombe*
  to obtain an idea of the magnitude and sources of the variability in the monthly catch rates by species (group) and gear and the consequences this has for the capacity of fisheries authorities to detect changes and trends in fisheries outcomes.
  Examine changes in water levels and relate these to changes in catch rates
- to obtain information on the relative effect of fluctuating water levels on catch rates;
  Finally, examine trends in fishing effort and relate them to trends in catch rates taking into account the effect of changes in water level.

In statistical terms, the capacity to detect a trend is determined by the statistical power of the information examined, which in turn depends entirely on the variance of the data, given the number of observations and statistical decision levels. The time series of estimated monthly catch rates from CEDRS surveys of Malombe by major stratum (i.e. East and West Malombe) represent the lowest level of data aggregation for this lake that are used in reports on the status of the fishery. The capacity to detect trends and evaluate the effects of resource management with the aid of these time series is therefore dependent on the variability within these series, given the present sampling and data handling methods in use.

A justification of the research strategy followed in this study and the methodology of analysis of catch, catch rate, effort and water level data (analysis of variance, trend analysis, trend-to-noise analysis, multiple regression analysis) is outlined in Zwieten and Njaya, 2003. A description of the data sets as well as a justification of the aggregation into species groups can be found in Appendix 1. Appendix 2 describes the method of reconstruction of effort data. In Appendix 3 we give an analysis of the error structure of the data, with particular attention to the causes and effects of administrative errors on trend evaluation.

3. RESULTS

We start with an assessment of the information value of the monthly catch rates by gear and species group of Lake Malombe as taken from the CEDRS of Malawi, through an analysis of variance and trends, summarized in Table 1 and Figures 3–7. We analyse the size and sources of variability: gear selection of species, co-variation of species in the catch (see section 3.1 of this paper) and seasonal variability (3.2), inter-annual variability (3.3) and patterns trends (3.4) in catch rates (as a proxy for fish biomass). Seasonal variation is predictable while (long-term) trend is the information of interest: other sources of variation obscure the perception of trends. The variability in the data remaining after removing variability caused by trends and seasonality is called basic-uncertainty, and we will show that this is very high on the aggregated level of monthly catch rate data in the Malawian CEDRS (3.5), increasing the trend-to-noise ratio and with that decreasing the administrative capacity to detect trends (3.6). Its causes are discussed in Appendix 3. Next we will turn our attention to two potential causal factors. We use a statistical correlative approach of the trends and inter-annual variation in catch rates assuming changes in water level as driving factor of, and fishing effort as main pressure on, fish stock levels. After describing the developments in water level since 1915 (3.7), we examine the effect of annual change in water levels on the annual change in catch rates i.e. irrespective of trends in both variables (3.8). Then we describe developments in fishing effort by number of fishermen (3.9) and gears and gear activity (3.10). Lastly we examine the combined effect of increased effort and changing water levels on the development of catch- rates (3.11).

Gears are species selective

In multispecies fishery different gears, their spatial allocation and mode of operation – together forming a fishing pattern – target different sections of the fish community. A low variability[1] in catch rates of a particular species, or group of species, compared to others caught by the same gear indicates an important target of a particular fishing pattern. Changes in stock-sizes are more easily detected by analysing catch rates of these gears. The lowest variability is found in the species-gear combinations *Oreochromis* in Chambo seines (F=4.8) and *Haplochromis* in Kambuzi seines (F=8.9) and Nkacha nets (F = 2.7). The lowest variability in gillnets are Cyprinid catch rates (F=6): though *Oreochromis* is known to be a target species for this fishery a large amount of variability is induced by the declining trend as a result of the collapse of Chambo (see further). For most other species-gear combinations the variability is around a factor F=10 or higher (Table 1; Figure 3).

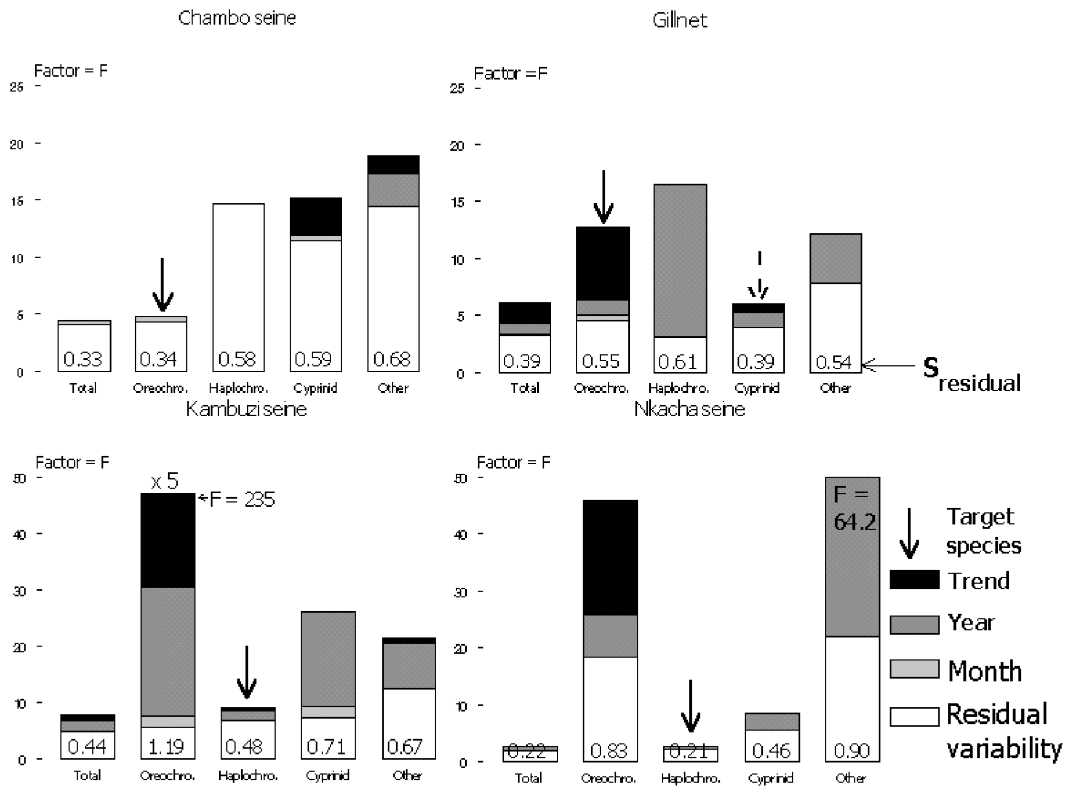

FIGURE 3. *The size of variability expressed as factor (F) around the geometric mean explained by trends (as linear regression), interannual, monthly and residual variability. The residual variability is also expressed as standard deviation (S) at the bottom of each column. The arrow indicates the target species of a gear. Basic uncertainty (see text) is the variability remaining when trend (black area) and seasonality (light grey area) are removed from the total variability.*

Aggregation of species into a total catch rate of a gear only leads to a slight reduction in total variability in all cases, and even in a slight increase in case of Nkacha seines. This indicates that though the gears are relatively specific in their target species, co-variation of the other

[1] Variability is described in this paper by a factor F around the geometric mean catch rate. A factor of F = 2.8 means that 95% of the data fall within the range of 2.8 times the Geometric Mean (GM) and the GM divided by 2.8. The Geometric Mean is the back transformed logarithmic mean of the data (=10 log10(M)) (see: Zwieten and Njaya, 2003).

species in the catch may be high leading to a lower reduction in CV of catch rates (Oostenbrugge *et al.*, 2002). The variability in total catch rates was lowest in Nkacha nets with a factor F= 2.8 followed by Chambo seines (F = 4.5), gillnets (F = 6.1) and Kambuzi seines (F = 7.2). Kambuzi seines exhibit a surprisingly high variability, compared to the other seines, which may be due to large differences in net sizes that were not taken into account in the correction of daily catch rate samples for effort, while before 1986 Nkacha and Kambuzi seines were not separated in the data collection.

TABLE 2. *Results of Analysis of Variance and regression analysis on monthly catch rates of Lake Malombe by gear and species groups as contained in the CEDRS of Malawi (see text for further explanation)*

Total catches	**Chambo *seine***						***Gillnets***					
	Model	**df**	**MSE**	**Factor**	**r2**	**p**	**Model**	**df**	**MSE**	**Factor**	**r2**	**p**
Total variance		90	0.108	4.5				234	0.153	6.1		
After Year	-	-	-	-	-	**ns**	*Year*	215	0.066	3.3	0.60	***
After Month	*Month*	81	0.095	4.1	0.20	*	*Year + Month*	204	0.063	3.2	0.64	***
Trend	-	-	-	-	-	**ns**	*Linear*	233	0.099	4.3	0.36	***
							Polynomial	232	0.084	3.8	0.46	***
							(quadratic term = 21% of total explained variance)					
	Kambuzi *seine*						**Nkacha *seine***					
Total variance		194	0.196	7.7				87	0.051	2.8		
After Year	*Year*	175	0.115	4.8	0.47	***	*Year*	76	0.021	1.9	0.65	***
After Month	-	-	-	-	-	**ns**	-	-	-	-	-	**ns**
Trend	*Linear*	193	0.172	6.8	0.12	***	*Linear*	-	-	-	-	**ns**
	Polynomial	192	0.164	6.5	0.17	***	*Quadratic*	86	0.040	2.5	0.23	***
	(quadratic term = 27%of total explained variance)											
Oreochromis spp.	**Chambo *seine***						***Gillnets***					
Total variance		90	0.116	4.8				231	0.305	12.7		
After Year	-	-	-	-	-	**ns**	*Year*	212	0.124	5.0	0.63	***
After Month	*Month*	81	0.101	4.3	0.21	*	*Year + Month*	201	0.110	4.6	0.69	***
Trend	-	-	-	-	-	**ns**	*Linear*	230	0.161	6.4	0.47	***
							Polynomial	229	0.141	5.6	0.54	***
							(quadratic term = 12% of total explained variance)					
	Kambuzi *seine*						**Nkacha *seine***					
Total variance		117	1.405	234.9				65	0.690	45.8		
After Year	*Year*	98	0.621	37.7	0.63		***	54	0.400	18.4	0.52	***
After Month	*Year + Month*	87	0.518	27.5	0.73	***	-	-	-	-	-	**ns**
Trend	*Linear*	116	1.190	152.0	0.16	***	*Linear*	64	0.500	25.9	0.29	***
	Polynomial	115	0.996	99.2	0.30		***					
	(quadratic term = 47% of total explained variance)											
Haplochromis spp.	**Chambo *seine***						***Gillnets***					
Total variance		1	0.341	14.7				12	0.371	16.5		
After Year		-	-	-	-	**-**	*Year*	6	0.062	3.1	0.92	**
After Month		-	-	-	-	**-**	-	-	-	-	-	**ns**
Trend		-	-	-	-	**ns**	*Quadratic*	11	0.227	9.0	0.44	*
	Kambuzi *seine*						**Nkacha *seine***					
Total variance		179	0.226	8.9				84	0.046	2.7		
After Year	*Year*	160	0.172	6.8	0.32	***	*Year*	74	0.024	2.1	0.53	***
After Month	-	-	-	-	-	**ns**	-	-	-	-	-	**ns**
Trend	*Linear*	178	0.215	8.4	0.06	***	*Linear*	-	-	-	-	**ns**
	Polynomial	177	0.208	8.2	0.09	**	*Quadratic*	83	0.035	2.4	0.26	***
	(quadratic term = 38% of total explained variance)											
Cyprinid spp.	**Chambo *seine***						***Gillnets***					
Total variance		74	0.349	15.2				232	0.151	6.0		
After Year	*Year*	62	0.248	9.9	0.41	***	*Year*	213	0.090	4.0	0.45	***
Trend	*Linear*	73	0.289	11.9	0.21	***	*Linear*	231	0.131	5.3	0.13	
	Polynomial	72	0.264	10.7	0.26	**	*Polynomial*	230	0.123	5.0	0.19	***
	(quadratic term= 21% of total explained variance)						(quadratic term= 29% of total explained variance)					
	Kambuzi *seine*						**Nkacha *seine***					
Total variance		149	0.503	26.2				81	0.215	8.4		
After Year	*Year*	130	0.233	9.2	0.60	***	*Year*	71	0.143	5.7	0.41	***
After Month	*Year + Month*	119	0.186	7.3	0.70	***	-	-	-	-	-	**ns**
Trend	*Quadratic*	148	0.449	21.9	0.11	***	*Quadratic*	80	0.190	7.5	0.12	***
Other spp.	**Chambo *seine***						***Gillnets***					
Total variance		70	0.409	19.0				189	0.293	12.1		
After Year	*Year*	59	0.336	14.4	0.31	*	*Year*	170	0.198	7.8	0.39	***
Trend	*Linear*	69	0.384	17.4	0.07	**	*Linear*	-	-	-	-	**ns**
	Polynomial	68	0.354	15.5	0.16	**	*Quadratic*	188	0.251	10.0	0.15	***
	(quadratic term = 54% of total explained variance)											
	Kambuzi *seine*						**Nkacha *seine***					
Total variance		139	0.443	21.5				70	0.818	64.3		
After Year	*Year*	120	0.302	12.5	0.41	***	*Year*	60	0.452	22.1	0.53	***
Trend	*Linear*	138	0.431	20.5	0.04	*	*Linear*	-	-	-	-	**ns**
							Quadratic	69	0.689	45.7	0.17	***

Significance level is indicated by asterixes: * p<=0.05, ** p<=0.01, ***p<=0.001

3.2 Seasonality only detected in *Oreochromis* catch rates

Seasonality could be significantly detected in 4 out of 20 time series examined (Figure 4, Table 1) indicating that the seasonal signal in the data sets for most species-gear combinations is low. Seasonality was seen in catch rates of *Oreochromis* spp. in gillnets (F=0.4; 6 percent of the total variance explained); Kambuzi seines (F=10.2; 10 percent) and in Chambo seines (F=0.5; 21 percent). Only gillnet catch rates displayed a regularly fluctuating pattern resulting in peak catches from November to March at low and increasing water levels and a low in June/July at decreasing levels.

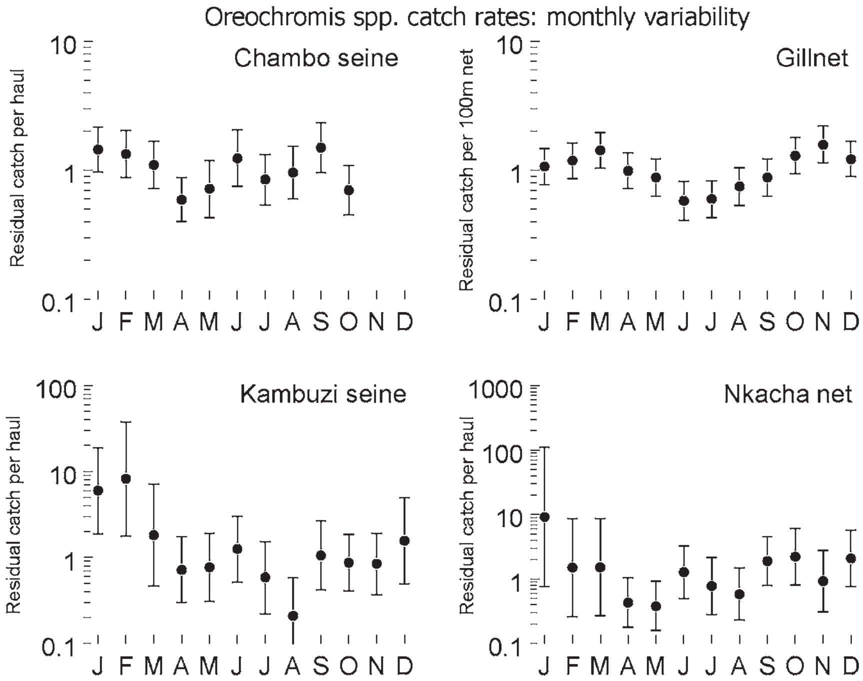

FIGURE 4. *Monthly variability in catch rates of Oreochromis spp. by gear. Vertical bars represent 95 percent confidence limits. The scale on vertical axes represents a multiplication factor of the of the ^{10}log annual mean catch rates (see Figure 5).*

Both Chambo seines and Kambuzi seines peaked in January/February at low water levels, while lower catch rates were experienced in Chambo seines during high levels in April/May and in Kambuzi seines at decreasing levels in July/August. No seasonality could be detected in Nkacha seines both in total catch rates, i.e. catch rates aggregated over species, and by species, a reflection either the low seasonality in the stock levels of the Kambuzi complex or the activity patterns of the fishery or both.

3.3 Annual variability is high and varies between different gears

Annual variability in average catch rates was high, with significant differences between years in 14 out of 20 time-series of species-gear combinations examined. Inter-annual changes, including both trends and differences between years (see also Figure 3) explained 45 – 65 percent of the total variance (Table 1). The exceptions were the total catch rates and *Oreochromis* catch rates of the Chambo seines, where no significant difference between years could be detected: average catch rates remained the same throughout the time-series. The four remaining cases were all non-target species for the various gears. Though annual averages varied much, no variability could be explained by temporal analysis: catch rate data for these series on the aggregated level of the monitoring data (month) indicated pure chance.

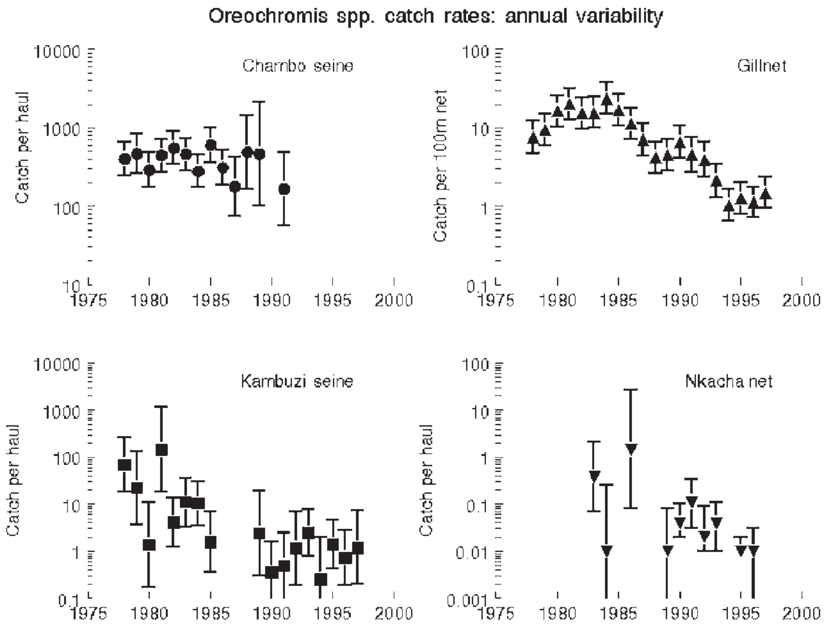

FIGURE 5. *Annual variability in total catch rates by gear. Vertical bars represent 95 percent confidence limits. Note ^{10}log scale on vertical axes. The higher confidence limits in catch rates of Chambo seines from 1987 onwards reflect the limited number of data for these years and gears respectively (see also Table 1).*

3.4 Patterns and trends in annual average catch rates

The most remarkable patterns in annual catch rates are found in Chambo seines (Figure 6 and 7): catch rates of *Oreochromis* spp. exhibited no trend with very little variability in yearly averages[1]. All other gears that catch *Oreochromis* but do not target them actively – stationary set gillnets catch the larger specimens, Kambuzi and Nkacha seines catch the juveniles as bycatch - do exhibit strong downward trends from 1984 onwards. This can only be explained if the fishing effort exerted by the Chambo seine fishery changed over this period, either by changing the gear (size), activity (more pulls per day, active hunting) or by changing the spatial coverage of the fishery. We have no information to decide on any of these possibilities, though it is known that shorelines were cleared to make the lake accessible for the beach seine fisheries. Gear activity changes are probable only if fishermen started fishing in shifts, as happened in Lake Mweru (Zwieten and Njaya, 2003) which may have occurred in Malombe as well (Weyl pers. obs.). The rapid increase in Chambo seine catch rates of Cyprinids (by a factor 28 over 15 years) and other spp. (by a factor 25 over 15 years), not repeated in any of the other gears, emphasizes that a change in effort – through gear size, gear use or spatial allocation of effort – must have taken place.

The drop in catch rates found in Kambuzi seines and gillnets shows that a comparable change in effort patterns did not take place in these gears. Annual variability for Kambuzi seines is high and highly significant: annual differences explain 47 percent of the variability. In

[1] The data series stopped in 1991, though the fishery in the lake stopped only in 1999, but not in the Upper Shire!

particular the drop in catch rate around 1987/88 and the subsequent increase to a peak in 1993 contribute to this (Figure 6). The pattern seen in the annual average total catch rates is reflected in all species groups (Figure 7): a low is reached between 1986 and 1987 and catch rates increased and stabilized after the collapse of the Chambo seine fishery from 1989 onwards.

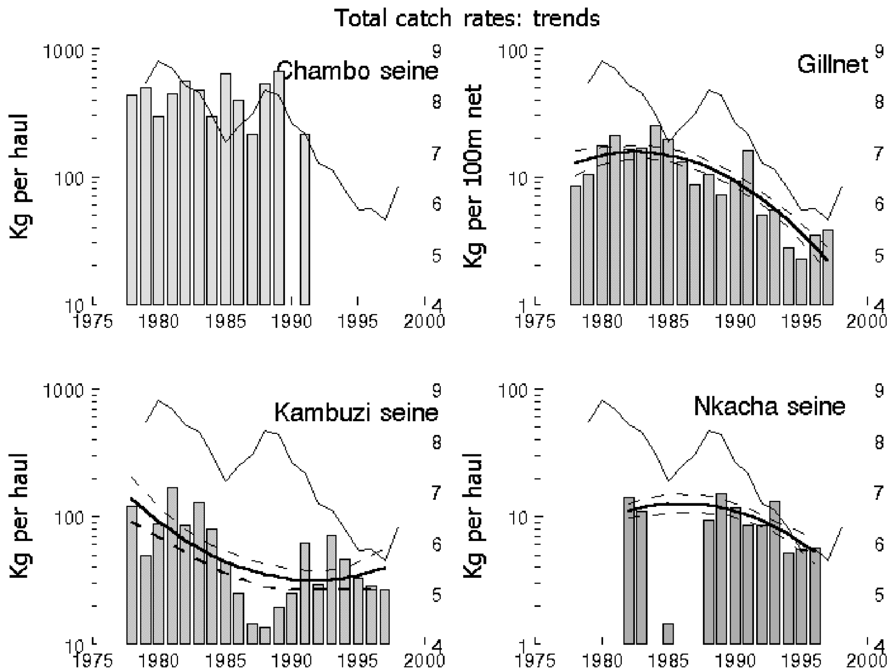

FIGURE 6. *Geometric mean annual catch rates (bars) by gear in Lake Malombe and polynomial trends (thick line). Trends are shown with 95 percent confidence limits (broken lines). The thin line is the relative mean annual water level of the lake.*

Gillnet catch rates show a less clear, but similar pattern with a drop in total (Figure 6) and *Oreochromis* catch rates (Figure 7) around 1987 followed by an increase up to 1991, after which catch rates collapsed by a factor 4-5. Gillnet total catch rates are composed of both a general decline and a shift in species dominance. The decline in total catch rates is dominated by the decline from 25 kg to 1 kg per 100 m net of *Oreochromis* catch rates from 1984 onwards. Catch rates of cyprinds increased and stabilized after 1989, while the category Other spp. remained relatively stable over the whole period peaking around 1985. The possible cause of the initial increase of catch rates of both Kambuzi seines and gillnets after 1987/88, could have been the release of pressure on fish-stocks as a result of the collapse of the Chambo seine fishery. However, as will be discussed later, this coincided with a period of increase in water level as well.

3.5 Basic uncertainty is extremely high

Basic uncertainty is defined as the variability remaining after removing the variability explained by a long-term trend and seasonality. It is the amount of variability around the long term-trend resulting from any other temporal, spatial or administrative source. When this variability is high on the aggregated level (by month) of the catch rate data analysed it indicates that trends will not be detected easily by the fisheries administration. Calculated on the level of the individual fisherman and on a daily basis it also indicates the randomness in

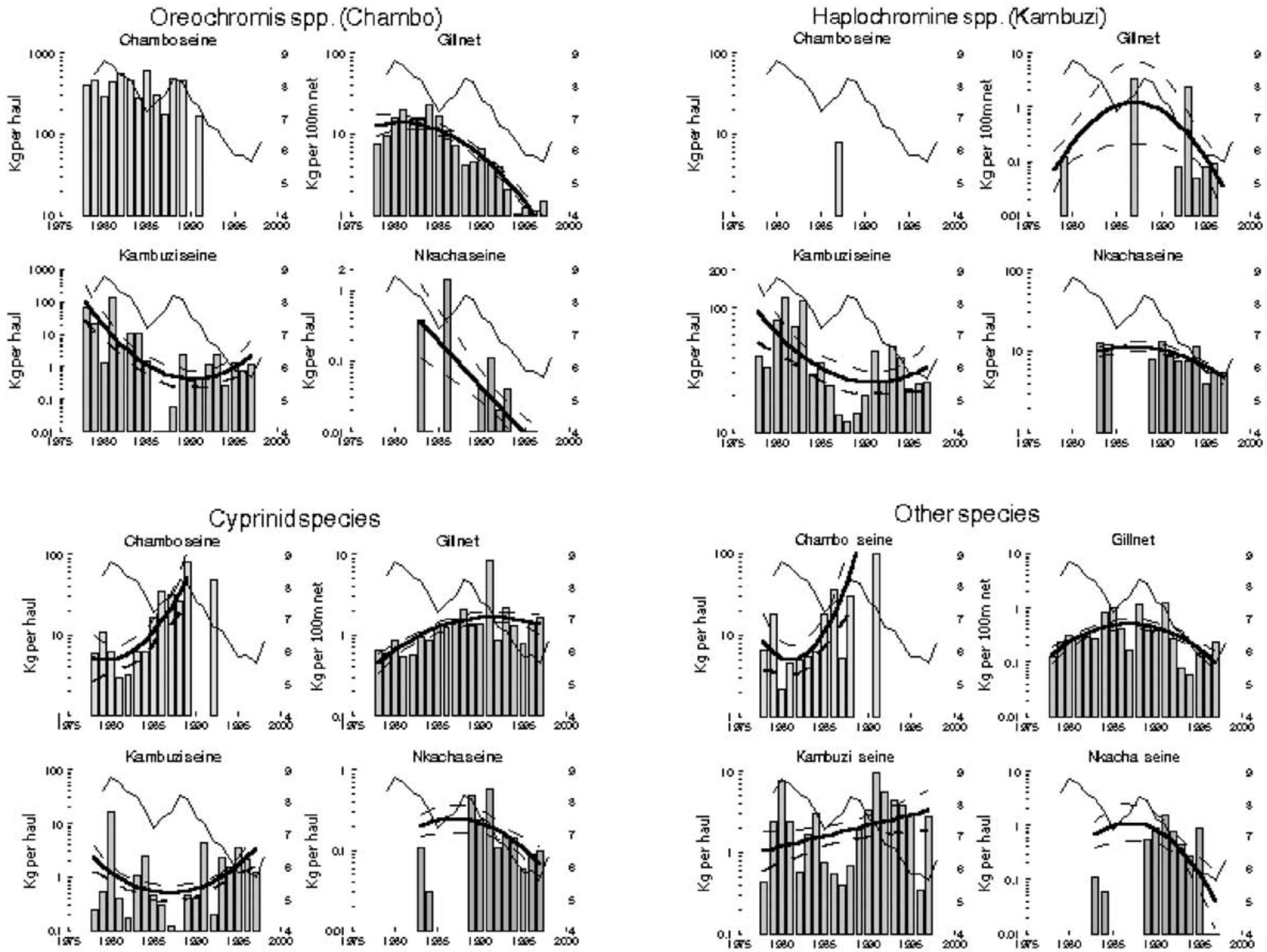

FIGURE 7. *Annual variation (bars) and polynomial trends (thick line) in geometric mean annual catch rates by species and by gear in lake Malombe. Trends are shown with 95% confidence limits (broken lines). The thin line is the relative mean annual water level of the lake.*

catches he has to deal with, i.e. variability in catches with no predictable patterns. This is an important indication of his limited capacity to observe spatial differences and temporal changes. At the same time it is an important factor to consider in the structural organization of the fishery (Oostenbrugge, *in press*).

On the aggregated administered level, basic uncertainty was high in all cases: 100 percent of the variability or a factor F = 4.5 around the mean total catch rates of Chambo seines, 55 percent for gillnets (F = 4.3), 82 percent for Kambuzi seines (F = 6.8) and 77 percent for Nkacha nets (F = 2.8). For target species of gears, basic uncertainty was sometimes lower – between 5 and 12 percent for *Oreochromis* , or was as high as or even higher than the total catch rates for haplochromines in Nkacha nets (74 percent) and in Kambuzi seines (91 percent). In other words the variability or noise around the long-term trend was high in all cases.

Basic uncertainty of Oreochromis catch rates in gillnets also became much higher after the collapse of the stocks: not only was the outcome of this fishery severely reduced, it became also much more unpredictable (Figure 8).

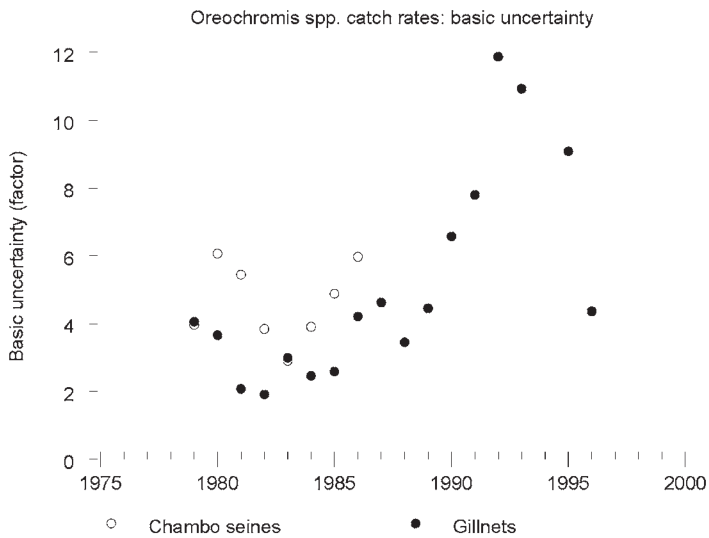

FIGURE 8. *Basic uncertainty in catch rates of Oreochromis spp. in gillnets and Chambo seines. Basic uncertainty is expressed as a factor around the geometric mean. Data points represent the factor around three year moving averages of the mean.*

3.6 Trend to noise: the administrative capacity to perceive trends

How fast can the fisheries administration decide on the direction of a long-term or short-term trend given the information at hand? Long-term linear downward trends, observed in three out of four time series of total catch rates were significant and statistically justifiable with 20 to 31 months of data (Table 3, Figure 9). Persistence, or non-random residuals that are auto-correlated at a time lag of one month, had little effect on the number of monthly data points needed, increasing by a mere one to two months (Figure 9). The trend-to-noise ratio was highest in Kambuzi seines, both in total catch rates as well as catch rates for the species groups, with 29 months of data points needed to detect a trend for Oreochromis, and between 40 and 44 months for all other species. For Nkacha seines the trend-to-noise ratio was lowest for Oreochromis and haplochromines. Thus for all time-series examined it is possible to significantly detect long and short-term trends in the various catch rate series within 1.5 to 2.5 years of monthly aggregated data. These time windows to detect a trend are not too bad, though it indicates a limit to the speed with which effects of management measures could be detected as the time lag that fish-stocks demonstrably react to measures taken needs to be taken into account as well.

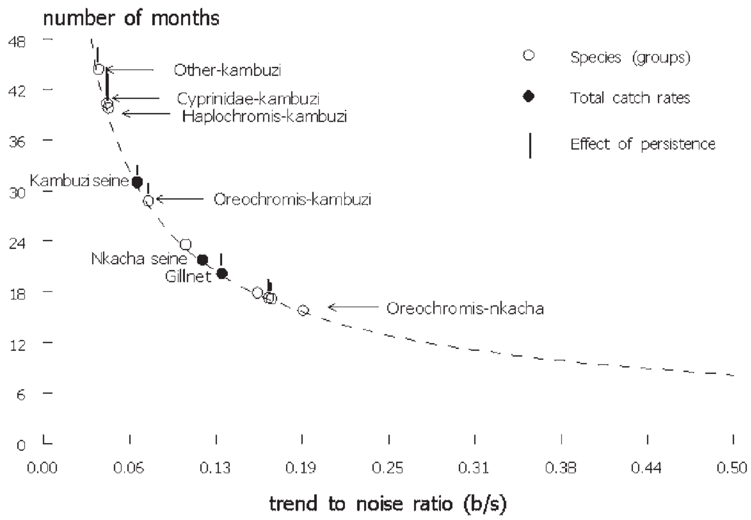

FIGURE 9. *The relation of the trend-to-noise ratio to the number of months of data needed to detect a trend in total catch rates and catch rates by species/gear combinations of including the effect of autocorrelation (persistence)*

How fast do long-term trends actually became visible in the data? For Kambuzi seines the long-term downward trend became statistically significant in 1984 and for gillnets three years later in 1987 (Figure 10a). Both remained negative from then onwards though increasingly less negative for Kambuzi seines after 1989. The long-term negative trend in Nkacha net catch rates became visible from 1993 onwards.

TABLE 3. *Trend, trend-to-noise ratio and number of months data needed to detect the observed linear trends with and without auto-correlation (persistence)*

Species	Gear	df	Trend (b)	Standard deviation (s)	Trend/noise (b/s)	N (months)	Autocorrelation coefficient (r)	N (months)
Total	Nkacha	87	-0.024	0.21	-0.12	22	0.33	23
	Kambuzi	194	-0.028	0.42	-0.07	31	0.42	33
	Gillnet	234	-0.041	0.31	-0.13	20	0.50	22
	Chambo	90	Ns				0.25	
Oreochromis	Nkacha	65	-0.133	0.71	-0.19	16	0.30	16
	Kambuzi	117	-0.083	1.09	-0.08	29	0.50	31
	Gillnet	231	-0.066	0.40	-0.16	17	0.53	19
	Chambo	90	ns				0.28	
Haplochromis	Nkacha	84	-0.030	0.19	-0.16	18	0.35	19
	Kambuzi	179	-0.021	0.46	-0.05	40	0.22	45
	Gillnet	12	ns					
	Chambo							
Cyprinidae	Nkacha	81	ns				0.45	
	Kambuzi	149	0.032	0.69	0.05	40	0.49	44
	Gillnet	232	0.025	0.36	0.07	31	0.38	33
	Chambo	74	0.087	0.53	0.16	17	0.50	19
Other	Nkacha	70	ns				0.68	
	Kambuzi	139	0.026	0.66	0.04	44	0.39	47
	Gillnet	189	ns				0.38	
	Chambo	70	0.064	0.62	0.10	24	0.17	24

However, investment or operational decisions as well as success of management measures are often to be considered in the short-term: both resource users and managers respond to short-term trends in particular. Many of the time series examined did not exhibit clear (significant) short-term – five-year – trends (Figure 10b). Catch rates in Chambo seines never exhibited upward or downward short-term trends. For gillnets this was the case in seven out of 16 five-year periods, for Kambuzi seines in five out of 16 and for Nkacha nets in one out of six. Furthermore, short-term trends in Kambuzi seines were much more erratic than those of gillnets, with much higher absolute trend-to-noise ratios. For instance trend-to-noise ratios flip-flopped from b/s= -0.67 to b/s=+0.56 between 1987 and 1991. Short-term trends are often not consistent between gears as well: for example in the five year periods before 1992 and 1993 Nkacha nets showed a downward trend, while over the same periods Kambuzi seines exhibited an upward trend while gillnets showed no trend. Some causation is hinted at in some of the short-term trends: as water-levels increased between 1985 and 1988, Kambuzi seines exhibited upward short-term trends in the five year periods before 1989 and 1993, while those in gillnet catch rates reverted from downward to upward over the same years.

In conclusion: long-term downward trends in catch rates became visible only after 1984 – 1987. The long-term pattern was confused by short-term patterns of increasing and decreasing trends, possibly as a result of environmentally favourable and unfavourable conditions, or as a result of large changes in fishing patterns. This will be discussed in the next paragraphs.

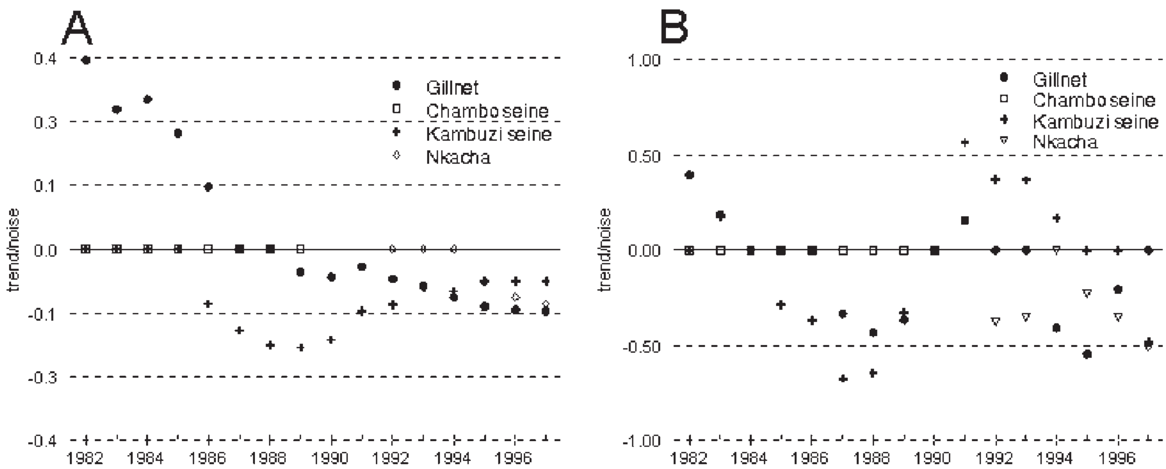

FIGURE 10A. *Long-term trends: development of the trend-to-noise ratio (b/s) in five years of catch rate data as observed in 1982 and onwards with successive addition of one year of monthly catch rate data for gillnets, Chambo, Kambuzi and Nkacha seines. 1982 is the b/s over 1977 to 1982; 1983 is b/s of 1978 – 1983 etc.* ***B****. Short-term trends: development of trend-to-noise over five year moving periods, each indicated by the last year*

3.7 Water levels were mostly decreasing from 1979 to 1998

When in 1915 Lake Malawi reached its historically lowest recorded lake level, a sand bar formed near Fort Johnston, present day Mangochi, and barred access to the Shire River. It brought to a halt its flow in all but the rainy season. By 1924, while the levels in Lake Malawi were rising, initially with no effect on the Shire River, most of Lake Malombe dried up almost entirely, "with food gardens being planted in large numbers on its bed" (McCracken, 1987).

After 1927 the water levels in Lake Malawi rose further still: in the years after 1934 the sand bar was swept away and Lake Malombe filled up again.

TABLE 4. *Cross-correlations between residuals of detrended annual average catch rates and detrended annual mean, minimum and maximum water levels of the Upper Shire at Mangochi. Analysis is done on total catch rates by gear and the target groups of the various gears. Regressions are done on lags with the highest significant correlation. N=number of observations, r^2 = proportion of explained variability, b= trend parameter. Significance is denoted by asterixes: * p<0.05, **p<0.01, ***p<0.001.*

Gear	CATCH	TREND					Cross-correlation						Regression on lags with highest correlation	
							Mean Water level		Minimum water level		Maximum Water level			
		N	R^2	s	b	p	Lag	Corr.	Lag	Corr.	Lag	Corr.	r^2	p
Gillnet	*Oreochromis*	19	0.85	0.156	-0.065	***	-4	0.43	-4	**0.48**	-4	0.38	0.26	*
	Cyprinidae	19	0.21	0.273	0.025	*	0	0.48	0	**0.54**	0	0.47	0.29	*
	Others					ns	0	**0.49**	-	-	0	0.45	0.24	*
Kambuzi	*Total*	19	0.29	0.323	-0.036	*	-2	**-0.80**	-2	-0.77	-2	-0.71	0.71	***
							-1	-0.77	-1	**-0.80**	-1	-0.68	0.64	***
	Oreochromis	19	-	-	-	ns	-2	-0.61	-2	**-0.70**	-2	-0.51	0.50	**
	Haplochromis	19	0.23	0.310	-0.029	*	-2	**-0.76**	-2	-0.74	-2	-0.67	0.64	***
							-1	-0.69	-1	**-0.74**	-1	-0.62	0.56	***
	Cyprinidae	19	-	-	-	ns	-1	-0.54	-1	**-0.58**	-1	-0.50	0.34	**
	Others	19	-	-	-	ns	-	-	-3	**-0.43**	-	-	0.37	*
Nkacha	*Total*	12	-	-	-	ns	-2	-0.79	-2	**-0.87**	-2	-0.76	0.67	**
	Cyprinidae	12	-	-	-	ns	-	-	0	0.63	-	-	0.53	*
Chambo	*Total*	12	0.64	0.281	-0.094	**	-	-	-1	**-0.54**	-	-	-	ns
	Oreochromis	12	0.66	0.296	-0.105	**	-	-	-1	**-0.54**	-	-	-	ns
	Cyprinidae	12	-	-	-	ns	-3	0.90	-3	**0.98**	-3	0.75	0.59	**
	Others	12	-	-	-	ns	-	-	-	-	-	-	-	-

Average annual water levels in the Upper Shire River near Mangochi, decreased by almost 1.5 m between 1980 and 1985, peaked in 1988 and continued to decline since then by almost 2.5 m reaching its lowest level in 1997. Over the period over which we are examining catch rates, a drop in average water levels of 3.5 m over 17 years, or 21 cm per year, took place (Figure 2A). Some contrast in the series, needed to be able to detect the effect of increased effort with changing water levels, is provided by a rise in water levels between 1985 and 1988, after which the drought of the early nineties commenced. Seasonal fluctuations vary around 90 cm per year with highest levels in April-May and lowest in November-December. Between years seasonal levels may vary between 20 and 45 cm during draw down, and much more during water level rises: in November and December minimum and maximum recorded levels could differ by up to 1m presumably depending on the onset of rains (Figure 2B).

3.8 Effect of changing water level detected in catch rates with a lag of 0–4 years

By excluding long-term trends in water-levels and catch rates and then cross-correlate or regress in steps (lags) of one year the residual variation – i.e. the variation around the long-term trends, gives an idea both of the size of the effect of changing water levels on changes in stocks and the period over which these effects become visible. The size of the effect is given by the amount of variation explained. Significant lags give an indication of the period. This can be calculated for the de-trended (=residual) time series of catch rates – indicating the speed of the reaction of stocks to changing conditions, as visible in the data. However, much more interesting is the size of such an effect of changing water levels in relation to the overall trend. Where an effect of changing water level on detrended catch rates could be detected, it explained between 3 percent and 50 percent of the residual variability in annual catch rates. For instance, approximately 26 percent of the residual catch rates of *Oreochromis* in gillnets were explained by minimum water levels with a lag of four years. But this effect amounted to the explanation of a mere three percent of the annual variability in mean catch rates: the effect is measurable but slight. In contrast, the effect in Kambuzi seines was much clearer. Highest significant regressions were found with minimum or mean levels one or two years earlier. These explained between 23 percent (*Oreochromis* – Kambuzi seines) to 71 percent (total catch rates – Kambuzi seines) of the residual variability, which amounted to a very significant 23 percent and 50 percent of the total variability in mean annual catch rates: in this case environmental effects clearly obscure the general trend, as could already be concluded from the discussion of the short-term trend-to-noise patterns. The effect in Nkacha seines was high as well, but only in total catch rates, that exhibited a negative regression with minimum water levels two years earlier, while cyprinids had a clear positive regression with this year's minimum water level.

Remarkable is that changing water levels affect catch rates in most species group and gear combinations negatively with a lag of one to three years. Negative correlations are found in minimum and mean water levels with Kambuzi seines, Chambo seines and Nkacha nets. In other words, high minimum or mean water levels seem to have a negative effect on catch rates one or two years later and vice-versa with low levels. An explanation could be that both Kambuzi seines and Nkacha nets target small species or juveniles of *Oreochromis* more effectively at periods of higher water levels resulting in lower recruitment a few years later, though it is not clear what could be the mechanism behind this. The exceptions are *Oreochromis* spp. caught by gillnets, where high water levels have a (expected) positive effect on catch rates four years later, and Cyprinidae caught by Chambo seines, with a positive effect three years later (Table 4). Gillnets with the mesh sizes used in the lake catch three-year-old *Oreochromis* spp.: high minimum water levels give increased production three to four years later.

3.9 Effort changes are relatively small in terms of number of operators…..

Fishing effort expressed as number of gear owners increased with around two percent per year over the period examined (Figure 11). This increase was mainly due to an increase in owners on the West side of the lake (app. 4.5 percent per year), whereas numbers on the East side remained relatively stable. Except gillnets, all main gears used in Malombe require high labour input in terms of numbers of people operating the gears. Judging from the statistics obtained during frame surveys the amount of labour input has only increased slightly, while a shift in activity has taken place from the East Side of the lake to the West Side. The number of assistants counted in the frame surveys varied between 1 400 and 2 841, but taken over the whole period only a slight positive trend was seen with an increase of 0.5 percent per year. But, while on the West Side of the lake numbers of assistants increased by 4.1 percent per year, numbers of assistants decreased at the East Side by 1.4 percent per year, indicating a shift in spatial allocation of effort.

3.10 …but changes in highly effective gears are dramatic

The effort development in terms of gear size or activity is unlike that of any of the other lakes investigated in this study (Kolding, Musando and Songore, 2003; Zwieten *et al.* 2002; Zwieten and Njaya, 2003). Four gears were important in the period from 1981 to 1999, but large shifts in numbers took place between these gears, with the result that presently only two gears are important in the fishery – gillnets and Nkacha nets (Figure 12)[1].

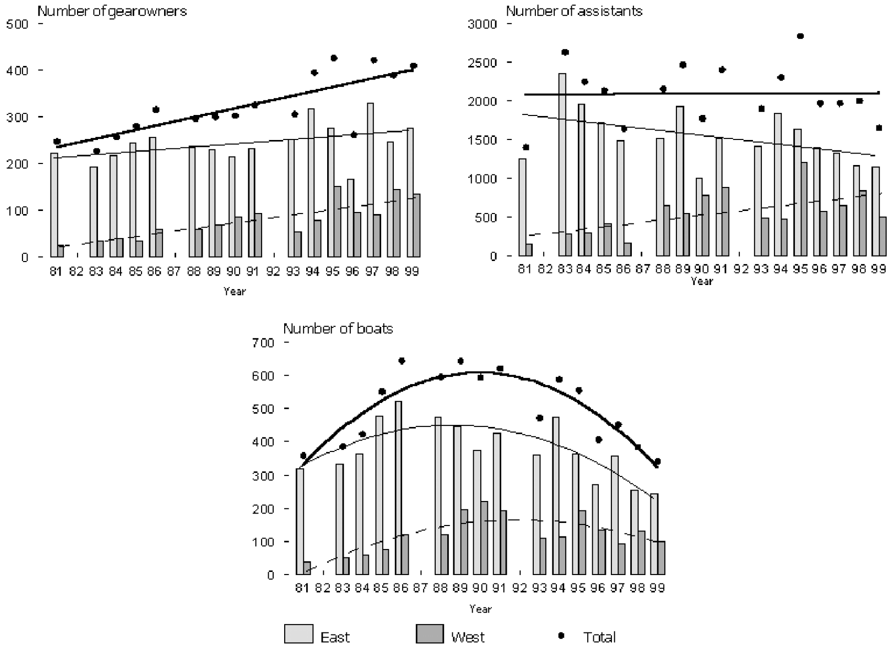

FIGURE 11. *Development in effort expressed as number of gear owners, number of assistants and number of boats in Lake Malombe. The bold line is the regression of the total numbers over time. The thin regression line refers to the numbers of eastern and the broken line is the regression of numbers of the western side of the lake.*

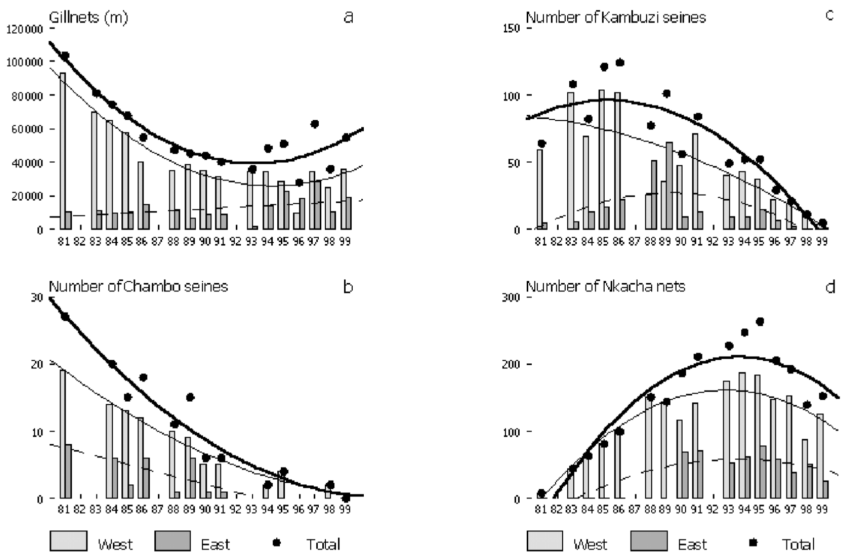

FIGURE 12. *Development in effort: number of gillnets,* Chambo *and* Kambuzi *seines, and* Nkacha *nets in Lake Malombe. The bold line is the regression of the total numbers over time; the thin regression line refers to the numbers on the eastern and the broken line to the numbers of western side of the lake. A Chambo seine net is made of approximately 750 m of gillnet. Material of one Kambuzi seine is estimated to make two Nkacha nets. Before 1989 Kambuzi seines and Nkacha nets were not recorded separately: numbers of both gears are reconstructed (see Appendix 2).*

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[1] See Hara and Jul-Larsen, 2003 for an explanation of these highly specific developments in Lake Malombe.

From 1981 onwards the number of gillnets dropped by more than 50 percent until 1991. Since then frame survey data exhibit a high variability with a slight increasing trend, particularly in West Malombe. The number of Chambo seines dropped from 27 in 1981 to 0 in 1999, with both East and West Malombe displaying a similar trend. Likewise the number of Kambuzi seines, peaking in numbers in 1986, dropped from 124 counted nets to five in 1999, with west Malombe lagging somewhat behind, as the number of seines peaked in 1989. Lastly, Nkacha nets, virtually non-existent around 1981, rapidly increased in numbers (7.5 percent per year) until 1995, when numbers dropped again. Frame survey statistics mention a number of other gears such as longlines, traps and various active gears (scoop nets, cast nets, mosquito nets and Chirimila nets).These do not seem to have much importance, though in particular traps and inexpensive active gears seem to gain some prominence in present years. This suggests that investment levels in boats and gears have decreased over time, which would be in accordance with a number of other observations that can be made based on frame survey data (Figure 13).

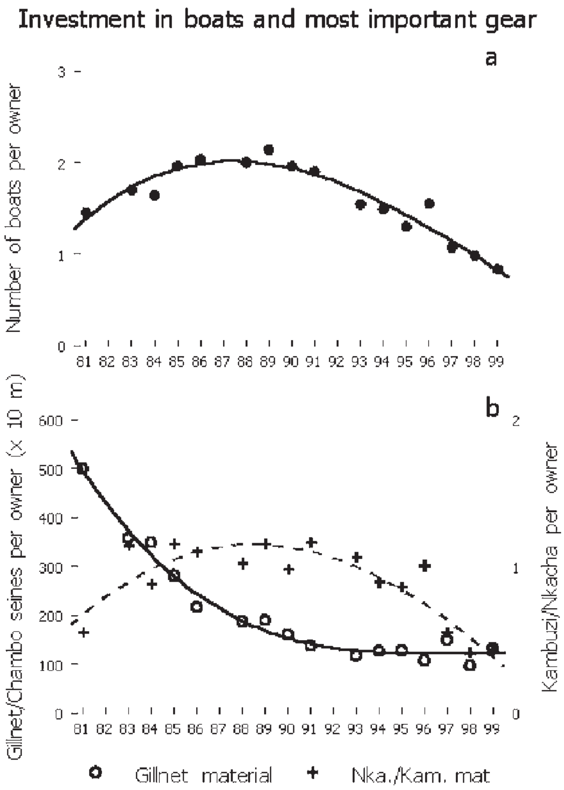

FIGURE 13. *Proportion of boats and netting material per owner as an indicator for development of investment levels in Lake Malombe*

The number of boats per owner increased from 1.5 in 1981 to 2.1 in 1989, and since has declined to less than one in 1998. Similarly, the total investment in material for Kambuzi seines and Nkacha nets increased until around 1988, and since has dropped to around the same levels as in 1981. Then, the amount of gillnets per owner dropped with a factor 5 to less then 100 m/owner in the 17 years from 1981. Lastly, the average number of assistants per owner decreases by around 30 percent over this period as well from 8.3 to 5.7, though data are highly variable due to the highly varying numbers of assistants counted (Figure 14). In other words, if these trends describe the developments in Malombe adequately, it would mean that fewer investments are done into gears for fishing activities that require a high labour input. If low investment gears indeed gain prominence, it can be concluded that the Malombe fishery has become poorer over the past 20 years (see also Hara and Jul-Larsen, 2003).

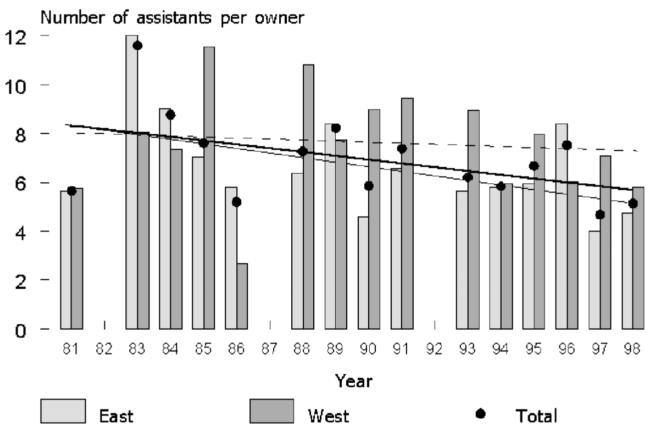

FIGURE 14. *Ratio of number of assistants and gear owners. The bold line is the regression of the total numbers over time. The thin regression line refers to the numbers of eastern and the broken line is the regression of numbers of the western side of the lake.*

3.11 Effort, water levels and catch rates

Changes in water level explained much of the annual variability in catch rates in gears targeting small species or juveniles; for those targeting older individuals – gillnets – changes explained only a small amount of the total annual variability (Table 4). The last result is rather surprising, were it not for the fact that a high technical interaction existed between gillnets and gears targeting the juveniles of *Oreochromis* spp. If a population recruits to different fisheries at different ages, the effect of year class variability induced by environmental variability will be reduced for the fishery targeting the older segment of the population.

Multiple regression explaining catch rates by the combined effect of effort, water level and its interaction was non-significant (Table 5) for any of the species groups and total catch rates examined in Nkacha seines and Chambo seines. For Nkacha seines the reason is clear: the series of annual average catch rates is short – from 1989 to 1997 – and coincided with a period of continuously declining annual average water levels: these two series were thus entirely confounded. With Chambo seines the problem is that change in the unit of effort over time renders any attempt to do this analysis impossible. For instance if the change in effort mainly was through a change in spatial coverage of the fishery, i.e. opening up new fishing grounds, an effect of annual variability caused by changing water levels, will be swamped under the effect of this change in effort. The noted increase in catch rate of non-target species in this fishery (Figure 7), with stable catch rates of the target species *Oreochromis* indicates the change in effort e.g. through larger spatial-coverage, which lead to fishing practices comparable to emptying a fishpond with seines.

Multiple regression models with number of gillnets as unit of effort and annual average catch rates of *Oreochromis* as explanatory variable either were confounded or gave counterintuitive results. Confounding means that depending on the order in which the two effects – water level and effort – enter the regression either of the two effects is significant while the other is not. Counterintuitive was the model result that indicated a positive sign to the effect of effort, implying that an increase in effort would result in an increase in catch rate. This puzzling effect can be explained if it is realized that the time series of catch rates of *Oreochromis* had a decreasing trend, while the number of gillnets was monotonously declining at the same time as well as water level – though the latter with some contrast. The decrease in catch rate was not the result of the gillnet fishery but of the Chambo fishery, though decreasing water level and associated productivity may have had an effect as well!

TABLE 5. *Proportion of variability in annual catch rates explained by the multiple regression model with water level (mean, maximum or minimum), with a lag phase of 2 – 4 years, fishing effort (number of gear) and their interaction as explanatory variables. The sign indicates the direction of the effect in the model. Analysis is done on total catch rates by gear and the main target species(groups) of the various gears. Only regressions explaining the largest amount of variability are shown. Df= degrees of freedom, SS = sum of squares, % = r^2 = proportion of explained variability, sign denotes the direction of the effect in the statistical model. Significance values are denoted by asterixes: * p<0.05, ** p<0.01, *** p<0.001*

Gear	Species	Model								Statistics of model				
		Water level				Gear		Interaction			Total error	Residual error	Total error explained by model	
			Lag	Sign	%	Sign	%	Sign	%	Df	SS	SS	%	
Gillnet	Oreochromis	Max	3	+	74	+	11			15	2.31	0.34	85	***
	Oreochromis	Min	4	--------- confounded ---------						14	2.10	------- confounded -------		
Kambuzi	Total	Mean	2	+	40	-	20			16	2.39	0.93	61	**
	Oreochromis	Min	2	+	32	-	21			16	22.70	10.40	54	**
	Haplochromis	Min	2	+	37	-	16			16	1.98	0.92	53	**

Only Kambuzi seine time-series behaved according to expectation: effort had a negative effect on catch rates, whereas the effect of water level was both positive and larger, i.e. explained more variation. That this result was reached with this gear should be qualified:

- In the course of the period studied Kambuzi seines both increased and decreased in numbers reaching a peak around 1986,
- The increase coincided both with a decrease and subsequent increase in water levels – the increase observed between 1985 and 1988 - and coincided with the peak in effort of Kambuzi seines which provided the contrast needed in the analysis,
- However, decreasing effort in Kambuzi seines coincided with both decreasing water level and decreasing effort of Chambo seines: a slight recovery of *Oreochromis* spp. during this last period will now be attributed to in particular this gear, as it has a similar spatial coverage as the Chambo seines.

Lastly from the analysis it can be concluded that Kambuzi seines catch species that are between one and two years of age.

3.12 No interaction between water levels and gears: no observed change in catchability

As argued by Zwieten and Njaya (2003), a significant interaction effect between gear and water level would represent a change in catchability of gears with changing water levels. Such an effect is not observed here, as the variability in water levels is much less extreme compared to Lake Chilwa, with the result that concentration of fish during receding water levels as occurs in this lake does not occur in Lake Malombe. Furthermore, two of the four gears of Malombe are used as active shore based gears. These shore-based gears are fishing in areas where concentrations of smaller fish are always present. A third gear, Nkacha nets, is an active boat based gear targeting small species and is thus are more dependent on recruitment effects than crowding effects.

4. CONCLUSION AND DISCUSSION

Does environmental variability matter? Lake Malombe presents an interesting and challenging case as it presents an example, still rare, of an African fishery that has collapsed as a result of overexploitation of its stocks. However, judging from the way fishing effort developed, it is also clear that it may represent a special case: a relatively small shallow lake has been fished with highly efficient gears that require a high investment. This is quite unlike many other similar small and medium African fisheries, where fishing effort develops more on the line of “more of the same” gears for which relatively low investment is needed. Unlike in Malombe many of these fisheries often still have under-exploited stocks. The answer therefore is no: environmental variability hardly matters where and when a complete mismatch between the scales of natural variability in fish production and human exploitation is reached through a highly efficient fishery.

But questions remains: did increased fishing effort on its own cause the collapse? Or was the collapse amplified by other factors? For instance, did habitat destruction and/or of changes in water level cause changes in productivity? Habit destruction is a side effect of the fishery itself, but has important consequences for the interpretation of our results. Sadly, not much is known about these effects as no information is available on the scale and rate of habitat destruction during the period of the collapse of *Oreochromis*. We also do not have direct evidence on changes in productivity but assume that fluctuating water levels causes them. In a small lake like Malombe the effect of surface runoff on productivity will be considerable. With highly seasonal water levels, with peaks during the rainy season, we could safely disregard the distinction between river inflow and surface, were it not that large changes in forest cover around the lake – as has occurred - not only increase the volume of surface runoff but also its sediment load, possibly bringing about structural changes in the bottom habitats of the lake.

We will now return to the two questions posed at the start of this paper and summarize our findings

- is there evidence for possible changes in productivity of Lake Malombe as a result of environmentally driven factors, such as changing water level?
- is it possible to detect the combined effects of productivity changes and increased effort through the existing monitoring of catch and effort and of water levels in Malawi?

4.1 Trend perception: The governance dilemma and the search for informative indicators

The high variability of the monthly catch rate information is, to a large extent, administratively induced (Appendix 3). After removing temporal effects (annual variability, seasonal variation) the remaining variability is about as high as in lake Chilwa (see Figure 2, Zwieten and Njaya, 2003). One of the results is that, while the high seasonal fluctuation in water level and runoff is expected to be reflected in the catch rates in particular of those gears targeting small species and juveniles, this is not the case in lake Malombe. Despite this conclusion, it is possible to detect long and short-term trends of statistical significance in the various catch rate series within 1.5 to 2.5 years of monthly aggregated data. These time windows to detect a trend are not too bad, though it indicates that there is a limit to the speed with which effects of management measures could be detected. This could be called a "governance dilemma" (Densen, 2001): the intended result of measures will take time anyway – a lag of 2–3 years – to take place (Pet, Machiels and Densen, 1996), but the number of years to detect an effect and causally attribute it to the measure taken will increase with increased natural and administratively induced variability. As the effect of a measure could be significantly detectable only after a long period – at least five years to a decade or longer, the proof of its effectiveness will be difficult to obtain, even if the necessity of the measures would be beyond doubt as in the case of Lake Malombe. Furthermore, though certainty on long-term trends could be obtained relatively fast – at least those of the magnitude discussed here, we have seen that short-term trends vary tremendously, in particular for the smaller haplochromines, which will make it difficult to decide on the causes of short run trends.

It should be noted that the analysis on trends was done on data aggregations by species. As a rule of thumb, observed variability expressed as CV will increase by $\sqrt{n}$, with n=the number of species in an aggregation, to obtain the average CV for the separate species, assuming lack of co-variation (Oostenbrugge *et al.*, 2002). With that assumption, the variability on a species level will be much higher. However, co-variation could be the rule in environmentally driven systems. In such a case species or species groups of which large amounts of information can be easily obtained could act as indicators for the state of all stocks.

4.2 Fluctuating water levels, effort and habitat

The effect of changing water levels on stock levels is large as it can be detected despite the high background noise in the data. Depending on the gear-target species combination the effect is detectable within 1–2 years for the small meshed seines and nets, and within 3–4 years for the larger meshed gillnets. Despite this, combined effects of fluctuating water levels and changing effort were difficult to detect, both due to problems of confounding of trends and of technical interactions between gears, in particular between gillnets and Chambo seines. The effect of Chambo seines on *Oreochromis*, exarcebated by the fishing on the juvenile part of the stock by Kambuzi seines, and in the early stages of the fishery with Nkacha nets as well, completely overshadowed possible effects of changing water level on the catch rates in gillnets. The catch rates in Kambuzi seines did show a clear combined effect of changing effort and fluctuating water level. This fishery was sensitive to short-term trends as it was fishing on the juvenile part of the *Oreochromis* stock. Both decreasing water levels and fishing effort may have caused the disappearance of submerged vegetation in the lake. If this habitat were important as nursery grounds for *Oreochromis*, it would mean that the level of the recovery of this species is dependent on the extent of restoration of this habitat.

The shift from gillnets (used in open water) and Chambo seines (used along the shore and in submerged vegetation) to Kambuzi seines (shore-based) and Nkacha nets (open water) is a shift from large species or specimens of species to smaller ones. The disappearance of *Oreochromis* from Nkacha nets indicates that the juvenile species disappeared from the open-water part of the lake – Mwakiyongo and Weyl (2001) found no change in species composition in Nkacha seines over the past ten years. The stabilization of juvenile *Oreochromis* in Kambuzi seines show that the species-group is still there and that juveniles are in in-shore areas.

Over the period examined only a limited increase in fishing effort in terms of people fishing is observed. Apart from that, two of the four gears, decrease in numbers and activity over this period, while a third - Nkacha seines – did so since 1987. The number of Nkacha nets and its activity levels has increased since the start of the series, but at present is decreasing and over the past year many operations have left Lake Malombe for the South-East arm of Lake Malawi or move between the two (Weyl, pers.obs.; Banda *et al*., 2002). Thus, the present situation of overexploitation has been caused mainly by the type of gear and their way of operation (fishing patterns), rather than demographic increase: in other words Lake Malombe does not present a case of Malthusian overfishing (Pauly, 1994), but is a case of over-investment in a fishery. With that the mode of exploitation of fish in lake Malombe seems fundamentally different from the mode of exploitation observed in the other fisheries reported on in this volume.

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Appendix 1: Data bases used and species grouping

1.1 Data used to examine trends and variability

- Monthly average catch rates by species (or species groups) and gear from 1978 - 1997,
- Fishing effort by gear, number of fishermen, assistants and boats from 1978 – 1999,
- Daily sampled catch rate and effort data from 1994 to 1998, and
- Daily water levels from 1976 to 1998.

Monthly catch and effort data were calculated from data collected through the CEDRS of Malombe and stored at the Monkey Bay Fisheries Unit, from where we obtained them. Frame survey data were obtained from the Mangochi Fisheries Office. From 1978 to 1993 the total monthly catch estimates were done using boats as unit of effort (see description in van Zwieten and Njaya 2003). In 1993 the system changed to the Malombe Traditional Fisheries (MTF) data collection system, in which monthly catch estimates are based on units of effort using gear size (gillnets) and gear activity (other gear). Daily sampled catch rate and effort data were obtained from the data as stored in the Mangochi Fisheries Office, and compiled by Weyl (1999) and Weyl *et al*. (2001). For a description of the methods of data collection in the Malawi CEDRS we refer to Alimoso (1991), FAO (1993) and Zwieten and Njaya 2003.

TABLE 6. *Species (groups) as distinguished in the CEDRS of Lake Malombe, percentage of total catch of a species by gear and % of total catch between 1981 and 1998. The last column indicates the grouping as used in this report.*

Species	Kambuzi Seine	Gillnet	Nkacha Seine	Chambo Seine	Other gear	% of total Catch	Category in this report
Kambuzi	65.1%	0.1%	32.4%	0.0%	1.7%	45.7%	Haplochromines
Chambo	1.5%	66.2%	0.4%	31.9%	0.0%	36.4%	Oreochromis
Other	43.1%	22.0%	27.3%	5.1%	2.0%	5.2%	Other
Utaka	63.3%	4.3%	28.6%	0.0%	0.2%	3.8%	Haplochromines
Other Tilapia	25.4%	44.9%	2.0%	27.8%	0.0%	3.7%	Oreochromis
Mlamba	17.8%	60.6%	12.4%	5.8%	3.2%	1.8%	Clariidae
Kampango	20.8%	60.7%	6.5%	11.3%	0.5%	1.7%	Bagridae
Mbaba	10.9%	0.9%	88.2%	0.0%	0.0%	0.9%	Haplochromines
Nchila	7.2%	83.0%	3.4%	6.4%	0.0%	0.6%	Cyprinidae
Usipa	18.1%	0.0%	5.0%	0.0%	76.9%	0.2%	Other
Kasawala	34.5%	0.1%	65.5%	0.0%	0.0%	0.0%	Oreochromis
Chisawasawa	38.2%	45.3%	16.5%	0.0%	0.0%	0.0%	Other
Sanjika	36.1%	35.9%	28.0%	0.0%	0.0%	0.0%	Cyprinidae
Mpasa	9.2%	56.3%	0.0%	34.5%	0.0%	0.0%	Cyprinidae
TOTAL	**36.6%**	**29.8%**	**18.7%**	**13.3%**	**1.2%**	**100.0%**	

Water levels are measured twice daily at the gauge in the Shire River at Mangochi. Average daily water levels from this station were obtained through the Water Department in Lilongwe. No lake levels of Malombe itself are available.

1.2 Species groups used in the analysis

The CEDRS distinguishes 14 species and species groups (Table 6. However, most of these species take up less than four percent of the total catch and therefore were combined in four species groups. “Kambuzi” is considered as cichlids other then “Chambo” of less then 8 cm. “Mbaba” are cichlids larger than 8 cm “Kasawala” is in general juvenile “Chambo”. “Other tilapia” is in general *Oreochromis shiranus*, a species not belonging to the “Chambo” complex.

Longlines and mosquito nets caught 1.2 percent of the catch as recorded in the CEDRS and were not considered here.

Appendix 2. Reconstruction of the number of Nkacha nets and Kambuzi seines

Before 1989 Kambuzi seines and Nkacha nets were not counted separately. To investigate the effects of changes in effort on the stocks, an estimate of the number in two types of gear was made, based on the assumption that from 1981 until 1989 both gears increased linearly in number over the years (Figure 15). Trend analysis of numbers of Kambuzi seines until 1991 where they were counted separately from Nkacha nets, of Nkacha nets after 1989, and of both gears combined before 1989 yielded three linear regressions. Adding up the estimated numbers from the regressions of Nkacha nets and Kambuzi seines yielded reconstructed numbers of both gears combined that were close to the actual numbers of both gears combined. By subtracting the estimated number of Nkacha seines from these numbers of combined gears an estimate for the number of Kambuzi seines before 1988 was obtained.

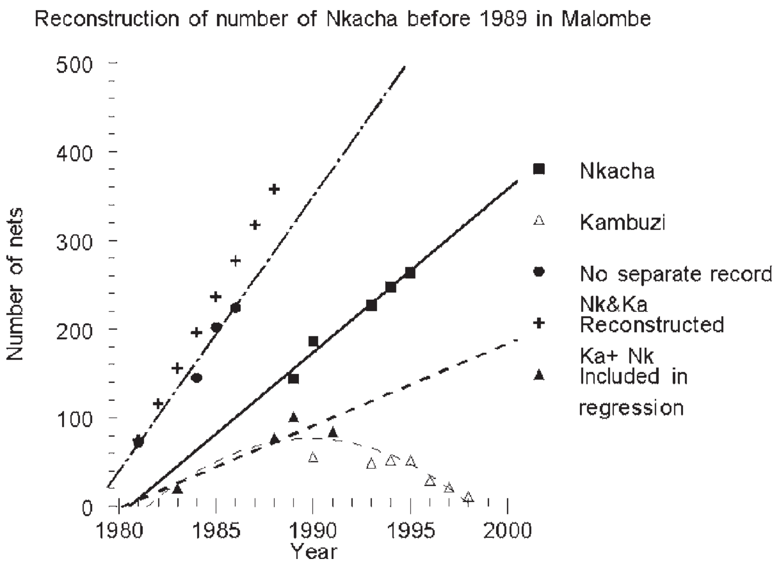

FIGURE 15. *Reconstruction of the number of* Nkacha *nets and* Kambuzi *seines between 1981 and 1989. See text for explanation*

Appendix 3: Analysis of variability in catch rates: effect of administrative error and aggregation

The total variability in the monthly mean catch rates series from 1978 to 1997 was high. For instance, the variance in catch rates of gillnets was 0.15 (=^{10}log s^2, see Table 1, main text), corresponding with a coefficient of variability (CV = standard deviation*100/mean) of 110 percent, estimated through CV = 100*√($10^{2.303*variance}$-1). This represents the variability of data aggregated over strata, fishermen, month and species. Aggregation in principle reduces variability: dis-aggregation over month and fishermen to daily catch rates of the estimated variability of CV= 110 percent would result in a CV that is outside the experience of any gillnet fishery. In general gillnet fisheries show variability in basic uncertainty of daily catches ranging between 50 percent and 80 percent (Densen, 2001). Daily catches as experienced by gillnet fishermen with a CV of for instance 80 percent would translate in an aggregated monthly CV of around 15 percent. Three sources of variability can account for this: (1) inter-annual variability – including trends (2) seasonal variability and (3) errors in data collection and handling or in other words “administratively induced” variability. Removing inter-annual and seasonal variability reduces the variance to 0.063 (Table 2), which calculates to a CV = 63 percent. This basic uncertainty at the aggregated level thus is still too high and can only be administratively induced. We will examine the causes of this type of error.

Digitized daily catch rates from the gillnet and Nkacha fishery obtained in the MTF from 1994 to 1998 were examined to assess the effect of outliers resulting from administrative errors in the data on the CV. The series contained both catch and effort data (number of hauls and length of the net). The data series contained daily catch rates of 3 031 gillnet and 7 901 Nkacha seine recordings, effort expressed as size of the net and, in case of Nkacha nets, number of pulls as well. From these sets random samples of 30 data were taken without replacement (Jack-knife procedure) repeated 30 times. This procedure was carried out both with the raw sampled catch rate data and the same catch rate data corrected for effort. Mean, standard deviation and CV were calculated for each sample and a frequency distribution of CV’s was obtained (Figure 16).

The mode of the distribution of CV’s in raw daily catch rate data in gillnets is at CV = 70 percent, which falls within the range observed in other gillnet fisheries. But, the average CV of the original series of sampled catch rates is 136 percent. Taking into account monthly and annual variance reduced this to a CV = 104 percent, indicating that the outliers in the distribution cause the remaining excess variability. The mode of the frequency distribution of CV’s calculated from the random samples increased slightly when corrected for effort. However, the average CV for the corrected series increases considerably to 190 percent. Removing monthly and annual variability reduced this CV to 110 percent, indicating again that outliers cause the excess variability. Aggregation of the corrected catch rates over months according to the procedure followed by the Malawi fisheries information system reduced the CV to 50 percent. This is somewhat lower than the CV = 63 percent of the basic uncertainty (i.e. with trend and seasonality removed) in monthly average catch rates of the complete series from gillnets analysed in this paper, while this behaviour is close to the expected reduction in CV through aggregation by multiplication with √a (with “ a” the level of aggregation, under the condition of independence of data). Annual variability in the monthly average catch rates calculated from the daily samples was significant, but the CV did not reduce when corrected for this source of variability.

Sampled catch rates in Nkacha nets exhibit more or less the same behaviour, though the distributions show less outliers: the mode of both the corrected and uncorrected distributions is CV = 80 percent. Average CV of the raw catch rate data = 92 percent, increasing only slightly to 96 percent as a result of correction by effort. However, aggregation of corrected catch rates over month only lowers the CV to 50 percent, more than twice as high than would be expected based on the theoretical behavior of the CV through aggregation. Removing significant annual variability reduced the CV to 34 percent, somewhat closer to the expected value. In other words, both examples show that outliers have a strong effect on the total variability of the data. The examples of gillnets and Nkacha nets were chosen as they clearly showed the narrow range of CV's to be expected from samples of daily catch rates of a reasonably well defined gear. Both for Kambuzi seines and Chambo seines this range was much broader both for sampled catch rates and corrected catch rates, though in both cases with a mode not much different from Nkacha nets. This indicates that a much less well-defined unit (gear size and activity) from which the daily catch rate samples are taken induces a lot variability.

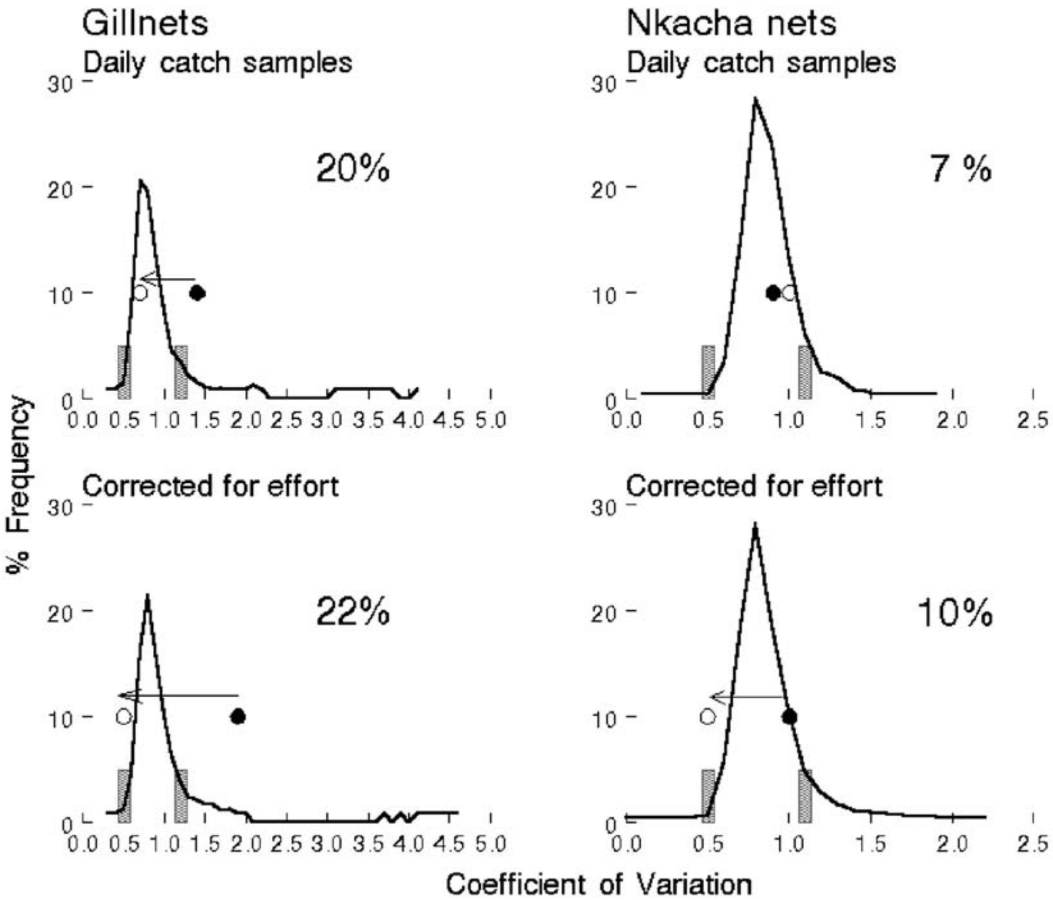

FIGURE 16. *(Top): % Frequency distribution of coefficients of variation (CV) calculated from 30 repeated random samples without replacement of daily catch rate samples from gillnets and* Nkacha *nets in the CEDRS of Malombe between 1994 and 1998. (Bottom): Same but sampled catch rates corrected for effort. The areas outside the vertical bars are outliers, the percentage outliers are indicated in each graph. Black dots: CV of the complete data set, open circles CV of the same data aggregated by month. See text for further explanation*

Probably, most of the high variability in the total series is caused both by administrative errors in data collection and handling and the effect of correction and raising factors. The behavior of the data from 1994 to 1998 in the MTF differs not much from the complete monthly catch rate series analysed here which is based on two different data collection systems. As there is no reason to believe that the administratively induced error changes over time it can be considered random.

TECHNOLOGICAL CHANGE AND ECONOMIES OF SCALE IN THE HISTORY OF MWERU-LUAPULA'S FISHERY (ZAMBIA AND DEMOCRATIC REPUBLIC OF CONGO)

David Gordon

Common Property Theory (CPT) has been an easy picking ground for social scientists since Scott Gordon first outlined the economic theory of fisheries and Garrett Hardin developed the analysis into the "tragedy of the commons" in 1968 (Gordon, 1954; Hardin, 1968). In a parody of the theory, criticisms of CPT have become so commonplace that each successive article holds much-diminished academic returns (McCay and Acheson, 1987). In an exceptional case, Ottar Brox, a scholar of the Norwegian fisheries, has launched a qualified defence of CPT. He argues that CPT should be treated as an analytical tool, a Weberian "Idealtypus", which models certain features of the real world to present an idea of reality rather than "real nature". However, Brox points out that the CPT model may blind us to other features of common property regimes. It ignores how local class and power relations mediate resource access since all resource users are assumed to be equal economic agents. Moreover, the tendency to focus on tragedy "prevents one from seeing that commons involve opportunities which are far from tragic for the people involved, but rather necessary for the maintenance of local communities and even national cultures. . . . CPT closes our eyes to the potential of common property to absorb surplus labour, function as a "safety valve" on the labour market and establish a floor under which wages or land rents cannot sink" (Brox, 1990: 232-3).

Brox argues that by distinguishing between "horizontal effort" (changes in the number of fishers) and "vertical effort" (changes in capital investment) we provide greater clarity to the class relations which underpin the economic and environmental process described by CPT. However, fishery biologists associate a different meaning to vertical and horizontal changes in effort. For them, vertical change in effort refers to changes in gear technology that increase catches and horizontal increases refer to an increase in the amount of similar gear that may increase catches. This article demonstrates that changes in technology need not be associated with Brox's changes in capital investment. It argues that the technological changes need not be associated with vertical increase in effort; changes in technology do not necessarily correspond to the capitalization of the fishery.

Distinctions in effort type seem especially appropriate to fisheries in Africa frequently exploited by poor and economically vulnerable social groups, either as fishers, labourers or traders. Small-scale fishing entrepreneurs benefit from easy access to resources that require relatively little labour or capital investment and at present do not have strong traditional or state controls over exploitation. This has led to great increases in the fishing population, that is horizontal changes in effort, with fisheries officials complaining of "overfishing" by locals and leading to socio-political struggles over the introduction of conservation regulations, which, for lack of state capacity in the countryside, are frequently defied by fishers (Aarnink, 1999). Yet fishers in Africa tend to adjust and incorporate technologies and fishing gear changes without necessarily becoming capitalist enterprises. Thus, in contrast to Brox's theory, technological change need not correspond to vertical changes in effort but can also be linked of a growing number of individuals who choose to fish due to lack of alternatives in either salaried employment or agriculture.

In this article I focus on changes over time in the vertical and horizontal growth of fishing effort in Mweru-Luapula. Over the last century the fishery has emerged as a common resource, which in times of need, such as economic recession and structural adjustments in the 1990s, provides Zambians and Congolese with an informal safety net. In periods of prosperity, the fishery may be an arena of profitable investment; during times of recession, however, the more important function of the fishery has been to provide a means of economic subsistence. In the 1990s the fishery acts as a form of unemployment insurance for those without jobs and without the means to farm (Gordon, 2000).

The Mweru-Luapula fishery is found on the border of Zambia and Democratic Republic of Congo (DRC). It is presently divided between two national administrations and a number of different autochthonous and migrant peoples. The unity of the area is primarily geographic; a valley bounded by escarpments to the east and west. Lake Mweru is some 120 kilometers long and 40 to 50 kilometers wide (a total area of 4 650 km^2), fed by the Luapula River. The lake and river form the southern-most section of the vast Congo drainage basin. The population of the valley has grown from about 50 000 in the 1920s to about 400 000 in the 1990s, an increase roughly in proportion to the national populations of Zambia and Congo, with at least 50 000 involved in fishing as gear owners, workers or traders.[1] In the 1990s the south of the valley was so densely-populated that there was little empty land; one village led directly into the next, and vacant land for cultivation could only be found several miles towards the plateau. The most important economic activities were cassava farming and fishing. Cassava farming was essential for local subsistence and fishing for a commercial economy linked to the towns of the Zambian and Congolese copperbelts.

Mweru-Luapula was not an *a priori* open-access common resource. Traditional settlement patterns and rights over resource exploitation had long been established. Certain aspects of these rights were reinforced in the colonial period by the machinations of Indirect Rule in the British case or *dominer pour servir* ("dominate to serve") for the Belgians. For the most part, however, fisheries officials and expatriate fishermen and traders undermined traditional restrictions to entry by replacing sacred Owners of the Lagoon with secular bureaucratic forms of government. A sudden vertical increase in effort in the 1940s led to the collapse of the lake's most important species in the 1950s. Yet increased exploitation of a smaller fish allowed for the resurgence of fishing activity from the 1970s. The new fishery was characterized by horizontal increases in effort as migrants from the declining urban areas became fishermen and women with decreasing access to farm land and fertilizer became fish traders.

1. PRE-COLONIAL RESOURCE MANAGEMENT

It is unclear when the first people settled in Mweru-Luapula. They were probably BaTwa, so-called "pygmies". Archaeological and linguistic evidence suggests iron-working people organized in matrilineal clans migrated into the region between 1 000 and 1 500 years ago. According to oral traditions, they set fire to a vast grass plain, which killed all but two of the original inhabitants who then bestowed the rights of the land to the new settlers. These rights were to be maintained through membership of a secret organization called *ubu-twa*. After the last Twa died, it rained until the plain became a lake so vast that the locusts could not cross it (Cunnison, 1959; Musambachime nd., 1991; Verbeek 1990).

[1] These are estimates based on a variety of sources. Since the fishery is split between two administrations and part of several different districts, it is difficult to compile accurate figures (Gould, 1989: 22-44; Zambia, 1980; Zaire, 1984).

The most significant pre-colonial event recorded in oral testimony was the conquest of the valley by a Lunda lord called Mwata Kazembe in the early eighteenth century. Over the next century he created a powerful empire that traded with the Swahili and the Portuguese on the Indian ocean coast and the Nuclear Lunda to the western interior. He also brought cassava from the Nuclear Lunda, which began to replace millet as the most important crop of the valley. As cassava replaced millet, women became more responsible for farming. Cassava did not require as much fertilizer as millet and thus there was less need for male labour to practise *citemene* agriculture, which had provided the soil with the nutrients needed for millet cultivation. Instead, men were involved in fishing and during the nineteenth century in the ivory and slave trades. Cassava farming and the relative absence of male labour in agriculture distinguished the Luapula Valley from the "Bemba" of the plateau area, traditionally renowned for millet cultivation in citemene fields (Richards, 1939; Moore and Vaughan, 1994).

Despite the reputation of the Eastern Lunda ivory and slave trading kingdom, the more important forms of resource regulation and allocation were decentralized and linked to sacred forms control by local leaders. Matrilineal clan leaders exerted a combination of spiritual and political power over the resources of the valley. They maintained authority over the land and lake through *ubutwa*, which paid deference to the ancestral spirits (*imipashi)* and nature spirits (*ngulu)* of the land and lakes. In the river area where fish spawned and were easy to catch with traps and floating nets, local leaders called Owners of the Lagoon (*Bamwine Kabanda*) marked out distinct areas of control. By prayer and giving libations, they ensured that nature continued to perform life-sustaining miracles such as the spawning of fish. Only after the correct rituals had been performed and the fishery "opened" (*kufungule isabi*) could fishers begin to harvest nature's bounty. It was primarily this form of sacred control that placed certain restraints on resource exploitation, although this was not its primary concern.[1]

In the actual catching of fish, there was little ethic of moderation. Fishermen in canoes caught spawning fish with floating nets in the river. Nearer the rapids and falls of Mambilima, villagers built dams and weirs (*amaamba* sg. *ubwaamba*) and installed traps (*imyoono* sg. *umoono*) to catch fish as the flood waters receded. Traps and nets were to catch everything they came across, like a hen that pecks at every last scrap, as indicated by this popular fishing song:

> You are the hen who searches in the rubbish pits
> look from one side to the other.
> You are the pecking beak of a hen
> that leaves nothing in the way (Musambachime, 1981:53).

Fishermen even attached parts of a hen to their nets to invoke the spirit of a hungry hen. However, although fishermen caught as much as they could, certain technological limitations and ecological conditions checked levels of exploitation. The *kaboko* fibers out of which nets were made were not as durable as nylon and easily broke. Crocodiles and hippos often destroyed nets that took weeks to manufacture. The number of nets and other fishing gear a fisher owned depended on the limited labour he could mobilize and control, and, for this reason, there was little vertical growth in effort in the form of capital accumulation and investment.

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[1] Interviews: Chief Mulundu and Traditional Councillor, Mulundu, 9 Jan. 1998; Chief Lubunda and Traditional Councillors, Lubunda, 8 Oct. 1997; Chief Mununga and Traditional Councillors, Mununga 16 June 1998. Also Musambachime, 1981: Vol 2: 2,13, 25.

2. COLONIAL CAPITALISM

It was only well after colonial “pacification”, accomplished in the early 1900s, that new trading networks emerged, based on an entirely novel political economy. The Katangan copper mining concern, *Union minière du Haut-Katanga* (UMHK), had to ensure a steady supply of cheap rations for their recruited workers. They built a road that joined Mweru-Luapula to the fast-growing town of Elisabethville (present-day Lubumbashi). The monetary value of the valley’s fish soared as a labour force attached to the new copper mines had to be fed. Entrepreneurs – locals and expatriates generally from Greece and Italy – came to exploit the fishing resource.

In the Belgian Congo (present-day Democratic Republic of Congo), where the administration distrusted African traders, large-scale expatriate traders were the main beneficiaries of the fishing business from the 1920s to 1940s. In Northern Rhodesia (present-day Zambia), however, where colonial control was more tenuous, many African businessmen and fishermen also prospered, and a monetized economy based on Congolese francs spread to both sides of the river. Traders and fishermen were predominantly male, although through barter the female cassava-farming economy was linked to the booming fishery. Moreover, female labour was needed to dry and smoke the fish.[1]

With increasing profitability and commercialization, the fishery became oriented towards the fresh fish trade and dominated by male traders. Ice plants were established next to the river and lake, first in the Congo, but later in Northern Rhodesia. Despite technological innovations in processing, at first increase in effort was horizontal. Predominantly expatriate traders bought fish along the Luapula where many African fishermen, locals and migrants from the plateau areas, had set up camps. They fished with weirs and traps and with nets made out of fibre taken from old motor tyres. Although this represented a certain degree of technological innovation, colonial reports suggest that the number of fishermen increased dramatically. Colonial administrators became increasingly concerned with fishing camps full of “uncontrolled and detribalized natives concentrated for the sole purpose of making money.”[2] In the catching of fish, at least, prior 1940 there had been little vertical growth in effort despite the significant growth of capitalized trading ventures.

Traditional restrictions enforced by Owners of Lagoon were undermined. Colonial officials appointed a network of chiefs to exercise power and these did not always correspond to the original Owners of the Lagoons. On the Northern Rhodesian side of the lake, colonial officials selected Mwata Kazembe and his subordinates as colonial chiefs since it was easier for the colonial administration to collaborate with a centralized ruler who would ensure that his subordinates respected and carried out colonial laws. Native Authorities became responsible for the enforcement of fishing regulations, and, most importantly, they received revenue from net licenses. This provided a major incentive for chiefly collaboration regarding fisheries. It was not, however, built on any traditional precedents: Mwata Kazembe had previously not shared the rights and responsibilities of traditional Owners of the Lagoon.[3]

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[1] The early history of the fishery is reconstructed through interviews conducted by the author and archival sources based in the National Archives of Zambia (NAZ) and the Archives Africaines (AA) in Belgium. For details see Gordon, 2000: 101-147 and Musambachim, 1981.

[2] Kawambwa Tour Report 5/1938, NAZ, SEC 2/872.

[3] This process was made possible through the Native Authorities and Native Courts Ordinance in 1929 and the Native Treasuries Ordinance in 1936. In Luapula, the process was accentuated with the appointment of Mwata Kazembe XIV Shadreck Chinyanta who was an educated and appreciated collaborator. Conflict with chiefs, especially Lubunda, Mulundu and Katuta Kambemba, who were subordinated to the Lunda Native Authority but were not traditionally Lunda, were frequent. Colonial policies are recorded in Kawambwa Tour Reports, 1936-1960, NAZ SEC 2/871-886 and NP 2/6/8-17, Lunda Native Government, NP 2/7/13. For conflict between Lunda and other chiefs see "Note on the Bena Mbeba and their Pretensions", Kawambwa District Notebooks, NAZ KSG 3/1. Also Interview with Mwata Kazembe XVIII Munona, Mwansabombwe, 19 Oct. 1997.

On the Belgian side of the river, colonial administrators were more heavy-handed; chiefs had less autonomy and were more reliant on the colonial state. In Mweru-Luapula, at least, the Belgian administration relied on dispersed chiefs, nineteen in total compared to the nine chiefs found in approximately the same area in Northern Rhodesia. When the Belgians attempted to rationalize their administrations in 1933, they appointed chiefs loyal to the colonial administration to head *secteurs*. At the same time, the state bureaucracy became responsible for control over fisheries with the formation of a *fonds poisson* and *mission piscicole* in 1946. These agencies were also responsible for sponsoring more advanced fishing technology, including the sale of nylon nets and establishing a fishing and boat-building school.[1]

The Belgian and the British administrations treated the resource in different ways. For the Belgians, the resource was open to all for exploitation. The British, by contrast, proclaimed the area "Native Trust", meaning that only indigenous fishermen could exploit the resource. The Belgians argued that such a policy prevented capital accumulation and improved fishing methods; the British countered that the development of the fishery should occur at a pace dictated by "native interests." In the Lugardian words of the British colonial official responsible for fisheries:

> They [the Belgians] look over the heads of the Africans; we must try to look through the Native Authorities. They draw no distinction between European and African fishing; we regard the fishery as in trust for the Africans.[2]

From the Belgian perspective, European investment in the fishery was desirable. "If one day the Natives will be able to fish in the lake," the Commissioner of Katanga Province argued, "the Europeans will have shown the way to fish."[3] The choice was between encouraging vertical growth in effort at the expense of undercapitalized indigenous fishermen or accepting a slower pace of vertical growth in effort by prohibiting outside investment in the fishery. The Belgian assumption was that technological innovation depended on the capitalization of the fishery and could not be accomplished by poor African fishers.

During the Second World War when the Allies required Katanga's copper and uranium resources for the war effort, exploitation of the resource increased. The fish of Luapula became even more crucial as cheap rations for urban workers. Africans could not even be trusted to fish. The Belgians encouraged the settlement of capitalized European fishermen who would exploit the fishery to its full potential without the threat of political instability.[4]

There was one environmental obstacle to the development of the fishery – crocodiles. In a fashion similar to the destruction of farms by elephants, crocodiles prevented growth in fisheries technology throughout much of central Africa by destroying long nets and thereby discouraging capital investment in better nets. In 1944 UMHK introduced a bounty for the capture of crocodiles – by 1946, 5 000 crocodile heads and 60 000 eggs were delivered to the administrative posts of Mweru-Luapula. After a few years, the crocodile no longer obstructed fisheries development; the bounty was abolished but numbers of crocodiles never returned to

[1] The creation of the fonds poisson and mission piscicole is documented in Mission piscicole divers and Rapports annuels, AA, IPAC AGRI 14.210-228. For documentation on the appointment and organization of chiefs in Mweru-Luapula see Chefferies Luapula-Moëro Dossiers Kasenga, Pweto, AA IPAC 14.160. Affaires Indigène et Main d'Oeuvre (AIMO) Rapports Territoire Kasenga, 1932-1950, AA RA/AIMO 106, Territoire Pweto, RA/AIMO 162.

[2] Director of Game and Tsetse to Member for Agriculture, 13 March 1953, NAZ, SEC 6/372.

[3] M. Scholler, Commissiare Provinciale du Katanga, Minutes of the Anglo-Belgian Fisheries Conference, Ft. Rosebery, 29 June 1953, NAZ, SEC 6/13.

[4] One of the reasons behind the creation of the fonds poisson and mission piscicole in the immediate post-War years was the recognition that the exploitation of the fishery was so crucial to the mining profits. Mission piscicole, Elisabethville, 1945-1948, AA, IPAC AGRI 14.210

pre-1944 levels.[1] Once crocodiles were no longer an obstacle, fishermen who had the capital, mostly Greeks, could lay bottom-set nets across the lagoons where the Luapula entered Lake Mweru and effectively block the spawning of the most profitable commercial species, the mpumbu (*Labeo altivelis*). Prior to 1947, African fishermen caught most mpumbu as they spawned in the river, after flooding in February and early March. But in 1946-47 catching techniques of mpumbu changed. European fishermen laid their long nets in Lake Mweru from July to December, when the mpumbu gathered at the inlet of Luapula before they spawned. The change is best demonstrated by considering the number of mpumbu purchased by UMHK The high catches between January and March in 1945–46 represent fish caught by small-scale African fishermen in the Luapula River during the spawning season using traditional gear. The trend in the late 1940s, however, was for increased catches in the July to December period, when the mpumbu gathered in Lake Mweru prior to spawning. This represented increased European fishing with motorized boats and nylon gillnets. In 1948 catches during this period far exceeded catches during the previous spawning seasons. In 1949, after the huge lake catches between August and December 1948, the mpumbu did not spawn.

When the number of mpumbu declined, the colonial administrators paid greater attention to the enforcement of conservation measures. Colonial efforts to conserve the fishery pre-date the disappearance of the mpumbu. In 1938 the Belgian administration had introduced a closed season, a restriction on the mesh size of nets, and a tax on nets. Yet all fishers and *commerçants*

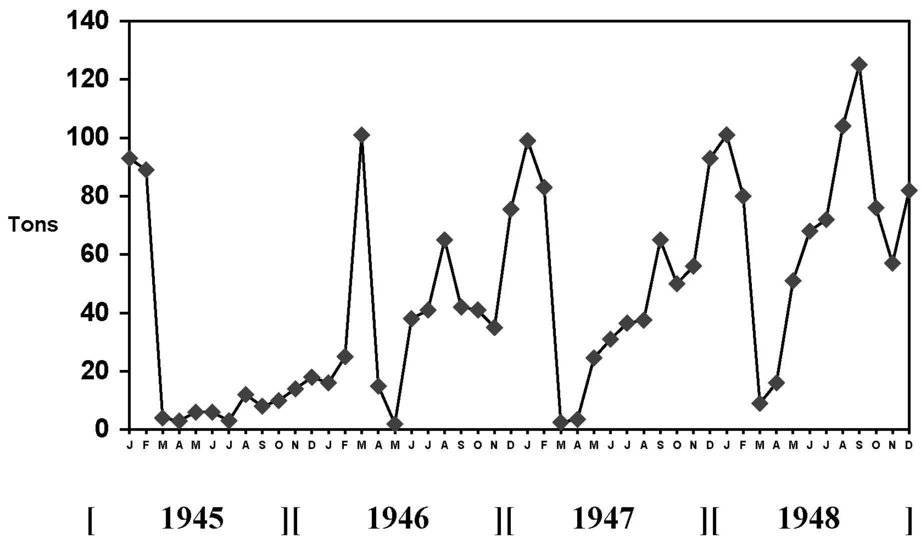

FIGURE 1 *UMHK Purchases of Mpumbu from Mweru-Luapula*

Source: Rapport Annuel, Mission Piscicole, 1947-8, AA IPAC AGRI 51.

ignored these measures over the war years when the Belgians desperately tried to furnish as many fish as possible for their mineworkers. In 1929 the Northern Rhodesian administration had gazetted legislative machinery for intervention in the fisheries, but did not embark on any concrete measures until 1943 when it introduced a minimum mesh size and a licensing system. In 1948, under the advice of the newly-established Anglo-Belgian Fisheries Advisory Board,

[1] Records of crocodile extermination can be found in Dossier Lutte Crocs. Correspondence and Statistics, AA Inventaire Provisoire Archives Venant du Congo belge (IPAC) AGRI 13.042.

the colonial regimes prohibited river fishing from 1 February to 31 March to protect the spawning run; fishing on the lake by expatriates was still permitted. The measures led to much resentment against the colonial states and collaborating chiefs who were called on cooperate in the enforcement of the regulations. In 1952–53 African fishers, who complained that laws favoured the Greek fishermen, rebelled and forced the colonial administrations to prohibit fishing on the lake as well. This was, however, viewed only as political concession to Africans, not an environmental necessity, although it became the basis for the three-month closed seasons implemented in future years. The conservation measures did not prevent the end of the mpumbu spawning run in the 1950s and the disappearance of the fish from Mweru-Luapula by the early 1970s.[1]

The 1940s and 1950s had been a period of unprecedented in capitalization, which, as would be expected, coincided with technological change. Predominantly Greek fishermen, supported by Belgian mining interests, invested in large boats and long nylon gillnets. This rapid vertical growth in effort led to a collapse in the stocks of the most exploited fish, the mpumbu. After the end of the mpumbu's spawning run, the Luapula River lost its importance as a commercial fishery to Lake Mweru. The sudden vertical increase in effort in the lagoon areas, not horizontal increases in effort, had changed the ecology of the fishery. With this change the commercial fishery relocated north to the shores of Lake Mweru and concentrated on the exploitation of pale (*Oreochromis macrochir*).

3. TECHNOLOGICAL CHANGE IN THE CHISENSE FISHERY

Through the 1960s and early 1970s there was a decline in Mweru-Luapula's fishing industry, especially in levels of technological investment. A combination of local and regional factors contributed to the decline. The fishery was not as profitable without the mpumbu, and by the 1960s catches of pale also diminished. Fisheries officials feared the fishery had been overexploited and was no longer a profitable endeavour.[2]

On a regional level, the Congolese mining companies no longer signed contracts with the expatriate fish traders as the mines abandoned their system of partial payment in food rations. In the 1970s, following the collapse in copper prices, urban demand for fresh fish further diminished. A few years later in Zaire, the confiscation of expatriate industries under Zairianization decree of 1973 contributed to the decline of the expatriate-run fishery. Northerners allied to President Mobutu sese Seko, often inexperienced in fishing, took over the businesses of expatriate fishermen and traders.[3] In Zambia, a parastatal, part of the INDECO group, called the Lake Fisheries of Zambia (LFZ), took over the ice plant at Kashikishi and the marketing of fish. They tried to enforce a maximum price and this led to bitter conflict as fishermen were forced to sell their produce at declining terms of

[1] Records of the series of negotiations between British and Belgian administrators and fisheries officials can be found in NAZ SEC 6/5,7,13 and AA IPAC 13.039. A detailed account of the "mpumbu rebellion" based on archival and oral sources is in Gordon, 2000: 148-193 and Musambachime: 1987.

[2] Between 1960 and 1967 production dropped by approximately 1 000 tonnes. It is unclear whether this drop was due to changing patterns in demand or the condition of the resource - probably a combination of both. Zambia, Dept. of Game and Tsetse, Annual Reports, 1960-1967.

[3] Interview with David Lupandula, Kasenga, 17 Dec. 1998. Kabundi-Mpenga Ka'mpeng "La problematique du développement rural au Zaire: Reflexion sur les conditions des masses rurales dans la zone de Kasenga." Memoire, UNILU, 1975-76, 72.

exchange relative to urban goods. Finally, other fisheries, especially Kafue and later Kariba, replaced Luapula as the most important supplier of Lusaka's urban market.[1]

By the late 1970s, only remnants of the colonial fishery were left. With the closure of LFZ in 1979, there were no more ice plants on either side of the river and lake. Traders returned to the dried fish business. On the Congolese side of the lake some large trading and fishing ventures re-established themselves following "retrocession" in 1976, when a few businesses confiscated during Zairianization in 1973 were returned to their original owners. Katebe Katoto, the son of an expatriate trader and Mwata Kazembe's sister, had a lucrative contract to supply the copper mines of Gécamine, formerly UMHK, with rations of fish. From his fishing camp at Mulonde, he dominated the entire northern Congolese side of the fishery. There was a joke that sometime in the mid–1980s Katebe Katoto attempted to buy the entire lake. Mobutu gave the matter some thought, and then replied that while he was responsible for the sale of diamonds and emeralds, only God could sell the lake; Katoto should ask him. But even with divine intervention Katebe Katoto's profits were tenuous.[2] As infrastructure and facilities deteriorated, as the copper price plummeted, and Zambia and Zaire fell into political and economic bankruptcy, the future well-being of the fishery seemed most precarious.

Fisheries officials continued to argue that levels of exploitation in the lake were unsustainable. There had been no closed season since the lifting of the colonial regulations in the early 1960s. The Mifimbo breeding ground, although formally prohibited to fishers in 1976, was often exploited. The mesh size of nets decreased, especially as state-provided nets became rare. Finally, a decade of limited rainfall had disrupted breeding patterns of the most stable exploited species, pale. Fishermen had to exert far more effort or own many more nets to maintain their previous catches – although the total catch remained at about 8 000 tonnes, the nightly catch per 100 m gillnet steadily declined from around 12 kg in the 1950s to 2 kg in the 1980s.[3]

The decline of the fish resource seemed a typical example of increasing competitive exploitation of a common resource leading to decreasing economic returns. Although the ecological dynamics behind the changes are unclear, in Mweru-Luapula fisherman began to "fish down" in size of fish and exploit smaller species. In the late 1970s women who washed food and dishes in the lake noticed that there was a proliferation of small fish called chisense (*Microthrissa moeruensis*). A fisheries official in 1982 reported that "stocks of this small fish

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[1] The creation of LFZ is recorded in Fish Marketing Board and Co-ops, Ministry of Lands and Natural Resources, NAZ ML 1/15/36, 39. Also see DoF, Chilanga, Annual Reports, 1965-1971. For conflict between fishermen and LFZ buyers see DoF, Chilanga, Luapula Monthly and Annual Reports, 1976-1979. According to the fixed prices, the real income of fishermen would have dropped by 16 percent between 1964 and 1969. This does not include any changes in catches. (Bates, 1976: 157)

[2] Interview with Abraham Soriano, 16 June 1998.

[3] Statistics from Zambian Department of Fisheries, Nchelenge (henceforth DoF), Report on Zambia/Zaire joint meeting held on 22 July 1996, 4. Reports of the fishery through the 1970s and 1980s are from DoF, Chilanga, Luapula Monthly and Annual Reports, 1976-1990. Also Service de l'environnement et conservation, Kipushi, Rapports annuels de Zone de Kasenga, 1986-96 (intermittent).

have, of recent, increased tremendously. . . ."[1] Women used pieces of cloth to catch chisense and prepare extra relish to accompany the cassava porridge eaten by their families. But due to the increasing amount of fish and the ease of capture they began to dry the fish and use them for barter and trade. Then, as their profitability became apparent, men became involved in their capture. Veteran fishermen from Lake Tanganyika, familiar with the capture of kapenta (*Limnothrissa miodon*) adapted fishing techniques to catch chisense. They used paraffin lamps to attract the fish at night and then dragged an expanse of small mesh or meshless material through the gathered shoal. With the spread of this technique, a new commercial chisense fishery emerged.[2]

Net fishing continued alongside chisense fishing and new patterns of economic interest and political conflict surrounded the rise of chisense fishery. Established gillnet fishermen had invested in their nets and knowledge of traditional fishing techniques; they did not find it easy to drop all these activities in favor of chisense. New equipment like paraffin lamps and fine mesh material needed to be bought and this was only done through the sale of other fishing equipment. Net fishers hardly earned enough to keep up their present equipment and had no investment capital. Indeed, they relied on patronage networks to access nets on credit, and these credit relationships tied many of them to their traditional fishing practices.[3] Moreover, the best areas for chisense fishing, sandy shorelines, were not always the same as those for gillnetting, meaning that fishers found it difficult to alternate between the two activities. Instead it was men with limited amounts of capital from urban employment who began fishing for chisense. The older migrants to the lake and local fishers who already owned gillnet equipment were reluctant to invest in the new fishery, learn new techniques and relocate their operations; they had a stake in their traditional businesses and many continued with gillnet fishing. Survey data collected near Chief Puta's area in the early 1980s, demonstrates that chisense brought in nearly 30 times more cash than gillnet fishing, although start-up costs were far greater and could only be afforded by 18 percent of all fishermen (Allen and Chileya, 1986: 13).

Interviews suggest that it was predominantly returning migrants to the lake who began fishing for chisense. They had usually acquired a small amount of capital in salaried employment in the urban areas, from fishing in Lake Tanganyika, or from trade, and were willing to invest in new money-making ventures, especially given their precarious positions in the urban economy.[4] Statistical evidence suggests that although these fishers had access to urban capital, they were not considered "foreigners" and more than 90 percent of them considered the fishery as their residence. Yet only 19 percent of chisense fishers owned gillnets, indicating that they formed a new class of fishers (Zwieten *et al.*, 1996). In this sense, the rise of the chisense industry, although dependent on access to capital and new technologies, was connected to growing number of fishers and can be considered a horizontal rather than vertical increase in effort.

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[1] DoF, Luapula Province Monthly Report, April-June 1982.

[2] Data for the rise of the chisense fishery are from reports of DoF officials and interviews conducted by the author in Mweru-Luapula, Lubumbashi and Lusaka. DoF, Chilanga, Luapula Monthly and Annual Reports, 1976-1994. The first reports of commercial chisense fishing to my knowledge are in DoF Annual Report of 1976, although colonial reports indicated that women caught chisense with cloth long before. Fish Ranger Report, 3/1948, NAZ, NP 2/1/19. The author interviewed fishermen in chisense and gillnet fishing camps. Traders were interviewed in Kashikishi, Mansa, Lusaka, Kasenga and Lubumbashi. A total of 56 in-depth interviews were relevant to the development of the chisense industry. Also see van Zwieten 1996.

[3] Jean Philippe Plateau has identified the lack of diversification due to limitations in access to credit as a widespread feature of Africa's fisheries (Plateau 1992: 101). Luapula data are based on my interviews with several older fishers all of whom did not consider changing to chisense fishing. Interviews Gabriel Kunda, Kasikisi, 14 July 1997; Daud Samual Kalaba, Kasikisi 12 Jan. 1998; Kabel Kaoma, Kasikisi, 11 Jan. 1998.

[4] Interviews with Bupe Mande, Kabwe Sande, Kavunda Hilbert, Kisamba Claude, Pweto, 12 July 1998; Gabriel Kunda, Kashsikishi, 14 July 1997; Daud Samuel Kalaba, Kashikishi, 12 Jan. 1998; Kabel Kaoma, Kasikisi, 11 Jan. 1998.

Perhaps the most profound effect of the chisense industry was the promotion of an independent class of female fish traders. While fishing was a male pursuit, women undertook the processing of fish – more than 90 percent of the local traders who were also processors were women. Women also became more involved in trade around the fishing camps and with the copperbelt urban areas, forming about half of the rural-urban chisense traders (Zwieten *et al.,*1996). There were two types of female traders in Mweru-Luapula. In a more nuclear-oriented household a woman might process the fish of her husband and husband and wife then traded the fish as a joint endeavor. These types of family businesses were typical of the wealthiest families. More common, though, were poorer households that belonged to extended family or clan networks usually organized according to matrilineal traditions where a mother and her children did not rely on the continued and faithful support of a husband (Poewe, 1976). These women increasingly sought money, primarily for the school-related expenses of their children. Since they did not automatically gain money or fish from their husbands, they had to look for other activities to meet their daily needs. Moreover, cassava farming for profit was increasingly difficult as land scarcity increased and unprofitable as prices fell due to state-sponsored maize (Allen and Chileya, 1986).

Chisense trading was one strategy adopted by poor women who needed to access cash. They bought small amounts of fresh chisense from the migrant fishermen with the little cash earned from other activities, or bartered chisense for cassava that they farmed. Once processed, they sold their dried chisense to urban traders, who at first were predominantly men. The initial capital of these women expanded and many went to the urban areas themselves to trade. Unlike the colonial period, there were no restrictions on women traveling to the urban centers. The chisense industry thereby paved the way for the rise of an independent class of female rural-urban fish traders. By the mid–1980s fish markets were full of female chisense traders. A few brought their profits back to Luapula and invested them in chisense fishing equipment, which would be used by their sons or by employees. They formed about four percent of the chisense fishing population (Zwieten *et al.,* 1996; Aarnink, 1999).

The rapid expansion of this industry transformed economic roles of village members and consolidated new social groups. Men with links to urban areas became the new chisense fishermen and rural women the new processors and small-scale traders. This alliance of capitalist-inclined fishermen and local women adopting a survival strategy was at the base of the new chisense fishery in the villages of Mweru-Luapula. By the 1990s, the fishery produced 30 to 40 000 tons, from three to five times the total catch of the demersal fishery.

Yet these vast catches have had to be distributed between an increasing number of fishers. Presently there are so many chisense fishers that at night it seems as if a city of lights dances on the lake – nearly 7 000 gear owners and 6 000 workers, not to mention those involved in trade (Zwieten *et al.,* 1996). In fact, gillnet fishers have reported increased catches of pale, makobo (*Serranochromis macrocephalus*), ntembwa (*Tylochromis mylodon*) and chituku (*Tilapia rendalli*), probably due to better rainy seasons. Combined with better catches, a new road in Zambia has encouraged a resurgence of the fresh fish trade. Katebe Katoto's operation, for example, has relocated to Zambia and is run by his younger brother Moses Katumbi, and called Tamba Bashila (previously Chani fisheries).

In the 1990s a donor-funded buying agency, Isabi Fisheries, Chani Fisheries, and the DoF began to negotiate over a closed season and attempts to restrict access to the fishery. Influenced by the idea of “co-management”, they incorporated several “community” organs in to their programme, including “traditional” chiefs and fishermen’s associations. To a certain extent they have succeeded in enforcing the measures in Zambia’s major fishing towns and camps; however, more remote camps and most of the Congolese fishery have not adhered to the closed season. Besides limitations on enforcement, the success of the regulations is difficult to measure given their ill-defined biological and economic goals (Aarnink, 1999).[1]

I have argued that changes during the post-colonial period – especially the the rise of the chisense fishery – represented more of a horizontal increase in effort than a vertical one. It has rested on an increase in the fishing population, especially men with urban contacts and women previously involved in agriculture. The chisense fishery relied on new capital-labor relationships, but this has not led to the growth in a capitalist class of fishers who invested in the fishery – although this occurred in certain cases. Instead, a growing number of men and women adopted new techniques and technologies as a livelihood strategy rather than a capitalist enterprise.

4. CHANGES IN FISHING EFFORT

Changes in horizontal and vertical effort depend on different constellations of social, economic and ecological forces. The history of Lake Mweru-Luapula suggests four factors that influenced patterns of vertical or horizontal growth in effort. The first two factors concern the market for fish, the third relates to the broader institutional environment, and the fourth is the interaction between the fishery and other sectors of the economy.

Contracts between fish traders and urban wholesalers who could absorb vast amounts of fresh fish encouraged vertical growth in effort. A purchasing arrangement between UMHK and the Greek fishermen and traders sponsored vertical increases in effort during the 1940s. Katebe Katoto’s business in the 1980s was built on his contract with Gécamines. Due to limited refrigeration facilities among urban consumers, the fresh fish trade could not exist without these arrangements. Where such arrangements were absent, the dried fish business prospered, allowing easier access to rural-urban exchange and horizontal increase in effort. With the dried fish trade, local processing techniques limited the growth in effort. Since drying fish required labour and inputs of firewood or salt, the amount of fish that could be processed limited the amount of fish caught. It is not uncommon that fishermen left fish to rot for lack of buyers or processors – clearly to avoid this situation, fishermen limited their catch. Where processing was easier, as in the case of chisense, which only needs sunlight and good weather, local processors could absorb more fish. In this case, horizontal increase in effort was unimpeded by marketing arrangements.

Another factor linked to marketing is transport infrastructure. In the face of other adversities Chani Fisheries emerged in 1991 following the construction of a good surfaced road through the length of the valley. Improved transport infrastructure benefited small-scale producers and traders as much as large scale, or even more. One reason for horizontal increases in effort in the chisense fishery was the surfaced road through the valley. By linking the rural and urban

[1] Details in Nchelenge District Council Files, Nchelenge Fisheries Coordinating Committee (NFCC) 3/14/2.

areas, if other factors prevent vertical growth in effort, infrastructural improvements may lead to greater horizontal than vertical increase in effort.

Thirdly, other institutional and financial factors affected the relative merits of investment in the fishery. Capital was essential, and usually had to be mobilized through bank loans, such as those that the European traders received during the colonial period. During colonialism, once the Europeans had built their boats and bought their nets, they faced few threats of confiscation, destruction or theft – the most serious problem facing the gillnet fishery in the 1990s. By contrast, after the colonial era, the unstable Zairian currency made rural-urban trade difficult since fishermen did not want to be caught with vast amounts of worthless currency. The Zairianization measures of 1973 precipitated the collapse of the commercial fisheries on the Congolese side of the Luapula. Fish marketing boards and co-operatives in Northern Rhodesia and Zambia led to much resentment among fishermen and distrust of government. Price controls, especially maximum purchase prices, had a similar effect, encouraging fishermen to evade the formal economy. Yet an unstable formal institutional environment was not necessarily to the disadvantage of small-scale producers and traders; in some cases informal markets, or illicit ones, were more profitable than formal. For example, presently the most profitable fish trade is with the diamond capital of Congo, Mbuji-Mayi, where sacks of fish can be traded for diamonds. In times of formal economic collapse or economic restructuring, such as DRC and Zambia have experienced in the 1990s, horizontal growth in effort can be expected.

The final factor is the alternatives to fishing. For vertical increases in effort to occur, fishers have to see the potential for greater returns on capital investment in the fishery than can be experienced in other economic sectors. Horizontal increases also depend on alternatives for investment of labor and capital; women who found that farming could not meet their cash needs turned to chisense processing and trading. Men who could no longer find urban employment, used their savings to begin businesses based on the chisense fishery. Horizontal increases in effort are not necessarily characterized by the growth in fishers using traditional methods; increasing numbers of fishers can make use of new technologies as a result of engagement with diverse economic sectors.

5. CONCLUSIONS

With the rise of the colonial regimes, traditional restraints and sanctions on fishing enforced by the Owners of the Lagoons were undermined in favor of a formal state authority carried out by colonial chiefs, administrators and fisheries officials. Vertical increases in effort occurred when expatriate entrepreneurs linked to the Belgian colonial regime invested in the fishery. They occurred during a period of resource regulation and led to the most marked ecological shock when the mpumbu disappeared from the fishery.

With the end of colonialism, state authority in the countryside was eroded and in many arenas collapsed. Since pre-colonial restraints had long been abolished, there were few formal restrictions on who could fish; even though local mechanisms restricted access in the more remote areas, the fishery became more “open access” than ever before, especially in the urban-like fishing towns and camps. This, along with a new local ecological and regional economic landscape, contributed to horizontal growth in effort. Retired or retrenched urban workers originally from Luapula invested in lamps, boats and meshless nets, and became chisense fishermen. Horizontal increase in effort was largely due to these migrants who returned from the copper mines and joined with rural women who found farming difficult and unprofitable. As long as the chisense fishery offered better opportunities than urban trade or cassava farming, new fishers and traders arrived, despite total yields remaining constant or decreasing per fisherman. This did not however preclude vertical changes in effort – indeed in many senses the chisense fishery, with its alliance of male fishers and female traders, relied on new types of capital-labor relations.

Those familiar with the patterns of development in the fisheries of Norway or elsewhere in the developed world would find this turn of events surprising and contrary to expected developmental patterns. Ottar Brox argues that horizontal increases in effort characterized "the peasant mode of production, subsistence fishing, and frontier phases in the development of the national economy"(Brox, 1990: 233). Vertical growth in effort, by contrast, occurred when investors participated in resource exploitation and dynamized the "stagnant" local economy. This presents an accurate picture of the fishery growth in the developing or developed world. In economies that have experienced long-term decline, such as Zambia and DRC, patterns of effort growth have been rather different. Technological change and commercial activity have not been bound to vertical increases in effort that imply labor-saving investments; instead, an increased number of fishers have made use of technological change and exploited urban markets. In Mweru-Luapula vertical growth – the combination of capitalization and change in gear technology – came and went between the 1940s and 1960s; the more technologically innovative and more commercial sector that has driven the development of the fishery since the 1970s has been characterized by more fishermen rather than more nets per fisherman. Over the last thirty years, as commercial and survival options for Zambians and Congolese have narrowed, horizontal increase in effort has been significant and has contributed to innovations in gear technology.

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THE "LORDS" OF MALOMBE; AN ANALYSIS OF FISHERY DEVELOPMENT AND CHANGES IN FISHING EFFORT ON LAKE MALOMBE, MALAWI

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1. INTRODUCTION

For the last 15 years or so, in much of the grey literature as well as in the general narratives about the status of freshwater fisheries in Southern Africa, the fishery of Lake Malombe has been considered a crown example of a common tragedy. As has been shown elsewhere (Zwieten, Njaya and Weyl, 2003) the fishery has seen a rapid and considerable growth in fishing effort. Great changes occurred in the period from the 1950s to the 1980s with regard to types of gear used and species targeted. Lately the dominant Chambo (*Oreochromis spp.*) has almost disappeared and total catches have decreased dramatically. This development is very different from the situation on other African lakes. On lakes like Mweru or Chilwa total catches have remained fairly stable despite a considerable increase in fishing effort. These fisheries are analysed in other papers in this publication.

The objective of this paper is therefore to investigate in some detail the characteristics of the effort development on Lake Malombe and to provide a sociological interpretation of the changes. We will do so by distinguishing between population-driven and investment-driven changes in effort. Ottar Brox (1990)[1] defines population-driven growth as increase in fishing effort resulting from increased human participation in fishing. This growth is often characteristic of the frontier phase of the development of national economies. In the context of Lake Malombe, it means increases in number of gear owners and crew members. Investment-driven growth is defined as growth in capitalization and in technological level. In our case this means increase in number of fishing gears per unit, improved technology and/or technological innovations of gear in use. We will demonstrate that until the 1970s, growth in effort was both population-driven and investment-driven, but that population-driven growth probably started to slow down sometimes in the 1970s and that it almost stopped around 1980. Since that time the number of production units has remained fairly stable until in the middle of the 1990s when it started to fall. During the 1970s and the 1980s the growth in effort was almost exclusively investment-driven, i.e. a growth due to accumulation of equipment and technological changes within the existing units. During the 1990s the reduced number of production units has been followed by reduced investments within these units so that effort reduction during this decade has been caused both by less people and less investments.

Our analysis of the sociological characteristics in the Malombe fishery shows that the dynamics behind effort development are quite complicated and only by taking account of the background of the owners and their relations with the rest of the population in general, and with the crew members they hire in particular, can the effort development on Lake Malombe be properly understood. The analysis demonstrates how labour migration options, owners' possibilities to invest in alternative economic activities, as well as their ability to control their labourers and to manage their units, are all factors influencing the effort development just as much as do the volumes and the prices of catches.

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[1] What in Brox' terminology is called horizontal change is here called population-driven change, and what he calls vertical change we choose to speak of investment-driven change.

As Brox (1990) demonstrates, investment-driven growth has generally different and often more serious and long lasting sociological effects than population-driven changes. The fishery on Lake Malombe (and on the southeast arm of Lake Malawi) represents one of the few cases known in southern African freshwater fisheries where investment-driven growth in effort – although moderate - has been more important than population-driven growth. It is therefore also the objective of this paper to explain how this development was possible and what seem to be the main constraints confronting further growth of this type. We will show that the investment-driven growth depended completely upon an influx of financial resources from outside. We also show that in the type of economy and production system that prevails around the lake, there are several mechanisms that reduce the incentives and the possibilities for investment-driven growth. Most of them seem to be associated with the particular type of patron-client relationship that exists between boat owners and crew members. Fisheries on Lake Malombe have for the last 25 years or so been dominated by less than 400 boat owners, of whom only 200 remain in the fishery. Within an estimated total population of more than 50 000 people the gear owners, in light of their economic wealth and social influence, are easily seen as some kind of lords. However, their lack of control over their own production units is an excellent illustration of the investment problems reigning in many African fisheries.

1.1 Method

Three sources of data and information have been used in this study: a field survey, relevant literature and archive material, and data from a parallel study on the biological development in Lake Malombe.

The approach used in the field survey was to build life histories of gear owners and crew members. For this, 42 gear owners (22 from the west bank and 20 from the east bank) were interviewed. 15 crew-members were interviewed (six from Malombe west and nine from Malombe east). In addition to interviews, a list, compiled in 1993 by the Fisheries Department, of all gear owners and details of their fishing gear was used to evaluate changes in gear numbers and gear ownership between 1993 and 1999. The Fisheries Department field staff (Messrs Kasuzweni and Thindwa on the west bank and Bezai on the east bank) helped in providing an update of the list. Where possible, the individuals on the list – or their relatives – were interviewed.

The second important source of information was literature concerning the historical political economy of agriculture and fishing in southern Malawi. Four authors – Chirwa (1995), Mandala (1990), McCraken (1987) and Vaughan (1982) – were particularly valuable. Furthermore, official government reports and other archival material relating to the period in question have been used extensively. Finally, the findings about trends and changes in fishing effort is also based on the parallel investigation into the biological explanation for the development of fishing effort within the framework of the same project (Zwieten, Njaya and Weyl, 2003).

1.2 Lake Malombe, its present fishery and the people

Lake Malombe is described as “an impoundment of the outflow of Lake Malawi via the Shire River, 12 kilometres south of Lake Malawi” (FAO, 1993:2). The lake is about 390 square kilometres in area and averages seven metres in depth with a maximum depth of 17 metres. It experiences the same climate regime as the southern part of Lake Malawi. This means that the influence of trade winds on productivity is paramount. Unlike in Lake Malawi though, rainfall run-off is believed to contribute significantly to the productivity of Lake Malombe. The hydrological parameters of the Shire River are nevertheless crucial for the conditions of the lake. In the early decades of this century the water levels of Lake Malawi were extraordinarily low and the outflow of the lake is reported to have stopped completely around 1915 (McCracken, 1987:417). During the next 20 years there was no outflow from Lake Malawi and the water levels in the Shire and Lake Malombe therefore varied dramatically[1]. It was only after the Bomani floods of 1939 that the water levels became less unstable (Mandala, 1990:6).

On the west bank side, the lake is bordered by the Mpiri Piri hills, which lie within three to seven km from the lake while on the east side it is bordered by the Mangochi hills. On the Southeast banks is the Liwonde National Park. The fishing villages are thus confined within narrow strips of land along the lake on both sides making the population densities very high and the amount of farming land within the village areas very little. This is especially so on the west bank where the population density averages over 500/km² (Bell and Donda, 1993). On the west bank is the main road from Lake Malawi and Mangochi Township to the urban centres of Zomba, Blantyre and Lilongwe. The east bank is very difficult to access. This is especially so in the rainy season as the area then can be reached only through a dirt road that branches off from the Mangochi-Namwera road.

A census conducted by the Ministry of Agriculture (Liwonde, 1998) showed that 8 396 ”farm families” existed in the villages on the west bank while another 2 657 families were to be found on the east bank. Using five persons per household, which is the national average household size, the population in the fishing villages can be estimated at 42 000 people for the west bank and 13 300 for the east bank. The annual rate of population growth in Mangochi district is reported to have been 1.7 percent per year in the period 1987–1998 (Malawi Government, 1999:19).

Our surveys showed that in June 1999, boat owners operated 173 production units – all types included – from the western shores of the lake while 22 units were operated from the eastern shores. Each production unit is owned by one person and the average number of crew members in the units is estimated at ten. Based on these figures, we see that only two per cent of the families on the west bank and less one percent of those on the east bank are owners of fishing units. On the west bank fishers represent no more than approximately four percent of the total population while they constitute less than two per cent on the east bank.

While the figures might underestimate the real numbers of people in the fishery, it is difficult not to view these figures as an illustration of the rather modest role the fishery is playing in the local economy although the total population figure includes children under the age of 15 years and adults over 65 years of age; groups that we must assume to be economically inactive. Furthermore, the figures only say something about the quantity of people involved and nothing about the financial importance of the sector. Nevertheless, they clearly indicate an important aspect of everyday life in Malombe which often tend to be overlooked: for most people fisheries is neither the only nor the most important economic activity.

1 In 1924 it is reported that the lake "dried up almost entirely, with food gardens being planted in large numbers on its bed" (McCracken, 1987:418), while in 1925 heavy rains again led to the flooding of the Lake and people's gardens were inundated as a result.

2. DEVELOPMENT OF THE FISHERIES BEFORE 1950: POPULATION-DRIVEN GROWTH IN EFFORT AND DEVELOPMENTS OF MARKETS

The development of fisheries around Lake Malombe should not be seen in isolation from what has happened in the far more important fishing area constituted of the Southeast Arm of Lake Malawi located less than 15 km to the north. Many of the fishermen exploiting Lake Malombe regularly have been exploiting Lake Malawi as well. In these two areas people are generally of the same origin with the same language and culture. Most of them identify as Yao, a tribe originally from an area east of the Rovuma River in Mozambique. This tribe has dominated the local political structures in the area since the 1860s. The economic tradition of the Yao is one of trade, developed through their long contacts and relations with Arab traders on the East Coast of Africa. The contact with Arabs also greatly influenced the Yao to adopt Islam (Rangeley, 1970). Thus although Christians are found in the area, the great majority of the population are Moslems.

Furthermore, macro-structural factors in the Malombe and Malawi fisheries – both political and economic – have largely been the same. Most of the Malombe area belongs to the same administrative and native authorities as areas along Lake Malawi, with Mangochi town (formerly Fort Johnston) the administrative centre located equidistant from the outlet of Lake Malawi and the inlet of Lake Malombe. The broad lines in the development of Lake Malombe fisheries are therefore the same as those of the southern parts of Lake Malawi. This is also reflected in the literature in which fisheries development on the two lakes tends to be dealt with together.

McCracken (1987) reminds us that commercial fishing in the area is an old venture and not something that started emerging in the 1950s. One of the major events that stimulated fishing for sale on the southeast arm of Lake Malawi is said to have been the need to provide fish to South African soldiers going to East Africa during the First World War. On Lake Malombe it is reported that the flood in 1925 led people to turn to fishing. People’s gardens had been inundated and as a result, many peasant farmers switched to fishing or fish trading as a means of raising money to buy food and, for men, also to pay their hut tax. But due to the unstable water levels in the Shire we must expect that extensive commercial fishing in Lake Malombe must have been difficult to perform before the water levels of the river stabilized.

In the 1920s and 1930s European and Indian traders had started to transport fish by lorry from Lake Malawi for sale in Zomba and Blantyre. Partly, this was fish they bought from African fishermen and partly it was their own catches from commercial production units that emerged in Lake Malawi after 1930. Also, a great number of Africans started to engage in fish trade, transporting fish by bicycle (McCracken, 1987). The different groups of traders demonstrated an interesting mixture of competition and collaboration where African traders often represented elements in the bigger trade networks of the Asians and Europeans. Given that the trade route from Lake Malawi runs along the western bank of Lake Malombe, we must assume that an increasing part of its fish was integrated into the same system, even if the centre of the commercial activities was located further north.

People had historically been using fish traps, weirs and nets made from *Bwazi or Chopwa* (a fibre from *Poolzolzia hypoleuca*). The 1930s also saw an increase in use of twine from disused bicycle tyres (locally called *Linye*) for making nets. At the same time, the Indian and European (mainly Greek) production units on Lake Malawi introduced manufactured cotton (later nylon) nets. They also introduced new technologies such as beach seines, and from 1938, trawling. If African fishermen only modestly copied these techniques in the years before 1950, we assume that the main reason was related to a combination of costs and the relatively high efficiency of their traditional gear.

Throughout the 1920s and 1930s, the colonial government made no attempt to stimulate the growth of the fishing industry. This was partly attributable to its policy of keeping Africans as a labour reserve for the European settler estates in the Shire highlands (Vaughan, 1982) and also a deliberate policy that attempted to force or coerce people in rural areas to go into cotton farming at the expense of food crops or other economic activities such as fishing (Mandala, 1990; Vaughan, 1982). The first official reports concerning fishing date from around the late 1920s. Two concerns seem then to have been of importance for the authorities: on the one hand the state of the resource and, on the other, peace and order.

Most important were probably questions related to peace and order. The increasing entry of European and Asian investors into the fishery and the emerging conflicts among various groups of Africans led to increased tensions. Authorities saw it as being extremely important to minimize these conflicts and tensions. Interestingly, and for various reasons, the policies of the government did not favour the foreigners; on the contrary one may say that most of the regulations introduced during this period favoured the position of the African fishermen compared to their European and Asian competitors. While African fishermen were largely left to themselves, a number of restrictions concerning licenses and gear were put on the foreigners (Chirwa, 1995; McCracken, 1987; Hara, 2000). However, this mainly applied in the Southeast Arm since the government had banned non-African fishing on Lake Malombe[1].

The other concern was related to the state of the resources. On this issue the government was ridden by rather paradoxical influences of thought. In the first half of the 1930s, the concerns seem mainly to reflect the well-documented tendency among colonial officers to view African methods of hunting and fishing as detrimental to the ecology and the reproduction of exploited species[2]. This led to the prohibition of most of the African fishing gears such as traps, weirs and poison. These regulations are reported not to have had much effect since local authorities did not enforce them. Towards the second half of the 1930s government attitudes changed and they came to see the non-African fishing methods as being the most challenging ones. This meant that fisheries on Lake Malombe were, to a large extent, left unregulated by officials except for the 1933 requirement to pay fees on canoes, through local chiefs, under the Native Authority Act (Chirwa, 1995:361-5).

The first attempts by the colonial government to stimulate the industry were in the early 1940s following two surveys by British led specialists, one of which had been led by Professor Platt in 1938 (McCraken, 1987). The report had pointed out the crucial importance of fish as the sole major source of animal protein in Nyasaland, since the country did not have good sources of meat. Platt’s Nutrition Unit experimented with intermediate fishing technologies for producing fishing equipment and processing fish. But the results of these experiments were largely disappointing. Apparently, the new techniques were less effective than what African fishermen were already using. In the 1940s, the industry was further depressed by the shortage of bicycle tyres due to the wartime restriction on the importation of rubber, which in turn meant a significant fall in the number of traders.

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[1] See "A Report of the Fish Ranger's work at Fort Johnston Station" by K.T. Howard 19/12/1962. Ref. no. 20/1/67. MNA 1/6/21/8/P.A.

[2] For an analysis of the development of fishing regulations in two British territories (Northern and Southern Rhodesia) see Malasha, 2002 and 2003.

3. THE 1950S AND 1960S: INTRODUCTION OF MANUFACTURED GEAR AND NEW PATTERNS OF INVESTMENTS

The second attempt by the colonial government to stimulate the fishing industry was made in the 1950s and it was more successful. The 1952 Nyasaland Report noted that African fishing was not a purely subsistence activity, but rather an undertaking that had a commercial side to it. Most of what fishermen produced was either sold to local consumers on the beach for people's own consumption or distributed among the members of the fishing crews for their personal needs. Some African fishermen on Lake Malawi who had been using inshore seine nets started increasingly to fish offshore using manufactured gillnets (Government of Nyasaland, 1952:53). It became more and more common for African fishermen to fish on commercial basis and the purchase and use of manufactured nylon nets among this group increased. Seine nets were also increasing in number and becoming longer as fishermen started to clear more and more beaches for their operations. In the 1950s it was still common among African fishermen to use nylon webbing for the bunt only and linye for the outer panels in the beach seines. Bigger nets and seines made it increasingly difficult to operate from dugout canoes and led to the emergence of bigger and more costly planked boats.

A combination of factors stimulated the development of the African fishing industry in the 1950s : the Government introduced a policy of the bulk sell of nylon nets and twine and plank boats to African fishermen; the establishment of the Horris Hickley netting company in 1959 (which became Blantyre Netting Company in 1979) made manufactured nets more and more common; and for the first time, Africans who had the potential were offered loans from the African Loans Board and the Native Development and Welfare Fund for the purchase of improved equipment (Government of Nyasaland, 1953:70-72).

Furthermore, the government introduced a policy that restricted non-African commercial fishermen from operating in Lake Malombe[1]. The arguments against permitting commercial fishing by non-Africans in Lake Malombe were twofold. First, the government feared that commercial fishing would be biologically detrimental to the fishery in such a small lake as Malombe. But, and this is the second reason, it also feared that a non-African presence would cause conflicts between African and non-African fishermen. The Director for Game Fish & Tsetse Control, M. J. Borley under which the administration of fisheries fell, argued that "where the fishermen were heterogeneous and where the standard of the non-native fishery is so far above that of the native as to put it in a totally different class", it seemed politically important to avoid even the risk of overfishing. In such a case, it appeared to him not improper to apply restrictions to the non-native effort as soon as effort and yield data indicated that they were very probably necessary, without waiting for incontrovertible proof that they were essential. Delaying imposition of restrictions and pending incontrovertible proof, entailed the risk of damage to the basic economy of the native fisherman through circumstances quite outside his control. Borley argued that if deterioration had resulted from delay in introduction of controls, the disadvantage of impaired race relations and political feeling would have been added to straightforward economic loss.

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[1] See letter from 1957 by A. Dickinson to M.D. Benders Esq. rejecting commercial fishing licence application for Lake Malombe by Benders. MNS19-4-4R / 3646 and letter of 31 August, 1957 by M.J. Borley, Director of Game, Fish & Tsetse Control, Fort Johnston to the his Chief Secretary on commercial license application for Lake Malombe by R.E. Hochschild. MNA 16-3-3F / 3645.

Finally, the creation of the Federation of Southern and Northern Rhodesia and Nyasaland in 1953 led to the lifting of the wartime ban on fish exports and allowed the large-scale purchase of fish for export mainly to Southern Rhodesia (Government of Nyasaland, 1962:81-82).

What we see emerging first in the southeast arm of Lake Malawi but also in Lake Malombe during the 1950s is a process that clearly differentiates between two groups; new African commercial fishermen on the one hand and, on the other, those who continued to fish mainly for their own consumption and for local barter. McCraken notes that in the 1950s, already, "perhaps the most remarkable feature of African fishing was the emergence of a small group of "big time" capitalist fishermen who employed labour on a regular basis and invested in imported nets and boats" (1987:427). Under this commercial orientation, group ownership of equipment was abandoned and instead nets and boats became private property of owners most of whom left the day-to-day control of the fishing to a son while they supervised the drying and selling of fish on shore. The 1962 Fish Ranger's report noted that there were 30 active African commercial fishermen on Lake Malombe[1].

However, this process is explained not only by changes in government policies. According to the same report, of the 30 commercial fishermen, only seven had obtained government loans of 200 to 300 pounds sterling. The rest had raised the money needed from elsewhere. With reference to the situation in the Southeast Arm, Fisheries Officer A.D. Sanson stated in 1956 that: *"Since 1950, there have been a few Africans who have attempted to set up fisheries on a real business basis. I think I am right in saying that not one is originally a fisherman himself. They are all African business men, some from other parts of the country and some belong to this part of the country and have spent most of their lives in South Africa or Southern Rhodesia and have come back to set up business. Local fishermen are employed. There are no co-operative fishing concerns; every one of these businesses is being run by one man[2]."* The growth in labour migration through organized recruitment agencies such as the Witswatersrand Native Labour Association (WENELA) to South Africa, but also to other places, were hence one important factor. It strengthened the processes which led to a more commercial fishery and in turn caused more and more of those who returned to invest their savings into the industry.

Finally, fish trading among Africans continued to increase. Partly because of the comparatively low wages and poor conditions that prevailed on settler tea and tobacco estates in the Shire Highlands, people started to take up fish trading in increasing numbers as it was more lucrative. Also it gave them an independence which wage labour denied (Vaughan, 1982). In addition to this, the price paid to peasants for cotton did not compensate them fully for their labour. African traders had started moving their fish by lorry, often teaming up with other traders to hire a lorry for the transport of their individual consignments. By 1962, there were an estimated 400 fish buyers in the Lake Malombe area[3]. This indicates that the investments required for entering fish trade must have been considerably lower than those required for commercial fishing. But despite the reported existence of 13 traders for every commercial fisherman, the reports of the Commission of Inquiry into the Fishing Industry clearly show that fishermen often experienced sale

[1] See "A Report of the Fish Ranger's work at Fort Johnston Station" by K.T. Howard 19/12/1962. Ref. no. 20/1/67. MNA 1/6/21/8/P.A.

[2] A.D. Sanson's statement in Record of the meeting of the Commission of inquiry into the fishing industry held at the courthouse, Fort Johnston, 8 and June 1956. (MNA/COM/9/3/1).

[3] See "A Report of the Fish Ranger's work at Fort Johnston Station" by K.T. Howard 19/12/1962. Ref. no. 20/1/67. MNA 1/6/21/8/P.A.

problems, particularly during the rainy season[1]. Fishing in Lake Malombe was concentrated in the northern part of the lake and landings on the west bank due to good access to roads and markets in that area. The few fishermen that fished on the east bank transported their catch by boat to Mtundu and Nkupekupe on the Upper Shire and to the north-west part of the lake.

4. THE 1960s AND 1970s: GROWTH IN EFFORT; MORE PEOPLE, MORE GEAR AND TARGETING OF NEW SPECIES

Whereas in the 1950s it was still common to use *Linye* for the outer net panels of the seine nets, the African commercial fishermen increasingly dispensed with the use of local materials in the 1960s and started to use nylon nets exclusively, thereby improving the efficiency of their operations. Furthermore, the use of static gillnets was abandoned in the late 1950s as these nets frequently were either destroyed by crocodiles and or stolen if left fishing over night. Instead, people started fish driving, locally called *chiombera*[2]. This was practised both during day and at night. Fish driving is reported to have been introduced in 1959[3] and within a few years, became the most common technique in Lake Malombe. Normally a net of as much as 1 000 yards long was set in a circle and a powered boat steamed round inside the circumference, with crew members beating the water to drive the fish into the net. This technique resulted in enormous increases in catches, fuelling further the commercialization of the fishery. In addition, government introduced a policy of shooting crocodiles to lessen the problem of net destruction. According to the 1962 Fish Ranger’s report, all the 30 production units of the commercial fishermen were motorized (the common type of engine they used was the “Seagull” 102 long shaft).

Sensing that they could increase their catches further by using gillnets as active gears like commercial trawlers on Lake Malawi, most gillnet fishermen started to trawl their gillnets using two boats and outboard engines. Used in this way, it was necessary to increase the depth of nets. Thus gillnets used as a *tolora* (trawler) or *kandwindwi*, (named after the trawler operated by the MALDECO Fishing Company on Lake Malawi) increased from 24 or 40 to a depth of 80 meshes[4].

With the commercially valuable Chambo in abundance and increased numbers of migrant returnees, the use of the seine nets became more and more prevalent in the 1960s and 1970s. At their height of operations, around 1980, seine nets had grown in size up to 1 000 metres long. While the 1962 Fish Ranger’s report indicate that there were five Chambo seine nets operating in Lake Malombe, the Director of Fisheries Frame Survey figures show that the number had increased to 27 by 1981 (Zwieten, Njaya and Weyl, 2003)[5]. The increased use of the seine net also saw the invention of the Chalira, a small seine net with small mesh sizes that was operated behind the bigger seine net in order to catch the fish that usually escaped from the larger seine as it was pulled close to the beach.

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[1] See e.g. statements of Fred Sinclair, Glab Khan, Amos Charles and Crispo Gwedela in Record of the meeting of the Commission of inquiry into the fishing industry held at the courthouse, Fort Johnston, 8 and 9 June 1956. (MNA/COM/9/3/1).

[2] Chiombera had been developed on Lake Malawi and it was already in use there by the time it was introduced on Lake Malombe.

[3] See "A Report of the Fish Ranger's work at Fort Johnston Station" by K.T. Howard 19/12/1962. Ref. no. 20/1/67. MNA 1/6/21/8/P.A.

[4] The first person reputed to have started using this technique on Lake Malombe was a Mr. Khan in 1973 who employed Maija as his head of crew. Later Maija left the employment of Khan to buy his own gillnets and fish on his own.

[5] Since the DoF figures start in 1981 and since they show a steady decline through the 1980s and 1890s, it is not improbable that the maximum number of chambo seine nets may have been even higher.

The 1960s and 1970s also witnessed the emergence of a seine net targeting new species: the so-called "Kambuzi seine net". Like the Chambo seine it is operated from the beach, but has smaller meshes and was initially about half the length of the Chambo seine. It was meant to target Kambuzi[1] like so many of the other gears used in Lake Malombe, the Kambuzi seine net had been developed in the Southeast Arm long before it emerged in Malombe. It is interesting to note that fishing for Kambuzi began well before the stress on Chambo became noticeable. An important reason for this is that in the 1950s, the tea and tobacco estates in the Shire Highlands (Thyolo, Mulanje, Zomba, Chiradzulu and Blantyre) had instituted a tenant labour system (McCraken, 1987) and they required cheap food for their tenants. Kambuzi was seen as one of the ideal food items. During the 1960s, Kambuzi also came into increasing demand among the low-income groups in the growing urban areas and there also proved to exist an export market to Southern Rhodesia. In addition to the stress on Chambo, caused by increased fishing effort, it seems that the increase in demand for fish and the growing consumer acceptability of smaller species also fuelled the expansion of the Kambuzi fishery. At the beginning of the 1980s, the demand for Kambuzi must have been high since the Department of Fisheries figures of estimated catch show that there existed between 60 and 70 Kambuzi seines in Malombe in 1981 (Zwieten, Njaya and Weyl, 2003).

The 1960s and 1970s continued to be good years for labour migration to South Africa, and to some extent also to Rhodesia, resulting in an increasing number of successful returnees who were willing to invest in fisheries. Except for the returnees, little is known about the relationship between work migration and economic activities at home. However, more recent information – including life stories collected for the present study – indicates that specific networks between migrants and some of their relatives remaining at home, developed in this period. These networks served to transmit and invest remittances from the migrants before the migrants decided to return to their home area for good, thereby rendering work migration even more effective in economic terms. Fisheries Department Frame Survey figures show that by the early 1980s, the number of owners of fishing units had reached around 230 (Zwieten, Njaya and Weyl, 2003).

The speed of the technological changes during these two decades also indicates that another important social process must have taken place simultaneously. Towards the end of the 1970s, it had become exceedingly difficult to operate at a subsistence or small-scale basis. In the Chambo fisheries, various types of active catch methods such as *chiombera* and *tolora*, as well as Chambo and Kambuzi seining, requiring heavy investments in the form of costly nets, out-board engines and planked boats had completely taken over from the passive methods practiced earlier. With this noticeable increase in investment-driven growth of effort we must assume that the catch rates for the older passive gears must have diminished, rendering the low investment fisheries very difficult to sustain, to say the least. It is therefore reasonable to assume that the great majority of the 230 boat owners in 1981, constituted the type of commercial fishermen that A.D. Sanson described already in 1956 (see citation above).

In his study of the development of access rights to fishing in the southeast arm of Lake Malawi W. C. Chirwa concludes, "*while no single group won the contest for access rights and control, the traditional leaders were the greatest losers as they failed to use their political position to block the success of other groups*" (1995:377). In the context of Malombe, where the African commercial fishermen did not have to face competition from non-African fishermen, they

[1] Kambuzi is a local name for a group of cichlids, mostly of the *lethrinops* genera.

were much more successful in asserting full access rights than were the African commercial fishermen on Lake Malawi. But, they were successful at the expense of those who were unable to follow suit in the race for new and more effective fishing gear. The new and extended fishing units required an extensive use of labour, but the people recruited to work as crews were often different from those who had just lost their access rights due to lack of investment capability. By the end of the 1970s the fishery in Malombe had to a large extent lost its role as a “commons” and since then the “Lords of Malombe” succeeded in establishing some sort of control over the fish resources in the lake.

However, the control of access exercised by the commercial boat owners has many aspects. The increased need for labour could not be fulfilled by recruiting labour from within the family as had been the convention until then. In the beginning it seems as if crew-members from outside the families were compensated through some sort of direct payment. McCracken (1987) shows that already in 1956 owners had considerable problems related to the control of their crews. Some owners then blamed crew members publicly for theft of catches and misuse of equipment. Towards the end of the 1970s, the pay structure changed to a share system based on 50 percent of the catch allocated for the investments and the other part for the labour. With minor modifications and variations between the different gear types, this system remains in use to the present.[1] The new system resulted in increased earnings for the crew members. Since their earnings depended on how much they caught, this gave an incentive for crew members to work harder and fish longer hours. Day and night fishing using gillnets became common. To what extent this shift altered the power relations between gear owners and crewmembers or solved the reported control problems of the gear owners will be discussed below.

The commercial gear owners also invested in the marketing of fish. It has been reported from the late 1950s that many gear owners had bought or intended to buy their own trucks and pick-ups[2]. Using these, they could move their own catch and also buy from their fellow fishermen, cutting out the middlemen. As fish sold retail at more than 100 percent mark-up, such forward integration further increased the earnings of commercial gear owners (Hara 1993). The growing urbanization in Zomba, Blantyre and Lilongwe in the 1970s and 1980s also acted to increase demand for both Chambo and Kambuzi. But contrary to what happened in the fisheries where the investments of some excluded the participation of others, investments in the trade system never excluded the participation of small-scale traders operating from bicycles and various types of public or private transport. Given that by using bicycles and pubic transport fish could be sold in a much dispersed and often inaccessible hinterland of small villages and regional towns but also in big urban centres, the trade system continued to remain decentralized and open to a wide range of people. In the early 1990s, an estimated 3 000 fish traders operated on the southeast arm of Lake Malawi, the Upper Shire River and Lake Malombe. Of these, approximately 50 percent concentrated their activities in Lake Malombe (FAO, 1993).

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[1] According to our information the system was brought about in the gillnet sector by default. In order to attract competent crew members while operating with a disadvantage of having no engines, Messrs Nkongwa and Wadi Ali from Ntundu offered to pay the crew members half of all the profits accruing from the sell of the wet fish in the late 1970s. Within a few years, all gear owners were forced to adopt this system through the claims of all crewmembers.

[2] See statements of Fred Sinclair, Glab Khan, Amos Charles and Crispo Gwedela in Record of the meeting of the Commission of inquiry into the fishing industry held at the courthouse, Fort Johnston, 8 and 9 June 1956. (MNA/COM/9/3/1)

5. THE 1980s

5.1 Reduction of Chambo catches and technological changes

Fishing effort on Lake Malombe had increased dramatically during the 1970s: in 1981, on a water surface of 390 km², 230 gear owners hired 1 400 crew members fishing from 350–360 planked boats and operating more than 100 km of gillnets, 27 Chambo seines and between 60–70 Kambuzi seines (Zwieten, Njaya and Weyl, 2003: Figures 11 and 12). Most of the boats were motorized. Total catches in the early 1980s fluctuated between 7 000 and 12 000 tonnes of which 6 000 to 9 000 tonnes were Chambo (Zwieten, Njaya and Weyl, 2003: Figure 1).

The 1980s saw both a decline in nominal catches of Chambo as well as in its relative importance of the total catches. By the early 1990s, Chambo catches had been reduced to around 1 000 tonnes while the total catches remain close to what they were a decade earlier. During this period we also observe great changes in technology and catch methods. By 1990 the amount of gillnets had been reduced to 45 km and only six or seven Chambo seines are reported to remain in the fishery. On the other hand the number of Kambuzi seines tended to grow in the first part and later started to fall so that the number of seines in the early 1990s remained somewhat lower compared to what it had been early in the 1980s. Also the use of outboard engines became more and more rare and by 1994 there were no engines left in the Malombe fishery (Fisheries Department, 1995).

The big change in the fishery for Kambuzi came when the *Nkacha* net was put into common use in the first part of the 1980s. Already in 1976, a Lake Malombe fisherman, Mr Galimbe Paudala, invented this new gear and fishing method which targeted Kambuzi in the open waters of the lake. But most of the fishermen only seem to have adopted the method and start using the Nkacha after the Chambo catches began to fall in the 1980s[1]. Until 1983 the number of Nkacha nets remained well below 50, but thereafter the number increased rapidly and in 1991 there were 180 such nets in Lake Malombe. Since the Nkacha was an open water seine, this meant that the fishers could fish all over the lake. Quickly, the Nkacha became the most important fishing gear as almost all gear owners switched from Chambo and Kambuzi seines to Nkacha nets. The number of gear owners and assistants did not grow much through the 1980s. Some additional gear owners seem to have been able to establish themselves, and in the early 1990s they are reported to number around 300, but the number of crew members remains stable (Zwieten, Njaya and Weyl, 2003: Figure 11).

The development of fishing effort in the 1980s represents something new in Lake Malombe. While effort from the early 1950s to the late 1970s had been growing as a result of increases in number of fishermen and in investments, the 1980s experience a noticeable reduction in the population-driven growth of effort. Besides, the new investments which continue to flow into the fisheries are no longer just added to already existing investments. It could have been expected that the Nkacha net would come as an addition to already established practices but instead they are used to substitute the previous investments in order to target new species in new environments. This change is a simple reflection of the disappearance of the Chambo, it

[1] Because it targets Kambuzi and looks similar to a Kambuzi seine net in terms of the gradation of its mesh sizes from the bunt to the wings, the Nkacha net was mainly referred to as *Khoka la Kambuzi* (Kambuzi seine net) in the early years. The name Nkacha only came into common use as referring to a separate gear from the Kambuzi seine in the late 1980s. This causes some problems in tracing the exact change process from Kambuzi seines to Nkacha nets.

does not make much sense to continue to chase a species which has become impossible to capture and this is the reason for giving up the Chambo gear[1]. Whether the change from gillnets and Chambo or Kambuzi seines to Nkacha nets represents an investment-driven increase of fishing effort is hard to say since it is difficult to compare one fishing method to another[2]. Nevertheless, there can be little doubt that although the investments and the technological development very much continued, the fishing effort tended to stabilize during the 1980s when it comes to investments.

5.2 Reduced recruitment of fishermen: the role of 'lords' and crew members

We must also ask to what extent the reduced recruitment of gear owners and crew members that took place in the 1980s reflected changes in the biology of the lake (reduced catches of Chambo as well as reductions in overall catch rates), and/or to what extent they were directly caused by social changes that took place, in particular the emergence of the new elite. The question is whether the stabilization in the number of operators was caused by economic incentives to leave the fisheries when signs of heavy fishing pressure emerges or whether it was the economic influence in general of the "lords" and their dominance in the fishery in particular that made them able to control – and even deny – individual's access to the resources of the lake so effectively, quite irrespective of whether the individuals wanted to participate as co-owners or as crew members. To answer these questions we need to investigate thoroughly who came to constitute this elite, how it was reproduced and what opportunities and constraints the elite faced in its daily economic operations.

To become a gear owner, especially a seine or a Nkacha net owner, means to have made it to the top of the social profile in Malombe. Only a couple of hundred individuals, out of a total population of more than 50 000, find the means to invest in a fishing unit. In the 1950s we saw how the Fisheries Officer in Mangochi linked the emergence of the first African commercial fishermen on Lake Malawi to businessmen from other parts of the country and labour migration returnees who invested their savings in fishing material. On Lake Malombe the emergence of commercial fishermen took place some years later and shows a slightly different picture. The authors interviewed a small number older people who had established themselves as gear owners in Malombe in the 1960s. These interviews indicate that very few "foreigners" seem to have invested in the Lake Malombe fisheries. Primarily labour migrants originally from Mangochi district started to invest in Chambo seine nets, in boats and in outboard engines, even if some local businessmen and retired civil servants also emerged among them.

It is important to notice that those constituting the elite today, only very rarely are the same individuals – or representatives of the families – that formed or constituted this elite 30 or even 20 years ago. Among the 42 gear owners interviewed, only three or four of them had been owners in 1980. Twenty four of them report that neither their father nor any of their uncles had owned fishing gear. However, this does not mean that the remainder – 18 of the interviewed gear owners – are sons or nephews of commercial fishermen, nor does it mean that they

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[1] FAO (1993) points out that the use of small mesh Kambuzi seine nets along the shores was also one of the major factors for the decline in the Chambo as these caught juvenile Chambo, contributing to growth overfishing. In addition, fishermen point out one of the causes of the decline of the Chambo was the Nkacha net. As the lake is very shallow, the Chambo used to breed all over the lake. The operation of the Nkacha required the removal of vegetation from the bottom which destroyed the habitat on the whole of the lake extensively (see also Zwieten, Njaya and Weyl, 2003).

[2] With reference to the conceptual framework in fisheries biology it would probably be more correct to talk about 'fishing mortality' in this case.

inherited their fishing gear. Only three or four cases are known were a presently active boat owner is the heir of a commercial fisherman. What this tells us is that the elites are not a fixed and stable group, but rather an assembly of those individuals who at any time have been successful enough to achieve a certain financial status adequate enough for investment in fishing, which many of them may lose again or, if they do not, may be dissipated at the time of the death of the person. All the life-stories indicate a pattern which is common in rural Africa; economically wealthy people are almost without exception "self-made". One of the main reason for this is that inheritance rules often are ambiguous and fluid and a source for serious conflicts (Berry, 1993). Matrilineal descent, like we find in Yao society, often complicates the principles of inheritance further. Common practice[1] is often that a person inherits the estate of his/her uncle, that is the person's mother's brother. Even then, it is usual that the equipment will be sold and money shared among the deceased person's family (sisters, father and mother) other than being left to a nephew to continue with fishing. In this way, the family avoids in-fighting for the estate. Apparently, even in cases where the deceased gear owner had expressed the wish that his children should take over his estate, it is common for his father or uncle to over-ride his wishes and take over the estate, unless the deceased had backed his wishes with a written will. Only 13 percent of the gear owners registered in 1993 and who had deceased before 1999 had left their equipment to their sons. In such cases, the sons were old and strong enough to assert their claims to their father's estate or their father left the gear in their hands well before they died[2]. The problems connected to the inheritance of gear have also led to some unintended consequences regarding ownership. In order to avoid the dissipation of assets in the inheritance process, ten women, either wives or sisters of the deceased, have managed to postpone the inheritance process and to establish some kind of control over the fishing gear. It is unclear, however, how and when the first female gear owners emerged. As will be shown below the female owners are under severe constraints and it is therefore improbable that they will constitute an important economic part within the elite.

Since inheritance is not an option, those who want to become boat owners have to find other means and these means prove to be fairly similar to what the first commercial fishermen used[3]. In most cases it means finding a source for accumulation of capital outside the fisheries. In the 1980s the most common options remained migrant labour savings, credits or loans and fish trading. The contract system to the South African mines continued but ended towards 1985 and also the migration directed towards the 'informal' sector – in South Africa as well as in Zimbabwe - started to show signs of stress. It was still possible to find interesting sources of income even if it was much less attractive than it had been in the past decades. The reduced opportunities, which have continued into the 1990s, can be observed in general social changes in the Upper Shire area. More than a reduction in emigration it has resulted in an increase of migration failures. A very high percentage does no longer achieve any measurable success in their quest to earn and save money for re-investment back home.

Fish trading seem also to have been a good alternative to labour migration in the 1980s. Sources of credit or loans could also be an option. In the 1970s and 1980s certain shop owners

[1] In most cases, the Yao custom is used to dispose of a deceased owner's estate and in this context, most of the estate is supposed to go to the nephews, his sisters' children. Being so many of them, the usual solution to dividing the estate within the family is to sell the items and share the money.

[2] In one case we observed that one son managed to appropriate his fathers fishing material, but in that case he sold it and invested the money outside fishery.

[3] In 1999, a new Nkacha net would cost about K100 000 (approx. US$2 300) while a good used net would cost about half that amount. The cost of the net represents approximately 75 percent of the total costs of the unit.

and the Blantyre Netting Company were sometimes willing to offer nets on loan to potential gear owners. Accumulation of savings as a crew member seems to be very difficult and only four of the 42 owners interviewed refer to this type of savings as their source of starting capital. Earnings are limited and receiving them in small daily instalments under the pressure of social and economic needs of an extended family system does not encourage savings which would require decades.

If it is difficult to become a gear owner, it is not necessarily easier to remain one once you have established a fishing unit. The management of the unit and its labour in particular has been found to constitute the main critical factors. Managing crews in commercial fishing units in Malawi has never been an easy task. The first entrepreneurs loudly complained to the Commission of Enquiry in Fort Johnston in 1956[1] about how they in various ways were fooled by their crews who sometimes destroyed equipment or stole fish they had caught. This is in no way an uncommon feature in African fisheries. On the contrary, the direct control of labour is often reported to be critical[2] particularly since norms and rules that regulate owner/crew relations are seldom shared. On Lake Malombe we found that, despite the seeming economic power of the 'lords', their ability to control the crews are often restricted. Some crews have over the years ascended their position to one that resembles that of shareholders. Sometimes they decide on the timing of work, the recruitment of new crew members or the sale and price of fish without consulting the owner. Despite the introduction of a share system in the 1970s some crews have later stopped contributing towards payment of operational and fixed costs for the unit, meaning that these are now solely borne by the gear owner.

The reasons behind the paradox of a numerically limited and economically strong elite with restricted power over their own employees are complicated and can only partially be dealt with in this work. The owners' problem is that few sanctions exist that do not hurt them as much as it hurts crew members. Owners can withdraw their nets and boats from operations in order to force changes or they can dismiss their crew and recruit new ones. In both cases the owner risks serious losses as a result of thefts, malpractices or inexperienced fishermen. Besides, the relationship between owners and crew members is not a single-function one, but complex and strongly embedded in the wider socio-cultural framework of the Upper Shire region. Sometimes one finds that crews are able to mobilize general support among the population preventing the owner's possibilities to employ new crews, or they organize and manipulate boycotts of specific owners who they claim are engaging in practices thought to be inconsistent with agreed norms and practices.

The owner/crew relationship proves even more complicated and in some cases the influence and power of the crews are found to serve the interests of their masters. One distinct feature of the 1993 survey of owners is the absence of non-local investors; that is of investors who do not claim to be from the Malombe area. Only a handful was identified, despite the fact that owners, crews and even individuals not participating in the fisheries, all claim that access to the lake is open to everyone. Thorough investigations showed that access regulation to a large extent was exercised by crews who put extra restrictions on the operations of 'foreigners'. It was reported that the outside boat owners seldom were allowed to inspect the catches of their

[1] See e.g. evidence of Crispo Gwedala cited by McCracken (1987:426-7).

[2] Labour control is a somewhat neglected issue in the literature on African fisheries, but in agriculture and other sectors it is widely referred to. Scholars like S. Berry (1993) are claiming that the lack of labour control may constitute the most important constraint to rural economic growth in rural Africa.

boats at landing and that all maintenance and repairs were under the control of the crews. This kind of owner could chose between appointing a local person to look after his interests or simply wait and receive his share from the crew after they had taken theirs. As a result, very few foreign gear owners are able to run a profitable fishing business. One may say that the barriers for "foreigners" entering fishery in Malombe mainly centre around their lack of inside knowledge about local rules and a certain general reluctance among local people to accept "foreigners" as boat or gear owners. This gives fishing crews possibilities to increase their influence. The same kind of cultural barriers were reported to apply towards the few women boat owners. They must contend with negative social and cultural perceptions to their participation in the fishery in what is a largely Moslem community.

This brief presentation of owner/crew relations demonstrates the complexity of factors influencing the effort dynamics on Lake Malombe. The reduction of Chambo catches is arguably part of the explanation for why the growth in number of owners stabilized during the 1980s. However, the reduced possibilities to accumulate wealth through labour migration were also important. The incapacity among the elite to convert economic power into direct social control indicates that their economic power were less important than what could be expected in explaining the reduced recruitment of owners. On the other hand, an increased power among the crews – mainly used to struggle against the owners – seem to have effectively prevented recruitment of new groups of owners, thereby indirectly supporting the interests of the same owners. As for the stabilization of crew members this is also affected by reduced catches and technological changes from Chambo and Kambuzi seines to Nkacha nets.
However, the increased power of crew members is also a factor which strongly influences crew recruitment. As shown, the owner's possibility to successfully manage his fishing unit is closely related to his control of the crew. But control of the crew is obviously related to the number of individuals to control. The owner has therefore a strong incentive in keeping the number of his employees as low as possible.

6. THE 1990s: STOP IN INVESTMENTS AND REDUCTION OF FISHING EFFORT

The 1980s saw dramatic changes in catch composition of the fishery on Lake Malombe, although the total biomass remained fairly stable in the lake. This picture changed again in the 1990s when total catches decreased from approximately 10 000 tonnes per year in the beginning of the decade to 3 000 tonnes per year in the period after 1995. The large share of the catch is Kambuzi, while Chambo has almost disappeared and now only constitute 200-300 tonnes per year. Parallel to this reduction we also see a clear reduction in fishing material such as boats and Nkacha nets. Chambo and Kambuzi seine nets have almost disappeared. Only the number of gillnets shows a modest growth in the 1990s (Zwieten, Njaya and Weyl, 2003: Figures 1, 11 and 12). The development in terms of gear owners and crew members is more unclear. The frame surveys of the Fisheries Department show an increase of owners in the 1990s. This increase was faster than what was observed during the 1980s; from approximately 300 owners in 1990-1991 to more than 400 owners in 1999 (Zwieten, Njaya and Weyl, 2003: Figure 11). These figures stands in clear contrast to the results of an update in 1999 of the 1993 gear owner register. This update shows that of the 332 gear owners that were recorded in 1993, 210 (more than 60 percent) had left the fishery by 1999. Meanwhile 73 new gear owners had joined the fishery, making it 195 gear owners operating on Lake Malombe in 1999 (see Table 1)[1].

TABLE 1. *Summary of the June 1999 updated information on the Lake Malombe 1993 gear owners' register*

Gear units	1993	1999		
		Left fishery	*New entrants*	*Balance from1993*
Gillnets	40			18
Nkacha	246			91
Chambo seines	3			0
Kambuzi seines	45			13
New entrants				
new gear			16	
used gear			57	
Left Lake Malombe				
died		30		
migrated		54		
sold gear/other reasons		126		
Total	**332**	**210**	**73**	**122**

It is difficult to explain how the big discrepancy between these two sources of data has emerged. Part of the explanation is probably that the 54 units, which according to table 1 have migrated and that for the great part now operate on the southeast arm of Lake Malawi, still are accounted for in the frame surveys. This accounts for about half of the discrepancy. Nevertheless, the accuracy of the update and a series of parallel indications supporting its results make us conclude that the number of gear owners operating on Lake Malombe has been considerably reduced since 1993 and that the number even may be lower than what it was at the start of the 1980s.

The frame surveys referred to by Zwieten, Njaya and Weyl (2003: Figure 11) state that the number of crew members has remained stable. The 1993 registry does not provide data on crew members, but given that the number of owners is believed to have fallen, one could assume that the number of crew members also has decreased. However, this is not necessarily the case. As the number of seine nets and Nkacha nets has declined, the owners have tried to compensate and to maximize effective fishing time by hiring an increased number of crews which are fishing consecutively within the same unit. In the late 1990s most Nkacha units had two and some even had three crews each and the number of crew members per owner is therefore probably higher in 1999 than what it was at the beginning of the decade.

There can be no doubt that the dramatic decline in catches is the main reason behind the decline in investments and fishing effort. While gear owners bought second and third units in

[1] One possible explanation may be that while the frame surveys include any person owning hooks, lines or some nets, the 1993 gear owner's register has concentrated on the wealthier.

the 1980s, it has become increasingly difficult to own and manage more than one net. Very few people in the 1993 registry have increased the gear they own. In most cases, those who had two or more Nkacha nets have either sold one or combined the two to make one. Most owners of Chambo seine nets who have either migrated to Lake Malawi or retired their nets. A good number of the Kambuzi seine nets were converted into Nkacha nets in the early 1990s or the units migrated to Lake Malawi. The few seine nets remaining on the lake are based at the outlet of the lake just outside the Liwonde National Park where they seem to benefit from the protection of the Chambo provided by the park.

However, the decline in catches does not explain the particularities of the reduced fishing effort in terms of the relative importance of changes in number of owners and crew members compared to the changes in volumes and quality of the fishing gear. In order to understand these particularities the constraints found to influence decisions and operations of the owners are important. Many of these constraints continued to prevail and were aggravated in the 1990s. All the sources for accumulation of external funds have become more difficult to access. Legal labour migration to destinations outside Malawi is no longer an option, even though various types of “informal” and very risky travels to the neighbouring countries are reported to continue to help potential newcomers. The update of the 1993 register shows that most of the 73 new entrants report that they obtained their capital from migrant labour savings in South Africa or Zimbabwe. Fish trade has lost much of its potential due to the fall in catches. It takes more and more time to gather a large enough consignment to take to the market so that traders make fewer trips. Since Kambuzi has less value than Chambo, trade in Kambuzi is unlikely to generate surplus capital. Whereas shop owners and the Blantyre Netting Company were willing to offer nets on loan to gear owners in the 1970s and 1980s, they have become more and more reluctant to provide such facilities in the 1990s. The ability of loanees to repay has declined due to declining profits and the sources for credit or loans have virtually disappeared and where they exist the interest rates are high and security difficult to provide.[1] As demonstrated in Table 1 the result is that new entrants more and more rely on buying used equipment.

The control of the “lords” over their crews has continued to weaken, and the owners have had to pay a stiff price for the introduction of more than one crew into their units. Due to the sharing of the material a crew no longer accepts any particular responsibility for the care of the equipment. Abuse and the careless use of equipment are reported to have become common in many cases. With the decline in catches the mobility of crew members between fishing units has increased and the feeling that crew membership is *ganyu*[2] has become increasingly entrenched. The lack of long term tenureship in a unit adds to the problem of responsibility and appropriate use of equipment.

The rules and norms regarding owner/crew relations have certainly not become clearer or more consistent over the last years and the management problems have increased, partly as a result of the increased number of employees. Until the 1990s most gear owners processed their catch before selling it to traders, thereby doubling their earnings. The crew members’ share was based on the price of the wet catch. They only got their share after the gear owner had sold the processed fish for the week in question. Crew members allege that most gear owners sold the

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[1] Loans tend to be very expensive. Commercial banks and the Malawi Rural Finance Company charge over 52 percent annual interest for their loans in 1999.

[2] Daily piecework.

catch to themselves at a very low price, thereby reducing their share. Some also did not give them their share as agreed at the end of each week or after the sell of a particular consignment. Due to such malpractices by gear owners, the crew members started pushing for changes to the system. If the gear owner wanted to process the catch, he had to compete with other potential buyers. Secondly, crew members decided that they would get their share immediately after the sell had been conducted. Thus gear owners who wanted to practice forward integration had to compete with other buyers (fish traders) for "their own" fish. Increasingly, traders bought the fish direct from the crews and processed it on their own other than buying processed fish from gear owners. For many gear owners, this meant an end to forward integration. Those who had bought pick-ups to market the processed fish in the cities sold their vehicles or deployed them for other businesses such as hiring them out to fish traders or for the transportation of people (*matola*). This brought about a fundamental change in power relations between gear owners and crew members. Whereas before the gear owners would take over the catch from the crew as soon as it was landed, nowadays he stands by as traders bid against each other for the fish until the highest bidder is found. The going price has to be agreed between him and the crew. The insistence by crew members that they get their share immediately after the sales have been conducted has also added to his short-term cash flow problems especially after catches declined in the 1990s.

For the owner the system presents a catch-22 situation; it can be difficult to save enough money to carry out major net repairs needed. At the same time, a net in poor state is not as efficient as one that has been properly maintained. The crews usually do not agree to forego their share of the money for a few days so that the gear owner can use accumulated funds for such expenses. The practice of many crews has become to abandon the net and to seek another owner if the net is not productive anymore. Thus if the gear owner cannot save enough money from his share of the catch or cannot borrow money for repairs elsewhere, the result will be that the net will continue to decline in quality and eventually, the crew members will abandon it if the owner does not suspend the operations before that happens. Inability to keep up with repairs leading to decline in productivity has been one of the major reasons for suspending fishing or complete wear out of nets, leading many owners to divest from the fishery. An added factor is that whereas the net owners in the 1970s and 1980s would subtract the operational costs such as money for fuel, twine for net repairs and breakfast for the crewmembers, the latter demanded that the sharing should be based on gross sells other than nets sells. Thus, the gear owner has been left with the sole responsibility for all the costs (capital and operational). As if this is not enough, the share proportions in the Nkacha have been changed to 45 percent for the gear owner and 55 percent for the crew members, since the diver (mtiwi) gets 10 percent of the gross sells before the sharing is done. The gear owner must also contend with increasing theft of fish or gear components by crew members as most Nkacha units started to deploy more than one crew to a unit.

One of the few possible responses from owners has been to revert to less capital-intensive gears than the Nkacha nets. Less expensive gear usually can be operated by smaller and fewer crews and the gear owner thereby is better positioned to exercise effective control over his employees. The modest increase in numbers of gillnets, longlines, handlines and traps in the fishery in the late 1990s (Fisheries Department, 1999) may have been caused by such considerations, but the problem remains that the catch rates for these types of gear remain very low.

As already mentioned, many of the management and control problems have been amplified by the lack of commonly shared rules, values and norms among owners and crew members. But it is probably also correct to say that, during the 1990s, the crew members have increased their control in terms of operational decisions and pricing of the catch and that many gear owners have lost much of whatever control they may have had earlier regarding these decisions. Those who in terms of economic wealth seemed to emerge as the lords and the elite of Malombe have at present far less influence regarding their own production units than what could be expected. This is an important factor explaining why so many owners, over the last years, have decided to leave the fishery.

However, in order to leave the sector people must also have alternatives. This seems never to have been a problem on Lake Malombe. The Yao are historically traders and business people (Rangeley, 1970) and this seems to define the attitude of the gear owners towards fishing. Fishing is not an occupation they are culturally or emotionally tied to. A fishing unit is considered an investment that must pay back in terms of profit; otherwise they will seek to sell it and invest their money in something considered more promising. Table 1 indicates that out of the 210 owners who left fisheries after 1993, 126 are still economically operational in the area. Some have moved into other business activities such as tobacco farming[1], or run minibuses or pick-ups for transporting people. Others again have built houses in Mangochi Township or in some larger villages where they consider the demand for rooms to rent to be high.

Such switches in economic activities are not necessarily very difficult or risky. Contrary to what has often been assumed the commercial gear owners have never exclusively relied on the fisheries in Lake Malombe for their incomes. On the contrary the life stories of gear owners demonstrate that all of them are involved in a range of different economic activities and that diversification always has been considered the best strategy. In addition to commercial agriculture, people transport and renting houses it is common for gear owners to run shops, maize mills, beer halls, local video cinemas and/or rest houses and to invest in cattle and in *dimba* gardens (Mandala, 1990). The various businesses are supposed to support one another and secure stable access to cash. Forward integration of the fishing business into fish trading used to be popular strategy among the gear owners, but fish trading has declined as an option. Most of them say it is hardly profitable anymore as the fish has become too expensive, especially after the crew members started to intervene in the pricing of the fish.

The shift in focus from fishing to other economic activities is also to some extent a self perpetuating process. The more the attention of a boat owner is directed towards other businesses, the less time he has to follow up and control his fishing crews. Many gear owners or ex- gear owners emphasized this dilemma and insisted that there exist a limit for how much time that can be spent in other activities before the fishing business starts suffering. The analysis of owner/crew relations demonstrates that many boat owners crossed this limit in the 1990s. It seems as the wealthiest among them decided to give up the fishery while those who can not afford larger investments in other sectors continue to operate as gear owners.

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[1] Tobacco farming among smallholders was first allowed in 1990 through the initiation of a pilot project in many parts of Malawi (Peters, 1999).

7. CONCLUSION

What makes effort development on Lake Malombe particularly interesting is what took place after 1950. Before this time, fishing effort was mainly characterized by population-driven changes, and the development seems to have been fairly similar to what has been the case on many other southern African lakes. However, from that time the investment-driven changes grew progressively in importance and in the 1980s it came to dominate the effort development completely. Zwieten, Njaya and Weyl (2003) show the serious effects this growth has had on the environment and the biology of the lake. Although not a proof, the case of Lake Malombe is an indication that investment-driven growth of effort, under such conditions, is more of an environmental and biological challenge than population-driven growth of the type observed in so many of the other water bodies of the region.

The case also demonstrates how the investment-driven growth as such caused the gradual reduction in the population-driven growth on the lake. The increased efficiency of the Chambo seine nets reduced the catch rates of the gillnets and other more conventional gear to a level where the operations of the latter became almost impossible. Thereby, a new group of “lords” managed to appropriate the access to the lake at the expense of other and less wealthy segments of the population. This effect is well-documented in many parts of the world when investment-driven changes of effort start to dominate in the development of a fishery (Brox, 1990).

However, as interesting as the effects of investment driven changes are, the findings connected to factors constraining investment driven changes to occur. First, the analysis shows how intimately related the investments in the Malombe fisheries have been related to economic opportunities external to the fisheries. Not only was it labour migration to countries abroad that facilitated accumulation of money and thereby initiated the investment processes. This is already well documented in the literature (McCraken, 1987), but our analysis also shows how important the flow of externally generated wealth has been to keep the investment level going. At least on Malombe it seems as if neither the seine net fisheries for Chambo or Kambuzi, nor the Nkacha net fishery, ever became able to sustain the actual level of investments observed in the 1970s and 1980s. More money was probably floating into the fishery than out of it, and this explains the high turnover rate in terms of gear owners. The reasons are not to be found in pure economic considerations connected to the volumes and the prices of catches. On the contrary, evidence exists showing how the potential profit margins were good for a long period of time. The main problems are more to be found in the institutional arrangements which are found to dominate in the Malombe fishery in particular and in the Upper Shire society in general. Unclear rules and norms regulating the life of extended families and social security networks makes it very difficult for people to make the savings required to keep a relatively capital-intensive operation going. Even more important is that the same lack of clarity is found to dominate in the regulation of owner/crew relations. Symptomatically, there is strong distrust between owners and crews and this leads to an extended need to control each other. Beside the reduced catches in the 1990s, the problems connected to the owner/crew relations are probably the most important factor explaining why so many owners have left the fishery in recent years. The Malombe society is in no manner unique regarding these sociological characteristics and similar phenomena are increasingly being reported from many rural communities in sub-Saharan Africa. This is why this case study is particularly instructive when it comes to understand why investment-driven growth of effort so seldom seems to take place in the fisheries of southern Africa.

Finally, the Malombe fisheries also show how inter-connected African artisanal fishery is to all other kinds of economic activities, both rural and urban. It adds to demonstrating the weak empirical foundation behind some popular and widespread representations about African fishermen being marginalized people and African small-scale fisheries being a “last resort”. In Malombe we have shown it to be the opposite: the most influential fishermen are found in the richest segments of the community and their decisions always reflect their assessment of the earning potential of the fishery on the one hand against other economic activities on the other.

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MARKET DEVELOPMENT AND INVESTMENT "BOTTLENECKS" IN THE FISHERIES OF LAKE KARIBA, ZAMBIA

Ragnhild Overå

1. INTRODUCTION

When Lake Kariba was created through the building of a gigantic dam across the Zambezi river in 1958 for the production of hydro-electric power, the fishery that evolved in the new and large water body was anticipated to become a major benefit for the Tonga people in the area. The relocation of 36 000 Tonga that became necessary as a result of the inundation of the Gwembe valley created many problems.[1] Nevertheless, a thriving fishery did develop, which created new livelihoods for a large number of both Tonga and migrant fishermen and fish traders on the Zambian side of Lake Kariba.

Four decades later, fish marketing continues to be in the hands of small-scale traders and fishing is conducted in unmotorised dugout canoes or "banana-boats". The fishermen constantly adapt to the environment and improve their fishing methods according to their acquired experience. However, apart from a shift to nylon nets and smaller mesh sizes, very few technological or institutional changes resulting in more efficient and profitable fish production have taken place since the creation of the lake. Not even in the semi-industrial Kapenta fishery – opened in the early 1980s and largely owned by white businessmen – have investments and technological growth "taken off". In light of recent research on the biology and ecology of Lake Kariba where no serious depletion of fishery resources is indicated (Kolding, Musando and Songore, 2003), this lack of investment may seem puzzling: given the relatively favourable resource situation in Lake Kariba one would, at least according to conventional common property theory, expect individuals to maximise profit through investment in technology and more efficient organization of production.

In order to understand the causes behind this apparent "lack of development", this paper situates the fishery of Lake Kariba historically, socially and economically (i.e. in the context of its market), and thereby discusses the "bottlenecks" (Brox, 1990) that impede investments, institutional development, and technological growth in this fishery. As it will appear, a capital extensive and technologically simple fishery is a necessary and rational adaptation to the type of context, or "imperfect market", in which Lake Kariba is located. Under the prevailing Zambian economic circumstances, over-capitalization of this fishery is not a threat. It is thus argued that rather than focussing on the regulation of fishing methods, public funding of fisheries management would be better spent on facilitating and securing a fair access to the lake's resources.

1.1 Fisheries investment and contracts in an uncertain environment

In most African fisheries, fishing effort is characterised by often dramatic fluctuations over time. As Jul-Larsen *et al.* (2003) make clear, fluctuations in the fisheries of Lake Kariba have mainly been observed in what Ottar Brox (1990) calls horizontal changes in effort. This relates to changes in such factors as the number of fishermen, the number of nets, and the frequency and spatial extension of fishing trips. In Lake Kariba population-driven changes, as we prefer to call them, have largely been related to migration processes and developments over time in

[1] Of the total of 56 000 Tonga who were relocated, 36 000 belonged to the Northern Rhodesian side (Scudder 1985:14).

other economic sectors than fishing. Furthermore, Brox distinguishes population-driven change in effort from changes in factors such as fishing technology, capital investments, labour organization and concentration of gear units per owner. Such vertical (Brox, 1990), or investment-driven, changes in effort have hardly occurred in Lake Kariba fisheries. Though some capital-intensive enterprises have been observed, they are very few and they have not lasted long. It thus remains to be explained why effort dynamics in Lake Kariba continues to be largely population-driven.

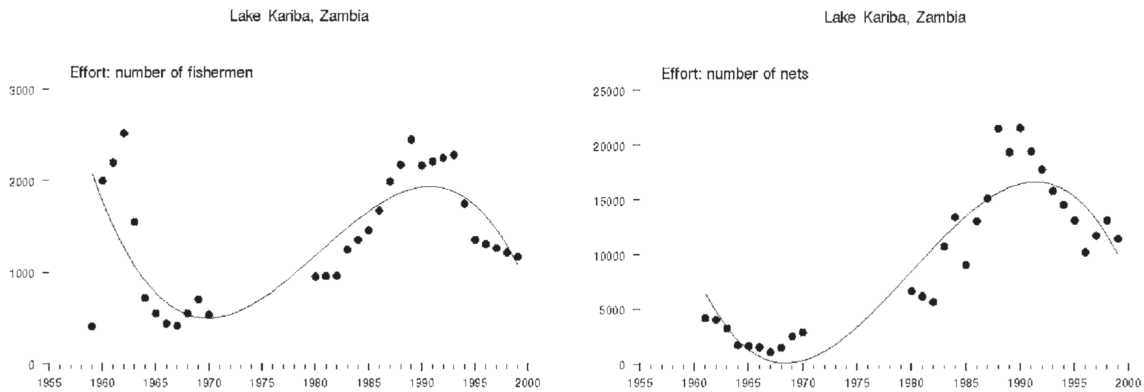

FIGURE 1. *Effort development: Number of fishermen and nets in the Zambian inshore fisheries of Lake Kariba 1960–1999. Source: Jul-Larsen et al. 2003.*

When investment-driven growth has been observed in small-scale fisheries, an influx of investment capital from beyond the fishing units themselves has often proved necessary. Where credit from banks or other official sources are not available for fishermen, access to credit from actors in the fish market is therefore crucial. Traders (with the aim of increasing their fish supply) provide fishermen with credit in order to enable them to invest in more capital intensive gear. New organizational forms (i.e. ownership of fishing boats by traders) and new institutions (i.e. credit and price agreements) may evolve and result in increasing productivity of the fishery. Historically, such “endogenous dynamics” (Chauveau and Samba, 1989) have been observed in many small-scale fisheries in developing countries. In most cases the degree to which traders and fishermen are able to enter into binding and long-lasting contracts is crucial for such investment-driven growth to take place.

According to new institutional economics, the development of credit institutions and supply contracts in fisheries are aimed towards reducing the transaction costs in a situation characterised by market imperfections (inadequate flow of information, lack of infrastructure and access to resources and markets). Jean-Philippe Platteau (1989), for example, sees interlocking credit-supply contracts as an outcome of uncertainty. In order to overcome the obstacles created by market imperfections institutions that “link up credit with marketing relations by offering loans to owners of fishing vessels on the security of future catches” (Platteau and Abraham, 1987:480) will develop. This enables the actors to spread risk and to ensure access to and control over fish supply, capital and – importantly – labour. As Platteau (1989) notices, the institutionalization of such arrangements have been observed in fisheries world-wide, for example through the institution of marriage between fishermen and traders, as in many West African fisheries, or through long-standing relationships of trust, as observed between Malay fishermen and Chinese traders.

In the canoe fisheries of Ghana for example, women traders found a new investment object when the outboard motor was introduced in the early 1960s (see, Vercruijsse, 1984; Hernæs 1991; Overå, 1998). By extending considerable investment loans to fishermen for the purchase of outboard motors and new types of nets and purse seines, the traders were able to increase their fish supply. Some of the women also became canoe owners themselves, hiring men to fish for them. External aid in this innovation process was negligible: it happened from "within" the fishing communities. As a result, the degree of motorization of the Ghanaian canoe fleet increased from zero in the late 1950s to 20–25 percent in 1970 and to 57 percent in 1990. The annual fish landings increased from 20 000 tonnes in 1960 to 300 000 tonnes in 1992. This represents an increase in the productivity from 0.6 tonnes/fisherman/year to 1.4 tonnes/fisherman/year (Degnbol, 1992:215). Important preconditions for this investment-driven growth were (a) institutionalized credit links between fish producers and fish distributors through marriage and kinship, (b) a local gender ideology that allowed for female traders' investment and control of male labour, and (c) the constant adaptation of culturally embedded local institutions to changing situations (male fishery leaders and female market leaders), through which credit and labour relations could be negotiated and sanctioned (Overå, 2001). Platteau's assumption that such "traditional" institutions are more efficient than "modern" institutions in a market characterized by numerous imperfections thus seems well suited to explain the Ghanaian case.[1] The question is, however, whether this approach is useful in explaining why a similar growth process, aided by the evolvement of mechanisms to reduce risk and enforce contracts, does not happen in the Zambian case of Lake Kariba.

The Zambian fish market must be said to be characterized by many "imperfections" that inhibit a free flow of goods, information and capital. The marketing of fish from Lake Kariba is thus neither particularly efficient, nor is the market well integrated with the fisheries through investments. Despite Lake Kariba's location only three to five hours drive from the capital Lusaka where fish is in high demand, the efficiency and profitability of fish trade is highly variable. Likewise, investment by fish traders in boats and fishing gear in order to enhance fish supply, is limited: it is too risky, they say. Indeed, fish traders, Kapenta operators and other potential investors, such as local shop-owners or Lusaka-based fish distribution companies, constantly attempt to enter into contractual relationships with fishermen in order to secure a stable and reliable supply of fish. However, apart from a few exceptional cases, credit relationships and supply contracts are very unstable and tend to fail.

As this situation indicates, it seems difficult to establish institutions – broadly defined as "informal constraints (...) and formal rules (...) devised by human beings to create order and reduce uncertainty in exchange" (North, 1995:97) – that are legitimate among the various stakeholders on the shores of Lake Kariba. The few examples that exist of credit institutions or other long-lasting binding commitments between fishermen and traders have not been of such a magnitude that they have resulted in any significant technological or organizational changes in the fishery at an aggregate level. What is it, then, about this particular context that prevents mutually beneficial contracts and an investment-driven growth in effort from developing?

Sara Berry has pointed out that historically, conditions for the evolvement of "constellations of social interactions, in which people move, acquire and exchange ideas and resources, and negotiate or contest the terms of production, authority and obligation" (Berry, 1997:1228), have

[1] The fact that the canoe sector - despite subsidizing of the industrial sector - continues to land 60-70 of the total marine catch in Ghana (Koranteng, 1996) is a clear indication of the advantages of this "small-scale" fishery.

been unfavourable in Africa. In the case of Zambia and Lake Kariba communities, one can mention quite a few factors that have hampered the creation of what Bierschenk and Olivier de Sardan (1997) call arenas in which stakeholders could come to some sort of mutual agreement about rules for cooperation and for the sanctioning of non-cooperative behaviour. Among these factors are: a lack of "traditional" institutions before the creation of Lake Kariba with rules for the economic organization of commercial fishing and trade; the initial displacement of the Tonga people that created political tension and constrained peoples' livelihood alternatives; subsequent macro-economic and demographic changes that resulted in a "fluid" situation with migration in and out of the fishery; land conflicts along the lake shore; destruction of infrastructure during the Zimbabwean liberation war; fluctuating lake levels and fish catches due to climatic variations; several shifts in administrative regimes and unclear authority structures at the local level. Thus, even if the relationship between fishermen and traders at Lake Kariba certainly is characterised by a recognition of the mutual benefit they have of each other, political and economic instability in the region often inhibit the development of enforceable contracts. When profit is made in fishing, it thus tends – as a perfectly rational strategy under the prevailing conditions – to be invested in a number of security networks (often with conflicting norms, rules and priorities) rather than in more efficient and capital intensive fishing gear.

Much research has been done on the importance of trust for the success of entrepreneurs and traders (i.e. Evers and Schrader, 1994). The Chinese business diaspora and Hausa trade networks are some of the classical examples. In Southern Africa, however, the development of long-term economic relations where trust goes beyond the short-term personal level has been constrained. In contrast to the durable networks of the famous Asian and West African cases, business networks in this part of Africa have been characterized (by the anthropologist Clyde Mitchell) as "instrumentally-activated personal networks" (MacGaffey and Bazenguissa-Ganga, 2000:12). The Zambian economy has thus in many ways come to resemble what Fafchamps and Minton (2001) call a "flea market economy": high risks of theft and embezzlement and breakdown of legal sanctions make traders refrain from entering into contracts and most transactions therefore take a "cash-and-carry form" (ibid:230).

With the high mobility out of formal and into informal occupations (among them fishing), Zambians increasingly find themselves in a situation where they are "faced with the need to build economic relations from scratch in a world lacking both orderly state regulation and the segmentary political structure of their customary society" (Hart, 1988:178). In such a situation the possibility of building durable economic relations based on kinship (ascribed status) is limited, and so is the possibility of relying on contracts legally sanctioned by the state or civil society. There thus remains, as Hart puts it, "the zone of free-floating social relationships formed by the expectation of mutuality" (ibid.), a zone of association and friendship where trust plays a prominent role. Whereas kinship and contract offer a durable model for hierarchy and control (parental and legal sanctions respectively), trust is based on the negotiation of risk occasioned by the freedom of others. Trust is thus central to social life when neither traditional nor modern probabilities hold, but does not hold as a basis for industrial production and division of labour (ibid:191). Sanctions imposed by kinship and formal or informal legal contracts are in other words a "more durable basis for society" (ibid.), and for economic growth beyond individual enrichment.

The case of the fisheries of Lake Kariba sheds light on some of the constraints that inhibit the development of institutions (that require more than fragile economic relations based on trust and mutual personal interest) in an imperfect market. Clearly, one cannot take for granted (as institutional economics tends to do) that common norms and legal sanctions that would reduce transaction costs and thus would reduce the risks of investment in the fisheries, necessarily and "naturally" will evolve in all types of contexts. The case also illustrates the degree to which investment "bottlenecks" at the local level are intrinsically linked to macro-economic and political processes.

1.2 Methodology

Methodologically, the focus of this study is on the multi-local nature of the activities of fish traders, through which they connect the Lake Kariba fishery and communities to the national and urban economic context. The study is based on secondary sources like the anthropological studies of the Gwembe Tonga in the 1950s and 1960s that documented the consequences of the construction of Lake Kariba (see Scudder, 1960, 1972, 1985; Colson, 1960, 1962, 1971; Colson and Scudder, 1975, 1988). Furthermore, information has been gathered from evaluation reports of development projects in the area (see Brandt *et al.*, 1973; Scudder, Colson and Scudder, 1982; Walter, 1988; Jul-Larsen *et al.*, 1997), from reports by the Zambian ministries (Beatty, 1969; Chipungu, 1988), and in the National Archives of Zambia. In addition to information from the general literature, qualitative data have been collected during three periods of fieldworks in Lake Kariba communities and in Lusaka fish markets in 1998 and 1999 (four months in total). Interviews were conducted with fishermen, traders, transporters, fish traders' organizations, Village Management Committees, Women's Clubs, shop owners, Kapenta operators, chiefs, and with the staff of the Department of Fisheries, of the Ministry of Agriculture, Food and Fisheries, and the Councils in Sinazongwe and Lusaka.

The study provides a chronological description of how a marketing system based on fish from Lake Kariba developed in the 1960s leading up to a contemporary analysis of the socio-economic organization of fish marketing in the late 1990s, and of the major investment constraints.

2. A MAN-MADE LAKE – A NEW MARKETING SYSTEM

2.1 Trade and infrastructure in the Gwembe valley before the creation of Lake Kariba

Before the creation of Lake Kariba, the Gwembe valley with the Zambezi flowing through it was bypassed by most trade routes. For a short period at the turn of the twentieth century, Gwembe lay across the direct route (through Kalomo) between the European centres on the high plateau north and south of the valley: a few shops, missionary stations, schools and administrative posts of the British South Africa Company, which took power in Northern Rhodesia in 1898, were established (Colson, 1971:15). However, in 1906 the railway was built on the plateau, and trade and traffic bypassed the valley again (ibid.). Trade stores and missionary stations gradually disappeared in the 1920s. After the 1930s the valley had no white residents and few strangers visited the Gwembe District other than occasional traders who came to collect tobacco (Colson and Scudder, 1975:194). The tobacco trade was based on long-term bond friendships between the urban-based traders and the Gwembe valley producers (Colson, 1960:47).

The Valley Tonga did of course not live in complete isolation. From 1900 many men (hardly any women) participated in an extensive labour migration system which provided most of the cash income that supplemented the sales of tobacco and subsistence grain production (Colson and Scudder, 1975:194). One of the reasons for Tonga men to migrate was the need for cash when the "hut tax" was introduced in 1904. In 1956 as many as 42 percent of the District's able-bodied men were absent as wage workers; mostly in the mines in Southern Rhodesia, especially Bulawayo, and in the Copperbelt in Northern Rhodesia. Thus the majority of the older men had at one time or the other travelled long distances, often walking on foot, in connection with labour migration (ibid.). Nevertheless, until 1950 there was no road in Gwembe (Colson, 1971:17). When colonial administrative officers toured the valley, they were carried by men who reluctantly were mobilized in the villages by appointed headmen. The first four cars owned by Gwembe Tonga were bought in 1956–57 (ibid: 18).

With the influx of money from migrant labourers and the building of roads, the establishment of trading stores followed, in addition to the emergence of "an increasing throng of itinerant traders" in the late 1950s (Colson, 1971:17). Fish trade, however, was not carried out on any significant scale. The seasonal surplus from fishing in the Zambezi was either bartered or sold locally (Scudder, 1960:42). As Colson (1960) put it: "a little dried fish was traded to the Plateau Tonga, but the Valley could not compete with the commercial fisheries of the Kafue and Luapula, handicapped as it was by its isolation" (ibid: 202).

With regards to infrastructure and commercialization, the above description provides a glimpse of the situation when the Kariba dam was sealed in 1958. Within five years a surface area of approximately 2 400 square kilometres would be covered by water. The dramatic and difficult relocation process of the Tonga has been described in detail in the above mentioned sources, and will not be discussed here. The main point is to say that when the new fishery in Lake Kariba emerged, there was neither a well developed infrastructure in the valley, nor a large body of Tonga traders with experience, interest, relevant knowledge or other resources, who stood ready to take care of the distribution of fish from within the new Tonga fishing communities.

2.2 Bumper catches and urban traders in the early years (1958–1962)

Until 1963 the Lake Kariba fisheries were reserved for the Tonga people, and its management was in principle under the control of the Gwembe Tonga Native Authority. The Northern Rhodesian government initiated training programmes. Bemba[1] and Lozi fishermen with experience from other Zambian lakes were appointed to share with the Tonga their fishing skills, and credit for fishing equipment was supplied to encourage local men to turn to fishing (Colson and Scudder, 1988:29). Due to the abundance of nutrients in the water during the first years after inundation, fish stocks multiplied quickly and the catches were very good. The government provided fish markets along the lake, i.e. cemented structures with roofing and scales for the weighing of fish. Around these markets fishing camps were established, which became centres of economic activity and social change. During the first boom years when the lake was filling up, the number of young Tonga men joining the fishery reached 2 500. The Tonga fishermen made nice returns in cash from their sales of fish, and many women from the surrounding farming villages became incorporated in the market economy through the brewing of beer for sale in the fishing camps. Even the District Council responded to people's new availability of cash by opening taverns and bottle stores near the fisheries: "In the early 1960s

[1] Throughout the study the term "Bemba" is used in the way informants in southern Zambia do. This means that "Bemba" is a collective term for people from "the North", and though they use Bemba as a "lingua franca", they may be of many different ethnic origins.

the camps were noisy with drumming and people making merry over beer" (ibid: 30). The income of the men from fish sales and the income of the women from beer and food sales (which indirectly gave women a share of the fishery profits), was mainly invested in cattle (oxen for ploughing), cotton production, bicycles, small grocery stores, and education of children. Obviously, the source of cash and other goods that led to these new patterns of consumption were the fish traders.

MAP 1. *Lake Kariba fishing camps mentioned in the text and their main fish marketing region along the line of rail and Lusaka*

Whereas the local population received training in fishing, no incentives through training or credit programmes were initiated to teach local people the skills of fish marketing. Moreover, "the Tonga were not traders by heart" (Colson, 1962:602). Thus, even though fishing was reserved for the Tonga, very few Tonga participated in the new fish marketing system.

Fishermen felt that processing and marketing involved too much time and labour compared with disposing of the fish for cash and quickly go fishing again. Another important factor was the reluctance of most Tonga men to let their wives leave the immediate vicinity to be involved in economic activities and to be exposed to town life. Thus, since the fishermen were either too young to be married or, if they were married, did not allow their wives to become fish traders, they depended on distribution by fish traders from outside the Tonga communities. So who were these fish traders?

It does not appear that relocated Tonga in the resettlement areas entered fish trade (Colson and Scudder, 1975). Since very few of the fishermen or other Valley Tonga traded in fish in the initial years, it is likely that most fish traders who came to Lake Kariba lived in urban areas. Indeed, they were welcome: “Traders with vehicles were coming into the fishery from Lusaka and the Native Authority did not put any barriers to the export of fish”.[1] It is also likely that these traders predominantly were male. In Nyirenda’s (1957) study based on a survey in the Lusaka markets conducted in 1954 it appears that only one fifth (18 percent) of all traders were women, and that almost all of the traders who dealt in fish were men. Three of the 122 fish traders in the survey were female, but these were wives who retailed the fish that their husbands brought to the market. In a follow-up of Nyirenda’s Lusaka market study, Miracle (1962) noted that the female proportion of traders had increased to almost one-third (29 percent). A major reason for the male dominance among urban traders was the colonial control on urban residence. Africans were mainly to reside in cities as migrant labourers, and it was assumed that the workers maintained families in the rural areas where they came from and that they would return to these upon retirement (Ferguson, 1999). However, restrictions on female residence in urban areas were never completely efficient, and increasingly the government provided housing schemes that included the worker’s family. Correspondingly, the proportion of economically active women in the urban areas, including female fish traders, increased from the 1960s onwards (Hansen, 1997).

None of the fish traders in Nyirenda’s Lusaka market survey were Valley Tonga. The Lusaka fish traders mainly came from the Northern and Western regions. It is thus possible that some traders with experience from the Copperbelt fish markets and from fish trade in Lake Mweru, Lake Bangwelu, the Upper Zambezi, and so on, tried out the new fisheries in Lake Kariba after having contact with the fishermen from these regions, who were appointed to teach the Tonga fishing.[2] Fish traders in Lusaka were considered as occupying a pre-eminent position compared with traders in other food items, and fish was the only trade “profitable enough to compete with the other occupations educated men may follow” (Nyirenda, 1957:44). Considering the high proportion of fish traders with an education higher than Standard III (43 percent of fish traders as compared to 33 percent of all traders), Nyirenda assumed that these traders were hoping to “develop a large business rather than just to pass time” (ibid.). Nevertheless, almost all of them were small-scale middlemen, travelling themselves to the various fisheries: buying, processing, transporting and retailing fish in the market.

During the years of inundation and high productivity in the lake, more fish was exported fresh on ice than in a dried or smoked form from Lake Kariba (Colson and Scudder, 1975). In 1963,

1 From District Commissioner's Kariba Resettlement Monthly Report, January 1958, National Archives of Zambia SP/4/1/61.

2 Another indication of the fish traders' experience from the Copperbelt is that many of the fish traders were organised in The Northern Rhodesia African Fishermen and Fish Traders Association (NRAFFTA), which was formed in 1960 after years of struggle over fish prices in the mining companies' markets in the Copperbelt (National Archives of Zambia ML 1/13/2 and ML 1/6/8).

for example, 63 percent of all fish was marketed in a fresh condition. Since only a small proportion of the fish in the Lusaka market places was sold fresh (Miracle, 1962), this means that much of the fresh fish from Lake Kariba reached a “luxury market”: the urban white population and hotels and restaurants. It is not clear where all the ice to chill and preserve the fish with came from, but at least a large proportion must have come from the ice plant put up by a commercial company owned by white European businessmen in Sinazongwe. In fact, at one time Kafue fish traders travelled all the way to Sinazongwe to buy ice to put on the fish they bought in Namwala (Lower Kafue) to sell along the line of rail and in Lusaka (Beatty, 1969:23).

The European company in Sinazongwe had obtained rights to purchase fish from the whole Lake in 1963 (Malasha, 2003). The company also had plans of extending their operations beyond the production of ice and purchasing of fish from the Tonga fishermen; they also applied for fishing concessions. This was, however, effectively prevented by both the Gwembe Tonga Native Authority and the Northern Rhodesia African Fishermen and Fish Traders Association. The traders and fishermen were in favour of the company’s production of ice (which the traders needed) but threatened to boycott the company (by refusing to sell fish to them or to buy ice from them) if it was given any right to participate in the fishery. Rights to the fishery was a “hot potato” in the independence struggle, and the fish traders association was known to be connected with the African National Congress (ANC).[1] The Northern Rhodesian Industrial Development Corporation, which had provided the company in Sinazongwe with a loan, therefore complained: “The system of marketing Lake Kariba fish is most inefficient in common with all other fisheries in the territory. This is mainly due to the fact that the entire control of the industry lies in the hands of the fish traders who use African Nationalist politics to obtain this control”.[2]

The pre-independence political climate in Northern Rhodesia thus made an industrial investment (by Europeans) in the fisheries impossible. Furthermore, the high costs involved in ice production powered with a diesel aggregate and the problems that the company had with the fishing concession, coincided with a biological decline in the fisheries from 1963 onwards (to which we shall return below). An industrial venture where capital was planned to be pooled into motorized fishing gear, ice production and efficient transportation and marketing therefore never happened. Politically it was unacceptable, and with declining fish catches it also proved to be unprofitable. In 1964 the company pulled out of the area and moved their ice plant to the Kafue River (Malasha, 2003).

Fish marketing thus remained in the hands of the urban fish traders. Very little information is available on the extent to which they invested in the fisheries through credit-arrangements or directly in gear ownership. Beatty (1969:75) indicates that fishermen often tried to steer clear of entering into credit arrangements with the traders to avoid them determining an unfavourable fish price. However, with the declining profit margins on which the majority of fish traders operated (Obershall, 1972:120), it may have been a very small minority of the fish traders who had the financial capacity to extend long-term credit of any significance at all. The general impression from Colson and Scudder’s works is that the only credit-arrangement

[1] The NARFFTA was associated with ANC during the liberation struggle, but lost its authority when United National Independence Party (UNIP) and Kaunda formed a government after independence in 1964 (Malasha pers. com.). See also Obershall (1972:121), who describes how various market places in Lusaka were organised by the different political parties.

[2] Minutes of a meeting between a Delegation of the Northern Rhodesia African Fishermen and Fish Traders Association, the Gwembe Tonga Native Authority, the Northern Rhodesia Government, and the District Commissioner, Gwembe, 18 July 1962 (National Archives of Zambia SP 1/3/42).

practised was the provision by fish traders of necessities on credit: mealie-meal (maize meal) and fishing nets were bartered with fish. This could probably work out well in the fishing camps around the fish markets. There, exchange between traders and fishermen was supervised by fisheries officers who were weighing the fish and calculating the price according to the gazetted fish price. Fish traders therefore had some security if they extended credit to fishermen. But any massive investment in gear by traders is not reported. Investments by the Tonga fishermen themselves tended to go in the direction of farming equipment and cattle (which represented their most valuable form of saving and wealth; *lubono*), rather than into more technologically sophisticated or capital intensive fishing gear.

2.3 Dispersion, migration, and new trading patterns (1963–1975)

Towards the end of 1962, Lake Kariba had reached its maximum level and the biological productivity declined drastically. This was not related to overfishing, but to natural processes in the "making" of a lake: nutrition levels in the lake sank, the catches and the size of fish decreased, whereas species diversity increased (Musando, 1996). Already by 1964 the catches had declined with 50 per cent, and the number of fishermen dropped from 2 500 in 1963 to 500 in 1969 (Walter, 1988:34). When fish catches in the vicinity of the fishing camps went down, most of the Tonga fishermen returned to farming; many of them producing cash crops (cotton and maize) (Colson, 1971:149). One important reason for a revived interest in farming was also the eradication of tsetse flies because all game had been shot in preparation for inundation of the Gwembe Valley (on the Zambian side) (Scudder, 1972). The end of sleeping sickness in combination with investment of profits from fisheries, led to a shift in the agricultural production system towards ox plowing.

Around the same time, in 1963, the ban on fishing by other ethnic groups than the Tonga was lifted. Whereas natural resources had been governed by Native Authorities (though under the indirect rule of the colonial government), rights to natural resources became centralized under the new government after independence in 1964, and should thus in principle be accessible to all Zambians. Native Authorities were replaced by Rural Councils. The fishery was now open to anyone, and predominantly Bemba men from the Northern Province started to move into the valley to start fishing. Some of these may have been fish traders who were familiar with Lake Kariba and who saw an opportunity in becoming fishermen when the ban on fishing by non-Tongas was lifted. Others were the appointed Bemba and Lozi "fisher trainers" and colleagues and relatives of theirs from their home regions.[1] Since most Tonga were leaving the fishery in favour of farming and labour migration, the new non-Tonga entrants in the fishery were not viewed as competitors. Apparently, although little information exists on this relationship, Tonga "traditional" political leaders (chiefs and headmen) did not resist the entry of "foreigners" into the fisheries.

Demographic and biological changes led to a reorganization of the fishery. First of all, as a result of the lower productivity of the lake, the fishermen had to chase fish where it could be found. This meant that they had to adopt a much more dispersed fishing pattern. Since the migrants neither had rights to land, nor a close attachment to the land in the Gwembe

[1] In addition, 20 people from Luapula and Eastern Province had been employed to clear forest in those parts of the valley bottom that were designated to become fishing areas, and many of these workers became fishermen (Malasha, 2003).

valley as a livelihood and way of life (as the Tonga had), they probably felt more inclined to migrate freely in search of good fishing grounds. The fishermen thus frequently changed fishing locations while their families stayed for prolonged periods on the numerous islands in the lake. Sometimes a fishing camp on an island could consist of only one fisherman and his family.

The spatial dispersion of fishing, the declining catches and the diversification of the fishermen's ethnic identity had far-reaching consequences for fish marketing. It became very difficult for traders to reach the fishermen. Only the harbours of Sinazongwe and Siavonga were accessible by road the whole year. Consequently, a shift from a predominance of trade in fresh fish to a reliance on drying and smoking as the main processing methods, occurred.[1] It was simply impossible to get ice to and from the fishing camps quickly enough, and even many of the lakeshore camps were not accessible at all with vehicles. The transportation problems led to a decrease in the number of traders who frequented the fisheries of Lake Kariba, and the fishermen increasingly had to process and transport their fish to the market themselves. In the migrant fishing households, some integration of production and distribution through marriage and kinship therefore became common. Their trading networks often extended to relatives living in town, with whom they stayed while selling the dried fish, or in whose hands they would leave the market retailing of fish altogether.

During the late 1960s and early 1970s, more of the fish from Lake Kariba was marketed in the Copperbelt than in the early years. This can be attributed to (a) the longer durability of dried fish compared with fresh fish and (b) the origination of many of the "foreign" fishermen in the Copperbelt where they had relatives living in the mining towns who were important co-operation partners in the marketing of fish, and (c) the high demand of fish from the copper mine workers.

Some of the Tonga who remained fishermen also started processing and marketing their fish themselves, and some of the women started trading. However, even in cases where Tonga husbands allowed their wives to market the fish, the women often felt that the incentives for going on a strenuous trading trip were small. In many Tonga households the wife had to account for all the profit she made on a trading trip for the husband, and wives generally had very little control over what the money should be spent on. Hence, most Tonga fishing households continued to rely on traders, and the majority of traders were still male (Obershall, 1972). Often fishermen developed bond-friendships with dried-fish traders who spent as long as a month in the fishing camp buying and drying fish, during which time he would often be associated with one particular household. Traders finding their way to the far-away fishing camps portrayed themselves as "orphans" who were given shelter by the fisher families, rather than as potential absentee owners of fishing gear.

The role of the traders in bringing goods from town into the fishing camps was important. The need to purchase goods was thus as important as selling fish when fishermen made time-consuming journeys to towns. But there was also another reason why fishermen started to bring their own fish to the market: the government had introduced a price policy

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[1] In 1972 in the Southern part of Lake Kariba (from Chiyabi to the mouth of the lake) 63 percent of the total catch was dried. Of the remaining 37 percent, 23 percent was consumed locally, while only 14 percent was sold fresh to traders (Brandt *et. al.* 1973).

whereby the official producer price too was very low compared with fish prices in urban markets (Brandt *et al.*, 1973:17). An organization of fish marketing like the National Marketing Board (NAMBOARD), a co-operative distribution system introduced to farmers, was thus impossible as long as the official producer price for fish remained unacceptably low (ibid.). In fact, deteriorating rural-urban terms of trade in general during the so-called “good” years of the urban copper economy (1964–73) meant that prices of agricultural goods declined by nearly 54 percent relative to the prices for the urban processed goods that villagers wanted to purchase (Colson and Scudder, 1988:125). Hence, fishermen either retailed what they produced themselves, which was time consuming and left them with less time for fishing (some of them sending their wives, which meant that they could fish more), or they relied on traders who were willing to pay a higher price than the official one. Another consequence of the price regulations was that it became even more preferable to fish from the islands and other far-away places where price agreements between fishermen and traders could not be observed by officials.

Declining profitability of fish trade and transportation problems were major bottlenecks in the development of the fishery. For example, the fish ferry service that the Gwembe Rural Council had been operating from Sinazongwe was shut down in 1968: the dispersed nature of the fishery had made it impossible to reach all the shifting fishing camps with the ferry. Neither did planners take the needs for improved infrastructure seriously. When a coal mine was established in Maamba in 1968, this opened up for a vibrant bicycle fish trade from the nearest fishing villages to supply the 700 coal mine workers. However, the potential benefits of the establishment of large-scale industry in the Gwembe valley were limited: the tarred road that was constructed from Batoka on the plateau down to Maamba was not extended to the lakeshore. And even if Maamba was electrified, no communities along the lake (the source of the electricity) were connected to electricity.[1]

In such a situation, it was obviously difficult for the traders to invest in the fisheries and establish stable contracts with fishermen. The main strategy for fishermen to increase their number of nets and other fishing gear, was thus to purchase these items themselves when they brought fish to the urban market.[2] With the low productivity of the lake and the amount of time the fishermen spent away from fishing while trading, it was unlikely that these investments would result in an increasing fishing effort. A report from 1972 probably describes the situation in a nutshell: “As the fishermen (…) suffer greatly from poor market integration, many of them have little incentive to catch more fish than is necessary for subsistence. High profit margins between producer prices and retail prices force the more enterprising fishermen into the fish trade which, due to bad transport conditions in Gwembe South, is very time-consuming” (Brandt *et al*., 1973:127).

A combination of ecological factors (declining nutrient levels in the lake resulting in declining catches and smaller fish), poor infrastructure and declining rural-urban terms of trade thus contributed to a continuing low level in fishing effort. In the early 1970s, the number of Tonga fishermen still remained around 500 with an additional 5–600 non-Tonga fishermen on the Zambian side of Lake Kariba.

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1 In fact, it was going to take almost thirty more years before electricity was provided in Sinazongwe, the administrative centre of the southern part of the Valley.

2 In 1972 two thirds of all new nets were bought outside the valley (Brandt et al., 1973:121).

2.4 War and collapse of infrastructure along Lake Kariba (1974–1980)

During the Zimbabwean war of liberation, several attacks by the Rhodesian army extended into the bordering Zambian areas. The Zambian shore of Lake Kariba was particularly hard hit, especially by land mines, and the dirt-road network along the lake that had existed (at least during the dry season) was blown up. Thus there were no longer any roads connecting the fishing villages. Only the main roads between the valley and the plateau remained. Rhodesian raids also destroyed all larger boats in Sinazongwe. No government development activity was implemented between 1975 and 1979 (Walter, 1988:17). On the whole, the war was the most serious setback since the relocation-process when the valley was inundated. After the attacks, shops in the Valley were few and poorly supplied. Whereas most homesteads had a bicycle in 1971, people again went on foot in 1981 as they had done in 1956–1957 (Colson and Scudder, 1988:35). In other words, a lot of the investments that the Tonga had been able to make from the first profitable years of the fishery, were destroyed.

Fishing did not come to a total standstill during the war years. The fishermen searched for fishing grounds in the safer areas, and they were allowed to cultivate some food for their own subsistence in the Tonga villages. However, as a result of the collapse of infrastructure and the danger involved in moving around in the Valley, fish traders almost completely stopped travelling to buy fish from Lake Kariba. A high density of land mines also prevented safe movement by traders for many years after the war. Therefore, fishermen and their families processed the fish themselves, bartered it for food locally and brought dried fish to urban markets when possible. If fish marketing networks with established links between urban traders and Lake Kariba fishermen at all had evolved in the 1960s, most of them dissolved during the insecure years of the latter part of the 1970s. The fish traders who had established bond-friendships with particular fishing camps or households had to seek opportunities elsewhere.

2.5 Lake Kariba as an opportunity for the unemployed (1980s)

The Zambian economy was ruined when the copper prices on the world market fell as a result of the oil crisis in 1973. In 1983 Zambia, as part of an International Monetary Fund (IMF) Structural Adjustment Programme (SAP), devalued its Kwacha by 20 percent (Banda, 1991:12). Furthermore, Zambia had a decline in formal sector employment from 27 percent of the labour force in 1976 to 15 percent in 1988 (Pearce, 1989:6). As a result of these macro-economic events numerous people all over Zambia, in particular in the Copperbelt towns, lost their jobs. Living conditions in general were deteriorating. When Lake Kariba became safe after Zimbabwe's independence in 1980, people thus came from a variety of occupational backgrounds to seek their opportunity in the fishery that for long had been almost unexploited. The number of fishermen thus increased to 1 500 in the mid-1980s and reached 2 500 by the early 1990s (the same number as during the peak of the fishery in 1962). In a survey undertaken by the current project (Jul-Larsen, 2003) it appears that these fishermen were not, as fisheries officers have often claimed, coming from other (presumably overfished) lakes. It rather appears that the great majority had lost various kinds of wage employment in urban areas, particularly in the Copperbelt, and sought the Lake Kariba fisheries as an alternative source of livelihood.

One woman, for example, who arrived at Lake Kariba in 1980 at the age of 37 together with her husband, and who presently lives in the fishing camp Sinalilongwe, said: "My husband was a bricklayer and I was selling buns and other small things in Mansa. But then my brother-in-law, who had already gone to fish in Lake Kariba, told us that we were wasting our time in Mansa and that there was good money to earn in fishing. So we went." Another woman moved from Eastern Province to Lake Kariba in 1982 at the age of 21. Her husband was a teacher and she was an untrained teacher: "It was my husband's idea to come to Lake Kariba. He said there would be money in fishing, so he went and tried. Then I came after him". Another fisherman had a background as a pharmacist who was not able to earn a viable income when people could no longer afford to buy drugs.

In the African context, the population of copper producing Zambia was one of the most urbanized. The rural-urban ratio had changed from 80:20 in 1963 to 60:40 in 1979 (Kaplan, 1979:86). However, this rapid urbanization trend slowed down for a while in the 1980s. Whereas it was expected that the urban rate would reach 46 percent in 1980, it landed at 43 percent, and between 1984 and 1988 there was in fact a modest reverse trend in the urban rate from 48.3 percent to 47 percent (Pearce, 1989:9).[1] Seen in this perspective, migrants coming to Lake Kariba were responding to a situation of national economic decline, increasing unemployment in urban areas and a continuing population growth rate of 3.7 percent per annum (Banda, 1991). At the same time, the Zambian government repeated its "Go back to the land"-slogan from the 1970s and implemented relocation programmes in the latter part of the 1980s (ibid:84). The copper mines even held workshops giving workers practical information about how to settle in rural areas upon retirement (Ferguson, 1999:72). The decline in the copper economy and the urban crisis – a phase in Zambian history that Ferguson (Ibid:11) characterizes as "de-industrialization" and "counter-urbanization" – affected people from all ethnic groups. According to Walter (1988), there were both local and migrant Tonga, and migrants from a wide range of ethnic groups (though predominantly Bemba), among the "new" fishermen in Lake Kariba. The impression that the migrants came from urban employment and not from overfished lakes is strengthened by Walter's finding that the migrants had a higher level of formal education than the Tonga (Ibid:40). Of those who had fished before moving to Lake Kariba, most of them had fished in Kafue (Walter, 1988:51).

Though both Walter (1988) and Chipungu (1988) point out that fishing and fish marketing were separate occupations, our data show that many of the fishermen started as fish traders. In 1988 Walter (1988:21) recorded a number of 800 fish traders out of which 180 were fishermen themselves. However, "the number of people seeking employment in fishing is higher than the number of jobs vacant" (Ibid:72). Many fish traders thus seem to have regarded fish trade as an entry ticket to the fishery, both economically and socially. A common career path could be like this: a man started trading, going to Lake Kariba buying and drying fish. After a while he might have established more stable contacts and could even be allowed onto the canoe of one fisherman to learn fishing. Sometimes this would be a relative who was already established as a fisherman. At this stage, the trader's wife and children would join him. If he did not have a wife, it is very likely that he would marry one of the numerous female fish traders who were now coming to the lake.[2] Through savings from his own and his wife's fish trade, perhaps with a contribution from the fisherman who taught him fishing, he would invest in a canoe and a few nets to start fishing on his own.

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[1] Nevertheless, by 1990 the urban-rural ratio had reached 50:50 (Jamal and Weeks, 1993).

[2] Some of the migrant fishermen left wives behind in the North who they never saw again. Only 7 percent of Lake Kariba fishermen lived without wives and children (Walter, 1988:21).

During the 1980s, fish prices fluctuated and alternated between being regulated and deregulated (Chipungu, 1988:31). The profitability of fish trade was highly variable. Walter, (1988:91) found through his calculations of fish traders' earnings that to sell fish as a wholesaler was comparably attractive in relation to wage employment. However, considering that 42 percent of the urban population subsisted below the poverty datum line in 1988 (Pearce, 1989:7) and therefore had a limited purchasing power – to the extent that many consumers had to skip meals (Ferguson, 1999) – fish trade was not particularly lucrative, even if it may have been regarded as one of the better alternatives. The price at which fish could be sold in a poor market remained limited. Considering the appalling state of infrastructure in the Lake Kariba area and the hardships involved in being a fish trader (like sleeping under a tree during the rainy season) it is perhaps not so puzzling that many traders preferred to become fishermen.

The poor profitability of fish trade can thus at least partly be seen as an explanation for the desire of traders to become fishermen. Many urban unemployed men first and foremost entered fish trade as a strategy to familiarize themselves with the Lake Kariba community and to establish personal relationships within the fishing camps in order to enter the fisheries at a later stage. Another strategy, which probably could only be employed after some contact with the fishing camps through trade, was to work as hired labour for the fishermen. Investments by traders in social relations in Lake Kariba fisheries was not, then, as in some other small-scale fisheries (i.e. West Africa and Asia), directed towards the creation of credit relations or ownership of the means of production. Zambian fish traders in the 1980s simply did not have any other capital to invest than their own labour. For women, their labour was not a valid currency in fishing, since it is considered a male activity, and their only niche in the fishing economy was thus in trade or in marrying a fisherman.

In the 1980s, fish processors at Lake Kariba largely dried or smoked the fish. One obvious reason was the problem of getting hold of ice. Lusaka did not have any large ice supplier until Kembe Coldstorage started producing ice blocks in 1989. Neither was electric power installed anywhere near the lake (except in Siavonga), so freezing of fish was not an option either. Traders thus had to stay for long periods in the fishing camps and on the islands buying and processing fish, and the practice of bartering and "subsistence" credit arrangements between fishermen and traders continued as before the war. Fishing camps were still extremely dispersed and variable in their duration. In a catch assessment report from 1986–87, only 26 percent of the fishing settlements identified were compatible with the settlements identified in a report by Beck from 1985 (Walter, 1988:34). Within a time span of two years, three quarters of the fishing camps must either have moved or been renamed. Furthermore, with the inadequate road system, unaffordable fuel prices, lack of accommodation and shelter both on the road and in the fishing camps, fish trade was extremely time consuming and exhausting. Both Walter and Chipungu report that because of their limited capital base, fish traders often did not purchase as much fish as they could have transported to the market. Most traders thus operated on a very "inefficient" level, making frequent trips trading in small quantities, and selling to poor customers in town.

2.6 New entrepreneurs in Kapenta fishing

Fishing techniques and gear types among the numerous new entrants in the inshore fisheries largely remained unchanged and – obviously – at a low cost level. However, another fishery expanded in Lake Kariba during the 1980s. The small sardine *Limnothrissa miodon* had been introduced in Lake Kariba from Lake Tanganyika in the late 1960s. In Zambia this fish is called Kapenta.[1] The stocks increased with an amazing speed, but were not exploited until 1981 when the first Kapenta licenses were issued. The catching of Kapenta requires a particular type of vessel (a so-called rig) and strong light bulbs to attract the Kapenta in order to catch them with dip nets in the dark of night. The inshore fishermen were thus unable to utilize this resource from their small canoes.[2] Neither did they have the capital nor technical or managerial know-how required to enter the Kapenta fishery. Hence, with the Kapenta fishery, a new group of entrants (in Zambia called Kapenta operators) with stakes in the lake and the land entered the Valley.

Unlike in the pre-independence days this fishery was not reserved for black Zambians, although 50 percent of the shares in each company had to be registered in the name of a Zambian. When the Zimbabwe war ended, a number of businessmen and commercial farmers thus stood ready to invest in the Kapenta industry. The new entrepreneurs were expatriates (for example Italian and Indian) who had worked for international companies and were resident in Zambia. But most of them were white Zambian commercial farmers or businessmen – many of them returning from years of “exile” in Southern Rhodesia and South Africa. Some Kapenta operators were South African or Zimbabwean (South Rhodesian) by birth. Capital for this new industry largely came from personal savings and loans from relatives abroad, and from the private sectors in Zambia, Zimbabwe and South Africa. No black Zambians have so far succeeded in entering the Kapenta industry on a permanent basis, except as workers employed on the rigs and in the drying and packing of Kapenta.

The first operators started fishing in 1981–1982, and several more established themselves in the following years. The Kapenta rigs were copies of those that already were in operation on the Zimbabwean side of the lake. On the Zambian side the rigs were built slightly smaller, and the technology in Kapenta fishing remains very similar today as when it started in the 1980s. Though some operators have diesel motors on their rigs, most of them are still operated manually with four workers hoisting the dip nets up from a depth of 20 metres with a crane.

Since Kapenta was a completely unexploited resource (at least on the Zambian side of Lake Kariba), the catches were tremendous during the 1980s. There was also a high domestic demand for dried Kapenta in the urban markets: Kapenta is ideal for the poor customer because it can be bought in very small quantities. The Kapenta operators thus made good money, not because prices were high but because Kapenta catches were good. Wholesaling and retailing of dried Kapenta became a new niche for urban traders. Walter registered a number of 200 Kapenta traders in 1988 (ibid:21). It does not appear that Kapenta traders combined trade in inshore fish with Kapenta trade, nor vice versa. Kapenta trade and inshore fish trade was – and still is – largely regarded as separate businesses by the individual traders.

[1] The word Kapenta means "ladies' painted lips", and was first used in the Copperbelt, indicating that kapenta is the perfect food to cook for urban ladies of the sort who do not have much time to spend on cooking (pers.com. John Zimba).

[2] The size of the *Limnothrissa miodon* in Lake Kariba is smaller and the shoals go deeper than in Lake Tanganyika, where an artisanal fishery thrives on the same specie.

TABLE 1. *Overview of Kapenta companies in the Sinazongwe district.*

Company started	No. of rigs	Processing (1998)	Marketing
1981	46	Dried	Outlets through agents in Monze, Mazabuka, Kabwe, Kitwe, Lusaka and Livingstone
1981	13	30% frozen, 70% dried	Dried to traders. Frozen delivered pre-packed to distribution company in Lusaka
1981	12	Dried	Through traders
1982	12	Dried, some salted	Through traders, some transportation directly to wholesalers in Maamba, Kafue and Lusaka market places
1984	4	Dried	Through traders in glut periods, otherwise only own transportation to wholesalers in Lusaka market places
1986	24	Dried and frozen	Dried to traders and pre-packed to supermarkets, frozen pre-packed to supermarkets
1988	10	Dried	50% to traders, 50% pre-packed to supermarkets
1992	7	Frozen	Pre-packed frozen to supermarkets
1997	4	Dried	Through traders

Source: Own and Turid Bøe's field data 1998.

In the early years of Kapenta fishing, the operators relied completely on traders coming to their premises to buy dried Kapenta. A system developed whereby the traders deposited the amount they intended to spend in the safe of the Kapenta company. On a first-come-first-served basis the traders are supplied with bags of dried Kapenta. The price per bag, however, is not decided at the point in time when the trader deposits the money, but when the operator supplies the bags. At times the traders will wait for many weeks, and in the meantime, the Kapenta operator gives them mealie-meal and Kapenta to eat. One may see this system as a kind of contract whereby the Kapenta operator gets an indication of how much Kapenta he will be able to sell. Since credit relationships between the Kapenta operators and traders very often fail (because an indebted trader can decide never to come back but to buy from other operators instead). He is also assured that the traders actually have enough cash to buy the volume of Kapenta that they have ordered. When the traders deposit money with a particular operator, he/she de facto commits himself/herself not to "run away" to buy from another operator even if his/her price is lower. The operator cannot prevent traders from leaving, of course, but traders rarely do this, since they come last in the queue for Kapenta if they switch to a new operator. Every month, a complicated price negotiation process is therefore going on: between the traders and each Kapenta operator, and between the Kapenta operators themselves.

As long as Kapenta catches were good, Kapenta operators did not worry too much about their marketing strategy. But as catches stabilised at a lower level after the first boom years, they had to make sure that they made enough profit to cover their costs. The paradox was, however, that the Kapenta operators were not able to co-operate amongst themselves in order to reach good prices. Instead, they underbid each other in the monthly negotiation process in order to ensure that the traders bought from themselves rather than from somebody else. The result of this lack of co-operation was that the prices of Kapenta remained low in the late 1980s, even if quantities of Kapenta on the market declined (due to stabilizing catch volumes). Despite this, the number of Kapenta traders remained quite stable: most of them just traded on a smaller scale than before. In my view, this indicates how "small" the Zambian market is: there is a clear limit to how much the Kapenta consumers, most of whom belong to the poorest segments of the population, can pay. In addition, competition from cheaper Kapenta, imported from Zimbabwe and Mozambique, has kept prices low.

Kapenta operators therefore increasingly had to try other marketing strategies (see Table 1), either they by-passed the traders by opening their own urban outlets, or they tried to get higher prices from a more wealthy segment of consumers, by pre-packing kapenta for distribution through supermarkets, a strategy which needed investing in freezing facilities. The Kapenta operators have faced many external constraints linked to macro-economic conditions in their strategies to increase the profitability of their business. But inevitably their inability to keep contracts (devised to create order and reduce uncertainty in exchange, to paraphrase North) has played a role in making expansion and investment difficult.

3. ECONOMIC LIBERALIZATION AND CO-MANAGEMENT IN THE 1990s

Continuously failing attempts by the United National Independence Party (UNIP) government at following its own version of structural adjustment after a break with the International Monetary Fund (IMF) in 1987, led to “food riots” among the population in the urban areas and to a reaction from the international donor community that decided to hold back bilateral aid (Banda, 1991). Eventually, the economic and political crisis led to a change in government, and the Movement for Multiparty-Democracy (MMD) gained power in 1991. Zambia embarked upon a new Structural Adjustment Programme (SAP). This involved liberalization of imports, trade and exchange rates, reduction of expenditures in governmental institutions, privatization of parastatal companies, removal of subsidies in the agricultural and transport sectors and introduction of user-fees in the health and education sectors. Unemployment rates increased. From 1990 to 1998 jobs in the formal sector fell from 543 000 to 465 000 (Rakner, van de Walle and Mulaisho, 1999:65). 26 000 jobs in mining and 15 000 jobs in construction were lost. The only alternative for the retrenched workers was to try to survive in the growing informal sector, one way or the other.

Considering this employment situation it is surprising, as Figure 1 showed, that the number of fishermen in Lake Kariba remained stable at around 2 200 from 1991 to 1994. Instead of increasing, the number dropped drastically in 1994 to 1 200 fishermen, a level that remained stable throughout the latter part of the 1990s. One explanation for the sudden decrease in horizontal effort could be environmental. Serious drought exasperated the economic crisis in Zambia in 1992. As a result Lake Kariba in 1992 reached its lowest water level since inundation (Karenge and Kolding, 1995), and this affected fish catches negatively. However, the lake level has risen again (it reached its maximum level in 2000). Consequently fish catches were good, but nevertheless the entry of newcomers into the fishery seemed limited. As local political access regulating mechanisms that reduced the growth in the fishing population are analysed in detail by others (Jul-Larsen 2003; Malasha, 2003), I will only briefly outline the major events as a background to facilitate an understanding of changes in the fish market.

3.1 Co-management through forced relocation

In the 1980s and 1990s there was increasing pressure on lakeshore land by migrant fishermen who needed to diversify their range of income generation. For example, many fishermen’s wives had small gardens where they grew vegetables, maize (for consumption and for beer brewing), and sometimes sunflowers as a cash crop. As increasing numbers of migrant fishing households settled in certain areas, Tonga farmers and village headmen found it difficult to accept additional clearing of land to make room for vegetable gardens. Tensions also arose because many fishermen and traders became involved in smuggling. Furthermore, Kapenta operators noticed increasing theft of fresh Kapenta from their rigs during the night. It was clear that the theft took place through transactions between rig-workers and traders in collaboration with fishermen who went out on the rigs with their canoes. Most of the stolen Kapenta was dried on the islands where many of the migrant fishermen lived. It was then smuggled out of the Valley through routes without police barriers. Kapenta operators also had interests in the development of wildlife tourism on several islands in the lake, and poaching of game by fishermen and others frequenting the islands was a thorn in their eyes.

In response to all these conflicts the Chiefs in alliance with the Kapenta Fishermen's Association (KFA), Rural Councils and the Department of Fisheries (DOF) initiated a "co-management" plan that involved relocation of fishermen into designated villages in 1993. Using arguments about fear for overfishing and the need for fisheries regulations, these strong stakeholders aimed to get the theft and smuggling under control. In their view, the unregulated mobility of the fishermen had to be controlled. According to the new management plan, fishermen and their families were not to stay on islands, and they were – in many cases with force – relocated to the shoreline in 1994 (Jul-Larsen *et al.*, 1997). The number of fishing camps was reduced from 278 in 1993 to 67 in 1995 (Jul-Larsen, 2003). Each camp elected a Village Management Committee (VMC), which in turn was represented in a Zonal Management Committee (ZMC), where fishermen, Kapenta operators, the Chief, the Rural Council, DOF, and the local business community (storekeepers) were represented. As part of the plan, levies were collected from both Kapenta traders and fish traders by the Rural Council. The idea was that this revenue, as a sort of motivation for compliance and as a compensation for the fishermen's removal from their best fishing grounds, would be pooled back into the fishing communities in the shape of schools, health clinics, building and maintenance of roads. The Kapenta operators would be "rewarded" with better policing of smuggling and Kapenta theft.

All stakeholders with interests in the fishery itself or in land went to great lengths in negotiating and reaching solutions in their new communication fora, the Zonal Management Committees. However, problems were not easily solved. Temporarily, the Kapenta operators in cooperation with the police managed to catch many Kapenta thieves. As one "ex-smuggler" described the situation at that time: "It was like a war where you have to send out scouts before you fight the battle". Gradually, however, the risk of being caught seemed to diminish again when funds collected by the Council through Kapenta levies failed to be allocated for the purpose of police patrols. The Kapenta operators also had problems amongst themselves in taking collective action. Finally, with accusations against the Council of embezzlement of funds, many Kapenta operators refused to collect the Kapenta levy on the Council's behalf anymore.

In the fishing camps, people were equally disappointed with the outcome of the co-management plan. Firstly, the Council's promises of improved infrastructure in the fishing communities never materialized. Secondly, the relocation of fishermen to the lakeshore led to an even higher degree of land conflict between fishermen and Tonga farmers. Many fishermen thus left the Lake Kariba fisheries in the mid 1990s. Some went back to the urban areas, others moved their equipment to other fisheries, like Kafue. The fishermen who remained, fished in the areas they could reach from their new locations.

Gradually catches within the “paddling-radius” of the fishing camps declined. Fishermen (usually without their families) started – at least periodically – moving back to the islands where catches were very good. With the high lake level and good catches, Tonga farmers also increasingly found fishing attractive again. Another reason for the Tonga’s resumed interest in fishing was that many cattle owners incurred great losses because of the “corridor” (foot and mouth) disease. Many Tonga farmers, especially young men, have therefore become part-time fishermen during the off-farm season. The number of people fishing may therefore be much higher than the number of full time fishermen registered by the Fisheries Department (Figure 1). Thus, even if many migrant fishermen left as a result of the relocation programme in the mid 1990s, fishing effort and total landings have probably increased in the late 1990s. This has provided numerous Zambians with a much needed possibility to earn a living at a time when other alternatives were hard to come by.

3.2 Unemployment-driven growth in the number of traders

Urban unemployed men and women continued flocking to Lake Kariba to buy inshore fish and Kapenta. In 1996, as part of the SAP, a large number of parastatal companies were privatized all over Zambia, a process in which 150 000 jobs were lost. Zambians were on the move in more than one sense: from formal to informal employment, moving between rural and urban areas, experiencing deteriorating living standards and moving down the social ladder (see Hansen, 1997 and Ferguson, 1999). A few examples of fresh fish traders’ backgrounds illuminate the enormous changes that Zambians were living through, and also the variety of actors that entered the fish market.

Mary, for example, was on her second fish-trading trip in Sinalilongwe in 1998. She had worked in the Ministry of Mines until 1996, when she lost her job. She had been trying to sell various things, but many other people were doing the same and she found it impossible to make a living that way. Mary took what she had left of the compensation from her former employer and tried out fish trade.

Charles, buying fish in Simuzila in 1998, lost his job in the Zambia Oxygen Company in 1994. Since his mother was a Kafue fish trader, he felt he had the competence he needed to become a fish trader. His mate, a local Tonga man lost his job in the Security Department of Zamtel, Lusaka, in 1994. He went home to farm, but sold most of his cows in 1998 in order to get capital to start up as a fresh fish trader.

Rose, whom the author met in Namafulu, had a husband who worked in the NAMBOARD. When he lost his job in 1996, Rose started fish trading. The husband joined her one year later. Since they have relatives who are fishermen, their aim is to settle and start fishing in Namafulu.

Peter, a young Bemba trader in Namafulu, was working in a bar in Lusaka. In order to make more money, he started selling “salaula” (second-hand clothes) in the Kamwala market (see Hansen, 2000). He left that trade in the hands of his brother and used his savings as well as his contacts with a fisherman uncle in Namafulu to start as a fish trader.

Anne used to work in the Ministry of Health until she quit her job in 1995. She felt that her salary was so low that she had to try something else. She therefore started buying bundles of “salaula” that she brought with her to Zimbabwe. She sold the clothes there and bought groceries that she took across the border to South Africa. She bought hardware for the profit and took it back to sell in Lusaka. This kind of cross-border trade has increased as a result of the lifting of import restrictions in Zambia and with the opening up of South Africa after apartheid. Through her international business, Jane managed to save enough to buy a pick-up, and she is now trading in fish as well as providing transport for other fish traders.

The fish traders try as much as possible to diversify income generating opportunities. This they have in common. Although some of them are aiming to become fishermen, this is not at all the case for all of them. Fish trade is just another source of many inadequate sources of income. On the lake they seldom buy fish from the same community for longer periods. Also they often shift to fisheries in other lakes and rivers when they hear that the catches and/or prices are better there. Most of the urban and semi-employed traders are thus neither interested in, nor capable of, investing in fisheries.

However, not only "retrenched urbanites" entered the Lake Kariba fish market. In particular, experienced traders with a long career in fresh fish trade in the Kafue (Lusaka's nearest fresh fish source) began to shift their focus towards Lake Kariba. They faced more and more competition from Lusaka residents who attempted to buy fish in Kafue. This crowding of traders combined with declining catches in the Kafue River (caused by high fishing effort and drying up of the Kafue River especially after the draught in 1992), resulted in diminishing returns from fish trade. These two crises – one economic and one ecological – happened to coincide with an increasing availability of ice. Kembe Coldstorage in Lusaka started producing ice blocks in 1989. In 1995, Sinazonge finally got electricity, and many of those "connected" started renting out space in their freezers to fish traders. Also, many Kapenta operators established crocodile farms and acquired cold storage facilities for the storage of crocodile meat and skins. Others acquired freezing facilities in order to find new market niches through the sale of packets of frozen Kapenta. Though production of ice was not the main purpose of the new equipment, Kapenta operators began to sell ice to fresh fish traders who were on their way to the fishing camps. This made it possible for traders to travel from town to the lake without ice (by which they saved on transportation costs), and to buy supplies if their ice melted while they were queuing up in a fishing camp to buy fish.

Some of the more experienced Kafue traders therefore found it attractive to take up fresh fish trade in Lake Kariba, despite its location further away (than Kafue) from Lusaka. With their long experience in fish trade, and their established positions among traders in the market places in Lusaka, many traders in this "Kafue-group" became, as we shall see in a moment, quite influential in Lake Kariba fishing communities.

3.3 Chaos and order in new locations

Since the mid 1960s, the dispersed nature of the fisheries had made it difficult for traders to reach the fishing camps (especially islands) with ice. With the relocation operation in 1994, the new camps became more easily accessible to traders. Whereas it had been a problem in many locations to get traders to come at all, traders with ice now flocked to camps accessible by road.

The influx of fresh fish traders has been encouraging for the fishermen, but this trend has also resulted in conflicts in many households. Fishermen increasingly sell their fish directly to fresh fish traders, and household members seldom process fish anymore. Women thus have less control with their husbands' income. Less is spent on food, and trading trips to town by wives also become less frequent. Women experience that men spend less on beer brewed by women locally, and spend more on factory-made beer on their fish-selling expeditions. Hence women not only lose track of how much their husbands earn and how they spend the income – they also lose an important source of income (see also Colson and Scudder, 1988). Not surprisingly, then, fish buyers report that wives enquire about the quantity of fish their husbands sell in order to get an idea about their income (whereupon husbands tell traders to underreport their catches).

There is little competition among fresh and dried fish traders. Dried fish traders still come, but mostly buy the fish that fresh fish traders are not particularly interested in: tiger fish (*H. vittatus*), bottle fish (*M. longirostris*), barbel (*C. gariepinus*), the largest and the smallest sizes of breams (*O. mortimeri*, *S. condringtonii*, and *T. rendalli*), and some other species.[1] Among the fresh fish traders, on the other hand, competition can be severe. A trader has to adhere to many unwritten "laws". His or her economic survival depends on knowing these rules, and success can be achieved when one knows how to use them favourably.

The first commandment for a trader is to build up a trustworthy reputation. Secondly, a trader must share information. By following these two thumb rules he or she can interact with other fish traders and acquire crucial resources: information, experience, credit and social relations – in the fishing camp, on the road and in the market place. Without these resources, it is difficult to gain economically, if not in the short run, then certainly in the long run. Unless a trader is substantially more powerful than the others, breaking of the rules (for example by hiding information or taking advantage of social relations in such a way that it economically harms others) will be sanctioned through the "setting of traps", as one trader put it. These traps can consist in not helping the "immoral" trader with ice supplies or with punctures, refusal of credit, spreading of unfavourable rumours about a trader to the extent that they result in witchcraft accusations, and appealing to fishermen and VMCs to refuse a particular trader access to their fishing camp. Importantly, the market system extends spatially from lake and fishing camp to city and market place, and a trader's reputation follows him or her in all these arenas. Information about a trader's actions in a fishing camp easily reaches traders in Lusaka and vice versa.

Time is a much more crucial factor in fresh fish trade than in dried fish trade because of the lack of storage facilities for ice. The only way to slow down the melting process is to cover it with sawdust. A first-come-first-served institution is the "line system". This institution is common in most Zambian fisheries, and is meant to prevent unfair competition among fresh fish traders. As one trader put it: "The line is our law". Upon arrival in a fishing camp, the traders' name is put on a list administered by the VMC. The first trader on the list ("in the line") is allowed to fill up his or her container (usually an old freezer) with fish before the next one is allowed to buy. An important principle is also that the trader must have enough cash to fill up the freezer without buying it on credit. This system is supposed to prevent that some traders are stuck with melting ice while others are given "special treatment" by the fishermen. The breaking of these rules by both traders and fishermen are, however, a recurring source of conflict in the fishing camps.

[1] During a market survey carried out by the author in all the main fish markets in Lusaka in September 1999, it was hardly possible to find dried fish from Lake Kariba at all. Most of the dried fish came from Luangwa River, Lake Mweru and Upper Zambezi (Mongu area). Dried fish from Lake Rukwa in Tanzania was also plentiful. Both Tanzanians and Zambians participated in this trade. This finding fits with the authors observation that most of the travelling dried fish traders interviewed along Lake Kariba, were retailing their fish in in Ndola and other Copperbelt towns. Fishermen or women in fishing camps tended to sell dried fish mainly in nearby towns like Maamba and Choma.

Another institution in the market is the "cov-ice" system. This is a credit system that provides traders with labour during the trading trip, and provides newcomers or traders who have "fallen" (into debt), with an opportunity to (re)enter the market system. A trader who has purchasing capital, and has hired transport and purchased ice and sawdust, hires a person as a helper for the trip. They stay in a fishing camp until they have filled up the freezer with fish. When it is full, the fish is covered with a layer of ice. On top of this ice, the helper is allowed to put a layer of fish ("cover the ice"), say worth 50 000 Kwacha, paid by the trader. This credit is the payment of the helper. When they reach the market in Lusaka, the helper sells the top-layer of fish, and pays back to the trader the 50 000 Kwacha: "No more, no less". This means that he or she can earn a small surplus, and may go on another trip and increase the volume of fish trade gradually.

As the examples of the line system and the "cov-ice" system illustrate, competition among small-scale traders combined with an increasing market preference for fresh fish, creates a situation where traders, in order to survive, create and adhere to "laws" or "trade regulations" that make it possible for a large number of people to find employment. Paradoxically, these mechanisms, which serve to limit the accumulation by some few traders at the expense of the majority, also make the establisment of credit-supply contracts between fishermen and traders extremely complicated. This may partly explain the limited investment in fishing equipment and absentee boat and net ownership by traders. Institutions like the line system thus enhance the security against "falling down" in the risky business of trading in a highly perishable good, but it also prevents individual traders and fishermen from entering into contractual agreements. A few exceptional cases exist of traders who have succeeded in establishing contracts with fishermen. The author will let them illustrate the strategies by which traders attempt to enter into binding contracts with individual fishermen and communities, but also the context-specific constraints that inhibit investments.

With more concentrated settlement of fishing households, some traders managed to establish themselves more permanently in particular camps. These were traders with long experience and wide networks of contacts in both fish market and fishing camps. Most of them belonged to the "Kafue-group" – usually a male trader organizing a core group of co-operation partners, including his wife, relatives, and traders known to be trustworthy. A few women were also leading traders. One of them is the "chairlady" of fresh fish traders in the largest open air fresh fish wholesale market in Lusaka.[1]

Each of these leading traders established themselves in one fishing camp striving to be the only leading trader in that camp. As long as one trader did not trespass the "territory" of another, these leading traders co-operated rather than competed. They developed good relations with the community by offering transport, supplying goods (especially mealie-meal and nets), by helping in the maintenance of roads, by giving assistance during funerals, and they participated in VMC meetings. As a result, they were given land to build more permanent houses in the fishing villages. As one VMC secretary commented: "He [the trader] has been very good. He has been coming regularly for more than five years. The most important thing is that he [unlike the other traders] comes even when the road is inaccessible". In this particular case, the trader

[1] This is the Kambilombilo market. It used to be located in a street near the New City Market. However, this informal market was moved to the New Chibolya Market during the Lusaka City Council's "clean-up" operation in May 1999. As a consequence, the fresh fish wholesale market lost some of its importance, at least temporarily, since its new location is too far away from the city centre, and also because of increasing competition from small fish shops in town.

has become a member of the VMC of “his” camp. He also owns nets that he entrusts in the hands of fishermen who fish for him, and he can buy fish on credit from fishermen. It takes many years to build up such relationships: “You must be very good to the fishermen. Time is the key”. This trader claims that by now he knows whom he can trust and whom he cannot trust among the fishermen. Importantly, his membership in the VMC also gives him a possibility to sanction those who cheat him, for example by reporting them for illegal fishing methods.

By making economic and social investments in the fishing camps, traders have a particular aim: to secure their supply of fish and to get privileges over other traders when supply is limited. In the established traders’ view, a trader who has made commitments and investments in a particular camp should be given precedence over the occasional “free rider” trader who seeks his or her fortune “here and there and now and then”, as one trader put it. One could say that the main difference is between those who attempt to institutionalize their relationship with the fishing community, and therefore have a long-term interest in this relationship, and those who do not have the means or skills to take part in the process, and therefore have an interest in defying the “traders’ ethics” in order to make short-term gains (see Evers and Schrader, 1994).

In order to exclude “free riders”, the established traders organize their fish supply according to the “swapping-method”. They have at least three freezers, one freezer by the lake, one on the road, and one in the Lusaka market where the fish is retailed. Through the “swapping” of freezers on the lakeshore – that is when one freezer is taken away from the village it is immediatly replaced – these traders always remain first in the line. However, to escape obeying the “law” of the fish market (the line system) the trader needs to be in alliance with the fishing community and be under the authority of the VMC. In some camps, the VMC has also allowed “their” trader to have his own purchasing spot independent of the line where other traders have to wait for their turn. One young man, who tried his fortune as a fish trader, told me that when he went to a fishing camp with such an established trader, “It’s just like fighting Mike Tyson. He will tell me: “Welcome my dear, but you will have to be number six in the line”.

In discussions with VMC-members, fears of tendencies towards monopsony by a limited number of traders were expressed, both because the fishermen felt that “their” trader kept the fish price too low, and because they were afraid of becoming too dependent on one particular trader. As it was put: “What if he dies?” Nevertheless, they acknowledged that as a VMC, and as a fishing community in the midst of Tonga farming communities, it was an advantage to be allied with prominent traders who in most cases act as spokespersons for the fishermen’s interests. One trader said: “We are part and parcel of the fishermen”, and the Tonga farmers clearly also see them as such. In land conflicts or in cases where suspicion is thrown on the fishermen because of their conspicuous (in the eyes of some farmers) consumption of beer and possession of “luxury” items like radios, it has happened that traders negotiate on fishermen’s behalf. When traders have tried to mobilize communal labour for maintenance of the dirt roads going through the farming villages, they are often met with very little enthusiasm and participation by the Tonga farmers, who see the initiative as primarily in the fishermen’s interest. In fact, the increasing conflict level after the relocation of fishermen to the “Tonga” lakeshore, is often mentioned by traders as a major obstacle in their attempts to establish permanent relations and supply contracts in fishing camps.

3.4 New actors in the market for frozen fish

In the 1990s there has been a trend towards a preference for fresh or frozen fish in Zambian urban markets. Partly this has to do with the emergence in the liberalized economy of a small (and increasingly health conscious) elite. However, also “average” Zambians who are used to eating smoked or dried fish, increasingly buy fresh or frozen fish, despite their low incomes and lack of freezers at home. Fish is still cheaper than beef or chicken. In September 1999 beef was K5 000 per kilogram and chicken was K4 000 per kilogram. In comparison, frozen large breams were K3 500 per kilogram. Especially the smaller breams “of the size of the palm of a hand”, are popular in poor segments of the urban market. Since breams of this size gives the trader high turnover, they are often called “money-makers”. In a fish shop, small breams were K3 000 per kilogram, which means that one such fish would be about K1 000. In comparison, a small cup of dried Kapenta – the “poor man’s food” – was also K1 000.

The growing number of fish shops in urban areas is an indication of the increasing demand for frozen fish. The shops prefer to have a variety of species and sizes of fish. This attracts customers of various ethnic backgrounds (urban dwellers often prefer the type of fish they can find in their home regions) and from various social classes. Even if imported marine fish from Namibia and South Africa, especially horse mackerel, is available in the supermarkets, Zambians still seem to prefer fish from rivers and lakes. Small-scale traders are therefore facing competition from investors who hope to make a profit on the trend among urban Zambians to eat fresh fish.

In the latter part of the 1990s, commercial companies have increasingly involved themselves in the fresh fish market. Chani Fisheries operating in Lake Mweru is the largest fish distribution company, and several smaller companies attempt to establish themselves in other fisheries, such as the Upper Zambezi and Lake Kariba. By “commercial”, I here refer to formally registered companies, whose activities are more capital intensive than in small-scale trade. They also have coldstorage facilities, trucks, shops with freezers, and telecommunication facilities. Companies normally use standardized measures, buying fish in kilograms instead of in the volumetric measure “heap”, which is an approximate kilogram that can be negotiated, and thus often preferred in exchange between fishermen and traders. There is little social interaction and face-to-face contact between the company owners and the fishermen, who sell fish to them through their buyers. These companies are often connected to other economic sectors than fisheries, as well as to important political and business circles.

In 1996, Chief Sinazongwe gave permission to a Lusaka company to establish itself on the condition that it “developed the area” (i.e. by connecting the site to electricity) and that it would employ local Tonga as workers. In addition to some Tonga workers, a young Bemba man with some experience from fish buying in Lake Mweru in Sinazongwe was employed as their manager in 1997. Headmen and VMCs in certain fishing camps were approached, and the company was allowed to put freezers with ice in their camps that would be filled with fish purchased by a local agent appointed by the VMC. The company’s buyers would regularly go around by boat to collect the fish and supply new provisions of ice. Fishermen could also sell fish directly at the company’s premises in Sinazongwe, and in the beginning, the company gave out free nets to certain fishermen in order to secure a steady supply of fish. Fish was stored in a freezer container and transported on a truck to the company’s fish shop in Lusaka. It has, however, been a problem for the company to financially sustain their capital-intensive operations, and they have not been able to compete with the small-scale traders price-wise. They have also had a problem of reliable supply of fish, both from the camps where they had contracts with the VMCs and from those of the fishermen they had supplied with free nets. By 1999, after a year's on-and-off operation, the company's scale of operation has decreased rather than increased.

Some of the local Kapenta operators seem to have more success in their attempts of entering the frozen fish market. At the same time as Kapenta catches showed a downward trend and the problem of theft continued, the operators observed that canoe fishermen had good catches of fine bream (because of the high lake level). Some of the Kapenta operators with freezing facilities therefore started buying fish from local fishermen on a small scale.

One Kapenta company started buying fresh fish for freezing on a larger scale, and opened fish shops in Lusaka and Kabwe. They made arrangements with the VMCs in two nearby fishing camps to purchase fish independently of the "line system". The company started out on a small scale by sending workers on bicycles to buy bream (and to a limited extent other species). The bargaining process was cumbersome, so the company opened up a sales point on their premises and announced their wish to buy fish on posters in the health clinic, the church and in the Kapenta-workers' living quarters. The word soon reached all the fishing camps in the vicinity, and fishermen started bringing their catch for sale. There have been many heated debates between the company and the fishermen about the price level, about whether to measure fish by the heap or by weighing it, whether payment could be received in the form of mealie-meal, and so on. The negotiation between the company and the fishermen may actually be seen as a discourse between two different market systems: one "European" based on fixed prices and standardized measures between "neutral" partners, and the other "African" based on negotiable prices and measures, and "personalized" economic relations. The buyers of the company therefore become crucial mediators between these two ways of thinking.

Despite winning the discussion about standardization of fish prices, measurement by weight and payment only in cash and not in kind, the company (as all other traders) discovered the problem of retrieving payment for nets given out on credit. Hence, they decided only to sell nets for cash. In addition, they mainly sold fishing nets with mesh sizes in the range between 3 and 6 inches in order to promote the supply of bream of 1–2 kilograms, which attract the best prices in the urban frozen fish market. To increase fish supply, the company also practiced a kind of lottery where fishermen who sell fish to them could win a net for free. Though there have been many obstacles in the relationship with the fishermen, the company was in 1999 buying almost all the bream above the "three-inch size". The fishermen in the closest fishing camps have therefore become quite dependent on the company for a market. Moreover, it is common knowledge among traders in every market place in Lusaka now, that there is no point for a trader in travelling to those particular camps anymore: he or she will only be left with the small-sized fish that the company does not buy. Therefore, when the company stopped buying fish for a month because they had to change the staff in their Lusaka shop, the fishermen faced serious problems in getting traders to their camps.

The Kapenta company has succeeded in entering inshore fish distribution through their conscious strategy of tending of a good relationship with the local VMCs and by temporarily offering higher prices than travelling traders. Marriage by a white owner and a black Zambian woman also opened up a new universe of information about the Zambian fish market and consumer preferences, as well as access to contacts and trustworthy workers through kinship links. This case illustrates that despite considerable amounts of capital (compared with the individual urban trader) and connections in the white business community, success in the Zambian fish market by a commercial company is achieved through similar strategies as those employed by the small-scale traders: through negotiation with local leaders; through the building of trust over time; and through social interaction whereby access to information and favourable contacts and contracts are achieved.

So far, the commercial companies have steered far away from investment in fish production. As most other actors in the market, they find it too risky. The risk is mainly related to the problem of controlling the labour and deliverance of fish by fishermen. Moreover, unlike the traders who establish long-term relations in the fishing camps, companies that are "modern", "commercial", "white", "industrial", do not hold the type of knowledge, skills, and cultural and social codes that are required to establish trust, loyalty and control in relations with the fishermen. This would be the main obstacle if companies attempted to invest in modern fishing equipment. As long as the company can maintain a steady supply by the fishermen themselves, they avoid the problem of controlling labour. Whether an enterprise on this scale can be sustained in times of decreasing catches (i.e. if the lake level drops), remains to be seen. Economic and political factors, such as local politics (i.e. chief disputes), urban consumer's purchasing power, or the future of the Kapenta industry, may actually be of far greater importance to fish distribution companies when they decide on whether or not to continue buying fish in the lake area than the condition of fish stocks in Lake Kariba. If the national economy of Zambia continues to decline and the profitability of fish distribution remains limited, individual small-scale traders will continue to play the main role in the fish market for many years to come. If this scenario becomes reality, no major investments in the fishery are likely in the near future.

4. CONCLUSIONS

Given the poor condition of the Zambian economy, the small scale at which traders operate, the inadequate infrastructure and the "fluid" power structure in lakeshore communities, population-driven rather than investment-driven changes in fishing effort will continue to be observed. Local access regulating mechanisms (in particular those regulating access to land) and political reforms (such as the regulation of fisher families' mobility), limit the number of new entrants into the fishery and thus also the population-driven growth in fishing effort. In addition to the limited purchasing power of Zambian consumers, social mechanisms in the fish market prevent accumulation of capital among small-scale traders. As a result of these constraints, Lake Kariba traders' activities remain small scale. Therefore, their possibility to exert control over labour and capital employed in the fishery, and their potential role as investors in new technology, are marginal.

Even if the fishery in principle is open to everyone, the same mechanisms that prevent a very large number of fishermen from entering the fishery also prevent those who do get access to the resources of the lake from maximising their output, and from expanding into more efficient fishing methods or distribution channels. Ever since the creation of the lake, the establishment of mutually beneficial credit-supply contracts between traders and fishermen has been economically, socially, culturally and politically complicated. Currently, a national economy in decline, local conflicts, and fragile stakeholder relations is not the kind of "environment" that enhances the evolution of common norms and rules that would make the outcome of contracts more predictable. Keeping investments in means of production at an absolute minimum – the strategy employed by fisher families and traders – may therefore be seen as their only choice.

Larger market actors, generally commercial companies with access to capital sources from other sectors of the economy, have to cope with constraints that are similar to those faced by the traders, since they operate within the same environment. Should commercial companies, despite all odds in the present macro-economic situation, be able to make substantial money on frozen fish marketing, it is nevertheless highly unlikely that they will make investments in fish production, let alone invest in technologically more sophisticated gear. Their main constraint is their inability to enforce labour contracts and credit-supply contracts. Over time, personal relations of trust and common interest can be established but only with a limited number of workers and middlemen. However, there is no shared legal framework beyond these small "trust circles" that can be activated when contracts are broken. Investments thus remain risky.

Turning back to the theoretical argument, the Lake Kariba case illustrates that even if credit institutions and technological development have been observed in small-scale fisheries in almost every corner of the world, it does not mean that such a modernization trajectory eventually will happen in all fisheries. The type of economic and institutional development required to set in motion a process of capital accumulation and increasing productivity must therefore be understood in particular historical, economic and cultural contexts. Contrary to Platteau's argument regarding the "natural" evolvement of institutions in order to overcome market imperfections, this study of market development and investment on Lake Kariba shows that economic actors' ability to reduce transaction costs through the establishment of risk-reducing rules for exchange and contracts is limited when the constraints are as many as described for lake Kariba . One may in fact conclude that the market is "too imperfect": at present the constraints are so insurmountable that they hamper institutional development.

The location of this particular fishery within the constraints of the Zambian economy is thus a major explanation for the limited profitability of the fishery and thus for the limited investment in more efficient fish production. An investment-driven growth in effort is therefore unlikely to happen unless either external capital is invested or Lake Kariba producers link up to more profitable (export) markets. And as biological case studies elsewhere in this FAO Fisheries Technical Paper have shown, the fisheries of Lake Kariba are characterized by a high degree of ecological resilience. Therefore, the (unlikely) scenario of uncontrolled external or foreign over-investment in the fisheries most likely would not lead to a "tragedy" for Lake Kariba fish stocks, but it would be a tragedy for the fishermen and fish traders, whose economic alternatives for the time being are meagre.

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ANALYSIS OF EFFORT DYNAMICS IN THE ZAMBIAN INSHORE FISHERIES OF LAKE KARIBA

Eyolf Jul-Larsen

1. INTRODUCTION

Fishing effort remains one of the crucial concepts in fisheries management and research. According to conventional management thinking, fishing effort is considered the main factor influencing stock dynamics and stock productivity, and a lot of research is invested to investigate this relation. It therefore appears as somewhat of a paradox that – at least in the case of African fisheries - very little research seems concerned with the question of what causes changes in effort. But, this lacuna in research often does not prevent experts, policy makers as well as some researchers often from having strong convictions regarding what factors influence fishing effort in what direction. They are strongly influenced by common property theory where the maximization of individual profit at the expense of a collective resource, is assumed to drive effort to increase, but also by the famous G. Hardin who was inspired by the old Malthusian concern related to the danger of demographic growth. In the view of many fisheries managers, maximization of profit and population growth tend to make the continuous growth of fishing effort a "natural" law. But fishing effort is an aggregated manifestation of millions of individual and collective micro-decisions taken by the producers every day. As such they are influenced by the totality of possibilities and constraints that the fishermen and their families are facing of which general population growth and levels of income only represent a fraction.

However, some influential social scientists have invested considerable effort in challenging this view. By questioning the assumption of free access to fish, an assumption on which common property theory rely, they argue that a series of mechanisms at the local level often limit people's access to the resource. In some cases it is argued that such mechanisms - often labeled community based management systems - are strong enough to prevent increase in effort beyond sustainable levels and that they may be considered to constitute types of local governance that distributes benefits amongst the local population. Similar lines of thinking are also the basic elements for community-based or co-management strategies in fisheries. These management strategies have gained a lot of support the last decade. It is characteristic though, that research which challenges the common property view of fisheries often has been more concerned by 'proving' that common property theory is wrong, by showing that free access does not exist, rather than by analysing effort development in a historical perspective through a reivew of fisheries statistics and other available data. With regard to southern African freshwaters, despite the considerable unreliability connected to catch and effort data, it is difficult to avoid concluding that, overall, fishing effort has increased considerably over the last 50 years (Jul-Larsen *et al.*, 2003).

Ottar Brox (1990) proposes an alternative perspective to the study of fishing effort which although not focused on African fisheries, is of relevance for them. One of his objectives is to show that there are different types of changes in fishing effort and that the effects upon the resources, as well as upon social development, may be very different from that predicted by common property theory. By introducing an analytical distinction between population-driven and investment driven changes in effort,[1] he argues that, until the last World War, fishing effort in the cod fishery in northern Norway was mainly characterized by fluctuations/growth in number of fishermen (population-driven) and that the relatively simple technology in use at that time made such fluctuations unproblematic and that indeed the fishery functioned as a commons but without causing a tragedy. The crisis in the cod-fishery first emerged after 1945 when introduction of increasingly capital-intensive technology (investment-driven change) became the characteristic variable in the effort development. In this way Brox wishes to emphasize that commons in fisheries does not automatically lead to tragedies and that they may serve useful functions, for the fishermen, their dependents and for the society at large.

Inspired by Brox's analysis, and his analytical distinction between population- and investment-driven change in effort, this study investigates in some detail the type, the causes and the effects of effort development in the Zambian inshore fishery on Lake Kariba. The author draws mainly on data sources generated by earlier social science research, on government produced fisheries statistics, on data collected by the author during two shorter visits in 1995 and 1997, on data collected by the author in May–June 1998 and on a survey of 426 fishermen undertaken in September-October the same year by an assistant.

By examining available catch and effort data, the study first seeks to establish what type of effort development has taken place. Lake Kariba is found to be a typical case of population-driven changes. They seem to have dominated effort development since the fishery started in the early 1960s until the end of the 1990s. Despite a strong and stable demographic growth,[2] the development is, over the years, characterized by substantial increases and decreases in number of fishermen. These fluctuations are found largely to rely on two different variables. Like in the study of Mweru fisheries by Gordon (2003), macro-economic conditions and wage labour opportunities in Zambia seem to effect the recruitment of fishermen to the fishery. It seems that when general economic problems increase the number of new fishermen grows and, when there are good job opportunities elsewhere the number of fishermen tends to fall. The other major variable influencing the number of fishermen are local access regulating mechanisms. That is, when the pressure on local resources increases, individuals who are not already part of the fishermen community are prevented from fishing on the lake. These mechanisms are particularly effective if inviduals are not from the area. In the case of Lake Kariba it is interesting to notice that the access regulating mechanisms have been brought into force not because of increased pressure on inshore fish resources, but because arable land and territories for tourist development are in high demand.

The results of this study clearly demonstrate the validity of Brox's argument: provided that effort development is population-driven, commons in fisheries may fulfil important functions as a buffer and a safety-valve for many individuals in times of national economic crisis. Local, access regulating mechanisms on the other hand, which are important elements in various co-management strategies, tend to reduce this function and may, like in the case of Kariba, lead to under exploitation of important natural resources. It remains to be noticed that one important issue is not being dealt with in this paper, namely the question why investment-driven changes do not seem to have taken place on Lake Kariba in all these years. Answers to this question may be sought in another of the contributions in this publication (see Overå, 2003).

[1] For clarity reasons, we have preferred to modify the terms used by Brox from "horizontal" and "vertical" changes of effort to "population-driven" and "investment-driven" changes respectively. The content of the distinction remains the same.

[2] According to FAOSTAT 2000 (http://apps.fao.org/lim500/wrap.pl?Population.LTI&Domain), population growth in Zambia 1970-1990, was 55.6 percent.

2. EFFORT DEVELOPMENT ON LAKE KARIBA ACCORDING TO AVAILABLE STATISTICS

Since its start in the late 1950s the inshore fishery on Lake Kariba has always remained a simple gillnet fishery, mainly undertaken by individual producers from small non motorized dug-out canoes. Fishing is done throughout the year and there is a constant and important mobility along the lakeshore and from the shore to a great number of unpopulated islands from where the fishermen - at least until 1994 - freely seek what they consider to be some of the best fishing grounds. Formally, access to fisheries is free for any Zambian citizen. The view among policy makers and fishery experts has been the conventional one that effort is continuously increasing causing reduced biological production and therefore to further increases of effort. We find this view being conveyed in most of the available policy documents and expert reports (Chipungu and Moinuddin, 1994; Walter, 1988) and even in some research works (Scholz, Mudenda and Möller, 1997). Musando (1996) is more cautious, but here too the image of a steadily increasing fishing effort is reiterated. There are many understandable reasons for this interpretation. First it should be recalled that many were produced in, or immediately after, the 1980s when effort arguably grew very quickly. In addition, the 1980s was the period where relatively good data on effort and catches were produced. However, this picture of steady increases in effort is hardly representative of what happened before and after the 1980s.

Data on effort and catches before 1980 are weak, unsystematic and scattered and it is not possible to establish the exact changes in effort with any reasonable degree of certainty. They derive from a multitude of different sources reflecting different methods of collection and seldom deal with more sophisticated variables than numbers of fishermen, boats and/or nets. Figures of total yearly catches are found in the annual reports from the Fisheries Department but it is unclear on what basis the figures were reached. It is only since the beginning of the 1980s that there has existed a fairly coherent system of data collection. The system is based partly on extrapolation of selected catch and effort data (slightly modified in 1992) and partly on frame surveys. These consisted of census of fishermen, nets and boats carried out in the Zambian part of the lake and were undertaken on average every three years. The two methods are tuned against each other. In this paper data from the 1980s are based on a combination of the catch and effort data and the frame surveys. In some cases data on fishermen and nets have been tuned against other sources considered to be more reliable (e.g. Walter, 1988). For the 1990s, catch data are estimated on basis of the catch and effort collection system, while data on numbers of fishermen and nets are based on frame surveys undertaken in 1990, 1993, 1995 and 1999. All are official data from the Zambian Department of Fisheries. Data on fishermen and nets in years when frame surveys have not been undertaken are simple interpolations made by the author.

Figure 1 shows the development in catches and numbers of fishermen and nets from 1982 to 1998. The data shows that effort must have grown considerably throughout the 1980s while there seem to have been a stabilization and later a reduction in effort after 1990.

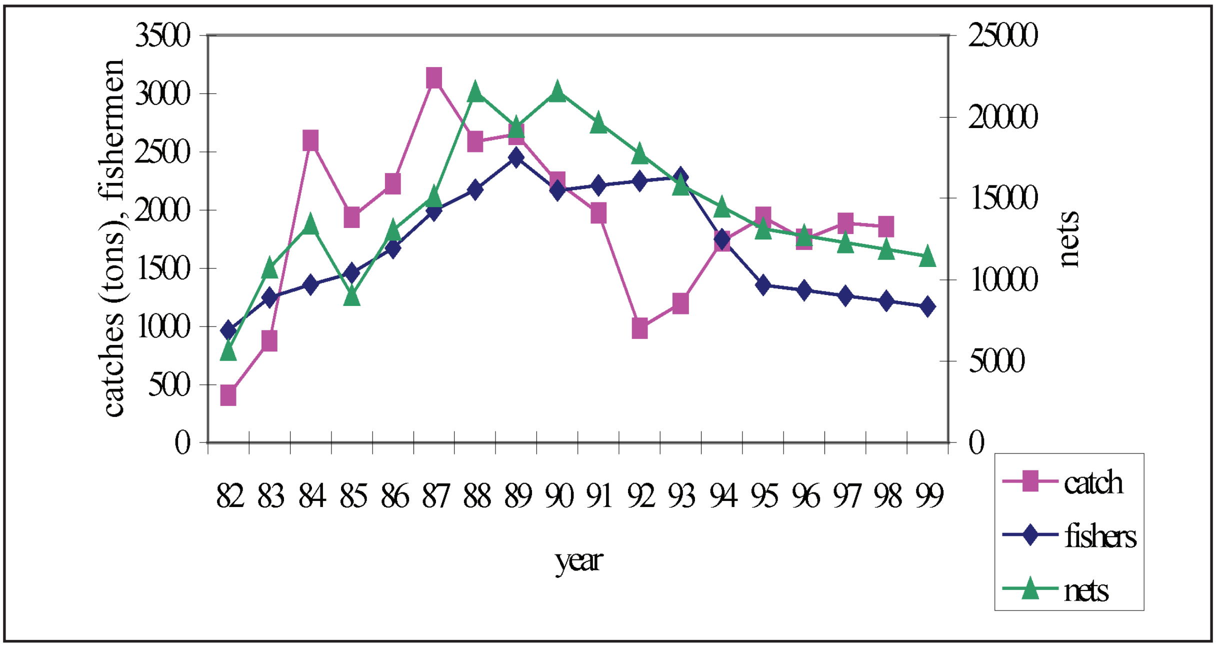

FIGURE 1. *Development in catches, fishermen and nets 1982-1998*

A rough estimate of changes in catch per unit effort (CPUE) expressed as catch per fisherman and year and as catch per net and year for the same period is presented in Figure 2. The similar shape of the two curves indicates that the number of nets per fishermen is relatively stable. It varies between six and ten nets. In both cases CPUE seems to have grown in the early 1980s. From a perspective of conventional fisheries sciences it seems strange that catch rates are growing in a period when effort also increases. After 1984–85 catch rates are falling until they reach a minimum in 1992. This is of course the expected development. Since 1992 catch rates have slowly increased.

Variables related to the frequency of fishing (number of fishing nights) are not taken into account, but there are few reasons to believe that frequency of fishing varies very much (see e.g. Scholz, Mudenda and Möller, 1997:259). Furthermore, no significant technological changes have taken place except for a tendency towards a reduction in the average mesh size. The author therefore considers the picture as fairly representative for how effort has changed during this period, and the trends also conform to what fishermen and other local producers in the area report.

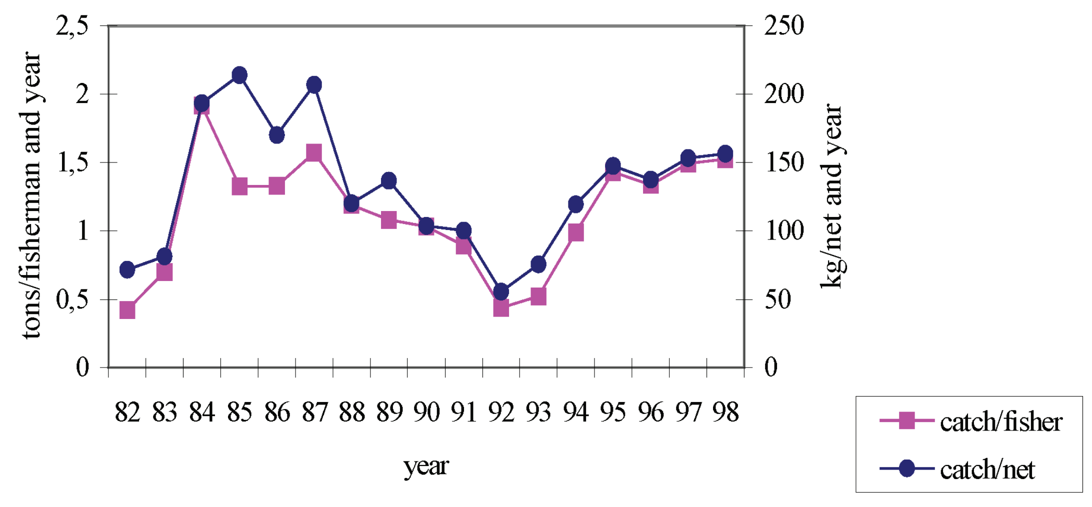

FIGURE 2. *Development in CPUE expressed as caches/fishermen and catches/net 1982-1998*

These preliminary results from the last 18 years are interesting. It would of course be desirable to have an idea of changes in effort for a longer period, but the data does not permit the development of such a view. However, if we go back to the earlier descriptions of the fishery, we discover that, technologically, it seems to have been practised without much change from the time the lake was created. So if we assume that the number of nets per fishermen, just like in later years, has not changed, this means that the number of fishermen in itself gives a fairly good picture of how effort has changed over the years.[1] Although all the older data must be considered unreliable, those on numbers of fishermen are, for purely methodological and practical reasons, relatively more reliable than the others: it is easier to count fishermen than nets and catches. The development in numbers of fishermen from the start of the fishery is presented in Figure 3.

If Figure 3 is seen as a picture of the development of effort it clearly indicates that we are faced with a history characterized by a highly fluctuating fishing effort. We therefore propose to investigate, in some detail, major sociological factors that may explain the fluctuations in the number of fishermen presented in figure 3. For the years preceding the middle of the 1960s, the analysis mainly reflects works of other social scientists (Colson, 1962, 1971; Scudder, 1960, 1965, 1972). From then on the analysis is that of the author. Although aggregated quantitative data do not exist for the period 1971-1979, qualitative data exist which indicate in which direction effort developed and we shall integrate these into the analysis. If the analysis of the period after 1980 is more detailed it only reflects the availability of better and more reliable data.

[1] Another article in this publication specifically concerned with effort in Kariba fisheries (Kolding, Musando and Songore, 2003) has later shown that this assumption may be too simplified since the number of nets per fishermen probably were lower in the 1960s (ibid. Figure 6). Although we accept that this most probably is correct we will maintain that effort development on Lake Kariba until today mainly remains a question of the number of active fishermen.

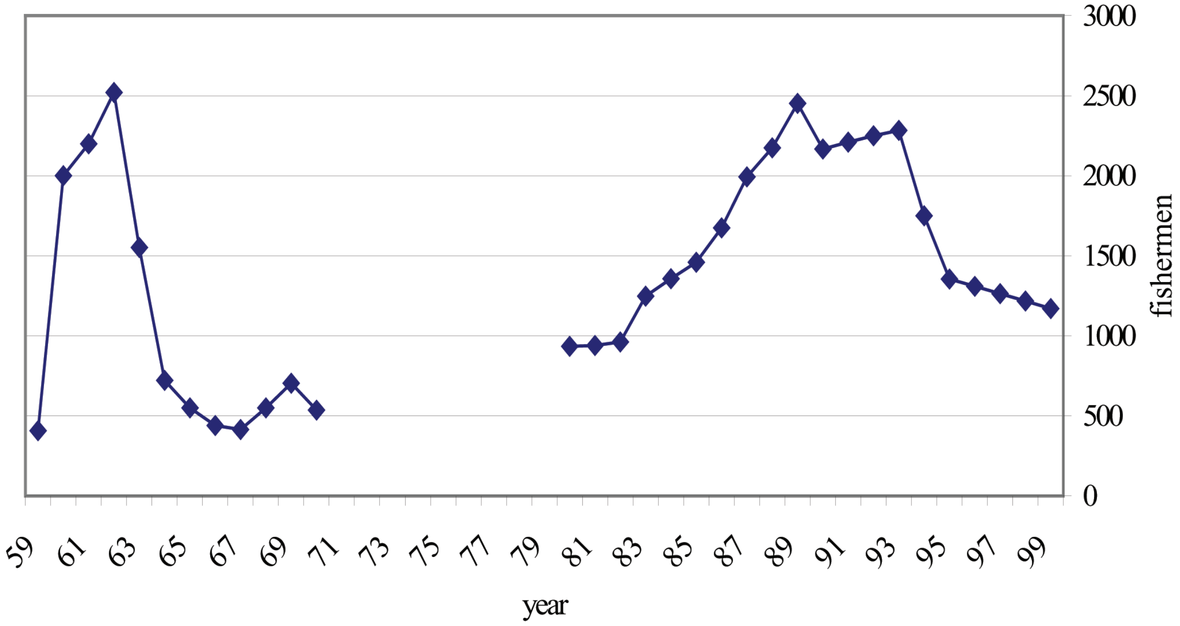

FIGURE 3. *Development in number of fishermen 1959-1999*

3. INTERPRETATION OF THE FLUCTUATING NUMBER OF FISHERMEN

3.1 1958–1980: continuous ups and downs

The construction of the Kariba dam and the consequent creation of a lake covering some 5 350 square kilometres of land in the Zambezi valley on the border between what was then Northern and Southern Rhodesia entailed one of the biggest resettlement schemes ever undertaken on the African continent. In Northern Rhodesia alone it is estimated that as many as 35 000 people were directly affected. Most of them were of Gwembe Tonga origin[1] and mainly practising an extensive type of agro-pastoral exploitation. The relocation process was complicated in that the non-inundated areas apt for this type of livelihood were already densely populated. There was therefore a strong need to establish alternative income generating activities and the colonial government made considerable efforts in facilitating the development of a commercial fishery in the new lake.

According to the then prevailing principles of indirect rule, land rights were formally allocated through the native authorities which in this case was the Gwembe Tonga Native Authority. It comprised the Mwemba, Sinazongwe, Chipepo and Simamba chieftaincies. Through negotiations with the colonial authorities the native authorities managed to acquire the authority to regulate the fishery on the lake. This meant that until 1963 when the system was changed, the Gwembe Tonga people exercised formal and exclusive rights to the fishery. These rights seem to have been respected in practice.[2] The British wished to establish a commercial fishery and employed large resources for that purpose. This effort included a series of projects such as stocking of fish, the cutting of trees in large parts of the inundated areas, establishment of facilities for training members of the Tonga community in skills needed to become

[1] The Tonga population of southern Zambia is generally divided into the people of the valley and those residing on the plateau immediately north of the Shire valley. The Gwembe are the valley Tonga.

[2] For a detailed analysis of the development of fisheries regulations in Zambia, see Malasha, 2002, 2003)

fishermen, establishment of fishing camps and marketing structures, as well as providing credits to fishermen for buying nets, boats and other material (Scudder 1965). The substantial government support and the high biological productivity that characterized the period immediately following the creation of the lake (Kolding, Musando and Songore, 2003) led to the realization of very interesting profits which attracted many young Tonga into the fishery. In the years following the start of the fishery, sometimes in 1958 or 1959, the number of fishermen grew rapidly to attain around 2 500 in 1963.

But, according to Colson (1971) commercial fishing was never taken up as an integrated part of the existing agro-pastoral economy of the Tonga households. On the contrary, fishing became an activity largely dominated by young men who sought a quick increase of their *individual* incomes. In this manner, fishing became an alternative to the long-established practice of labour migration for the young Tonga. The difference was mainly that an increased number of young people were given the opportunity through fishing. But, in a society where authority and power to a large extent were based on seniority, large incomes for younger people created a series of social problems between the fishermen, the households they belong to and their families. As is often reported to be the case in rural communities in Africa, the prosperous young men, difficult to control, were regarded as a challenge to the established leadership of elders to an extent that the most successful fishermen risked severe problems of non co-operation in their home communities.

This, together with concerns about fishing not being easy to combine with other economic activities and requiring a life apart from the villages for long periods of the year, led a great majority of the fishermen to reinvest profits into other productive sectors, such as agricultural cash cropping (also made possible by the creation of the lake) or trade. The removal of tsetse flies, which also were part of the government's undertaking when building the dam, opened up for important investments in cattle.

By September 1962 the lake had reached its maximum level. But already by 1964 a 50 per cent decrease in total annual catches was reported, clearly indicating a strong reduction in biological productivity compared to the inundation period. Retaining the previous profit margins could only be done by intensifying the fishing effort, either through higher investments or through more intensive exploitation of the lake which meant also increased mobility on the lake and along its shores. Since profits already were channelled into other economic projects, increased mobility would amplify the need to coordinate with other activities and lead to stronger tensions in the local communities. Most of the newly established fishermen chose therefore to leave fisheries as quickly as they had entered the profession. In the three years after 1962 their number is reported to have fallen from approximately 2 500 to 500.

This pattern of leaving a newly created occupation and investing accumulated profits in more established occupations is a well known and quite common strategy (see e.g. Henriksen; 1974, Jul-Larsen 1981 concerning the attempt to establish a fisheries among the Turkana in Northern Kenya). The works of Colson (1971) indicate that the young men either resumed to labour migration, started cash cropping (cotton) or took on other types of salaried employment. A few remained in fishing, but it is symptomatic that these individuals disengaged increasingly from Tonga social life. At the start of political independence for Northern Rhodesia, as the Republic of Zambia, we must conclude that the objective of the colonial power to establish individuals of the Tonga as fishermen largely had failed.

As planned, the concessions given to the Gwembe Tonga Native Authority of restricting access to fisheries to the Valley Tonga were abolished by the colonial powers in 1963. The reason for this may be found mainly by studying the political preparations for national independence in 1964. The policy of indirect rule and territorial rights according to tribal identity and origin was to be substituted by a concentration of power at the level of the central government and the new constitution clearly stated the supreme rights of the government to all natural resources in the country. Therefore, the institutions creating native authority, which had been established by the colonial powers in the 1930s, such as the one for Gwembe Tonga, were formally dismantled. This does not mean that traditional political authority[1] disappeared. The system certainly took new forms and new strategies were developed among its main actors in order to assure continued access to vital resources. Interesting accounts are found about how traditional authority and tribal identity have been strategically utilized in order to improve access to fishing grounds in southern African freshwaters (e.g. Chirwa, 1995; Aarnink, 1999). However, the disappearance of most of the Tonga from fisheries did not create much incentives for chiefs and village headmen to insist on the exclusive rights to the lake for the Tonga. On the contrary it could prove useful (and profitable) to allow new actors onto the scene.

Colson (1971) dates the entry of foreigners (i.e. people from outside the Gwembe district) to 1963 and the abolition of the native rights. However, Malasha (2002) indicates that their presence may be traced back to before the start of the fisheries. Already in the middle of the 1950s, the government had introduced a certain number of people from the north to help to clear trees from the areas to be inundated. Later, people with the same origins were recruited to help in the training of the new Tonga fishermen. Most of them belonged to different groups of Bemba speaking people who already had long experience from lake fisheries in Bangweulu and Mweru Luapula. A certain number of these individuals seem to have chosen to assimilate with the Tonga and ally with Tonga political leaders. The fishing experience of the Benga speakers and their local knowledge probably caused the Tonga leaders to treat them as allies and use them to recruit and build a new ‘tribe’ of fishermen on Lake Kariba. Unfortunately, not much is known about the relationships between the first foreigners and the local chiefs and headmen after 1963. It is not know to what extent the work of the foreigners depended on or was approved by the chiefs. In any case, the fact that the rights of the Tonga to the lake were abolished at the same time as the Tonga left the fisheries, opened up for the foreigners to invite other newcomers, mainly from their own area of origin, to come and join them. Initially the increase in number is limited. Figures do not exist for the early 1970s, but according to interviews with fishermen operating at that time, and who were still present in the area at the time of the study, the influx of foreigners was limited. The modest growth is somewhat surprising when we know that both the new government as well as the international community continued to support the development of fisheries in the lake[2], and when we compare it with what happened some 10–15 years later. Although few data on the ethnic or regional composition of the fishermen exist after the mid 1960s, it is in the first half of the 1970s that the presence of foreigners becomes ‘common knowledge’ with regard to the Kariba fisheries.

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[1] In lack of better options we continue to use the term "traditional authority", despite the fact that the Tonga chieftaincies, just like many other authorities said to be traditional, had been constructed by the colonial state only half a century before (Colson, 1960).

[2] The policy of the new government was to encourage rural development through the creation of co-operatives. Paradoxically, the aid from the international community to fisheries in Kariba came as a result of a delayed concern for the relocated Tonga (Colson, 1971).

Whether Valley Tonga or newcomers from outside, the fishermen were forced to reorganize their activities. The mode of work used during the first years was not longer appropriate. Not only fish had become scarcer but also fishing gear and other vital commodities became less easily available. In addition access to arable land was limited. The only way fishermen could compensate for these developments was to increase mobility and to constantly seek new resources as well as gear and fish traders. Contrary to the initial ideas, which envisage to group fishermen and traders in a selected and limited number of fishing camps, the new modes of operation meant the formation of a mobile, dispersed and individualized fishing population. Attractive areas were found around the more than 100 islands in the Zambian part of the lake. The shore-lines of these islands account for more than 20 percent of the total shorelines in the Zambian part of the lake (Pearce, pers.com.). One week a fisherman could spend in a village with fellow fishermen, while in the following weeks he would reside alone on one of the islands, before going back to the village to take his wife and their children with him to some inaccessible area on the mainland far from other people. Evidently, work units operating according to such principles have to be small and “one-man” enterprises were quite common, even though most fishermen were reported to be married and be accompanied by both wife and children. A consequence of this shift in exploitation patterns was a brake down of much of the infrastructure which initially had been put in place by the authorities such as houses and marketing facilities in the centralized camps. It meant a complete reshuffling of marketing structures which introduced serious constraints for increases in production.[1] To some extent it was compensated by a shift in processing methods from sales of fresh fish towards more drying. But, little is known about how the commercialization of fish developed in this period.

By 1974 the Zimbabwean independence struggle had entailed a series of attacks by the Rhodesian army into bordering Zambian areas and the Zambian shores of Lake Kariba were particularly affected. The increased insecurity forced the Zambian government to officially close the fisheries in 1974. However, the closure did not lead to a complete halt of the fishery but rather to another restructuring. Information from fishermen operating during this period indicates that few of the foreigners left, neither the lake area nor the fishing. Instead, they were forced to choose fishing grounds and whereabouts according to the degree of security they provided, rather than according to how much fish they thought could be caught. At the same time fish traders are reported to have stopped coming to the lakeshore. The fishermen had therefore few opportunities but to seek as much protection as the Tonga villages could provide and seek to survive through barter and some cultivation of food crops for their own subsistence. Life stories from people having experienced this period tell us that a quite common strategy at the time for foreigners was to assimilate to Tonga customs and ways of life. No doubt fishing effort must have come down to a minimum in this period even if as many as 900–1 000 fishermen are reported to have operated in the Zambian part of Lake Kariba at the time of independence in 1980. It seems fair to assume that the number of fishermen may already have been of that amplitude when the fishery was formally closed six years earlier, since the recruitment of newcomers can not have been very high in that period.

3.2 The 1980s: the big increase in the number of new fishermen

At Zimbabwe’s independence the improvement in the security situation meant that fishing could be taken up as before. In some ways this is also what happened. But while the period

[1] This reshuffling was equally dramatic to the traders who had to try to keep trace of the fishermen they dealt with (see Overå, 2003)

from 1963 to 1974 had been characterized by a modest increase of fishermen, the 1980s saw a noticeable acceleration, particularly from 1983 and onwards. The accepted view has been that the foreigners continued to constitute the bulk of the newcomers, but already in 1985, Beck (1985) documented that the increase was constituted as much by Tonga as by Bemba people and the work of Walter (1988) confirms this. According to Walter's findings, the Gwembe Tonga constituted between 30 and 40 percent of the fishermen in 1988. Furthermore, the data also show that among the foreign fishermen, there was by that time a great variety of origins and ethnic identities represented and Bemba speaking people only constituted somewhere around 35 percent of the total population of fishermen. These findings in many ways contradict the very resilient image among government staff that the increase has to be seen as a result of overfishing in the Bemba dominated waters in the north (Luapula, Mweru, Bangweulu) and a subsequent turn of these people towards Kafue and Lake Kariba.

The two questions that need to be answered are: why was the acceleration of newcomers in the 1980s so much stronger compared to the period before 1974? And, how to explain the changes in composition of the fishing population? Very little had happened in relation to the inshore fishery which can explain such dramatic changes and the main answers have therefore to be sought elsewhere. In the survey undertaken for this study in 1998, including 426 fishermen located in the Mwemba and Sinazongwe chieftaincies in the two eastern fishing zones of the lake,[1] the foreign fishermen were asked about their immediate occupation before they started fishing on Lake Kariba. Seventy-three percent of those who started fishing in the 1980s reported to have come directly from some kind of wage labour, most often in the Copperbelt or in Lusaka and that the reason for shifting to fisheries was connected to the loss of their employment. The crisis in the Copperbelt and in the Zambian economy is generally seen to have started after the oil crisis of 1973. However, at that time the security situation at the Lake had already begun to deteriorate and a year or so later the fishery was formally closed. It was a risky venture to move to Kariba in that period. However, when it reopened people soon sought the opportunity represented by the underexploited lake.

After 1980 it is hence the general crisis in the Zambian economy and the subsequent reductions in wage employment which seem to constitute the main reason for the sharp increase of newcomers. This also explains the changes in the composition of the population. The crisis struck all ethnic groups and all regions of the country equally. The valley Tonga as well as Bemba and other groups were all involved in labour migration to the Copperbelt or sought wage labour in the cities and major towns. All had equally good reasons to seek the opportunities of fishing and the financial capital requested was as we already have indicated very moderate. The form and organization of the fishery remained very much the same as the type that developed after 1963; a fishery that was very dispersed and individualized with a high degree of mobility. The islands again became a preferred base to operate from. The normal procedure for entering the fishery would be to join an already established fisherman for six months to a year to learn enough about the local conditions (both environmental and social) to operate on your own. According to numerous interviews with chiefs and headmen, little was done by the local and the traditional authorities to prevent the newcomers in establishing themselves as long as they did not request, or claim land.[2] If little was done it also had to do

[1] Fisheries administration is organized according to four zones which largely follow the borders of the four chieftaincies bordering the lake.

[2] Non-involvement here does not mean that the various actors within the traditional authority - on their own or in groups - did not try to take advantage of newcomers and the increased demand for access to the lake. The point is that no action aiming to prevent increased entry was taken.

with the fact that the establishment of new individual settlements or fishing camps was extremely difficult to control. As we shall see this situation was soon going to change.

There was also an additional reason why Lake Kariba emerged as a particularly promising venture for many jobless people in the 1980s. In 1983 the Zambian authorities opened the fishery for *Kapenta*, a small pelagic offshore species which in 1967 had been introduced into the lake from Lake Tanganyika.[1] Kapenta fishing requires mechanized rigs, (electric) light attraction, winches and big dip nets. The Kapenta fishery is undertaken at night by paid workers recruited locally, but not necessarily from the area. The fish is then taken either to one of the islands close to where the rigs are fishing or to the shore to be dried and commercialized. The fishery needs investments and technological knowledge far beyond what was within reach of the inshore fishermen. From the beginning all the operators were white settlers/entrepreneurs from the plateau who either established themselves, or a managing representative, at the lake. Most of them were also involved in a range of other economic activities.

For people who recently had lost their jobs and wages, the Kapenta fishery represented an alternative, even if they had to travel to Kariba to seek employment in the fishery. While waiting they sought to survive as well as they could and many of them found a means in the inshore fishery. Some who were not employed on the rigs or who simply changed their minds became part of the increase of inshore fishermen. It is unclear to what extent crew members on the rigs later sought to establish themselves as inshore fishermen, In our conversations with people it was referred to as a common strategy, but in the 1998 survey there is not a single fisherman who reports to have come from the Kapenta industry.

Kapenta operators soon discovered how difficult it could be to control employed labour and the catches landed by them. According to the operators, fresh and processed Kapenta soon became subject to a substantial illegal sale, taking place between the crews on the rigs and the traders. The inshore fishermen, occupying the islands and disposing of canoes were considered as essential allies in the conduct of this trade, but it goes without saying that in the absence of data their role is difficult to establish with certainty. The delicacy of the relationship between Kapenta operators and inshore fishermen may explain why no inshore fisherman in the 1998 survey wanted to admit any connection to the Kapenta business. Nevertheless, it is probable that 'opportunities' in the trade of stolen Kapenta contributed to the increased recruitment of inshore fishermen in the 1980s.

3.3 The 1990s: reductions among the 'foreigners'

In 1989 the number of fishermen had attained around 2 500 individuals or about the same number as had been registered in 1962. From then on the number of fishermen seems to stabilize before it starts falling sometime in 1994 or 1995. With reference to the causes for the preceding growth, just being discussed, both the stabilization and the fall are surprising as the national economic situation and the prospects for jobs and wages in fact did not improve. Even if the introduction of multipartism in 1991 and the subsequent liberalization of the economy could tempt analysts to think that the macro-economic conditions would have improved, a recently published World Bank report (Rakner, Walle and Mulaisho, 1999) concludes that, on

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[1] In Zimbabwe the Kapenta fishery was opened already in 1974, the same year as Zambia had to close its inshore fishery.

the contrary, living conditions and employment opportunities continued to decrease in the 1990s. The causes of the fluctuations in fishing effort – as indicated by the number of active fishermen – must be sought elsewhere. One possible reason for the stabilization of their number could have been the low water levels which started to appear around 1990 (Kolding, Musando and Songore, 2003). But this factor can not explain the reductions after 1994 as employment then started to fall at about the same time as the climatic conditions once again began to improve. We therefore propose to focus in some details on the competition for resources taking place locally.

As already mentioned, the local chiefs and headmen did not, or were not able to, intervene effectively with regard to the establishment of all the newcomers in the 1980s. As long as the newcomers' activities only affected fisheries it was not really a problem. The competition for the fish resources were modest, even if the number of Tonga participating in the fishery started to grew again in the 1980s. However, the increased presence of foreigners inevitably led to competition and conflicts regarding other resources. In order to understand this situation a certain number of additional factors need to be taken into account.

Lake Kariba is characterized by considerable variations in climatic conditions which directly influence the biological productivity of the lake. In particular the hydrological levels of the lake (Kolding, Musando and Songore, 2003) are important. Furthermore, partly due to the considerable shifts in fishing effort over the years, and partly as a result of the dispersed location patterns of this fishing, the marketing systems on the lake have remained weak. In various ways both factors augment the insecurity of anyone who tries to adapt to circumstances by specializing in fishing and forces fishermen, irrespective of their origins, to seek access to alternative resources to sustain themselves and their families. The most obvious alternative resource is land for agriculture or for animal husbandry. If access to the lake has been relatively unproblematic to attain for people from outside, access to land has not. In fact, the persistent struggle by the Tonga to avoid outsiders being given access to land has been a permanent characteristic in the Tonga/outsider relations since the creation of the lake.

At the entry of the 1990s the Kariba inshore fishery found itself in a somewhat paradoxical, but not necessarily uncommon situation; it had become seriously constrained by social conflicts. These had built up progressively during the 1980s and were created as fishermen increasingly demanded access to agricultural land, while the local population would use drastic means to prevent them from getting it. A good example coming to the attention of the author occurred in 1997 when Tonga villagers, with the consent of their headman, fiercely opposed the establishment of a cemetery for foreign fishermen nearby their camp. The Tonga claimed – not without reason – that the existence of the cemetery would improve foreigners' rights to claim agricultural land in the area.

The reasons why competition for land leads to such serious conflicts is complex, but should first of all be sought in the unclear rules for and underlying values about the principles guiding the allocation of land existing in the area. From research on local access regulating mechanisms in sub-Saharan Africa (for Zambia, see e.g. Berry, 1993 and Moore and Vaughan,

[1] Such principles can be kinship (as a member of a lineage, I am the "owner" of the land), marriage (I'm married to the "owner" of the land), social position in the community (as headman I have certain rights to these territories), labour (I and my family have been working and developing the land for many years), investments (I have improved on the use of the land), etc. All these principles may be valid; the problems emerge when they are claimed to be valid at the same time and no-one really knows which principles have priority over others.

1994), it is known that there are normally not one set of (more or less consistent) regulating principles. Rather there tends to exist a whole range of principles, often based in contradictory logics. This leads to a situation of uncertainty and ambiguity as to how land and other vital resources are being allocated and regulated. Hence, different group of actors can, with some kind of legitimacy, claim rights to land (or parts thereof) by referring to all sorts of personal connections to it.[1] On the one hand such a situation offers actors to seek access through a range of different strategies; on the other hand no-one really knows which principles are effective when and where. This unclear situation is also prevalent in the communities on the shores of Lake Kariba. The regulating principles increasingly being used by the foreigners to get access to land included marriage into Tonga lineages, alliances of various kinds with chiefs and headmen and investments. Some of the individuals employing these strategies have succeeded, some have failed and given up, but the majority remain in a state of uncertainty. Some Tonga may say they are allowed to cultivate, or keep animals in certain spots, while others contest any right to land whatsoever for foreigners. Inevitably, this has led to a considerable increase in conflicts, not only between outsiders and Tonga, but also among the foreigners and, may be most important, among the Tonga population itself.

To understand the stabilization in the number of fishermen the increased level of conflicts over land represents an important factor. It does so in two different ways. On the one hand is the stress it imposed on the outsiders causing some of them to decide to leave the area. On the other, and probably as important is that those in the fishing camps invested with the traditional authority realized that the growth in newcomers had to be stopped, and that – overall – the number of fishermen had to be reduced. However, the chiefs did not try to expel people already operating, but when possible limited recruitment of newcomers. According to themselves, they tried new means to reduce the recruitment of outsiders mainly by influencing the outsiders already in place, not to recruit apprentices. The author’s survey also indicates that the stabilization after 1989 mainly was due to reduced number of newcomers. While the average number of foreign newcomers in a total population of 313 foreign fishermen was 16.7 newcomers per year in the 1980s, this dropped to 10.7 newcomers per year in the 1990s.

The chiefs and the headmen had an additional reason to actively try to reduce the number of fishermen. Their location in a border area made smuggling and poaching a flourishing business. By occupying the islands and being among the few with access to boats, the fishermen were extremely difficult to control and the problems they faced in getting access to land only increased their incentives to use smuggling to diversify their risks. Although, not directly a responsibility of the traditional leaders, increased level of smuggling fuelled the general conflict level in the valley even among the Tonga population itself. According to Chief Sinazongwe, the high level of conflict over land and other activities forced the chiefs to take action. Since the late 1980s control over the recruitment of fishermen was constantly discussed among the chiefs and headmen. But one thing is to realize the problems, another is to find adequate means to solve them. Even though increased conscience and some control measures may explain a part of the stabilization of fishermen, neither the traditional nor the local authorities (councils, police, customs or fisheries department) were strong enough, to influence the number of fishermen to any significant degree. The local authorities certainly functioned as an ally to the traditional authority at a rhetorical level, but they lacked both means and incentives to exercise the control required by the chiefs.

What was going to make the big difference was the entry of the Kapenta operators in the overall competition for resources in the lake. Their non-involvement in the inshore fishery had made the Kapenta operators keep in the background during their first years of their operations. However, the problems of theft from the rigs soon made them realize that it was also in their interest to control and limit the number of inshore fishermen. Besides, the economic liberalization which followed the political changes of 1991, created prospects of tourism which interested the Kapenta operators as potential investors. The biggest islands became potentially important for establishment of lodges and wildlife sanctuaries. In May 1995 the author were informed by the Local Council in Sinazongwe that five major islands already had been leased to tourist/Kapenta operators on 50 years lease contracts. Also from this viewpoint the limitation and control of inshore fishermen became crucial for some of the Kapenta operators. The operators could do little alone; as whites and wealthy they were and are the 'real' strangers in the valley. They depended on the Tonga chiefs in order to be able to operate successfully. Chiefs had to approve the land allocations necessary to establish their production facilities and to support them in order for the operators to remain on good terms with the local population. The Kapenta operator/chief relationship was mainly established on individual basis and was often delicate and on occasions even hostile. Nevertheless it soon became quite tight and characterized by an understanding of some sort of mutual dependency. This dependency derived from the simple fact that, unlike all other local actors, the operators disposed of considerable financial resources and modern equipment which was crucial in exercising control of inshore fishermen. So, the chiefs had the legitimacy and the Kapenta operators had the means.

Therefore the alliance between the chiefs and the Kapenta operators, supported by the local authorities, is likely to be the main reason for the reduction in the number of inshore fishermen. Already in the early 1990 it is reported that Kapenta operators, in various ways, practically supported the chiefs and village headmen in their attempts to improve control over the fishermen. They provided the necessary means (speed-boats, petrol, etc.) for control trips to the islands and they supported the organization of local meetings. Already from the beginning of the 1990s, one can trace effects of this alliance, but paradoxically, it was an initiative coming from the government in 1994 which should render their alliance particularly effective.

General concerns about falling catch rates, and about what many believed to be overfishing, led the Zambian Department of Fisheries to launch a new co-management plan for the inshore fisheries early in 1994. In addition to employing traditional measures related to mesh sizes and prohibition of certain types of fishing techniques, the new plan would make it possible to allocate exclusive rights to fishermen in defined areas, by relocating and concentrating them into a more limited number of permanent fishing camps (Chipungu and Moinuddin, 1994; Malasha, 2002). It was argued that exclusive rights would eliminate the problems of free riders and irresponsible behaviour. The shores of the islands would still be open for fishing, but it would be prohibited to stay there at night. Such a prohibition *de facto* meant that the islands would become inaccessible for inshore fishing, given their distance from the shore. The new permanent camps were to be governed and managed by a committee elected among the camp population. In turn camp-committees should elect representatives to one of four "zonal" committees where, except for fishermen, there would also be representatives from local government, traditional authority, Kapenta operators and the traders' community. The plan specified that the funding needed to run this co-management system should be assured by the retention of a part of the fishing licenses collected by the Department of Fisheries and by trade levies on fish collected by the Local Councils.

It appears that this plan contained so many ambiguities and unresolved issues that it became impossible to reach the objectives specified in it. Also, the fact that fishermen strongly resented parts of the plan made its implementation an illusion. In particular, the question of closing the islands to the fishermen was resented, even if all sorts of promises were made regarding improved living conditions in the new permanent camps. Nevertheless, most of the relocation of fishermen had been implemented less than two years after the plan had been presented. According to the Department of Fisheries' frame survey of 1993 and 1995, the number of fishing camps had been reduced from 278 in 1993 to 67 in late 1995. As a result the conditions imposed on individuals wanting to operate as specialized inshore fishermen became so constraining that a considerable number of foreign fishermen chose to leave the Kariba fisheries altogether. According to the same frame surveys, the total number of fishermen fell from 2 238 in 1993 to 1 355 in 1995.

Unlike what many observers of Lake Kariba fisheries tend to believe it was neither the Department of Fisheries nor the management plan as such that caused the considerable reduction in number of fishermen in 1994-95. The reason why the relocation of fishermen took place so quickly was the fact that the alliance between Kapenta operators and chiefs made the initiative a reality. Long before the Department of Fisheries had started to consider specific actions, the Kapenta operators through their Kapenta Fishermen's Association (KFA) and the chiefs (sometimes with the consent of the Local Council) started implementing the plan by pushing for a relocation of fishermen from the islands (Jul-Larsen, 1995). Chiefs, accompanied by with impressive courts, travelled around in the area by car and to the islands by speed-boat, explaining to the population how good things would become in the new permanent camps and threatening those who resisted moving. As always in such cases far more was promised than could be kept and particularly serious were many promises given regarding access to land. These campaigns and meetings were to a large extent funded and organized by the KFA[1]. The drama was completed when in early 1995 the chiefs and the local Council managed to convince a troop of the military police force, attending a training camp in Sinazongwe, to undertake some 'reality training' by landing soldiers on the islands and remove inshore fishermen by force (Pearce, 1995). In such a situation it is understandable that the foreign fishermen, despite a lack of good opportunities elsewhere, preferred to abandon the area.

Even after the forced relocation, KFA continued to support the establishment of the camps, both practically and financially.[2] But as time went by little was done on the part of chiefs or by local and central government in providing the infrastructure and the social services which had been foreseen. The chiefs met strong resistance from many of their village headmen concerning the promises made on land allocations, local government proved to be reluctant to allocate the promised part of the trade levies of fish to the management committees, and government had no additional funds to provide. The Fisheries Department never established the exclusive fishing zones which, from the point of view of fishermen, were one of the most important aspects of the whole plan. Despite the interest by some KFA board members, it

[1] To be more precise, it was in particular the chairman and two other board members who pushed KFA's involvement in the co-management plan and the relocation process. Many of the members were strongly opposed to this policy and wanted KFA to remain uninvolved. It is therefore difficult to say how much was funded by KFA and how much came from these three companies' own budgets.

[2] A meeting for representatives of four permanent camps in the Mwemba chieftaincy in late May 1995 (attended by the author) was chaired by one of the KFA board members. Neither the local authorities nor Fisheries Department participated. In the meeting which lasted one whole day the chairman promised to deal personally with many of the complaints brought forward by the fishermen such as grading of roads to the camps, establishment of shops and some other facilities. The chairman also provided meals and drinks for the 25 participants in the meeting.

became impossible for them to continue their support under such conditions and they slowly withdrew from the whole process. A common experience recorded from earlier relocation processes of rural populations in Africa, is that people start returning to their old places and continue to live and work as they did before. Here is how Sara Berry describes relocation of farmers in northern Zambia*: "Moreover during the first decade of independence, the government pursued a policy of village regrouping which bore a close resemblance to colonial efforts to stabilize rural settlements. At first, villagers showed some enthusiasm for 'village regrouping', but voluntary relocations declined as promised services and amenities failed to appear. People who were already well situated in terms of access to jobs and markets or who were loathe to give up established gardens for an uncertain future never participated at all"* (Berry, 1993).

Also in Lake Kariba the same tendencies soon became evident. Some of the individual Kapenta operators who had leased islands tried to prevent the return of inshore fishermen by use of force, but they failed. It is probably correct to say that, already in 1997, the fishermen made as much use of the islands as they had done before the relocation started. However, it seems as if the extremely mobile and individualized fishing that was common until 1994 were given up and that fishermen, at least to some degree, had accepted to use the permanent camps as a residential base (Overå, 2003). It should also be mentioned that one of the results has been a clear switch in the identity of fishermen in the camps. Tonga fishermen are now a much larger proportion of the total number of fishermen than before and for the first time since 1963, they were able to establish their influence and exercize some power in the fishing communities.

One important question remains: why has the number remained so low also after the dramatic reductions in 1994-95? A growth in numbers could have been expected as a result of the collapse in the alliance between the chiefs and the Kapenta operators. It was this alliance which provided the means and the legitimacy to enforce the relocation process and as per 1999, there were no institutions, alone or in cooperation, which could effectively control the recruitment and the mobility of inshore fishermen. From this perspective it is surprising that, according to Department of Fisheries' frame surveys 1995, 1997 and 1999 no growth has taken place. On the contrary, there has been a continued but slight reduction; from 1 355 fishermen in 1995 to 1 263 in 1997, to reach only 1 170 fishermen in 1999. The author is uncertain of how to interpret this latest development and can not provide any well developed explanation. First of all the quality of the frame survey data needs to be checked. It may be that the number of fishermen recorded after 1995 is not directly comparable with numbers of fishermen reported before that year, since some informants claim that the frame surveys of 1995 and after only have included the "official" permanent camps. So, qualified interpretations must await study of the frame survey data.

4. CONCLUSIONS

Brox's (1990) analytical distinction between population-driven and investment-driven changes in fishing effort relates to whether the changes are the result of changes in the number of fishermen or in individual accumulation of gear and technological changes. The reason for making this distinction is that it permits the analyst to study separately the underlying causes of change. These causes are not the same for population-driven and investment-driven changes. Therefore, often the consequences for biological sustainability, for social welfare and for equal rights to natural resources also will differ. This review of effort development in Kariba shows first of all that, although changes in fishing effort and changes in the number of fishermen is not one and the same thing, the number of fishermen probably constitutes the most important variable in determining effort development. Effort development in the inshore fishery of Lake Kariba is arguably much more population-driven than investment-driven. Furthermore, it demonstrates that population-driven changes are not simple reflections of demographic trends. The changes in Kariba are characterized by a considerable growth in, as well as by reductions in, the number of fishermen, even in a situation where the general demographic growth is noticeable and fairly stable. In Lake Kariba the main factors influencing the changes in number of fishermen can be summarized as follows.

First, the overall changes in what may be termed the macro-economic (to some extent also macro-political) conditions at the national and regional levels. The overall economic situation in the country and thereby the opportunity for jobs seem to have significantly influenced some of the most dramatic changes in numbers of fishermen. It is the war for independence in Zimbabwe that explains fishing effort at a minimum in the late 1970s, even after the general economic crisis had emerged in Zambia. And it is the same crisis that drives thousands of recently jobless people to try fishery on Lake Kariba. But this variable can not be seen in complete isolation; it must also be compared to changes in the opportunities created by the specific fishery in question. In 1963 when there are relatively good prospects for finding jobs in the Copperbelt and in cities inside or outside Zambia, the reduction in biological productivity in the lake is part of the context that explains the rapid decrease of fishermen at that stage.

Secondly, the analysis shows that changes in the macro-economic conditions together with the situation in the fishery do not always act alone. While the general economic crisis in Zambia to a large extent explains the growth in the number of fishermen in the 1980s, the prevalence of the crisis through the 1990s did not lead to continued growth during that period, but to stabilization and a subsequent decrease. In this context the analysis shows that local access regulating mechanisms also may be crucial. The larger the pressure on natural resources in Kariba, the more important local access regulating mechanisms become, even if these resources are not those of the inshore fishery . It is the pressure on arable land and on the territories of the islands (even the thefts of Kapenta may be seen as increased competition for resources) which explains why certain groups of actors such as chiefs, headmen and Kapenta operators see an interest in pushing and even implementing policies aiming to exclude inshore fishermen from the same resources. Although many social scientists are right when they insist on the problematic assumptions of free access regimes in fisheries, this analysis shows that assumptions that local access regulations are effective also can be quite problematic. The study shows that local access regulation is not particularly effective in maintaining biological productivity or in assuring the equal distribution of resources at the local level. Local access regulating mechanisms seem to have developed more in response to peoples struggle for control of and access to the resources, than as a manifestation of collective concerns for the sustainability of the resources or for the welfare of the communities.

The implications of these findings clearly demonstrate the utility of Brox’s analytical distinction. The role of macro-economic conditions in determining people’s wish to join fisheries as well as the great mobility of people implicates that this sort of fishery serves as a buffer and a safety valve to ease the consequences of fluctuations in the macro-economy. Such a situation makes it problematic to define “who are the fishermen” because those who are not fishing today may easily become fishermen tomorrow. And later, both tomorrow’s fishermen and those already in business today may decide to leave if conditions elsewhere improve. But, of course, the very high geographical and social mobility of Kariba inshore fishermen is not necessarily a bad thing from the point of view of society. They move over long distances and between countries and they easily switch occupations according to what they can obtain and what they think may generate the most interesting profits. From 1963 to 1994, it can be said that Lake Kariba functioned as a commons to the benefit of all those who fished there and without creating any fishery tragedy.

On the contrary, the establishment of strong access regulating mechanisms at the local level, which also was the intention of the proposed co-management regime, has limited the access to the commons to an extent that the lake is left considerably underexploited. By saying so the author does not underestimate the problems caused by the high number of foreigners in 1989-1990: the Tonga naturally have to protect what land had been left for them after the Zambian society took its share in the 1950s, the Kapenta operators are entitled to protect what was and is their property, tourism may prove beneficial to more than the investors and the chiefs in lake shore communities have a legitimate right and duty to minimize the levels of conflicts in their communities. But, the important question is: to what extent all these legitimate concerns can be adequately dealt with without removing what has proven to be an important safety valve for a great number of Zambians? Co-management in fisheries certainly has many faces.

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COLONIAL AND POST-COLONIAL FISHERIES REGULATIONS: THE CASES OF ZAMBIA AND ZIMBABWE

Isaac Malasha

1. INTRODUCTION

Fisheries management and the regulations on which it is based have mainly been premised on the values of positivistic science with its strong emphasis on rationality and impartiality. Positivistic science tend to portray the universe as mechanistic and deterministic and its workings as being governed by a few fundamental and unvarying laws. Based on these laws scientists can derive regulations that inform the manner in which a particular natural resource such as fish should be exploited to ensure the sustainability of the stocks. However, the implementation and enforcement of these regulations have to fit into the political and economic rationality of the state in which they emerge and these rationalities may be at variance with those of science. The purpose of this paper is to explore the reasons for the type of fisheries regulations that emerged in Zambia and Zimbabwe.[1] It will be shown that although there were attempts to justify the regulations with reference to scientific principles, the regulations had to fit the political and economic interests of their respective states as well as they reflected the dominating representations and images of the man-nature relationship that prevailed among the agents of the states. This resulted in conflicts between fishermen and government agents and ambiguity in implementing the regulations. Using examples from Lake Kariba the paper shows how efforts to develop uniform fishing regulations for the fishery of the man-made lake were not successful because of fundamentally different state interests towards fish and fisheries in the two countries.

2. THE MANAGEMENT OF FISH AS GAME

One of the most noticeable relationships between game and fisheries is the manner in which these resources have been managed especially in a southern African context. In most African countries game and fisheries have been managed under the same bureaucratic institution.[2] But much more fundamentally is the similarity in the regulations defining the way in which they are accessed and utilized. The scientific arguments that had been used to develop game laws were transferred to the way the fisheries sector would be regulated. Consequently, fisheries regulations emerged as an adjunct of the Game Laws. From 1925 the fisheries sector in Zambia was managed under various Game Laws until 1943 when the Fish Control Regulations Act was enacted. Similarly, in Zimbabwe the Game Laws that were introduced in 1891 were also applicable to fish until 1938 when a section specifically dealing with fisheries was incorporated into the Game and Fish Amendment Act. In these various acts a fish was classified as an "animal" and fishing was perceived to be another form of "hunting".[3]

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[1] Before Zambia's independence in 1964 and during the Federation of Rhodesia and Nyasaland between 1953 and 1963 the two countries were known as Northern Rhodesia and Southern Rhodesia respectively. Following the dissolution of the federation Southern Rhodesia became known as Rhodesia and in 1980 was re-named Zimbabwe. Unless specifically mentioned the paper will use the post-colonial names.

[2] For instance, the former Director of Game and Fisheries in Zambia argued that fish was a kind of wildlife for this reason fish and game had to be managed jointly (Zambia National Archives Ref. No. Sec 6/508 'Memorandum on the Expansion of the Fisheries Section of this Department,' Director of Game and Fisheries, Ministry of Native Affairs, 25/9/61.

[3] Zambia National Archives (ZAMBIA NATIONAL ARCHIVES), Ref. No. ML 1/7/19, Vaughan Jones, `Preliminary Report on the Fishing Industry and Its Markets, 1942.

Hunting restrictions that are a common feature of game legislation were applied to fisheries. Restrictions through various means such as closed seasons, protection of young game and licensing are meant to allow for selective removal of certain specimen at particular times to avoid over-hunting. When regulations for the management of game were being developed there was emphasis on the protection of young specimen to only allow for the hunting of animals that had reached a particular age. This was meant to prevent the removal of specimen that would not have a negative impact on the ability of the remaining specimens from replenishing themselves. This legislation is comprehensible in that most game, especially those that the laws sought to protect, such as elephants, do not reproduce rapidly and in large numbers. When specific fishing regulations began to emerge in Zambia and Zimbabwe there was emphasis on setting minimum mesh sizes of fishing nets and the admissible width of apertures in fishing traps and baskets. These clauses on minimum mesh-sizes were aimed at preventing the harvesting of fingerlings.

Ideological reasons were also behind some of the regulations that emerged. As legislation for the conservation of game was emerging calls were made to proscribe certain hunting methods considered to be ‘unfair’ to the hunted animal (Beinart and Coates, 1995). This was advanced into the public domain as the element of “sport” in game management began to be pushed to the top of the conservation agenda.[1] When hunting game, an animal had to be given an opportunity of escaping in the spirit of “fair play”. Hunting methods considered as not giving hunted game a chance to escape were considered ‘unsportman-like’ and prohibited. For instance, Section 33 of the Game Ordinance of 1941 specified that during hunting no person was to drive, stampede or unduly disturb any animal for any purposes whatsoever. This “fair chance” approach to the hunting of game proved to have considerable impact on formulation of fisheries regulations. When new legislation on fishing was drawn-up in 1943 in Zambia, active fishing or *kutumpula* as it is locally known, was banned. This fishing method of driving fish into nets by splashing and beating

However, these scientific and ideological justifications mask the economic and political interests of groups that pushed for their implementation. In the colonies regulations for the utilization of resources such as game and fisheries were designed to meet the economic and political interests of dominant group. Licensing of fishermen was justified on the need to control access to fisheries. However, it also provided revenue for the authorities. This was particularly the case in most British colonies where fish levies were used to fund administrative structures in rural areas known as Native Authorities. The revenue was used to pay the salaries of chiefs and other employees of the authorities. Gordon (2000) notes that in 1943 chiefs in the fisheries in northern Zambia were eager to enforce fishing regulations because they benefited from the fish-licensing system. For instance, the Shila and Chishinga Native Authorities derived most of their income from this fish levy.

3. EMERGENCE OF FISHERIES LEGISLATION IN ZAMBIA

It was only after 1940 that efforts to develop a local policy for the conservation of fish were made in Zambia. Firstly, while fishing had been a source of food and employment, even before the colonial period, it was now discovered that it would benefit the economy more if some

[1] According to Mackenzie (1987:22-40) hunters also anthropomorphized animals in attempt to suggest a degree of equality in the contest and therefore emphasise the physical endurance and courage required in the hunt. Thus, the killing of intelligent animals such as the elephant provided the greatest exhilaration.

measures were implemented to control the industry. This was based on the prevalence of numerous water bodies that were estimated to have produced fish worth more than one hundred and fifty thousand British Pounds per annum.[1] Secondly, the need to support the booming copper industry with the provision of cheap food prompted the authorities to begin to draft fisheries legislation. Although beef had initially been used to feed the labour on the mines, problems associated with supplies that occurred in the early 1940s, prompted the authorities and mine owners to begin to explore alternative sources of cheap food supplies for labour. Gordon (2000:91) observes that severe beef shortages that occurred in 1941, 1943 and later in 1948 compelled mine owners to import five hundred tons of fish from a Congolese supplier to pacify the restless workers. During these food shortages prices went up causing instability in the urban areas. This compelled the authorities to impose price controls as a short-term measure. The Provincial Commissioner (PC) responsible for the Copperbelt implored the Director responsible for the fisheries sector to maximize fish production by also suspending the existing fishing regulations that were still under the Game Ordinance Act of 1941. The strict enforcement of the regulations was seen as contributing to the shortage of fish in the Copperbelt. The PC argued that:

> "We are having some difficulty in keeping our workers contended here owing to short supplies. The point may be reached when discontent will have serious repercussions on copper production, which would be more disastrous even than upsetting the internal economy of Northern Province or depleting its fish supplies for a time. Bangweulu fish supplies have some bearing on copper production."[2]

This statement is evidence of the importance with which copper production was linked to the availability of cheap food for the labour. Although the fishing regulations had been implemented to protect the fishing industry, these were now seen as hindering copper production. To the State, the collapse of the fishing industry was not paramount as long as copper production was sustained. The Director of Game and Tsetse Control concurred with the Provincial Commissioner by observing that the importance of maintaining a smooth atmosphere on the Copperbelt was so great that fish supplies should be given a high importance relative to that of opposing factors. Consequently, fishing regulations were relaxed and the supply of fish to the Copperbelt improved.[3] Following other food shortages that occurred on the Copperbelt in 1943 the authorities responded by invoking Emergency Powers (Control of Fish) Regulations. These emergency measures were designed to control the distribution of food, especially fish.[4] These regulations gave the Director of Game and Tsetse Control a wide range of powers to deal with the distribution of fish by prohibiting the importation or export of fish into or from any Fishery Area.[5] They further empowered the Director to limit weight of fish or the market

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[1] ZAMBIA NATIONAL ARCHIVES Ref. No. Sec 6/190, Correspondence from Acting Director of Game and Tsetse Control to Secretary to Cabinet, 1943.

[2] ZAMBIA NATIONAL ARCHIVES, Ref. No. Sec 6/190, Correspondence from Provincial Commissioner, Western Province to Director of Game and Tsetse Control 1943.

[3] Although fish supplies temporarily improved following the suspension of the fishing regulations, the fish-price controls that were also imposed at the same time merely drove fish from the formal into the parallel market.

[4] According to the Provincial Commissioner in charge of the Copperbelt, which was then known as the Western Province, beginning in 1943 there was a shortage of various commodities on the Copperbelt, including foodstuffs. The consequence of these shortages was that fish prices went up and controls were introduced. However, this only led to drive fish off the official market into the parallel market where prices were high (ZAMBIA NATIONAL ARCHIVES, Ref. No. 6/190, 1/8/1943).

[5] A Fishery Area was a fishery covered by the Fish Control Regulations.

in which it was supposed to be sold. These controls were only abolished in 1946 when the distribution of fish improved.[1]

4. AMBIGUITY IN THE APPLICATION OF FISHERIES REGULATIONS

Because of the diverse manner in which fisheries regulations had emerged and were implemented their application was bound to cause ambiguity and resentment. This was also compounded by the fact that the Department of Game and Tsetse Control, under which fish was managed, did not have adequate staff to implement the fishing regulations. In some of the fisheries in remote areas it was left to the District Commissioners and other colonial officers acting on basis of their own (sometimes preconceived) assumptions of fisheries management to enforce the fishing regulations. The issuing of fishing licences was particularly problematic. Native Authorities issued licences to fishermen who fished in water bodies under their jurisdiction. However, local fishermen could migrate from one fishery to another for different reasons. This movement of fishermen across boundaries proved to be a problem in some Native Authorities as it deprived them of much needed revenue.

The enforcement of minimum net mesh-sizes and types of nets to be used were also a contentious issue between the authorities and fishermen. The minimum mesh sizes were designed to ensure that all the fish caught in a net would have bred once. This regulation ignored the fact that some fish species could reach their maximum size without being caught in the minimum allowed mesh-sizes. In 1949, fishermen in Kasempa in the north-western part of the country complained that the institution of minimum mesh-size for their fishing nets caused them to lose many fish.[2] They argued that the fish species that they particularly targeted were so small even at maturity as not to be captured in the nets that they were legally allowed to use. The District Commissioner disputed this argument by observing that the fish that was not caught in the legally allowed nets was not of economic value and did not warrant the change of the mesh-size regulations. In 1953, a Fisheries Officer in Kawambwa reported that he was unable to enforce the mesh-size regulations due to resistance by local fishermen. He complained that the mesh system in the fisheries under his jurisdiction was farcical due to non-observance of the regulations by the local fishermen. He recommended that fishing regulations should no longer apply in that fishery.[3] In another example, in 1954 it was agreed that due to resistance by local fishermen and the lack of adequate personnel, fish conservation regulations in the Northern Province be abandoned in all but the following fisheries; Mweru-Luapula; Mweru-wa-Ntipa; Lake Tanganyika and Bangweulu-Luapula.[4] The regulations were relaxed but despite the abandonment or suspension of all or certain provisions, the clause pertaining to licensing was always retained. This was meant not to disrupt the collection of revenue for Native Authorities.

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[1] It was during this period that the Director of Game and Tsetse recommended that fish exports to Zimbabwe be banned. This ban affected the urban population in Zimbabwe that was reliant on fish supplies from Zambia. These fish- exports had amounted to about 5 000 kilograms in 1943. However, the ban on fish-exports did not stop Zambian fish-traders from smuggling large quantities of fish into that country. (ZAMBIA NATIONAL ARCHIVES, Ref. No. Sec 6/190, Correspondence from Provincial Commissioner to Chief Secretary, 1944.).

[2] ZAMBIA NATIONAL ARCHIVES, Ref. No. SEC 6/570, Acting Director of Game and Tsetse Control, `Preliminary Report on the Fishing Industry and its Markets, 21/10/1949.

[3] ZAMBIA NATIONAL ARCHIVES, Ref. No. SEC 6/570 Correspondence from Fisheries Officer, Fort Roseberry to District Commissioner, Kawambwa, 1953.

[4] ZAMBIA NATIONAL ARCHIVES, Ref. No. SEC 6/570 Correspondence from Director of Game and Tsetse Control to Fisheries Officer, 1954.

The restrictions on the use of weirs were also declared ineffective and impossible to enforce especially in the swampy Bangweulu fisheries. Faced with these problems, the Fisheries Officer for the area unilaterally declared that weirs did not in fact destroy the fry in the lake and called for their relaxation in the fishery. The Fisheries Officer was also compelled to take this decision following the Luwingu Native Authority's refusal to fine fishermen brought before it for using weirs. Such fishermen were usually discharged with verbal warnings and not fined.[1]

The ambiguity in the application of fishing regulations was also premised on the preconceived ideas that local fishing methods were inherently harmful. This prompted authorities to unilaterally declare certain methods illegal even when there was no scientific evidence to prove it. The problem with this evidence was that it was more often based on perceptions. In 1942, the seine net was banned after one District Commissioner observed that it was destructive and would lead to depletion of fish.[2] In 1948 the Director of Game and Tsetse control wrote to a Game Warden based in Fort Rosebery (Kasama):

> "*Labeo* and *Hydrocyon* (sic) are agreed as being in need of control so far as trade in immature specimens is concerned. I feel that *Auchenglanis* (sic) is badly in need of protection, though I have no data at present to support this general opinion. *Chrysichthis* is perhaps fairly safe; if, however, it is likely to have to come into this restriction within the fairly near future, it had best be put in now. Are there any other species which should be considered in this connection?"[3]

To conduct research, it was argued, was not necessary in the face of a perceived catastrophe in the fishing industry if regulations were not implemented. Proper research would take time and the results might be too late to prevent a tragedy in the colony's fisheries:

> "We cannot proceed very far without proper research, but as, even if commenced now, that would take some time to give results, I consider that our present action on empirical lines is fully justified in view of the urgency of the fishery problem in the territory."[4]

In the absence of a full-fledged research framework it is not clear what the Director of Game and Tsetse Control referred to as "empirical lines" in terms of the policy towards the fishery sector. It can however be assumed that due to the importance of the fishing industry to the economy of the country one would not take chances. The other reason why the authorities could not wait for scientific research was the perception by staff of the Department of Game and Tsetse Control that their primary function was to protect the destruction of natural resources and not that of conducting research.[5]

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1 ZAMBIA NATIONAL ARCHIVES, Ref. No. SEC 6/570, Correspondence from Fisheries Officer to Director of Game and Tsetse Control, 1954.

2 ZAMBIA NATIONAL ARCHIVES, Ref. No: SEC 6/508, Correspondence from District Commissioner, Gilbert Phillips to Provincial Commissioner, Kasama, 7th November, 1942.

3 ZAMBIA NATIONAL ARCHIVES, Ref. No: SEC 6/158, Director of Game and Tsetse Control to Fisheries Officer, Fort Rosebery, 1941.

4 ZAMBIA NATIONAL ARCHIVES, Ref. No. SEC 6/10 Correspondence from Acting Director of Game and Tsetse Control to member for Agriculture and Natural Resources, 16th January, 1951.

5 Vaughan-Jones, T.G.C., 'Memorandum on Policy Concerning the Foundation of a Game Department and the Conservation of Fauna in Northern Rhodesia,' Government Printers, Livingstone, 1938.

Differences in the efficacy of the fishing regulations were not only confined to the authorities and the fishermen but were also present within the colonial establishment itself. In 1953, a biologist from the Commonwealth Office in London challenged the manner in which fisheries regulations were designed and implemented in the colonies. He observed that fisheries regulations in the colonies were modelled on United Kingdom Fisheries Regulations of 1866 and on game laws and thus faulty. He said that these 1866 laws had borrowed heavily on game laws and the analogy between game and fish was dangerous because stocks of game can be watched and even enumerated and their breeding rate is slow. On the contrary, fish stocks had an extremely rapid rate of breeding, and they cannot be directly watched, but only indirectly by conclusions drawn from the results of commercial fishing and of biological research. He observed that most of the restrictions and prohibitions currently in use in the colonies were of a doubtful nature. The licensing of gear or nets required large and expensive enforcement staff. Other measures such as closed seasons; mesh-size restrictions and size of fish regulation were not very useful either. Fish fences were also harmless because if only a small number of fish suffice to replenish stocks, then there was no need in allowing excessive numbers to spawn and the capture of the surplus was an economical exploitation. He argued that mesh-size regulations, which were designed to take only the largest category of fish, must result in the dysgenic removal, for generation after generation, of the best-growing strains.[1] This left future breeding increasingly to the poorer strains and the result of attempts to restrict capture only to the larger fish might be fewer and fewer large fish to be caught.

The reaction to the biologists' observations by officers in the Department of Game and Tsetse Control was mixed but generally reflected the government's political and economic interests in the fishing industry. While agreeing to the biologists' general thesis, a Fisheries Officer observed that the former was ignorant of "factors important in Central Africa." He said that African fishing methods "so primitive that weirs across tributaries allowed no fish to escape and that some river-pools fished communally by spears and baskets had no survivors".[2] The Director in the same department was more open about the political and economic objectives of the fishing regulations in the colony. He said that the reasons for the existing regulations were that licensing was a source of revenue for Native Authorities.[3] Secondly, it was argued that fishing was the major industry in which most of the Africans in rural areas were employed. These local people were so dependent on fishing and had not developed alternative economic activities that there was a need for the existing fishing regulations to avoid an unemployment catastrophe in the event that the fishing industry collapsed. Such fishing regulations, observed the director, were "not only reasonable but positively desirable."[4] Thirdly, he acknowledged that the mesh size regulations may or may not be an unnecessary restriction, but as it already existed it was going to be a psychological error to abolish it until it was quite certain that it was not necessary.

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[1] ZAMBIA NATIONAL ARCHIVES,Ref. No. 6/560 Hickling, C.F., "Memorandum on Fisheries regulations," Colonial Office, London, November, 1952.

[2] ZAMBIA NATIONAL ARCHIVES, Ref. No. 6/560 Correspondence from Fisheries Officer to Director of Game and Tsetse Control, Dr. Hickling's Circular on Regulations, 1953

[3] Officially this was not put so openly. It was usually said that the main reason for licensing was "to stimulate the Native Authorities interest in the conservation of fish" (ZAMBIA NATIONAL ARCHIVES, Correspondence from Fisheries Officer to Director of Game and Tsetse Control, Dr. Hickling's Circular on Regulations, 1953).

[4] ZAMBIA NATIONAL ARCHIVES, Ref. No. 6/190, Correspondence from Colonial Office, London, to Governor of Northern Rhodesia, 18th May, 1944

Following this debate the Fish Conservation Ordinance of 1955 was enacted. The new ordinance sought to remove the clause of leaving a gap in a weir. It was reasoned that licensing weirs would in itself be a hindrance to the making of the same gear and would automatically cease to be used.[1] However, the principal objectives of the new ordinance remained the same as those of the previous ones. It regulated fishing appliances, placed restrictions on minimum mesh sizes and also prescribed that offences and penalties to be meted out to those fishermen who violated the ordinance. In particular it also specified that licensing would continue to be imposed on all fishermen operating from fisheries under the control of the various Native Authorities.

In 1963, the Department of Game and Tsetse Control was renamed the Department of Game and Fisheries. It was also transferred to the Ministry of Lands and Natural Resources following the abolition of the Ministry of Native Affairs under which it had been located. In 1965, the Fish Conservation Ordinance and the Fish Control (Mweru-Luapula Fisheries Area) Regulations were amended. In 1974 all the different pieces of regulations such as Fish Conservation Ordinance and the Fish Control (Mweru-Luapula Fisheries Area) Regulations were combined to create the Fisheries Act of 1974. In the same year, the Department of Fisheries (DoF) was also established. The Fisheries Act currently provides for the development of fishing in the country. It is principally still based on the restrictions that emerged in the game laws of the 1940s. However, due to the manner in which the regulations emerged coupled with reduced government funding to DoF, the implementation has not been effective. Most fishermen admit that the fishing regulations are not an inconvenience to their fishing activities.

5. FISHERIES REGULATIONS IN ZIMBABWE

It was also during colonial rule that regulations for the management of fisheries began to emerge in Zimbabwe. In a Proclamation of 10 June, 1881 issued under Order-in-Council of 9 May, 1891, the Game Law Amendment Act, 1886 of the Cape of Good Hope became the game of laws of Zimbabwe. This piece of legislation was aimed at protecting big mammals such as elephants that were considered to be in danger of being over-hunted by ivory hunters, missionaries and builders of railway lines and roads.[2] In 1929 the Game and Fish Preservation Act was passed. It was in this new act that there was a direct reference to the way fisheries resources were to be utilized in Zimbabwe. The new act attempted to consolidate and amend the law for the better preservation of game and to design an act that would reflect the realities in Zimbabwe. The amendments dropped all references to Cape Province that had remained in the previous pieces of regulations. It was in this act that a section dealing with fishing was also included. As in the way that game was conserved, the section on fish in the act prohibited the use of drag, cast, stake or other nets and determined that any under-sized fish shall be returned to the water. The act also prohibited the use of dynamite or chemicals or fishing without a licence. As with other pieces of regulations on natural resources these restrictions on hunting methods marginalized Africans' access to fisheries or game. Most of them could not afford to obtain the required licences and did not have resources or time to utilize the required hunting or fishing implements and methods.

Reflecting the emerging discriminatory land tenure system in the country the Game and Fish Preservation Act made it a punishable offence to enter or trespass the land of another person

[1] ZAMBIA NATIONAL ARCHIVES, Ref. No. 6/570, Director of Game and Tsetse Control, Notes on New Features in the Draft Fisheries Conservation Bill, 11/12/1952.

[2] It is during this phase of colonial penetration into the interior that Mackenzie has associated with the transformation of hunting into the Hunt for the benefit of a few people from among the settler community (McKenzie, 1987: 41-62).

in the pursuit of game or fishing without the authority of the landowner. The ordinance gave a wide range of powers by those who had water bodies on their private properties to prosecute anyone who poached or trespassed with the intention of poaching. This provision engendered the emergence of a strong lobby-group from among the settler community that started importing exotic fish species for stocking local waters. Although these initiatives to import exotic species had been started in the late 1920s they were now officially recognized in the new act. It gave powers to any association or person to introduce, in defined waters, any fish not native to such water and making provision for that introduced fish to grow to exploitable levels. These groups formed associations and lobbied government for funding to import ova from the Cape and further north as Scotland. In 1938 trout ova were imported from Scotland for the stocking of the colony's fisheries (Bell-Cross and Minshull, 1988). Later an umbrella organization known as the Trout Acclimatisation Society was formed to co-ordinate the operations of associations interested in the importation of trout ova. Imports consisted mostly of the Largemouth Black Bass, Carp, Rainbow and Brown Trout. One common feature of these imports is that they were meant to improve the fish-angling facilities in Zimbabwe and little attention was paid to their potential as food (Toots, 1970). The rise in the importation of exotic species led to the this emergence of a strong sport-fishing lobby. It was such lobbies from among the settler community that pushed for legislation to protect their sport. In 1938 the Game and Fish Preservation Act was renamed the Game and Fish Amendment Act. These amendments were a result of strong pressure that was being exerted on government by associations with an interest in angling; sport and fly-fishing that wanted direct government funding for their activities. Institutions such as the Flyfishers Association of Southern Rhodesia lobbied government to provide financial assistance to angling clubs that wished to import exotic fish species from outside the country. The society also asked for more powers to control the manner in which the exotic species were stocked and harvested. Between 1936 and 1946 a total of seventy-three government notices were made in relationship to the Game and Fish Preservation Act of 1929. Most of these notices were to authorize an organization known as the Rhodesia Angling Society to introduce alien fish into the waters of the colony and also to ban fishing for a period of five years to allow the introduced species to expand.

In 1944, the Southern Rhodesia National Anglers Association was formed. By 1947 similar associations had become so politically entrenched that they began to lobby government to amend the Game and Fisheries Act to give more responsibilities on the management of water bodies to its members. These amendments were made towards the end of 1947 when the act made members of the Angling Societies into Honorary Fish Wardens. The wardens had powers to prohibit fishing and apprehend those doing so in water-bodies located on private property.[1] Those caught were liable to fines ranging between five and twenty-five Rhodesian pounds. The various angling associations also established research stations in the country to improve the strain of imported fish species to local conditions. Some of these research stations were privately run while others relied on government subsidies. These included the Mashonaland Highveld Research Centre at Lake McIlwaine, Trout Station at Nyanga, Matopo's and Southeast Lowveld at Kyle. The research station at Kyle was responsible for research on Bass. It was only in 1966 that the Department of National Parks and Wildlife Management assumed responsibility for all fish research in the country.[2]

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[1] Zimbabwe National Archives, Ref. No. S482/637/39, Correspondence from Parliamentary Secretary to the Secretary, Department of Agriculture and Land, 2/4/1942.

[2] Government of Southern Rhodesia, Ministry of Mines and Lands, "Reports of National Parks Advisory Board and Director of National Parks and Wildlife Management for 1966", Government Printers, Salisbury, 1967.

In Zimbabwe the development of fishing regulations were driven more by individuals, associations and clubs with an interest in sport fishing than government initiative. The government's involvement in the industry was not as manifest as was the case in Zambia. Partly, this is because the agricultural industry was well developed and able to provide cheap food products such as beef to labour. Secondly, fish requirements, especially for the large immigrant community in the mines and farms, were met through imports from Zambia and Malawi (Chirwa, 1996).[1] Thirdly, as fishing did not contribute much to the economy except through tourism, the government did not invest much in personnel and infrastructure. This was left to private interests. It was only in 1949 through the passing of the National Parks Act that for the first time the government created a National Parks Board and employed officers specifically responsible for fisheries. However, even the policy thrust of the new board was to support sport angling. It promoted sport angling in all water bodies in the country's national parks.[2]

The change in government policy which led to the establishment of the board was prompted by the findings of a 1948 consultancy report commissioned to advise the country on the potential of inland fisheries.[3] The report observed that the country already had water bodies that were well stocked with fish. The report recommended that the creation of a new fisheries department was necessary as was the need to maintain water bodies that had already been stocked with exotic species. This department would maintain breeding pools, hatcheries, and a central experimental fish farm to serve the dual function of producing fish for stocking and conducting experiments in fish farming. The major recommendation, however, was that fisheries policy should generally put emphasis on sport fishing to attract tourists (Hey, 1948). Furthermore, the restocking of some of the country's water bodies should concentrate more on fishes that had virtues of superiority in fighting ability (ibid.). The emphasis on sport angling was based on the premise that the diet of white settlers was wide ranging enough so as not to make fish a staple. Instead fishing was to be promoted as a sport. Even the consultancy report recommended that priority should be given to the import of 'angling species' into the country's water bodies while undesirable (or unsporting) species such as catfishes were to be got rid of (ibid.:9).

African fishing methods were marginalized on the grounds that they were destructive and unsportsmanlike. African fishermen were accused of using explosives and throwing poisonous plants and remnants of beers dregs into the water and scooping out all sizes of the dazed fish. These methods, it was argued, did not give fish a 'sporting chance' and hence needed to be banned.[4] These views completely ignored the importance of fish as a means of food or employment for the majority of the local African fishermen. They merely re-emphasised the prejudices of the settler-community towards local fishing methods. African fishermen were further marginalized as most of the water bodies were on private lands or in National Parks. Existing legislation and land tenure system made it almost impossible for local people to access these water bodies for fishing purposes. However, other non-white races were treated much better. In 1952, it was decided that no restrictions should be placed on the rights of Asiatic and Coloured people to fish in park waters on the same basis as Europeans who were not members of particular Angling Societies concerned.[5]

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[1] Zambia National Archives, Reference No. Sec 6/190, Correspondence from Director of Game and Tsetse Control to Mine Office, Shabane Mine, 17/9/1946.

[2] Federal Ministry of Agriculture, 'Memo on Fishing, Salisbury, 1955 pp.1-6.

[3] Hey D., `Report of A Survey During July-August 1948 on the Potentialities of Inland Fisheries in Southern Rhodesia, Stellenbosch, Inland Fisheries Department, Cape Town, 1948.

[4] Bulawayo Chronicle, "Letter to the Editor", 28 June 1948.

[5] Government of Southern Rhodesia, Ministry of Mines and Lands, "Report of the National Parks Advisory Board for the Year ended 31 December 1953," Government Printers, Salisbury, 1954.

In 1975, the National Parks Board was renamed the Parks and Wildlife Board. This followed the repealing of various acts related to the conservation of wildlife among them the Fish Conservation Act of 1960. The new act became known as the Parks and Wildlife Act of 1975. In terms of fish conservation the act still retained provisions on how fishing is to be conducted and the fishing methods that were not authorized. The act authorized the minister responsible for the country's fisheries to declare any person to be the Appropriate Authority for any waters in the country. The act further empowered the minister to declare any waters as Fish Conservation Areas if it was considered that there was a threat to the fish in those particular waters. However, further controls on actual fishing were instituted: no person was allowed to fish in any waters without a permit with the exception of those given Appropriate Authority. Other prohibitions included the use of poisons, chemicals or explosive devices in the killing of fish. It was also an offence to disturb any fish on its spawning run or in such areas as spawn is deposited. The provisions on the introduction of alien fish were retained from the previous acts. A number of gears was totally banned. These included spears, spear guns or basket traps. To date, the Parks and Wildlife Act of 1975 governs the conservation of fish in Zimbabwe.

6. FISHING LEGISLATION AND REGULATIONS FOR LAKE KARIBA

By the time that Lake Kariba, which lies on the Zambia/Zimbabwe border, was constructed in the late 1950's two different fishing policies and regulations had emerged in each of the two countries. In Zambia the regulations supported the utilization of the fishing industry to feed labour in urban areas and to pay for the running of Native Authorities. These objectives were met by allowing local fishermen access to the country's numerous water bodies. In Zimbabwe the fishing policy and regulations were on the promotion of fishing as a sport. Individuals and private associations imported exotic fish species for stocking water bodies most of which could not be accessed by local people. In addition to these differences, the fishing regulations in each of the two countries did not apply to the Zambezi River upon which the lake was to be constructed. The Fish Conservation Ordinance and subsequent ones in Zambia could only apply to fisheries that had been prescribed by the director responsible for fisheries. The Zambezi River was not a prescribed fishery and consequently the ordinances did not apply to it. Similarly, the Game and Fish Preservation Act in Zimbabwe did not apply to the Zambezi River.[1] This meant that new fishing regulations for the Lake Kariba fishery would have to be drawn-up.

As a precautionary measure the two governments had agreed that a 100 mm mesh-size be employed, as the lake was filling-up. At the same time the Zambian authorities began to conduct experiments upon which to justify the new regulations. There wasn't much research conducted on the Zimbabwean side of the lake at the time. By 1960 results from these experiments began to be available. It was on the strength of these results that the Zambian authorities began to advocate for the type of regulations that they felt would be suited to the fishery. The first differences in developing uniform fishing regulations were on the question of the appropriate mesh-size to be employed. Results from the Zambian experiments had indicated that there was no need to have a mesh-size restriction on gillnets to be used.[2] They argued that the initial 100 mm mesh size restriction had been an arbitrary one meant to protect species during the

[1] Zimbabwe National Archives, Ref. No. S1194/1647/12, Correspondence from Conservator of Forests to the Secretary, Department of Agriculture and Lands, 1945.

[2] ZAMBIA NATIONAL ARCHIVES, Ref. No: ML 1/15/17 Correspondence from Director of Game and Fisheries to Permanent Secretary, Native Affairs, 20 July 1962.

stocking exercise as the lake was filling up. The Zambian argued that the dominant species caught in the 50 and 70 mm mesh-size nets were *Alestes imberi* and *Hydrocynus vittatus* (Tiger Fish), which, between them, comprised eighty six percent of fifty millimetres net catches and 38 percent of the 70 mm net catches in experimental netting.[1] These species were not commercially attractive. Furthermore, the effects of using 50 and 70 mm mesh-size nets was not harmful. This is because these nets did not affect dominant commercial species such as *Tilapia, Labeo* and *Distichodus* to a significant extent because they would already have spawned by the time they were caught.[2] The nets would not affect *Alestes imberi* either as this fish has already bred before being caught in even a 50 mm mesh-size net. On the other hand, these nets would remove large quantities of the voracious *Hydrocynus vittatus* which would be of considerable benefit to the fishery (ibid.). It was further argued that the prevailing emphasis of removing vegetarian species tended to produce an imbalance in the predatory/prey proportions of the fish population.[3] It was observed that the continued use of 100 mm mesh-size nets was allowing a constant removal of the bigger fish and best breeding stock, reproduction of the race being left to the small and poorer stock. The Director of Game and Fisheries argued that:

> "In the light of information from research, it was fully agreed that there was no necessity whatsoever for continuing to impose the four-inch mesh size as a minimum. If anything, encouragement should be given to the use of smaller meshes in an endeavour to achieve a more balanced take-off from the fish population. It is not known on what evidence Southern Rhodesia bases its desire to persist with the four-inch minimum restriction."[4]

The Zimbabwean authorities rejected this proposal arguing that they did not favour any changes to the proposed mesh size of 100 mm. They counter-proposed that the 100 mm mesh size should be adhered to until commercial fishing on the lake as a whole had been in operation for a minimum of six months.[5] Secondly, the Zimbabwean authorities argued that they did not have adequate data to support the Zambian argument on mesh-sizes because information collected from their commercial fishing concessionaires was confidential and not for public use. Thirdly, the Zimbabwean authorities argued that they felt it undesirable to remove restrictions 'to avoid confusion to African fishermen.'[6]

The other difference in fishing policy and regulations between the two countries was the question of allowing for full-exploitation of the entire fishery. The Zambian authorities sought to allow for full-scale commercial fishing using gillnets even before the lake had reached its maximum extent. Their counterparts on the Zimbabwean shoreline refused to open the entire fishery to fishing. They argued that there should be no net fishing in the fishery until stocks had stabilized.[7] However, this restriction on the use of nets applied to African fishermen only and

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[1] Ibid.

[2] Ibid.

[3] ZAMBIA NATIONAL ARCHIVES, Ref. No: ML 1/15/17 Correspondence from Director of Game and Fisheries to Permanent Secretary, Native Affairs, 20 July 1962.

[4] ZAMBIA NATIONAL ARCHIVES, Ref. No. ML 1/15/17, Correspondence from Director of Game and Fisheries to Permanent Secretary, Native Affairs, 20/7/60.

[5] ZAMBIA NATIONAL ARCHIVES, Ref. No. ML 1/15/17, Correspondence from Secretary of Lake Kariba Co-ordinating Committee to Permanent Secretary, Native Affairs, Northern Rhodesia, 27/6/62.

[6] ZAMBIA NATIONAL ARCHIVES, Ref. No. Sec 6/560 Lake Kariba Co-ordinating Committee, Technical and Organisational Matters relating to Fishing in Lake Kariba, 21/3/1963.

[7] ZAMBIA NATIONAL ARCHIVES, Ref. No: SEC 5/201, Summary Record of a Meeting of Ministers Held in Salisbury on 29/2/60, Kariba Lake Development Company.

did not extend to the white-owned fishing concessionaires. This discriminatory policy was justified on the grounds that the concessionaires had different contracts with the government and were also assisting in the collection of data and could thus not be restricted from fishing (ibid.). Consequently, gillnet fishing for African artisanal fishermen on the Zimbabwean side was not allowed until the passing of the Fish Conservation (Kariba Controlled Fishing Area) Regulations in 1962. This contrasts with the Zambian side where fishing had commenced as soon as the lake began to fill-up.

The differences between the Zambian and Zimbabwean authorities reflect the different roles of the fishing industry to the two countries social and economic interests. The Zambians advocated for a policy and regulations that would maximize the exploitation of commercially important fish species. This was in line with the need to make the fishery provide food to labour in the urban areas. To the authorities species such as *Hydrocynus vittatus* (Tiger Fish) were not commercially important and thus of little value. However, this contrasted with the Zimbabwean fishing policy that put emphasis on sport fishing for recreation and tourism. Within this policy the promotion of fish species such as Tiger Fish that “have virtues of superiority in fighting ability” was paramount. The second difference reflects the Zambian policy of using natural resources such as fish to raise revenue for Native Authorities. It was on this basis that they advocated for full-exploitation of the fishery as a means to raise money for the local Native Authority known as the Gwembe Tonga Native Authority (GTNA). Owing to the manner of colonial rule such a policy did not emerge in Zimbabwe and, much more fundamentally, there were no permanent human settlements along the shores of the lake whose inhabitants would have befitted from such a revenue.[1] All the local people who had lived on the banks of the river had been resettled further from the lakeshore. There was also a general belief on the Zimbabwean shoreline that local fishing methods were inherently harmful. Therefore, there was need to control the activities of local fishermen to avoid the new fishery, which became the biggest in the country, from being overfished.

These differences were not resolved. To date, the fishing policy and regulations between the Zambian and Zimbabwean fisheries have remained different. The entire Zambian shoreline is fished and the minimum mesh-size net employed is 75 mm. This contrasts with the Zimbabwean shoreline where about only 60 percent of the lakeshore is open to artisanal fishing. The rest of the grounds are closed to fishing as they lie close to National Parks area where only sport angling is permitted or they are used to re-stock the fished areas. Artisanal fishing is also not authorized in river mouths that are considered to be breeding areas of fish species such as Tiger Fish. On this shoreline the minimum mesh size allowed is100 mm. Evidence from both shorelines, however, indicates that the use of methods considered illegal is still prevalent. Active fishing or *kutumpula* is still widely practised by artisanal fishermen especially on the Zambian shoreline. The fishermen contend that the method is not harmful to the fishery. They observe that without employing this method they would not catch particular size and specie of fish. On the Zimbabwean shoreline the violation of fishing regulations such as fishing from parts of the lake that are closed to fishing is also rampant. Fishermen contend that their existing fishing grounds are not adequate and hence they have to encroach on closed areas. In order to counter the policing activities of the authorities, fishermen have formed networks that they use to evade arrest. Furthermore, these encounters with the authorities have led to the development of a vessel that consists of corrugated iron and a thin strip of wood. These

[1] Zambia National Archives, Reference No. SP 4/7/16, Minutes of a meeting of ministers held in Salisbury on 11/12/1959.

vessels are used to fish from closed areas especially estuaries. Being simple to make the boats can be easily abandoned whenever there is a confrontation with the authorities.

7. CONCLUSION

The paper sought to show that although it is generally believed that fishing regulations are based on science, their implementation have to meet the economic and political interests of the state. It was shown that the scientific arguments that had been made to justify the management of game were transferred to the way fisheries were to be managed. It is for this reason that fishing restrictions through licensing, the setting of minimum mesh sizes and the manner in which certain fishing implements such as weirs were to be used became part of the new fishing regulations. However, these restrictions not only masked the economic interests of the state, such as the need to obtain revenue from fishing licences, but their implementation was also haphazard and brought conflicts between government agents and fishermen. This was particularly the case in Zambia where the government sought to maximize fish production to meet food requirements for labour in the mines while attempting to protect the industry from the destructive fishing methods of local fishermen.

In Zimbabwe fishing regulations emerged as a result of pressure from a sport-fishing lobby from among the settlers. Here there was emphasis on stocking water bodies with exotic fish-species that were amenable to angling. With the emerging land tenure system that placed most of the water bodies in private and state lands, most of the local people were marginalized from fishing. These differences in approach to fishing regulations were to manifest themselves when attempts to have joint fishing regulations for Lake Kariba were made. The Zambian sought regulations that would maximize fish production to feed labour and meet the revenue requirements of the local Native Authority. The Zimbabweans wanted regulations that would promote sport fishing and control the fishing activities of local fishermen. These differences in approach to regulations were not resolved and each country went on to implement its own type of regulations.

This study has shown that although science influenced the manner in which regulations emerged, regulations have to fit the economic and political interests of the country to which they apply. As these interests may be at variance with scientific conclusions there is conflict and ambiguity in the manner in which regulations are developed and implemented.

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Fisheries in the Southern African Development Community (SADC) freshwaters are found to function as an economic buffer and as a safety valve for thousands of people moving in and out of the fisheries according to the opportunities in the national economies. At the same time the stocks tend to be less threatened than many tend to believe. Classical management theory's emphasis on limiting numbers of fishermen and co-management strategies such as exclusive economic zoning may represent a danger to the stability of this situation, even if management may be required to maintain biodiversity. There may be a need also to monitor and establish measures to control investment-driven growth in effort.

This volume contains reports of ten case studies of freshwater fisheries in southern Africa. A synthesis of these reports can be found in FAO Fisheries Technical Paper 426/1. The case studies were conducted in five medium-sized lakes in four countries: the Democratic Republic of the Congo, Malawi, Zambia and Zimbabwe. Five of the case studies focus on the biological and environmental effects of fishing while the remaining five are concerned with historical and sociological analysis. In different ways all of them address one or more of the following three features, relevant for the management of freshwater fisheries in the SADC region: Has fishing effort developed in these lakes over the last 50 years? What causes the changes in fishing effort? How do fishing effort and environmental factors compare in their effects on the regeneration of fish stocks?

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