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

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## 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).

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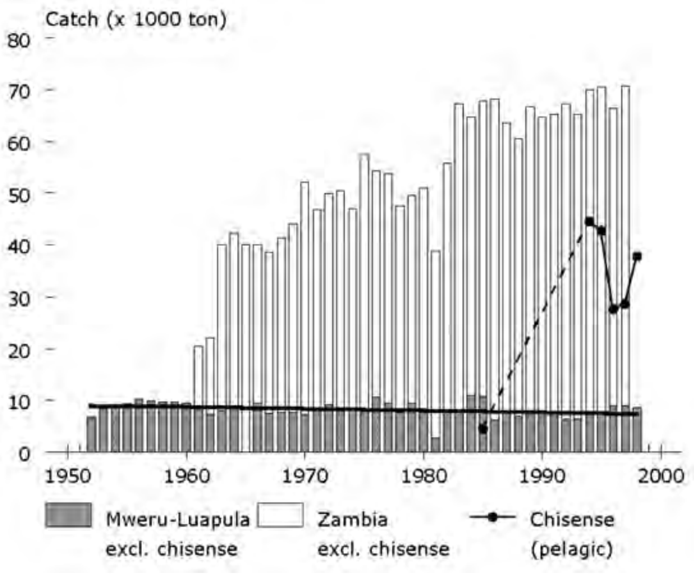

**FIGURE 1.** *Zambian catch from Lake Mweru and the total catch of Zambia, in both cases excluding the catch of the pelagic fishery on Microthrissa moeruensis ("chisense"). The monitored ("demersal") catch of Lake Mweru decreases slightly over 45 years. The long-term mean catch is 8 350 tonnes. The 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

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[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,

$\mu_{ij}$ = 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

$D_{\cdot j}$ = 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 $\lambda$ 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-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

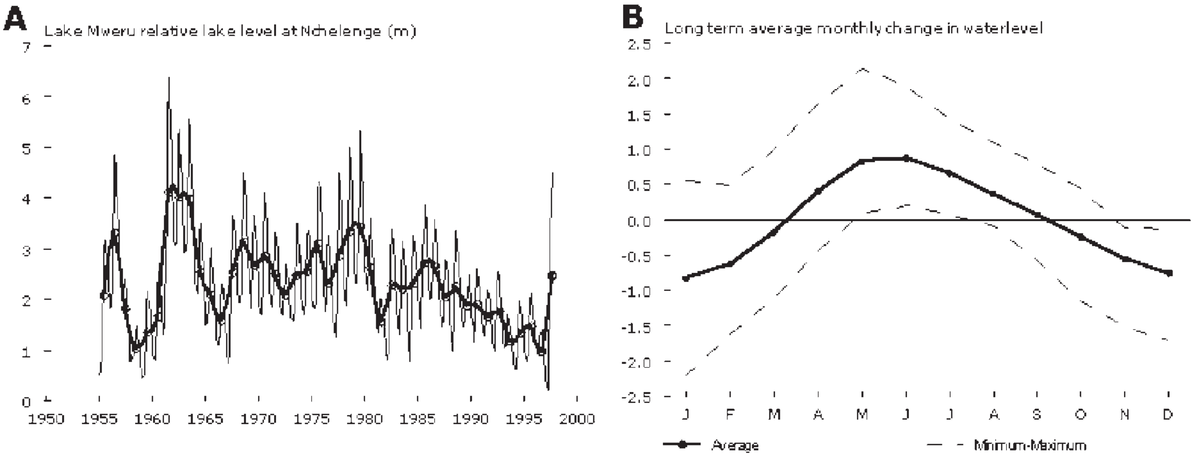

**FIGURE 3**. ***A***. *Annual average water level (thick line) and mean monthly water level (thin line) of Lake Mweru from 1955 to 1998.* ***B***. *Long term average and minimum and maximum relative change in monthly water levels as a factor of the annual average water level.*

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].

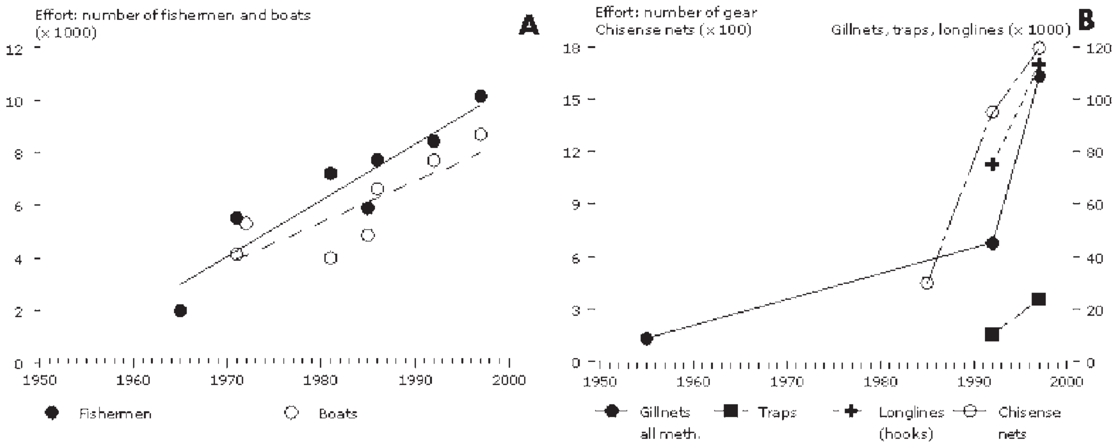

**FIGURE 4.** *Development in fishing effort expressed as **A**. number of fishermen (=male gear owners), boats (plank boats and dugout canoes) and **B.** gears: chisense nets, gillnets, traps and long lines (number of hooks). 'Gillnets' include all methods such as beach-seining, drift netting, driving ("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.*

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[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

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[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 |
| Miscellaneous | 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.

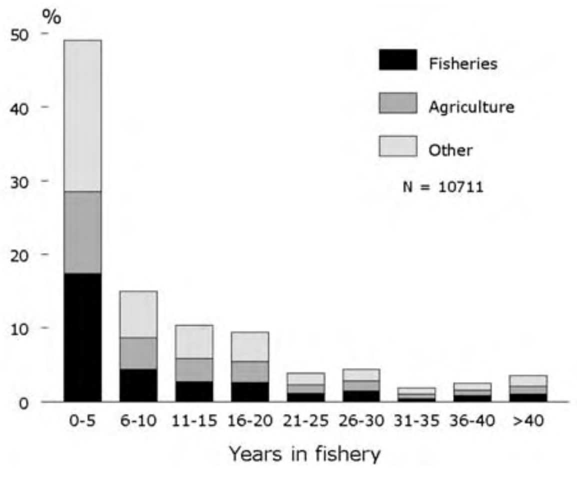

**FIGURE 5**. *Relative frequency distributions of the total number of fishermen by number of years in the fishery: 1-5 = fishermen started fishing between one and five years ago i.e. between 1993 and 1997.*

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.

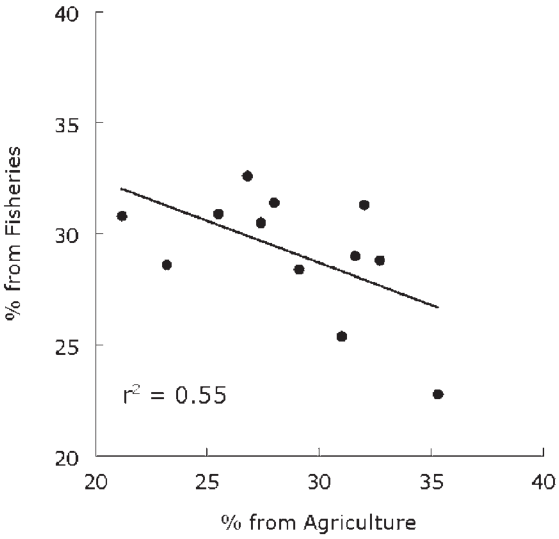

**FIGURE 6**. *Proportion of total number of fishermen that were occupied in fisheries before owning their own gear against the proportion of those fishermen mentioning agriculture as their preceding occupation for each interval of five years between 1937 and 1997 that was mentioned as starting year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

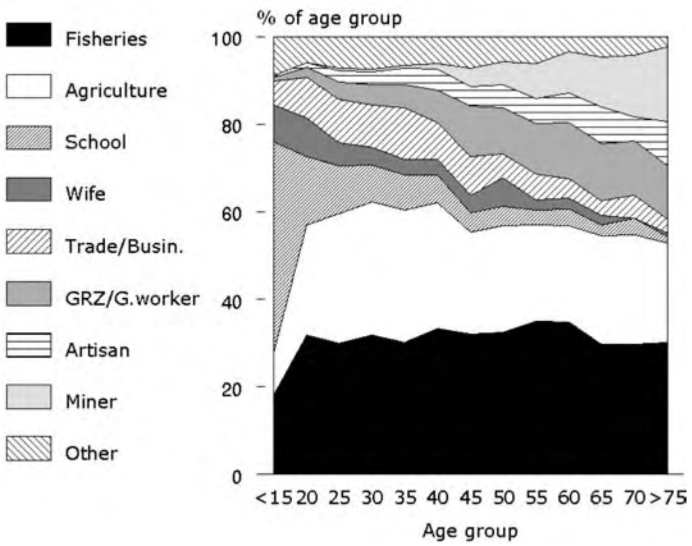

**FIGURE 7**. *Proportion of fishermen categorized in occupation before becoming a fishermen (=gear owner) by age-group*

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**<br>**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).

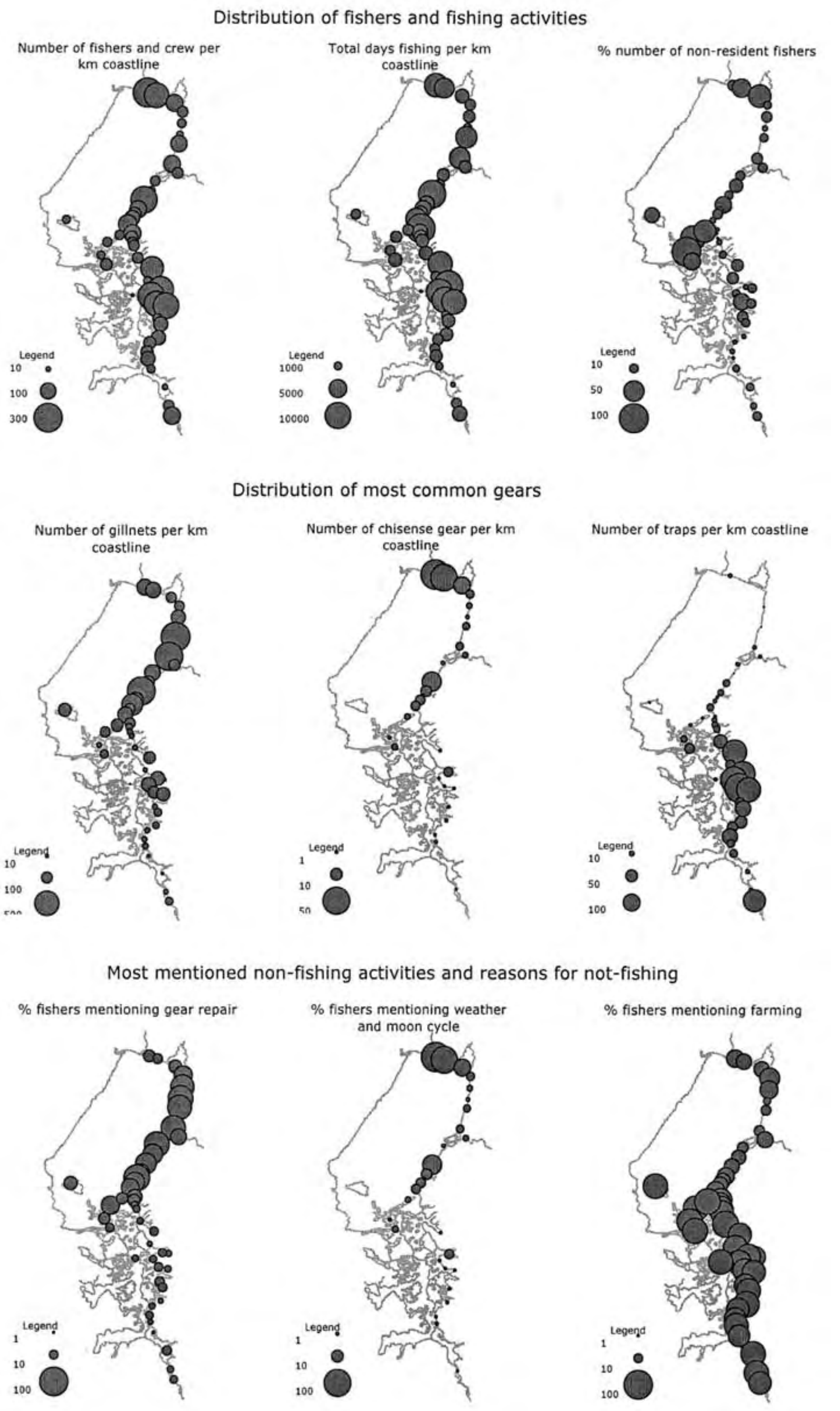

**FIGURE 8**. *Distribution of fishermen, gear and fishing activities per kilometre of coastline (frame survey 1992). Each bubble represents a fishing community. Top: number of fishermen and crew are added; fishing days=average activity level by community multiplied by the number of fishermen; non-residents 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<br>2. Lake South<br>3. Lake Middle<br>4. Lake North | 1. large variety of species (T)<br>2. *Oreochromis mweruensis* (T)<br>3. *Serranochromis* spp.(T)<br>4.*Tylochromis mylodon* (T);<br>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);<br>"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<br>(1) large hooks (6,8,10); bait: fish; overnight<br>(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)<br>(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).

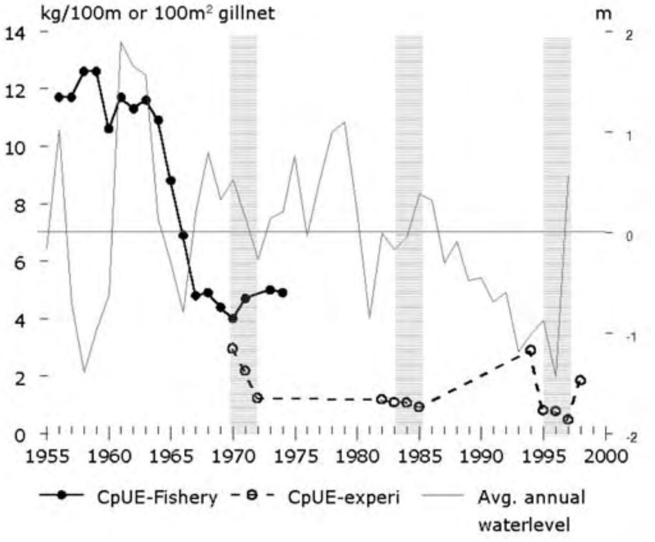

**FIGURE 9**. *Development of catch rates in the fishery and in experimental surveys with gillnets of dominant mesh sizes in the fishery (76–102 mm in 1970s and 63–76 mm in 1980s and 1990s). Catch rates from the fishery are standardized to 100 kg/m gillnet; catch rates from experimental gear = kg/100 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

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[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± 0.07 (mean and confidence interval) via 1.21 ± 0.12 to 1.49 ± 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

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

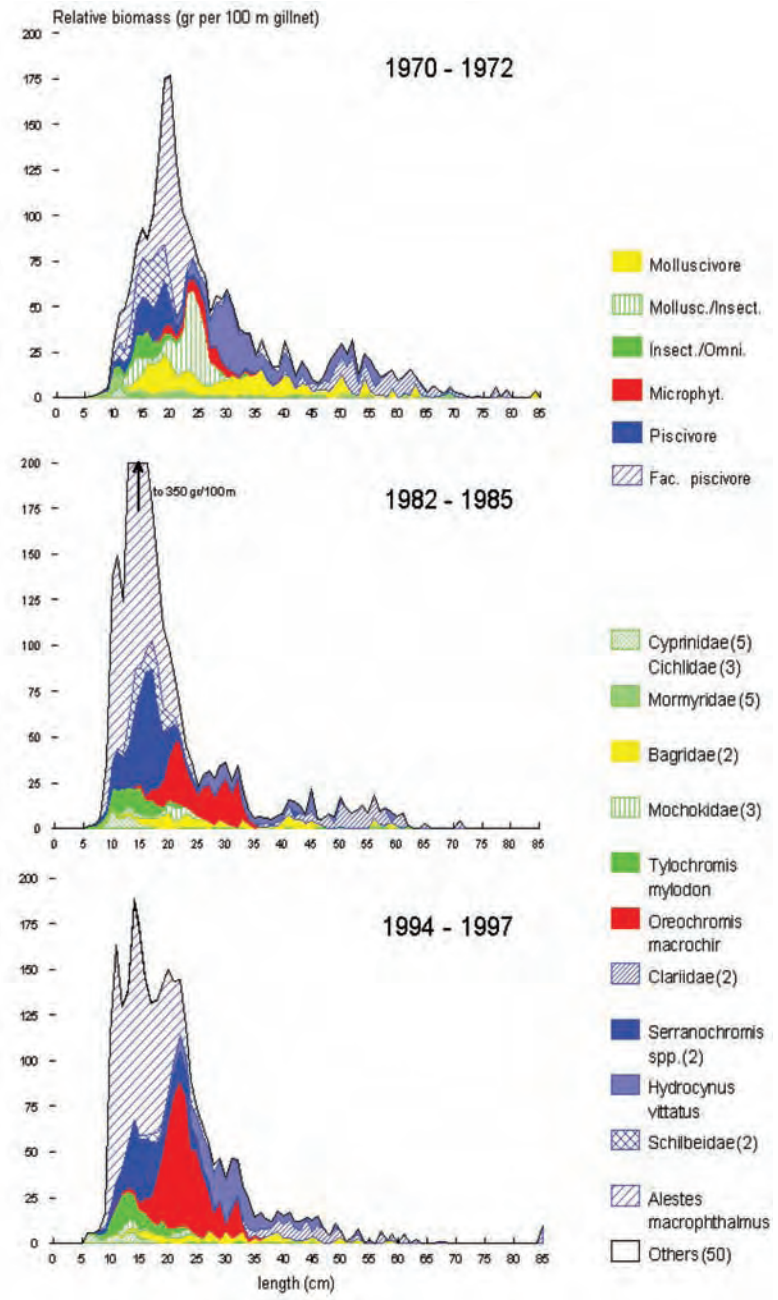

**FIGURE 10.** *Biomass-size distributions of Lake Mweru over three periods. Stacked areas in the graph indicate species (groups), colours indicate broad trophic categories. Biomass is expressed as standardized average catch per unit of effort of 100 m2 of gillnet by 1 cm length class in the catch over 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

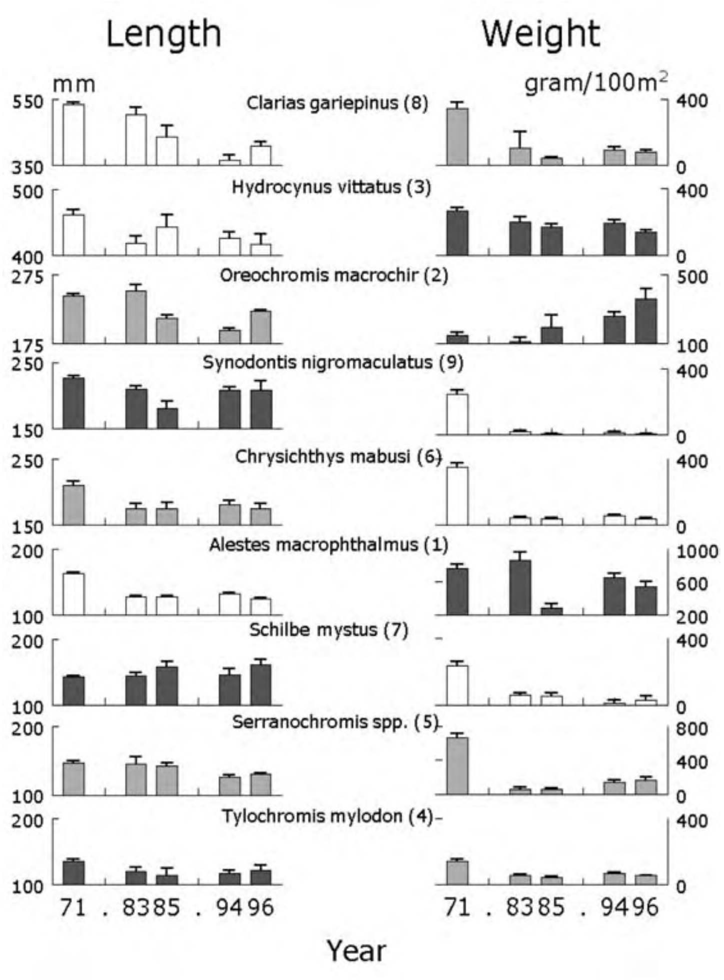

**FIGURE 11**. *Mean length and weight in the catch per 100 m*$^2$ *net of fleets of experimental gillnets of the nine most important species in Lake Mweru from 1971 to 1996 (order of importance in brackets according to the percent Index of Relative Importance (Kolding, 1999). From top to bottom species 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.

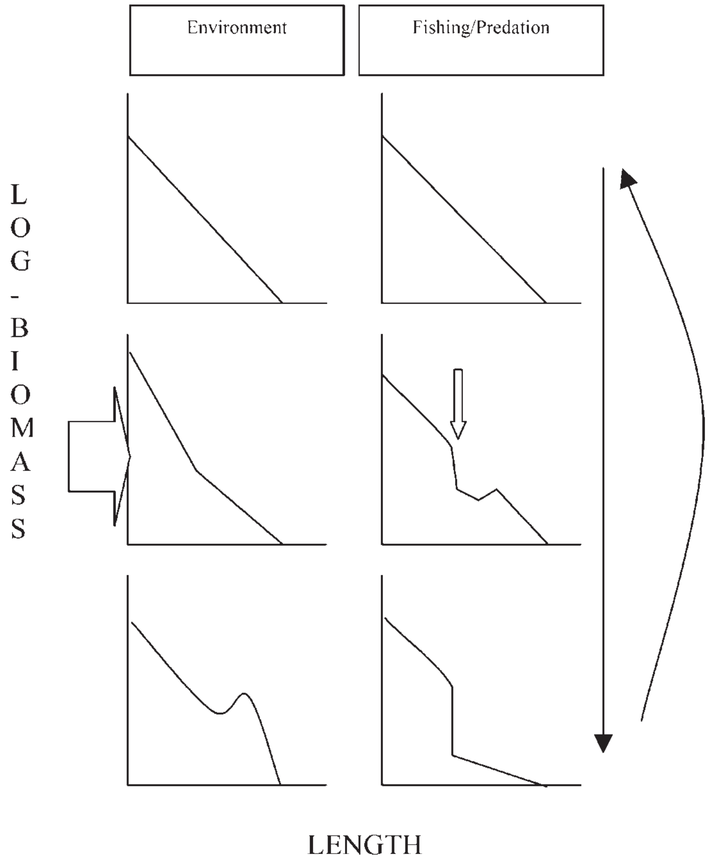

**FIGURE 12**. *Effect of change in productivity (environment) and length selective fishing pressure or fish predation on the biomass-size structure of a fish community. The biomass-size structures discussed further, are combinations of these processes. Black downward arrow indicates the direction of 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.

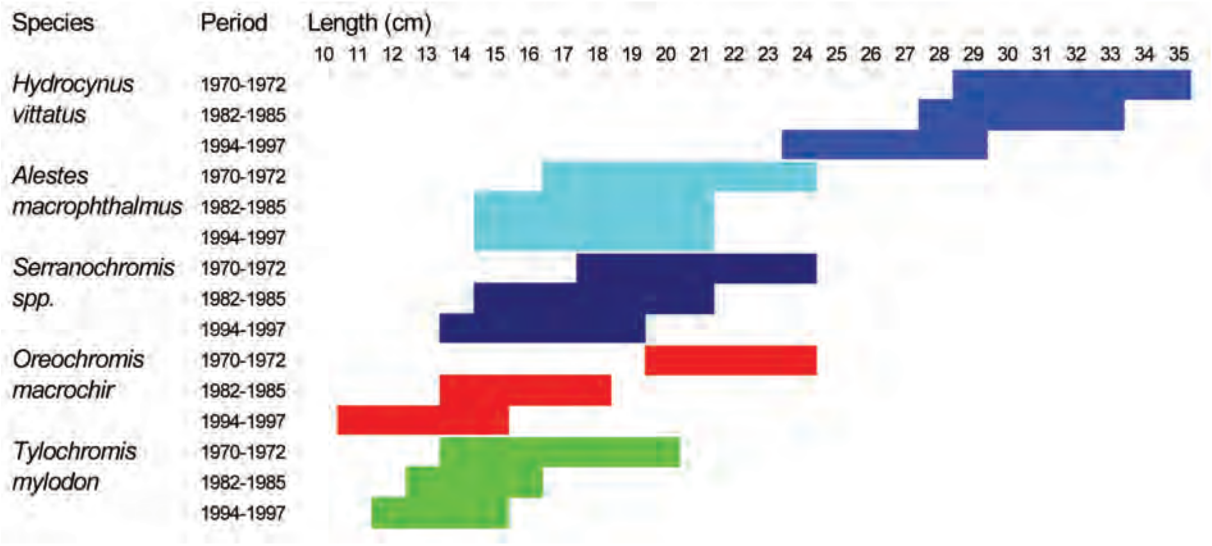

**FIGURE 13**. *Length selectivity of dominant mesh sizes in the fishery with stationary gillnets of Lake Mweru for the five commercially most important target species. Mesh size changes from 102 mm in the 1970s via 76 mm in the 1980s to 63 mm in the 1990s. The top three species are all piscivores. Active 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

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[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.

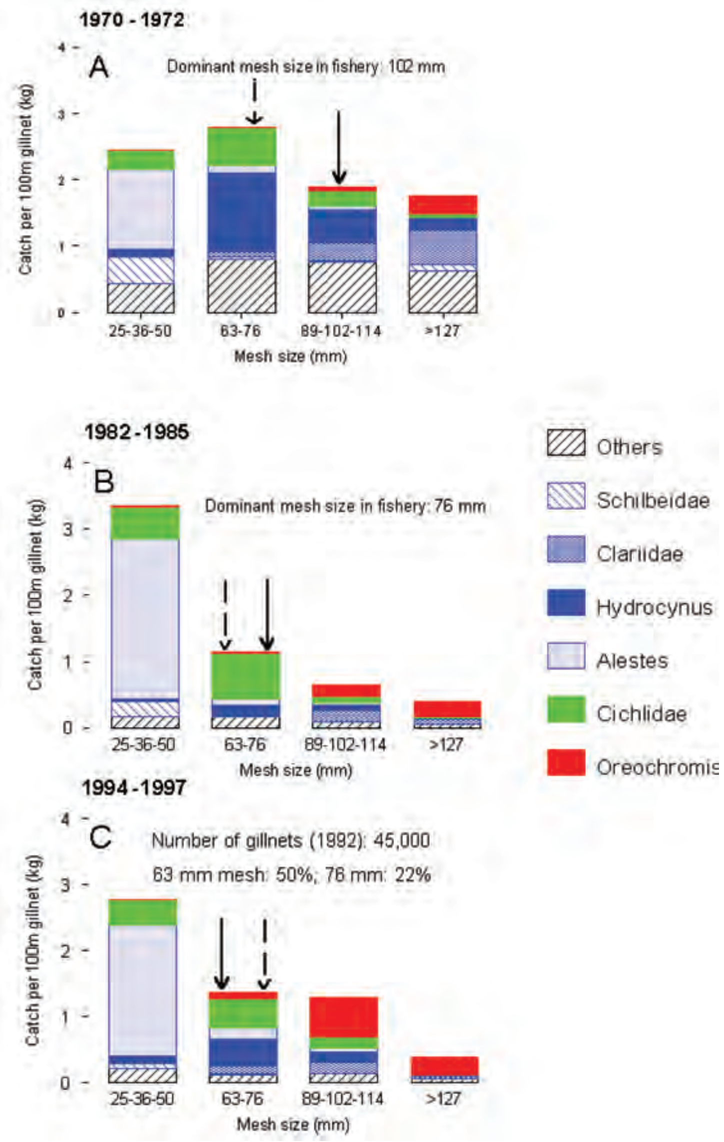

**FIGURE 14**. *Catch rate composition of experimental gillnets in groups of four mesh sizes in three periods from 1970 to 1996. Shown are the six most important species in the catch and a rest group containing all other species. Solid and broken arrows indicate the first and the second dominant mesh 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 <u>as well as</u> 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

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[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<br>B ~ L | 163 | 56.59 | L | 1 | 41.40 | *** | -0.029 *** | -0.227 |
| Separate slopes<br>B ~ L(D) | 163 | | L | 3 | 41.76 | *** | -0.029 ***<br>-0.026 ***<br>-0.033 *** | -0.227 |
| Separate slopes compared to overall slope<br>B ~ L + L(D) | 163 | | L<br>L(D) | 1<br>2 | 41.40<br>0.36 | ***<br>n.s. | -0.033****<br>n.s.<br>n.s.<br>-- | -0.227 |
| Separate intercepts<br>B ~ L + D | 163 | | L<br>D | 1<br>2 | 41.40<br>1.71 | ***<br>*** | -0.030 | -0.315***<br>0.209***-<br>0.075 n.s.<br>-- |
| Full model: separate slopes and intercepts compared to overall slope and intercept | 163 | | L<br>D | 1<br>2 | 41.40<br>1.71 | ***<br>*** | -0.037*** | -0.386***<br>0.292***<br>0.080 n.s.<br>-- |
| (see figure 13)<br>B ~ L + D + L*D | | | L*D | 2 | 0.86 | ** | 0.010**<br>0.008*<br>-- | |

*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.

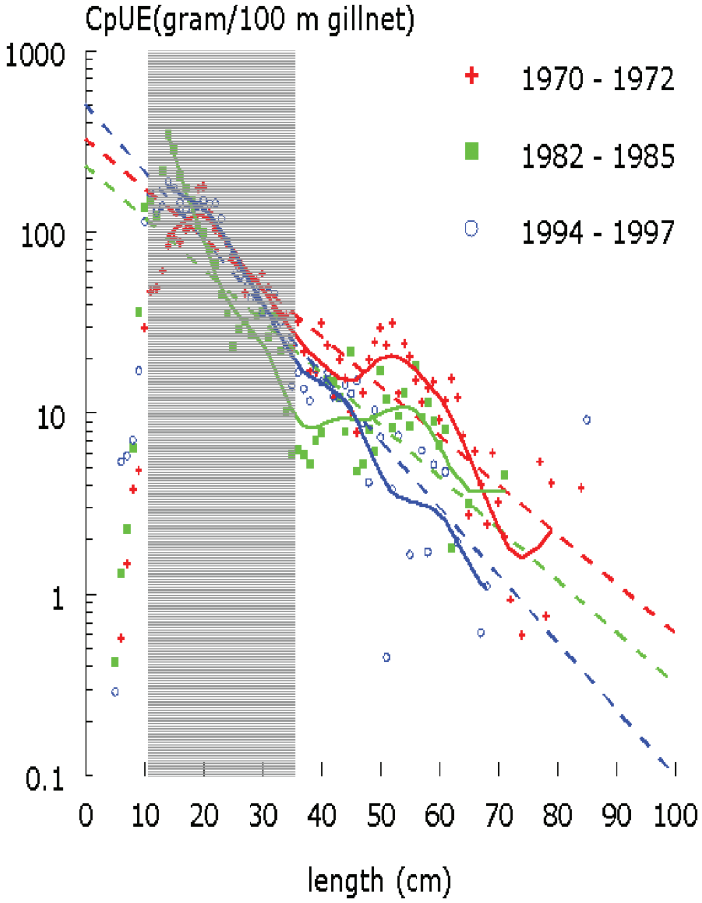

**FIGURE 15** *Biomass-size distribution with linear regression lines and spline by period. Splines were constrained at lambda =100 explaining 91-92 percent of the variation. Linear regression was done from lengths $\geq$14cm. The parameters from the linear regressions for respectively the 1970s, 1980s and 1990s are as follows ($^{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.

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[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 |