INTEGRATED MANAGEMENT OF ZAMBEZI / CHOBE RIVER SYSTEM - TRANSBOUNDARY FISHERY RESOURCE, NAMIBIA / ZAMBIA / BOTSWANA

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Analysis of Historic Fisheries Research Data for the Caprivi Region
April 2009

New makoro being delivered for sale

Oreochromis andersonii, main commercial species

Tigerfish, *Hydrocynus vittatus*, in research gillnets

Hauling research gillnets

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Technical Report no. MFMR/NNF/WWF/Phase I/2

Analysis of Historic Fisheries Research Data for the Caprivi Region

For submission to the Namibia Nature Foundation

April 2009

Photo: The dug-out canoe plays an important role in the subsistence fishery in the Upper Zambezi. This Zambian man is on his way to meet potential buyers for his canoe.

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1. Introduction

This is a summary report taken from the reference document that was prepared for the Namibia Nature Foundation. The study was commissioned to analyze all available data collected since 1997. The objectives of the report are spelled out in this document. This summary document highlights the important findings.

1.1. An overview of previous fisheries research conducted in Caprivi.

Freshwater fish has always been a very important food source in the Caprivi and has been ranked over beef, game and poultry (Turpie et al. 1999). Apart from the fact that the fish resource was important for the daily livelihoods for a large section of the households in the region, it was also seen as an important food source to fall back on during periods of drought. It is a fast cash converter when times are difficult and expenses have to be covered.

Approximately 100 years ago only 6000 people lived in the region (Mendelsohn and Roberts 1997). Protection of the fish resource would not have been an issue during those times, but with an 18-fold increase in people in the area and the same fish resource available, things changed. It is therefore imperative to find ways to manage the utilization of the fish stocks.

Prior to 1992, inland fisheries resorted under the jurisdiction of Nature Conservation and it was only after 1992 that the Ministry of Fisheries and Marine Resources took charge of the inland fisheries resources in the country. The Department of Nature Conservation conducted earlier research with particular interest in Lake Liambezi. Despite the importance of freshwater fish in the Caprivi and also in the Kavango Region, no official offices were present in these regions. The main office responsible for the inland fisheries resources was at Hardap Dam, 1000km from the Kavango Region and 1500km distant from the Caprivi Region. The result was that research in these areas was scaled down to the minimum due to the long distances. It was only recently that offices were established in these regions and Government could get involved in more detailed research projects. It was actually during a WWF funded project “Shared Resource Management on the Zambezi/Chobe Systems in Northeast Namibia: Current Practices and Future Opportunities” that official staff were appointed in Caprivi.

The Ministry initiated a monitoring program at selected stations along the Zambezi, Chobe and Kwando Rivers in 1997 to build a baseline dataset that could be used as a reference point for future studies. Furthermore the Ministry linked up with the World Wildlife Fund LIFE-Project in Windhoek that further strengthened the capacity and resource base in the area. (Several reports have been published for further background information).

Since 1997 a large amount of data were collected in the region, but not all has been analyzed. Data collected during this period included biological data on the fish stocks, migratory behaviour of selected fish species, socio-economic data on the fisheries and the fish markets, management structures in place and catches from the subsistence and recreational fisheries. During the same period the Ministry developed the Inland Fisheries Act and Regulations (Act of 2003) based on the Inland Fisheries Policy that was approved in 1995. As can be expected from any new development, teething problems were encountered with the legislation and with the implementation. The fact that the fish resource is also shared with Zambia does not make the management thereof any easier. The Ministry was also involved in several initiatives to set up joint working groups between neighbouring countries to jointly manage these shared resources. Despite the fact that valuable connections were made and some very valuable results were obtained, it could not be sustained. One of the biggest problems was the lack of funds to continue the working relationships between countries once the donors left.

With all the data available, but no detailed analysis thereof, it was decided to initiate a study to ensure that some recommendations could come forward from the data collected that will assist the Ministry to amend the Inland Fisheries Legislation where needed and assess the state of the fish population in Caprivi. The Minister further required answers on what the impact was of the fishery on the resource, whether the fish resource was overfished and which management measures are to be taken to protect the resource from overfishing. The issue regarding a closed season was also a priority. The assessment of the fish community is especially critical, as this will hopefully convince all stakeholders to buy into a joint management plan for the area that would benefit all.

1.2. Objectives of the study

The "**Integrated Management of the Zambezi/ Chobe River System Fishery Resource Project"** funded by WWF-LIFE through the Namibia Nature Foundation (Windhoek) aims to establish an improved and effective system for fisheries management both in Namibia and in Zambia in the Upper Zambezi and Chobe River System. Under this project, a study was commissioned to analyse the historic fish data from the Zambezi and Chobe Rivers to assist with the development of recommended measures. The objectives of the report can be summarized as follows:

- Describe changes in fish production and fish species composition in the region and important sub regions and their possible causes in terms of floods and fishery impact.
- Investigate the possible need [or not] for management options including a closed season, reduction in harvesting effort [restriction of number of nets, fishing quotas] dedicated fisheries reserves or restriction on certain mesh sizes.
- Investigate the need for a closed season in harmonization with the closed season in Zambia.
- Consider the need for a revision of the present Fisheries Act and regulations in terms of closed season, restriction on mesh sizes and possession of fish.
- Prepare a joint scientific paper ready for publication in a regional fisheries/fresh water journal on the main findings in terms of changes and need for long term monitoring of fish life and fisheries.
- Design a database suitable to enter and analyse the accumulated data on "River Surveys". These data have to be analysed and interpreted. As they have not yet been entered, a database design is required now with analysis at a later stage.

1.3. Scope of the report

This report involves the consolidation and analysis of biological fish data collected between 1997 and 2007 from the Zambezi, Chobe and Kwando Rivers. This data will be interpreted to study the spatial and temporal variability, identify trends in fish communities and evaluate whether structural changes took place within the fish community. Historical data from Lake Liambezi and the subsistence gill net fishery at Impalila will also be analyzed.

The following activities were undertaken:

- Data formatting and interpretation
- Data quality evaluation
- Establishing baseline data for assessment purposes
- Data analysis, using standard software packages

The report makes implemental recommendations, addresses specific concerns regarding present data sampling and suggests activities that should be undertaken including:

- important concepts necessary for future evaluation
- data gaps which need attention
- amendments to the Inland Fisheries Legislation relating to Caprivi
- importance of maintaining databases.

Writing of the report involved accessing data and reports from several sources. The databases and reports used for this report are:

- Monitoring data from the Ministry collected between 1997 and 2007.
- Subsistence gill net fishery collected through a WWF funded project between 2001 and 2003.
- Fish ecological survey done by Van der Waal on Lake Liambezi between 1973 and 1975.
- Fish ecological survey conducted by Grobler between 1985 and 1986.
- All reports produced through the WWF funded project "Shared Resource Management on the Zambezi/Chobe Systems in the Northeast Namibia: Current Practices and Future Opportunities."
- All reports on the migratory behaviour of selected fish species in the region.

1.4. Approach

The intent of the report is to analyze all available data to generate results stating the present state of fish stocks in the Upper Zambezi and Chobe Rivers. Detailed analysis will be done on selected fish species for which the criteria would be:

- importance in the subsistence fishery,
- importance on fish markets,
- species not considered important by the subsistence fishery, but relatively abundantly sampled in experimental nets.

The effect of flood regime on the fish population will also be investigated, attempting to distinguish between anthropogenic impacts and natural variability within the fish populations.

The subsistence fishery data available will give an overview of catches with gill nets, related to species composition for the different mesh sizes used and catch per unit effort for the different mesh sizes. This can provide an estimate of expected annual yield for the fishery in Caprivi.

The outcomes of these results will enable the formulation of recommendations for the amendment of the Inland Fisheries Legislation where deemed necessary. This will be done in such a way as to visualize what is optimal and what is practical. Experience has taught that the development of legislation is a slow process and may take time to mature before all stakeholders take ownership.

An important component of the report will be the proposal for a monitoring program ensuring that data are collected in a format giving anticipated results. Databases will also be proposed for data capturing and data analysis.

Analysis will be done in the following sequence:

- The selectivity of the sampling gear.
- The importance of fish sanctuaries.
- The fish population structure and changes over time.
- The importance of the main habitat types.
- Species composition of the gill nets.
- The subsistence gill net fishery.
- Estimated yield
- Growth and mortality rates
- Effect of the annual flood.
- Lake Liambezi.

Two reports will be produced. One will include a detailed analysis to be used as a reference document and the second one will summarize findings for management purposes.

1.5. Study area

The Caprivi Region has the highest rainfall in Namibia, although the mean value of 600+mm is still considered low in a global perspective [mean value 800mm]. Higher rainfall is documented in the upper catchment of the Zambezi River and decreases towards the Namibian/ Zambian border. The rainfall in Caprivi has very little effect on the annual discharge of the Zambezi River. The Caprivi Region experiences extensive annual flooding of the Zambezi River and large floodplains form on the Namibian side of the river during late summer and early autumn. These floods are the main stimulus for biological interactions in the system and the floods play a major role in the movement and seasonal activities of the riverine communities. During the wetter part of the flooding cycle, the Kwando – Linyanti –and the Zambezi – Chobe River Systems are interlinked at Lake Liambezi for a number of months. Large sections (30%) of the Eastern Caprivi [area east of the Kwando] are then inundated.

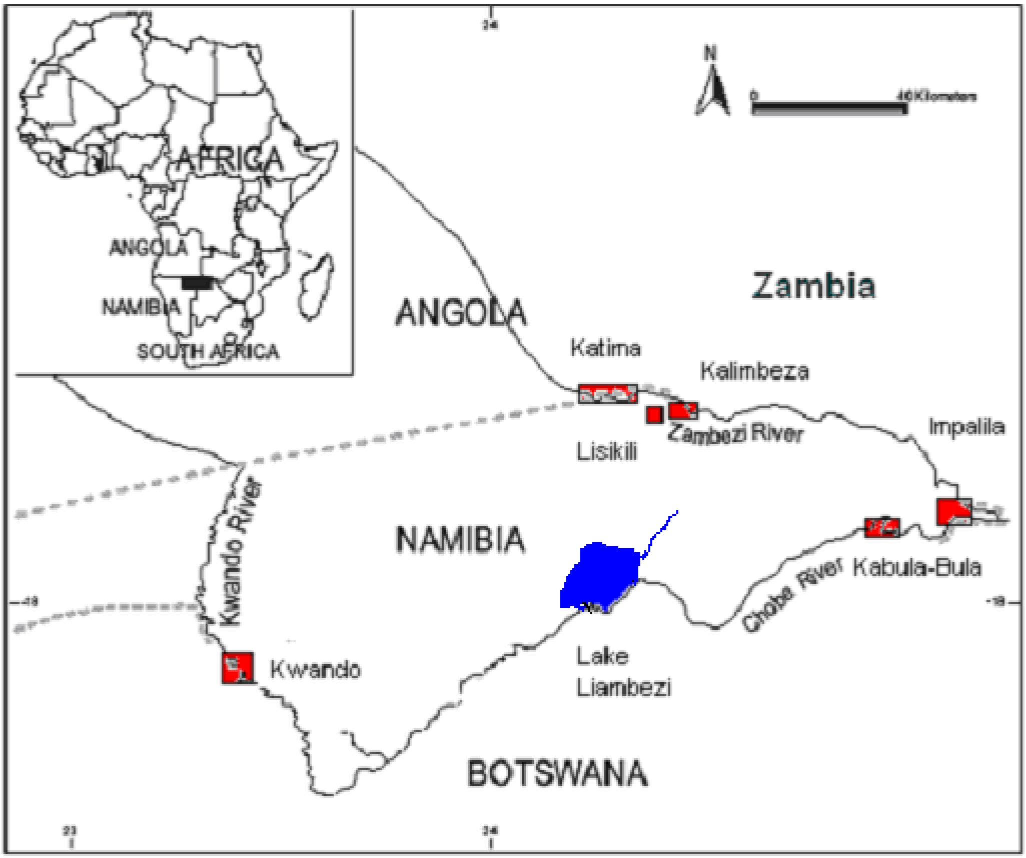

Figure 1.1. The six stations used for fish surveys (in red) in the Zambezi River (Katima Mulilo, Lake Lisikili and Kalimbeza), Impalila at the confluence of the Zambezi and Chobe Rivers, Kabula in the Chobe River and the station in the Kwando River. Lake Liambezi is also indicated on the map.

1.6. Hydrology

The water level of the Zambezi River usually starts to rise in December, with a drastic increase during January and February. The river reaches its peak between the end of March and beginning of May after which the level recedes until the end of September. The duration and the peak of the annual flood vary considerably. The flood during 2007 had a much earlier increase compared to the previous ten years of data, but also an earlier receding phase. The highest peak during the last ten years was also reached in 2007 with a level higher than seven meters. According to figure 1.3, relatively low floods were encountered during 1996, 1997, 2002 and 2005.

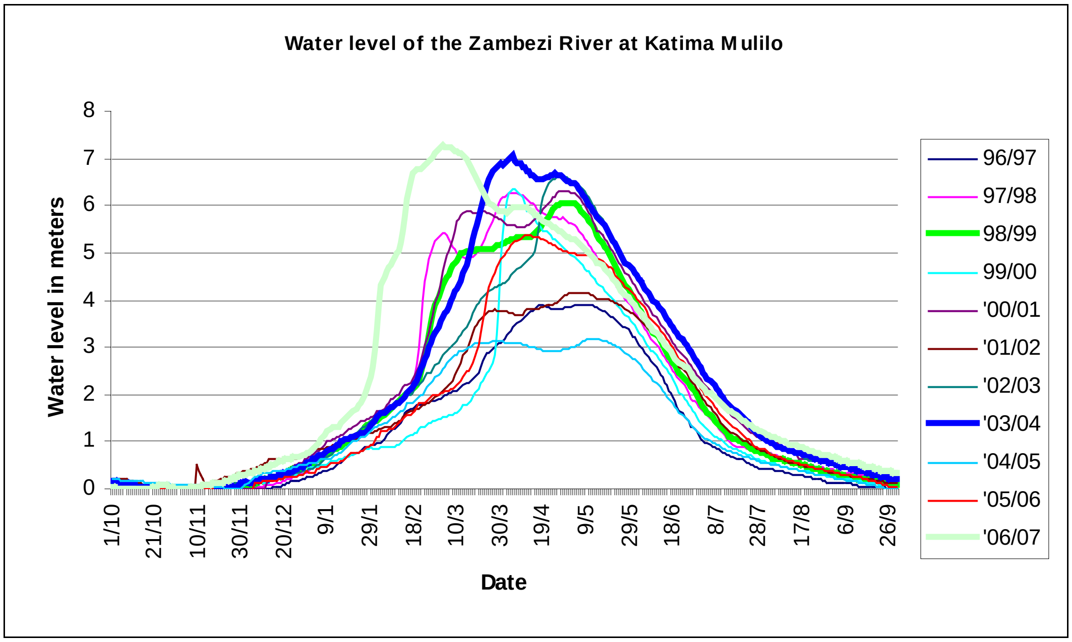

Figure 1.2. Water level of the Zambezi River measured at Katima Mulilo in meters for periods 1st October to end September for the years 1996 to 2007. (Data received from Namwater).

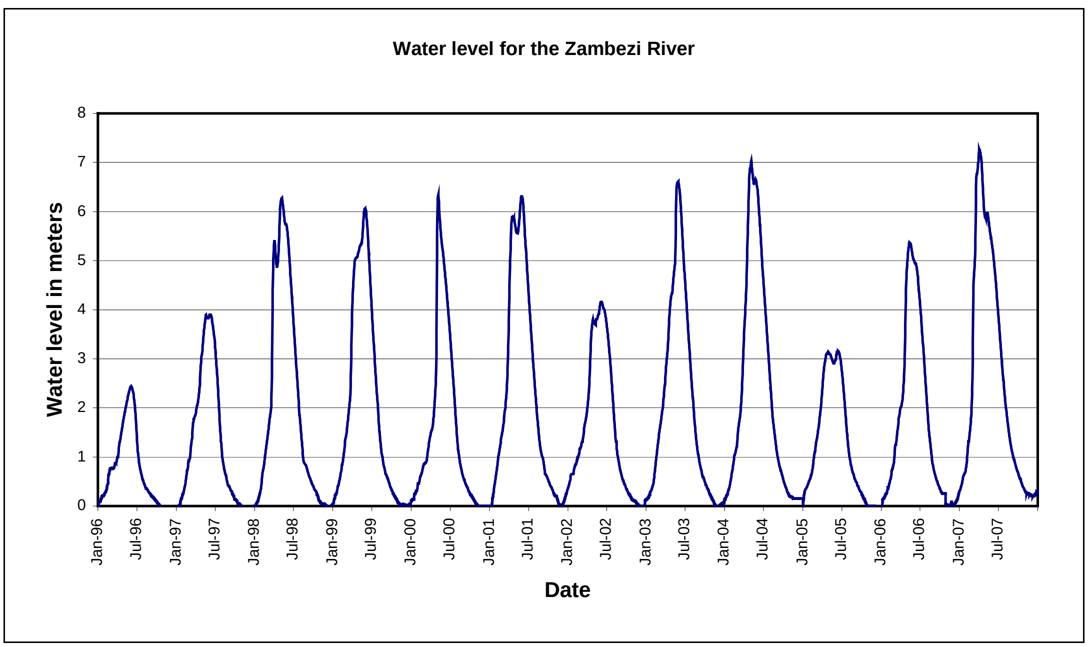

Figure 1.3. Water level of the Zambezi River measured at Katima Mulilo in meters for the period 1996 to 2007. (Data received from Namwater).

1.7 Species list from the Zambezi, Chobe and Kwando Rivers

Table 1.1: Scientific, common and local names (SiLozi) of fish species in the Zambezi, Chobe and Kwando Rivers in Caprivi, Namibia

Family	**Latin name**	**English**	**Local name**
Mormyridae (snoutfishes)	*Mormyrus lacerda*	Western bottlenose	Ndikusi
	Hippopotamyrus ansorgii	Slender stonebasher	Niinga
	Hippopotamyrus szaboi	Zambezi stonebasher	Niinga
	Cyphomyrus discorhynchus	Zambezi parrotfish	Sakulo
	Marcusenius macrolepidotus	Bulldog	Nembele
	Petrocephalus catostoma	Churchill	Niinga/Kupandula
	Pollimyrus castelnaui	Dwarf stonebasher	Niinga
Cyprinidae (barbs, yellowfish, labeos)	*Barbus afrovernayi*	Spottail barb	Mbaala
	Barbus barnardi	Blackback barb	Mbaala
	Barbus barotseensis	Barotse barb	Mbaala Linyonga
	Barbus bifrenatus	Hyphen barb	Mbaala
	Barbus codringtonii	Upper Zambezi yellowfish	Ijungwe, linyonga
	Barbus eutaenia	Orangefin barb	Mbaala
	Barbus fasciolatus	Red barb	Mbaala Linyonga
	Barbus haasianus	Sickle-fin barb	Mbaala
	Barbus kerstenii	Redspot barb	Mbaala Linyonga
	Barbus lineomaculatus	Line-spotted barb	Mbaala
	Barbus multilineatus	Copperstripe barb	Mbaala
	Barbus paludinosus	Straightfin barb	Linyonga, Mbaala
	Barbus poechii	Dashtail barb	Mbaala, Ijungwe
	Barbus radiatus	Beira barb	Mbaala ,Liminolale
	Barbus thamalakanensis	Thamalakane barb	Mbaala
	Barbus unitaeniatus	Longbeard barb	Mbaala, Linyonga
	Coptostomabarbus wittei	Upjaw barb	Mbaala
	Labeobarbus codringtonii	Upper Zambezi Yellowfish	Linyonga
	Labeo cylindricus	Redeye labeo	Linyonga
	Labeo lunatus	Upper Zambezi labeo	Linyonga
	Mesobola brevianalis	River sardine	Mbaala
	Opsaridium zambezense	Northern barred minnow	Mbaala
Distichodontidae (citharines)	*Hemigrammocharax machadoi*	Dwarf citharine	Mbaala
	Hemigrammocharax. multifasciatus	Multibar citharine	Mbaala
	Nannocharax macropterus	Broadbar citharine	Mbaala
Characidae (characins)	*Brycinus lateralis*	Striped robber	Mbaala
	Micralestes acutidens	Silver robber	Mbaala
	Rhabdalestes maunensis	Slender robber	Mbaala
	Hydrocynus vittatus	Tigerfish	Ngweshi
Hepsetidae (African pike)	*Hepsetus odoe*	African pike	Mulumesi/ Mweru
Claroteidae (claroteid catfishes)	*Parauchenoglanis ngamensis*	Zambezi grunter	Siabela
Amphiliidae (mountain catfish)	*Leptoglanis cf dorae*	Chobe sand catlet	
	Leptoglanis rotundiceps	Spotted sand catlet	
	Amphilius uranoscopus	Stargazer mountain catfish	
Schilbeidae (butter catfishes)	*Schilbe intermedius*	Silver catfish	Lubango

Table 1.1: Continued.

Clariidae (air-breathing catfish)	*Clariallabes platyprosopos*	Broadhead catfish	Silutupi/Ndombe/Nenge/
	Clarias gariepinus	Sharptooth catfish	Ndombe/Mbundamusheke/ Mangwana
	Clarias liocephalus	Smoothhead catfish	Lihwetete/ Mabbozwe/Ndombe
	Clarias ngamensis	Blunttooth catfish	Nkoma/Sitama/ Ndombe
	Clarias stappersii	Blotched catfish	Lihwetete/ Mabbozwe/ Ndombe
	Clarias theodorae	Snake catfish	Kaminga/ Kakokwe /Ndombe
Mochokidae (squeakers, suckermouth catlets)	*Chiloglanis fasciatus*	Okavango suckermouth	
	Chiloglanis neumanni	Neumann's suckermouth	
	Synodontis nigromaculatus	Spotted squeaker	Singongi
	Synodontiswoosnami	Upper Zambezi squeaker	Singongi
	Synodontis macrostigma	Largespot squeaker	Singongi
	Synodontis macrostoma	Largemouth squeaker	Singongi
	Synodontis leopardinus	Leopard squeaker	Singongi
	Synodontis thamalakanensis	Bubblebarb squeaker	Singongi
	Synodontis vanderwaali	Finetooth squeaker	Singongi
Aplocheilidae (annual killifishes)	*Nothobranchius sp*	Caprivi killifish	Mbaala
Poeciliidae (topminnows)	*Aplocheilichthys hutereaui*	Meshscaled topminnow	Mbaala
	Aplocheilichthys johnstoni	Johnston's topminnow	Mbaala
	Aplocheilichthys katangae	Striped topminnow	Mbaala
	Aplocheilichthys sp	Pigmy topminnow	Mbaala
Cichlidae (cichlids)	Cichlidae	Cichlids, 'bream'	Papati
	Hemichromis elongatus	Banded jewelfish	Liulungu
	Oreochromis andersonii	Threespot tilapia	Njinji
	Oreochromis macrochir	Greenhead tilapia	Muu
	Pharyngochromis acuticeps	Zambezi river bream	Mbanda
	Pseudocrenilabrus philander	Southern mouthbrooder	Kambanda
	Serranochromis altus	Humpback largemouth	Naluca /Mushuna
	Serranochromis angusticeps	Thinface largemouth	Mushuna
	Serranochromis longimanus	Longfin largemouth	Ngenga/Njenga
	Serranochromis macrocephalus	Purpleface largemouth	Ngenga/Njenga
	Serranochromis robustus	Nembwe	Nembwe
	Serranochromis thumbergi	Brownspot largemouth	Ngenga
	Sargochromis carlottae	Rainbow bream	Imbuma (Mbuma)
	Sargochromis codringtonii	Green bream	Imbuma
	Sargochromis giardi	Pink bream	Siyeo
	Sargochromis greenwoodi	Deepcheek bream	Ngenga
	Tilapia rendalli	Redbreast tilapia	Mbufu
	Tilapia ruweti	Okavango tilapia	Situhu
	Tilapia sparrmanii	Banded tilapia	Situhu
Anabantidae (labyrinth fishes)	*Microctenopoma intermedium*	Blackspot climbing perch	Singulungwe
	Ctenopoma multispine	Manyspined climbing perch	Singulungwe
Mastacembelidae	*Aethiomastacembelus frenatus*	Longtail spiny eel	Musioka
(spiny eels)	*Aethiomastacembelus vanderwaali*	Ocellated spiny eel	Musioka

2. Analysis and synthesis of data from existing databases

2.1. Selectivity of experimental gillnets and the subsistence gill net fishery at Impalila.

2.1.1. Background

The main objective of this section is to estimate the gill net selectivity curves of all fish species combined and separately for certain selected fish species sampled with the experimental multifilament gill nets. The criteria used for selection were, (1) important species in the subsistence gill net fishery and (2) abundance and ecological importance in experimental gill nets.

Multifilament gill nets are all selective in the sampling of fish due to differences in the morphology and behaviour of species. It is important that the sample recorded is representative of the fish community at the site where the sampling was done. Gear selectivity curves enables one to observe the accuracy of the range of mesh sizes used during the study. A correction can be made if considered that the sample is not representative of the actual fish community.

The selectivity of experimental gill nets is presented for the mesh sizes 12 to 150mm and in the reference document also for the mesh sizes 22 to 150mm. The reason is that the majority of the analysis for this report was done using only the 22 to 150mm mesh, as the 12 and 16mm mesh were only used since 2003 as part of the experimental gill nets. The mesh sizes used in the subsistence fisher folk survey were 50, 75 and 100mm. These mesh sizes were all used to determine the gill net selectivity of the fishery. The gill net selectivity curve was only calculated when using all the species collectively for the subsistence fishery.

2.1.2. Selectivity curves of the experimental gill nets

2.1.2.1. All species combined

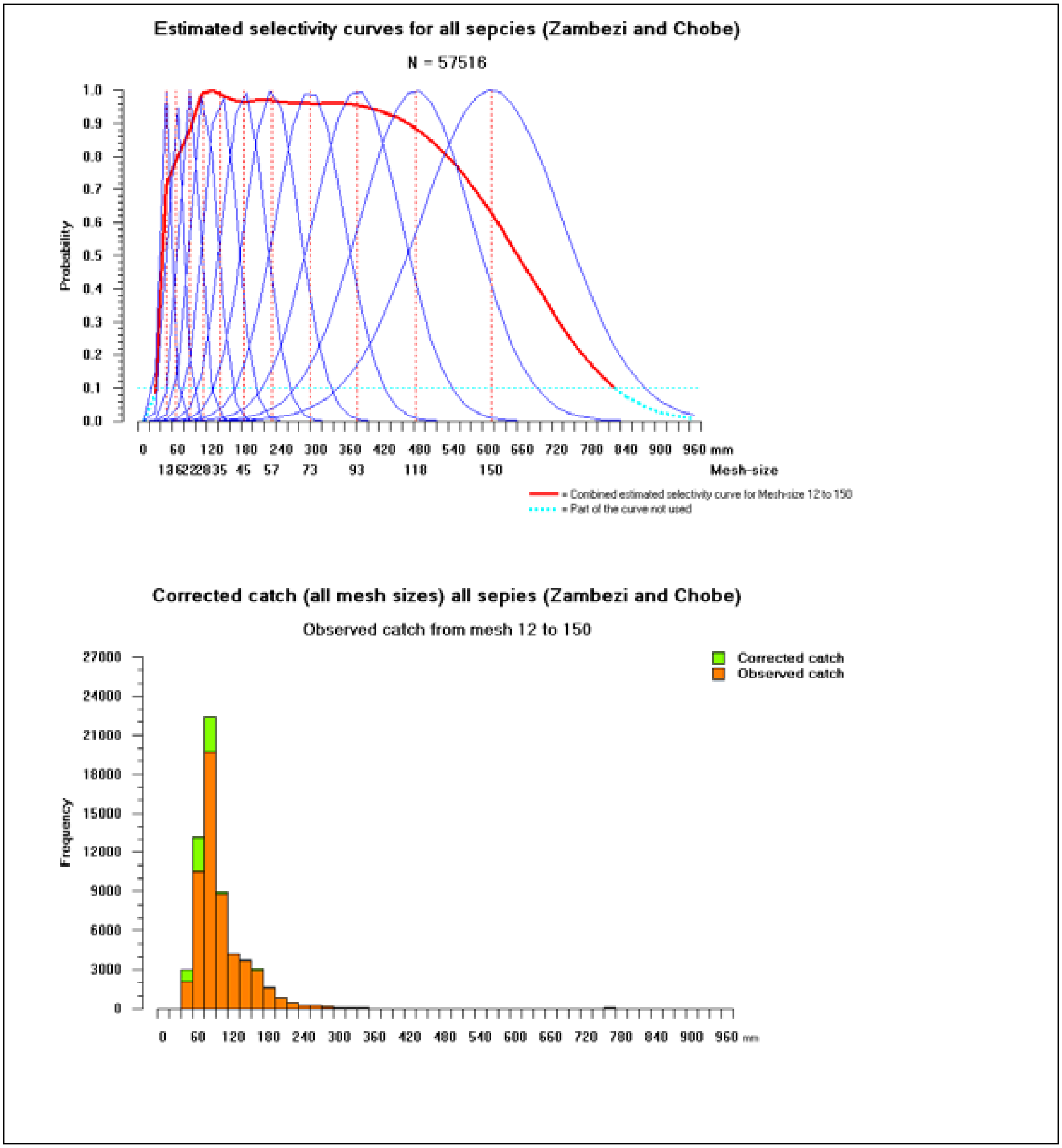

Figure 2.1. a) Multifilament gill net selectivity for all species for each mesh size from 12 to 150mm (blue lines) and combined estimated selectivity curve for all selected mesh sizes (red line). b) Corrected catch within selected mesh range (12 to 150mm) for all the species sampled from the Zambezi and Chobe Rivers during the study period with the multifilament gill nets.

The 12 to 150mm range were sampling length classes 80 to 560mm effectively. Only 10.7% accounted for the corrected catch. The corrected catch graph justifies the inclusion of the 12 and 16mm mesh sizes in future surveys (Figure 2.1).

2.1.2.2. Selected species selectivity curves

2.1.2.2.1. *Hydrocynus vittatus*

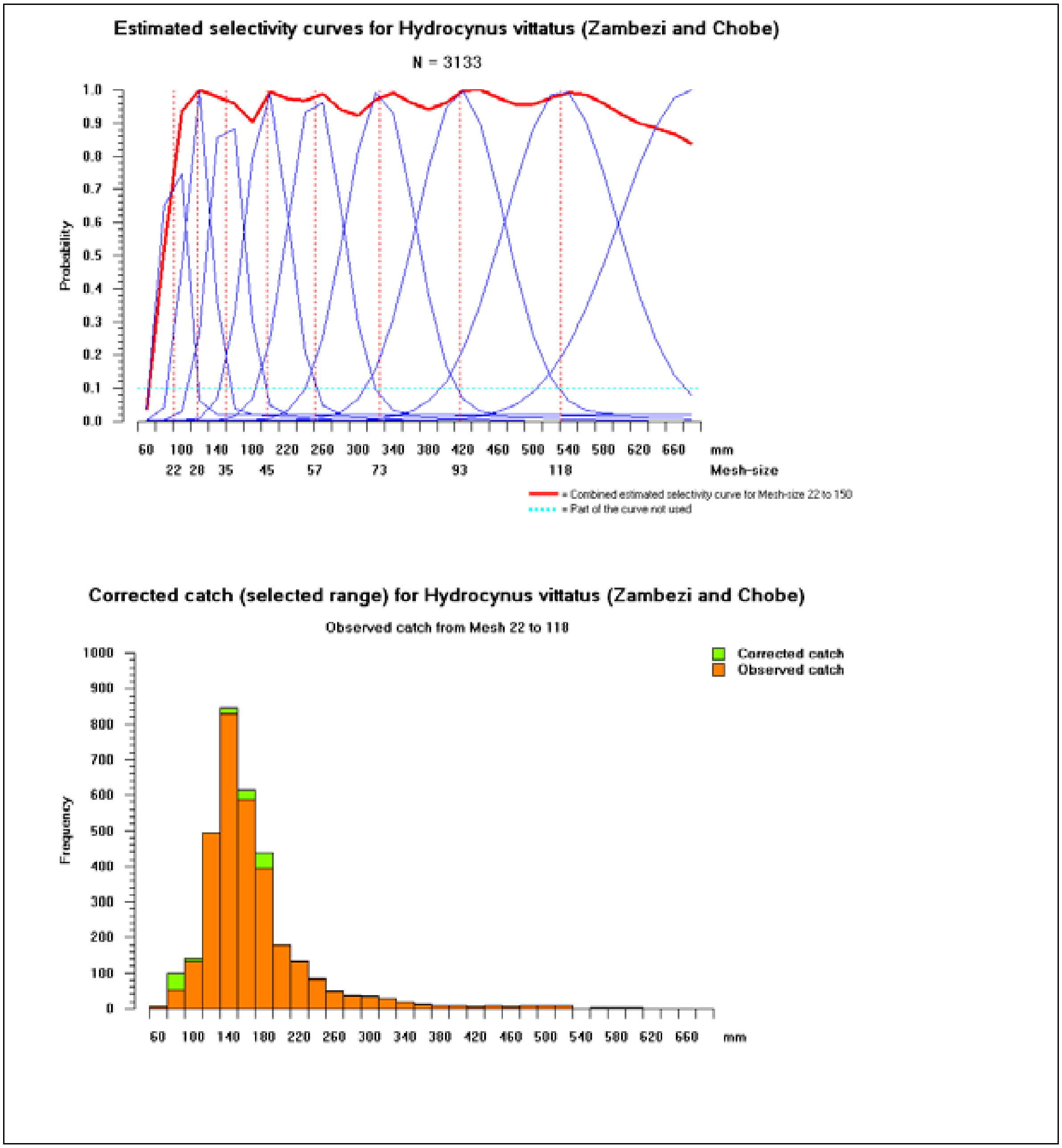

Figure 2.2. a) Multifilament gill net selectivity for *Hydrocynus vittatus* for each mesh size from 22 to 118mm (blue lines) and combined estimated selectivity curve for all selected mesh sizes (red line). b) Corrected catch within selected mesh range for *Hydrocynus vittatus* sampled from the Zambezi and Chobe Rivers during the study period with the multifilament gill nets.

Hydrocynus vittatus was effectively sampled with the multifilament gill nets with mesh sizes 22 to 118mm and between the length classes 100mm to 560mm. *Hydrocynus vittatus* is not always gilled and can be caught by the teeth. This resulted in a slightly skewed selectivity as can be seen with the presence of small depressions in the combined selectivity curve. This can also be clearly seen with the corrected catch graph at the length classes, 80, 140, 180 and 300mm. The corrected catch of *Hydrocynus vittatus* consisted only 5.1% of the total catch.

2.1.2.2.2. *Oreochromis andersonii*

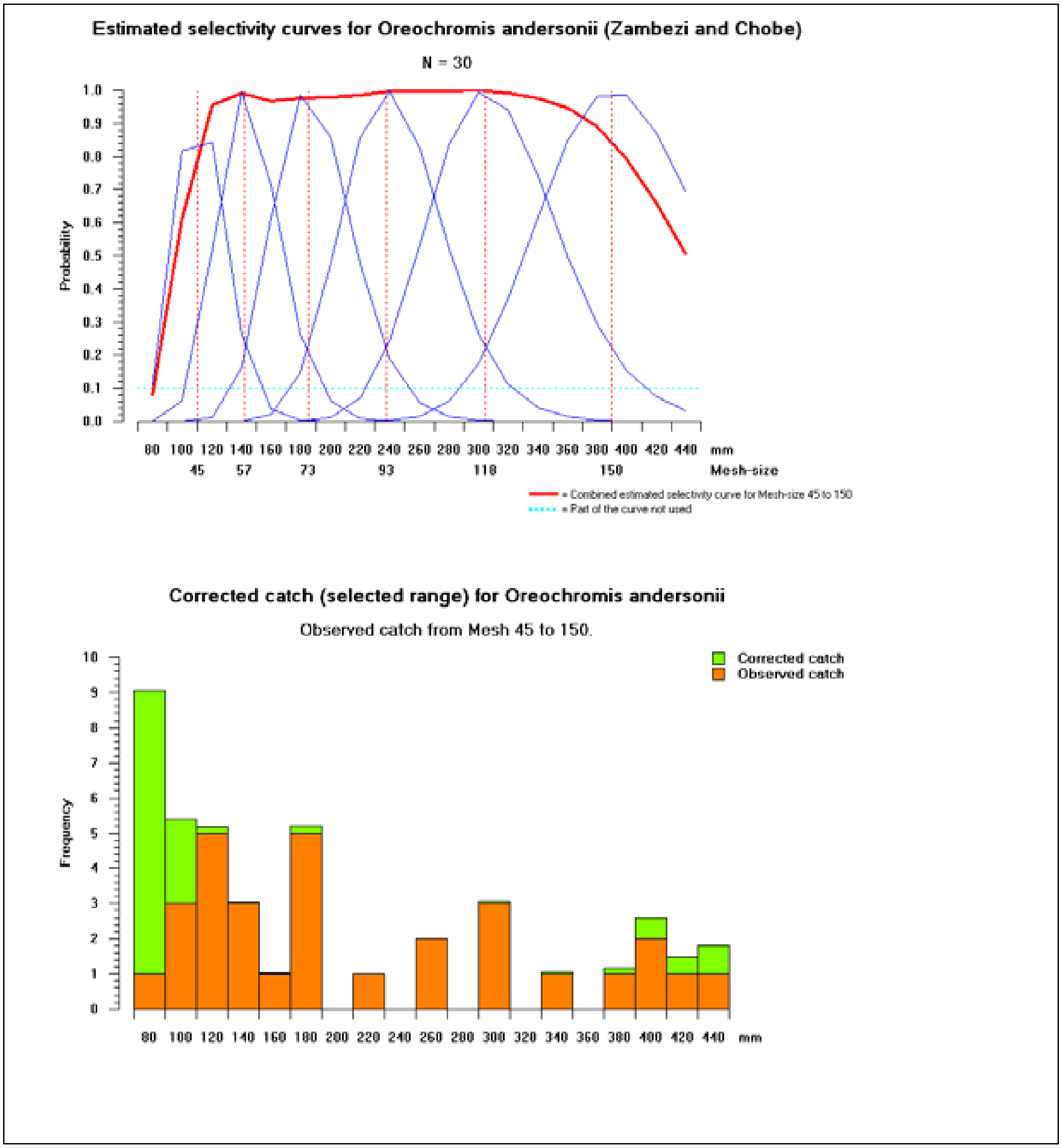

Figure 2.3. a) Multifilament gill net selectivity for *Oreochromis andersonii* for each mesh size from 45 to 150mm (blue lines) and combined estimated selectivity curve for all selected mesh sizes (red line). b) Corrected catch within selected mesh range for *Oreochromis andersonii*

sampled from the Zambezi and Chobe Rivers during the study period with the multifilament gill nets.

The selectivity curve for *Oreochromis andersonii* indicated that the length classes between 120 and 360mm were effectively sampled from the Zambezi and Chobe Rivers. Length classes smaller than 120mm and larger than 380mm were under sampled during the surveys. A small number of fish were sampled with the experimental gears and may have affected the results. The low number sampled already maybe an indication of the state of the stock in the river.

The following conclusions can be made:

- The selectivity curves calculated for the multifilament gill nets with the mesh sizes 12 to 150mm indicated that the fish sampled could be considered representative of the fish stock in the Zambezi and Chobe River. The catches were effectively sampled between the length classes 80 to 560mm. It is therefore very important that all these mesh sizes continues to be used for future surveys.
- The sampling done for *Hydrocynus vittatus* was also considered a representative sample for the population in the Zambezi and Chobe Rivers. The fact that large individuals are also caught in the small mesh sizes due to their teeth, make them slightly more non-selective than for instance the Cichlidae. Despite this, the catches recorded can still be seen as representing the population and definite conclusions can be made.
- *Oreochromis andersonii* was effectively sampled between the length classes 120mm and 360mm. The only concern was the low number sampled during the study period.
- When considering the catches of all species combined and for the selected species, it is concluded that the present mesh sizes used are representative of the fish stock and that valid conclusions can be made from these catches.

2.1.3. Selectivity curves of the subsistence gill net fishery

2.1.3.1. All species combined

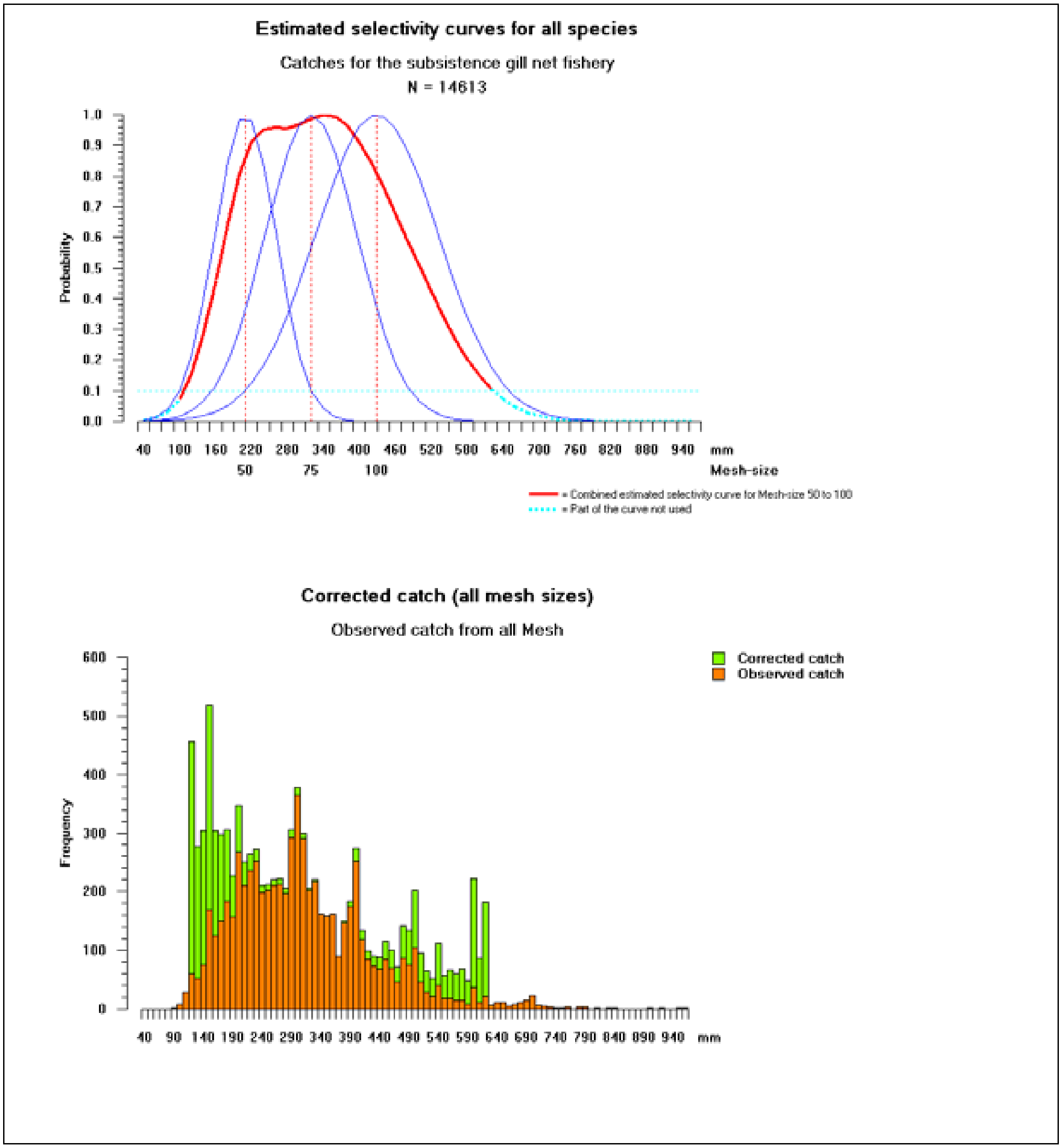

Figure 2.4. a) Multifilament gill net selectivity for all species for each mesh size from 50 to 100mm (blue lines) and combined estimated selectivity curve for all selected mesh sizes (red line) for the subsistence gill net fishery at Impalila Island. b) Corrected catch within selected mesh range for all species sampled at Impalila Island by the subsistence gill net fishery with mesh sizes 50, 75 and 100mm.

The subsistence gill net fishery at Impalila using 50, 75 and 100mm mesh sizes effectively sampled length classes 210 to 410mm for all species combined. Length classes smaller and larger were under sampled. The corrected catch contributed 32.2% to the total catch.

The following conclusions can be made:

- The gill nets used by the subsistence fishermen had mesh sizes between two inch (50mm) and four inch (100mm). These catches were selective as length classes smaller than 210mm were not effectively sampled. This is to be expected, as the size of fish is important for the subsistence fishery.
- The catches from the subsistence fishery did not represent the fish stock in the river. The gill net subsistence fishery targeted only a small portion of the fish species and certain length classes, which is not considered a healthy situation.

2.2. Fish community structure in fish sanctuaries versus open access fishing areas

2.2.1. Background

To comprehend what a virgin fish community would look like is challenging, as such a community seldom exists in nature these days. Fishing has been taking place in Caprivi for many years and it is a foregone conclusion that this has impacted on the fish stocks in the region. As soon as fishing starts in a system, some impact takes place. The important question is not whether the fish resource in Caprivi had been impacted upon, but whether the impact can be considered biologically undesirable or sociologically unacceptable. A further complication is that the fish community of the Upper Zambezi and Chobe Rivers has a natural variability correlated with the annual flood cycle. The difficulty is to identify what percentage of the variability can be attributed to the environment and what percentage to the fishery.

This section will attempt to compare the fish community structure of species not targeted by the fishery to those species regarded as high value species. Another point of investigation will be the comparison of the population structure of open access fishing areas, to areas protected under the legislation developed by the Ministry of Environment and Tourism and declared a national park preventing fishing communities to fish in those waters.

Two such areas have been identified to illustrate the impact of commercial and subsistence fisheries on the fish resource: 1) the Mudumu National Park in the Kwando River for comparison with the intensively fished Zambezi and Chobe Rivers; 2) the Mahango National Park in the Kavango River for comparison with the intensively fished areas in the Kavango River between Nkurenkuru and Popa Falls. Although the Kwando River is not permanently linked to the Zambezi and Chobe Rivers (linked during high floods), it is the only area that can be considered to be an unfished area in the Caprivi Region. One aspect to consider is that there are ecological differences between the Kwando River and the Zambezi and Chobe Rivers making any direct conclusions unwarranted. Comparisons between the Kwando River and the Zambezi and Chobe Rivers may not be the perfect scenario, therefore the Mahango National Park and the rest of the

Kavango River was added as comparison in the analysis. Firstly, all species were used for the analysis between the intensively fished areas and the protected areas. Selected species (only for the Caprivi) were then analysed separately to highlight any possible impacts the subsistence fishery may have on these selected species. Several of these selected species are considered economically important. Other species presently not considered to be of high value on the Katima Mulilo fish market were also studied to evaluate the fishing affect on separate fish species.

The following aspects were studied:

- The relationship between small and large individuals within protected and unprotected areas. (All species combined and for selected species)
- The comparison of the biomass between protected and unprotected areas. (All species combined and for selected species)
- The spatial and temporal variability between protected and unprotected areas. (All species combined and for selected species)
- Species composition changes over time between these two areas.

2.2.2. Biomass distribution and length frequency (all species collectively) comparisons between open access areas and refuge areas

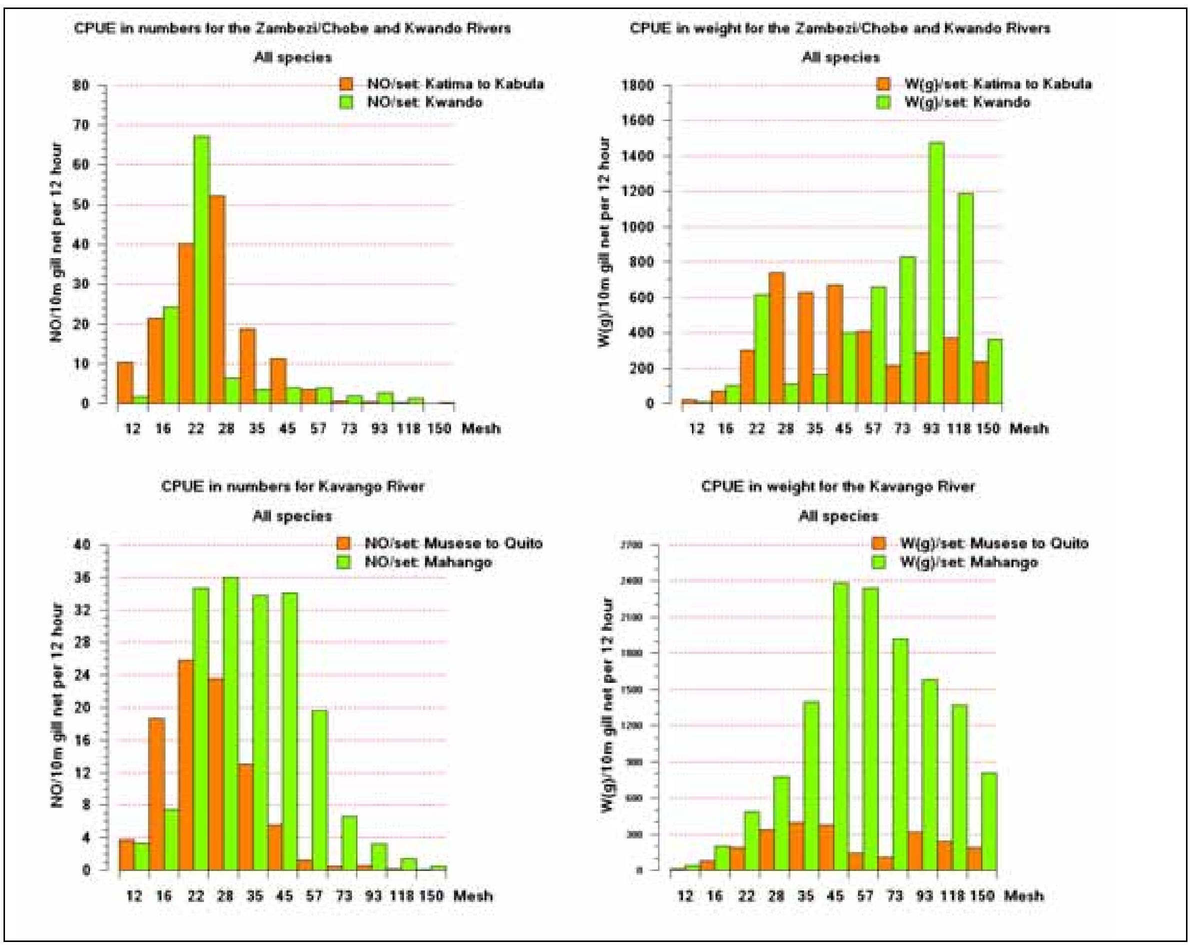

Figure 2.5. Catch per unit effort per mesh size in number and weight of experimental gill nets (12-150mm mesh) for the intensively fished section of the combined stations in the Zambezi and

Chobe Rivers and for the unfished Mudumu National Park, Kwando River, Caprivi. This is also done for the combined stations Musese, Rundu and Cuito and for the unfished protected section in the Mahango National Park, Kavango River Namibia.

The following can be observed from the catches in the different mesh sizes between the fished and unfished areas both in the Caprivi Region and the Kavango River:

- The catches in the larger mesh nets were consistently higher in the unfished areas, both in the Mudumu National Park and the Mahango National Park. This tendency is more evident from the Kavango River, even where the smaller mesh sizes recorded higher catches from the protected areas. In the Zambezi and Chobe Rivers, the smaller mesh sizes sampled more fish than those from the Kwando River.
- There was a decline in the weight per unit effort at the same mesh sizes that were also used by the subsistence gill net fisheries (73mm and larger) in the Zambezi and Chobe Rivers, but not from the Kwando River.
- The modal lengths for weight in the protected area were larger than those from the intensively fished areas (93mm mesh compared to 28mm mesh for the Caprivi and 45mm mesh compared to 28mm mesh from the Kavango River).

The following conclusions can be made:

- The Zambezi and other rivers have fish communities dominated numerically and mass-wise by smaller fish as shown by higher catches, especially in numbers, in the smaller mesh gill nets
- In the fished areas, there is lower occurrences of larger fish, both in terms of numbers and weight
- This decrease in catches in the larger mesh nets is ascribed to the effect of prolonged fishing pressure

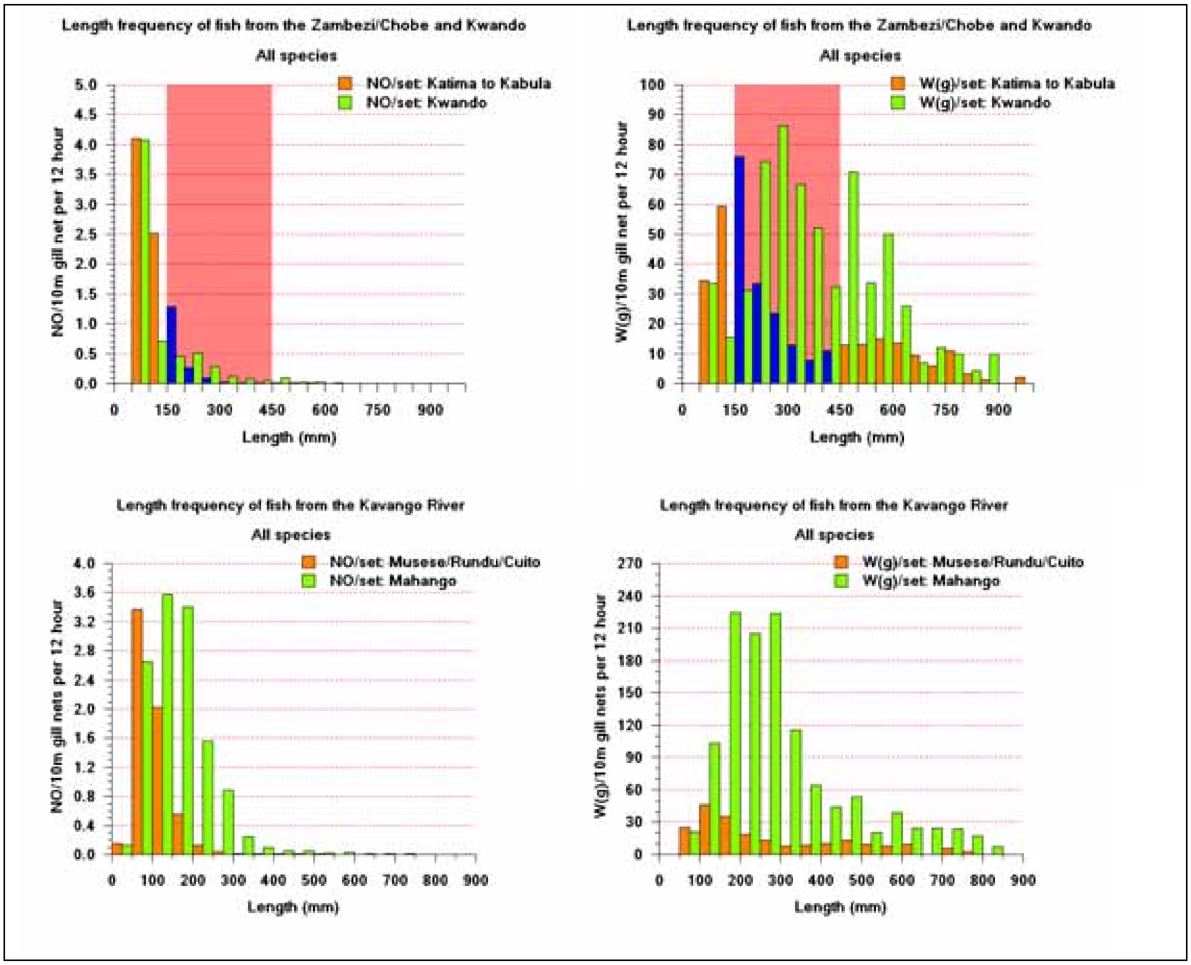

Figure 2.6. Length frequency in number and weight of experimental gill nets (12-150mm mesh) for the intensively fished section of the combined stations in the Zambezi and Chobe Rivers and for the unfished Mudumu National Park, Kwando River, Caprivi. This is also done for the combined stations Musese, Rundu and Quito and for the unfished protected section in the Mahango Game Park, Kavango River, Namibia. The pink and blue are the length classes targeted by the commercial gill net fishery in Caprivi.

The catch per unit effort (in number and in weight) (Figure 2.6) is expressed in the different length classes for both Caprivi and for the Kavango River. Again the differences between the fished and unfished areas are compared.

The following can be observed between the fished and unfished areas:

- According to the number per length group there is a sudden drop in catches between the 150 and 200mm length group (catches in number) for the fished areas in the Zambezi and Chobe Rivers. This drop can be related to the size of fish caught by the subsistence gill net fishery. The shaded area and the blue colour indicates the length classes at which the majority of the fish were caught by the subsistence gill net fishery.
- A similar pattern was repeated in the Kavango River with larger fish present in the protected area.
- The small fish, although slightly larger, were also dominating the catches from the protected area in the Kavango River. This is much clearer when considering the catches in weight.

The following conclusions can be made:

- Smaller fish up to 150mm dominated the fish communities in both the fished and unfished areas in both the Zambezi and Kavango Rivers – this is therefore considered a normal situation.
- There are indications that small fish are more common in the Zambezi and Chobe Rivers than in the Kwando River, which may be the result of the fish community adapting to the high selective fishing pressure in the Zambezi River.
- Larger fish predominated weight-wise in both the unfished areas in the Zambezi and Kavango Rivers.
- A dent is visible in the weight graph for the lengths at which the fishery removes fish, reflecting the direct impact this had on the fish community

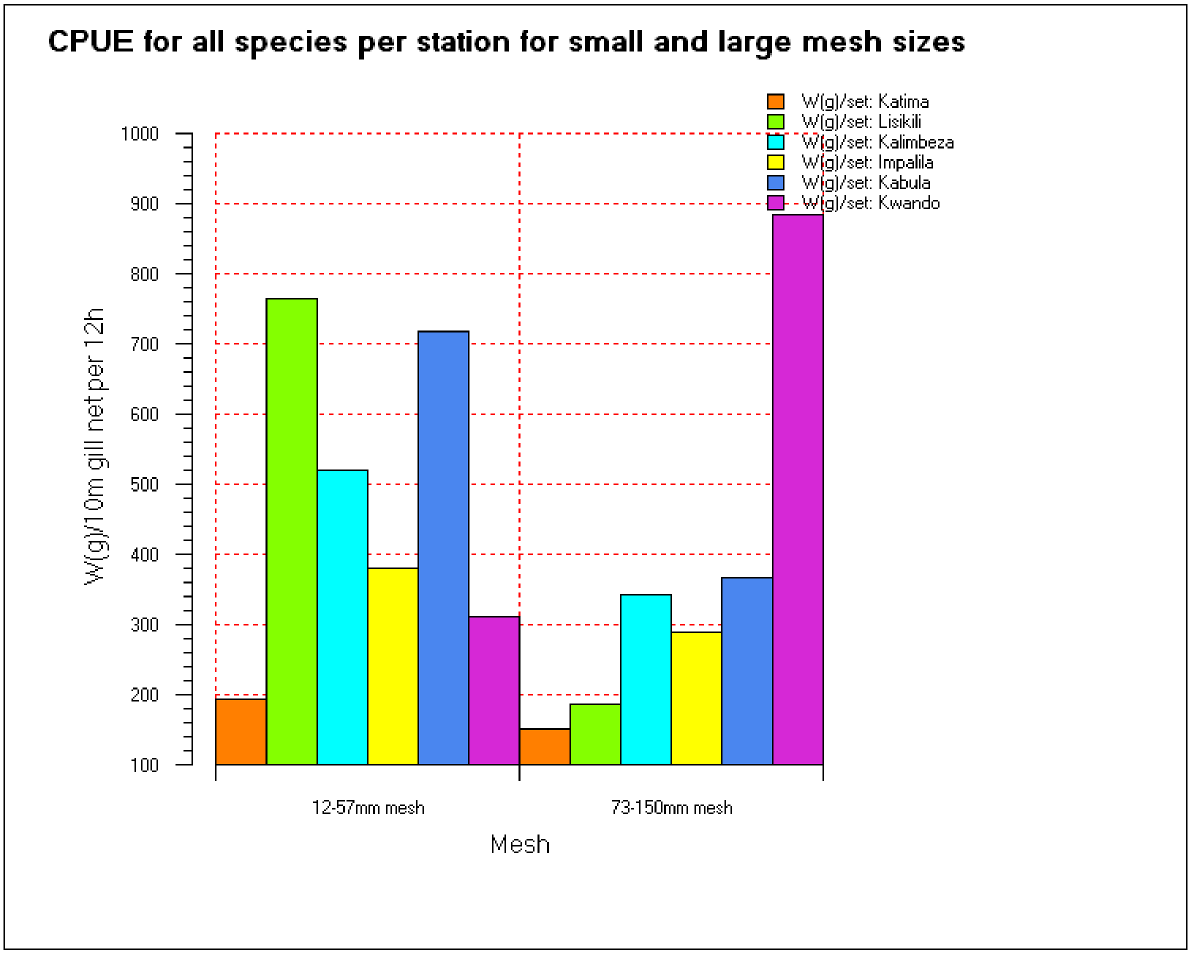

Figure 2.7. Catch per unit effort in weight for six stations in the Caprivi for small mesh nets (12-57mm) combined and for large mesh sizes (73-150mm) combined.

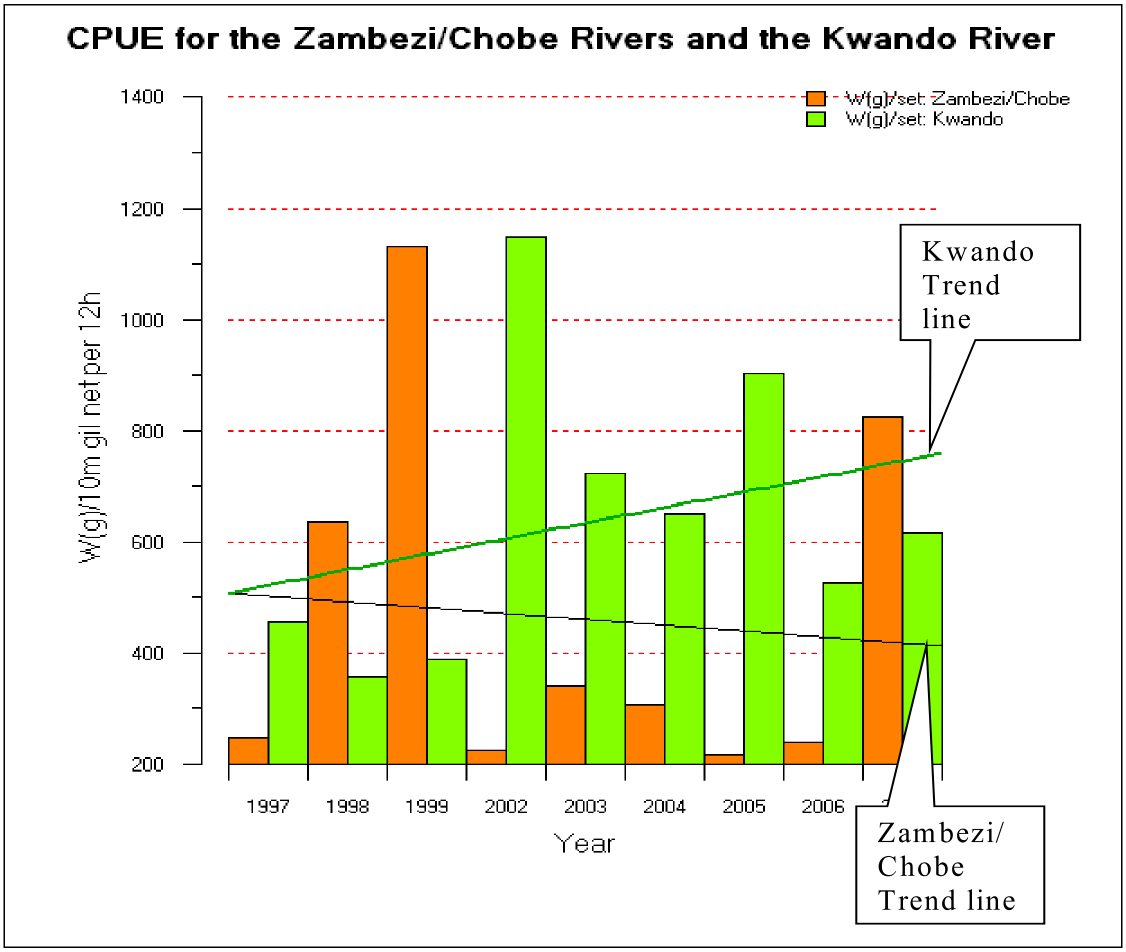

Figure 2.8. Catch per unit effort for the combined stations from the Zambezi and Chobe Rivers and for the Kwando River for each year with the multifilament gill nets. The mesh sizes 22mm to 150mm are included and only the surveys done between April and August. The trend line indicates the tendency during the study period.

The following can be observed in the catch per unit effort between the fished and unfished stations:

- Figure 2.7 shows the catch per unit effort in the combined small mesh and the combined large mesh nets in the intensively fished areas of the Zambezi and Chobe Rivers and the unfished Kwando River. The Kwando River had lower catches in the smaller nets but the highest catch per unit effort in weight for the combined large mesh sizes. The catch per unit effort from the Kwando River for the large mesh sizes combined was more than double that of the other stations from the Zambezi and Chobe Rivers. The large mesh sizes were similar to the sizes used by the commercial fishery. The species dominating the catches in these mesh sizes in the Kwando River were *Clarias gariepinus, Oreochromis andersonii, Clarias ngamensis, Hydrocynus vittatus* and *Hepsetus odoe.*

- The catch per unit effort of all the experimental gillnets in the six stations from the intensively fished Zambezi and Chobe Rivers showed a decline in weight per unit effort during the period from 1997 to 2007, although the catches varied considerably. The Kwando River in contrast increased in catch per unit effort with time. (see the trend lines in Figure 2.8). An increase during 2007 was observed for the Zambezi and Chobe Rivers, which may be flood related. The overall catches were higher from the Kwando River (except for 2007). For both areas the catch per unit effort varied considerably over the years.

The following conclusions can be made:

- More large fish were present in the unfished area, with catches double that of the fished areas.
- The catch per unit effort from the fished areas had lower catches during the latter part of the study period compared to higher catches during the same period for the unfished areas.
- The fishery in the Zambezi and Chobe Rivers had a negative effect on the fish stock with a decline in the large fish.

2.2.3. Biomass distribution and length frequency for selected fish species; comparisons between open access areas and refuge areas

2.2.3.1. *Hydrocynus vittatus*

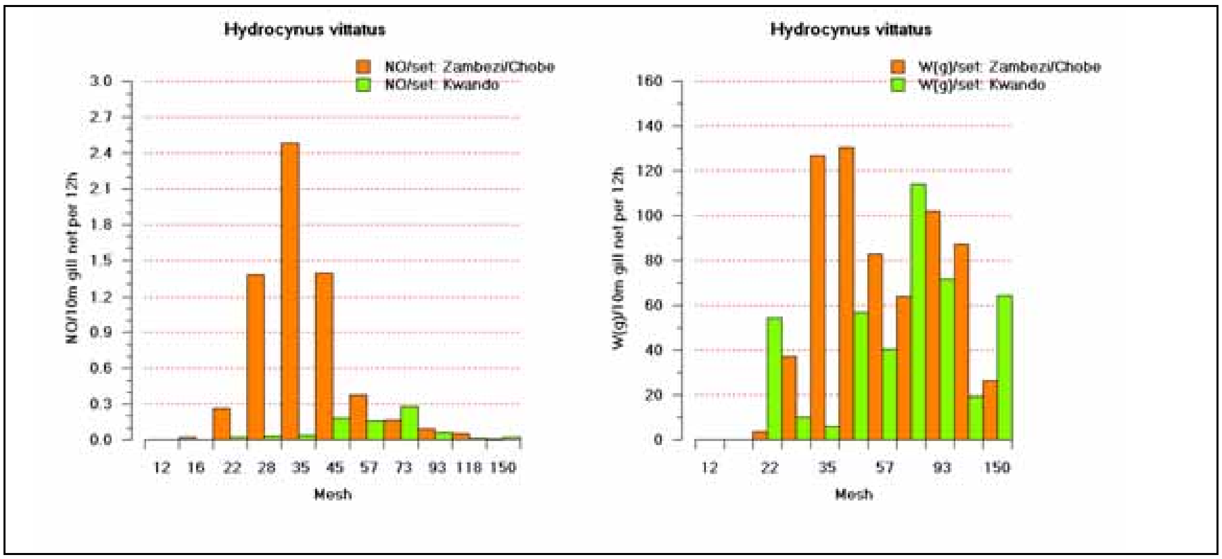

Figure 2.9. Catch per unit effort per mesh size for *Hydrocynus vittatus* in number and weight of experimental gill nets (12-150mm mesh) for the stations in the Zambezi and Chobe Rivers and for the Mudumu National Park, Kwando River, Caprivi.

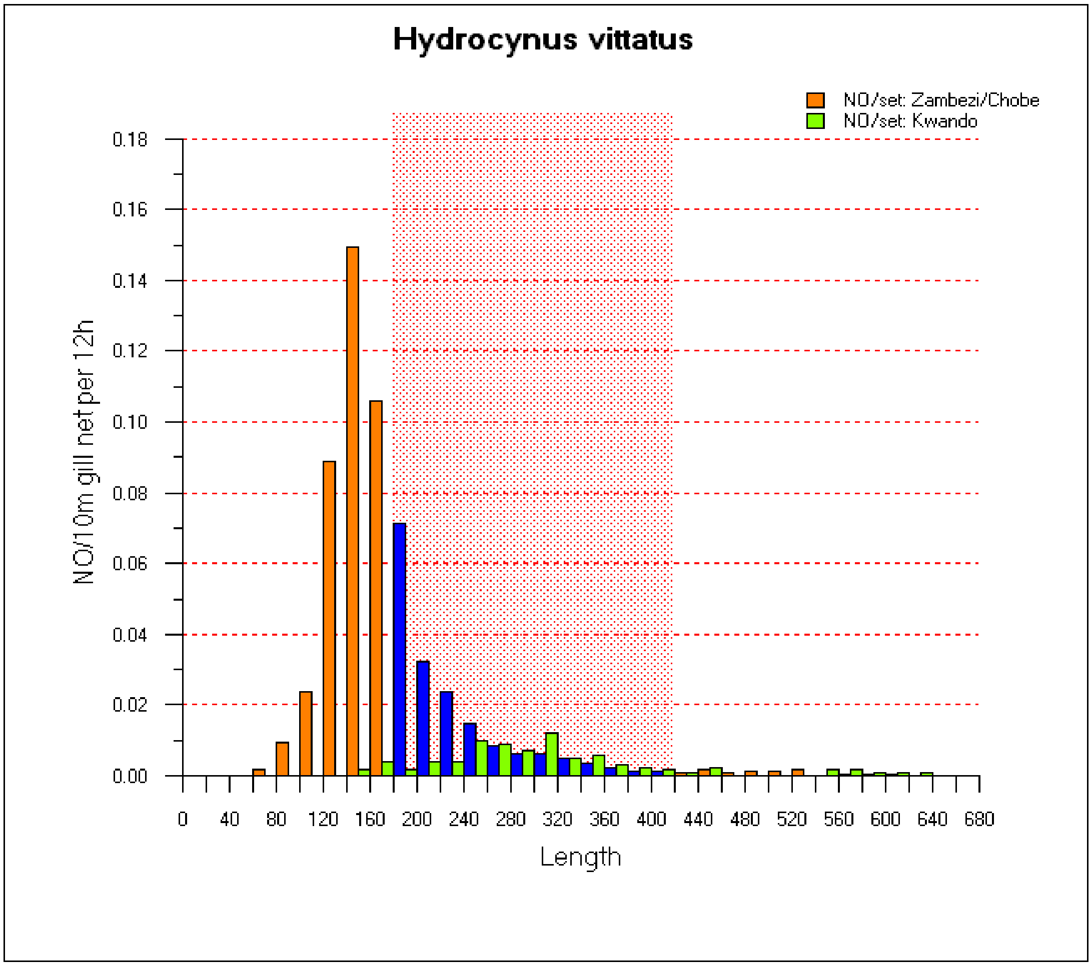

Figure 2.10. Length frequency in number of experimental gill nets (12-150mm mesh) for *Hydrocynus vittatus* for the stations in the Zambezi and Chobe Rivers and for the Mudumu National Park, Kwando River, Caprivi.

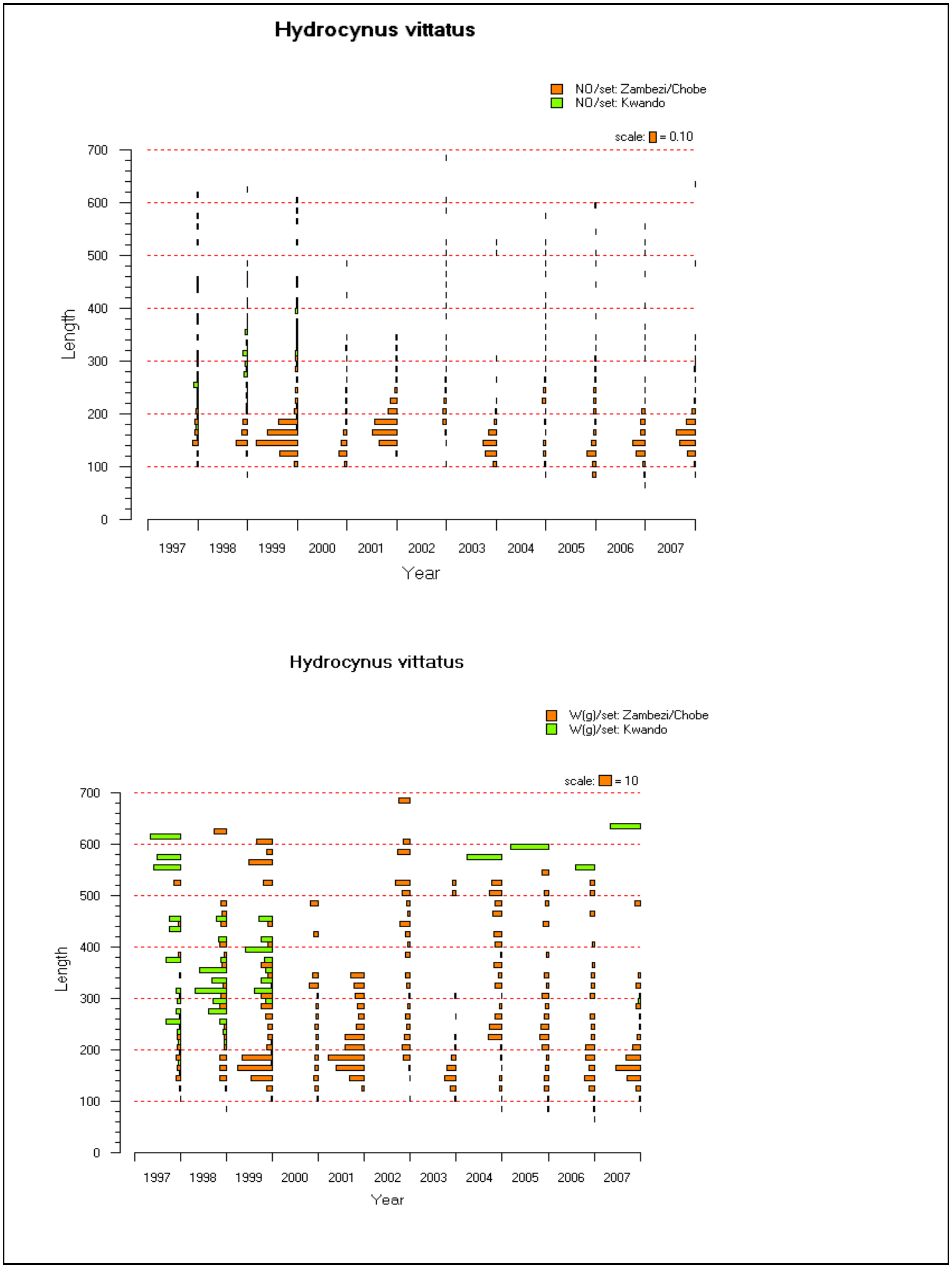

Figure 2.11. Length frequency per year for *Hydrocynus vittatus* in number and weight of experimental gill nets (22-150mm mesh) for the stations in the Zambezi and Chobe Rivers and for the Mudumu National Park, Kwando River, Caprivi.

The following can be observed regarding *Hydrocynus vittatus* between the fished and unfished areas.

- According to Figure 2.9, the smaller mesh sizes in the Zambezi and Chobe Rivers had higher catches in number than the larger mesh sizes, also compared to the catches from the unfished Kwando River. It seems that small individuals were not readily recorded from the Kwando River, possibly indicating poor recruitment. The 28 to 45mm mesh sizes had the highest catches in number. According to weight the larger mesh sizes dominated the catches even in the Zambezi and Chobe Rivers.
- Figure 2.7 further strengthens the argument that healthy recruitment was found from the intensively fished areas in the Zambezi and Chobe Rivers with very low catches for the smaller individuals from the Kwando River. Although the subsistence gill net fishery at Impalila recorded *Hydrocynus vittatus* as the most important species in number, weight and frequency it does not seem to be substantially affected by the fishery. There was a drop in the length classes targeted by the fishery in Figure 2.10 (the shaded and blue colour), but the fish community still seems to be relatively healthy with strong recruitment. This was, however, very low in the Kwando River and may be related to the absence of suitable habitats, such as large open water bodies. The catches at the protected area overall were lower than in the intensely fished areas.
- Although the recruitment in the Kwando River appears low, possibly as a result of the lack of suitable breeding habitats, the catches indicate a healthy larger and older fish population and thus low mortality. In the Zambezi the situation is the opposite with good recruitment, especially in certain years (Figure 2.11) and small numbers of larger fish, indicative of a high mortality rate in which the fishery may play a role.
- Figure 2.11 indicates recruitment during most of the different years in the period studied from the Zambezi and Chobe Rivers. Only 1997, 2002 and 2004 had relatively low recruitment. Cohorts from larger length classes were also visible from different years from the intensively fished areas in the Zambezi and Chobe Rivers. Larger fish were present from the Kwando River during the period 1997 to 1999. Overall the population seems to be much healthier on an annual basis in the Zambezi and Chobe Rivers.
- A recent radio-tagging program from the Upper Zambezi River indicated that *Hydrocynus vittatus* moves over large distances and may not be susceptible to a localized fishery. Recently fishermen have started using new fishing methods. Drift netting is used over long distances where large numbers of tigerfish are netted in the Zambezi River during the low-flow months; this practice may have serious effects on the tigerfish populations.

The following conclusions can be made:

- The Zambezi River had a healthy tigerfish population with high recruitment rates in good years.
- The harvesting rate was also high with few larger fish caught in larger mesh nets.
- In the unfished Kwando, this fish did not show good recruitment but large and small fish were caught, indicating lower mortality rates.

2.2.3.2. *Oreochromis andersonii*

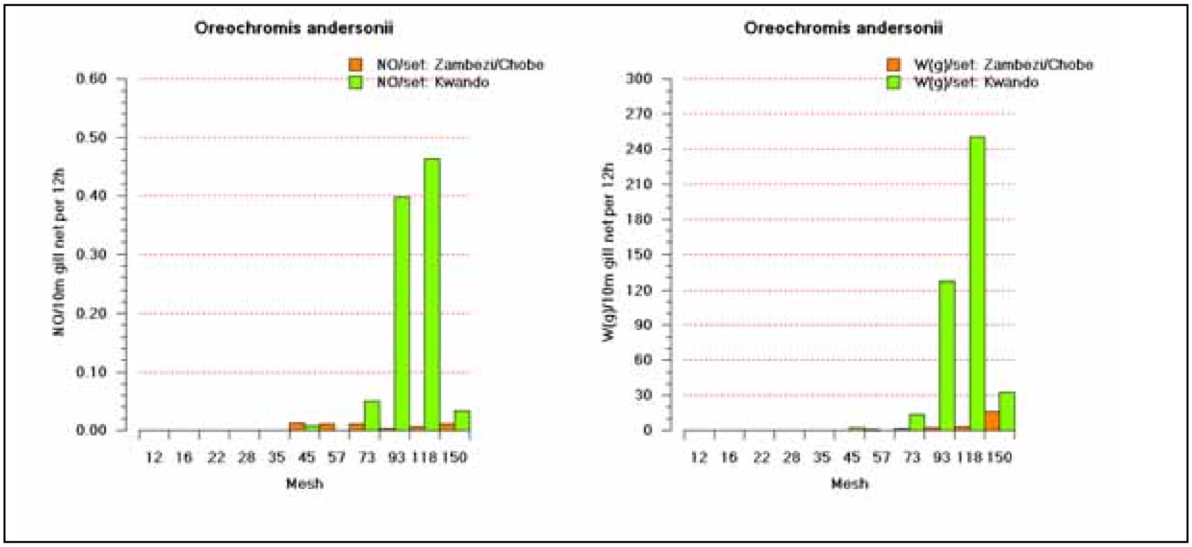

Figure 2.12. Catch per unit effort per mesh size for *Oreochromis andersonii* in number and weight in experimental gill nets (12-150mm mesh) for the Zambezi and Chobe Rivers and Mudumu National Park, Kwando River, Caprivi.

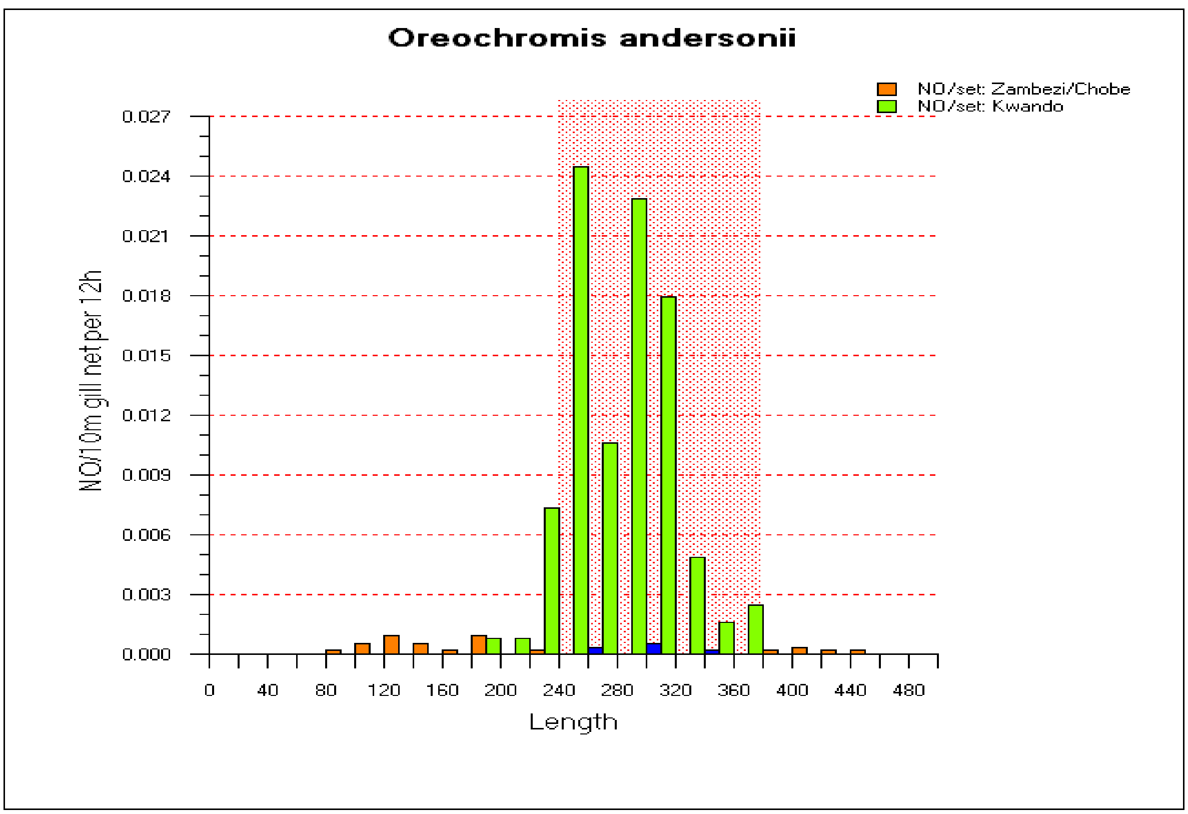

Figure 2.13. Length frequency in number of *Oreochromis andersonii* caught in experimental gill nets (12-150mm mesh) in the Zambezi and Chobe Rivers and in the Mudumu National Park, Kwando River, Caprivi.

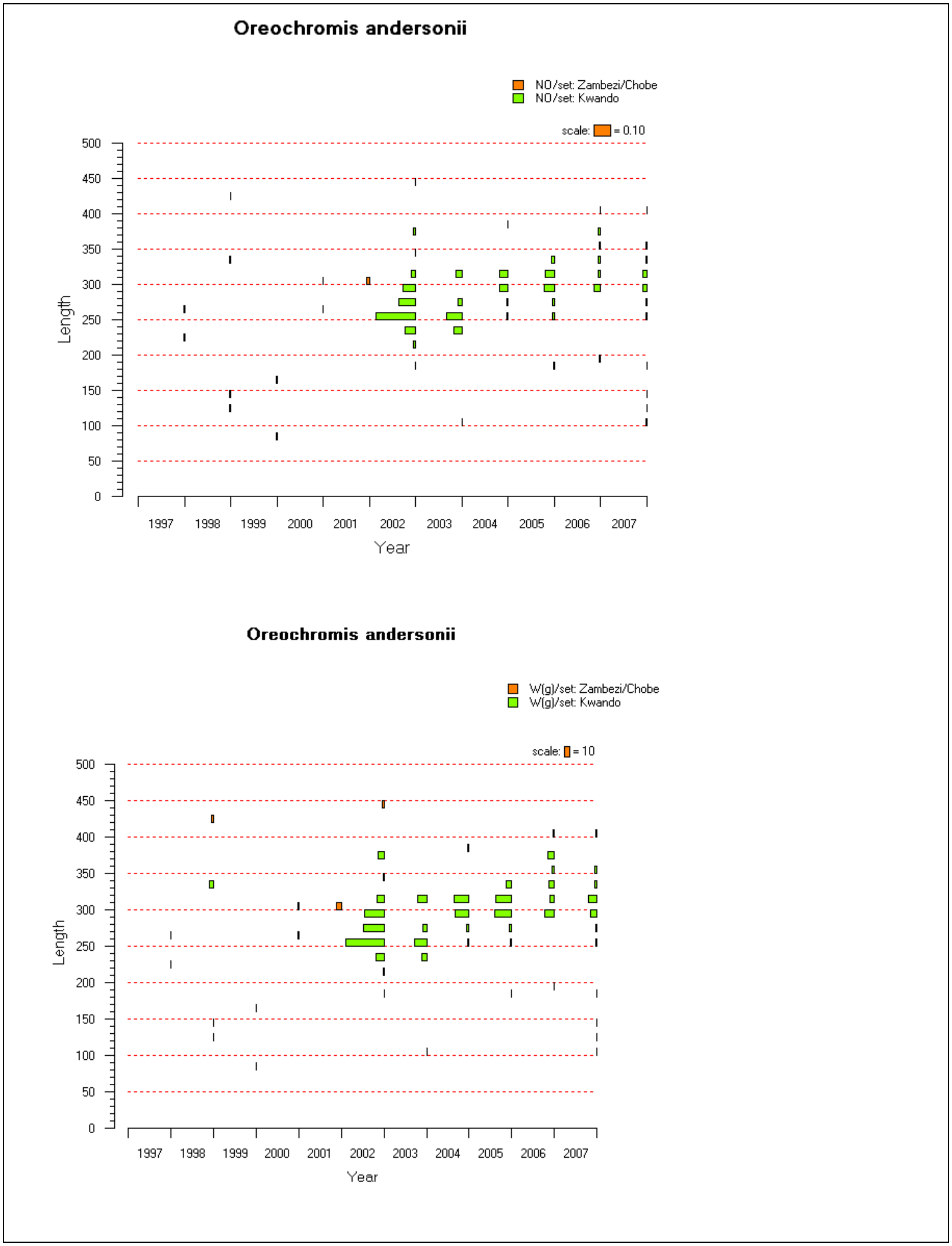

Figure 2.14. Length frequency per year for *Oreochromis andersonii* in number and weight of experimental gill nets (22-150mm mesh) for the Zambezi and Chobe Rivers and Mudumu National Park, Kwando River, Caprivi.

The following can be observed regarding *Oreochromis andersonii* between the fished and unfished areas.

- Extremely low catches were recorded for *Oreochromis andersonii* from the Zambezi and Chobe Rivers. No fish were caught in the 12 to 35mm mesh sizes. In the Kwando River, the 93 and 118mm mesh sizes had very high catches compared to the other mesh sizes. The absence of fish from the small mesh sizes from the Kwando River as well as the Zambezi could be due to sampling methodology and especially evasive behaviour of small cichlid fish. With the presence of large fish, recruitment is likely to have taken place. The low catches of larger fish from the Zambezi and Chobe Rivers are of great concern and may be indicative of heavy pressure from utilization by the fishery.
- Some recruitment is however apparent for *Oreochromis andersonii* from Figure 2.13 in the Zambezi and Chobe Rivers. The majority of *Oreochromis andersonii* caught by the subsistence gill net fishery were at length classes 230mm and larger (shaded and blue areas). These length classes were common in the Kwando River (Figure 2.13) but low in numbers from the intensively fished Zambezi and Chobe Rivers. However, larger fish were caught in the subsistence gill nets. This is also reflected in the relative good angling catches for large *Oreochromis andersonii* in the Zambezi River as evidenced during annual angling competitions. These large fish have outgrown gillnets and live in relatively well protected deep holes where they are not so vulnerable to netting operations.
- It seems that this species is susceptible to the subsistence fishery and was heavily impacted by the utilization. There was a slight increase from 2002 in the catches from the Kwando River. During a radio-tagging project done on this species it was found that it moves around actively, but not necessarily over long distances, making it more vulnerable to widely distributed gill nets. From this figure it can be seen that *Oreochromis andersonii* is under pressure most probably due to the heavy gill netting and drag netting taking place in the Zambezi and Chobe Rivers. It is one of the target fishes of the fishery and a sought after species, obtaining high selling prices at the local markets, which further puts pressure on the species. The fishermen are prepared to invest in sampling gear that targets this species due to the high market demand. The weak recruitment could be due to the destruction of nests during drag netting, resulting in a low spawning success rate.

The following conclusions can be made:

- The fish populations in the Zambezi River and in the unfished Kwando River were very different.
- Small *Oreochromis andersonii* seemed to be very difficult to collect in gill nets and were under represented in all sites.
- Larger *Oreochromis andersonii* were commonly caught in the Kwando River but were very rare in catches in the Zambezi and Chobe Rivers.
- This is due to selective and intensive fishing pressure, including drift netting, drag netting and bashing to catch more fish.
- *Oreochromis andersonii* is very susceptible to the subsistence fishery and is presently heavily utilized.

2.3. Fish community structure

2.3.1. Background

This section of the report will investigate the effect of extended gill net fishing on the fish community by looking at differences in the fish population structures between the Kwando River (regarded as a fish sanctuary) and the stations from the Zambezi and Chobe Rivers which are under constant pressure due to the commercial and subsistence fisheries.

The present fishing regulations developed for the Caprivi prevent the utilization of the fish resource across the entire fish community by restrictions on small mesh size nets. This effort-based regulation places a burden on a small portion of the fish community. It is therefore important to study what effect this may have on the structure of the fish community. It is however doubtful whether the fisheries actually adhere to these regulations. Surveys done during 2002 indicated that the mesh sizes used by the fisher folk were between 39mm and 229mm with the majority used between 39 and 114mm.

A log base catch per unit effort (in weight) was plotted against length for both the combined stations from the Zambezi and Chobe Rivers and also for the Kwando River. The overall shape of the biomass-size distribution is a descending curve as the biomass is higher for the smaller individuals than for the larger individuals. Variations in the shape, slope and the intercept indicate a change in the population structure, which can be related to mortality. The difference in the intercept is indicative of a change in biomass. Due to mesh size restrictions in most fisheries, the size information can tell us something about the susceptibility towards fishing mortality. As minimum mesh size regulations (76mm) are in place in the Caprivi it can be said that the length groups towards the left side of the graph are less susceptible to fishing, whereas those fish towards the right are more susceptible, especially when considering the commercial fishery, where large fish are targeted for the markets.

2.3.2. Biomass-size distribution

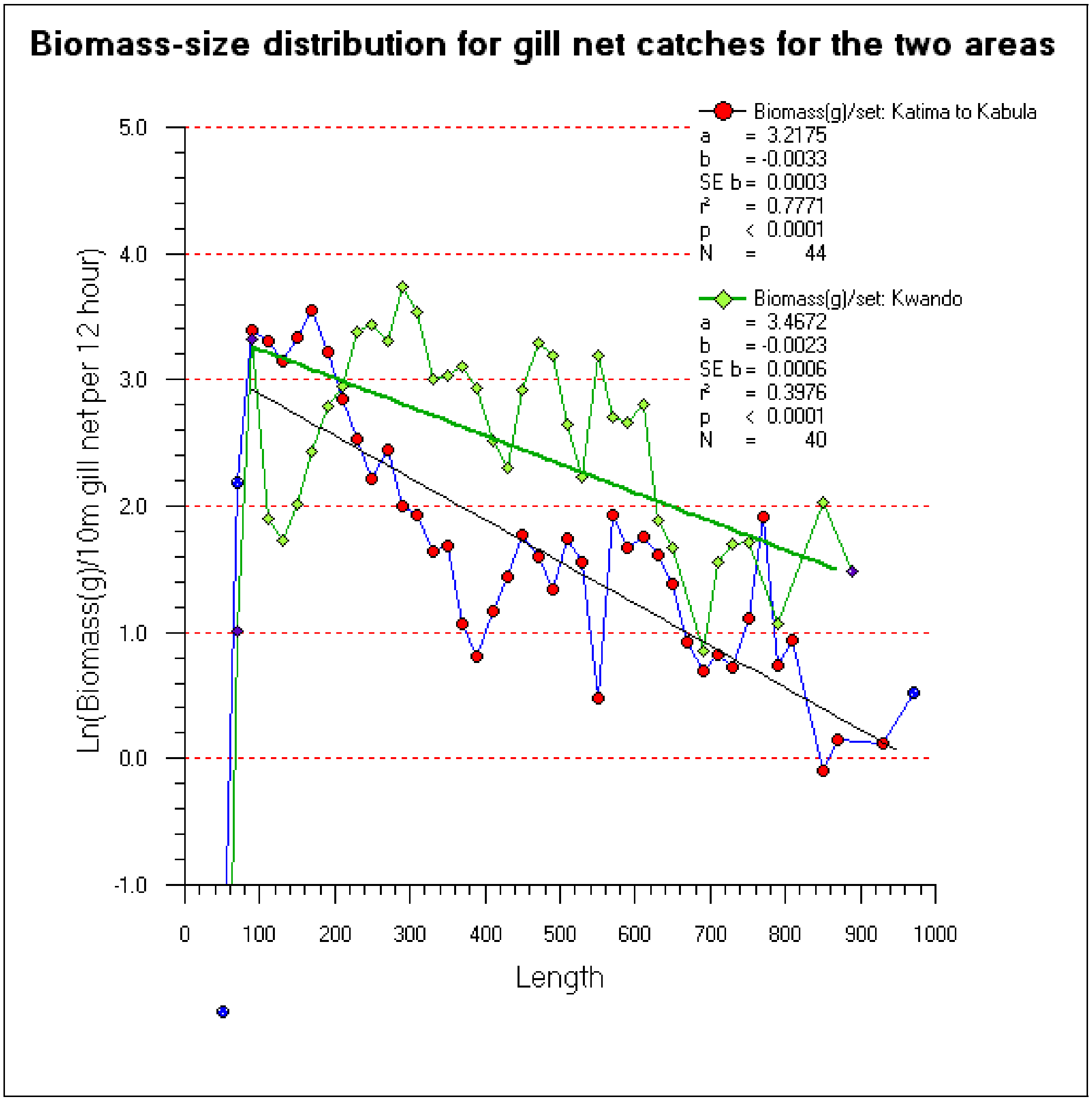

Figure 2.15. Biomass-size distribution for the multifilament gill net catches (22-150mm mesh) for the stations Katima Mulilo to Kabula combined and for the Kwando for the study period 1997 to 2007. The green trend line is for the biomass from the Kwando River and the black trend line for the Zambezi and Chobe Rivers.

The following can be observed from the biomass-size distribution between the fished and unfished areas.

- There is a difference in the slope between the two areas indicating larger fish present at the Kwando River and a higher abundance of smaller fish in the Zambezi and Chobe Rivers.

- The difference in the intercept a for the two trend lines, gives the difference in biomass between the two areas whereas the slope b gives an indication of the community structure. The Kwando River may have had a higher biomass, but not necessary a higher productivity.
- The Kwando River had a higher biomass for the larger length groups and the Zambezi and Chobe Rivers for the length groups smaller than 200mm.

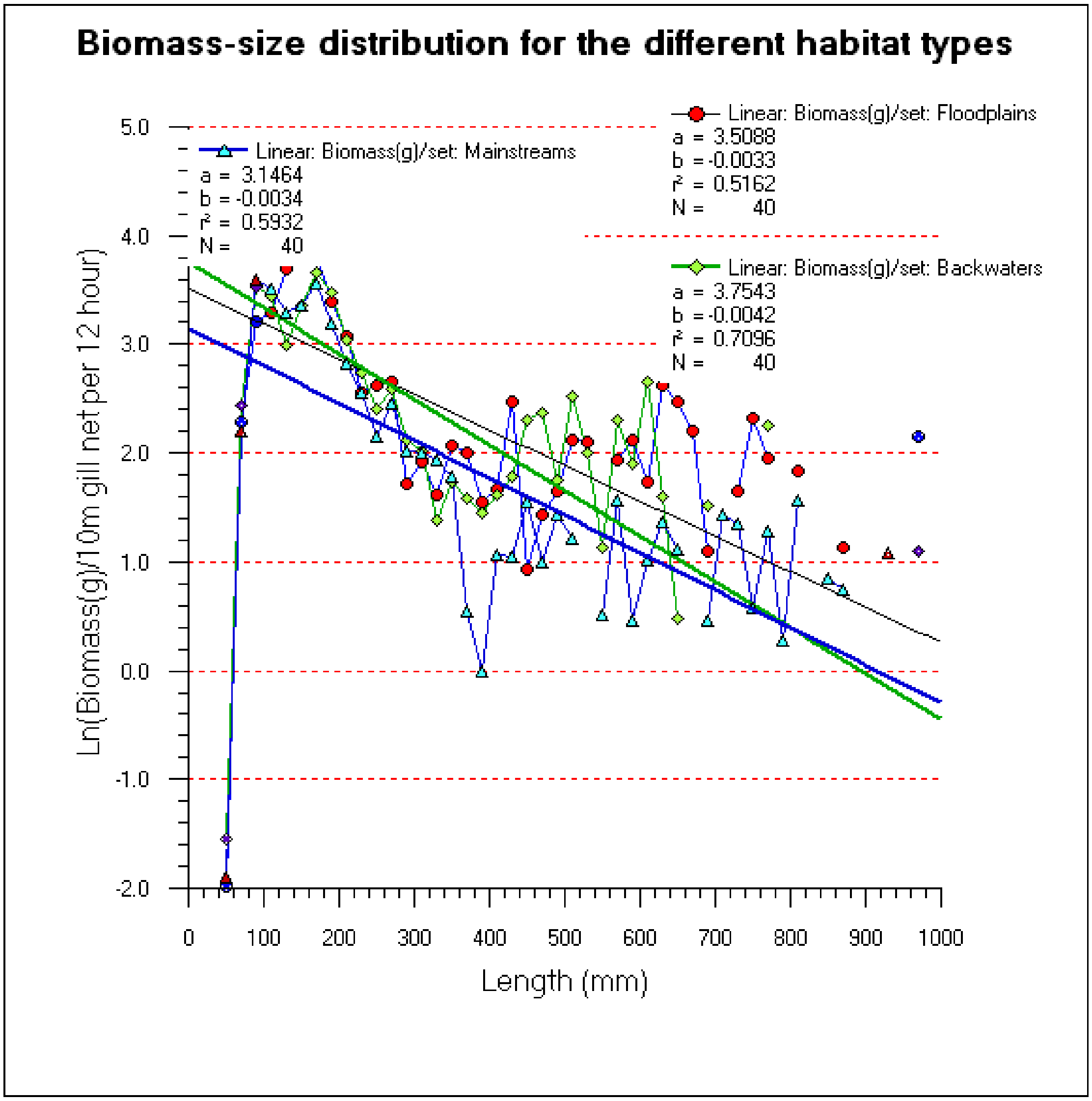

Figure 2.16. Biomass-size distribution for the multifilament gill nets (22-150mm mesh) for the stations Katima to Kabula for the different habitat types (Floodplains, Backwaters and Mainstreams). The data from 1997 to 2007 are included.

- The size structure of the fish communities from the floodplains was similar to the community structure from the mainstreams. The only difference was that the floodplains had a higher catch per unit effort. The fish size structures from the mainstreams and floodplains differed from the size structure from the fish sampled from the backwaters. According to this figure a higher number of smaller fish were present in the backwater habitats, but fewer large fish than in the other two habitat types. Usually backwaters are favorite habitat types for the fishermen and can be heavily utilized at times, which will impact on the large individuals

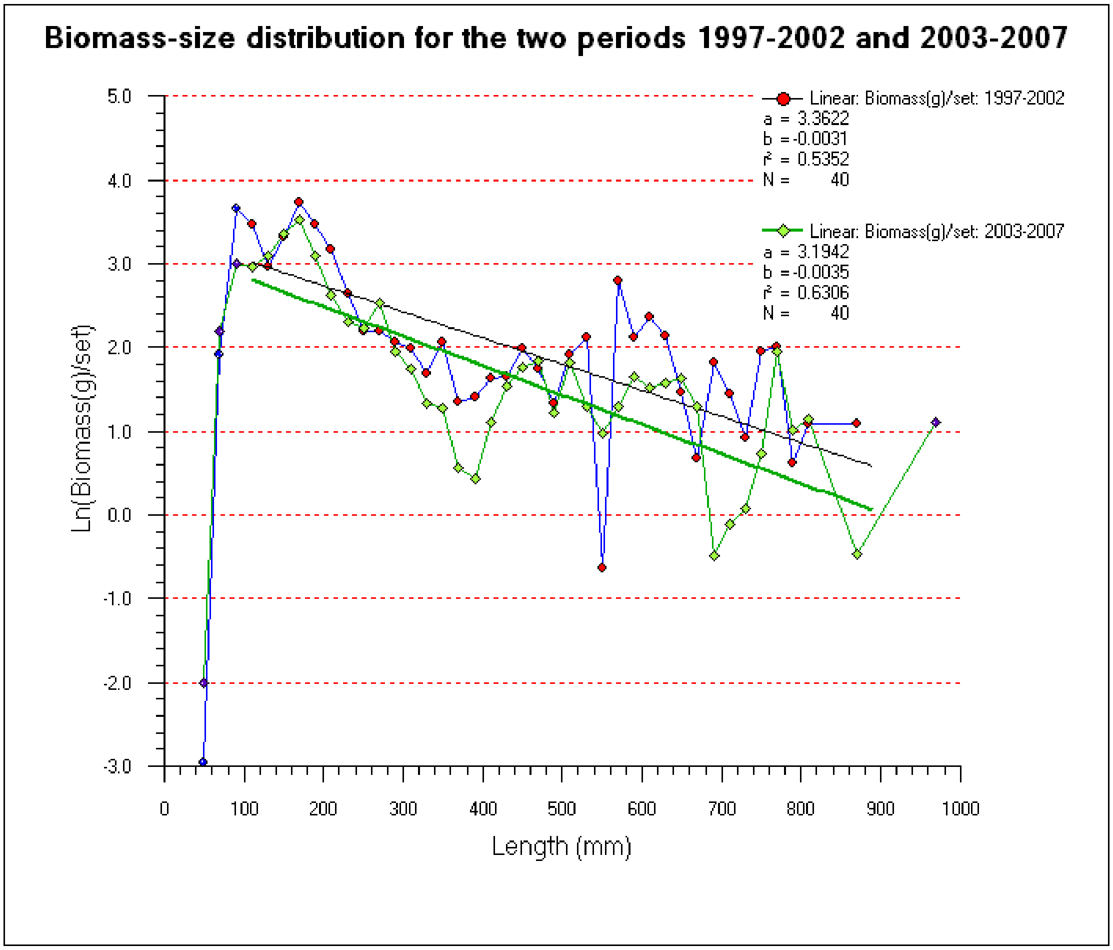

Figure 2.17. Biomass-size distribution for the multifilament gill nets (22-150mm mesh) for the two periods 1997-2002 and 2003-2007. Data analyzed was sampled between April and August to only include the winter months. The stations Katima to Kabula are included.

- For this analysis, only data collected during the winter months were analyzed. The recruitment during the spring and summer months would have influence the results, seeing that no spring and summer surveys were conducted during the period 2003 to 2007. There was a slight difference in the fish population structure between the two periods (b = 0.0031 compared to b = 0.0035) 1997-2002 and 2003-2007 and also in the catch per unit effort that was higher in the period 1997-2002. According to this figure, there had been a change in the catch per unit effort during the study period and a small change in the community structure, with a slight change in the ratio between small and large fish. Therefore a decline in large fish was found since 1997.

The following conclusions can be made:

- There was a definite difference in the population structure between the fished and unfished areas.
- The population structure was similar between those from the mainstream and the floodplains, but differed from the backwaters.
- The population structure of the Zambezi and Chobe Rivers differed between the early and latter parts of the study period.
- The fishery did influence the fish population structure negatively in the Zambezi and Chobe Rivers.

2.4 Home ranges and habitats used by selected fish species

Table 2.1. Fish species studied using radio telemetry to investigate home ranges, habitat preferences and sections of the river used during the flooding, high water and receding periods in the Upper Zambezi River.

Species	**Home range (km^2)**	**Habitat used**	**Mean river stretch used (km)**	**Mean distance traveled by individual (km)**
Hydrocynus vittatus	0.28	Mainstream (81%) Backwater (7%) Mouth of backwater (0.3%) Side-channel (7%) Permanent swamp (2%) Floodplain (2%)	18.8	26.5
Oreochromis andersonii	0.30	Mainstream (39%) Backwater (26%) Mouth of backwater (0.5%) Side-channel (12%) Permanent swamp (16%) Floodplain (7%)	5.4	13.5
Serranochromis robustus	0.18	Mainstream (69%) Backwater (1%) Mouth of backwater (0.2%) Side-channel (17%) Permanent swamp (12%) Floodplain (0%)	1.3	3.2
Oreochromis macrochir	3.1	Mainstream (46%) Backwater (14%) Mouth of backwater (1%) Side-channel (24%) Permanent swamp (4%) Floodplain (11%)	2.5	4.0

Table 2.1 is a summary of the results from telemetry studies done for adults of selected species to determine the migratory behaviour of these species. The home ranges stated fall within a 95% probability of localization. *Oreochromis macrochir* had the largest home range of the species listed in the table. *Hydrocynus vittatus* had the largest mean river stretched used, as well as the longest mean distance travelled by an individual.

The following can be observed from Table 2.1:

- *Hydrocynus vittatus* had the largest mean stretch of the river used, followed by *Oreochromis andersonii*.
- *Serranochromis robustus* was found to be very localised with a mean stretch river usage of only 1.3km.
- The large percentage occurrence of *Oreochromis andersonii* in backwater habitats makes this species very vulnerable towards drag netting.

The following conclusions can be made:

- *Hydrocynus vittatus* uses large river stretches and is therefore less impacted upon by the fishery, whereas the behaviour of *Oreochromis andersonii* makes it an easy target for the fishermen.

2.5. Species composition from the multifilament gill net catches

2.5.1. Background

The objective is to determine whether there had been a change over years in the species composition for the combined stations from the Zambezi and Chobe Rivers that are intensively harvested by the subsistence fishery. This comparison was done between all the stations, including the Kwando River and also between the main habitat types. The subsistence fisheries are not dependent on species preferences and will probably depend on the balance between input costs versus catch returns, as fishing communities are usually the poorest of the poor. With an increase in the market prices for fish, the subsistence fishery is likely to change into a commercial fishery, as more people will fish for cash with less emphasis on fishing for the household. The underlying principle is that the species composition is most likely to change with selective fishing pressure. Species have different tolerances towards harvesting and will react differently to fishing mortality as already shown above.

The species diversity calculated as the Shannon's diversity index was determined as well. It is important to note that there is a difference between species composition and species diversity. Species composition as used in this section depends on the total number, the total weight and the frequency of occurrence whereas species diversity is the number of species and the total number of individuals per species sampled. The Shannon index of diversity (H′) is a measure of the number of species weighted by their relative abundances. The Shannon index assumes that individuals are randomly sampled from an indefinitely large population, and that all species are represented in the sample. The value of the Shannon diversity index is usually between 1.5 and 3.5. A high value indicates high species diversity.

2.5.2. Species composition

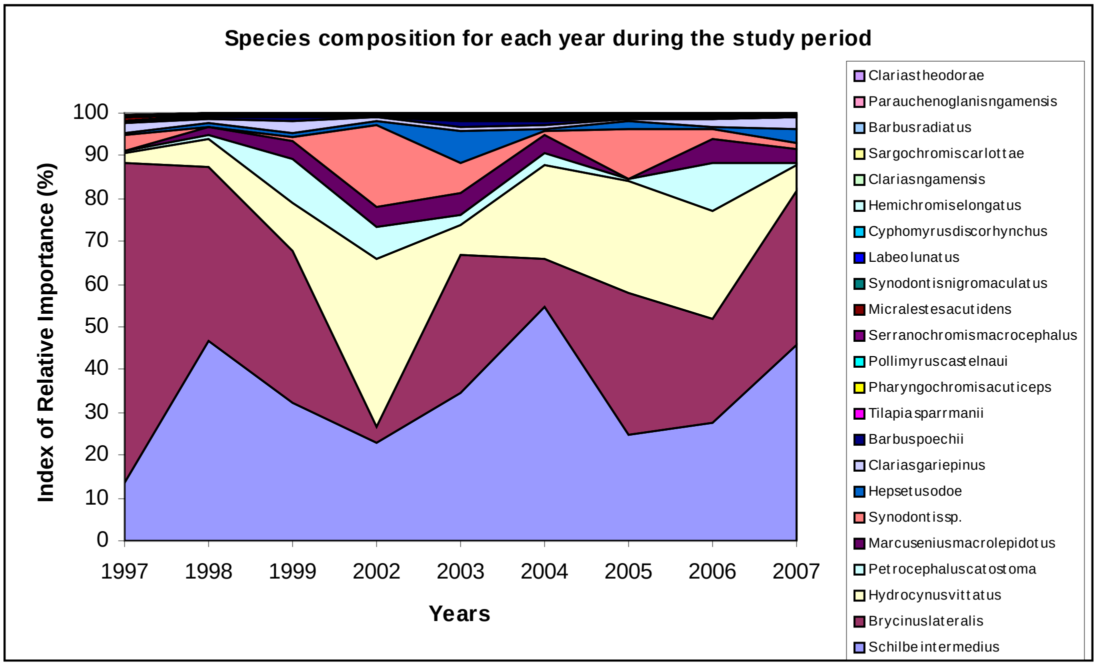

Figure 2.18. Species composition (as Index of Relative Importance) of the multifilament gill nets (22-150mm mesh) for each year for the study period 1997 to 2007 (only the winter surveys) for the stations Katima to Kabula combined.

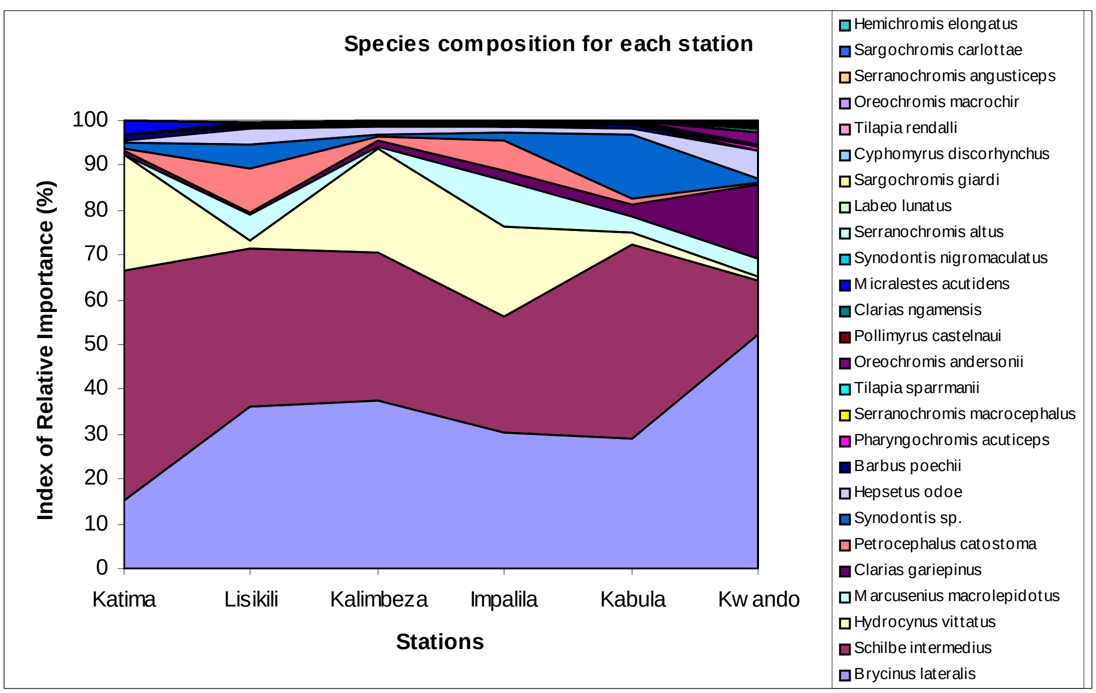

Figure 2.19. Species composition (as Index of Relative Importance) of the multifilament gill nets (22-150mm mesh) for the study period 1997 to 2007 (only the winter surveys) per collecting station.

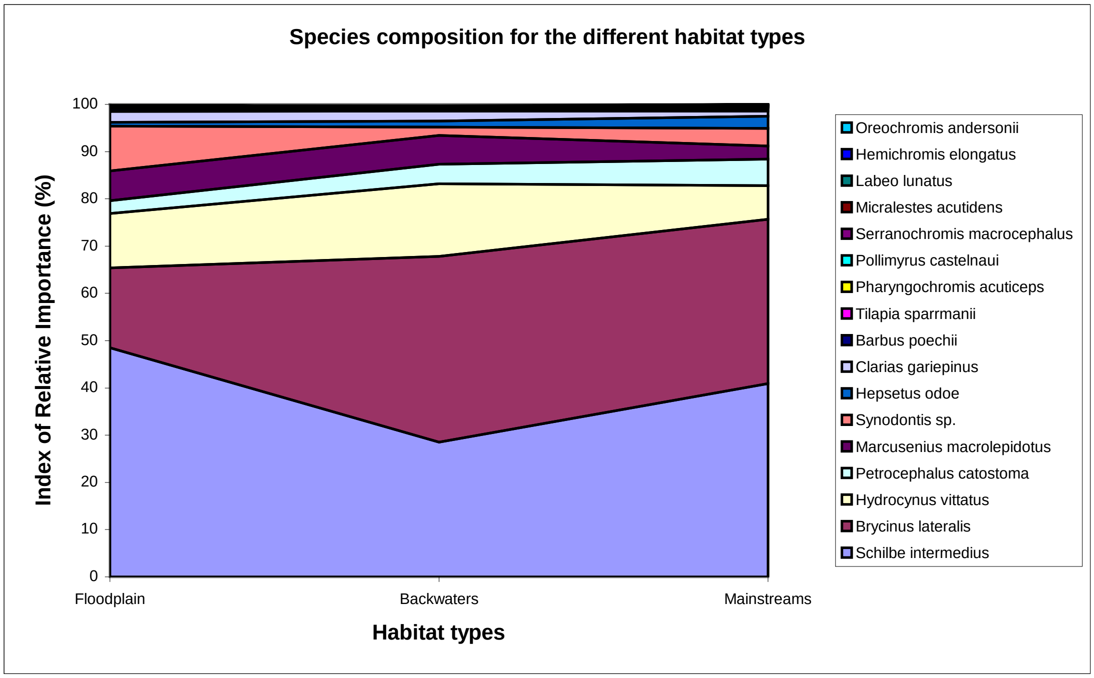

Figure 2.20. Species composition (as Index of Relative Importance) of the multifilament gill nets (22-150mm mesh) for the study period 1997 to 2007 (only the winter surveys) for main habitat types for the stations Katima to Kabula combined.

- No significant change over the ten-year period was found in the species composition for the winter surveys for the Zambezi and Chobe Rivers (Figure 2.18). *Schilbe intermedius, Brycinus lateralis* and *Hydrocynus vittatus* were the important species throughout the study period. A small number of species dominated the catches throughout the study period. The commercially important Cichlidae did not feature under the important catches from the experimental catches. This was due to the much smaller mesh sizes included in the experimental gear as well as the known evasive behaviour of small cichlids to gillnets and the absence of strong populations of large fish. Another important factor was that the subsistence fishery set their nets selectively to target the important species. This was not the situation with the experimental gear. *Hydrocynus vittatus* considered an important economical species did feature in Figure 2.18.

- The two species *Schilbe intermedius* and *Brycinus lateralis* dominated the catches (Figure 2.19) at all the stations, except for the Kwando, which was only dominated by *Brycinus lateralis*. Very low catches of the economically important Cichlidae were recorded from all the stations. The river stations Katima and Kalimbeza had a similar species composition and also the backwater stations Lisikili and Kabula. The Kwando River showed a slightly different species composition with *Clarias gariepinus* and *Hepsetus odoe* more important than in the Zambezi and Chobe Rivers.

- The differences between habitats were however insignificant (Figure 2.20) when comparing the Index of Relative Importance. Again three species dominated the index.

The following conclusions can be made:

- The species composition did not change during the study period 1997 to 2007.
- A very small number of species dominated the catches during this period.
- The economically important Cichlidae were caught in very low numbers.
- The dominance of species was the same in all the major habitats.

2.6. The subsistence gill net fishery

2.6.1. Background

Data from the subsistence fishery in Caprivi had been lacking and is seen as one of the main stumbling blocks in assessing the state of the fish stocks in the Caprivi. The major factor contributing towards this lack of fisheries data is the shortage of personnel to collect the data from the fishing grounds. Another factor that further complicated the matter is the remoteness of the area and the vast floodplains making communication and data collection difficult. The fishermen usually empty their nets early in the morning on the riverbanks just after sunrise. Within a couple of hours all fish have been removed, sold or processed or transported to the nearest fish market, resulting in ineffective data collection.

To initiate a program to collect fishery data along the Zambezi and Chobe Rivers was one of the priorities of the Ministry of Fisheries and Marine Resources. A project was developed in collaboration with the World Wildlife Fund (LIFE project), *"Shared Resource Management on the Zambezi/Chobe Systems in Northeast Namibia: Current Practices and Future Opportunities"* whereby data from the subsistence fisheries were collected during a one year period (February 2002-February 2003) at certain areas along the Zambezi and Chobe Rivers. The objectives were to:

- Collect quantitative, qualitative and replicable data regarding the nature and characteristics of the subsistence and recreational fisheries on the Zambezi and Chobe Rivers.
- Develop a system for data collection and analysis of subsistence and recreational fisheries for future use by the Ministry.
- Train personnel in data collection and analysis while developing working relationships with colleagues in the Department of Fisheries, Zambia.

The present means to collect data for stock assessment purposes is by annual biological surveys, using a wide variety of sampling gears and sampling all the representative habitats. It has been argued that while the biological surveys are suitable for insight on stock assessment and biodiversity, it is not reasonable to expect that the results will adequately reflect the exploitation patterns by the inhabitants, due to the limited sampling window of surveys and the habits of fishers. Consequently, policy and legislation emerging to address perceived patterns of overexploitation of fisheries may risk being ineffective or counterproductive if based entirely on the limited knowledge provided by biological surveys.

The Ministry further proposed a pilot project, where selected participants (fisher folk at Impalila) would record their catches on a monthly basis. This would not only provide a year-round source of data reflecting actual exploitation levels, but would also be a means of promoting a new devolution of powers and functions to the community level. With limited manpower at the Ministry's disposal, the incorporation of the communities into the research activities makes sense. This would ensure a relatively inexpensive way of recording data on a monthly basis.

Impalila Island was selected as the site of the Community Catch Data Collection pilot project for three reasons: (i) Fishing composed a significant part of the majority of inhabitant's livelihoods, thereby making the pool of potential participants relatively large; (ii) the island had relatively well developed local institutions, namely the *khuta* or traditional authority, as well as a committee for the emerging area Conservancy, (iii) the island was relatively close to roads that could be used even during the flood season, making follow up visits more feasible.

2.6.2. Results from surveys of subsistence and recreational fisheries in 2002 and 2003.

The following results were published during the project: *"Shared Resource Management on the Zambezi/Chobe Systems in Northeast Namibia: Current Practices and Future Opportunities."* The information documented here were taken from the two reports: River Fisheries Study: February 2002-February 2003 by Næsje et al. 2003 and Interim Report of the Ngweze/Katima Mulilo Fish Market Survey April 2002 to January 2003 by Abbott et al. 2003

2.6.2.1. Subsistence fisheries

During these surveys a total distance of 7850km of river was covered by boat and 4895 fishing gears were recorded. The areas surveyed were mainly Kalimbeza and Impalila, with fewer surveys done at Impalila and Ihaha. The majority of the mesh sizes used for the gill nets were between 39mm and 114mm stretched mesh. The fishing intensity increased between July and November with the lowest fishing intensity in April and May. Overall less than one fisherman per kilometer was recorded during the period and only during October at Kalimbeza 1.2 fishermen per kilometer were recorded. The backwater habitats were found to be the preferred habitats at Kalimbeza with fishing taking place on the floodplains only during the autumn when these habitats are inundated. At Impalila, the mainstream was considered important and the backwater habitats between September and January.

It was found that drag netting targeted the large Cichlidae, especially *Oreochromis andersonii* and *Oreochromis macrochir* whereas *Hydrocynus vittatus* was an important catch with the gill nets.

2.6.2.2. Recreational fisheries

During the same period a total distance of 12383 kilometers was surveyed recording the recreational fisheries. The fishing intensity was very low with an average of 0.017 fishing parties per kilometer. The intensity was the highest in November with the optimum fishing period to be between July and November.

The important species targeted by the recreational fishery are *Hydrocynus vittatus*, *Clarias gariepinus* and the large Cichlidae. The fishermen release the majority of the fish after capture with only trophy individuals kept for mounting purposes.

A report (Van der Waal) on a fishing competition held during August 2008 in the Zambezi River reported the following:

- Although the Zambezi River is renowned for its angling potential, it is not easy to catch certain legally sized fish species anymore. Skill and correct approach is required.
- The catches are dominated by the sharptooth catfish, which is not regarded as the most attractive angling species.
- Catches of the most valued tilapia or 'bream' species were very low.
- It now appears that angling success has seriously declined over the last 20 years. Comparison with earlier records can substantiate this impression.
- Fishing in August should have been a good period, the water temperature was about 20^{o} with tilapia and nembwe and catfish very active and fishing by the local people just starting after the winter.

2.6.3. Species composition of the subsistence gill net fishery at Impalila

Table 2.2. Species composition of gill net catches from the subsistence fishery at Impalila for the community catch data collection project. The species composition for each mesh (50mm, 75mm and 100mm) is indicated separately and for the total as number (N) and weight (W).

	50mm mesh		**75mm mesh**		**100mm mesh**		**Total**	
Species	**% NO**	**% W**	**% NO**	**% W**	**% NO**	**% W**	**% NO**	**% W**
Hydrocynus vittatus	13.4	24.769	21	30.81	19.8	26.6	16.6	27.065
Mormyrus lacerda	0.5	0.422	3.1	2.645	4.6	2.67	2.1	2.299
Serranochromis angusticeps	1.8	1.045	5	4.428	7.2	4.99	3.8	4.253
Sargochromis giardi	0.9	0.918	4.9	6.962	6.9	8.8	3.2	7.198
Clarias gariepinus	0.9	1.392	8.1	9.33	17	20.3	6.5	15.285
Serranochromis robustus	1.2	1.426	3.9	5.245	8.8	9.98	3.7	7.749
Serranochromis macrocephalus	2.4	1.708	8.6	7.153	8.9	5.02	5.3	4.866
Tilapia rendalli	0.6	0.892	4	6.562	6.7	6.9	2.8	5.867
Oreochromis macrochir	0.7	0.632	4	5.95	7.3	5.55	3.1	4.826
Tilapia sparrmanii	5.1	4.073	7	2.824	0.2	0.05	4.3	1.196
Synodontis spp.	23	21.895	8.5	5.194	0.8	0.19	14.4	4.597
Marcusenius macrolepidotus	28.9	19.957	0.6	0.265	0.2	0.12	15.8	3.355
Oreochromis andersonii	0.3	0.388	2.7	1.902	7.6	6.64	2.7	4.784
Schilbe intermedius	13.7	10.578	8.6	3.373	0.3	0.08	9.2	2.366
Labeo spp.	0.2	0.248	0.4	0.341	0.3	0.22	0.3	0.248
Hepsetus odoe	5.8	9.394	8.3	6.246	2.5	1.46	5.5	3.597
Serranochromis altus	0.1	0.06	0.4	0.273	0.3	0.18	0.2	0.174
Parauchenoglanis ngamensis	0.1	0.052	0	0.009			0	0.01
Sargochromis carlottae	0.1	0.058	0.5	0.172	0.5	0.2	0.3	0.174
Clarias stappersii	0.1	0.021	0.4	0.301	0.1	0.03	0.2	0.076
Hemichromis elongatus	0.1	0.073	0	0.019			0	0.015
Total	**7869**	**794.9kg**	**3042**	**877.9kg**	**3702**	**3239.3kg**	**14613**	**4912.0kg**

Hydrocynus vittatus was the most abundant species sampled with the 75 and 100mm mesh nets and the third most abundant sampled with the 50mm mesh net (Table 2.2). The most abundantly sampled species with the 50mm mesh was *Marcusenius macrolepidotus*. *Hydrocynus vittatus* however, contributed the highest percentage in weight for all three-mesh sizes. The Cichlids were important in the weight contribution with 41.2%. In the 100mm mesh the weight contribution of the Cichlids was 48.4%, in the 75mm mesh 41.6% and in the 50mm mesh only 11.3%. The Cichlids, *Hydrocynus vittatus* and *Clarias gariepinus* are the major contributors in weight for the subsistence gill net fishery. These species contributed 83.6% of the total weight sampled. The species sampled with the 50mm mesh can be considered mainly for own consumption presently, as these fish seldom reach the markets. This is however already changing as evidenced by smaller fish now marketed at Katima Mulilo and Sesheke in Zambia where smaller species such as *Schilbe intermedius* and *Marcusenius macrolepidotus* form a significant part of the fish on offer. The 50 to 100mm mesh gill nets from the subsistence fishery caught only 21 different fish species compared to the 73 from the experimental gill nets.

The following conclusions are made:

- *Hydrocynus vittatus* was the most common species recorded by the gill net fishery.
- The Cichlidae, *Clarias gariepinus* and *Hydrocynus vittatus* contributed 83.6% of the total weight sampled.
- Smaller species, *Schilbe intermedius* and *Marcusenius macrolepidotus*, are entering the fish market.

2.6.4. Catch rates and length frequency of the subsistence gill net fishery

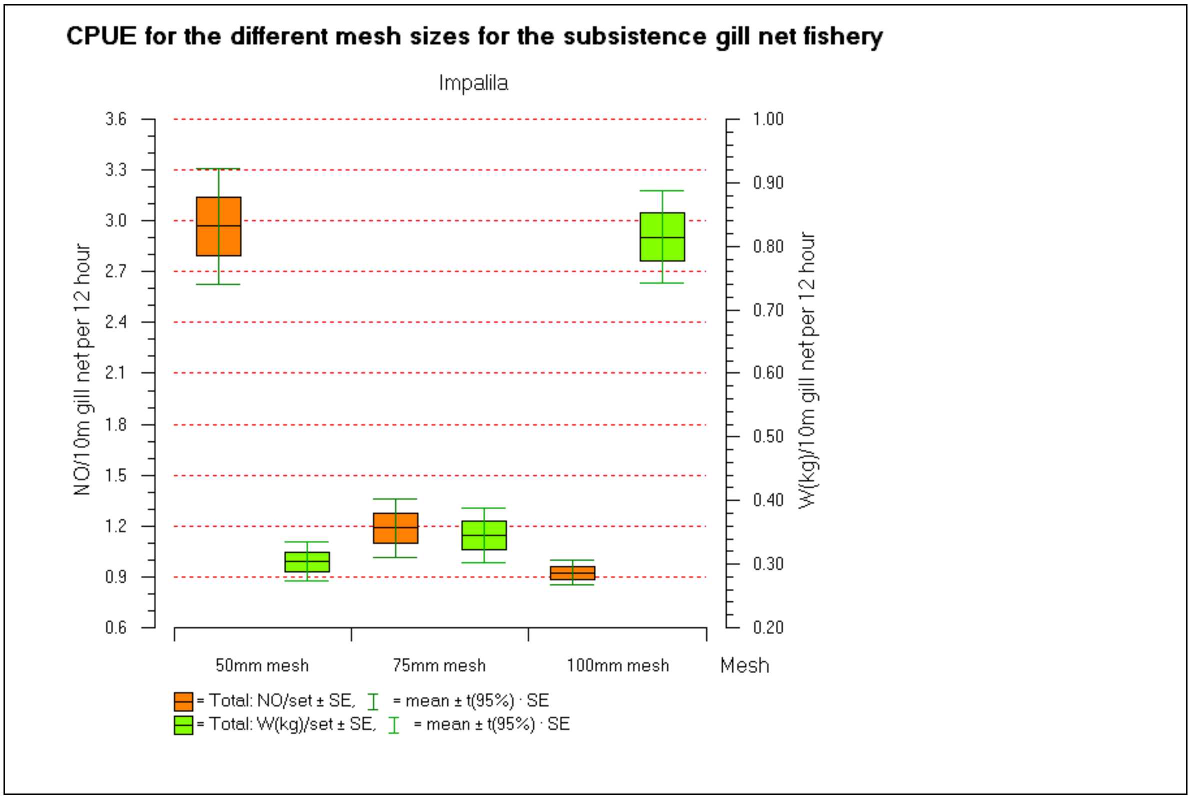

Figure 2.21. Catch per unit effort for the different mesh sizes used by the subsistence gill net fishery at Impalila. This is for both the number and weight.

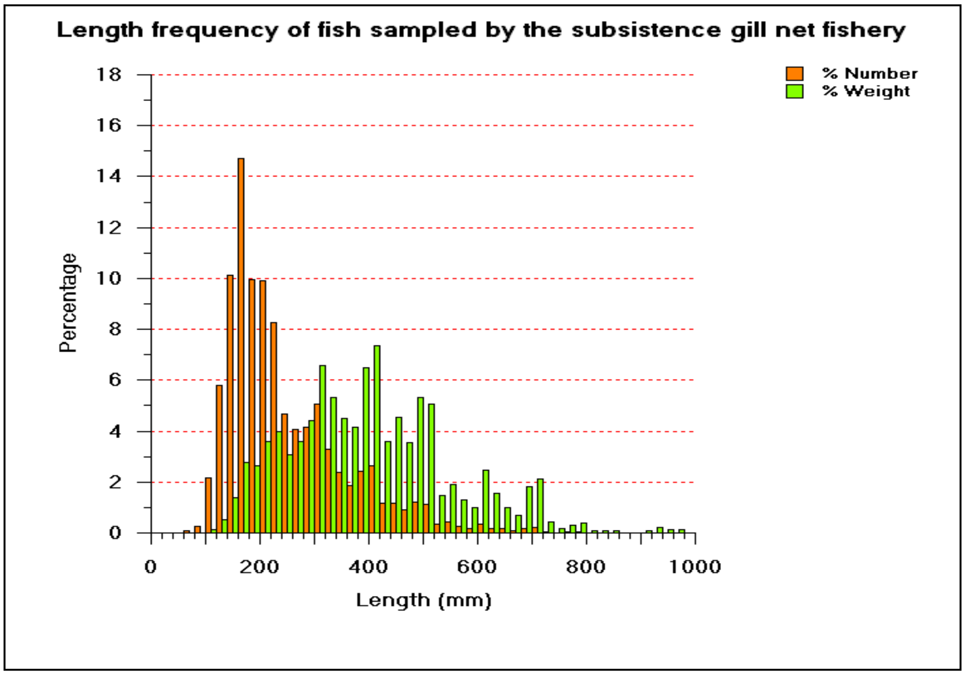

Figure 2.22. Length frequency in percentage number and weight of all fish sampled with three mesh sizes (50mm, 75mm and 100mm) by the subsistence gill net fishery at Impalila during the community catch data collection project.

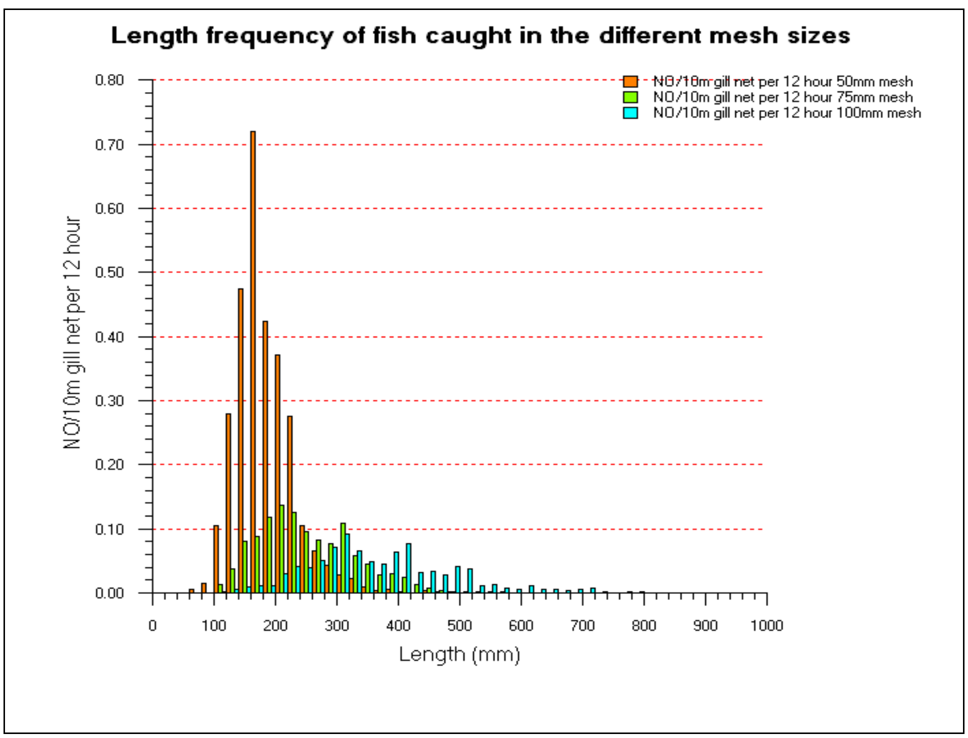

Figure 2.23. Length frequency (Number per 10m gill net per 12 hour setting) for the three mesh sizes used by the subsistence gill net fishery at Impalila for the community catch data collection project.

The catch per unit effort in weight (Figure 2.21) was directly related to the mesh sizes and inversely related to the number per unit effort. Similar mesh sizes used with the experimental gill nets had higher catches in the smaller meshes than those from the subsistence fishery, but similar catches in the 100mm mesh net [see Figure 2.21]. The catches did not have the same pattern as the experimental gill nets, as the largest mesh sizes from the experimental gill nets did not record the highest weight per unit effort. It is not certain whether the fishermen recorded all empty settings. Figure 2.22 gives an overview of the length and the weight frequency per length class of the fish caught during the community catch data collection project at Impalila. The majority of fish were recorded between the 100 and 200mm length classes, but the greater biomass were found between the 300 and 550mm length classes.

Modal fish lengths (Figure 2.23) for the 50mm, 75mm and the 100mm mesh were 160mm, 200mm and 300mm respectively with average lengths of 182mm, 249mm and 366mm. The average weight for each mesh size was 102g for the 50mm mesh, 291g for the 75mm mesh and 881g for the 100mm mesh. The majority of the fish caught with the 50mm mesh were between 100 and 220mm, between 180 and 300mm for the 75mm mesh and between 260 and 400mm for the 100mm mesh.

The following is concluded:

- Catch per unit effort in weight is directly related to mesh size and inversely related in number.
- The majority of the fish caught were between 100 and 200mm in length and the majority of the biomass between length classes 300 and 550mm.

2.7. Estimated yield

The gill nets used during the community catch data collection project at Impalila used 50mm, 75mm and 100mm mesh sizes that was representative of the gill nets used by the subsistence fishery. Although the present legal minimum mesh size according to the Inland Fisheries Legislation is 76mm, small mesh size gill nets are still being used. The calculated catch per unit effort in weight from the project for all three mesh sizes combined are 2.7kg/50m gill net per 12 hour setting. Although the number of nets presently used per day are unknown, a figure of 1500 gill nets per day are set is estimated. When considering that an estimated total of 1500 nets are set per day, this calculates to a total yield of 1478 tons per annum. This is only for the gill nets and does not include all the other fishing sampling gears. This estimation can be considered acceptable if the following hypothesis is true:

- The gill nets used are 50m in length and set for 12 hours per day.
- An average of 1500 gill nets are set per day for a 365-day year (average of 10 nets/km of river, laterally dissected).
- The gill nets used by the project at Impalila have the same selectivity as the nets used by the subsistence fishery throughout the system.

The yield estimated by a household survey (Stephanus et al. 2002) done in the region was between 733 and 2568 tons per annum depending on the number of gill nets used by the households. The yield calculated during this report (1478 tons) corresponds with the yield from the household survey (1478 tons) if three gill net sets (1467 tons) are used per fisher.

2.8. Growth and mortality rates

2.8.1. Background

In the absence of scale data for the determination of age and growth rates for selected fish species, length frequency data was used to determine relative age and growth rates. The data recorded were stored in the customized database Pasgear2 (version 2.3 01/09/2008, Jeppe Kolding and Aasmund Skaalevik). The data output from Pasgear were temporal length frequencies for the selected species. Data collected using all the different gear types were used for the calculation of the growth parameters needed for the Von Bertallanfy growth equation. This ensured that the smallest individuals were also taken into account for the growth predictions. The data used for the mortality estimates were only from the gill net catches and the selectivity (selectivity is explained in the report) of the gill nets was also taken into account. The data were exported to FAO-ICLARM Fish Stock Assessment Tool (Fisat II Version 1.2.0.2. by Gayanilo 2002) for the growth and mortality estimates.

The following calculations were made:

1. Estimation of the basic growth parameters (L-infinity (L_∞) and the curvature parameter (K)) were done by doing a K-Scan with the direct fit of the length frequency data exported from Pasgear in the ELEFAN I module. The Von Bertalanffy growth curve is then superimposed on the length frequency data. It is important to note that K, on its own, cannot be used to compare growth rates. L infinity must also be taken into account. Therefore phi-prime (**Ø)** is calculated for the growth rate.
2. Total mortality (Z) is estimated from a linearized length-converted catch curve using the length frequency data exported from Pasgear with the selectivity of the gill nets taken into account.
3. The natural mortality (M) is estimated using Pauly's empirical formula with an input water temperature of 23 °C (mean annual water temperature from the Zambezi River).
4. With the Total mortality being Z = M+F, the fishing mortality (F) was calculated by subtracting the natural mortality from the total mortality.
5. The Exploitation rate was also calculated by F/Z. E is the fraction of the total production. It is expected that the maximum exploitation rate should be 0.5.

The species selected for the analysis were all important in the catches of the subsistence fishery at Impalila. This also included catches from the two-inch gill nets.

2.8.2. Basic growth and mortality parameters

During the estimation of the growth parameters, it was found that the data is not well suited for the calculation of the growth parameters L_∞ and K. The reason is that the surveys were too widespread and that cohorts, especially for the r-selected fish species, may disappear between surveys. However, growth estimations could be done for the larger growing species. Unfortunately, again for the *Oreochromis andersonii* and *Oreochromis macrochir*, the absence of certain length classes did create difficulties during the analysis.

The growth rate for *Hydrocynus vittatus* is similar to the growth rates found from Lake Bangwuelu (Kolding *et al*. 2003). Different mortality rates were found for the smaller and for the larger individuals of *Hydrocynus vittatus*. As can be expected, the total mortality for the smaller individuals was higher than those for the larger individuals.

It is important to keep in mind that there is a difference between production and productivity. According to Kolding and Giordano (2001) production is a density dependent quantity expressed in a weight unit in a given area or volume whereas productivity is seen as the rate at which production is generated and is related to the individual biological regenerative capacity of a species and the density of the stock.

Table 2.3. Summary of the growth and mortality parameters calculated from the length frequency analysis of fish sampled in the Zambezi and Chobe Rivers between 1997 and 2007. L_∞ and K are the growth parameters for the von Bertalanffy growth equation. Ø is the growth performance index calculated with L_∞ and K as input. Z and Clz are the estimated total annual mortality and the 95% confidence intervals. M is the natural mortality (from Pauly's empirical equation), F the fishing mortality and E the exploitation rate (F/Z).

Species	L_∞	**K**	**Ø**	**Z**	**Clz**	**M**	**F**	**E**
Hydrocynus vittatus	71.4cm	0.26	3.122	0.99	0.82-1.16	0.53	0.46	0.46
Marcusenius macrolepidotus	22.5cm	0.52	2.420	2.07	1.90-2.25	1.15	0.92	0.44
Clarias gariepinus	101.8cm	0.19	3.294	0.54	0.45-0.63	0.39	0.15	0.28
Schilbe intermedius	31.0cm	0.26	2.398	1.37	1.28-1.46	0.67	0.70	0.51
Oreochromis macrochir	31.0cm	0.220	2.325	1.42	1.17-1.66	0.60	0.82	0.57
Oreochromis andersonii	46.7cm	0.17	2.569	1.03	0.85-1.21	0.45	0.58	0.56
Serranochromis macrocephalus	37.3cm	0.42	2.767	1.27	0.85-1.68	0.87	0.40	0.31

One could elaborate and say that as long as the CPUE of the unfished areas are not more than double those of the fished areas; a system is theoretically not over fished. Meaning that as long as the exploitation rate (E) is less than 0.5 a species can be considered not over utilized. Taking this into consideration, Table 2.3 indicated that only two species (*Clarias gariepinus* and *Serranochromis macrocephalus*) were under utilized, whereas *Oreochromis andersonii* and *Oreochromis macrochir* were over utilized in the system. The other species were utilized close to their carrying capacity. The fishing mortality for *Oreochromis andersonii, Oreochromis macrochir* and *Schilbe intermedius* was actually higher than the natural mortality according to table 2.3.

Despite the importance of *Hydrocynus vittatus, Clarias gariepinus* and *Serranochromis macrocephalus* in the subsistence gill net fishery, these species were not overfished. It must be taken into consideration that the importance of *Clarias gariepinus* in the catches by the subsistence fishery was due to the weight. Also the people in Caprivi do not prefer this species and fisher folk will not target this species. *Hydrocynus vittatus* is a migratory species, which may mitigate the effect harvesting may have on it.

Oreochromis andersonii and *Oreochromis macrochir* were found to be very susceptible to drag netting especially during the breeding season when these species aggregate in shallow habitats constructing nests. This makes these species a very easy target during these periods. Migration and breeding behaviour of species are aspects that will affect their vulnerability. This may have played a role with *Marcusenius macrolepidotus* with a high fishing mortality. During a telemetry study on *Oreochromis macrochir*, a high recapture percentage by the subsistence fishery was found. *Oreochromis macrochir* has small movements and may be locally vulnerable to over fishing. Multilateral management regulations should be put in place to protect species such as *Oreochromis macrochir* to prevent similar species being protected in one area and over fished from other areas. *Serranochromis robustus* show similar movements as *Oreochromis macrochir* and will need similar management approaches. A study on the drag netting of the subsistence fishery found that certain species were more susceptible to drag netting than others, especially the *Oreochromis, Tilapia* and *Sargochromis* spp. The large species of the Cichlidae were all vulnerable to selected fishing by the subsistence fishery and needs to be addressed.

The following conclusions can be made:

- The data are not well suited for the calculation of growth and mortality parameters.
- Different mortality rates were found between the small and large individuals of *Hydrocynus vittatus*.
- *Oreochromis andersonii* and *Oreochromis macrochir* were found to be over utilized.
- Despite the importance of *Clarias gariepinus, Serranochromis macrocephalus and Hydrocynus vittatus* within the subsistence fishery, these species were not over utilized.

2.9. Annual flood cycle

2.9.1. Background

The annual flood cycle is the main stimulus of the production of any floodplain river system. Production is enhanced with the influx of nutrients that get released into the system when terrestrial plant material become flooded and starts to decompose. The annual flood is also the stimulus for several fish species to start breeding, several fish migrations are initiated during this period, both laterally and longitudinally. The newly inundated areas also serve as refuge sites for fish larvae and the sudden increase in food improves the survival rate of the juveniles.

The magnitude of the flood may influence the fish production in more than one way. An increase in water temperature is the main stimulus for the Cichlidae to start breeding, so the magnitude may not affect the level of success of breeding for these species, but may contribute towards the survival rate of the juveniles. For other species, such as the Clariidae, successful breeding depends on the annual flood and therefore also on the timing of the flood.

To determine the effect flooding has on the fish production, the average catch per unit effort of the different stations was used as an indicator for fish production. Surveys done at the stations Katima Mulilo, Kalimbeza, Impalila and Kabula during the winter months were taken into account. Lake Lisikili was not included as this is considered a lake and might have influenced the results from the riverine stations. Furthermore, the catches were divided into three groups, those sampled with the small mesh sizes (22 to 35mm), the medium mesh sizes (45 to 73mm) and the large mesh sizes (93 to 150mm). The reason is to see whether there is a time lag effect between the different size classes.

A simple regression was calculated to determine the functional dependence of the one dependent variable (the CPUE) on the other independent variable (the annual flood). An index was developed for the flooding to take into account the duration of the flood as well as the height of the flood. The index was formulated as follows:

Flood index = N x H
Where:
N = Number of days of flood higher than 2m
H = average height of flood level in meters during that period

The effect the peak level of the annual flood had on the catch per unit effort was also studied.

2.9.2. Effect of flood on the CPUE

The results indicated the following:

Table 2.4. The correlation between the catch per unit effort in weight of experimental gill nets for the 22 to 35mm mesh group and the flood index (taking into account the number of days the flood exceeded 2m and the average height during that period).

R^2	P-value	Flood year
0.47	0.0608	Same year
0.11	0.4212	One year
0.32	0.1427	Two years

Table 2.5. The correlation between the catch per unit effort in weight of experimental gill nets for the 45 to 73mm mesh group and the flood index (taking into account the number of days the flood exceeded 2m and the average height during that period).

R^2	P-value	Flood year
0.35	0.1196	Same year
0.07	0.5436	One year
0.67	0.0125	Two years

Table 2.6. The correlation between the catch per unit effort in weight of experimental gill nets for the 93 to 150mm mesh group and the flood index (taking into account the number of days the flood exceeded 2m and the average height during that period).

R^2	P-value	Flood year
0.37	0.1104	Same year
0.001	0.9999	One year
0.27	0.1853	Two years

Table 2.7. The correlation between the catch per unit effort in weight of experimental gill nets for the total mesh group and the flood index (taking into account the number of days the flood exceeded 2m and the average height during that period).

R^2	P-value	Flood year
0.46	0.0653	Same year
0.06	0.5555	One year
0.45	0.0685	Two years

Table 2.8. The correlation between the catch per unit effort in weight for the 22 to 35mm mesh group and the peak flood level.

R^2	P-value	Flood year
0.35	0.1203	Same year
0.04	0.6448	One year
0.60	0.0241	Two years

Table 2.9. The correlation between the catch per unit effort in weight for the 45 to 73mm mesh group and the peak flood level.

R^2	P-value	Flood year
0.29	0.1715	Same year
0.01	0.8179	One year
0.84	0.001	Two years

Table 2.10. The correlation between the catch per unit effort in weight for the 93 to 150mm mesh group and the peak flood level.

R^2	P-value	Flood year
0.27	0.1819	Same year
0.01	0.8661	One year
0.40	0.0944	Two years

Table 2.11. The correlation between the catch per unit effort in weight for all mesh groups combined and the peak flood level.

R^2	P-value	Flood year
0.35	0.1215	Same year
0.01	0.7942	One year
0.69	0.0107	Two years

The flood level had a significant impact on the catch per unit effort two years prior to the sampling of the fish. This is when tested against a 95% significant level. This was for the mesh group 45 to 73mm when considering the flood index and for the mesh groups 22 to 35mm and 45 to 73mm and also for all the catches combined when taking the peak water level into consideration. The impact of the flood level is considered significant for the 93 to 150mm mesh group at a 90% significant level. This is only for the peak water level. The overall low number of fish sampled with the 93 to 150mm mesh sizes might have affected the outcome of the results for this particular mesh group. The flood level one year prior to the sampling did not have any impact on the catch per unit effort.

The peak water level was the main contributor towards fish production. It is likely that fish production may be influenced by the flood cycle from more than one specific year. A combination of two years or even more may culminate in the effect the flood cycle has on fish production.

The flooding occurred between February and the beginning of July and the catches recorded between April and August. Although the flooding after April may not have contributed towards the breeding success, it did play a role in the survival of the larvae but only after two years these small fish were big enough to be caught in the nets.

The following conclusions can be made:

- According to these results, there was a two-year time lag before the effect of a flood could be detected within the fish stock.
- The highest peak of a flood two years prior significantly impacted on the CPUE for the mesh groups 22 to 35mm, 45 to 73mm and all the mesh sizes combined.
- The 93 to 150mm mesh group was impacted by the flood tested against a 90% significance level although a low number of fish were sampled with this mesh group.

2.10. Fish population dynamics of Lake Liambezi

2.10.1. Background

Lake Liambezi was flooded periodically during the last two centuries. The lake receives water via the Linyanti swamps from the Kwando River when in flood, although the flood may take time to reach the lake due to the vast floodplains and marshes in the Kwando River. Water will also reach the lake via the Bukalo channel from the Zambezi River when the level is seven meters or more at Katima Mulilo. A considerable amount of water can enter the lake from the backing up of the Chobe River if the period of flooding is sufficiently long and height high enough (about six meters at Katima). Direct rain and runoff from its own catchment play a role during wet years with above average rainfall. Outflow into the Chobe River will take place when the lake is filled to capacity.

The cyclic episodes of drying and filling of the lake and also the variability of the lake level when full make Lake Liambezi a very productive area for fish. These episodic events determine the usage of the lake by the communities. During flooding periods, fishing will be an important income provider whereas the lake is utilized for cattle grazing and for the planting of crops during the dry periods.

The water level during 1985 to 1986 declined to such a level that the lake was totally dry in March 1986. The surveys done during this period represents a fish population composition where changes took place during a decline in the water level. In contrast, the surveys done during 2004 to 2005 can be seen as representing pioneer fish species entering the lake during initial flooding of the lake.

Three survey periods in Lake Liambezi were carried out since the early 1970's. These were surveys done by van der Waal in 1973 to 1975, Grobler in 1985 to 1986 and by the Ministry of Fisheries and Marine Resources from 2001 to 2007.

The following analysis will be done:

- Data collected by the Ministry between 2001 and 2007
- Comparison between surveys 2004-2005 and 1985-1986.
- Data collected by van der Waal between 1973 and 1975
- Comparison between the three datasets

Firstly analysis will only include the surveys done in 1985-1986 and 2004-2005. The reason is that the same multifilament gill nets with the same mesh sizes were used in both periods. Only the 35mm to 150mm mesh sizes were analyzed from 2004-2005, as these were the only mesh sizes used during the 1985-1986 surveys.

2.10.2. Surveys done between 2001 and 2007

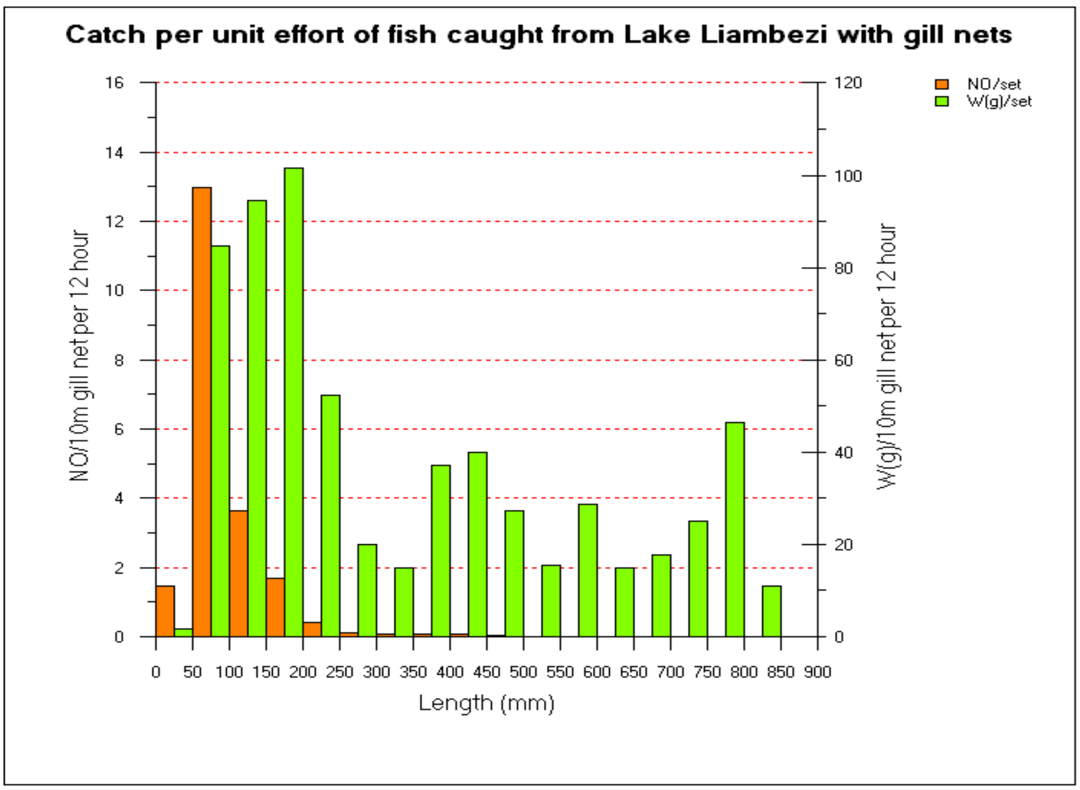

Figure 2.24. Catch per unit effort (in number and in weight) per length group of fish caught from Lake Liambezi between 2001 and 2007 with the multifilament gill nets (12-150mm mesh sizes).

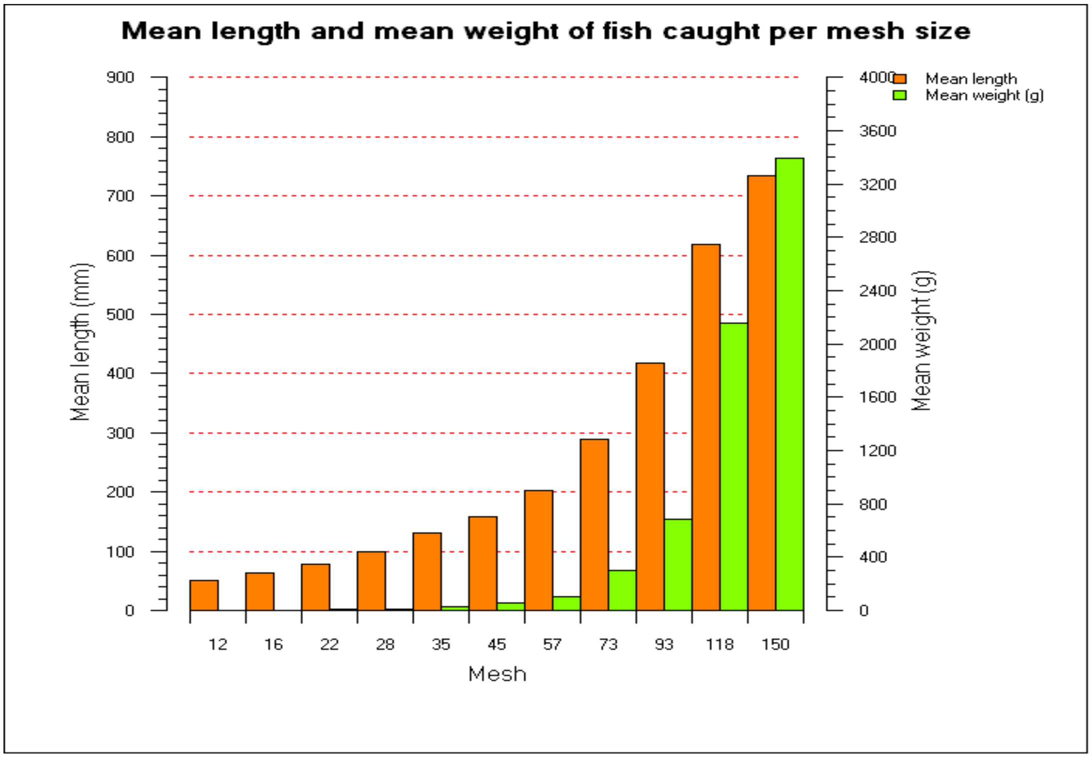

Figure 2.25. Mean length and mean weight of fish caught from Lake Liambezi per mesh size of the multifilament gill nets (12-150mm) during the period 2001 to 2007.

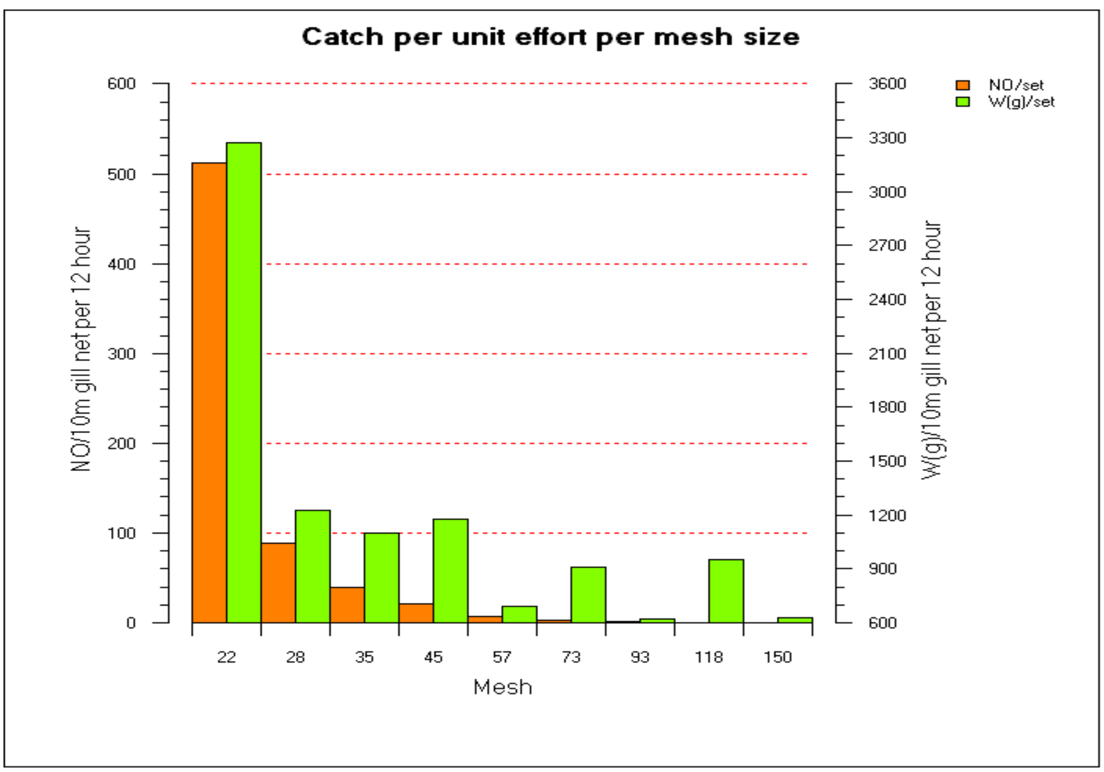

Figure 2.26. Catch per unit effort of fish caught per mesh size (22-150mm) from Lake Liambezi for the period 2001 to 2007. The catch per unit effort is calculated in 10m gill net per 12 hour setting.

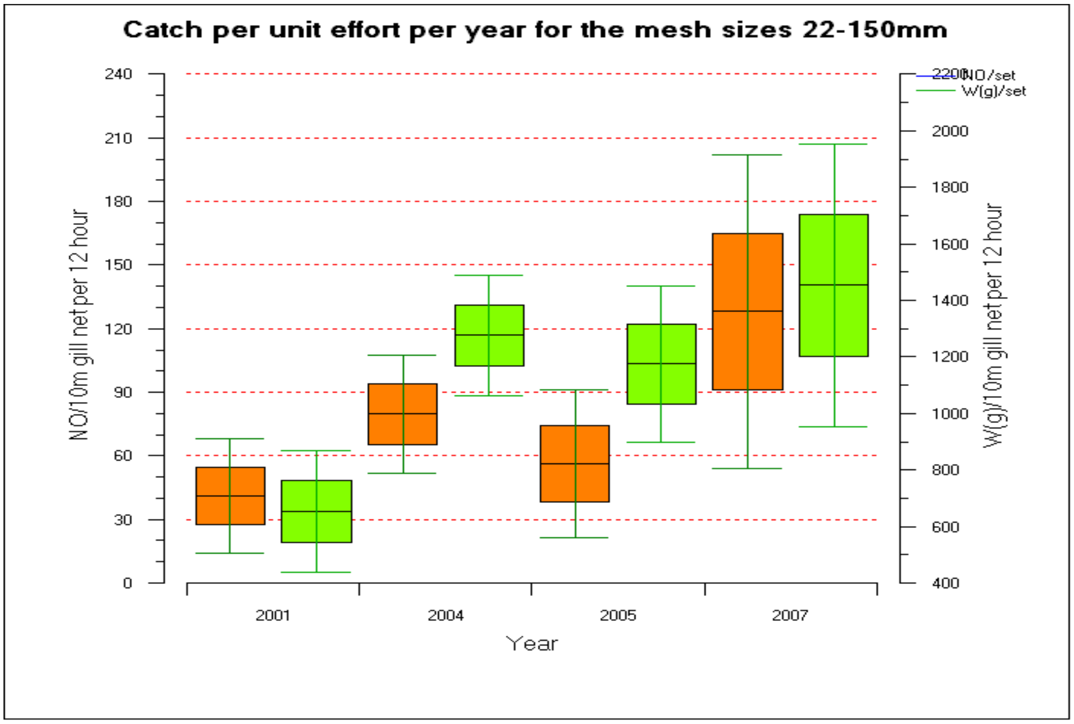

Figure 2.27. Catch per unit effort from Lake Liambezi for the different years for the mesh sizes 22-150mm.

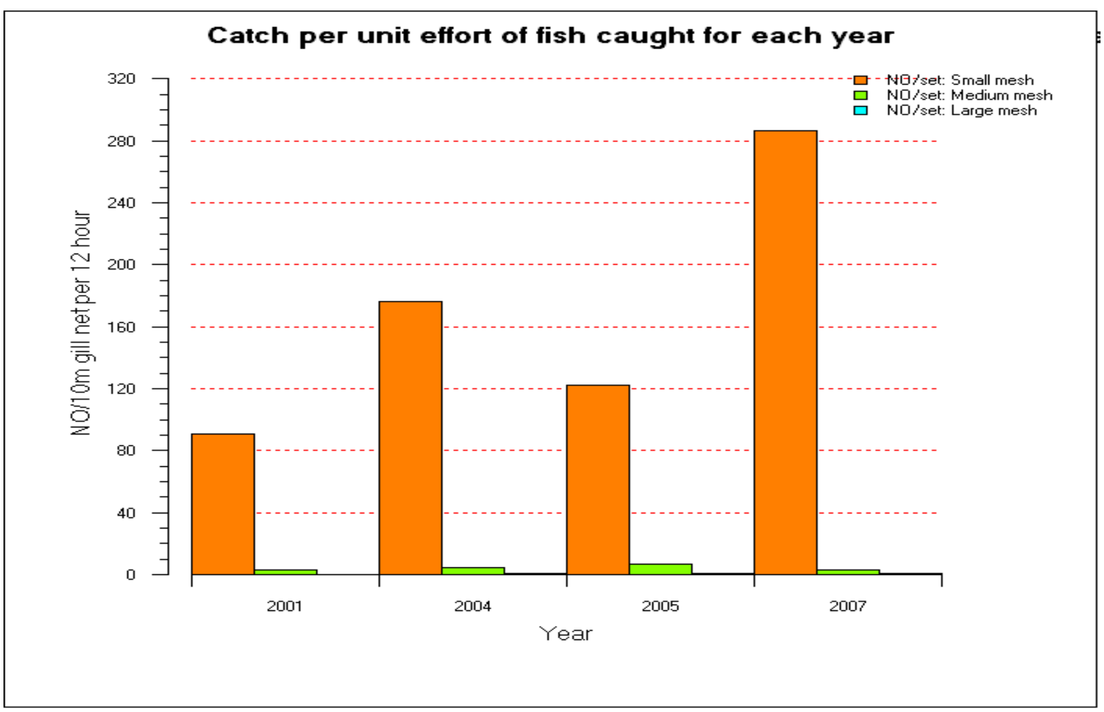

Figure 2.28. Catch per unit effort in number for the small mesh sizes (22-45mm), the medium mesh sizes (57-73mm) and the large mesh sizes (93-150mm) of fish caught from Lake Liambezi for each year for the multifilament gill nets.

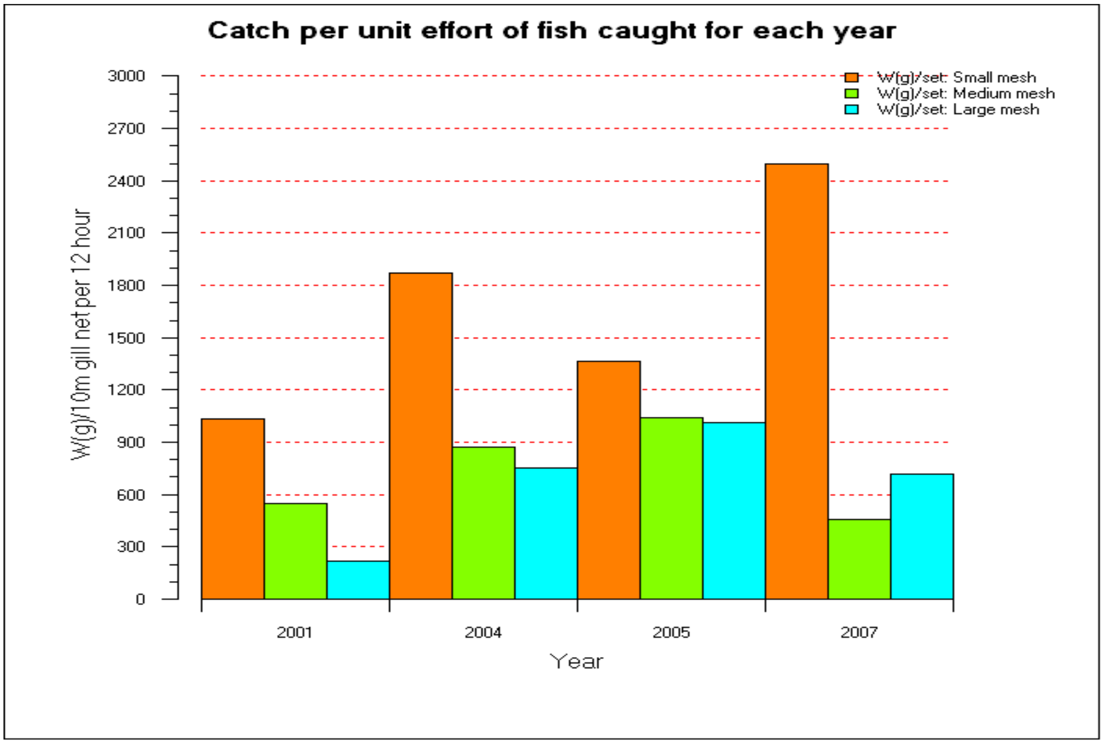

Figure 2.29. Catch per unit effort in weight for the small mesh sizes (22-45mm), the medium mesh sizes (57-73mm) and the large mesh sizes (93-150mm) of fish caught from Lake Liambezi for each year for the multifilament gill nets (22-150mm).

The majority of fish caught with the multifilament gill nets were smaller than 200mm. Very few fish smaller than 50mm were sampled. Small fish dominated the catches also in weight where the length classes 100mm to 250mm had the highest weight per gill net set.

Both the mean length as well as the mean weight per fish increased per mesh size with the largest mean length and mean weight sampled with the 150mm mesh. The increase per mesh size in length and weight is exponential.

The 22mm mesh had the highest catch per unit effort both in number as well as in weight. The catches in number decreased with an increase in mesh size with a similar tendency for the catches in weight. The smaller species were dominating the catches in number and in weight in Lake Liambezi.

The survey during 2007 had the highest catch per unit effort in number and in weight. Very few fish were sampled during 2001. The trend shows an increase in catches between 2001 and 2007.

The catch per unit effort in number was dominated by the small mesh sizes with the highest catch in 2007. The medium and large mesh sizes sampled very few fish in number compared to the small mesh sizes.

The small mesh sizes even dominated the catches in weight. The highest catch for the small mesh sizes was also in 2007 with the highest catch for the medium and large mesh sizes in 2005.

The survey during 2003 will be disregarded during this report due to the low number of fish sampled. *Barbus paludinosus* was the most dominant species in number (38 236 fish) sampled from Lake Liambezi and had an Index of Relative Importance of 51.4%. *Barbus poechii* was the second most common species in numbers (14523 fish) sampled. *Clarias gariepinus* had the highest weight contribution with a total weight of 146.59kg sampled.

Barbus paludinosus had the highest Index of Relative Importance for all the different sampling periods followed by *Barbus poechii*. *Barbus poechii* was only replaced by *Schilbe intermedius* as the second most important species during 2005.

The most important family from Lake Liambezi was the Cyprinidae which was represented by 12 species. The Cichlidae, although not very important according to the Index of Relative Importance, had the highest diversity with 14 species. *Oreochromis andersonii* was the most important Cichlidae, but was not considered very common in the lake.

The highest number of species was sampled during 2004 with 34 species, followed by the survey during 2001 with 27 species and 22 species sampled during 2005 and 2007.

The surveys done by van der Waal during 1973 to 1975 had a different species composition than the surveys done during 2001 to 2007. *Barbus paludinosus*, the most common species sampled during the latter surveys was not even present during the 1970's. *Oreochromis macrochir* on the contrary was a common species during the 1970's with very few individuals sampled during the period 2001 to 2007.

Table:2.12. Comparison between CPUE (10m/12hour) during the three different survey periods.

1973 to 1975		**1985 to 1986**		**2001 to 2007**	
Mesh (mm)	**Weight/10m net**	**Mesh (mm)**	**Weight/10m net**	**Mesh (mm)**	**Weight/10m net**
-		-		22	3.3
25	1.9	-		28	1.2
-		35	0.4	35	1.1
50	3.7	45	0.7	45	1.2
60	5.0	57	1.2	57	0.7
80	4.0	73	2.0	73	0.9
96	1.7	93	1.0	93	0.6
127	0.7	118	0.7	118	1.0
140	0.7	150	0.5	150	0.6

Although the mesh sizes differed between the two sampling periods, there is an indication that the earlier surveys had much higher catches than those during 2001 to 2007. Only the second largest mesh size had a higher catch during the latter surveys. Much higher catches were recorded during the 1970's with the medium size meshes.

2.10.3. Species composition comparison between the three different survey periods

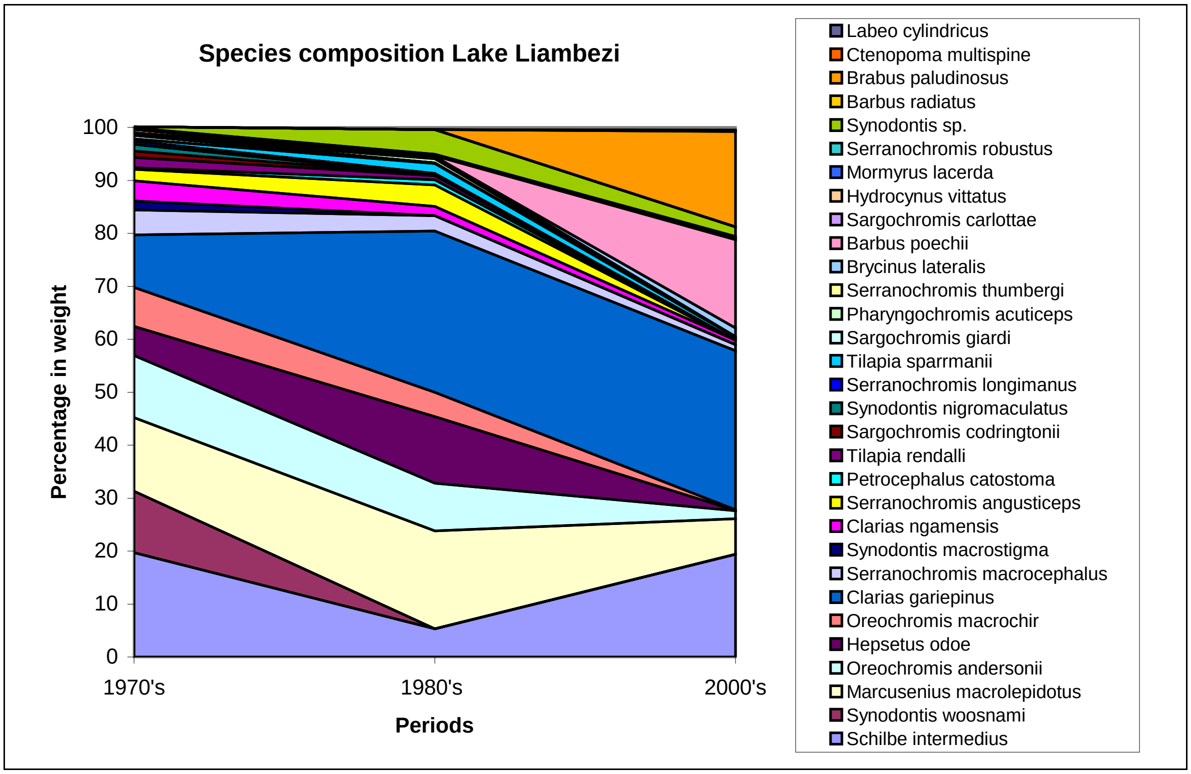

Figure 2.30. Species composition (percentage weight) of fish caught in Lake Liambezi for the three different survey periods. These periods were 1973-1975, 1985-1986 and 2001-2007.

The species composition differs between the three different survey periods. A higher number of species can be seen from the 1970's compared to those from the latter surveys between 2001 and 2007. It is important to keep in mind that the mesh sizes were not the same. The species composition for the surveys 2001 to 2007 was dominated by a small number of pioneer species such as *Schilbe intermedius, Clarias gariepinus, Barbus poechii* and *Barbus paludinosus*. The important species in weight during the 1980's were *Marcusenius macrolepidotus, Hepsetus odoe, Clarias gariepinus* and *Oreochromis andersonii* and in the 1970's *Schilbe intermedius, Marcusenius macrolepidotus, Oreochromis andersonii, Clarias gariepinus* and *Oreochromis macrochir*.

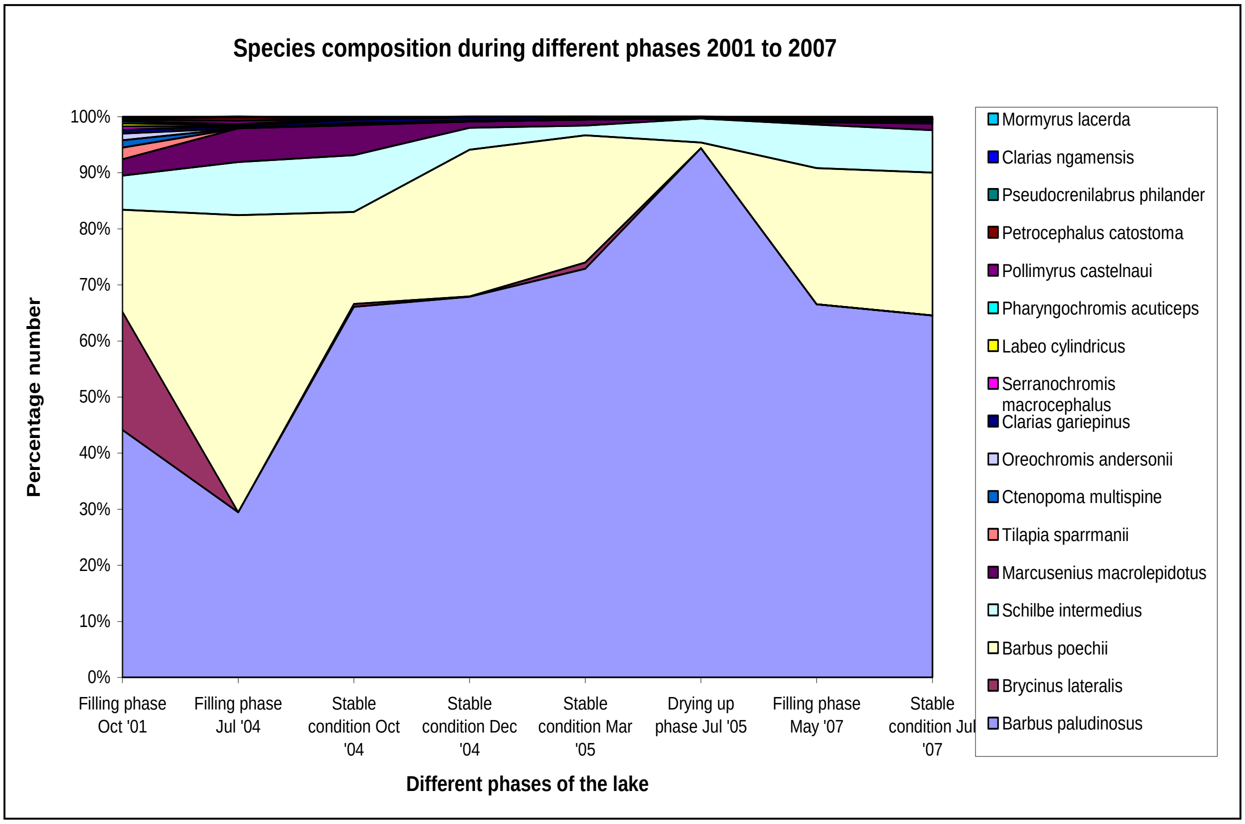

Figure 2.31. Species composition in percentage number sampled with the multifilament gill nets from Lake Liambezi during different phases of the lake (2001 to 2007).

The number of species was the lowest during the drying up phases of the lake and the highest number of species during the filling phase in October 2001. *Barbus paludinosus* became increasingly important as the lake level decreased with this species really dominating the catches in July 2005.

The picture is slightly different when considering the weight contribution of the different species with *Clarias gariepinus, Barbus paludinosus* and *Schilbe intermedius* the important contributors.

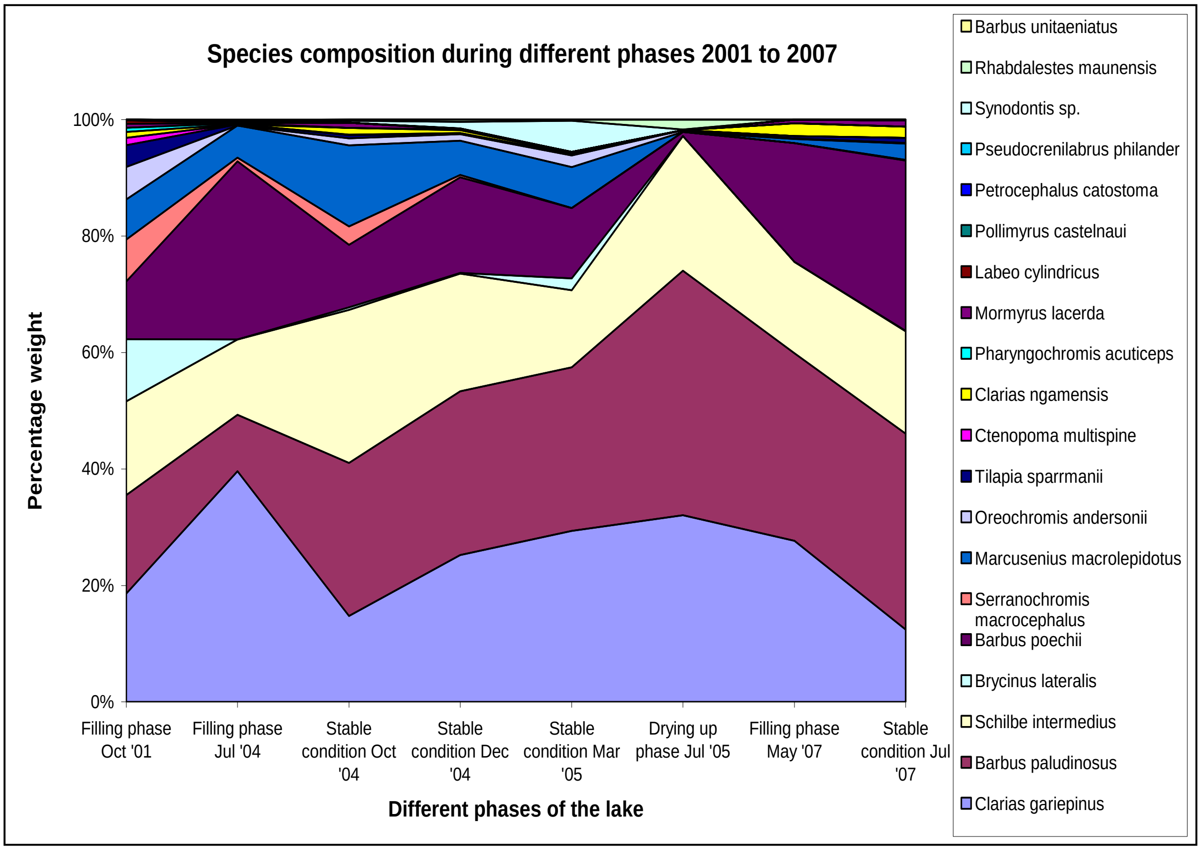

Figure 2.32. Species composition in percentage weight sampled with the multifilament gill nets from Lake Liambezi during different phases of the lake (2001 to 2007).

3. Managing a floodplain fishery

3.1. Background

Management of freshwater fish resources (in particular floodplain fisheries) has been debated in depth all over Africa. Whether management is actually effectively implemented is questionable if one studies the history of fisheries management in different parts of Africa. Fisheries management is not about managing the fish stocks, but rather managing the fishing activities by fishermen and the communities. The development of a management plan can be considered the easy part when compared with the implementation process. The question should be asked whether management of such a dynamic and fluctuating system as the Zambezi Floodplain River would have any impact on the fish community at all and then in such a way that it would benefit the rural communities. The government is bound by the Namibian Constitution (Article 95) *"The state shall actively promote and maintain the welfare of the people by adopting --- policies aimed at --- maintenance of ecosystems, essential ecological processes and biological diversity of Namibia and utilization of living natural resources on a sustainable basis for the benefit of all Namibians, both present and future."* The fact that the Upper Zambezi River flows through several countries further complicates the management aspect of the resource. To develop legislation in any particular country is already a very difficult task, but to expand this to include several countries asks for patience, skill and trust.

One aspect, which had not been taken much into consideration during most of the stock assessment studies, is the inter- and intra annual environmental variability of a pulsed system. The annual flood cycle of the Zambezi River is the main driving force of nutrient input into the system stimulating biological productivity. Variability of fish stocks in pulsed river systems such as the Zambezi River occurs naturally whether the system is exploited or not. Several aspects of the flood play an important role in the biological production and can be listed as follows:

- The timing of the flood.
- The magnitude of the flood.
- The duration of the flood.
- The number of flood peaks.
- The rate at which the floodplains inundate and the rate at which the flood recedes.

Fish species and communities in highly pulsed systems naturally respond to the unpredictability of the flood regime. They compensate for the variability by having short trophic pathways, lateral and longitudinal migratory behaviour, many are colonizers, have short life cycles, seasonal spawning with a high fecundity with no parental care. These species are also *r*-selected, growth to maturity is fast, within 1-2 years. The natural mortality is variable, the biomass is low, but the productivity is high. Furthermore, the species are very resilient, with a high potential yield. Some of the larger species do however exhibit some K selected traits such as slow growth, late maturity, high age and size and feeding specialization. This group of fish is thus more susceptible to fishing pressure than the first group.

Fishing mortality can be seen as ‘unnatural’ in that the mortality impact by fishing is sometimes selective depending on factors outside nature, such as demand and supply.

Many floodplain fisheries in Africa have a tendency to target the larger fish species, which can be seen as market related and more energy efficient. This selective fishing may lead to the phenomenon where the small short-lived species replace larger longer-lived species as the fishery matures. The reason usually is that the short-lived species can better withstand higher fishing pressure (mortalities) due to their short turn-over rate. This can also be described as fishing down the food web as new small sized fish resources are entering the fishery with a decrease in abundance of the larger individuals. Any floodplain fishery is likely to move towards targeting smaller fish species as the large species start to disappear from the catches. Fishermen have the ability to adapt to changes in the catches, especially if it is for household consumption. Fishermen would then easily change to smaller mesh sizes or using traditional gear to target smaller floodplain species, especially during the receding phase of the flood or during migration periods. Fishing for a market with a specific preference could lead to a totally different scenario where the increase in effort becomes capital driven. This is where more efficient sampling equipment or methodologies are incorporated. By doing this, it is imperative that catches justify the investment. The rural poor seldom form part of the capital driven fishery that is undertaken by the wealthier section of the community, who do not depend on the fish resource for a daily protein source. This can lead to a fishery where the rich get richer and the poor even poorer. For this reason the Namibian Government decided that the poor rural communities should be protected and that a commercial fishery on the floodplain rivers would not be desirable.

An example of a collapsed *Oreochromis* spp. fishery can be found in Lake Malombe in Malawi. The annual yield declined from 9300 ton to between 50 and 200 ton per year. The United Nations Food and Agricultural Organization (FAO) concluded that the 0+ and 1 year juveniles were overfished mainly by small mesh beach seine nets and purse seine nets. Destruction of the breeding habitats by dragging nets further aggravated the problem. Fish that escaped the seine nets were targeted by the gill nets in the deeper water habitats. This combined effect probably led to the collapse of the *Oreochromis* spp. fishery in Lake Malombe in Malawi.

The Ministry of Fisheries and Marine Resources engaged in the development of an Inland Fisheries Policy and Legislation in 1993. All important fishery regions were visited by the Ministry to acquire input from the stakeholders to ensure that their fisheries experience and concerns regarding the resource are noted. Whether all stakeholders had the opportunity to air their views is debatable, but at least a forum was created where all stakeholders could participate. There is a saying "You do not have to be good to start, but you have to start to be good". At least the Ministry developed a policy and legislation that could be modified over time. The White Paper *"Responsible Management of the Inland Fisheries of Namibia"* was published in 1995 and the Act was promulgated in 2003.

The Inland Fisheries Policy addresses the sustainable management of the inland fish resources and is based on the following principles:

- To allow sustainable utilization of resources and to protect the biodiversity of the freshwater fish in the country.
- Different management approaches are devised to deal with each particular river system.
- The interest of the subsistence households are protected in terms of the availability of fish as a supplement to their diet and is given priority over the commercialization of the fish resource.
- The control of fishing and the protection of the resources through gear restrictions are adopted. Preference is given to passive gear and traditional gear in preference to modern equipment.
- The control and law enforcement will be carried out by law officers already employed by other Ministries with assistance from the traditional authorities.
- The principle that local people in communal areas should share in the income generated by commercialization or use of communal resources is followed.
- Future research policies on freshwater fish and the establishment of a multi-disciplinary research station to eventually serve the region is addressed.
- The need for regional co-operation on inland waters and related matters between states in the region that share these river systems is emphasized.

The present management of the fish resource in the Caprivi is twofold; management by central government and management by the traditional authority. The management by central government is formalized by the Inland Fisheries Resources Act of 2003 and based on the concept of restriction of fishing effort in the form of restricting fishing gear type allowed, minimum mesh size, maximum number of gill nets allowed per fisherman and the method used to catch fish. Further restrictions may include closed fishing seasons or the establishment of fish sanctuaries.

Management by the traditional authority is not yet formalized in any document or regulation and takes effect by means of the restriction on the use of certain gear types and also access rights to certain fishing grounds as arranged by the Traditional Authority (Khuta), Silalo induna and village induna. No access restriction to fishing areas is enforced during the high water period. During low water periods, permission is needed for fishing in isolated pools (known as mulapo [pl milapo] and lisa [pl masa]) and backwaters. Usually the mainstream is seen as open access and permission is not needed to fish in these waters.

The communities are all supportive of the management of the fish resources and the reasons listed by them are:

- Increasing number and magnitude of conflicts over the fisheries.
- A perceived decline in the fish stocks.
- Population driven increase in the fishing effort due to people migrating into the region due to the failure of crops because of droughts.
- Price increase at fish markets.
- Fish are seen as a quick cash converter when needed.

3.2. Fishery management approaches and their present application in Caprivi

3.2.1. Effort regulation

Management of tropical multi-species fisheries in Africa had historically mainly been effort driven whereby the fishing effort of fishermen was regulated. One of the most implemented controlling methods was the introduction of a minimum mesh size for multifilament gill nets. The underlying principle was that to ensure a sustainable fish resource, the juveniles of larger growing species should be protected to allow time for the successful reproduction of the species. This resulted in highly skewed exploitation where catches of the smaller size classes, which naturally had high mortalities, were reduced and the larger size classes of the larger species, which naturally had lower mortality rates, were intensified. This highly selective fishing approach for larger individuals in a species placed an unnaturally high pressure on the highly successful individuals with the necessary genetic material to ensure successful offspring.

The same restriction can be placed on the number of gill nets, which are allowed for each fisherman. This could either be in a manner that restricts the number of gill nets allowed to be in possession, or the number of gill nets that are allowed to be set simultaneously.

It has been observed in certain lakes in Africa that a population driven increase in effort, but where the effort is diversified, is biologically less harmful than an increase in investment in more effective sampling gear. The latter usually is selective fishing whereby the commercially important species are targeted to justify the investment.

Certain fishing methods are prohibited such as drag netting, fishing with a lamp during the night, using poison and bashing. With the recent increase in fishing pressure and simultaneous decrease in catch per unit effort, more and more cases of ignorance of the present fishery regulations are experienced, fishermen resorting to smaller mesh gillnets, dragging during low water periods and bashing and driving fish into set nets.

3.2.2. Closed or protected areas

This management approach is primarily implemented for the protection of spawning and nursery areas, and prevention of the destruction of habitats. The regulations stipulated for a fish sanctuary can be defined in such a way to accommodate local needs. Fishery reserves or fish sanctuaries would be community supported, developed in conjunction with the local communities and be of such size that subsistence fishing is still possible.

3.2.3. Closed seasons

Closed seasons, involve larger areas than protected areas where no commercial fishing is permitted and is usually during a period when communities have alternative ways of generating income. The communities generally accept this method as fishing for subsistence is usually allowed during this period. A closed season is a method to protect the fish community during the reproduction phase to ensure successful recruitment. Logistically, it might be more difficult to manage a closed season than a smaller protected area.

A closed season was implemented (21 December 2006 to 28February 2007) in Namibia after the fish disease Epizootic Ulcerative Syndrome (EUS) was discovered in the Zambezi River. The outbreak of the disease was the main reason for the closure of the fishing in the Caprivi. Local fishing communities ascribe the significantly improved catches experienced in 2007 after the flood, partly to this closed season. This has motivated fishermen to accept a closed season in the future.

3.2.4. Licensing

Licenses can be issued permitting the usage of gill nets, with certain conditions attached, relating to the number of nets, mesh size limitations, net length and even the way a gill net may be operated. The rationale behind licensing is to record the effort input in a particular system and to identify illegal gill nets. This will also assist in the calculation of the annual yield. Another perceived benefit is the revenue generated when issuing licenses, which should be channeled back to the local authorities. Presently licenses are only issued by the Caprivi Regional Council in Katima Mulilo and constituency offices making it difficult for rural fishermen to obtain them, thus resulting in many fishing illegally. Generated funds are also not ploughed back into fisheries management.

3.2.5. Aquaculture

Although not an actual management tool, aquaculture has been seen in the past as a method to alleviate the fishing pressure on the natural resources. Although aquaculture may have a role to play, it has not been very successful in Africa.

3.2.6. Minimum length restriction

Minimum lengths for fish species, mainly those that are important for the sports fishery had been included in legislation. The rationale is that immature fish should be given the opportunity to breed before entering the fishery. This however is impractical for the subsistence fishery and the concept questionable in the light of high natural mortality experienced by smaller fish anyhow.

3.2.7. Bag limit

Bag limits are also included in the Inland Fisheries Regulations and states that a recreational license holder is not allowed more than 10 fish species in the aggregate of any species in one day. Also such a person is not allowed to catch more than 2 tiger fish in one day for recreational purposes. In the light of the modern practice to release most fishes caught, this regulation is again not needed to protect fish resources.

3.3. Closed seasons versus fish sanctuaries

Closed seasons is one of the management options mentioned in the Inland Fisheries Policy and is currently one of the regulations in place in Zambia on the Upper Zambezi River. The closed season lasts from the beginning of December to the end of February. Riverine fishermen are allowed to use hook and line during this period and only for subsistence. The Mwandi Traditional Authority even put up roadblocks to confiscate uncertified fish. People have to certify fish caught in the other provinces during these periods if they need to transport fish. Recently conflicts have been reported between Zambian and Namibian fishermen during the closed fishing season with the crossing of fishermen from Zambian to Namibian fishing grounds. The density of fishermen on the Zambian side is much higher than on the Namibian side (25 times more households were identified on the Zambian side), which further puts pressure on the resource in Zambia.

The reason for the timing of the closed season in Zambia derives from other systems and may not be the most appropriate for the protection of the upper Zambezi cichlids needing protection foremost. It is very important that there be a scientific and social rationale behind a closed season and that the impact on the rural community be minimal. Both the fish community as well as the fisher folk should benefit by such a management approach. Although this practice has been in place for several years in Zambia, the impact of the closed season is unknown but it is supported by the strong traditional authority in the Western Province adjacent to the Caprivi. The breeding season for some of the cichlids already starts in late August or early September and continues till April. The cichlids are highly vulnerable to fishing with active fishing gear such as drag nets during the spawning season (when they build and defend nests on sand banks) as well as during the low level period in September to December, when drag netting is exceedingly common on the Zambian side. Being the most important family in the subsistence fishery, a closed season, which only covers three of the eight months breeding period, may not be effective at all. The present closed season may not benefit all species due to the temporal difference in breeding strategies of the different species. A management strategy that results only in long-term incentives for communities is unrealistic, as the communities may not appreciate “delayed gratification”.

Protected areas or fisheries reserves may contribute significantly to the survival and the sustainable use of the fish resource along the Zambezi and Chobe Rivers. The advantages of such fisheries reserves or sanctuaries are the following:

- Smaller areas can be more effectively controlled.
- Devolution of responsibilities to traditional authority level.
- Access to fishing grounds (areas outside the protected zones) is possible throughout the year.
- Protection of these areas for the full biological cycle of the majority of fish species.
- Protection of all habitat types throughout the year.
- Immediate gratification if recreational anglers compensate for the privilege to practice catch and release within these areas and pay for fishing rights to the community controlling the fish sanctuary.

- The river system and fishermen will capitalize from the fish sanctuaries, as new recruitment is likely to disperse to the rest of the river system.
- Sufficient effective fisheries reserves in a river will prevent collapse of the fisheries even when minimal control of the fishery is possible outside such fisheries reserves.

Telemetry studies were conducted to determine the spatial behaviour and habitat utilization of the economically important fish species in the Upper Zambezi River. These species included *Hydrocynus vittatus, Oreochromis andersonii, Oreochromis macrochir, Serranochromis robustus, Sargochromis giardi* and *Hepsetus odoe*. The home ranges, habitat preferences, the mean river stretch used by the fish and the mean distance traveled per individual for each of these species are illustrated earlier in the report. Such studies are important to collect information necessary for the establishment of fish sanctuaries.

The following need to be taken into consideration for the establishment of fish sanctuaries.

- Consent from the traditional authority for the establishment of a sanctuary in their area of jurisdiction.
- It should be large enough to incorporate the home ranges of the economically important species (if practical).
- It should include a wide range of habitat types.
- It should include spawning grounds, nesting and nursery areas for economically important species.
- It should be accessible for communities to assist in patrolling the sanctuary.
- It should have the potential to attract recreational fishermen to fish in those waters for a fee.
- The availability of biological data from these areas to study future impacts.

Although these conditions may not all be met when initially establishing a sanctuary, it would be sensible to work towards these. The most important point is the consent from the traditional authorities for the establishment of a sanctuary in their region. It is imperative that the communities fully support the concept and are willing to assist in managing the sanctuaries. Without their support, the sanctuaries are destined to fail.

3.4. Diverse fisheries operating together in Caprivi

Harvesting of the fish resources is done at various levels in the Caprivi, which have different impacts on the fish stocks in the long term. The following gives an overview of the diverse fisheries.

3.4.1. Recreational (sports) fishery

Little data are available for the sports fishery, although an initial study was done during 2002 and 2003 to study the impact it has on the resource. Some fishing competitions were visited after that and data collected. During the initial survey in 2002 and 2003 it was determined that the number of fishing parties per kilometer was very low with an average of only 0.017 parties/km. The highest frequency was during August and the lowest during January and June. The larger species are considered important for this industry, although species diversity is becoming increasingly significant with artificial lure competitions becoming more popular. Even international artificial lure competitions are being held which helps to diversify the catches that are targeted by the sports fishery.

Presently the important trophy species for the tourists visiting the area for fishing expeditions are *Hydrocynus vittatus, Serranochromis robustus, Serranochromis angusticeps, Serranochromis altus, Oreochromis andersonii, Oreochromis macrochir, Sargochromis giardi, Tilapia rendalli* and *Clarias gariepinus*.

Mainly catch and release is practiced with only large trophy fish kept for mounting purposes. During the international fishing competition held in 2007 and 2008, 83% and 94% of the fish caught were released respectively. These competitions have minimal effect on the fish community as the majority of the fish are released alive. Not all species are hardy and practicing catch and release may not actually benefit all species. *Hydrocynus vittatus* was found to be very sensitive to handling, especially the large individuals, and such individuals may have a lower survival rate after released. During a tagging program in the Zambezi River, *Hydrocynus vittatus* was successfully handled. It is maybe important to teach anglers the handling of fish to ensure an even higher survival rate of fish after being released.

3.4.2. Commercial fishery

The commercial fishery is stimulated by lucrative markets in the area, in particular the large-sized Cichlidae that are fetching high prices on the market (more than N$30 per kg in 2008). This increases selective fishing by the fisher folk to ensure maximum return on their investment, both financial and effort input. Better market opportunities for some species, such as *Clarias gariepinus,* exist outside the Caprivi Region and are exported to other parts of the country. Another factor is the employment segment branching off from this fishery. Relative wealthy individuals, who have the capital to invest in some fishing equipment, employ locals and Zambians to do the fishing for them at a certain price tag. This further creates a snowball effect where capital investment is increased as the value of the fishery increases and some of the profits are channeled back to the fishery. This is why the Ministry has restricted the number of gill nets that may be used per fisher to prevent the development of a commercial fishery (mainly for the large cichlids) in Caprivi. Unfortunately these regulations are not enforced. There are signs that this commercial fishery is presently expanding, at the cost of the subsistence fishery

3.4.3. Subsistence fishery

The subsistence fishery can be seen as the activity where the majority of the catch goes for own consumption. Although gill nets are also used, the emphasis is not on specific species and is not size related, but rather on the availability of a protein source for their daily needs. Some fish however will be sold to cover basic expenses such as school fees. Traditional fishing gear will also be used alternatively and may target species, which are not normally sampled with the gill nets. The gear used is flood level and flood stage related. Fish species at all trophic levels are sampled and utilized, especially if gill nets are also used. This fishery is very important during periods of drought or scarcity when more people may turn to the river for food. The river then acts as a safety net to help people through difficult times.

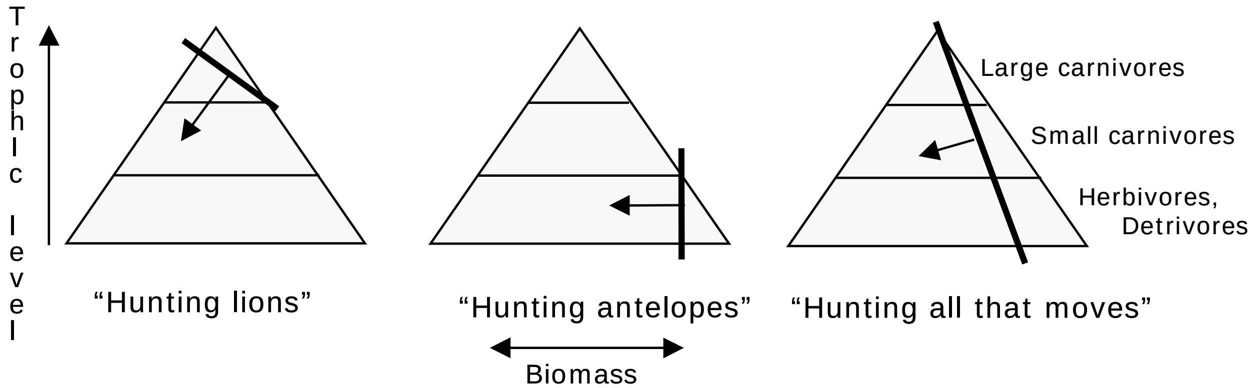

Figure 3.1. The following has been taken from a FAO Fisheries Technical Paper 426/1 by Jul-Larsen et al. 2002 and can also be applicable to the Caprivi fisheries. *The trophic levels in a community at which a fishery intervenes. Triangles represent trophic pyramids of animal communities with predators at the apex and animals feeding on primary production and detritus at the bottom. The width of the triangle at any level represents the relative biomass of that level. Black lines represent selective exploitation, arrows the direction of increased pressure. The three triangles each could represent a different fishery, for example: a sport fishery on tigerfish ("Hunting lions"), a gillnet fishery on tilapiine fishes such as the Oreochromis fishery in Mweru comparable to grazers in wildlife ("Hunting antelopes") and a fully developed fishery in which all trophic levels are harvested proportionally to their biomass ("Hunting all that moves").*

Figure 3.1 illustrates the ways the fishery targets different segments of the fish population. This is very important to consider when a management plan is developed for the Caprivi. A fishery where all size classes are harvested proportionally to their numbers is considered healthier for the fish community and on the long-term also for the people. This may result in a higher annual yield as the presently unutilized section of the fish community forms part of the harvest. Only a small percentage of the fish community is large fish, presently harvested by the fishery, leaving the majority of the species untouched. The present regulations however prevent the fishery from fishing across the entire spectrum of the fish population and this has to be addressed.

A specialist fishery for mormyrids exists at Impalila Island on the rapids of the Chobe and Zambezi Rivers. Special long traps (lukuko) are used only during two periods, during the dark phase of the moon in June and July, by more than 200 fishermen all using traditionally owned sites in the rapids where they hang their traps. Up to 50kg per funnel of mainly Mormyrids is caught.

4. Conclusion

4.1. The representativeness of the multifilament gill nets (experimental and subsistence) used during the study period to reflect actual fish populations.

4.1.1. Did the experimental gill nets reflect the actual fish populations in the rivers?

The experimental gill nets used by the Ministry during the study period (the 22 to 150mm mesh sizes) could be considered representative, especially between the fish length classes 100mm and

560mm. The representativeness for the smaller lengths will improve with the inclusion of the 12 and 16mm mesh sizes. When comparing the catches of the gill nets and other gear types, the ineffectiveness of sampling fish smaller than 80mm with gill nets was emphasized. It is therefore critical that other gear types are included during the surveys, to specifically identify successful recruitment and nursery areas. Several fish species did not enter the experimental gill nets due to their small size. The data recorded can then serve as the basis for establishing fish sanctuaries. Small individuals are also important for the calculation of growth parameters. It is important to allow for fish behaviour when considering gear selectivity. Very active species will have a greater chance of being caught with gill nets. Also habitat preferences will affect the selectivity. A study was done in the Upper Zambezi River funded by the African Wildlife Foundation to determine the effectiveness of three different sets of gill nets. The study revealed that the gill net set currently used to be the most effective of the three different gill net sets used.

When studying the gill net selectivity of fish species separately, it was found that the selectivity varied between fish species. This was done for only selected fish species that were considered important for the subsistence fishery and those who had a high number sampled to facilitate analysis. The selectivity curves show that young fish were under sampled for several fish species including *Oreochromis andersonii, Oreochromis macrochir, Marcusenius macrolepidotus, Brycinus lateralis* and *Petrocephalus catostoma*. In contrast all length groups of *Hydrocynus vittatus, Brycinus lateralis, Schilbe intermedius* and *Serranochromis macrocephalus* were well represented by the gill net catches. *Clarias gariepinus* was under sampled both for the small and the large individuals. Despite this variation, the samples of the different species were still well represented and can be used for the identification of changes that may take place in these populations in future.

One other factor to consider when using gill net catch as representative of the actual fish community composition is the difference in catch susceptibility of different species. Some seem to be able to avoid gill nets as a result of their body shape (*Tilapia rendalli*) or behaviour (young cichlids) whereas other species are 'accident prone' and get caught easily. Species suspected to have been over represented in gillnet catches include especially the following species:
Brycinus lateralis, Schilbe intermedius, Synodontis spp

There is a smaller possibility that some overrepresentation also occurs in gillnets catches of the following fish species: *Hydrocynus vittatus, Barbus poechii, Barbus paludinosus and Marcusenius macrolepidotus* and *Petrocephalus catostoma.* All these species have the ideal fusiform body shape and are active open water species.

The high figures for some fish in gill net catches as represented in numbers, frequency and sometimes weight and reflected in the IRI may thus be an overestimate of active and net-prone species. Unfortunately no information is known on the factor by which fish species are under or over represented. All gillnet catch results (and that of other collecting gear as well) therefore have to be interpreted with caution and evaluated. This does however not mean that conclusions on changes in fish populations cannot be drawn from long-term gill net results, which was found to be the case with this study. This aspect was also found during the fish ecological studies done in the other perennial rivers of Namibia.

4.1.2. Did the subsistence gill net fishery at Impalila catch fish representative of the fish community?

When considering the gill net catches of the subsistence fishery at Impalila (using 50, 75 and 100mm mesh sizes) it was shown that fishes from length classes 210 to 410mm were effectively sampled. When, however, the corrected catch graph was interpreted, it was clear that a large section of the fish population was not utilized when only these mesh sizes were used. The fishery did not harvest the available small species. The current legislation will enhance this unbalanced, skewed utilization pattern of the fish stocks with its prescription of a minimum stretched mesh size of 76mm for the multifilament gill nets in Caprivi.

The present gill net selectivity as determined for the subsistence fishery did not lend itself to an optimal utilization of the fishery in Caprivi. The gill nets used by the fisher folk did not effectively target fish smaller than 210mm and the majority of fish species were not utilized at all. The experimental gear types sampled a total of only 27 species with maximum lengths greater than 200mm during the study period compared to 49 species with maximum lengths smaller than 210mm. The gill net fishery will not target the 49 species (64.5% of measured fish species) if mesh sizes larger than 50mm is used. This scenario will even worsen when the minimum legal size of 76mm, according to the Inland Fisheries Legislation, is implemented.

In the light of the presented information, reconsideration of a mesh size restriction should be a matter of priority. The danger that the permission to use smaller mesh nets can lead to misuse of gillnets for dragging, needs to be addressed through consultation, extension and participation by the community through fisheries committees and conservancies. The principle should however be established and a policy formulated that is less prescriptive. Community participation and co-management are required to change the present situation.

4.2. Were the fish populations in conserved and in fished areas actually different?

There are important differences.

- Open access areas constantly had a lower catch rate for larger fish than the areas that were protected against utilization of the resource. The catch rates were at least double in protected areas compared to those from areas subjected to fishing. This implies a lower biomass in intensely fished areas. This trend was also found in the Kavango River where protected areas had higher catches than the heavily fished areas.

- Smaller mesh nets had higher catches in the Zambezi and Chobe Rivers compared to the protected Kwando River. It is possible that the proliferation of smaller fish in the Zambezi is possibly the beginning of a reaction to the constant fishing pressure on larger fish, resulting in more space and food for smaller fish (Larsen et al.2002).

- Another finding was that the annual catches from the Kwando River had a definite upward trend since 1997, compared to a trend of decline in catches from the Zambezi and Chobe Rivers. This continuing downward trend in the Zambezi may be partly caused by overfishing.

- A drop was noticed in catches of those mesh sizes corresponding with subsistence gill net fishery nets in the Zambezi. Length frequencies also dropped for length classes corresponding with those harvested by the subsistence fishery.

- An inverse relationship existed between the average length and weight of individual fish and the catch rates in number and in weight. This was found in the Zambezi and Chobe Rivers as well as the Kwando River. In spite of this, the Kwando River showed a higher large to small fish ratio than the Zambezi and Chobe Rivers.

Table 4.1. Summary of observed changes taking place in the fish communities in the Zambezi/Chobe and Kwando Rivers.

Parameter	**Zambezi/Chobe Rivers**	**Kwando River**
Number of small fish	↑	↓
Number of large fish	↓	↑
Average length	↓	↑
Average weight	↓	↑
CPUE	↓	↑
Biomass	↓	↑

- The trend is that the number of small fish is increasing in the Zambezi and Chobe rivers with a subsequent decrease in the number of large fish.
- This trend is reversed in the protected Kwando River areas sampled.
- The average length and weight were higher in the Kwando River than in the Zambezi and Chobe Rivers.
- The catch per unit effort and the total biomass were higher in the Kwando River than in the Zambezi and Chobe Rivers.

4.3. Did all fish react in a similar way to the fishing pressure in the Zambezi/Chobe Rivers?

Not all fish react similarly to the constant fishing pressure. The effects of fishing were studied separately on high value species and common species that are not targeted by the fishery:

Marcusenius macrolepidotus (Not really a high valued species, but the fourth most important species in the subsistence gill net fishery - mainly caught with two inch gill nets, presently an illegal mesh size).

- Larger fish were sampled from the protected areas than from the intensively utilized areas.
- There was a reduction in the length classes targeted by the subsistence fishery in the unprotected area, which was not the situation in the protected area.
- Very little recruitment was evident in the Kwando River, compared to the Zambezi and Chobe Rivers. Environmental factors (e.g. lack of major floods) may play an important role.
- Fishing pressure is not intense and populations of this fish appear to be healthy.

Hydrocynus vittatus (although not preferred this is the most important species in the subsistence gill net fishery).

- Despite the heavy utilization, the population still appears to be healthy in the Zambezi and Chobe Rivers.
- Length classes targeted by the subsistence fishery were present in the experimental gill nets, with no indication of depletion.
- Recruitment was clearly observed for the Zambezi and Chobe Rivers.
- This species moves over large distances as found by the radio telemetry study, which may mitigate the impact the local subsistence fishery might have on this species.

Oreochromis andersonii (most important and high valued species on the fish markets, but 13^{th} most important species in the subsistence gill net fishery)

- Very low catches in the Zambezi and Chobe Rivers but higher catches of large fish from the protected areas.
- The length classes targeted by the subsistence gill net fishery were present in the protected areas, but absent or low in number in intensively utilized areas.
- The radio telemetry study indicated that this species may be susceptible to the gill net fishery. The breeding behaviour (aggregate during breeding) may be another reason this species is susceptible to over utilization.
- This species is under severe pressure from the fishery.
- This species is very vulnerable to drag netting.

Serranochromis macrocephalus (Sixth most important species in the subsistence gill net fishery, high valued species).

- Larger fish were more numerous in the protected area compared to the intensively fished areas.
- Although the majority of the length classes caught by the subsistence gill net fishery were still present in the unprotected areas, some negative impact can be observed.
- The resident and crepuscular behaviour of *Serranochromis macrocephalus* may mitigate the effect the fishery might have on this species.

Brycinus lateralis (very common but not high valued species and not harvested by the subsistence gill net fishery).

- No difference in the length frequencies between the protected areas and the intensively fished areas.
- Healthy annual cohorts were observed from the length frequency.

Schilbe intermedius (very common and fifth most important species in subsistence gill net catches, not regarded as a high valued species).

- Population healthy despite utilization with small gill nets (illegal mesh size) by the subsistence fishery.
- Some impact was observed: fewer large fish from the intensively utilized areas than protected areas.
- Healthy annual cohorts were observed from the intensively fished areas, breeding successfully.

Clarias gariepinus (The second most important species in the subsistence gill net fishery, mainly due to weight).

- Large fish are more commonly sampled in the protected areas.
- Population may be under estimated, as this species is not easily sampled.

Oreochromis macrochir (important on fish market, 11th most important species in the subsistence gill net fishery).

- Larger fish were sampled from the protected area compared to the intensively fished areas of the Zambezi and Chobe Rivers.
- The majority of the length classes caught by the subsistence gill net fishery were present in catches in the protected areas, which was not the situation from the intensively fished areas.
- This species is under severe fishing pressure.
- This species is very vulnerable to drag netting.

Petrocephalus catostoma (Not important in the subsistence gill net fishery, but valued and important in traditional fishery).

- A healthy population was present in all systems.
- Slightly larger fish were however sampled from the protected areas.
- This species is harvested with traditional gear in the Zambezi and Chobe Rivers.

The conclusion is made that fish species responded differently to subsistence fishery pressure:

- Fish species presently not captured and under utilized by the fishery showed healthy populations, e.g. *Brycinus lateralis, Petrocephalus catostoma, Barbus poechii* and *Tilapia sparrmanii*.
- Some species have the ability to mitigate impacts from the subsistence fishery, e.g. *Hydrocynus vittatus, Serranochromis macrocephalus, Marcusenius macrolepidotus* and *Schilbe intermedius.*
- Other species are sensitive to the impacts of subsistence fishery as a result of their schooling and general behaviour, vulnerable nesting and spawning behaviour and slow growth rate. Species include *Oreochromis andersonii*, *Oreochromis macrochir* and *Sargochromis* and *Serranochromis* species.
- One other aspect is the strong preference for certain species at the market. Harvesting may become very selective and innovative for cichlids putting further pressure on selected fish species.

4.4. Did the fishery affect the fish population structure in the rivers?

The catch per unit effort in the Zambezi and Chobe Rivers decreased over time with a lower biomass in the fished areas compared to the unfished areas. When considering all species combined, the population structure did change over the years. There may be a compensating factor in operation where replacement of larger by smaller fish species takes place. Once species were analyzed separately, important changes became apparent.

The following issues are raised:

- A difference in the population structure between the fished and protected areas was detected. The larger fish are disappearing from the fished areas and are replaced by smaller fish. This is not the situation at the conserved areas.

- The fish population structure changed slightly from the period 1997 – 2002, to the period 2003 – 2007, with a decrease in the large fish compared to earlier surveys. This trend may have been present long before the surveys were conducted.
- The fish population structure sampled from the backwater habitats differed from the fish sampled from the floodplain and mainstream habitats, in that more smaller fish are present in the backwater habitats.
- The protected areas had a higher catch per unit effort in weight and therefore a higher biomass than the intensively fished areas.

It is concluded that the catches declined during and especially before the last decade and that the commercial and subsistence fisheries contributed to this. The fish population structure showed signs of change. Structural changes took place with a decline in the large fish and an increase in small fish that have a higher turnover rate. It is entirely possible that further capital driven increase in effort by the fishing community may seriously impact on the resource. This will, over time, influence the daily livelihoods of especially the rural communities

4.5. What are the habitat preferences of the targeted species at selected stations?

Larger *Hydrocynus vittatus* were mainly caught in the Zambezi River (at Kalimbeza and at Impalila) with fewer catches from the Chobe River (Kabula). Of interest was the sudden drop in catches of the 57mm and higher mesh experimental gill nets. Large numbers of sexually immature fish were present, with the majority of the fish caught at Kalimbeza and at Impalila smaller than 210mm and smaller than 150mm at Kabula. The growth rate of this species was approximately 150-200mm in the first year, suggesting that the majority of the fish caught were approximately one year old.

Large cichlids were collected at all three stations but sexually immature fish mainly sampled from the floodplain habitats. At Kabula, virtually all fish smaller than 80mm were sampled on the floodplains whereas fish between 60 and 120mm were caught mainly in the mainstream at Kalimbeza. The floodplains are thus very important nursery areas for the large cichlid species. These species are especially vulnerable to drag netting in all habitats. The multifilament gill nets were effectively used in the backwater habitats to catch large Cichlidae. Large individuals were sampled at Impalila and the catches indicated that Kabula was a very productive breeding site for the large cichlids.

Marcusenius macrolepidotus was collected at Kalimbeza and at Impalila mainly from the backwater habitats. At Kabula it was sampled at all the different habitat types. The multifilament gill nets were the most effective sampling gear used for this species, even in the vegetated habitats such as the floodplains. A sudden increase in catches could be observed from the length class 80mm and larger. Larger individuals were sampled from the floodplains. The nocturnal behaviour of this species might have influenced the sampling at the different habitats.

When considering all the stations collectively, it was established that the two important subsistence fishery species, *Oreochromis andersonii* and *Oreochromis macrochir*, use the floodplains as nursery habitats, as the juveniles move onto the floodplains, but larger individuals stayed near the deeper streams.

4.6. What is the species composition of the experimental multifilament gill nets and did it change over time?

The species composition in the section of the river system studied was dominated by a small number of species. No significant changes in the species composition took place since the start of the surveys in 1997 for the Zambezi and Chobe Rivers. Also the Shannon's diversity index indicated no significant change during the same period. This however was not the case for the Kwando River where a decline in the diversity index was found. A possible reason for this could be the relatively low floods the Kwando River received during the study period. Unfortunately no significant data are available prior to 1997 to indicate whether any changes took place in the intensively fished areas of the Zambezi and Chobe Rivers or whether any changes that might have occurred prior to 1997 could be related to the fisheries. Despite the fact that several species are habitat specific, these species did not contribute much to the index when separating the catch into the different habitat types. The dominant species were present in all the major habitat types throughout the system, except maybe the rapids, which were not included due to the difficulty in having a standardized sampling method for these habitat types. This lack of change reflects the inbuilt ability of the system to handle pressure and variation.

4.7. What are the catches in the subsistence gill net fishery?

The gill net fishery is selective in its sampling methodology with *Hydrocynus vittatus*, the large cichlids and *Clarias gariepinus* the important fish species caught. The importance of these species is market driven. The smaller fish species sampled with the smaller mesh sizes and with some other gear types are mainly for own consumption, although these species are becoming increasingly important for the fish vendors. The fish length classes targeted by the gill net fishery was between 180mm and 400mm. The catch per unit effort (kg/10m gill net/12 hour) for each mesh size as calculated from the fishery at Impalila was 0.31 for the 50mm mesh, 0.35 for the 75mm mesh and 0.83 for the 100mm mesh. These values compare with the catch per net in experimental gillnets. The fishermen gill nets deteriorate with time, which in turn affects the efficiency of the catches. Gill nets, which are not repairable anymore, are sometimes left in the water, catching fish, which are not removed.

Using these values, an estimated 1478 tons of fish were harvested annually form the Caprivi Region from the gill nets alone if the assumption is correct that 1500 gill nets are set per day in the region and that fishing takes place 365 days per year. This corresponds with the household survey in 2002 (1467 tons) when a total number of three gill nets per household were used with a fishing effort of 4.5 days/week.

4.8. What are the exploitation rates of different fish species by the subsistence fishery

The exploitation rates of *Hydrocynus vittatus, Clarias gariepinus, Marcusenius macrolepidotus, Schilbe intermedius* and *Serranochromis macrocephalus* confirmed the outcome of the length frequencies stating that these species were not over utilized despite being considered important in the subsistence gill net fishery. Contrary to these species, the two Cichlidae, *Oreochromis andersonii* and *Oreochromis macrochir*, were over utilized, which is also accentuated by the length frequency results shown earlier in the report.

It is interesting that although the subsistence fishery utilized all these species, the actual impact differs from species to species. The need to understand the biology of each species utilized, as well as the energy cycling and food webs, is extremely important as this will enable the prediction of the impact fishing pressure will have on the fish stocks.

4.9. What is the influence of flood level and duration on fish production in the system?

The highest peak level in a particular flood cycle, the duration as well as the average peak level of the annual flood all played an important role in the determination of fish production. The highest peak of a particular flood had a significant impact on the fish production two years later. This was tested against a 95% significance level for the small and medium size fish. For the large fish, it was found to be significant against a 90% significance level. It was also found that according to the index developed, the average height and the duration of the flood had an impact on the medium size fish.

Although this is only a preliminary analysis, it seems that a combination of several factors relating to the present and previous flood cycles may play a role in fish survival and production.

4.10. What are the historical trends in fish population changes in Lake Liambezi?

It must be remembered that Lake Liambezi was stable and full during the seventies, then started to dry out in the mid 80's, dried out completely and only started to receive some water and colonizing fish in 2001, in 2004 and again in 2007. Some definite differences were detected in the species composition during the full stage period (1973 – 1975), drying out period (1985 – 1986) and filling period (2004 – 2005). Some of the major differences were the higher percentage of predatory species and large species of the family Cichlidae during the drying phase of the lake. The low number of predatory species is to be expected during the initial phases of the flooding of the lake. During stable full level stage, large cichlids and medium insect eating fish such as mormyrids and *Schilbe intermedius* dominated the lake. The food chain will progress from the primary producers through to the tertiary consumers as the lake fills up. Pioneer species identified were *Schilbe intermedius, Marcusenius macrolepidotus, Clarias gariepinus* and the *Synodontis* spp. In comparison, the most abundant species during the last phase of the lake prior to drying up were *Marcusenius macrolepidotus, Oreochromis andersonii, Petrocephalus catostoma,* and *Oreochromis macrochir*. *Schilbe intermedius, Clarias gariepinus, Marcusenius macrolepidotus* and the *Synodontis* group were species that were common during both study periods.

The three most abundant species during 2004 - 2005 contributed 85.7% of the total number sampled compared to the 55.9% during 1985-1986. A small number of species dominated the gill net catches during the flooding of the lake in contrast to the period prior to the drying up of the lake.

Compared to the 2004-2005 period, the period 1973 - 1975 can be seen as a settled and stable environment, as the lake had been flooded for several years. Species which thrived in stable environments and which were present in the 1970's were *Petrocephalus catostoma, Hepsetus odoe, Serranochromis longimanus, Serranochromis angusticeps, Serranochromis thumbergi, Mormyrus lacerda* and *Oreochromis macrochir*.

During the 1980's the most common species were *Marcusenius macrolepidotus, Oreochromis andersonii, Petrocephalus catostoma, Schilbe intermedius* and *Pharyngochromis acuticeps*. In the latter surveys in the 2000's these species were *Barbus paludinosus, Schilbe intermedius, Barbus poechii, Marcusenius macrolepidotus* and *Brycinus lateralis*.

A definite change in the species composition was found between the 1970's and the 2000's. During the 1970's large numbers of Cichlidae were recorded and also more species contributed a major portion of the catches. During the period 2001 to 2007, four species contributed 96.1% of the total IRI.

The pioneer species invading a recently filled lake were species such as *Barbus paludinosus, Barbus poechii, Schilbe intermedius* and *Clarias gariepinus*. Once the lake stabilised, the dominating species were *Petrocephalus catostoma, Hepsetus odoe, Serranochromis longimanus, Serranochromis angusticeps* and *Oreochromis macrochir*. Species present during the last phase before the lake went dry were *Clarias gariepinus, Clarias ngamensis, Schilbe intermedius* and *Oreochromis andersonii*.

5. General conclusions

- The gill net set used by the Ministry gave an accurate representative but not absolute impression of the different fish populations in Caprivi within certain length groups. Factors such as fish behaviour, habitat preferences and flood levels may have an impact on this.
- The gill nets used by the subsistence fishery are such that the larger fish are targeted, thus catching a greater biomass per effort, which also has a higher demand at the fish markets.
- The fish populations in the conserved areas differed from that of the fished areas. This change was ascribed to the effects of continuous subsistence fishery pressure in the Caprivi. These changes were: Higher fish abundance in the conserved areas. Higher abundance of large fish in the conserved areas. Higher abundance of small fish in the fished areas. Structural changes in the fish populations between conserved and fished areas and structural changes even took place during the study period.
- Fish species reacted differently to fishing pressure. Some fish seem to withstand the fishing pressure whereas others have declined and are becoming scarcer.
- Some species had the ability to mitigate impacts from the subsistence fishery. These were *Hydrocynus vittatus, Serranochromis macrocephalus, Marcusenius macrolepidotus* and *Schilbe intermedius.*
- Species sensitive to the impacts of subsistence fishery were *Oreochromis andersonii* and *Oreochromis macrochir.*
- A small number of species dominated the catches of the fishery.
- No change in the species composition was found in the Zambezi and Chobe Rivers during the study period. However, a decline in the diversity index was found for the Kwando River which might have been flood related.

- The annual exploitation by the subsistence gill net fishery is estimated at 1478 ton per annum.
- The exploitation rates of *Hydrocynus vittatus, Clarias gariepinus, Marcusenius macrolepidotus, Schilbe intermedius* and *Serranochromis macrocephalus* confirmed the outcome of the length frequencies stating that these species were not over utilized, despite being considered important in the subsistence gill net fishery.
- The two Cichlidae, *Oreochromis andersonii* and *Oreochromis macrochir*, were over utilized, which is also accentuated by the length frequency results shown earlier in the report.
- Other larger cichlids, including *Tilapia rendalli, Sargochromis giardi*, *S. codringtonii, Serranochromis robustus, Serranochromis altus* and *Serranochromis angusticeps* are considered to be negatively affected in a lesser degree than the two *Oreochromis* species.
- The peak flood level of a particular year impacted on the fish production two years later. This is mainly for the small and medium size fish.
- The species composition in Lake Liambezi had changed since the early 1970's, progressing from a pioneer community consisting of small insectivore species to valuable and sought-after, long-lived herbivore and detritus feeders.
- Higher catches were recorded from Lake Liambezi during the early 1970's.
- Species diversity in the region may be affected on the long run by the present fishery with continued decline in catches of certain preferred species.

6. Proposed management measures and recommendations

6.1. Information required for stock assessment

To understand a floodplain fishery and the dynamics of the fish community, high quality data are needed. Before emphasis is placed on the data, one must know what information is needed to manage a fishery. The following will give an overview of the critical information needed to assess the fishery in the Caprivi:

- The biology of the different fish species, especially the commercially important species such as:
    - *Oreochromis andersonii*
    - *Oreochromis macrochir*
    - *Serranochromis robustus*
    - *Serranochromis angusticeps*
    - *Tilapia rendalli*
    - *Sargochromis giardi*
    - *Sargochromis codringtonii*
    - *Hydrocynus vittatus*
    - *Clarias gariepinus*
- This will include data on:
    - Growth parameters
    - Mortality rates
    - Length frequencies

    - Sexual maturity
    - Migratory behaviour
    - Breeding information
    - Food niches
    - Habitat preferences
- Time series of standardized experimental sampling gear
- Information on experimental gear selectivity
- Information on the catches of the subsistence, commercial and the recreational fishery which include:
    - Species composition
    - Length frequencies
    - Catch rates
- Information on fishing activities include:
    - Types of gear in use
    - Net lengths and mesh sizes
    - Where and how sampling gear are set and used
    - Effort input by the fisher folk
- Information on fishing households
- Information from fish markets
- Water quality data
- Water level data

6.2. Proposed data recording

The present experimental dataset that was recorded by the Ministry since 1997 was adequate to do an initial assessment of the fish population of the Zambezi and Chobe Rivers. However to do a more detailed assessment of the fish stock and to predict future trends, one will need particular spatial and temporal datasets. The following protocol for the data collection of biological data is proposed:

- A standardized multifilament gill net set should be used with mesh sizes 12, 16, 22, 28, 35, 45, 57, 73, 93, 118 and 150mm.
- A trial should be done with larger mesh size nets to increase the effort in the collection of the larger fish.
- The panel length should then be increased to 40m for larger mesh nets to increase effort.
- Seasonal surveys should be done at selected stations and sites.
- An increased effort at the stations to increase the number of fish collected in the larger size classes.
- Non-gill net gear types are used to supplement the data collected with the multifilament gill nets. Increased number in juvenile fish collected to determine breeding seasons and growth rates.
- Water quality data are recorded at each station, especially water temperature, dissolved oxygen, turbidity and conductivity.
- The Kwando River must be included in the survey schedule.
- Once a fish sanctuary is established, a database should be developed for evaluation purposes and regular surveys conducted in such a fish sanctuary.

The following protocol for the data collection of the commercial, subsistence and recreational fishery is proposed:

- River surveys conducted every second month at selected stations to record fishery activities.
- It is suggested that local people be trained to collect the data.
- Recording of catches from the different fisheries at pre-determined landing sites.
- Establishment of a fishery group that will assist with the recording of their catches.
- A frame survey done along the Zambezi and Chobe Rivers every third year.
- Two weekly surveys at the Katima Mulilo fish market.
- Monitoring of fishing competitions.
- Monitoring of catches from fishing lodges.

Data recording forms with the critical parameters needed were developed and are available.

6.3. Proposed software

Capacity building is needed for staff from the Ministry in the usage of software to conduct the necessary data analysis. The specialized software needed are:

- Pasgear, a customized data program for biological analysis.
- Fisat (FAO-ICLARM Stock Assessment Tool) for stock assessment.
- A consultant could be brought in to conduct a training course in Pasgear and Fisat.
- Kamutjonga Fisheries Research Center can play a vital role in this regard.

6.4. Proclamation of fish sanctuaries

According to Section 22 of the Inland Fisheries Resources Act (Act No.1 of 2003), the following is stated "*The Minister, on his or her own initiative, or in response to an initiative of any regional council, local authority council or traditional authority, and in consultation with the regional council, local authority council or traditional authority concerned, may by notice in the Gazette declare any area of inland waters as a fisheries reserve if the Minister considers that special measures are necessary*"

The results indicated that the Kalimbeza Channel is ideally placed to be proclaimed as a demonstration fish sanctuary. The border of the proposed Kalimbeza fish sanctuary is outlined in figure 6.1. The following important points are highlighted:

- The backwater habitats serve as a nursery area for *Hydrocynus vittatus*.
- The mainstream at Kalimbeza plays an important role for the juveniles of the large species of the family Cichlidae that are presently targeted by the subsistence fishery with drag netting.
- Shallower parts of the Kalimbeza Channel are spawning sites for *Oreochromis, Tilapia* and *Serranochromis* species.
- Both floodplains and backwater habitats were found to act as nursery areas for fish, especially for the large Cichlidae.
- A fisheries committee was established at Kalimbeza that could act as the coordinating body for the sanctuary.
- The upcoming Sikunga Conservancy is proposed for the Kalimbeza area that would further support the establishment of a sanctuary.

- Lodge owners in the area already responded positively towards a fish sanctuary in this area.
- Recreational anglers could then be allowed to practice catch and release in these waters at a pre-determined fee.
- Income from the fish sanctuary goes directly to the community through the fisheries committee and/or conservancy.

Kalimbeza would be used as a model that could in future be duplicated in other areas in the Caprivi. The emphasis of the sanctuary is to protect the habitats in the area and also to allow uninterrupted breeding of fish. This will further allow the protection of large mature individuals of fish that do not migrate long distances. Especially the large Cichlidae such as *Oreochromis andersonii* and *Oreochromis macrochir* will hugely benefit from such a sanctuary.

Proposals for fish sanctuaries have been accepted in principle by the Impalila and Kasika Conservancies. Lake Maningimanze north of Lisikili is also suggested by the Lisikili Fisheries Committee as a possible fisheries sanctuary. There seems to be interest amongst the communities for this concept. If large areas seem to be impractical, several smaller areas forming a web could be developed, still allowing sites between the protected areas for the subsistence fishery.

6.5. Closed season

A closed season is not recommended for the Caprivi due to the following reasons:

- No scientific proof exists that this is enhancing fish production in Caprivi or in Zambia.
- It is extremely difficult to control fishing activities in such a large area.
- The present timing of the Zambian closed season does not protect the breeding cycle of all species or even the important Cichlidae family.
- It creates unnecessary pressure for semi commercial fishermen and fish vendors, most of whom are women heading their households.
- Fish should be protected during the most critical times of the year, namely the very low water periods, which presently falls outside the closed season period.

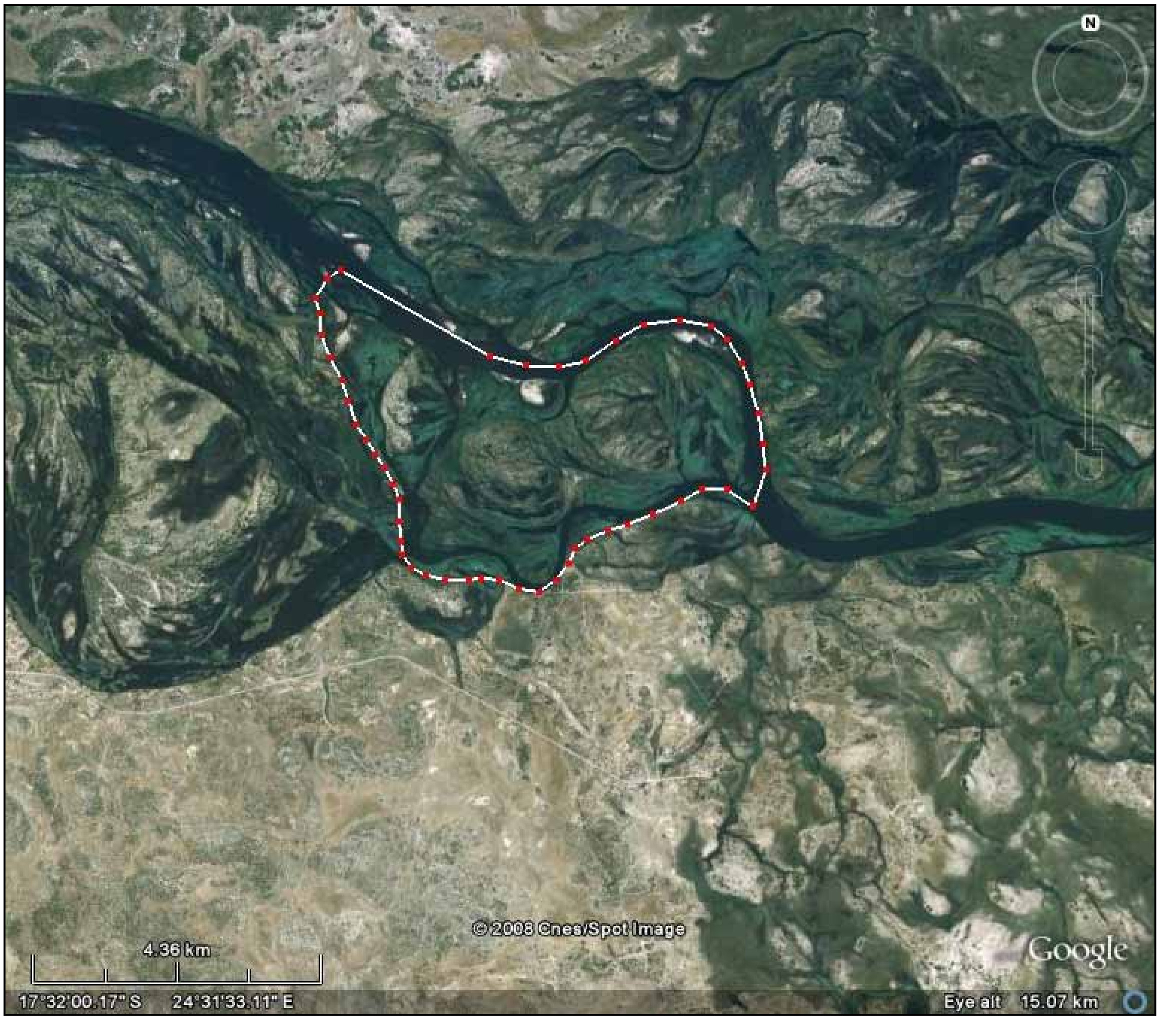

Figure 6.1. The proposed fish sanctuary at Kalimbeza. The sanctuary will include the Kalimbeza channel, the mainstream and all associated floodplains and backwater habitats.

6.6. Regional cooperation

The shared nature of the river system in the Caprivi makes cooperation with especially Zambia vital in managing the fish stocks. Although none of the previous joint working groups between neighbouring countries had been sustainable, the Ministry should persist with the approach of setting up platforms to encourage sustainable regional collaboration. A low-level approach is recommended that will ensure continued participation from both countries with financial, equipment and manpower support from their own departments.

The groundwork for regional cooperation was done and all the necessary documentation is available stipulating the different protocols needed to initiate collaboration between the different stakeholders. Different templates for data recording were also developed and are ready to be used.

6.7. Aquaculture

Although aquaculture does not form part of the study within the scope of this report, it can play an important role in food security and alleviate some pressure on the wild fish. Fish ranching is a new option that is better suited to the local situation than the semi intensive fish farming practiced at the three current fish farms. This will be controlled through the Aquaculture Act of 2002. Juveniles of selected species bred at a fish hatchery or fish project, are stocked in isolated or connected natural or man-made (gravel pits) water bodies, that were either devoid of fish or where the cichlids were under represented, to be harvested later. Fish production is artificially enhanced allowing higher productivity than would naturally have been the case. Secondary industries can be developed, further creating income and employment. Areas identified are mulapos present on the floodplains during the receding phase of the flood and the recently filling Lake Liambezi. The issue regarding fish diseases and the genetic material of the brood stock must be considered.

6.8. Proposed amendments to the Inland Fisheries Resources Act and regulations

6.8.1. Inland Fisheries Council

It is important that the Council becomes fully functional to ensure that Inland Fisheries features at the highest level. The fisher folk need a forum to make sure their concerns receive the needed attention, which is presently a major stumbling block. Communities should be kept informed about scheduled council meetings to give them ample time to raise their concerns. The Council should be decentralized and structured in a way to allow representation of the rural communities. Provision should be made for the establishment of an Inland Fisheries Committee that will link up with the Council to ensure two-way communication between the Ministry and the communities.

6.8.2. Fishing licenses and registration of nets

Presently a major area of frustration is the difficulty in obtaining a fishing license or to register a gill net. Only the Regional Council at Katima Mulilo and constituency offices have the responsibility of issuing angling and netting licenses and they only operate during official hours. The fisher folk must also, according to the regulations, inform the Regional Council within seven days if a net has been lost or destroyed. Logistically, this is not always possible for these people, adding to their burden.

The responsibility of issuing licenses and registration of gill nets should be decentralized and conservancies, fisheries committees, traditional authorities and lodge owners must be equipped to assist with this. The funds raised through the issuing of licenses should stay in the area where it was issued and used for applying the law and managing the fisheries activities in that particular area. The income generated by the traditional authorities will create incentives for the communities to assist with the control of the Inland Fisheries regulations. The feeling of ownership will snowball into a more effective implementation of these regulations.

6.8.3. Control of fishing activities

The biggest present threat to the fish communities and especially to the cichlids, is the use of large dragnets during the low water periods when these species move to shallower areas to build nests. Despite the fact that the Act explicitly prohibits the use of these nets, drag netting is taking place throughout the system on both sides of the river. The best means to deal with this issue is to include the communities in the management structures and impose stiff measures for lawbreakers, such as confiscation of all fishing gear and transport vessels/vehicles plus fines. The impact drag netting has on the resource must be effectively communicated to the communities. This will set the foundation from which to work from. Fish sanctuaries and conservancies will play a major role in managing fishing activities in future.

Presently, the minimum mesh size of 76mm for the gill nets to be used intensifies the fishing impact on a small selected group of larger fish species. The majority of the fish in the Zambezi and Chobe Rivers are not utilized at all when using only large mesh sizes. It is recommended that the minimum mesh size clause be removed or a minimum mesh size of 25mm (stretched mesh) be implemented. The potential danger of this is that these small mesh sizes may be used as drag nets, further damaging the resource. Methods have to be found to convince fishers never to misuse trust placed in them.

The minimum lengths attached to the fish caught by the recreational anglers should be removed. A maximum length where larger species should be released should replace the minimum length. This will ensure the survival of the individuals with the highest breeding success rate. These individuals have the highest number of eggs and also have the genetic material to grow to such large lengths.

6.8.4. Enforcement

The Inland Fisheries Resources Act commenced in June 2003, but no proof exists that the Act is successfully implemented. Very little has changed since the promulgation of the Act. The main reason is that presently only the fisheries inspectors of the Ministry of Fisheries and Marine Resources are responsible for patrolling the rivers. The Ministry does not have the manpower to effectively patrol and enforce the regulations. The Act makes some provision for the delegation of powers to other individuals to act as inspectors, but this has not materialized and should be changed so that community fish guards can be appointed as well. Until the communities buy into the legislation and become part of the management structure, the Act will not be effectively implemented.

To facilitate the involvement of the communities is to start with structures that are already on the ground (such as the conservancies), and then buy in on their approaches and methodologies. Conservancies should be formally acknowledged and empowered and the role they should play in the fishery should be incorporated in the Inland Fisheries Resources Act.

7. List of main findings of the study

- The fished areas have a lower density and fewer larger fish than conserved areas. This can be attributed to the effects of selective overfishing of larger species.
- The smaller faster growing species are replacing the larger slower growing species.
- The fish biomass in conserved areas is higher than in fished areas.
- This study indicated that the fishery did fortunately not affect the fish species diversity.
- The net fishery in Caprivi negatively impacted especially on *Oreochromis andersonii* and *Oreochromis macrochir*.

- Some other larger fish species such as catfish and tigerfish seem not to be affected by the fishery, possibly the result of the migratory habits and high reproductive potential of these species.
- The magnitude and peak level of a flood affects the fish catches and production two years after such flood. This is explained by the time needed for the fish to grow large enough to be caught in nets.
- Ways in which the fish community of Caprivi can be utilized sustainably include the slackening of present restrictions on smaller mesh gillnets. This will result in a more balanced harvesting and fishing pressure on smaller and larger fish species.
- Closed seasons are not recommended but rather the creation of community supported fisheries reserves where fish are not disturbed by any netting.
- The fish species composition in Lake Liambezi changed since the early 1970's. It was then dominated by cichlids, particularly greenhead tilapia (*Oreochromis macrochir*) and medium sized fish.
- After drying out and refilling, the catch per unit effort in weight in Lake Liambezi declined.
- Lake Liambezi requires restocking to revive the previous fish production potential.
- The large economically important species in the Zambezi and Chobe Rivers will decline further in future if the fishery is left unmanaged.
- A decline in large fish occurrence may impact on the recreational angling tourist industry in the region with the possibility of cuts in employment and income to communities.
- A non-management strategy of the fishery may impact especially on the poor rural communities (in particular women and children), putting further pressure on government for aid.
- The final conclusion is that if the fishery is not properly managed, the fish resource will continue to decline in biomass and fish size to where fishermen adapt their fishing methods to enable them to have enough protein for the family. This decline may further to continue to such an extent that even this may become difficult.