ASSESSMENT OF THE LAKE LIAMBEZI FISHERY, ZAMBEZI REGION, NAMIBIA

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ABSTRACT

Lake Liambezi in the Zambezi Region of Namibia, formerly known as the Caprivi Region, is shallow (<6m deep) and characterised by cyclic episodes of filling and drying. When full the lake supports a highly productive fishery and when dry the lake is completely dry and used for agriculture and grazing. In 2000 the lake filled, and between May 2011 and April 2012 was surveyed using beach seine, experimental gillnets and catch landing surveys to obtain information for conservation and management recommendations for the fishery.

Littoral fishes in Lake Liambezi and the Kavango floodplain were sampled using seine net and physicochemical properties were measured. Seine net surveys demonstrated that Lake Liambezi littoral zones were dominated by fishes of the family Alestidae (59.7%) while Cichlids constituted the most diverse family. Juvenile *Tilapia rendalli* and *Oreochromis macrochir* were among the five most important species in the littoral zone, indicating that these commercially important species use the littoral zone as a nursery ground. Since *T. rendalli* and *O. macrochir* are commercially important species, because of this, it is advised that seine nets should not be used.

Catch efficiency between monofilament and multifilament gillnets in Lake Liambezi offshore waters were assessed. Catch efficiency experimental fishing trials showed that monofilament gillnets catch per unit effort (CPUE) was three times higher than that of multifilament gillnets for *Oreochromis andersonii, O. macrochir, T. rendalli*, *Serranochromis macrocephalus* and *Clarias* spp. *Oreochromis andersonii* comprised over 66% of the overall CPUE for both net types combined indicating the importance of this species in the gillnet fishery on the lake.

A fishery has been established on the lake with more than 300 canoes and 120 fishermen using monofilament and multifilament gillnets. CPUE was 15 kg/canoe/day and was significantly ($P < 0.05$) associated with monthly temperature and moon phase parameters indicating that the fishery of Lake Liambezi may be altered by climate and environmental factors. Annual catch from Lake Liambezi was estimated at 3193t with an estimated productivity of 106kg/ha, suggesting that Lake Liambezi makes a significant contribution to the fish supply in the Zambezi Region.

Recommendations were made to manage the Lake Liambezi fishery by imposing restrictions on effort (number of fishing boats), gear type, mesh sizes and access. Proper fisheries management and monitoring should incorporate climatic and environmental factors such as temperature and moon phase to meet the challenges of global climatic changes as well as other environmental issues.

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Table of Contents

CHAPTER 1

GENERAL INTRODUCTION

1.1 INTRODUCTION

The surface area of Namibia is 826 635km^2 of which approximately 5 000km^2 is covered by water (Naesje, 1999) (Figure 1.1a). About 92% of Namibia's surface area is classified as arid (Naesje, 1999). Fishing waters are mainly located in the northern parts of the country (Kavango and Zambezi Regions) with additional fisheries in the regions of Oshana and Hardap, and on some of the more isolated inland lakes such as Lake Liambezi and Lake Lisikili.

Namibian fishery plays a major role in the riparian communities, and at present provides livelihoods for an estimated 100 000 people (MFMR, 1995). Fishing provides employment opportunities in catching, processing and trading activities. Fish farming in Namibia dates back to 2005 with the introduction of Carp (*Cyprinus carpio*) and Mozambique tilapia *Oreochromis mossambicus* at Hardap Fisheries Research Institute. Small-scale fish farming was introduced earlier in 2003 with the establishment of Onavivi Aquaculture Centre in Oshana Region and six community-based fish farms in the Kavango and Zambezi Regions. Annual fish production from these sectors is very small, yielding less than one tonne per year, except for Onavivi Aquaculture Centre which yields more than one tonne in a good year. The major challenges are how to promote fish production from ponds on a commercial basis in a way to enhance local fish supply countrywide.

Fish processing and marketing is a major occupation among many fishing communities in the north and north-eastern regions of the country. Most of the fish is dried for easy storage and sold to distant markets. Fish processing facilities range from traditional open pits to drying mats. Fish trading has also increased since Independence in 1990. This increase was observed with innovations such as the introduction of nylon thread in the 1960s instead of homemade plant-fibre nets. Detailed figures for production of fish from inland sources in Namibia are lacking; however, Seki & Bonzon, (1993) reported that production of inland fish in Namibia was 2800t/year. Tweddle & Hay, (2011) reported that Lake Liambezi alone produced approximately 1700t in 2011 and that the Zambezi Region's floodplains as a whole produced 6000t/year.

1.2 THE ZAMBEZI REGION

The Zambezi Region, formerly known as the Caprivi Region, is a narrow strip of land extending eastwards from the north-eastern corner of Namibia (Figure 1.1b). Angola and Zambia border the region to the north, Botswana to the south and Zimbabwe to the east (Figure 1.1b). The region is flat and characterized by numerous swamps and slow-flowing rivers such as the Kwando and Zambezi (Figure 1.2). Each of these rivers supports extensive floodplains in the Zambezi Region. The magnitude, timing and duration of floods are variable and depend largely on rainfall in the upper catchments of the Kwando and Zambezi Rivers (Peel, 2012). During high water flows, the Kwando and Zambezi Rivers breach their banks annually, inundating large plains. These seasonally inundated floodplains form extremely productive wetlands and account for much of the species richness found in the open waters of the region.

The Zambezi wetlands support an important catfish and cichlid fishery involving more than 700 fishermen and yielding 6700t/year (Tweddle & Hay, 2011).

Households rely on fish consumption on a daily basis and fish is the most important source of protein, ranked over beef, game and poultry (Turpie *et al*., 1999). The local population lives a rural life-style, and depends heavily on subsistence fishing as an affordable source of protein (Koekemoer, 2003). Seventy-five percent of the households are physically engaged in subsistence fishing, with an average reported catch of 370kg per household. Fish trade benefits the poorest households, who have limited access to other means of income (Purvis, 2002).

1.2 LAKE LIAMBEZI

Lake Liambezi is a large floodplain lake in the Zambezi Region (Figure 1.1c). The lake receives water from four sources (van der Waal, 1980), (Figure 1.2). To the west, the Kwando River, which originates in the Angolan Highlands, forms the boundary between Angola and Zambia. Passing through the Zambezi Region, the Kwando percolates through the Linyanti swamps on the Namibian-Botswana border before feeding into Lake Liambezi. A second important source is direct rainfall and surface run-off from the area to the north of the lake, which also feed the lake. Floodwaters from the Zambezi enter the lake from the east in two directions during high flood years. The Chobe River reverses flow direction annually when the Zambezi floods and enters the lake from the southeast, while the Bukalo channel enters the northeast of the lake from the Caprivi floodplain.

When full, Lake Liambezi is a shallow lake that does not exceed 6m depth at peak water levels. Because of its shallowness, nutrient recycling is efficient, making the lake highly productive. Previous reports on the Lake Liambezi fishery and its production potential have been presented by van der Waal, (1980) and Tweddle *et al*., (2011). In 1974, fish production from Lake Liambezi was approximately 1 400t/yr but in 1976 it dropped down to 115 tons. This is considerably lower than an estimated value of 1 700 tonnes reported by Tweddle *et al*., (2011).

Catches of fish were reduced at times of low water levels when fishing became difficult and the water notably alkaline and unsuitable for some species (Seaman *et al*., 1978; van der Waal, 1980). The importance of the Lake Liambezi gillnet fishery was first recognized in the 1970s when it was reported that valuable cichlid species such as *Oreochromis andersonii* had been exported to neighboring countries in Botswana and Zambia in 1960 and 1970 (Tvedten *et al*., 1994). The lake dried up in 1986 and refilled in 2000 when once again the fishery became important. For the newly inundated Lake Liambezi, it is important to determine the state of the fish stocks and their response to both human intervention and environmental variables in space and time.

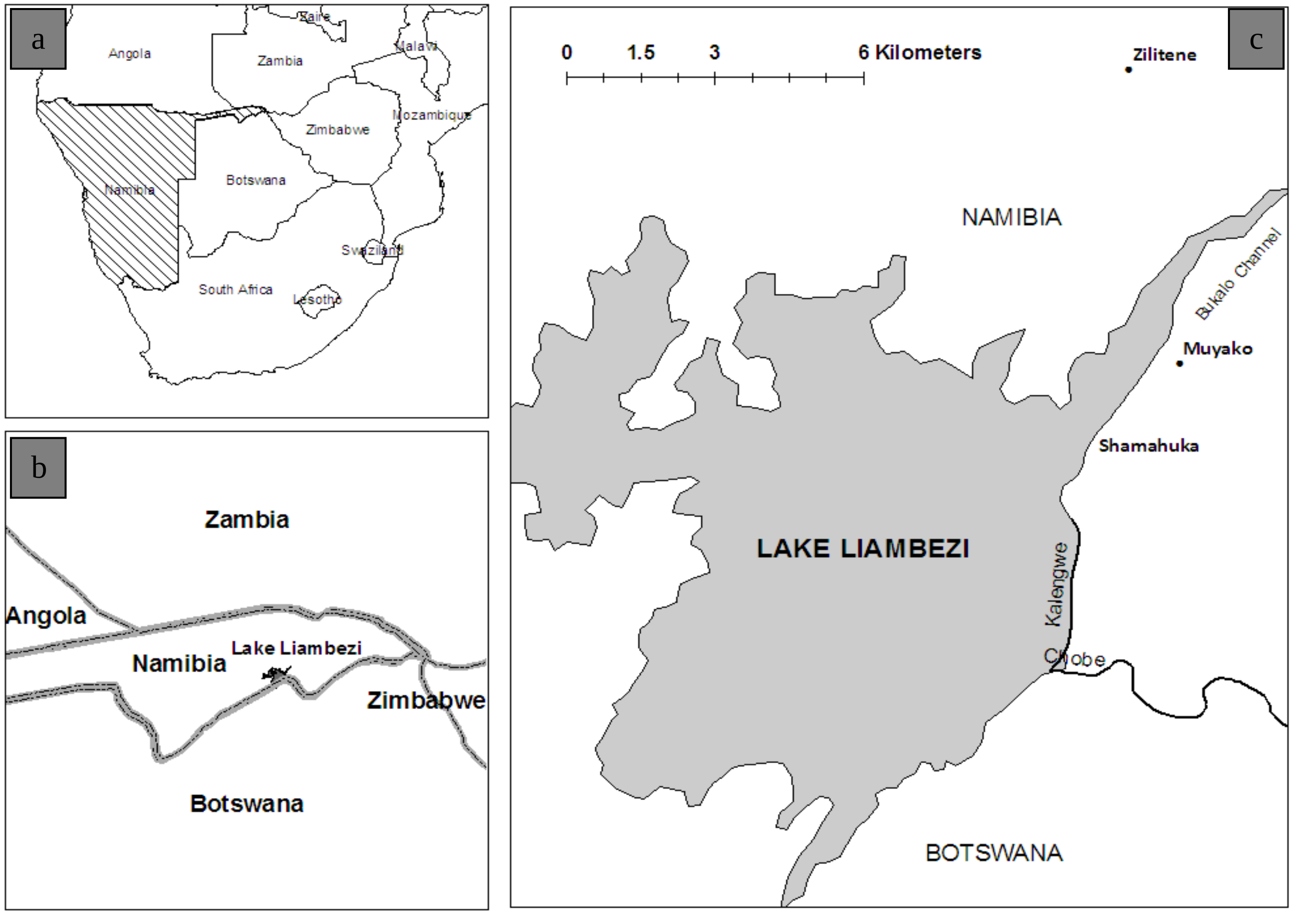


Figure 1.1. Map of Southern Africa, showing (a) Namibia, (b) the Zambezi Region, and (c) Lake Liambezi, generated using ArcGIS 9.3.

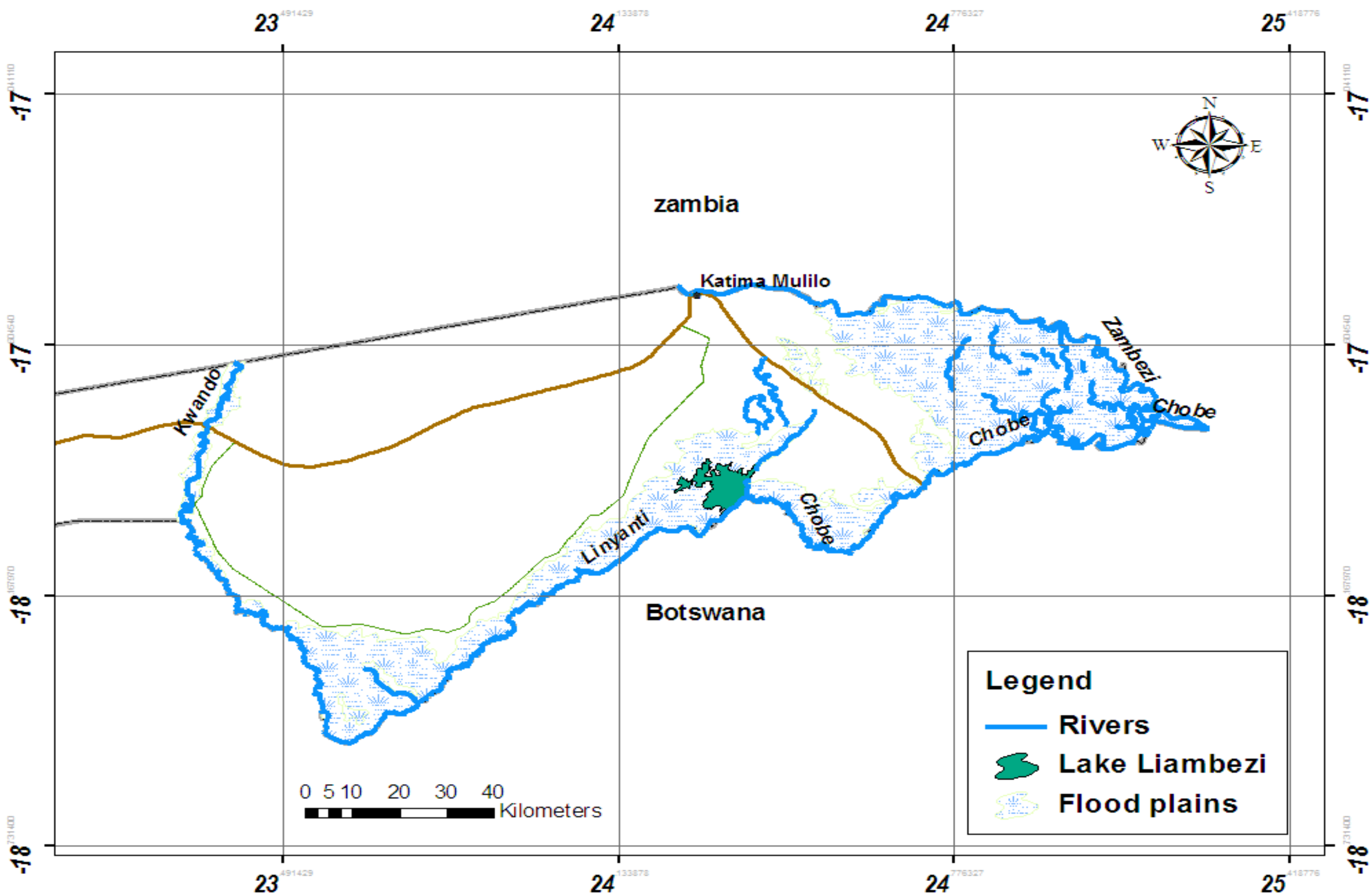


Figure 1.2. Map of the Zambezi Region, showing main water bodies: Zambezi River, Chobe River, Lake Liambezi, Linyanti River and Kwando River, generated using ArcGIS 9.3.

1.4 THE FISHERY IN THE 1970s AND 1980s

From 1973 to 1976, van der Waal, (1980) conducted a detailed study on the fishery in Lake Liambezi. According to van der Waal, the fishery on the lake started in 1959 and was typically a seasonal and part-time activity carried out by men only (Windhoek Consulting Engineers, 2000), with fishermen returning to their villages in spring to plant crops and resuming fishing methods after the rains (van der Waal, 1980). With the exception of spears, no traditional fishing activities were used and the main gear used by fishermen was the multifilament nylon gillnet, with variable stretched mesh sizes between 3" and 7" (inches) (van der Waal, 1980). Nets were initially homemade from raw materials such as motor tyre cords, but these were replaced with nylon nets in the 1960s.

The number of fishermen fishing the lake decreased from a maximum of 120 in 1974 to a minimum of 17 during 1976 and 47 fishermen in 1980 (van der Waal, 1980). The decline was linked to a temporary lowering in catch rates with a rise in lake levels during 1973-1976 (van der Waal, 1980). After 1981, very little floodwater from the Zambezi or the Linyanti Swamp entered the lake because of a decline in water level in 1985. A drop in the numbers of fishermen also coincided with a bloom of *Phragmites mauritianus*, which hampered access to the preferred fishing grounds (Seaman *et al*., 1978). Prior to 1970, no catch or effort data were recorded on the lake; however Beatty, (1969) reported that fish were caught on a large subsistence-scale level and exported to Livingstone in Zambia. During the 1980s, the average yield for the open water lake was 34.5kg/ha but if one includes the inaccessible reed swamp area, this decreased to 11.5 kg/ha (van der Waal, 1980).

1.5 FISH MARKETS

Prior to the drying up of Lake Liambezi in 1985, marketing the fish was initially a problem when fish had to be transported by bicycle over rough tracks and through flooded areas to the market at Ngweze in the Katima Mulilo urban area (van der Waal, 1980). The key players in the value chain were the fishermen, fish traders and fish vendors. Fishermen were defined as the individuals who were involved in the fishing operation, landed their catches and sold them to fish traders. Traders were defined as the group of people who bought fish, usually in bulk, and sold them wholesale to fish vendors at a local or regional level. Fish vendors were defined as the group of people who bought their fish wholesale from traders and sold them to the consumers. Other role players, who were not directly involved with the product, were the governing bodies, such as the Ministry of Agriculture, who aimed to ensure sustainable use and exploitation of the fishery resources (van der Waal, 1980).

The market place itself was poorly designed, consisting of a concrete table below a corrugated iron roof for dried fish, while fresh fish were sold exclusively in bags (Purvis, 2002). Alternatively, there was a more dependable fish market in Satau, Botswana closer to Lake Liambezi where fish was sold by a Botswana cooperative to Zambian and Zimbabwean fish traders. Most fish traders packed their fish on ice in large cooler boxes and shipped them on small lorries for sale in Livingstone and Bulawayo (van der Waal, 1980). Fish prices varied between N$1/kg and N$2/kg. The deteriorating political situation eventually caused a collapse in this fish cooperative around 1976 (van der Waal, 1980), but in 1975, the development of a paved road between Muyako village (in which the lake is situated) and Bukalo settlement, together with the availability of a cold storage, enhanced the supply of fresh fish to the fish markets at Bukalo and Katima Mulilo. This process was led by the Department of Agriculture and Forestry (van der

Waal, 1980). Once again in 1977, the chain of demand and supply for fresh fish was interrupted by technical problems with the storage freezer. The freezer was restored to operation in 1978 and from that point onwards a continuous supply of fish into Katima Mulilo fish markets was sustained until the lake dried up in 1986.

1.6 FISHERIES MANAGEMENT AND REGULATIONS OF LAKE LIAMBEZI

In recognizing the importance of freshwater fisheries in the country, the government of Namibia developed policies and laws to guide the management of freshwater resources. In the Zambezi Region, management approach includes technical measures such as gear restrictions, mesh size regulations, method of capture, and the number and length of gillnets per fisherman (Peel, 2012). These techniques may increase catches with some gear and reduce catches with others.

Lake Liambezi fishery is controlled by the state through the Ministry of Fisheries and Marine Resources (MFMR). Two directorates under the MFMR are responsible for inland fisheries management. The Directorate of Aquaculture and Inland Fisheries conducts research and renders extension services to small-scale fish farmers, while the Directorate for Operations is responsible for enforcing regulations, as stipulated in the Inland Fisheries Act (MFMR, 1995). As a possible solution towards the growing problem of resource over-exploitation, responsibility for resource management is shared between the Government and various user groups. This concept is defined as co-management, which focuses on the recognition that user groups have to be more actively involved in fisheries management if the regime is to be both effective and legitimate. In 2010, the MFMR together with the traditional authorities constructed a centralized fish landing at Shamahuka to act as a focus for extension work.

Management measures are targeted entirely at fishing for the most valuable tilapiine cichlids; the lesser-value non-cichlid species are partially incorporated. A permit system is in place whereby the MFMR informs the local authorities about the limits placed on the number of fishing permits that may be issued for a particular year. The regional councils then issue these fishing permits to the individual fishers. The distribution of permits can differ from one local authority to another. For instance, most individual fishermen in the 1970s were not restricted to the number of nets and mesh sizes used, whereas fisherman in 2009 were allowed to use only a limited range of mesh sizes. The official limits set by the MFMR do not however specify the maximum number of fishers to be involved.

The fishing patterns are very simple because only one type of gear (gillnet) is used throughout the whole offshore fishery of the lake. Fishing is not permitted using nets of less than 3 inches mesh size. In addition, explosives, chemicals, poisons, intoxicating substances, scoop nets, jigging and fish driving may not be used to catch fish, as stipulated in the Inland Act (MFMR, 2003). An important management issue, particularly on the lake, is the high fishing pressure and changing fishing patterns in terms of increased use of small mesh sizes and the use of customary, but illegal, fishing methods, such as dragging and drive fishing (Kutumpula).

1.7 THESIS OUTLINE

The primary aim of this thesis is to assess and provide management recommendations for sustainable utilization of the newly inundated Lake Liambezi Fishery in Zambezi Region in north-eastern Namibia. This was achieved by assessing the dynamics of Lake Liambezi fishery using beach seine, experimental gillnets and catch landing surveys to obtain information for conservation and management recommendations for the fishery.

This thesis is divided into six chapters: Chapter 1 is the general introduction, and literature review of the cyclic episodes of inundation and drying of Lake Liambezi. Chapter 2 briefly describes the study area and the basic water parameters, including the sampling protocol and the data sources used in the thesis. Species composition in the littoral zones of Lake Liambezi and the Kavango floodplain is dealt with in Chapter 3. Chapter 4 compares the efficiency between monofilament and multifilament gillnets in Lake Liambezi, while Chapter 5 explores the new commercial gillnet fishery on Lake Liambezi. Chapter 6 is a general discussion on the findings of the study and recommendations on the best management measures in order to ensure sustainable utilisation of the fisheries resources of the Lake Liambezi.

CHAPTER 2

DESCRIPTION OF THE STUDY AREA AND METHODOLOGY

2.1 LAKE LIAMBEZI

Lake Liambezi (17°53'S, 24°17'E) is situated on the Namibian/Botswana border between the Linyanti Channels in the west and the Chobe River in the south-east. The lake was sampled at Muyako and Shamahuka, one of the few areas where there is easy access to the lake shore from the east (Figure 2.1). In 1975, the lake covered a surface area of about 300km^2 of which 101km^2 was open water (Seaman *et al*., 1978; Peel 2012).

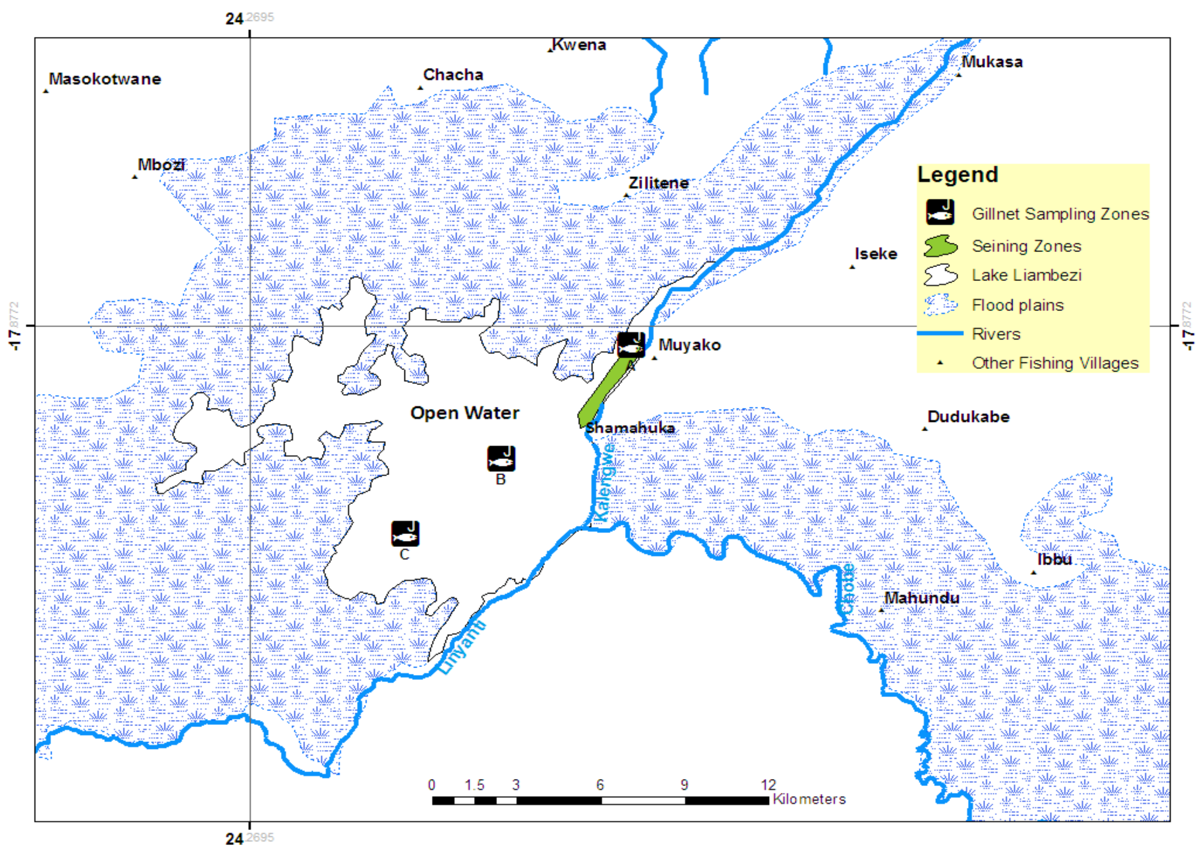


Figure 2.1. A map of Lake Liambezi, showing the sampling stations (Muyako and Shamahuka), seining zones and gillnet sampling zones along the Lake Liambezi, between May 2011 and April 2012, ArcGIS 9.3.

2.2 PHYSICAL FEATURES

Lake Liambezi has retained many of its physical features from the time before it dried up in 1985 (Peel, 2012) (Figure 2.2). The swamp area of the lake is surrounded by woodland savannah and lies in the Kalahari basin where soils are mainly fine secondarily-deposited aeolian sands with well-developed secondary horizons (Windhoek Consulting Engineers, 2000). The open water of the lake is bordered by a reed swamp comprised mainly of *P. mauritianus* (Seaman *et al*., 1978). In sheltered areas there are dense beds of submerged macrophytes. The reeds appear to act as nutrient sponge, which absorbs available nutrients and releases nutrients in detritus form into the open lake (Seaman *et al*., 1978).

The availability of nutrients to the algae therefore depends on recycling, and on the rate at which detritus decomposes in the water. Extensive *P. mauritianus* reed beds extend to the south, southwest, west and north, and the open water can only be reached from the northeastern and eastern shores. Since the majority of the ichythyomass is dependent on the quantities of zooplankton and algae in the water, it follows that the reeds are the most important primary producers in the system (Seaman *et al*., 1978).

Figure 2.2. Habitat types in Lake Liambezi, (a) open water with reeds, (b) dense macrophyte beds, (c) flooded marginal grasses and (d) open water.

2.3 THE HYDROLOGY

The hydrology of the Lake is complex with two distinct flood peaks each year, during years of high floods in the Zambezi and Kwando Rivers. The first flood occurs between March and May as a result of inflow from the Zambezi at its flood peak through the Chobe River and Bukalo Channel (van der Waal, 1976). The second flood occurs between August and September as a result of inflow from the Kwando-Linyanti River whose floodwaters are delayed by the reservoir-like properties of the Silowana floodplains and by the Linyanti Swamp (van der Waal 1976). Strong seasonal water level fluctuations with relatively low annual variation create annual changes in habitat availability (areas of inundation), fish migration corridors and pulses of food availability in the lake. Hydrological data for the mean monthly water levels in metres were collected at a hydrological station situated in the mid-zone of the lake. Data were recorded on a weekly basis and are represented in Figure 2.3; Appendix 1.

2.4 WATER QUALITY

Temperature and secchi depth were measured in situ. Water temperature was measured using a digital thermometer and water transparency was estimated using a secchi disc. Water temperature ranged between a winter minimum of 19.0 °C and a summer maximum of 28.0 °C (Figure 2.3b; Appendix 2). The annual average water temperature during the sampling period was 24.0 °C. Secchi depth ranged from 0.6 m to 1.6 m (Mean = 1.0 m) (Figure 2.3c; Appendix 3). Water collected from the eastern shore of Lake Liambezi in October 2001 (Palmer, 2001) was characterized by low pH (5.1), excessive hardness (calcium carbonate 968 mg/ℓ), high iron levels (2.2 mg/ℓ), high turbidity (29.3 NTU), high salinity levels (222 mS/m), and high numbers of heterotrophic bacteria (10 944 cells per mℓ). Ammonia levels were sufficiently high (30.6 mg/ℓ) to be chronically toxic to certain aquatic fauna, and salinities were sufficiently high to be toxic to certain crops. The water quality reflected severe decomposition of organic material, mainly terrestrial grass (*P. mauritianus*) that had been inundated. Overall, the quality of this water was considered poor (Class D) (Palmer 2001). These data highlight the highly variable and unstable limnological features of Lake Liambezi. These results are very different to conditions recorded in 1974 and 1975, when the lake was full (Seaman *et al.* 1978). The most notable changes were lower transparency, significantly higher salinities, and high concentrations of ammonia and phosphate, indicating a severe state of decomposition of recently inundated organic material.

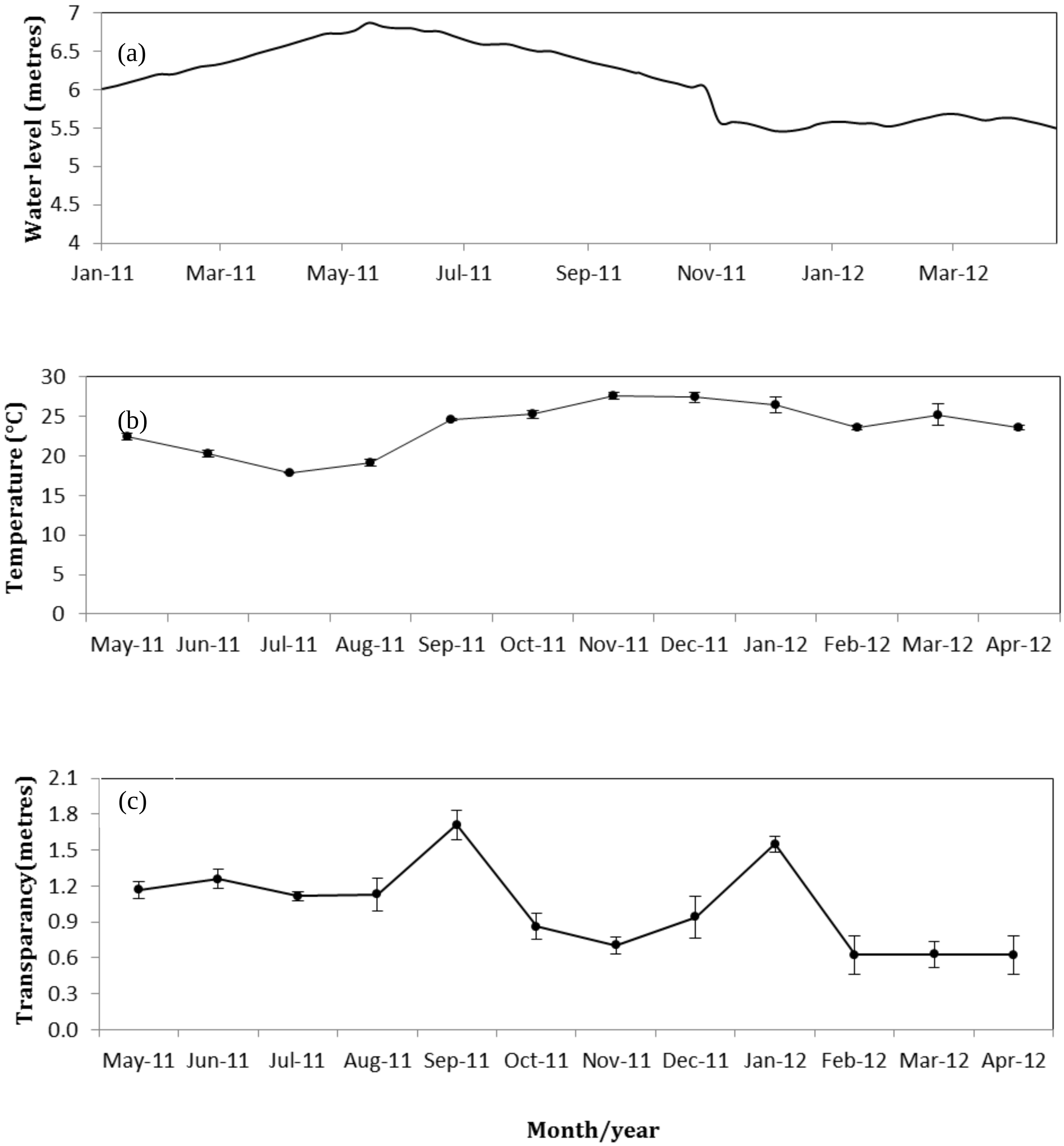


Figure 2.3. (a) Water level; (b) mean (± standard deviation) monthly water surface temperature and (c) secchi depth readings from Lake Liambezi between May 2011 and April 2012.

2.5 FISH FAUNA

The fish fauna of Lake Liambezi is linked to the Kwando and Zambezi waters, with subsequent colonisation of migratory species. The fish community and biology of the fish species have been described in a number of reviews and research works (van der Waal, 1980; Grobler, 1987; Koekemoer, 2003; Peel, 2012). Several of these discuss the observed biological succession in detail and only a brief update will follow. Van der Waal, (1980) reported 43 different fish species from Lake Liambezi, of which 29 were frequently collected. The fish species of the lake represented the more floodplain-loving species found in Zambezi Region and in the upper Zambezi system (Bell-Cross, 1971).

Most recently, the flood waters entering the lake basin during the large flood of 2009 brought opportunistic pioneer species. Most were small *Barbus* spp, characins and catfish (*Clarias* spp), but also tilapiine cichlids, *Oreochromis andersonii*, *O. macrochir* and *Tilapia rendalli*. Largemouth predatory cichlids included *Serranochromis robustus jallae* and *S. macrocephalus*. These thrived in the new lake, benefiting from high nutrients from the flooded terrestrial vegetation and soils (Tweddle *et al*., 2011). Peel, (2012) reported 29 different species and his species list was dominated by non-cichlids such as *Brycinus lateralis*, *Schilbe intermedius*, *Marcusenius altisambesi* and *Petrocephalus* spp. (Table 2.1). Cichlids were the most diverse family while *Micralestes acutidens* was the rare species. The same author noted a significant change in fish fauna of the lake in the 1970s and since it began to refill in 2000.

Table 2.1. Catch composition in order of Index of Relative Importance of the fish species sampled in Lake Liambezi, using experimental gillnet fleet (Peel, 2012).

Species	%IRI
Brycinus lateralis	53.756
Schilbe intermedius	27.112
Rhabdalestes maunensis	5.454
Petrocephalus spp	3.249
Marcusenius altisambesi	2.993
Tilapia sparrmanii	2.627
Serranochromis macrocephalus	1.026
Clarias gariepinus	0.659
Pharyngochromis acuticeps	0.627
Barbus radiatus	0.477
Synodontis sp	0.424
Hepsetus cuvieri	0.283
Barbus poechii	0.277
Pseudocrenilabrus philander	0.215
Oreochromis andersonii	0.166
Tilapia rendalli	0.16
Barbus paludinosus	0.139
Sargochromis sp."Green bream"	0.137
Clarias ngamensis	0.076
Oreochromis macrochir	0.071
Micralestes acutidens	0.03
Labeo cylindricus	0.025
Mormyrus lacerda	0.012
Pollimyrus marianne	0.011
Barbus bifrenatus	0.01
Synodontis nigromaculatus	0.009
Barbus unitaeniatus	0.002
Sargochromis carlottae	0.002
Barbus barnardi	0.001

2.6 SAMPLING METHODS

Monthly field sampling was conducted between May 2011 and April 2012 using beach seining, monofilament and multifilament gillnet experiments, hydrological data, catch landing and market data and creel surveys (Figure 2.1). Specific methods will be elaborated in each chapter.

Beach seining

The littoral ichthyofauna was sampled using a 20m long x 1.5m deep seine net with 5mm stretched mesh size with a bunt. Seine nets are used for capture-recapture techniques where population studies are undertaken. Clear marginal zones between 50 and 60m wide along the shore were the prime sites for seining on the lake. Nets were laid out at a distance of 20 to 40m from the shore (Figure 2.4).

Figure 2.4. Beach seining along the marginal zones of Lake Liambezi between May 2011 and April 2012.

Monofilament and multifilament experiments

A series of 10 gillnet panels belonging to two net types, 5x monofilament gillnets (Figure 2.5a-b) and 5x multifilament gillnet types (Figure 2.5c-d) were used. Each panel was 100 m long with the stretched mesh sizes of 3” (inches), 3.5”, 4”, 4.5”, and 5”. All fish specimens were identified to species level using Skelton's (2001) taxonomic keys, counted and measured to the nearest millimetre total length (TL).

Figure 2.5. (a) and (b) experimental gillnet catches in Lake Liambezi, using monofilament; (c) and (d) multifilament gillnets between May 2011 and April 2012.

Lake Liambezi fish landings and fish market data

Monthly catch landings and market surveys were conducted concurrently twice a week at Shamahuka landing site and at the Katima Mulilo fish market between May 2011 and April 2012. Daily fish landings at the lake and the weights of fish entering the market were measured using a hanging scale (Figure 2.6). The Katima Mulilo market is located in the administrative and economic centre of the Zambezi Region of Namibia. The market is located close to the central business district (CBD) and across the road from a large shopping complex. Access to the market from other parts of the region depends on proximity to well-maintained tarmac and gravel roads, as well as an extensive transport system of semi-formal taxis.

Creel surveys

The fishery was studied through frequent surveys at different landing sites and all the fishing camps on the lake. A questionnaire was formulated and composed of questions regarding the fishermen's fishing activities in a week, mode of transport to various fishing grounds, number of canoes, gear type and mesh sizes, Appendix 4. Surveys were concurrently conducted with the fish landing data collection at Shamahuka.

Figure 2.6. Weighing of fish using a hanging scale at Lake Liambezi, between May 2011 and April 2012.

CHAPTER 3

SPECIES COMPOSITION IN LAKE LIAMBEZI LITTORAL ZONE AND THE KAVANGO FLOODPLAIN, NAMIBIA

3.1 SPECIES IN THE KAVANGO RIVER AND LAKE LIAMBEZI

The perennial rivers of the Zambezi and Kavango Regions are home to a diverse fish community (Tweddle *et al*., 2004; Peel, 2012). The Zambezi and Kavango Region support over 77 and 71 fish species respectively (van der Waal, 1980, 1991; Tvedten *et al*., 1994). The fishes of Kavango River have been studied by a number of investigators dating back to pioneering work by Castelnau, who in 1861 described the first species from the Okavango swamp region of Lake Ngami collected by Daviaud (Jubb & Gaigher, 1971). Van der Waal & Skelton, (1984) provided a summary of the previous ichthyofaunal collections in the Zambezi Region. Fowler, (1935) and the second Bernard Carp Expeditions of 1949 and 1952, respectively, added important data on the fish biodiversity of the Zambezi Region (Van der Berg, 1956). Van der Waal's own collections on Lake Liambezi commenced in 1973 (Van der Waal & Skelton, 1984).

A synthesis of the collection by Peel, (2012) culminated in the most recent checklist of the fish fauna in Lake Liambezi and the Kavango River. Twenty-nine species, represented by eight families, nine cichlids and 20 non-cichlids, occur in Lake Liambezi, whereas 41 species, represented by 9 families, 13 cichlids and 28 non-cichlids, were found in the Kavango River (Peel, 2012). These species range in size from the largest fish species, *Clarias gariepinus* to small size barbs, e.g. *Barbus afrovernayi*. The majority includes the characin species as striped robber (local name: mbaala) and tilapiine cichlids, three spot tilapia (*Oreochromis andersonii*), green head tilapia (*Oreochromis macrochir*) and the redbreast tilapia (*Tilapia rendalli*). These are large size fish species growing over 2kg.

Other high value fish species such as the predatory largemouth cichlids *Serranochromis* spp including purple face largemouth bream (*S. macrocephalus*) are present.

Species diversity and richness were more pronounced in the Kavango River than in Lake Liambezi (Peel, 2012). The Kavango River's high diversity was linked to its origin, and a wide range of habitat types (Hocutt & Johnson, 2001). Lake Liambezi is subjected to high fishing pressure, caused by the use of efficient gears in the form of monofilament and multifilament gillnets (Peel, 2012). The fisheries of the Kavango River have remained largely subsistence (Hay *et al*., 2000; Peel 2012). Presently the fish stocks in both localities are not considered at risk of over-exploitation (Peel, 2012).

Lake Liambezi and the Kavango River are both subjected to flooding at different times of the year. In most river-associated wetlands in South Africa, such as the Pongolo floodplain and the Shire River's Elephant Marsh, the summer rainy season produces a natural rise in water levels, water temperatures are high, and food and shelter are readily available to fish (Bruton & Jackson, 1983). Most species in this environment use these favorable conditions to breed, a process that typically results in temporal segregation of juvenile cohorts (van der Waal, 1985; Merron, 1991).

Previous studies on Lake Liambezi and the Kavango River have focused mainly on open-water adult fish, and much of the littoral zone has never been studied. The aim of this chapter is to provide information on the temporal dynamics of the littoral fish communities in Lake Liambezi and the Kavango River floodplain, so as to contribute to the understanding of the functioning of the littoral zones. To do this, three hypotheses were tested:

1) Species diversity of small fishes in the littoral zone of Lake Liambezi was similar to that of other floodplains in the region e.g. the Kavango floodplain.

2) Juvenile fish densities catch per unit effort (CPUE) of the most abundant taxa were similar between Lake Liambezi and the Kavango floodplain.

3) Lake Liambezi littoral zone and the offshore zone are dominated by different species.

3.2 MATERIALS AND METHODS

Sampling

Seine net surveys in Lake Liambezi and the Kavango floodplain were conducted between March and October 2011. The Kavango floodplain was sampled at the Ministry of Fisheries and Marine Resources (MFMR)'s Kamutjonga Inland Fisheries Institute (KIFI) in the Mukwe constituency, Namibia (Figure 3.1).

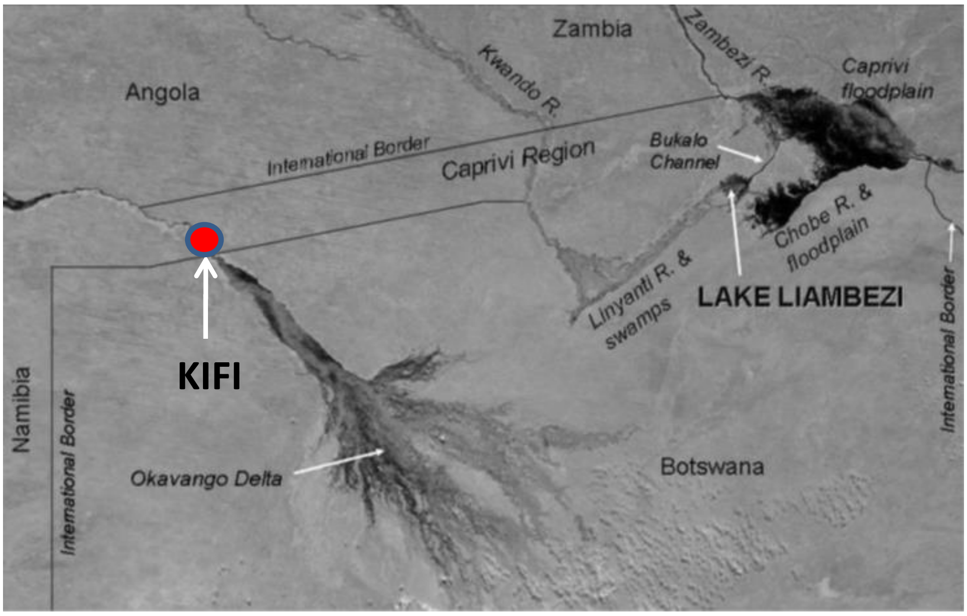


Figure 3.1. Map of the north-eastern Namibia showing the location of KIFI institute and water bodies in the Zambezi Region during the high waters in 2009. Source: Tweddle *et al.*, 2011).

Lake Liambezi provided limited opportunities for seine netting. The highly vegetated marginal zone of the lake made it difficult to seine throughout the year. Hence, comparisons between Lake Liambezi and the Kavango floodplain were based on a three month data set from May 2011 to July 2011. On each sampling day, the littoral ichthyofauna was sampled using a 20m long x 1.5m deep beach-seine with 5mm stretched mesh size with a bunt.

Clear marginal zones between 20 and 40m wide were randomly selected as the prime sites for seining. The net was laid out and hauled from a distance of 20m offshore. Fish were herded into the net by disturbing the vegetation or substratum that might provide refuge. Preliminary trials on Lake Liambezi with a seine net indicated that five to seven consecutive hauls per trip were sufficient to get a good representation of the fish families within the study area. As a result, seven hauls were made per trip. The catch per haul within a towed distance of 20m was used as an index of relative abundance. This assumed that: (1) the seine efficiency remained uniform in all the areas since there were no modifications to the net over time and (2) that the net was effective at collecting a representative sample of the littoral fish fauna. After sorting by species, all fish species were measured to the nearest mm total length (TL) and weighed to the nearest gramme (g). In cases where the catch of a species was large, the catch was sub-sampled.

Species diversity

Species diversity is defined as both the variety and relative abundance of species. Indices used to quantify biological diversity can be used to infer a measure of the health of the fish assemblages in these rivers (Peel 2012). To calculate the relative importance and diversity of different species, an index of relative importance (IRI) was used, as well as a measure of the number of species weighted by their relative abundance, expressed as the Shannon diversity index (H’). An index of evenness (J’), which is the ratio between observed diversity and maximum diversity, was also calculated. Information on species diversity in Lake Liambezi and the Kavango floodplain was based on monthly pooled samples during the period of the study.

The index of relative importance (IRI) was used to reflect the most important species in seine net catches by number, weight and frequency of occurrence from different sampling localities. This index is a measure of relative abundance or commonness of different species in the catch and was calculated as: IRI = (%N + %W) X (%FO) where %N = Percentage contribution of each species by number to the total catch per system; %W = Percentage contribution of each species by weight to the total catch per system; and %F = Percentage frequency of occurrence of each species in the total number of seine hauls.

The Shannon-Wiener index of diversity is a measure of species richness, weighed by their abundances or evenness and was calculated as: $H' = -\Sigma\, p_i \ln p_i$

where p_i is the proportion of individuals found in the *i*th species. The Shannon index assumes that individuals are randomly sampled from an 'indefinitely large' population, and that all species are represented in the sample. Shannon's index takes into account the evenness of the abundance of species, but the ratio of observed diversity to maximum diversity was used to calculate the index of evenness as follows: $J' = H'/H_{max}$, where $H_{max} = \ln H'$

Where J' is constrained between 0.0 and 1.0, a value of 1.0 means all species are equally abundant in the area. Both H' and J' assume that all species in the area are accounted for in the sample. The hypothesis that species composition was similar between localities was tested using a 2 systems x 42 species contingency table, based on numbers and H´ and J´ between systems.

Catch Per Unit Effort (CPUE)

When a standard fishing gear is used, the catch per unit of effort may be used as an indicator of the density of fish in the fished area. Seine net CPUE was defined as the number of fish caught per haul. CPUE was calculated as: CPUE = C_i/E_i, where C*i* is the catch of species *i* (in numbers) and E*i* is the effort expended to obtain *i*.

Statistical analyses

A contingency table (2 systems x 8 families) was used to test whether species diversity was similar between systems. A contingency table (2 areas x 5 species) was used to test for similarities in CPUE of the 5 abundant taxa between systems. The Kruskal-Wallis one-way analysis of variance (ANOVA) test was used to examine for seasonal changes in relative abundance (total CPUE). Data for each species were grouped by month. A Mann-Whitney U-test was used to test for habitat differences in total CPUE between Lake Liambezi and the Kavango floodplain.

3.3 RESULTS

Catch composition

A checklist of all species sampled from Lake Liambezi and the Kavango floodplain between March and October 2011 in Table 3.2 shows differences in species composition between the two localities. A total of 1756 specimens, representing 4 families, and 18 species were sampled from Lake Liambezi littoral zone and 2053 specimens, represented by 8 families and 24 species were sampled from the Kavango floodplain. Fishes of the family Alestidae dominated samples from Lake Liambezi, contributing 59.7% of the total catch by number, while cichlids dominated the seine catches in the Kavango floodplain, accounting for 73% of the total catch by number (Table 3.1 & Appendix 5). Some species such as *Barbus paludinosus, B. afrovernayi, B. radiatus, B. haasianus, Hydrocynus vittatus, Micropanchax hutereaui, Sargochromis giardi, Serranochromis angusticeps, Pollimyrus* spp, *Schilbe intermedius, Clarias ngamensis* and *Synodontis* spp were only sampled from the Kavango floodplain while others species such as *Barbus poechii, Labeo cylindricus, Micralestes acutidens,* and *Serranochromis macrocephalus* were exclusively sampled from Lake Liambezi (Table 3.2).

In Lake Liambezi, the small characin *Rhabdalestes maunensis* was the most numerous species accounting for 33% of the total catch while *Brycinus lateralis* accounted for the greatest weight 29% (Table 3.2 & Figure 3.2 a). The five most important species accounting for 80% of the IRI were, *B. lateralis* (27%), *R. maunensis* (21.3%), *T. rendalli* (14%), *Pharyngochromis acuticeps* (9%) and *O. macrochir* (9%) (Table 3.2).

In the Kavango floodplain, the banded tilapia, *Tilapia sparrmanii* was the most numerous species accounting for 32.9% of the total catch, while the green head bream *O. macrochir* contributed the highest weight 47.1% (Table 3.2 & Figure 3.2b). The five most important species accounting for 90.7% of the IRI were *O. macrochir* (40.3%), *O. andersonii* (19.3%), *T. sparrmanii* (17%), *T. rendalli* (10.2%), and *Pseudocrenilabrus philander* (3.9%). Juvenile cichlids, dominated by *T. rendalli, P. acuticeps, O. macrochir, P. philander* and *O. andersonii* constituted 25% of the total catch in Lake Liambezi.

Table 3.1. Percentage numeric contribution of the most abundant families in Lake Liambezi littoral zone and the Kavango floodplain, sampled between March and October 2011.

Families	Lake Liambezi littoral zone	Kavango floodplain
Cichlidae	25.8	73.0
Alestidae	59.7	15.4
Cyprinidae	14.6	2.6
Poecilidae	0.2	5.9
Others	-	2.7

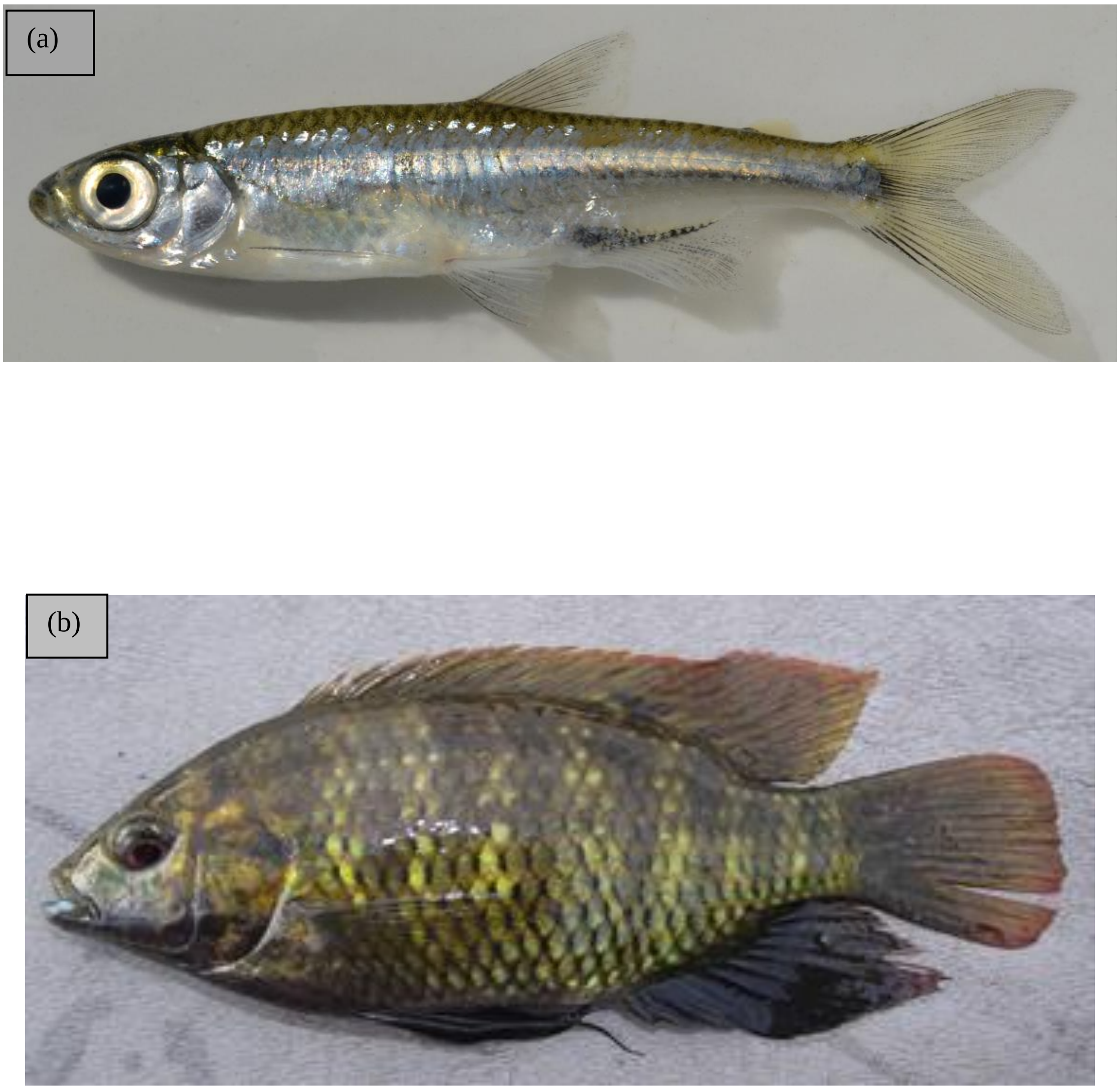


Figure 3.2. (a) *Rhabdalestes maunensis* and (b) *Tilapia sparrmanii*, the most dominant species in Lake Liambezi littoral zone and the Kavango floodplain. Source : Peel, 2012.

Table 3.2. Seine net catch composition in percent numbers (%N), percent weight (%W) and percent frequency of occurrence (%FO) and the percent index of relative importance (%IRI) of all species sampled in Lake Liambezi and the Kavango floodplain, Namibia , between March and October 2011.

	Lake Liambezi Littoral zone (n = 1756)				Kavango floodplain (n = 2053)			
Species	%N	%W	%FO	%IRI	%N	%W	%FO	%IRI
Mormyridae								
Pollimyrus spp	-	-	-	-	0.0	0.0	5.0	0.0
Cyprinidae								
Barbus afrovernayi	-	-	-	-	0.4	0.1	15.0	0.1
Barbus bifrenatus	0.2	0.0	4.3	0.0	0.0	0.0	5.0	0.0
Barbus paludinosus	-	-	-	-	0.1	0.0	15.0	0.0
Barbus poechii	9.3	6.0	47.8	7.1	-	-	-	-
Barbus radiatus	-	-	-	-	0.2	0.1	5.0	0.0
Barbus haasianus	-	-	-	-	1.9	0.3	20.0	0.4
Labeo cylindricus	5.1	28.1	21.7	7	-	-	-	-
Alestidae								
Brycinus lateralis	25.5	29.3	52.2	27.8	9.3	4.1	10.0	1.2
Hydrocynus vittatus	-	-	-	-	0.3	2.5	15.0	0.4
Micralestes acutidens	1.3	0.7	17.4	0.3	-	-	-	-
Rhabdalestes maunensis	32.9	6.0	56.5	21.3	5.8	1.5	10.0	0.7
Schilbeidae								
Schilbe intermedius	-	-	-	-	2.6	3.2	30	1.6
Clariidae								
Clarias ngamensis	-	-	-	-	0.1	0.3	10.0	0.0
Mochokidae								
Synodontis spp	-	-	-	-	0.0	0.0	5.0	0.0

Cichlidae								
Oreochromis andersonii	1.7	2.3	34.8	1.4	7.8	15.9	90.0	19.3
Oreochromis macrochir	4.6	7.3	73.9	8.5	21.6	47.1	65.0	40.3
Pharyngochromis acuticeps	7.5	4.7	73.9	8.7	0.2	0.2	15.0	0.1
Pseudocrenilabrus philander	2.1	1.1	56.5	1.7	8.6	2.2	40.0	3.9
Sargochromis sp.	0.2	0.4	4.3	0.0	-	-	-	-
Sargochromis sp. "Green bream"	0.1	0.2	4.3	0.0	-	-	-	-
Sargochromis giardi	-	-	-	-	0.0	0.1	5.0	0.0
Serranochromis angusticeps	-	-	-	-	0.0	0.1	5.0	0.0
Serranochromis macrocephalus	1.0	2.2	21.7	0.7	-	-	-	-
Tilapia rendalli	6.9	10.4	82.6	13.9	7.8	9.5	65.0	10.2
Tilapia sparrmanii	1.5	1.3	52.2	1.4	22.3	10.4	60.0	17.7
Tilapia ruweti	0.2	0.0	8.7	0.0	4.7	1.8	50.0	2.9
Poecilidae								
Micropanchax hutereaui	-	-	-	-	0.3	0.1	10.0	0.0
Micropanchax katangae	0.1	0.0	4.3	0.0	0.1	0.0	10.0	0.0
Micropanchax johnstoni	0.1	0.0	4.3	0.0	5.5	0.4	25.0	1.3

Species richness and diversity

The species diversity in communities, taking both total number of species and evenness into consideration, was calculated using the Shannon index H. More species were sampled from the Kavango floodplain (24 species) compared to 18 species from Lake Liambezi (Table 3.2). This is also reflected by the H´ and J´ indices which suggests higher diversity in the Kavango floodplain samples than in Lake Liambezi (2.3 v. 1.9) but this was not significant (2 x 42 contingency table: $P > 0.05$) (Table 3.3).

Table 3.3. Shannon-Wiener diversity (H') and evenness (J') indices for seine net catches in Lake Liambezi and the Kavango floodplain, Namibia.

Indices	Lake Liambezi littoral zone	Kavango floodplain
H'	1.9	2.3
J'	0.69	0.72

Species composition in the lake littoral and offshore zones

In the species list comparison between the littoral and offshore zones in the lake, the eight most abundant taxa in Lake Liambezi littoral zone were six cichlids *O. andersonii*, *O. macrochir, T. rendalli*, *T. sparrmanii*, *P. acuticeps*, and *P. philander* and the two alestids *B. lateralis* and *R. maunensis* (Table 3.4). These species combined accounted for 82.2% of the total catch in Lake Liambezi. The offshore species list is cited from the experimental gillnets surveys carried out by Peel in 2012. Lake Liambezi littoral zone (this study) was dominantly inhabited by similar species as those from the experimental gear (Peel, 2012) in the offshore zone (Table 3.4). However, most littoral species were mainly in their juvenile stage with most offshore species being in their adult stage. Alestidae, mainly *R. maunensis* and *B. lateralis*, were the most abundant species associated with both zones (Table 3.4).

Table 3.4. Species list comparison in percent numbers (%N), percent weight (%W) and percent frequency of occurrence (%FO) and the percent index of relative importance, between Lake Liambezi littoral and offshore zones.

	Lake Liambezi Littoral zone (n = 1756)				Lake Liambezi Offshore zone (n = 21194)			
Species	%N	%W	%FO	%IRI	%N	%W	%FO	%IRI
Mormyridae								
Marcusenius altisambesi	-	-	-	-	1.8	4.0	84.4	2.9
Mormyrus lacerda	-	-	-	-	0.0	0.2	8.9	0.1
Petrocephalus spp	-	-	-	-	3.8	1.5	93.3	2.7
Pollimyrus marianne	-	-	-	-	0.1	0.0	15.6	0.1
Cyprinidae								
Barbus barnardi	-	-	-	-	0.0	0.0	8.9	0.0
Barbus bifrenatus	0.2	0	4.3	0	0.1	0.0	22.2	0.0
Barbus paludinosus	-	-	-	-	0.3	0.1	53.3	0.2
Barbus poechii	9.3	6.0	47.8	7.1	0.5	0.2	60.0	0.4
Barbus radiatus	-	-	-	-	0.8	0.2	77.8	0.5
Barbus unitaeniatus	-	-	-	-	0.0	0.0	8.9	0.0
Labeo cylindricus	5.1	28.1	21.7	7.0	0.1	0.1	20.0	0.1
Alestidae								
Brycinus lateralis	25.5	29.3	52.2	27.8	67.1	38.7	100.0	52.9
Micralestes acutidens	1.3	0.7	17.4	0.3	0.0	0.0	4.4	0.0
Rhabdalestes maunensis	32.9	6.0	56.5	21.3	10.8	1.1	84.4	6.0
Hepsetidae								
Hepsetus cuvieri	-	-	-	-	0.1	1.7	26.7	0.9
Schilbeidae								
Schilbe intermedius	-	-	-	-	10.4	38.9	100.0	24.6
Clariidae								
Clarias gariepinus	-	-	-	-	0.1	3.3	28.9	1.7
Clarias ngamensis	-	-	-	-	0.0	0.8	13.3	0.4

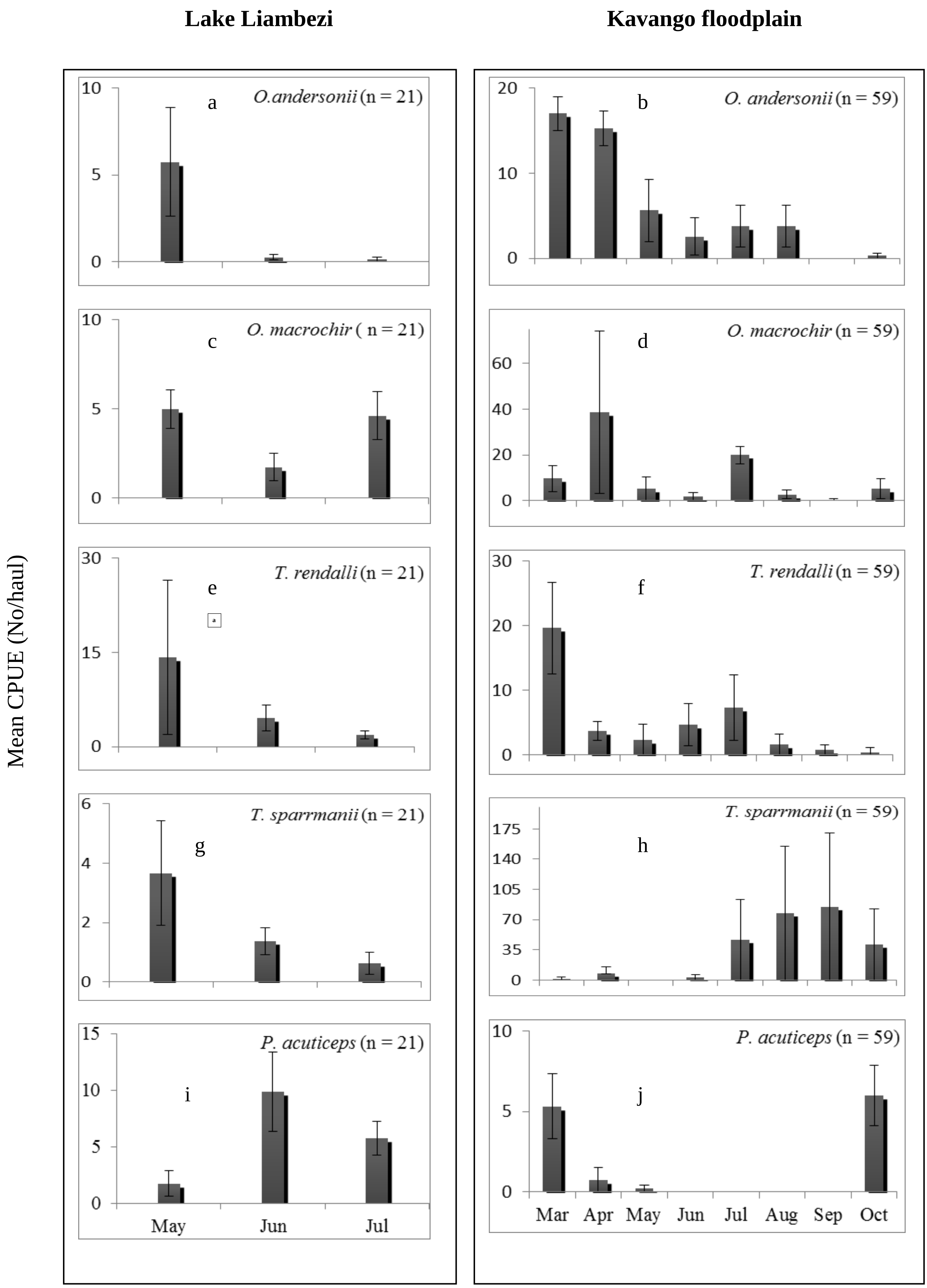
Mochokidae								
Synodontis nigromaculatus	-	-	-	-	0.0	0.1	8.9	0.1
Synodontis spp	-	-	-	-	0.5	1.1	62.2	0.8
Cichlidae								
Oreochromis andersonii	1.7	2.3	34.8	1.4	0.1	0.7	28.9	0.4
Oreochromis macrochir	4.6	7.3	73.9	8.5	0.1	0.5	20	0.3
Pharyngochromis acuticeps	7.5	4.7	73.9	8.7	0.6	0.7	77.8	0.7
Pseudocrenilabrus philander	2.1	1.1	56.5	1.7	0.4	0.1	62.2	0.3
Sargochromis carlottae	-	-	-	-	0.0	0.1	6.7	0.0
Sargochromis sp.	0.2	0.4	4.3	0.0	-	-	-	-
Sargochromis sp."Green bream"	0.1	0.2	4.3	0.0	0.1	0.6	28.9	0.3
Serranochromis macrocephalus	1.0	2.2	21.7	0.7	0.3	2.2	66.7	1.3
Tilapia rendalli	6.9	10.4	82.6	13.9	0.2	0.4	42.2	0.3
Tilapia sparrmanii	1.5	1.3	52.2	1.4	0.9	0.3	34.2	0.4
Tilapia ruweti	0.2	0.0	8.7	0.0	-	-	-	-
Poecilidae								
Micropanchax katangae	0.1	0.0	4.3	0.0	-	-	-	-
Micropanchax johnstoni	0.1	0.0	4.3	0.0	-	-	-	-

Relative abundance of the common littoral taxa among the sampling localities

Overall CPUE of the eight most abundant taxa differed significantly between Lake Liambezi and the Kavango floodplain (2 x 42 contingency table; $p < 0.05$) (Table 3.2), but on a species and seasonal level the variability between individual samples (hauls) was high and differences in abundance were mostly not significant. In Lake Liambezi, *O. andersonii* and *O. macrochir* were most abundant in May 2011 and least abundant in June 2011 (Figure 3.3 a and c). These differences were significant (Kruskal Wallis test, df =2, $P < 0.05$) for *O. andersonii*. In the Kavango floodplain, the highest abundance of *O. andersonii* and *O. macrochir* was in March and April 2011 and CPUE was lowest from June to October 2011, however no statistical difference were detected for both species ($P > 0.05$) (Figure 3.3 b and d). In Lake Liambezi, *T.rendalli* and *T. sparrmanii* were most abundant in May and lowest in July 2011 (Figure 3.3 e and g). These differences were not significant (Kruskal Wallis test, df =7, $P > 0.05$) for both species. In the Kavango floodplain, the highest CPUE for *T. rendalli* was in March and lowest in October 2011 (Figure 3.3 f). *Tilapia sparrmanii* CPUE was highest in September and lowest in March and June 2011(Figure 3.3 h). These differences were not found significant for both species ($P > 0.05$).

In Lake Liambezi, *P. acuticeps* and *P. philander* were insignificantly more abundant in June than in May 2011($P > 0.05$) (Figure 3.3 i and k). In the Kavango floodplain, the highest abundance of *P. acuticeps* was in October and *P. philander* were most abundant in September 2011 (Figure 3.3 j and l). These differences were not found significant for both species ($P > 0.05$). In Lake Liambezi, *R. maunensis* were most abundant in June and *B. lateralis* were most abundant in May 2011 (Figure 3.3 m and o). The lowest CPUE for *R. maunensis* and *B. lateralis* was in May and June 2011. However, these differences were not found significant for both species ($P > 0.05$).

In the Kavango floodplain, the highest abundance of *R. maunensis* and *B. lateralis* was in June and July 2011. Both species were least abundant in October 2011. These differences were not found significant for both species ($P > 0.05$).


Lake Liambezi
Kavango floodplain
Mean CPUE (No/haul)
a
O.andersonii (n = 21)
b
O. andersonii (n = 59)
c
O. macrochir (n = 21)
d
O. macrochir (n = 59)
e
T. rendalli (n = 21)
f
T. rendalli (n = 59)
g
T. sparrmanii (n = 21)
h
T. sparrmanii (n = 59)
i
P. acuticeps (n = 21)
j
P. acuticeps (n = 59)
May
Jun
Jul
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct

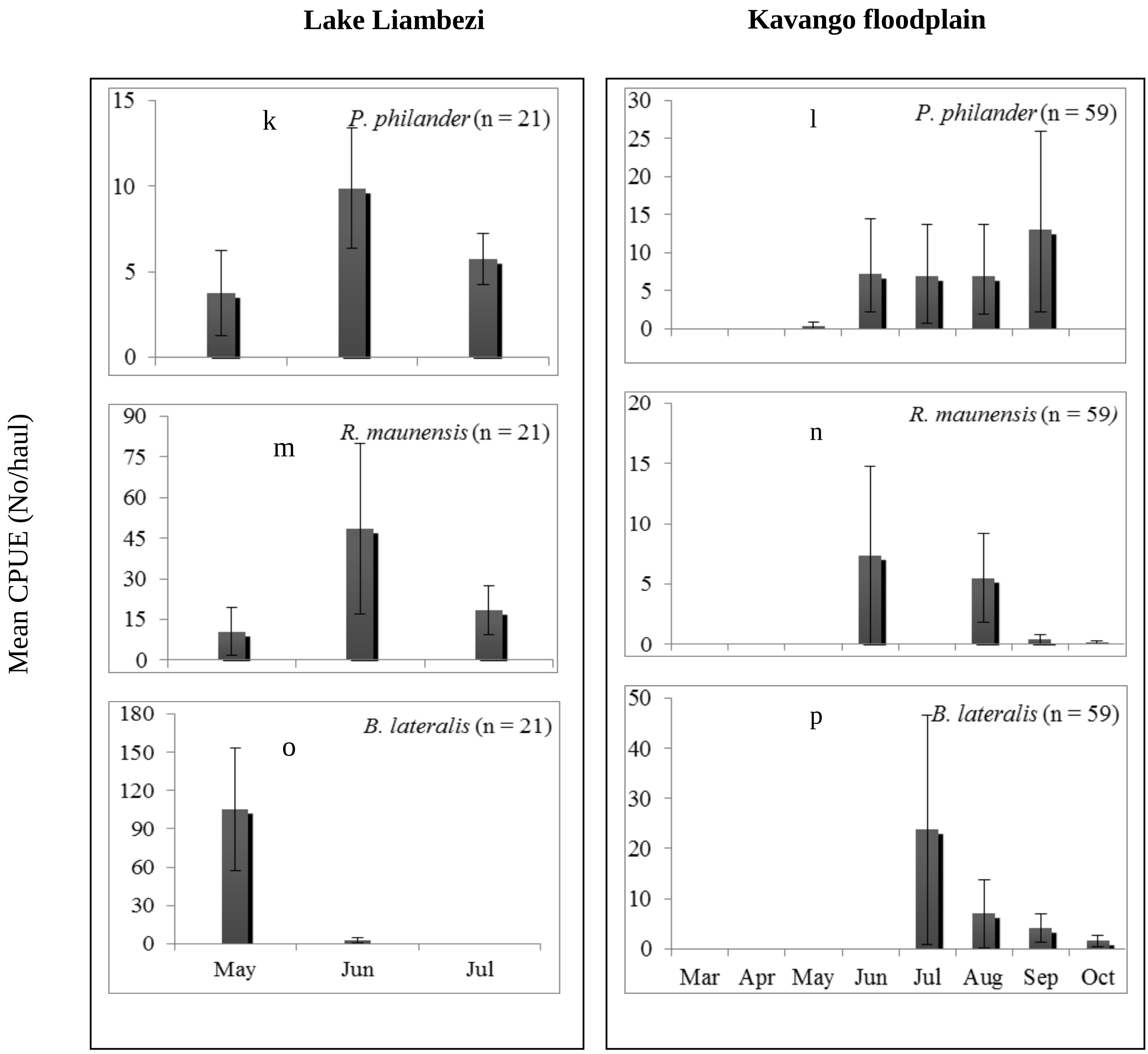


Figure 3.3 a-p. Mean CPUE for *O. andersonii*, *O. macrochir*, *T. rendalli*, *T. Sparrmanii*, *P. acuticeps*, *P. philander*, *R. maunensis*, and *B. lateralis*, in Lake Liambezi littoral zone and the Kavango floodplain in March – October 2011; n= the total number of hauls conducted.

Length structure of common species

In Lake Liambezi, juvenile *O. andersonii* and *T. rendalli* were largest in May and declined in June 2011 (Figure 3.4 a and e). These differences were highly significant for *T. rendalli* (Kruskal Wallis test, df = 2, P < 0.01). Higher frequencies of larger *O. macrochir* were observed in June and July than in May 2011 and these differences were significant (Kruskal Wallis test, df = 2, P < 0.05) (Figure 3.4 c).

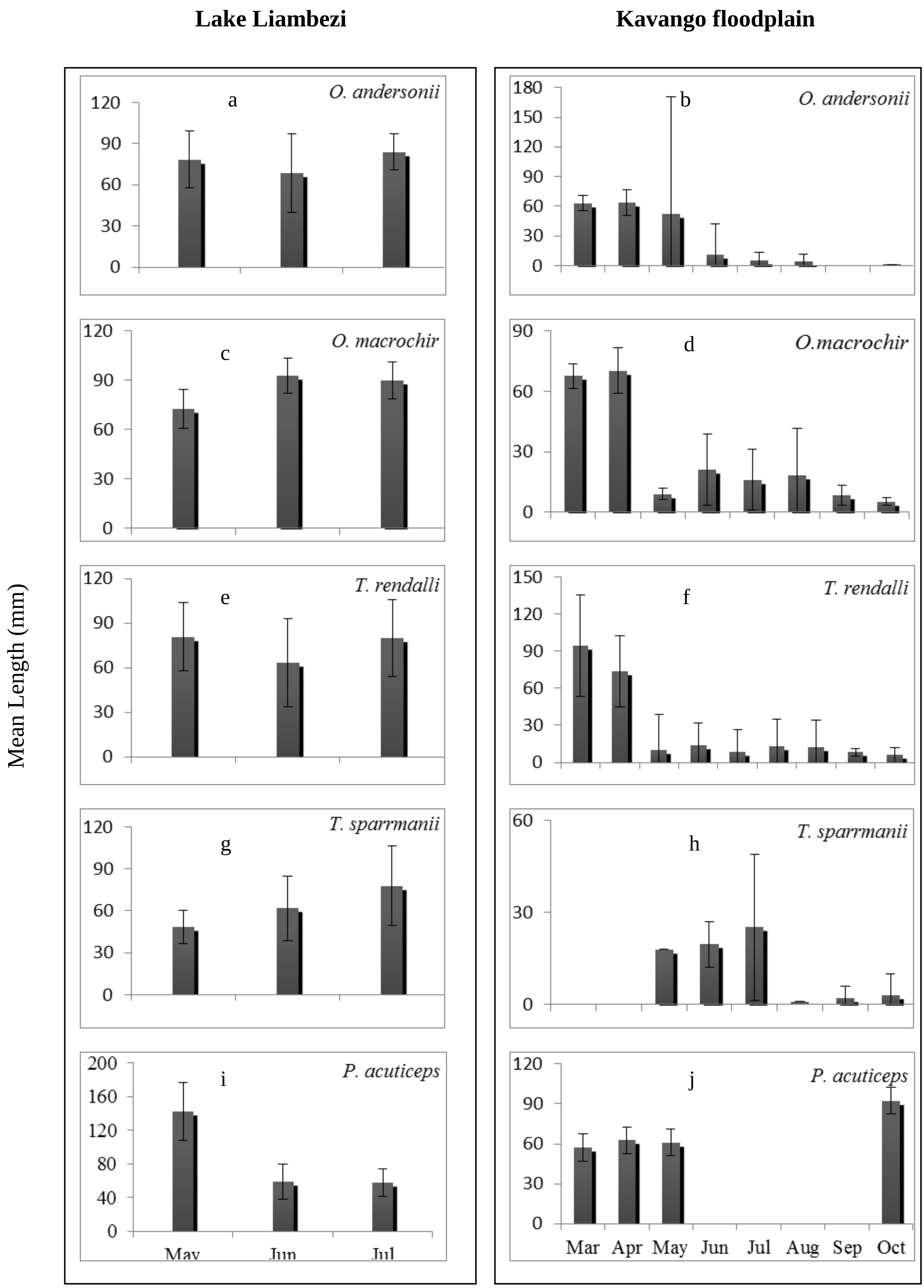
In the Kavango floodplain, higher frequencies of larger *O. andersonii*, *O. macrochir* and *T. rendalli* were observed between March and April 2011 and declined between May and November that year (Figure 3.4 b, d and f). These differences were significant for *O. andersonii* (Kruskal Wallis test, df = 4, P < 0.05), *O. macrochir* (Kruskal Wallis test, df = 6, P < 0.05), and *T. rendalli* (Kruskal Wallis test, df = 6, P < 0.05).

In Lake Liambezi and the Kavango floodplain, length frequencies of *T. sparrmanii* were similar for all samples, with higher frequencies of larger *T. sparrmanii* observed in July 2011(Figure 3.4 g and h). In Lake Liambezi, this increase in body size was followed by a decline in June and between August and November in the Kavango floodplain (Figure 3.4 g and h). These differences were significant (Kruskal Wallis test, df = 6, P < 0.05) for *T. sparrmanii* in the Kavango floodplain.

P. acuticeps, *P. philander*, *R. maunensis* and *B. lateralis* are small sized species, which can rarely grow to a larger size. In Lake Liambezi, higher frequencies of larger *P. acuticeps* and *P. philander* were observed in May 2011, and declined between June and July that year (Figure 3.4 i and k). These differences were highly significant for both *P. acuticeps* (Kruskal Wallis test, df =2, P < 0.01) and *P. philander* (Kruskal Wallis test, df =2, P < 0.01).

There were no seasonal differences detected in length frequencies of *R. maunensis* and *B. lateralis* (P > 0.05) (Figure 3.4 m and o).

In the Kavango floodplain, higher frequencies of larger *R. maunensis* and *B. lateralis* were observed in June and October 2011, (Figure 3.4 n and p). These differences were found significant (Kruskal Wallis test, df = 3, $P < 0.01$) for *B. lateralis*. A slight difference in length frequencies of *P. philander* was observed between May and October 2011 (Figure 3.4 l). These differences were found significant (Kruskal Wallis test, df =5, $P < 0.05$).


Lake Liambezi
Kavango floodplain
Mean Length (mm)
a
O. andersonii
b
O. andersonii
c
O. macrochir
d
O.macrochir
e
T. rendalli
f
T. rendalli
g
T. sparrmanii
h
T. sparrmanii
i
P. acuticeps
j
P. acuticeps
May
Jun
Jul
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct

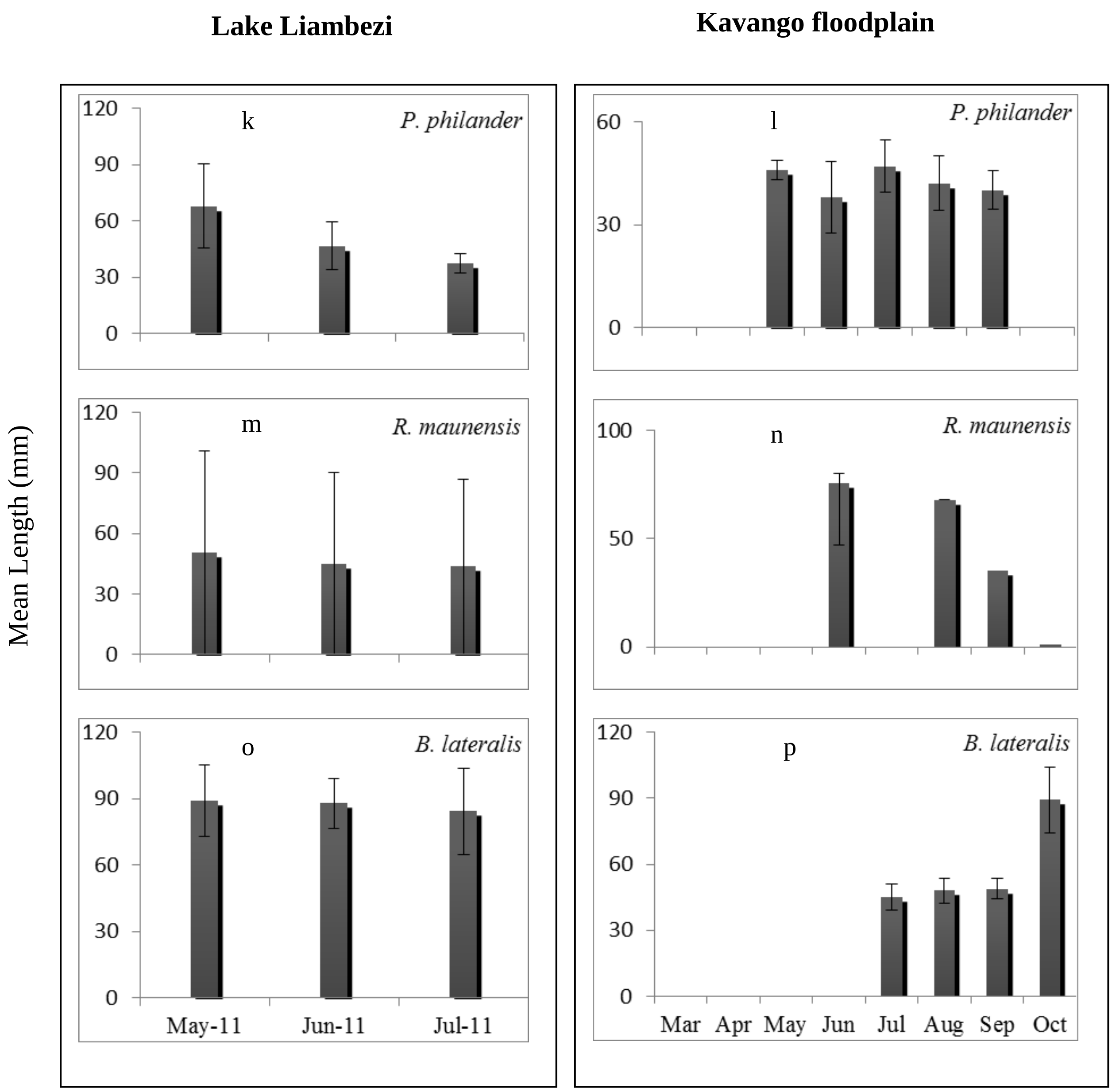


Figure 3.4 a - p. Mean total length (TL)+(SE) for *O. andersonii*, *O. macrochir*, *T. rendalli*, *T. sparmanii*, *P. acuticeps*, *P. philander*, *R. maunensis*, and *B. laterals*, in Lake Liambezi littoral zone (left panels) and the Kavango floodplain (right panels) during March – October2011.

3.4 DISCUSSION

Small fish assemblages varied considerably over time and between sampling localities. Van der Waal, (1980) recoded 24 species littoral fishes in Lake Liambezi, whereas Siziba *et al*., (2011) recorded 38 species of littoral fishes from the Okavango Delta. Both collections recorded more species than during the present study (18 in Lake Liambezi and 24 in the Kavango floodplain). Differences in species abundance and diversity may be explained by differences in sampling methods employed by this study and the preceding studies. Van der Waal, (1980) used two large seine nets in combination with explosives over a longer sampling period, while Siziba used a throw net in combination with Lundgren gillnets. In Lake Liambezi, however, seven additional species that were not listed by van der Waal, (1980) were recorded. These species included *B. poechii*, *B. bifrenatus*, *L. cylindricus*, *M. acutidens*, *Sargochromis* sp. "Green bream", *S. macrocephalus* and *Tilapia ruweti*. This indicates that the fish fauna in Lake Liambezi has undergone significant changes since it began to refill completely in 2009, and is likely still different from the community composition of the lake prior to it drying up in 1985 (Peel, 2012).

In the Kavango floodplain, species diversity and richness were higher, though not significantly so, than in Lake Liambezi. Hence the hypothesis that species diversity of small fishes was similar between Lake Liambezi and the Kavango floodplain was accepted. Peel, (2012) also reported higher species diversity in the Kavango River than in Lake Liambezi. The observed differences in species diversity may be explained by Lake Liambezi and the Kavango floodplain being distinct and disjunct from each other. The absence of a riverine habitat in Lake Liambezi could exclude some riverine fish species such as *H. vittatus*, as they might be unable to establish successful breeding populations (Peel, 2012). The fish in Lake Liambezi could be more constrained by the lake size and hydrology, while the Kavango Floodplain may increase in species diversity mainly through additional species migrating from the main river to more productive habits favourable to feeding and spawning (Welcomme, 1979; Junk *et al.*, 1989). Some fish taxa were collected in the floodplains whose adults do not regularly inhabit the river channels, but prefer floodplain habitats (eg. *Micropanchax johnstoni* and *M. katangae*). Thus, high species richness in the floodplain may partly stem from the presence of fish of both river and floodplain species. The low number of fish species in the semi-endorheic Lake Liambezi could be linked to the filling and drying phases of the lake.

The cichlidae was by far the most speciose family in each sampling locality, with ten species recorded from Lake Liambezi and nine species from the Kavango floodplain. These observations are consistent with the findings of van der Waal, (1980) on Lake Liambezi and Siziba *et al*., (2011) on the Okavango Delta, who also noted that cichlids were the most diverse family in the two sampling localities. Alestids, dominated by *R. maunensis,* were the most numerous species in the seine catches from Lake Liambezi; *R. maunensis* shoals in shallow lake water and flood plains, mainly feeding on small aquatic insects and other invertebrates (Skelton, 2001). The high abundance of this species is related to its environmental preference in the lake. This contention agrees with Peel, (2012), who also noted that Alestids were overwhelmingly dominant in the experimental gillnet surveys in Lake Liambezi. Cichlids, particularly the banded Tilapia, *T. sparrmanii,* were the most numerous species in the seine catches from the Kavango floodplain. Similarly, Siziba *et al*., (2011) reported high densities of *T. sparrmanii* in the temporary floodplain of the Okavango Delta. Cichlids are known to use diverse habitats for feeding and shelter, but these were caught in low densities from the littoral zones of Lake Liambezi.

Cichlids were also abundant in the Kavango floodplain, accounting for more than half of the total catch by number. As many cichlids migrate to and use floodplains for spawning, nursery and refugia or ranging movements (Bell-Cross & Minshull, 1988), this may explain the prevalence of this fish family in the Kavango floodplain. The lower numbers of cichlids in the Lake Liambezi littoral zone may further be explained by the rarity of the large predators such as *H. vittatus.* To avoid predators, diurnal movements into and away from shallow nursery areas are characteristic for many cichlid fishes (Marshall, 1982). Juvenile fish in Lake Liambezi may not be restricted to the marginal zones of the lake and therefore make use of a wider range of habitats in the lake. Underwater observations carried out by van der Waal, (1985), revealed that *O. andersonii* bred in channels leading into Lake Liambezi, whereas *O. macrochir* was observed breeding in bays and offshore waters while seine net operations were mainly restricted to the marginal zones. The diverse number of cichlid species collected in low numbers from the littoral zones of the lake suggests that these species are not rare, but their capture could have been disrupted by the highly vegetated littoral zone and the offshore spawning behavioral species such as *O. macrochir*.

Seasonal catch per unit effort (CPUE) of the eight most abundant littoral taxa varied significantly between the sampling localities, and therefore the null hypothesis that seasonal CPUE was similar among the sampling localities could be rejected. Juvenile *O. andersonii*, *O. macrochir* and *T. rendalli* showed similar trends in their seasonal CPUE. In Lake Liambezi, the abundance of early juvenile *O. andersonii*, *O. macrochir* and *T. rendalli* peaked early in April, while in the Kavango floodplain, their peak recruitment was in advance of flooding which occurs in December every year. *O. andersonii* and *T. rendalli* bred earlier than *O. macrochir*, with their juveniles being most abundant in March 2011. *O. macrochir* juveniles were most abundant in April 2011. Peaks in CPUE of all three species coincided with the warm, wet season (March – April 2011). Breeding peaks during the warm wet season were also reported by Peel, (2012), who found that breeding peaks of *O. andersonii, O. macrochir* and *T. rendalli* occurred in January – March, with reproductive activity throughout summer, September – April. In Lake Liambezi, van der Waal, (1985) also reported that, *O. andersonii* and *O. macrochir* had long breeding season with ripe females found in August – March. On the Zambezi floodplain, high concentration of nesting activities of *T. rendalli* was observed from November – March (van der Waal, 1985). These observations are also in agreement with Weyl & Hecht, (1998) who reported high abundance of juvenile *T. rendalli* and *Oreochromis mossambicus* in the marginal areas of Lake Chicamba during summer. Similarly, *O. mossambicus* were observed to be in low numbers during winter in Lake Sibaya's marginal areas (Bruton & Boltt, 1974).

In Lake Liambezi, the abundance of juvenile *T. sparrmanii* peaked in April while on the Kavango floodplain, *T. sparrmanii* entered the plain in April, with a peak recruitment period in September 2011. Late recruitments in juvenile *T. sparrmanii* in the Kavango floodplain show its breeding season occurs once in early summer (van der Waal, 1985). This species lagged behind *T. rendalli* in using the Kavango floodplain. In Lake Liambezi, the relative abundance of *P. acuticeps* and *P. philander* peaked in June, while in the Kavango floodplain *P. acuticeps* peaked in October and *P. philander* peaked in September 2011. These observations follow the breeding season noted for both species, which occurs in October for *P. acuticeps* and in September for *P. philander* (van der Waal, 1980). Thus seasonal peaks in juvenile cichlid abundance are related to the warm wet seasons in agreement with van der Waal, (1985) and Peel, (2012).

In Lake Liambezi, seasonal peaks in CPUE of the two small characins, *R. maunensis* and *B. lateralis* were in synchrony with the peak flood (June – July 2011). Seasonal flooding may contribute positively to the small fish population peaks in two ways: firstly, the inflowing water is likely to bring nutrients from the river and flooded agricultural land into the floodplain. These nutrients will trigger an increase in phytoplankton production and consequently zooplankton productivity, which is crucial as a source of food. Secondly, the floodwaters may also inoculate the floodplain with riverine species. Hocutt *et al*., (2001) also noted that, under normal flow conditions, fish reproduction reaches a peak during high flood levels, when there is an important input of nutrients into the system. This may be responsible for the brief appearance of *R. maunensis* and *B. lateralis* during peak flood.

In both Lake Liambezi and the Kavango floodplain, juvenile mean total length and fish densities declined to low levels between June and October 2012. These observations may be related to seasonal variation, water levels and life stage. Marshall & Lockett, (1976) reported a variation in crop estimates in Lake McIlwaine's marginal areas in Zimbabwe because of fish movement in response to temperature variations. The temperature, time of the day, wind, current etc. are all variables which could influence catches. Ellender *et al.*, (2008) also noted that cichlid fish are reproductively inactive during the cold season (June – August) and this may account for the reduced body length and low numbers of fish specimens recorded in winter. Hocutt *et al*., (2001) noted that, during the subsiding phase, which is characterised by high water temperature and low dissolved oxygen (August – December 2011), juvenile fish migrate from ephemeral floodplain habitats into deeper main channels and lagoon habitats. During these harsh conditions, fish become trapped in higher concentrations in isolated pools, where they are subjected to heavy predation and intense biotic competition. One of the most necessary attributes of fish and other mobile animals is the ability to move away from unsuitable conditions (Siziba *et al.*, 2011).

Cambray *et al.*, (1978) observed that larger *Labeo capensis* juveniles migrated out of the marginal area of the Hendrik Verwoerd dam leaving smaller sized individuals. *Barbus anoplus* also leave the marginal habitat before they are 190 mm (Cambray *et al*., 1978). Ellender *et al*., (2008) observed juvenile *O. mossambicus* moving offshore into deep estuary channels after attaining an average size of 80 mm (SL). Jackson, (1961) also found that juvenile *O. macrochir* in Lake Mweru live along the swampy edge of the lake and enter the open water at a length between 180 mm and 200 mm when they are active enough to escape from fish predators such as *H. vittatus*. This may further explain the observed variation in abundance and mean length exhibited by the littoral fishes in this study.

Spatial variation in juvenile fishes in Lake Liambezi littoral and the Kavango floodplain may also be explained and related to predator prey effect induced by Catfishes (*C. gariepinus* and *C. ngamensis*) and the African Pike (*Hepsetus cuvieri*) on small fish. *Clarias gariepinus* is an ecologically adaptable species. It has a broad diet spectrum and occupies habitats ranging from the offshore to the littoral areas in lakes, to floodplains and to river channels upstream (Wudneh, 1998). Both *C. gariepinus* and *C. ngamensis* feed predominantly on fish, especially sleeping juvenile cichlids (Bruton, 1979). Carey, (1971) noted that cichlids constituted up to 19% of the food diet of *H. cuvieri*, and the rest of the stomach contents comprised of *B. lateralis*. This may have contributed to a regulatory effect on small fish in Lake Liambezi littoral zone and the Kavango floodplain.

Comparisons between the littoral and offshore species composition (Peel, 2012) on Lake Liambezi showed that the most abundant littoral taxa tend to extend into the offshore zones, mainly as adult fish. Jackson, (1961) hypothesized that many of the smaller African fish species are excluded from open waters of the principal river channels and restricted to marginal and back waters owing to the threat of predation by *Hydrocynus* in deep open waters. This implies that the switch in use of the littoral and offshore zones by fishes is life-stage dependent. Mainly juveniles inhabit the littoral zone and adults inhabit the offshore zone. Both the littoral and offshore zones were abundantly colonised by alestids, hence the null hypothesis that Lake Liambezi littoral and offshore zones are dominated by different species, was rejected.

Conclusion

The littoral zone in Lake Liambezi and the Kavango floodplain play a role as a nursery ground for many fish species. Comparison of fish assemblage structure in Lake Liambezi and the Kavango floodplain indicated that these isolated habitats were similar with regard to fish community structure. High fish species richness and diversity in the Kavango floodplain was related to the influence of the riverine area. Species diversity was lower in Lake Liambezi, mainly due to the rarity of riverine specialist species. Lake Liambezi littoral zone supported more alestids, while the Kavango floodplain supported more cichlids, consistent with the findings from other studies (Siziba *et al*., 2011; Peel, 2012). Overall, CPUE differed significantly between Lake Liambezi and the Kavango floodplain. High annual CPUE in early juvenile cichlids corresponded with seasonality of reproduction, while CPUE of alestids was in synchrony with peak flooding. A high proportion of the littoral taxa were offshore species in Lake Liambezi, indicating the importance of the littoral zone as a nursery ground from which some fishes are recruited to their parent stocks in deeper offshore waters. Seine net catch composition in Lake Liambezi and the Kavango floodplain comprised largely juvenile fishes. These findings caution against use of a seine net gear in these crucial habitats as this may result in growth overfishing.

CHAPTER 4

COMPARISON OF THE EFFICIENCY OF MONOFILAMENT AND MULTIFILAMENT GILLNETS IN LAKE LIAMBEZI, NAMIBIA

4.1 GILLNETS

Gillnets are widely used in artisanal fisheries in developing countries because they are relatively inexpensive and efficient in catching commercially valuable species (Oginni *et al*., 2006). A gillnet comprises one sheet of twine head rope with floats and the footrope is weighed so that the net forms a vertical wall of netting. Gillnets are set to intercept migrating fish and fish caught when they try to swim through it (von Brandt, 1984), mainly by gilling but also through entanglement and snagging of teeth or fin spines (Sainsbury, 1986). Gillnets in Lake Liambezi are set by two fishermen from wooden canoes. One man manoeuvers the canoe with a paddle and the other man sets the net, which is packed in the canoe with the floats line separated from the sinkers line and gradually released into the water. As the setting progresses, the net is released astern while the fisherman paddling the canoe manoeuvers ahead to the direction of current flow for ease of operation.

Gillnets are among the most selective gears in terms of both species caught and the size range retained (Gulland, 1983). Selectivity of gillnets has attracted the attention of various workers in different areas of the world as reviewed by Hamley, (1975). The meshes of a gillnet are uniform in size and shape, hence highly selective for a particular size of fish. Fish which are smaller than the net are able to pass through unhindered, while those too large to push their heads through the meshes may escape being captured (Puente, 1997). The probability of a fish being caught when it comes in contact with a gillnet is dependent upon fish size. Gillnets are therefore size selective (Potter & Pawson, 1991). A specific mesh size catches fish in a certain length category and is often most effective within a narrow length group.

However, gillnets may discriminate among species according to fish morphology, for example body form and the presence of spines. Gillnet use is also restricted to specific habitats, which will also influence the species selectivity of this gear. The body length distributions of fish in the different gillnet mesh sizes are the simplest way to express and compare selectivity of gillnets of different mesh sizes.

In African inland fisheries gillnets were made of multifilament nylon twine until the mid-1990s where after the use of monofilament nets has gradually increased (Balik, 1998; Tweddle *et al.*, 2011). This has increased the catch efficiency of gillnets because efficiency is increased by the use of thinner and less visible material (Potter & Pawson, 1991). This increased efficiency needs to be taken into account in fisheries management and it is therefore important that the efficiency of monofilament and multifilament gill nets is compared.

Many studies have been carried out elsewhere comparing catching efficiencies of multifilament and monofilament nets (Njoku, 1991; Kusat, 1996; Balik, 1998; Balik & Cubuk, 2000; Balik, 2001). Most of these have shown that monofilament nets were more efficient than multifilament nets (e.g., Balik, 1998; Thomas *et al.*, 2003). However, Machiels *et al.*, (1994) found that multifilament nets were more efficient than monofilament nets for catching pikeperch in Lake Beysehir, Turkey.

Equally important is knowledge of the size-selectivity of the fishing gear so that gear regulations can be set to avoid growth overfishing and maximize yield (Millar and Holst, 1997; Emmanuel *et al.*, 2008). It is therefore important to determine gillnet selectivity, which is an expression of the probability of capturing a certain size group of fish in a specific gillnet mesh size (Næsje *et al*., 2004). Gillnet selectivity may be affected by elasticity and flexibility of net twines. Meshes of a more elastic twine can be stretched to catch a large struggling fish but a small fish may be too weak to stretch the twine. Nets of thinner twine are less visible and easy to stretch and more flexible, therefore they should tangle more fish and catch larger fish, as long as the twine is not broken by those large fish. According to Potter & Pawson, (1991) there are four main ways of fish getting caught by gillnet: (1) snagged - the fish will be attached to the netting at the head region; (2) gilled - the fish will be meshed immediately behind the gill cover; (3) wedged - the fish will be meshed around the body somewhere behind the gill cover and (4) entangled - the fish is wrapped into the netting, held by teeth, fins, spines or other projections. Generally, indirect estimates of gillnet selectivity are obtained by comparing the observed catch frequencies across several meshes (Millar & Holst, 1997). The size frequency, distribution of the population and the selectivity parameters are thus estimated simultaneously (Hovgard & Lassen, 2000). Different approaches to indirect estimates have been used to obtain the selection curve using various manipulations of the selection equation. Holt's method is one of the most commonly used methods for estimating gillnets selectivity.

Two statistical methods are used to represent the selection curves. The standard normal function is applied for species that are mainly entangled by their gills; whereas a skewed normal function is used for species that are caught by other body structures e.g. fin rays or spines.

Proper assessment and management of the lake requires a better understanding of how the fishery operates in respect to the gear type, mesh sizes and catch composition. As there is currently no assessment of gillnet selectivity and efficiency on the Zambezi Region's fish species, the primary aim of this chapter is to quantify and compare the catch efficiency (CPUE) between monofilament and multifilament gillnets based on an experimental approach.

A second objective is to combine species-specific selectivity parameters to compare selectivity of common gillnet mesh sizes on the four commercially important fish species in Lake Liambezi. Three hypotheses were tested:

1) Catch per unit effort (CPUE) is similar between the monofilament and multifilament nets.
2) CPUE differs between the same mesh sizes of both nets.
3) CPUE differs across the sampling seasons for both nets.

4.2 MATERIAL AND METHODS

Sampling

Monthly capture experiments were carried out in the same area of the lake to give approximately identical fishing conditions from May 2011 to April 2012 resulting in a total of 45 gillnet night sets being made. Experimental gillnets were similar in length and mesh size to those used in the commercial fishery. Each experimental gillnet set comprised five monofilament and five multifilament nets. Individual nets had a length of 100m, with stretched mesh sizes of 3" (inches), 3.5", 4", 4.5", and 5". The depth and hanging ratio of each net were 38 meshes and 0.50 respectively.

Three stratified offshore areas (zones) were selected for this study (Figure 3.2, in Chapter 3): (A) characterised by sheltered and shallow water; (B) areas characterised by scant vegetation cover, isolated reed beds and deeper waters; (C) areas characterised by scant vegetation cover, reed beds, and deeper waters. Gillnets were randomly set in the offshore waters at approximately 17h00hrs in the evening and lifted at 06h00hrs the next morning. Soak time difference between nets was minimized by hauling in the order in which they were set, as recommended by Losanes *et al*. (1992).

In all experiments the nets were joined to one another with a 2m interval between each net. The position of individual nets was changed in turns between the sampling zones A - C. Gears were changed seasonally to eliminate the effect of age/wear on seasonal efficiency. On landing, the fish caught in each net were removed and sorted into species, according to net and mesh sizes using the taxonomic keys by Skelton (2001). All fish were measured to the nearest millimeter total length (TL) or fork length (FL) depending on the species, and weighed to the nearest gramme (g) to determine and compare catch rates for the two net types.

Data analyses

Catch per unit effort (CPUE)

In this study, gear efficiency refers to the catch of a net for a given amount of effort; CPUE = numbers or weight of fish/100 m net/night.

Hence, CPUE was calculated from the following equation:

CPUE = C*i*/E*i*

Where C*i* is the mean catch per unit effort for a given species (weight) and E*i* is the effort expended to obtain *i*.

Selectivity

Selectivity parameters for *Oreochromis andersonii, Oreochromis macrochir, Tilapia rendalli* and *Serranochromis macrocephalus* were estimated using the regression framework method described by Hovgård and Lassen (2000). All fish were grouped into 10 mm TL size class for any given mesh size. The selection of a given length class by mesh size was calculated as:

$$S_t^{GN_i} = \exp\left(-\frac{(t - t_r^{GN_i})^2}{2(\delta^{GN_i})^2} \right)$$

Statistical analyses

A pair-wise t-test was used to test for statistical differences in total CPUE between the monofilament and multifilament gillnets. The CPUEs of both net types were separately compared for each fish species and season. Difference in CPUE between mesh sizes and seasons were determined using the non-parametric Kruskal-Wallis one-way analysis of variance for both net types. Tukey test was applied for comparisons of pairs of mean CPUEs for seasons. The relative catch rate of the two gears is expressed as the ratio obtained by dividing monofilament catches by multifilament catches when effort was equal.

4.3 RESULTS

Overall catch comparisons by gear type

During the study, 45 gillnet settings were conducted for each mesh size and material. Catch by species and species group are presented in terms of both numbers and weight (Table 4.1). A total catch of 3741 fish weighing 717.1 kg were caught in monofilament gillnets while 719 fish weighing 183.6 kg were caught in multifilament gillnets (Table 4.1). Over 45% of the total fish catch composed of *O. andersonii* for both net types. Efficiency ratios varied from monofilaments being 2.5 times more efficient for *S. macrocephalus* to 9 times more efficient for *O. andersonii.*

Table 4.1. Catch composition in numbers of the commonest species group caught in monofilament and multifilament gillnets with equal effort from Lake Liambezi, Namibia between May 2011 and April 2012; n=99 per gillnet set

	Monofilament		**Multifilament**	
	No	Kg	No	Kg
Oreochromis andersonii	1406	365	156	47.5
Oreochromis macrochir	625	82.2	74	14.5
Tilapia rendalli	181	27.1	22	5.2
Serranochromis macrocephalus	624	85.9	249	55.9
Schilbe intermedius	295	26.2	43	6.6
Clariids	180	81.2	39	20.9
Others	430	49.5	136	33
Total	**3741**	**717**	**719**	**184**

Figure 4.1 (a) *Oreochromis andersonii*, the most abundant species in monofilament gillnets catches and (b) *Serranochromis macrocephalus*, the most abundant species in multifilament gillnet catches in Lake Liambezi, Namibia

CPUE comparisons

The total catch per unit effort (CPUE) expressed as weight (kg) per 100m length net was compared between the monofilament and multifilament gillnets (mesh sizes 3"-5"). Combined species analysis (Figure 4.2) showed that CPUE (by weight) was 3-fold higher in catching most of the fish by weight for monofilament nets than for multifilament gillnets (paired t-test, $P < 0.05$).

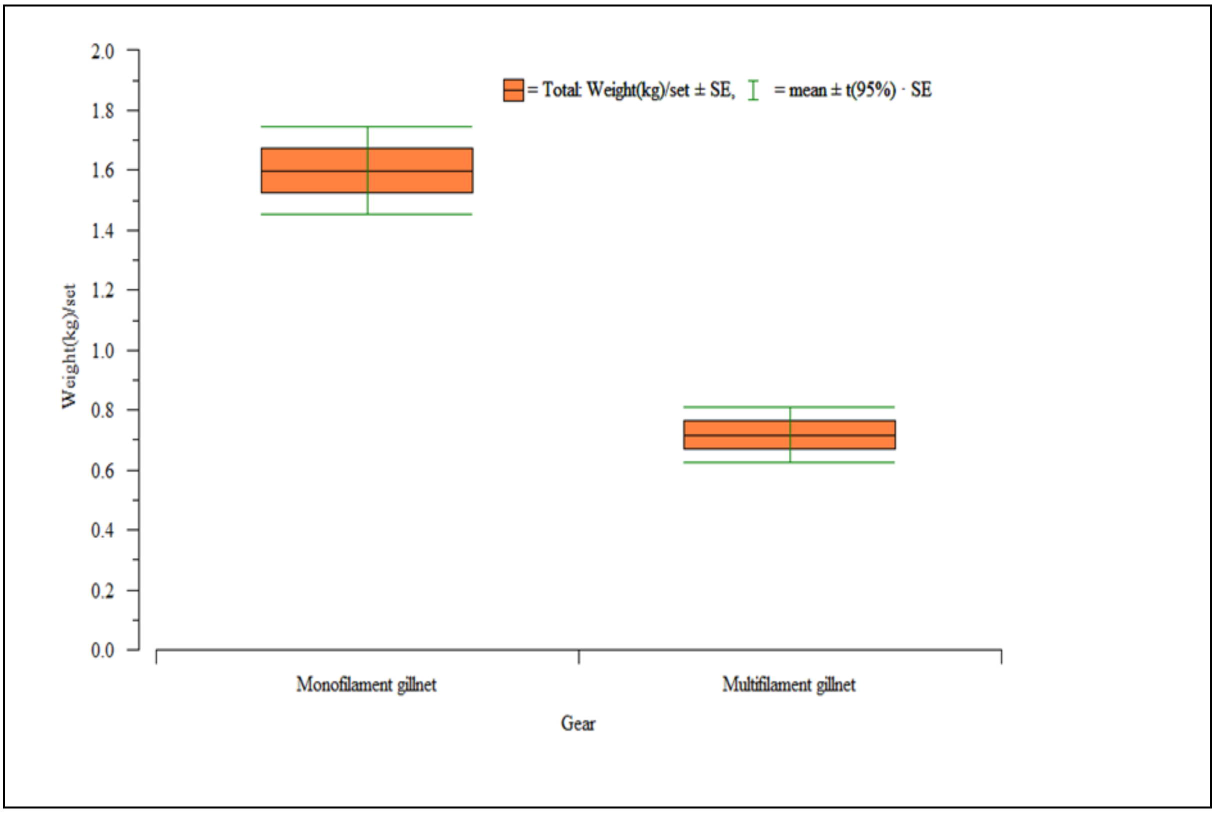


Figure 4.2. Mean CPUE (kg) with 95% confidence limits for all species combined in monofilament and multifilament gillnets (mesh sizes 3" - 5") in Lake Liambezi, Namibia, sampled between May 2011 and April 2012

Gear type and mesh size comparisons

The total CPUE of all species combined differed significantly between similar mesh sizes of both net types (paired t-test, $P < 0.05$), except for the 4.5'' mesh size ($P > 0.05$) (Figure 4.3). CPUE comparisons for the 5" between the two net types were not possible due to a small sample size caught in the multifilament net type (Figure 4.3).

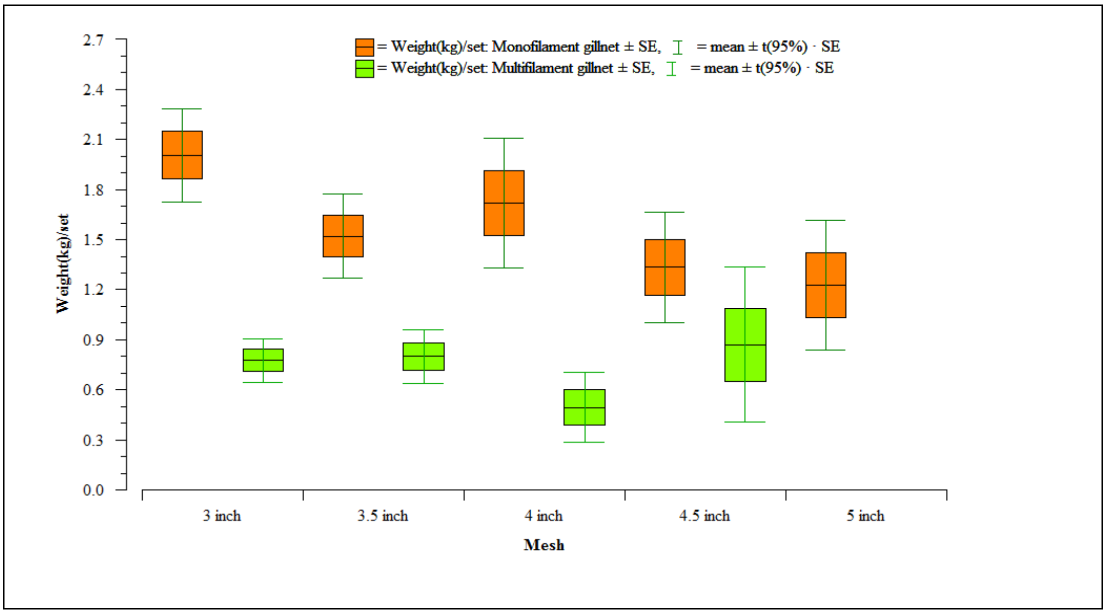


Figure 4.3. Mean CPUE (kg/100m net) with 95% confidence limits of all species combined in mesh sizes (3"-5") in Lake Liambezi, Namibia, sampled between May 2011 and April 2012

Comparisons by species

In the mesh sizes shown in Table 4.2, the total mean CPUE for the monofilament and multifilament gillnets was 1.461 ± 0.296kg/100m net and 0.493 ± 0.082kg/100m net respectively. CPUE analyses by mesh sizes for *O. andersonii* showed significant differences between the 3"monofilament v. 3" multifilament net, and 3.5" monofilament v. 3.5" multifilament net and between the 4" monofilament v. 4" multifilament net (pair wise t-test; $p<0.05$). CPUE by mesh sizes for *O. macrochir* showed significant differences in 3" monofilament v. 3" multifilament net and between 3.5" monofilament net v. 3.5" multifilament net (pair wise t-test; $p<0.05$). CPUE for *T. rendalli* and *S. macrocephalus* however did not differ between the same mesh sizes of the two net types (pair wise t-test; $p>0.05$).

Seasonal trends

The mean CPUE of monofilament net differed significantly between the four seasons (Kruskal-Wallis ANOVA; $P<0.05$). Significant differences in CPUEs were observed between winter and summer ($P<0.05$), but no significant differences detected between summer and winter, spring and autumn ($P>0.05$). The mean CPUE of multifilament nets between seasons were however not found statistically different ($P>0.05$) (Table 4.3).

Table 4.2. The mean CPUE (weight/100m net) of the net types by mesh sizes and fish species in Lake Liambezi, Namibia, sampled between May 2011 and April 2012

	Monofilament						Multifilament					
	3"	**3.5"**	**4"**	**4.5"**	**5"**	**Mean**	**3"**	**3.5"**	**4"**	**4.5"**	**5"**	**Mean**
Oreochromis andersonii	0.355	0.665	1.248	0.951	0.962	0.836	0.348	0.257	0.050	0.009	0.458	0.224
Oreochromis macrochir	0.278	0.252	0.140	0.131	0.035	0.167	0.039	0.060	0.085	0.000	0.000	0.037
Tilapia rendalli	0.088	0.081	0.047	0.041	0.025	0.056	0.010	0.034	0.019	0.000	0.000	0.013
Serranochromis macrocephalus	0.575	0.161	0.055	0.034	0.012	0.167	0.348	0.257	0.050	0.009	0.000	0.133
Schilbe intermedius	0.138	0.043	0.049	0.028	0.003	0.052	0.056	0.010	0.021	0.004	0.000	0.018
Clariids	0.278	0.178	0.175	0.103	0.173	0.181	0.092	0.115	0.006	0.130	0.000	0.069
Total	**1.712**	**1.380**	**1.714**	**1.288**	**1.210**	**1.461**	**0.893**	**0.733**	**0.231**	**0.152**	**0.458**	**0.493**

Table 4.3. The mean CPUE (weight/100m net) + (SE) of the net types by fish species and seasons in Lake Liambezi, Namibia, sampled between May 2011 and April 2012

	Monofilament				Multifilament			
	Winter	**Summer**	**Spring**	**Autumn**	**Winter**	**Summer**	**Spring**	**Autumn**
Oreochromis andersonii	0.416 ± 0.068	1.068 ± 0.292	0.695 ± 0.223	1.093 ± 0.185	0.02 ± 0.007	0.226 ± 0.048	0.168 ± 0.037	0.302 ± 0.115
Oreochromis macrochir	0.133 ± 0.039	0.232 ± 0.193	0.217 ± 0.241	0.106 ± 0.027	0.010 ± 0.007	0.107 ± 0.029	0.070 ± 0.017	0.014 ± 0.008
Tilapia rendalli	0.270 ± 0.009	0.101 ± 0.057	0.066 ± 0.055	0.022 ± 0.010	0.007 ± 0.005	0.032 ± 0.016	0.026 ± 0.013	0.010 ± 0.008
Serranochromis macrocephalus	0.385 ± 0.069	0.131 ± 0.108	0.147 ± 0.133	0.124 ± 0.041	0.302 ± 0.047	0.187 ± 0.047	0.213 ± 0.039	0.103 ± 0.039
Schilbe intermedius	0.030 ± 0.007	0.109 ± 0.103	0.041 ± 0.052	0.031 ± 0.007	0.024 ± 0.011	0.046 ± 0.013	0.025 ± 0.007	0.005 ± 0.004
Clariids	0.191 ± 0.057	0.240 ± 0.139	0.103 ± 0.045	0.220 ± 0.454	0.620 ± 0.039	0.136 ± 0.041	0.031 ± 0.020	0.118 ± 0.054
Total	**1.425 ± 0.668**	**1.881 ± 0.892**	**1.269 ± 1.203**	**1.596 ± 0.724**	**0.983 ± 0.116**	**0.734 ± 0.194**	**0.533 ± 0.133**	**0.552 ± 0.228**

LENGTH, FREQUENCY AND GILLNET SELECTIVITY FOR FOUR COMMERCIALLY IMPORTANT CICHLID SPECIES

Net and mesh analyses of catch length frequency distribution were possible only for some of the mesh sizes belonging to two net types. This was due to limitations imposed by small number of individuals that were caught in large mesh sizes (4.5" and 5") (Table 4.5). The gillnet selectivity and length frequency for four selected cichlids (*O. andersonii, O. macrochir*, *T. rendalli* and *S. macrocephalus*) are illustrated in Table 4.4 a - b and Figure 4.4 a - h. In general, the five mesh sizes caught a wide range of modal length for the four selected species, which gradually increased with increasing mesh sizes (Figure 4.4 a - h).

The length frequency of *O. andersonii* caught in monofilament and multifilament net are shown in Figure 4.4 a and b. According to the regression model, the modal length for the smallest mesh size (3") is 210 mm TL in monofilament net and 190 mm TL in multifilament net (Table 4.4 a and b).

The length frequency of *O. macrochir* caught in monofilament and multifilament net are shown in Figure 4.4 c & d. The regression model shows that the modal length for the smallest mesh size (3") is 190 mm TL for both net types (Table 4.4 a and b).

The length frequency of *T. rendalli* caught in monofilament and multifilament net are shown in Figure 4.4 e and f. According to the regression model, the modal length for the smallest mesh size (3") is 210 mm TL in monofilament net and 220 mm TL in multifilament net (Table 4.4 a and b).

The length frequency of *S. macrocephalus* caught in monofilament and multifilament nets are shown in (Figure 4.4 g and h). The regression model shows that the modal length for the smallest mesh size (3") is 190mm TL in monofilament net and 240mm TL in multifilament net (Table 4.4 a and b).

Table 4.4. Predicted length class (mm) at maximum selectivity for different gillnet selective curves for four selected species

a) Monofilament gillnet

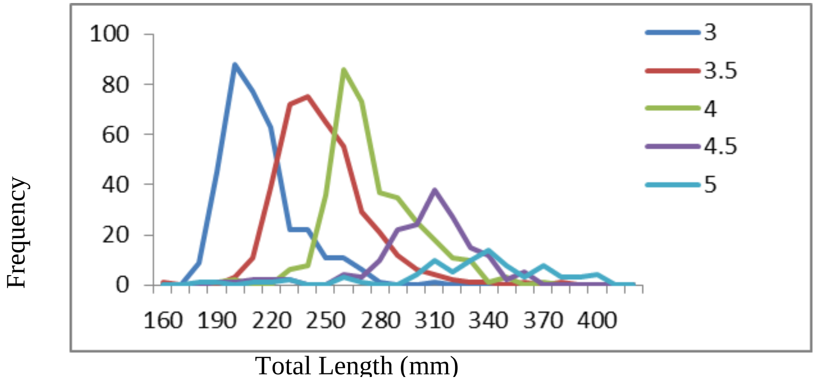
	Monofilament mesh size				
Species	3"	3.5"	4"	4.5"	5"
O. andersonii	210	250	290	320	360
O. macrochir	190	240	260	290	340
T. rendalli	210	240	290	310	360
S. macrocephalus	190	240	270	290	320

b) Multifilament gillnet

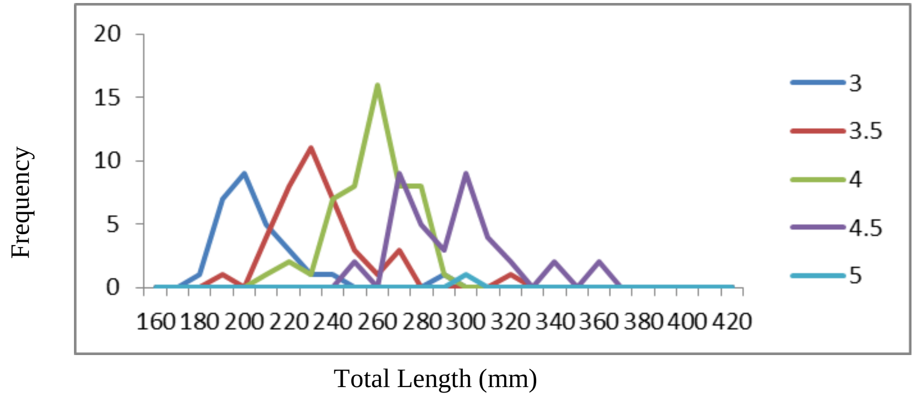
	Multifilament mesh size				
Species	3"	3.5"	4"	4.5"	5"
O. andersonii	190	240	260	290	340
O. macrochir	190	220	240	-	-
T. rendalli	220	260	290	-	-
S. macrocephalus	240	270	320	-	-

Table 4.5. Total numbers of all specimens per gear type and mesh sizes

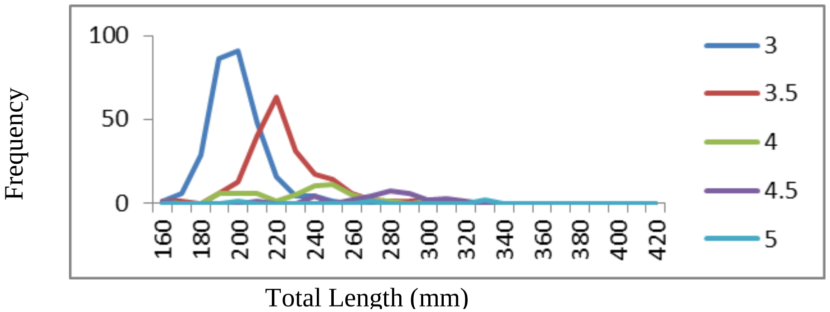
	Monofilament					**Multifilament**				
	3"	**3.5"**	**4"**	**4.5"**	**5"**	**3"**	**3.5"**	**4"**	**4.5"**	**5"**
O. andersonii	357	399	354	170	82	28	39	52	38	1
O. macrochir	288	198	55	31	4	23	29	22	0	0
T. rendalli	110	46	16	6	1	3	3	2	0	0
S. macrocephalus	486	105	20	13	0	146	93	10	0	0



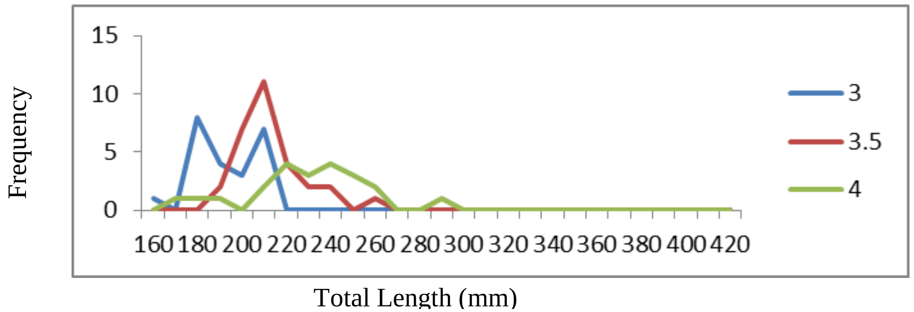
a) *O. andersonii* (monofilament gillnet)



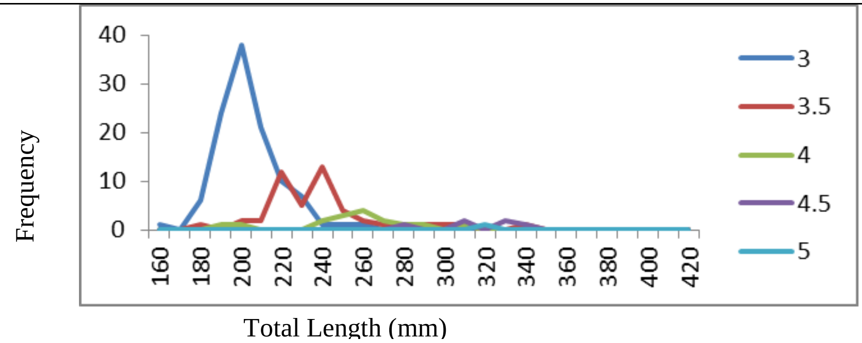
b) *O. andersonii* (multifilament gillnet)



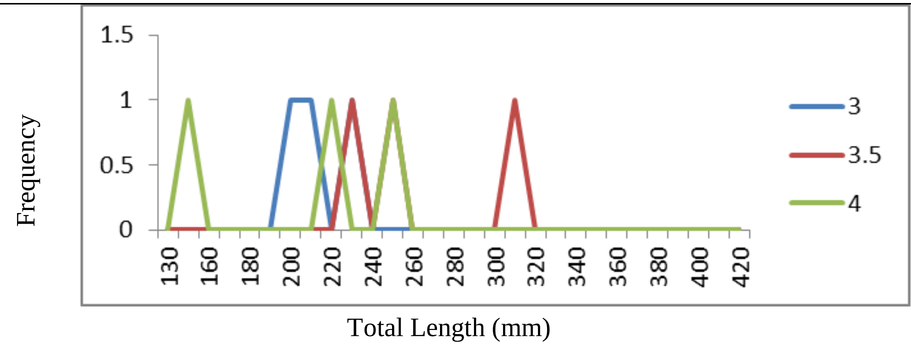
c) *O. macrochir* (monofilament gillnet)



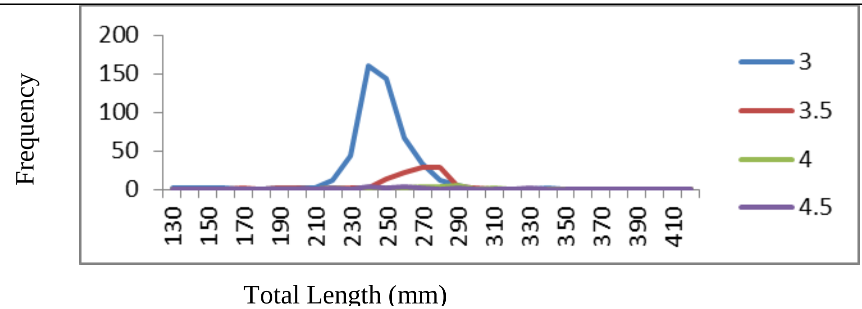
d) *O. macrochir* (multifilament gillnet)



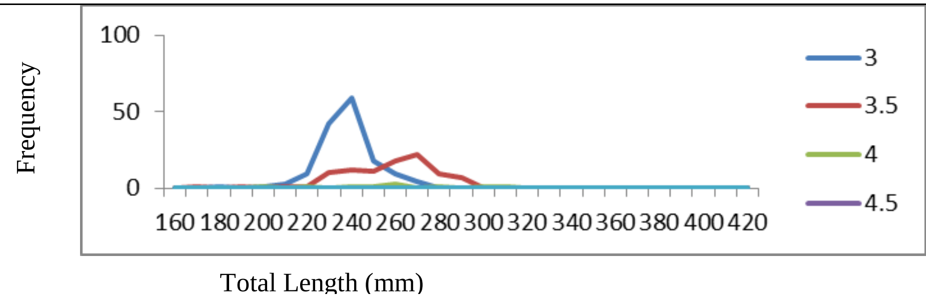
e) *T. rendalli* (monofilament gillnet)



f) *T. rendalli* (multifilament gillnet)



g) *S. macrocephalus* (monofilament gillnet)



h) *S. macrocephalus* (multifilament gillnet)

Figure 4.4. Catch length frequency distribution for *O. andersonii*, *O. macrochir*, *T. rendalli* and *S. macrocephalus* caught with monofilament and multifilament gillnets in Lake Liambezi, Namibia, sampled between May 2011 and April 2012.

4.4 Discussion

Monofilament nets were three times more efficient than multifilament nets in catching fish in Lake Liambezi. Significant differences in catching efficiency of monofilament and multifilament gillnet were found (P<0.05), hence the null hypothesis that CPUE was similar between the two net types could be rejected. Direct comparisons of gillnet CPUE and efficiency with other studies in the study area is limiting, therefore comparisons were allied to previous studies conducted elsewhere in temperate regions. The results of this study agreed with previous studies. Balik & Cubuk, (2000) found that monofilament nets caught 2.08 times more tench than multifilament nets in Lake Beysehir in Turkey. For catching pikeperch, Kusat, (1996) & Balik, (1998) reported monofilament gillnets as 1.85 and 1.98 times more efficient than multifilament gillnets in Lake Egirdir and Baysehir, respectively both in Turkey. Although Lake Liambezi has recently refilled, *O. andersonii* was caught in large numbers, indicating that the population of this species has rapidly increased. Tilapiines made up three-quarters of the commercial gillnet fishery catch in Lake Liambezi prior to it drying up, half of which was *O. andersonii* (van der Waal, 1980). The current catch composition in the lake is similar, with *O. andersonii* playing a more important role than in the past (Tweddle *et al*., 2011). Interestingly the catch rate of *S. macrocephalus* in fishing with multifilament nets was higher than that of *O. andersonii*. The results from this chapter also indicate that *O. andersonii* may be more abundant than is indicated by multifilament results. Machiels *et al*., (1994) showed that monofilament gillnets were more efficient than multifilament gillnets for catching bream (*Abramis bramo*) but less efficient for pikeperch. On the contrary, Balik, (1996) found that monofilament nets were more efficient in catching pikeperch than multifilament nets due to visibility of netting material.

The observed differences in CPUE between the two net types in this study may be explained by the differences in net twine and visibility of the net in water (Tweddle & Bowa, 1990a). For effective catching, the nets must have low visibility to the fish in water (Klust, 1982). Although fish are known to be myopic, they can see up to 10m distance in 20m depth (Balik, 2001). Generally, low visible nets catch more fish than more visible nets (Backiel & Welcomme, 1980). Typically the white multifilament net twine is more visible than the fine twine monofilament nets. Therefore, fish can more easily notice multifilament nets. Thus the catching efficiency of monofilament nets is mostly higher than multifilament nets (Karlsen & Bjarnason, 1986). Some net colors discourage the fish from attempting to force a way through the netting prior to their entanglement (Tweddle & Bodington, 1988). This may partly explain the low catch efficiency when fishing with the multifilament nets compared to the monofilament nets in this study. The results of this chapter are however in contrast with Potter, (1983), who reported that monofilament gillnets do not always perform better than multifilament nets for salmon fisheries. This is likely due to differences in target species between the two studies.

The catch rates of the clariids were found to be similar between monofilament and multifilament net type (pair wise t-test $p>0.05$). Tweddle & Bodington, (1988) suggested that efficiency of different colors of netting is related to the degree of reliance on vision in certain fish species. For instance, the catch rates for catfish which rely on their sensory circum-oral barbels may not be influenced by the net color, and hence visibility of the net type in water. Cichlids which are primarily reliant on sight were however twice as likely to be caught in monofilament net types than in multifilament nets. This is an indication that most cichlids in Lake Liambezi are more likely to attempt to force a passage through a curtain of the invisible monofilament net than the more visible white multifilament net, and hence are at greater risk of getting tangled therein.

Tweddle & Bodington, (1988) suggested that it was not the invisibility of a net that makes it an efficient catcher of fish but the nature of the visibility of the net.

Seasonally, the mean CPUE of monofilament nets differed significantly between the four seasons, but no significant differences were detected between seasons for the multifilament nets. The null hypothesis that CPUEs were different between seasons was accepted for the monofilament net type and rejected for the multifilament net type. The mean CPUE of all species combined, was higher in summer for the monofilament nets than the multifilament nets. The low catches with multifilament nets could be associated with their visibility in water during summer. Visibility of the net can be affected by weather conditions, turbidity and the depth of the lake water (Balik, 2001). Turbidity can vary according to seasonal variations. Fish in clear water can recognise the net more easily. The water of Lake Liambezi is generally clearer in summer than in the other seasons. This is because during summer rains there is an inflow of less turbid water from the catchment drainage and this situation increases the visibility of the multifilament nets in lake waters (Emmanuel *et al*., 2008). Similarly, seasonal differences have also been observed for salmon catches, greater in monofilament gillnets during the warm season and smaller in the cold season due to changes in net visibility caused by plankton blooms (Washington, 1973). Steinberg, (1964) also stressed the need for nets with low visibility and found that monofilament nets had a higher catching efficiency than multifilament nets.

Generally, the catchability of *O. andersonii*, *O.macrochir*, *S. macrocephalus* and *T. rendalli*, decreased with increasing mesh sizes for both net types. The observed lower numbers of fish caught in the larger mesh sizes, agrees with Psuty & Borowski, (1997), who reported a similar trend for *Abramis brama* species of the Vistula lagoon. While selectivity acts upon fish size and shape (Hamley, 1975), net perception and net avoidance responses could change with age. Visual acuity may have improved as fish size increased (Hester, 1968), and if gillnet avoidance is learned, older large fish may have been more adept at avoiding multifilament nets than the newly introduced monofilament nets.

Regarding the mesh sizes per net type, the best overall catch rates were achieved with a 4" monofilament and 3" multifilament gillnets. The observed bimodal mode in length frequency distribution of *O. andersonii* for the 4.5" multifilament net might reflect the presence of two cohorts, while the bimodal mode in length frequency of *T. rendalli* for 3.5" mesh, might reflect a small sample size of fish caught or presumably masked seasonal effect (Oginni *et al*., 2006). CPUE of the most abundant species differed significantly between the mesh sizes of both net types and the null hypothesis that CPUE was different between mesh sizes of both net types was accepted. The minimum legal gillnet mesh size under the regulations of the Inland Fisheries Resource Act (2003) in Namibia is 3". The 3" monofilament gillnet comparatively corresponds to peak selectivity modes of 190 mm TL for *O. macrochir* and 210 mm TL for both *O. andersonii* and *T. rendalli* (Table 4.4 a) while the 3" multifilament gillnets corresponds to peak selective modes of roughly 220 mm TL for *T. rendalli*, 190 mm TL for both *O. andersonii* and *O. macrochir* (Table 4.4 b). The impact of small mesh size on fish stocks is discussed in the next chapter (Chapter 5).

CONCLUSION

Gillnets vary in their efficiency for catching fish species in Lake Liambezi. Monofilament nets were more efficient than multifilament nets as reported by several authors (Machiels *et al*., 1994; Balik, 1996). The mean CPUE of monofilament nets differed significantly between winter and summer, but no significant differences were observed between summer and winter, spring and autumn. The mean CPUE of multifilament nets between seasons was however found to be not different. *O. andersonii* was the most abundant species caught by both monofilament and multifilament nets. The introduction of monofilament nets has increased netting efficiency for *O. andersonii* and in the absence of some compensatory constraint, has intensified the exploitation pressure. Such changes must be dealt with to ensure both conservation of the stocks and maintenance of the fishery. Gear efficiency must be continually evaluated if management decisions are based on catch statistics and where commercially important species such as *O. andersonii*, *O. macrochir* and *T. rendalli* are stressed by intensive exploitation. Hence, some control over the use of more efficient gear is necessary. The dynamics of the new Lake Liambezi fishery and recommendations regarding its management are addressed in the next chapter (5).

CHAPTER 5

A PRELIMINARY ASSESSMENT OF THE FISHERY

5.1 INTRODUCTION

During its previous inundation phase the fish yield from Lake Liambezi was estimated at 637t/year (van der Waal, 1980). During the current inundation phase, the fishery developed from scratch as the lake began filling in 2000. Initial catches in 2009 were dominated by *Clarias gariepinus*, with few of the tilapiines (Tweddle *et al.*, 2011). As the tilapiine cichlids multiplied and grew rapidly, they began to appear in the fishermen's gillnet catches. In 2010 the rapid increase in the catch of large cichlid species inspired many fishermen to enter the fishery (Tweddle *et al*., 2011) and resulted in the development of the vibrant small-scale fishery at Shamahuka landing site (Figure 5.1). Catches quickly became dominated by large cichlids, with *Oreochromis andersonii* and *Tilapia rendalli* comprising approximately 90% of the landings (Tweddle *et al.* 2011). Shamahuka is now the major landing site along Lake Liambezi from where catches are transported mainly to the urban fish market in Katima Mulilo.

The availability of fish also resulted in an influx of fishermen from outside the area, such as Zambia and the Democratic Republic of Congo (DRC). These fishermen are mostly of Subia tribe origin and come to the lake specifically to fish. In order to regulate the number of fishermen, a register of all participants was compiled in 2010, and fishing was restricted to residents of Muyako fishing village on Lake Liambezi (Tweddle *et al.*, 2011). The registration system was not exclusive, as the local owner of the registered and licensed gear could employ foreigners from Zambia who had good fishing skills.

During November 2010, 125 fishermen, 91 canoes, and an average of two fishermen per canoe were registered (Tweddle *et al*., 2011). These fishermen live among the most important fishing villages around the lake which are Muyako (Shamahuka), and Zilitene/Kwena to the north and Masokotwani and Lusu to the west. Temporary fish camps are located on small islands in the western and southern part of the lake.

The types of gear used on the newly inundated lake are monofilament and multifilament gillnets, with some use of the prohibited dragnets and mosquito nets (Simasiku, pers. obs.). Gillnets are readily available on the open market in Katima Mulilo (Simasiku, pers.obs.) and from dealers in Zambia at low cost. Monofilament gillnets cost between N$250 (US$ 24.00) and N$300 (US$ 29.00) in Zambia while a customer pays N$500 (US$ 48.00) for the same net type at the Katima Mulilo open market. Nets are obtained unmounted and mounted by the fishermen prior to fishing activities. The low cost of nets and the relative ease with which fish are caught in the lake, makes commercial fishing an attractive option for potential entrepreneurs. In gillnets, both the top and bottom ropes are made of hessian material. The bottom rope is twisted into the meshes and bricks attached at irregular intervals to serve as weights. Highly buoyant pieces of white styrofoam box are tied to the top rope at intervals of 1m to serve as floats. Gillnets are hung 2.5m deep and mounted at 50 percent of the stretched length. Nets are usually set out in series over two weeks and inspected for fish each morning. Dugout canoes (*mukolo*) remain the mode of transport to access fishing grounds and deploy fishing gear on the lake (Simasiku, 2009 pers.obs.). The best wood for constructing canoes is kiaat (*Pterocarpus angolensis*) and sausage tree (*Kigelia africana*) (van der Waal, 1980).

Fish trade begun in 2009 as an influx of Namibians, Angolans, Zambians, and Congolese settled at Shamahuka landing site for weeks or months at a time while topping up their target consignments of fish for sale (Simasiku, pers. obs.). Fish were caught mainly by the Namibian fishermen and sold to both local and foreign fish traders. While at the lake, most of the foreign fish traders split and dried their fish or preserved them in salt before shipping them to Livingstone and Lusaka in Zambia, or further into the Democratic Republic of Congo (DRC) (Tweddle *et al*., 2011). Alternatively, fish would be transported by taxi to local markets at Bukalo and the Katima Mulilo fish market.

In addition to the continued search for appropriate fisheries management models, some authors have outlined some of the challenges of managing fluctuating ecosystems, which are influenced mainly by climatic variability. Winpenny, (1991) stated that fisheries are highly susceptible to natural variability in their environment, which can be both complex and unpredictable, and may interact with human interventions to produce serious consequences on the fishery. The rapid response of many freshwater fish stocks to fluctuating environmental conditions provides an accurate assessment of the resource situation. The aim of this chapter was to account for statistical data at Shamahuka landing site in order to:

1. Assess the harvesting patterns of the local fishermen on the lake
2. Estimate the annual catch from Lake Liambezi
3. Attempt to correlate climatic factors such as water level, temperature, and lunar phase with the fish catches on the lake
4. Evaluate the contributory value of Lake Liambezi into the Katima Mulilo Fish Market

Figure 5.1. Increase in fishing activities at Shamahuka landing site between (a) February and (b) November 2010. (c) Zambian truck loaded with fish stuck in mud at Muyako village and (d) Namibian single cab loaded with fresh fish for export to Zambia (Tweddle *et al.* 2011 and Shapi, 2012).

5.2 MATERIAL AND METHODS

Shamahuka Landings and Market Data

Catch surveys were conducted twice a week at Shamahuka landing site between May 2011 and April 2012. Individual fishermen landing their catch were approached and questioned regarding their canoes, net types, stretched mesh sizes, net length and frequency of fishing activities. The daily catch of fish per canoe was weighed collectively using a hanging scale under a pole tripod with a large platform (Figure 5.2). Sorting to species level was not possible as fishers were often in a hurry to get their fish to market. The weighing station was strategically placed on the shore point where most fishermen landed their catch.

Information on the number of fishermen was obtained by questioning the village headman. Responses regarding the frequency of fishing, gear type and mesh sizes were obtained directly from the fishers available and willing to participate in short interviews. In total, 106 fishermen operating on Lake Liambezi were interviewed between May 2011 and April 2012. A special attempt was made to count all the canoes at various landing sites along the lake between September and October 2012. Two teams undertook the surveys simultaneously, one supported by boat operating along the northern and central lake at Muyako and Zilitene, while the second team, supported by one vehicle, operated along the western lake at Lusu and Masokotwani.

In addition to the catch data being recorded at Shamahuka landing site, staff from the Ministry of Fisheries and Marine Resources, in conjunction with the Namibian Nature Foundation (NNF), recorded the origin and weight of fresh fish entering the Katima Mulilo Fish Market. All fish from various fishing areas were brought into the market using mainly three different sized cooler boxes: large, medium and small, and weighed using the hanging scale described above.

Figure 5.2. Recording catches at Shamahuka landing site, Lake Liambezi between May 2011 and April 2012

Data analyses

Species composition was derived from the experimental gillnets in as described in Chapter 4, while catch per unit effort (CPUE) was defined as the number of fish caught per canoe. CPUE was calculated as:

$$\text{CPUE} = Ci / Ei$$

Where C*i* is the biomass of fish (in kg) and E*i* is the effort expressed per canoe.

Total (TC) catch was calculated as:

TC (kg) = mean CPUE (kg/canoe/day) × fishing days/year × effort (number of canoes).

The non-parametric Spearman's rank correlation coefficient was used to assess correlations between CPUE and three environmental factors: temperature, water level, and lunar phase. Temperature and water level data were collected by the author during the study period (see Chapter 3).

The lunar phase calendar was obtained from the link http://home.roadrunner.com/~davejessie/-MoonPhases/calenders/2012 jpg. As a quantitative way of describing the lunar phase, the author decided to use the fraction of the moon's disk that was illuminated in a day. This quantity could take values between 0% (new moon) and 100% (full moon).

5.3 RESULTS

Fishing craft

All vessels counted during the surveys were dugout canoes (mukolo). In total, 353 canoes were recorded on the lake. The greatest number of canoes (62%) were recorded from Shamahuka landing site (Muyako village), with the lowest being recorded from Zilitene (4%) and Lusu (4.4%) (Table 5.1).

Table 5.1. Percentage distribution of canoes per landing site on Lake Liambezi, between May 2011 and April 2012

	Number of canoes recorded per landing site					
Landing sites	**Muyako (Shamahuka)**	**Zilitene**	**Lusu**	**Masokotwani**	**Islands**	**Total**
Number recorded	220	14	15	25	69	343
Percentage	64.1	4.1	4.4	7.1	20.1	100

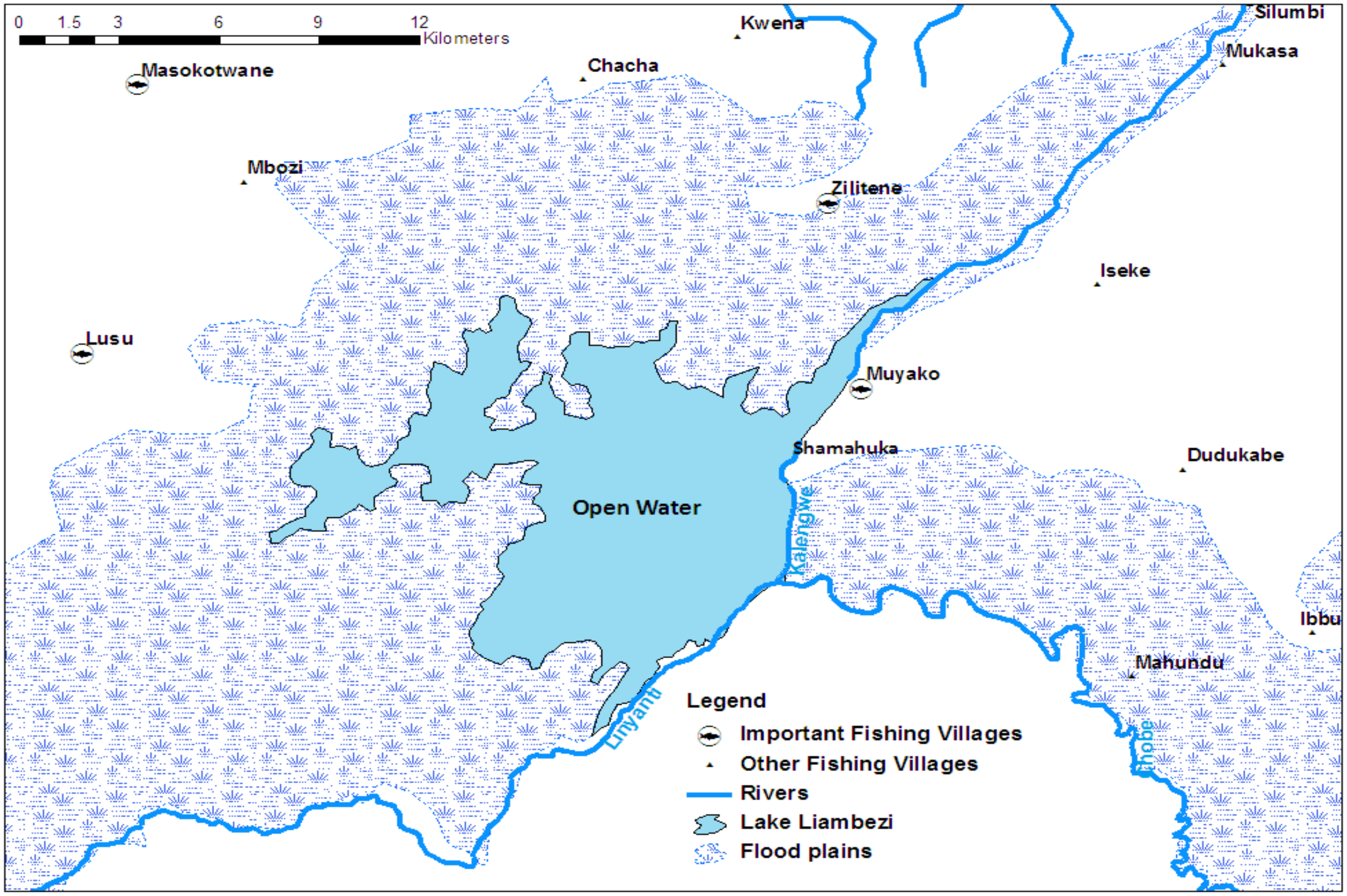


Figure 5.3. Map of Lake Liambezi showing the important fishing villages around the lake and from where the fish is landed and shipped to the open markets at Katima Mulilo open markets and for export into Zambia and the Democratic Republic of Congo, generated using ArcGIS 9.3.

Frequency of fishing

Fishermen were asked how many days in a week they spent fishing. The results are summarised in Table 5.2. More than 60% of the fishermen indicated that they fish for five days in a week while 16% indicated they fish for 7 days a week. As a result an average of five fishing days per fishermen per fishing week was obtained during the creel surveys. All the fishers interviewed during the course of this study indicated that they fish every month of the year.

Table 5.2. Percentage distribution of fishers in terms of fishing frequencies on Lake Liambezi, between May 2011 and April 2012

Status of fishermen	Number recorded	Percent
Once a week	0	0
Twice a week	0	0
Three times a week	4	4
Four times a week	5	4.7
Five times a week	70	66.0
Six times a week	10	9.4
Seven times a week	17	16.0
Total	106	100
Average number of fishing days/fishermen=sum of fishermen/number recorded	**5.29**	

Gear type and mesh sizes

Species composition of the commercial gillnet fishery as simulated by the experimental catches (Chapter 4) showed that commercial catches were dominated by cichlid species, mainly: *Oreochromis macrochir*, *O. andersonii*, *T. rendalli* and *Serranochromis macrocephalus*. During the study, 92.2% of the fishermen showed a high preference for monofilament gillnets to catch these species (Figure 5.4 a). Mesh size is one of the principal factors determining both the species and fish sizes caught by the fishermen. The most frequently used mesh sizes on the lake were 3.5” (38.7%) and 4” (48.7%) respectively (Figure 5.4 b).

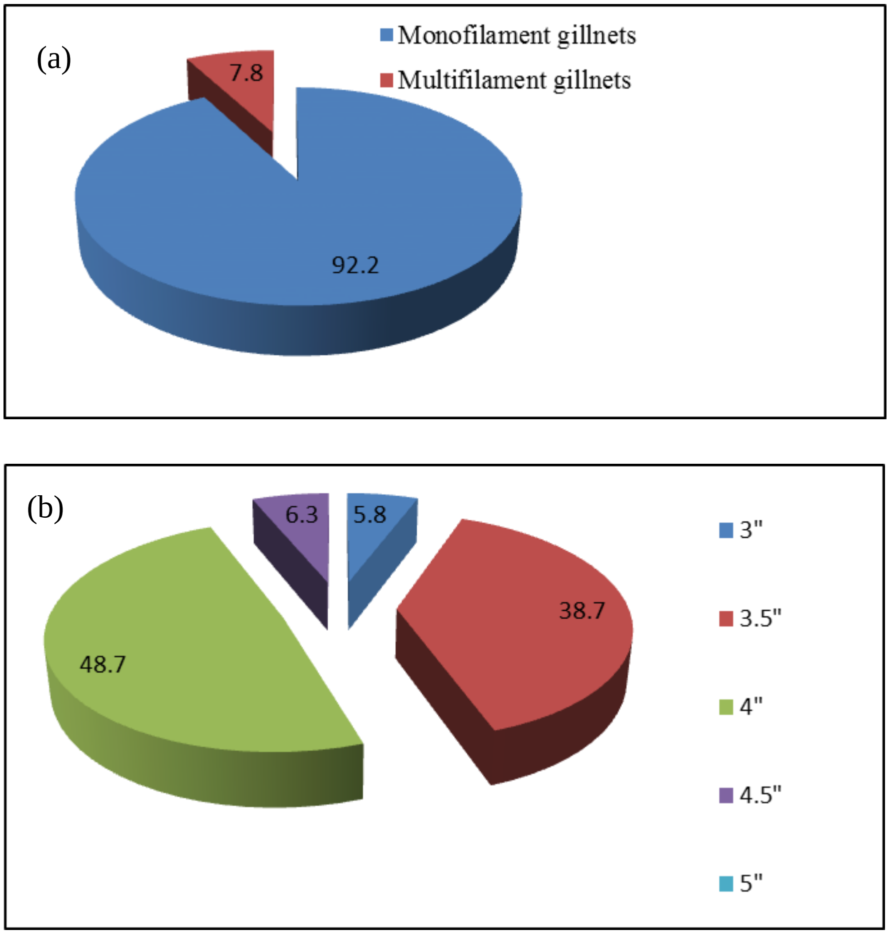


Figure 5.4 (b). (a) Percentage gear type and (b) mesh size preference recorded from a sample of 599 gillnets at Shamahuka, along Lake Liambezi between May 2011 and April 2012.

Fish landings per canoe at Shamahuka

Monthly fluctuations in monthly mean weight (CPUE) of fish from the lake between May 2011 and April 2012 are shown in Figure 5.5, Appendix 6. Average monthly catches increased from 15 ± 7.18 kg/canoe/net night in May 2011 to 44.6 ± 17.8 kg/canoe/net night in August; declined to 14.6 ±7.6 kg/canoe/net night in October and peaked at 53.1 ± 31.8 kg/canoe/net night in April 2012. The average catch rate per canoe per day trip was 35.8 ± 20.7 kg/day (Table 5.3). Analysis of CPUE indicates that catches were lognormal distributed and that most (70%) of the time, a fisherman's daily catch would range between 11 kg and 50 kg (Figure 5.6).

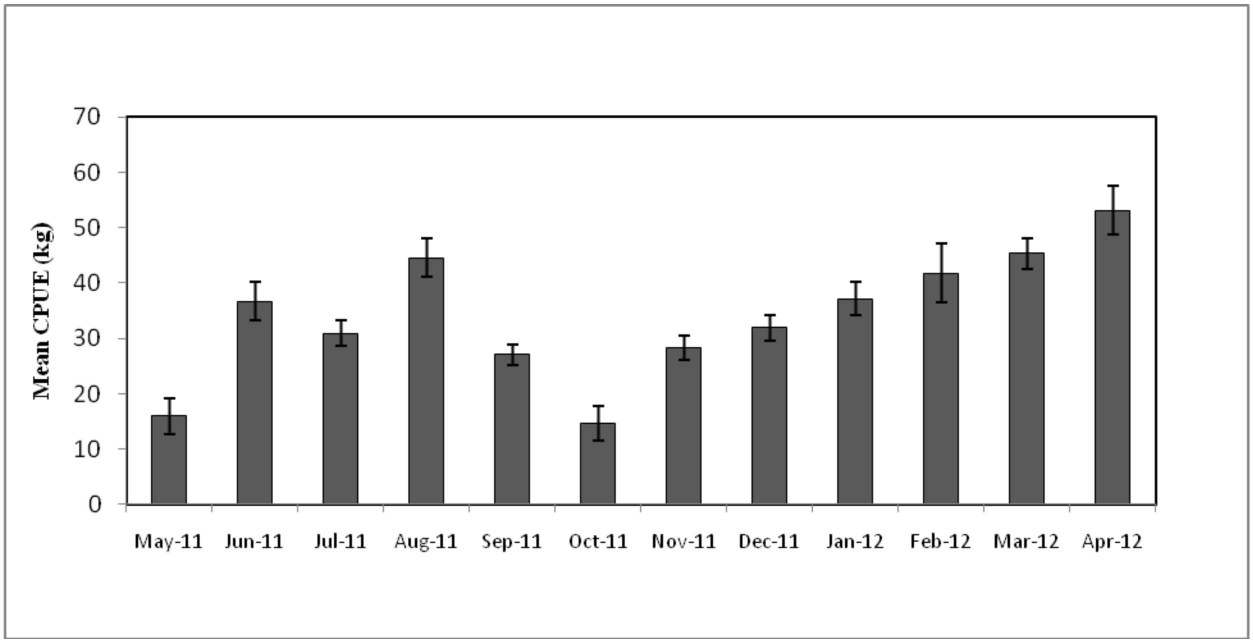


Figure 5.5. Monthly total catches per canoe per net night recorded from a sample of 602 canoes/days at Shamahuka landing site, on Lake Liambezi between May 2011 and April 2012.

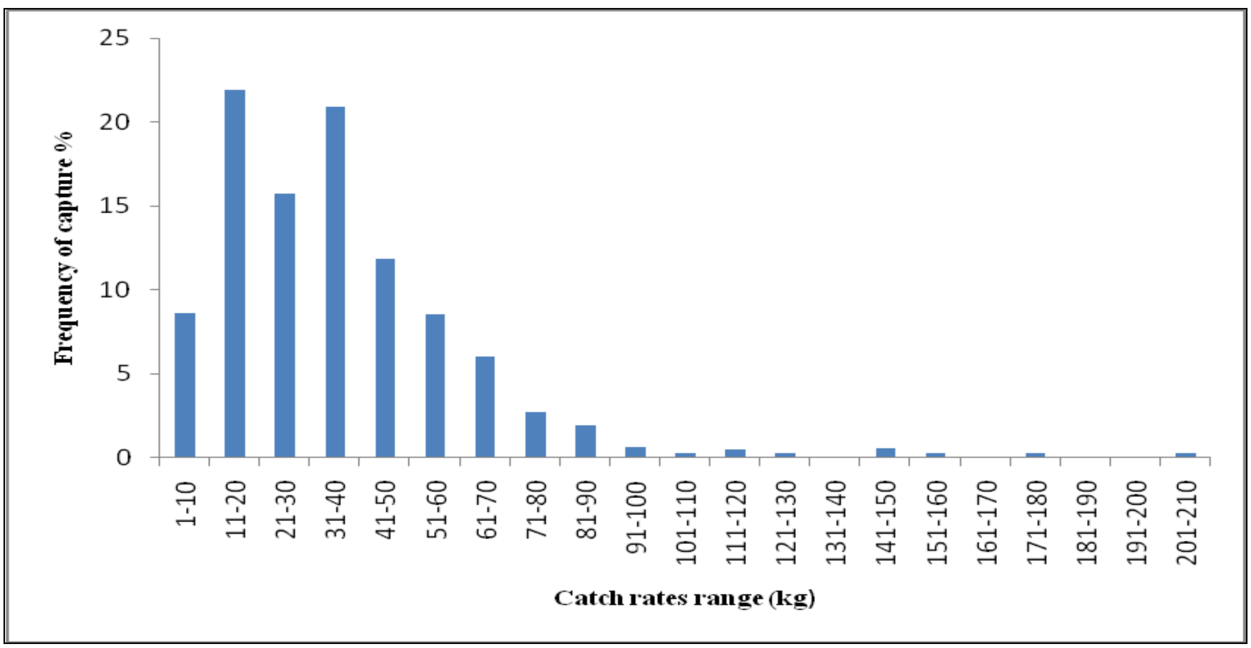


Figure 5.6. Frequency of capture per fishing day recorded from a sample of 602 canoes at Shamahuka landing site, Lake Liambezi, between May 2011 and April 2012.

Table 5.3. Average, median, variance and range for all catches recorded from a sample of 602 canoes at Shamahuka landing site between May 2011 and April 2012.

Parameter	**Statistical value**	**95% confidence interval limit**	
		Lower	*Upper*
Mean	35.8	33.9	37.8
Std.error of mean	0.99		
Median	32.5	30	35
Variance	592	450.8	741.7
Range	201		
Minimum	1		
Maximum	202		

Fishing effort and total catch

Effort was determined as the total number of canoes operating on the lake for five days in a week per month (Table 5.1). According to the results presented earlier in this chapter, a total of 343 canoes were recorded from the entire lake with the highest record being 220 canoes from Muyako fishing village, which includes the Shamahuka landing site. Based on the above statistics, a total catch of 2219 ± 57 t/year was landed at Muyako landing site only, eastern lake side. This was computed from an average catch rate of 35.8 kg/fishermen per canoe/day, determined from an estimated number of 220 canoes recorded from Muyako village and 5/7 weekly fishing days of 365 days in a year (260 days) (May 2011 – April 2012). Total fish yield for the entire lake was approximately 3193 ± 88t in a year computed from an average catch rate of 35.8kg/canoe/day, determined from a total estimate of 343 canoes recorded for the entire lake.

Correlation between catches and climatic factors

Separate correlation analyses were performed to assess the relationship between the monthly catch rates at Shamahuka landing site with the three climatic factors of temperature, lunar phase and water level. A negative significant correlation between the monthly catch rates and temperature was found (r = -0.37; P<0.01) (Table 5.4). Similarly, a negative significant correlation between the monthly catch rates and lunar phase was also found (r = -0.14; P<0.05) (Table 5.4). However, no correlation between the monthly catch rates and water level (P>0.05) was found (Table 5.4). A pair wise correlation analysis showed a positive significant correlation (r = 0.16; P<0.05) between the monthly catch rates with water level and lunar phase as a combined factor (Table 5.4), whereas a negative significant correlation was found between the monthly catch rates with temperature and water level as a combined factor (r = -0.83; P<0.01) (Table 5.4). However no significant correlation was found between the monthly catch rates with water level and lunar phase as a combined factor (Table 5.4).

Table 5.4. Correlation coefficients between CPUE (kg) and temperature (in °C), water level (m) and lunar phase (%) in Lake Liambezi, between May 2011 and April 2012. (**: All values are significant; P<0.05).

Variable	**Date**	**Temperature**	**Water level**	**Lunar phase**
CPUE	0.49	-0.37	-0.72	-0.14

Fish market data

The amount of fresh fish supplied to the Katima Mulilo market was determined from the total weight of all fish recorded between May 2011 and April 2012. Analysis of the fish market data showed a significant increase in fish supply during the study period (Figure 5.7). The daily average wet weight of fish supplied to the fish market during the study period was 5237 ± 193 kg/day in 2011 and 6293 ± 363 kg/day in 2012. The total annual average wet weight of fish supplied to the fish market was 1634 tons in 2011 and 1963 tons in 2012 (Table 5.5). Peaks in wet weight of fish were observed in summer, coinciding with the flood recession period and a drop in water level; hence fish became easier to catch on the floodplain rivers. According to the interview surveys, the majority of fish recorded at the Katima Mulilo fish market came from the villages along Lake Liambezi such as Muyako, Kwena, Lusu, Machita and Masokotwani (Figure 5.3). Other important fishing villages such as Ngala, Mahundu, Zillitane and Malengalenga also contributed to the fish supply to the fish market (Figure 5.3).

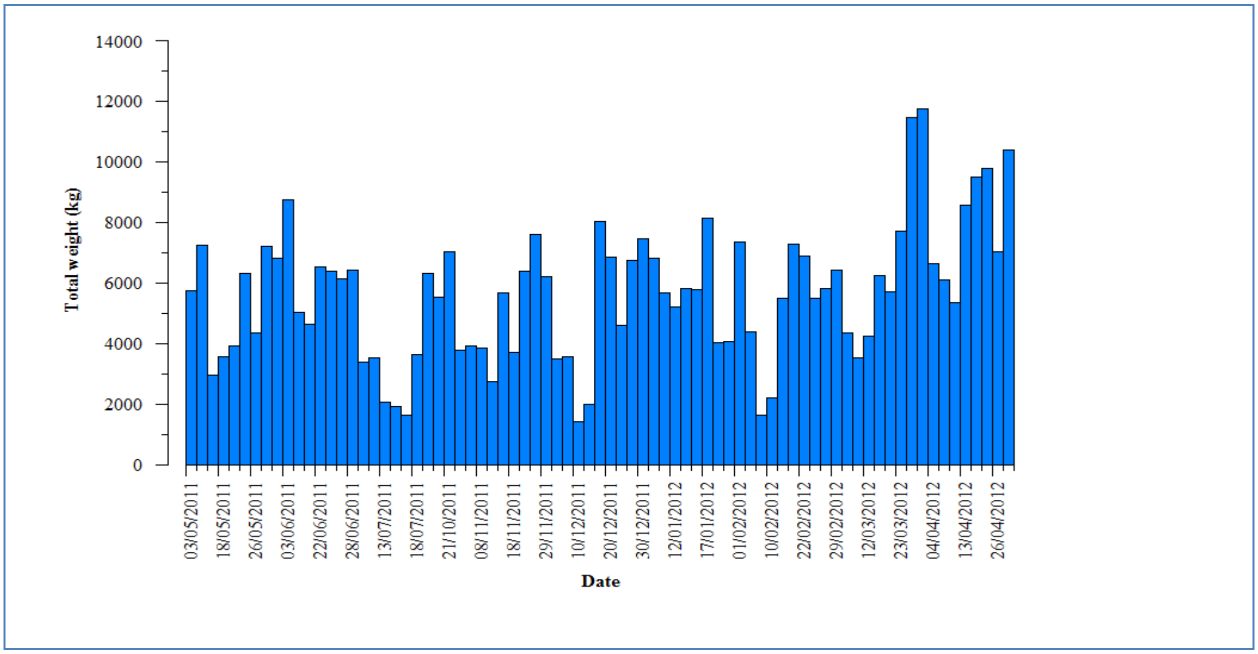


Figure 5.7. Total weight (kg) per day entering the fish market at Katima Mulilo, between May 2011 and April 2012 for export mainly to Zambia.

Value

The fish entering the Katima Mulilo fish market was sold wholesale in large, medium and small cooler boxes (Figure 5.10). Price was dependent on quantity and the exchange rate was set at 1US$ = N$10.50. For example, a large cooler of fish weighing 67kg sells at N$7.50/kg

(US$78,75) while a customer pays N$8.10/kg (US$ 85.05)for a medium cooler weighing 37kg and N$15.00/kg (US$ 157.50) for a smaller cooler weighing 16.5kg at the fish market.

Further analysis showed that there was a significant increase in the total amount of money made during the study period (Table 5.5). The total estimate of the revenue from the fish market was based on the assumption that all fish entering the fish market on a daily basis was kept there until it was sold. Based on a total estimate production of 2040 tons of fresh fish traded wholesale by April 2012, and an average value of N$8.00/kg, the value of the Katima Mulilo fish market was approximately N$15.8 million per annum (Table 5.5).

Table 5.5. Annual turnover of fish at the Katima Mulilo fish market, between May 2011 and April 2012, currency set at 1US$ = N$10.50.

	May 2011 - April 2012
Biomass (kg)	
Average weight (kg)/day	5668
Per month (30 days, excl. Sundays) (kg)	170040
Per year (tonnes)	2040
Revenue (N$)	
N$/day	43951
N$/month (30 days)	1318530
N$/year	15.8 million

Small Cooler (16.5 kg)

Medium cooler (37Kg)

Large cooler (67 Kg)

Figure 5.10. Examples of small, medium and large coolers used for the wholesale of fish at the Katima Mulilo fish market (Shapi, 2012).

5.4. DISCUSSION

Fishing gear

No major changes in harvesting patterns were observed before the lake dried up in the 1980s (van der Waal, 1980) and after it refilled in 2009. However, the gillnet fishery now uses monofilament gillnets rather than multifilament gillnets. The change to monofilament gillnets in the Zambezi Region seems to have started in 2010. Modern gear increased in importance from mid-2011 to 2012. The reason for this change is attributed to the higher catch efficiency associated with the monofilament gillnets and the increasingly dominant market economy, and the creation of formal employment and urbanization. In Malawi fish trading has been increasing since the Second World War in response to the doubling of the population between 1945 and 1966 (Njaya, 2001). The introduction of machine-made nylon thread nets by a Blantyre factory instead of the fibre of local plants in 1958 was one of the most dramatic innovations of the fishing industry in Malawi (Agnew & Chipeta, 1979). In the past, fishers repaired their own nets, but now that nets are cheaper, in a cash-driven economy, they simply replace them.

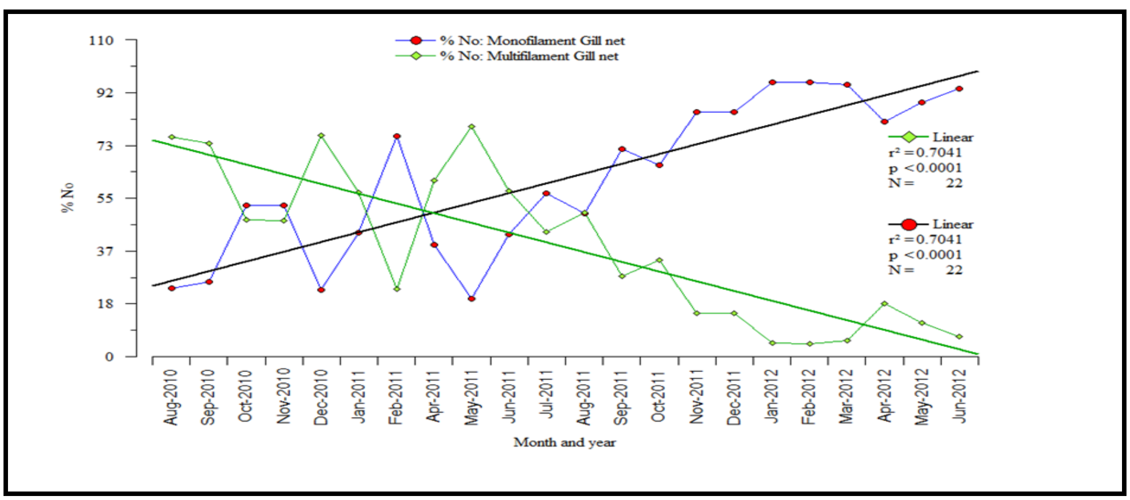


Figure 5.11. A change in gear use from multifilament to monofilament gillnets in the Zambezi Region's floodplains between August 2010 and June 2012.

Monofilament and multifilament gillnets are selective towards the large cichlid species such as *O. andersonii*, *O. macrochir*, *T. rendalli* and *S. macrocephalus.*

Selectivity towards large cichlids is demand driven as they command a much higher price than non-cichlid species e.g. *Hydrocynus vittatus* and *Clarias* species (van der Waal, 2011). The most preferred mesh sizes are 3.5" and 4" as these mesh sizes target medium-sized fish (Tvedten *et al*., 1994). As a passive gear, gillnet mesh size largely determines both the size and type of fish caught. The use of 3" mesh size by some fishermen on Lake Liambezi poses a threat to the fishery as it has been shown to select *O. andersonii* and *O. macrochir* at lengths lower than their reported length at 50% maturity of 254 mm TL for *O. andersonii,* 221mm TL for *O. macrochir* and approximately 212mm TL for *T. rendalli* (Peel, 2012). Hence the use of 3" mesh size for both monofilament and multifilament net types should be discouraged. The 3.5" gillnet mesh size corresponds to peak selectivity modes nearing or over the reported length at maturity for *O. andersonii, O. macrochir* and *T. rendalli* for both net types (Peel, 2012).

In order to balance resource control with benefits to stakeholders, it would be reasonable to adjust the minimum legal mesh size to 3.5" against the 3" mesh size as recommended by Peel, (2012). This will ensure that *O. andersonii* and *O. macrochir* re-enter the fishery at or near the length at 50% maturity (Peel, 2012). The impact of small mesh sizes can be detrimental to the fishery and has resulted in failure of cichlid fisheries and rarity of certain valued species from the fisheries of Lake Malawi and Malombe in Malawi (Tweddle *et al*., 1994; Turner *et al*., 1995; Peel, 2012). The use of an appropriate mesh type and size in gillnet fishing prevents the catch of juveniles while promoting the catch of preferred sizes due to its selectivity (Hamley, 1975).

Landings

Monthly catch landings at Shamahuka per day increased over the study period. This increase can be explained by an increase in fish recruitment, and effort over time. These observations confirm that there are migrations of fishes in the lake and that fishing is good after breeding seasons. Fluctuations in catches were related to climatic factors such as water level, temperature and lunar phase. Correlation analysis showed no significant relationship between the catches and water level. However, a significant negative correlation was found between average monthly temperature and monthly catches. Similarly there was a significant negative correlation between lunar phase and monthly total catch.

In spite of there being a lack of correlation between water level and monthly total fish catches in this study, previous studies conducted by van der Waal, (1980) showed that low lake levels produced high catches in Lake Liambezi. Welcomme & Hagborg, (1975) also reported that for African floodplain fisheries, "variation in the intensity and duration of the floods and severity of draw-down conditions during the low water produces corresponding fluctuations in many biological parameters". Thus year-classes of fish from years of good flooding and slight-draw-down show greater growth and survival than year-classes from years of poor conditions. Similarly Furse *et al*., (1979) observed that the yield and species composition in the shallow Lake Chilwa (Malawi) varied as lake levels fluctuated. Hence the observed lack of correlation between water lake levels and monthly total fish catches in the present study could be attributed to slight seasonal changes in lake level during the course of this study. Surveys conducted by van der Waal, (1980) were very extensive (1973-1976) compared to the single year of data presented in this study. During the period covered by van der Waal's study Lake Liambezi should have been through minor and moderately severe recessions resulting in significant impacts on the fish mortality.

This study showed a fall in fish catches with an increase in temperature and vice versa. There are three possible causes of these results. Firstly, the fall in fish catches during the warmer months coincided with the spawning seasons for most cichlids in the lake, as reported by Peel, (2012). Secondly, the twelve-month fishing season was further reduced by strong rainfall and wind experienced annually between October and April, which could have negatively influenced the fishing activities on the lake. Thirdly, a fall in catches may have been attributed to an increase in fishing pressure driven by increasing effort in the fishery. This has been shown in the Zambezi River where stocks of the larger, commercially more valuable cichlids species have been declining due to fishing effort (Hay *et al*., 2000).

A significant correlation between lunar phase and daily CPUE was also observed in this study. Lunar cycles are commonly observed in the movements, feeding and reproduction of marine and freshwater fish and invertebrates (Ortega *et al*., 2008). Both professional and recreational fishermen believe that catch per unit effort (CPUE) in many fisheries depends on lunar phase (e.g. Johannes, 1981). Catch rates were observed to decrease from new moon (0%) to full moon (100%) irrespective of fishing effort. A decline in fish catches during the full moon days can be attributed to an increase in the visibility of the netting as well as the influence of the moonlight on fish behaviour and distribution of its prey species (Di Natale & Magano, 1995). The only exception to this pattern was observed in November – December 2011, when a relatively high catch rate was made over the full-moon periods. These observations agree with Lewis and Tweddle, (1990) who pointed out that weather conditions influence catches during the rainy season, and concluded that overcast conditions would create good fishing conditions during periods of full moon, whereas periods of strong winds or thunderstorms on moonless nights would restrict fishing. However, it is noteworthy that the effect of lunar phase may vary, depending on the study fish species. For instance, Bigelow *et al*., (1999) demonstrated that tuna catches using long lines peak during the full moon phase because predatory fish are better able to locate baited hooks in the moonlight. The contrasting effects of lunar phase on catchability of predatory fish illustrate the fact that lunar phases can have varying effects on CPUE, depending on the nature of the fishery considered. The classification of the fisheries into "day or night" fisheries does not uncover any apparent patterns in respect to lunar phase effects.

Total yield

Fish production per surface area of 3 193 t/year and 100 kg/ha was computed from the entire lake (size 300km^2). The results obtained in this study are compared in Table 5.6 with statistics of commercial fisheries on a number of African Lakes and swamps. The average production of the entire Lake Liambezi is comparable to the quoted figures which were computed in a similar way. The figure of 100 kg/ha is relatively low compared to Lake Chilwa (160 kg/ha) but however within the range of other lakes such as Lake Chiuta, Lake Malombe and Lake Mweru (Table 5.6). There is a contrast between these three lakes. Tweddle, (1983) addressed the fisheries of Lake Chiuta located on the Malawi – Mozambique border. It is a permanent lake covering an area between 25–130 sq km and a maximum depth of 3 – 4 metres. Gillnets, beach seine and long lines were the most important gears operated in the open water of the northern area of the lake, with fish traps being more apparent in the weedy central area. Tarbit, (1972) noted 36 fish traders establishments and estimated that they were exporting some 60 tons of *Oreochromis shiranus* per month, while mormyrids, catfish and *Barbus* species were being utilised mainly by the local population. Fish production of the entire lake was estimated at approximately 1400 tons per year.

Jul-Larsen *et al.*, (2003) addressed the fisheries of Lake Malombe. The lake is shallow, twice as long as wide, and lies in the outflow of Lake Malawi through the upper Shire River. The average depth is 5-7 m with a maximum of around 17 m. The exploitation of Lake Malombe is dominated by two artisanal fisheries; gillnet and purse-seine type of fishery locally known as Nkacha. Annual catches of the three species that formed the Chambo complex (*Oreochromis lidole, O. squamipinnus* and *O. karongae*) dropped from 9300 tonnes in 1982 to a mere 50-200 tons from 1993 onwards. Subsequently the *Oreochromis* fishery was almost completely replaced by the low valued haplochromine cichlids Kambuzi which reached levels of 9500 tons in 1987.

Jul-Larsen *et al.*, (2003) further addressed the fisheries of Lake Mweru. The lake is situated on the border of Northern – Zambia and the Democratic Republic of Congo in the Luapula valley. The lake is about 115 km long, 45km wide and 2m deep. It gradually deepens to 10 – 14 m in the northern part of the lake. The three dominant fishing gears in the lake are gillnets, trap and types of scoop nets used in the light fishery. The largest output of the fishery is *Microthrissa moeruensis* (chisense) caught by a limited set of gear types. Many different gears and methods employed based on gillnets targeted the endemic *Oreochromis mweruensis*, the second most important species of the fishery. The lake had a long-term annual average production of 8350 tons per year. The total demersal fishery was estimated from 12500 to 22000 tons/year. The productivity of the lake based on the “demersal” catch was estimated between 20 – 36 kg/ha and between 67–108 kg/ha in inclusion of the pelagic fishery.

The current Lake Liambezi fish production is higher than the 1700t/year previously reported by Tweddle *et al*., (2011). It is possible that the preceding study had underestimated the yield based on the total number of fishermen on the lake, whereas the current yield in this study was computed from the total number of canoes that were enumerated by the author. Information on the total number of fishermen on either side of the lake was obtained from headmen and this is usually undependable. It is also possible that catch rates were generally lower in 2011. An increase in fishing canoes, fish trade and export and the use of modernised fishing gear are some of the innovations employed in boosting production from the lake.

Table 5.6. Fish yield from selected water bodies in Africa

Water body	Yield (kg/ha/year)	Surface area(km^2)	Reference
Lake Kainji	4.7	1270	Balogun & Ibeun, (1995)
Lake Kariba	57.0	5364	Machena, (1995)
Lake Nasser	39.0	900	Rashid, (1995)
Lake Volta	52.0	8300	Braimah, (1995)
Lake Mweru	108.0	5175	Jul-Larsen *et al*.,(2003)
Bangweulu swamps	1.9	15100	Jul-Larsen *et al*.,(2003)
Lake Chilwa	160.0	750	Jul-Larsen *et al*.,(2003)
Lake Malombe	77.0	390	Jul-Larsen *et al*.,(2003)
Lake Chiuta	100.0	199	GoM, (2005)
Lake Liambezi	106.0	300	This study

As a result, Lake Liambezi has significantly contributed to the fish supply in the Zambezi Region. By the end of 2010, three tonnes/day of fresh fish passed through the Katima Mulilo market en-route to Zambia, of which 90% came from Lake Liambezi (Tweddle *et al*., 2011). The fish market at Katima Mulilo was valued at N$15 million by mid-2012, while the yield from the entire fisheries of the Zambezi Region’s floodplain is approximately 6700 tonnes, worth N$92 million (Tweddle & Hay, 2011). This indicates that freshwater fish is highly rated as a key food item in the north eastern regions of Namibia. Fish is thought to contribute around 35% of total animal protein intake in Africa. The importance of fish in the Zambezi Region is evident, confirming that fish is the dominant commodity at the central market place in Katima Mulilo.

Conclusions

This chapter revealed that the present gillnet fishery on Lake Liambezi is selective towards cichlid species of the genus *Oreochromis*, *Tilapia* and *Serranochromis*. Monofilament and multifilament gillnets have been identified as the main gear used by most fishermen on the lake and the fishing community around Lake Liambezi has shifted towards the frequent use of monofilament gillnets of medium mesh sizes (3.5 and 4 inches). The use of a small mesh size (3 inches) by a certain group of fishermen on the lake could be harmful for such a small lake. The danger is that a small mesh size will lead to overfishing. Gillnets only last for a few years and a whole fishery can shift from one dominant mesh size to another in response to changes in biomass and size of the commercially important species in a fish community. Observations at fish landing locations and collection of metric data of landed fishes are commonly used methods supporting fisheries management (Rijnsdorp *et al.*, 1996). Monthly landings (CPUE) at Shamahuka increased from 15kg to 53kg per standard net. An increase in CPUE over the study period was observed, possibly indicating that over – exploitation of fish caught in gillnets did not take place. Variation in monthly CPUE was relatively altered by climatic factors such as temperature and moon phase. A yield of 100kg/ha was computed from the entire water surface of Lake Liambezi (size 300km^2). This confirms that Lake Liambezi is a productive lake with a significant input towards the nutritional requirement of the Caprivi Region.

CHAPTER 6

GENERAL DISCUSSION AND MANAGEMENT RECOMMENDATIONS FOR LAKE LIAMBEZI FISH STOCKS IN THE ZAMBEZI REGION, NAMIBIA

The importance of understanding any fishery is to be able to make informed conservation and management decisions. Management of inland fisheries requires an understanding of the biology of the target species as well as knowledge of the dynamics of the harvesting fisheries. This thesis contributes to the knowledge base by having investigated juvenile population dynamics in the floodplain as well as by comparing catch rates between monofilament and multifilament gillnets in Lake Liambezi.

The littoral zones along the marginal areas of Lake Liambezi and the Kavango floodplain have been demonstrated as important nursery grounds for small fishes, particularly cichlids. The high macrophyte growth in the littoral zone showed to serve as nesting areas, feeding zones and refugia for most small fish communities in this study. Most small fish used the floodplain throughout the year, so that access to these areas must be maintained throughout the reproductive seasons. Therefore, considerable use of a seine net or small mesh gear in these crucial habitats may result in growth overfishing where fish are harvested before they are given a chance to grow to a size at which they would contribute significantly to the yield, especially for cichlids with low fecundity and small clutch size (Brichard, 1978). High annual rates of juvenile mortalities may result in small adult populations, implying that stock recovery after a reduction in adult population numbers through fishing may be slow (Ellender *et al*., 2008). Hence, it would be best to discourage seining operations which would target primarily juvenile cichlids as an initial step towards protecting immature fishes and avoiding the foreseeable danger of over-exploitation. For instance in Lake Malawi, the chambo (*Oreochromis* spp) fishery collapsed as a result of the introduction of purse seine (Kauni) nets that targeted juvenile fish in areas which were already being fully exploited (Tweddle *et al*., 1995; Peel, 2012).

Comparison of the efficiency of monofilament and multifilament gillnets in the offshore waters of Lake Liambezi was assessed. Gillnets, both monofilament and multifilament are the main gear used by the subsistence and commercial fishermen on Lake Liambezi. In Lake Liambezi monofilament nets were shown to be three times more effective than the multifilament nets in catching fish in Lake Liambezi. Overall CPUE (expressed as kg/100m net/night) between the two net types was determined by the visibility of the net twine, thinness, and net twine strength. The low visibility monofilament net performed better than the more visible multifilament nets. The six most abundant species caught with the two net types were *Oreochromis andersonii*, *O. macrochir*, *Tilapia rendalli*, *Serranochromis macrocephalus*, *Schilbe intermedius*, and the two clariids (*Clarias gariepinus* and *Clarias ngamensis*). In general, *O. andersonii* was the overall dominant species, reflecting a similar trend observed by van der Waal, (1980) before the lake dried up in 1986. *Oreochromis andersonii* has increased rapidly in the few years from the time when the great floods of the Zambezi filled the lake.

CPUE varied significantly between seasons in monofilament nets, while no significant differences were detected in seasonal CPUE in multifilament nets. Mean CPUE was greater during summer in monofilament nets and relatively lower in multifilament. These observations were associated with the water quality of the lake, which is generally clearer in summer and spring than other seasons. As a result, the white multifilament nets are more visible than the clear monofilament nets. These observations conclusively indicated that the cichlids in Lake Liambezi rely on vision and light as a primary sense. It was also concluded that, during summer time, most cichlids were able to notice and avoid the white multifilament net type more easily than the monofilament net type. CPUE of the most abundant species differed significantly between the five mesh sizes (3" – 5") in monofilament and multifilament net types. Selectivity of the different mesh sizes of both net types was also assessed and showed that the mean CPUE of the most abundant species: *O. andersonii, O. macrochir, T. rendalli* and *S. macrocephalus* decreased with an increase in mesh size.

The new commercial fishery on Lake Liambezi was described in Chapter 5. Most fishermen on Lake Liambezi prefer monofilament gillnets rather than multifilament due to high catching efficiency associated with the monofilament net type. The most frequently used mesh size per net type was the 3.5" and 4". This practice is sustainable; however, the use of 3" to catch fish in the lake may adversely affect juvenile recruitment. This mesh size has been shown to target immature fishes of *O. andersonii* and *O. macrochir* in monofilament and multifilament gillnets (Peel, 2012). The 3.5" mesh was proposed to be optimal in catching *O. andersonii*, *O. macrochir* and *T. rendalli* in the experimental gillnets (Peel, 2012). The use of smaller mesh sizes, targeting juvenile fishes, is detrimental to the fishery. For instance, the case study on Lake Malombe and Lake Malawi revealed that the impact of heavy fishing pressure on both adults and juvenile fish of *Oreochromis squamipinnus* by a multi-species fishery using seine nets and gillnets led to the collapse of the fishery (Tweddle *et al*., 1995; van Zwieten *et al*., 2003; Peel, 2012). The collapse of the Lake Malombe and Lake Malawi fishery is a salutary lesson of the dangers of uncontrolled fishing in African water bodies. Large mesh size alone does not necessarily protect a stock from overfishing, unless effort is also controlled.

The catch landing data at Shamahuka (Chapter 5) showed the importance of stock assessment, yield calculation, and catch trends over time to determine the response of the fish stocks to change in climatic factors, as water level, temperature, lunar phase etc. However, lunar phase and temperature had large reaching effects on the catch rates from Lake Liambezi. This implies that, in addition to fishing effort, the fishery of the lake is significantly influenced by some climatic variables such as lunar phase. The greater importance of climate in driving the dynamics of fish stocks in many Africa's inland waters suggests that effort should be redirected to protecting wetland functions and broader ecosystem integrity (Sarch & Allison, 2000). This calls for other, alternative sources of income generation to be identified and promoted.

A total mass production of 3 000 t/year was removed from the entire lake between May 2011 and April 2012, which may underestimate the actual value of the lake but indicates that Lake Liambezi is a highly productive water body. Accurate production estimates can be achieved by taking an inventory of all fishing practices in Lake Liambezi, and harnessing the involvement of the fishing communities in fish catch and effort data collection through a participatory framework. Establishing Beach Village Committees (BVCs) for Lake Liambezi could be essential to advocate the involvement of local institutions in making decisions about the management and utilisation of the resource they depend on. The rationale for instituting fish catch and effort data collection using BVCs is suggested for a number of reasons, fundamental among them being the state of Ministry of Fisheries and Marine Resource where insufficient resources negate efforts towards sustaining data collection systems. The required resources in this regard include finance, trained personnel, equipment and other research facilities. The current fish catch and effort data collection system for the MFMR in Namibia is not very effective because of limited capability. The conventional data collection system in place demands more resources and technical establishment. There are variations in landing times for many fishers and most of the fishing trips go unrecorded because of budgetary and logistical constraints. Using the BVCs to collect fish catch and effort data will capture information that could not be possible with the MFMR's current data collection system.

MANAGEMENT RECOMMENDATIONS

Past experience of the episodic drying and filling of Lake Liambezi shows the lake takes approximately three years to dry out when deprived of water inflow from its four sources (Tweddle *et al*., 2011). Considering the high floods for the three years 2009 to 2011, the same authors noted that it is likely that the lake can remain as a significant water body for several years. This time span allows for fisheries management plans and management measures for the Lake Liambezi fishery. The aims of the fisheries management in a wetland will determine the nature of that management (Bruton & Jackson, 1983). In southern Africa, most river-floodplain fisheries are managed through regulatory measures such as gear type and mesh size restrictions (Welcomme, 1979, 2001; Jul-Larsen *et al*., 2003; Peel, 2012).

Prohibition of beach seining

Seine net catches on the Kavango floodplain comprised largely juvenile fishes, especially the cichlids which accounted for 79% by number. If permitted as a commercial fishing gear, seine nets could result in growth overfishing (Peel, 2012). This study demonstrated that juvenile cichlids used floodplains and the inshore area of Lake Liambezi as a nursery area. In Lake Malombe the development of a seine net fishery that targeted juvenile Chambo (*Oreochromis* spp.) ultimately resulted in the collapse of that fishery (Tweddle *et al*., 1995). It is therefore recommended that seining operations on the floodplains in the Kavango and Caprivi Region should be prohibited.

Mesh size restriction

The minimum legal mesh size of 3" for both net types as stipulated by the Inland Fisheries Act in Namibia has been observed to target immature *O. andersonii* and *O. macrochir*. Therefore, it is recommended that a 3.5" mesh size for both net types should be introduced immediately. The 3.5" mesh size has been observed to be better for both net types, as this selects *O. andersonii*, *O. macrochir* and *T.rendalli* at lengths close to their length at 50% maturity. This initiative would avoid the consequences of "growth over-fishing" as well as "recruitment overfishing" where the spawner-stock is reduced to levels at which recruitment is negatively affected (Peel, 2012). This study suggests that, if catching efficiency of nets improves, some regulations in terms of mesh size restriction for fishing in the lake should be imposed at the same time to prevent over-exploitation of fish stocks.

Continuous monitoring of the lake

The Lake Liambezi fishery should be monitored on a quarterly basis to assess the development of the fish stock over time. This will provide information for adaptive management decisions as the fish stocks progressively develop. As fluctuations in temperature and moon phase were shown to play a significant role in determining daily fish landings, such monitoring should incorporate these climatic and environmental factors to meet the challenges of global climatic changes as well as other environmental issues.

Limiting access

Although fishermen access was not the scope of this study, the community-based records on the number of fishermen and canoes on Lake Liambezi are unreliable. The current registration system operated by the Muyako Community is not exclusive as it was noted during creel surveys that most Namibian gillnets owners employ foreigners (mainly Zambians and Angolans) to fish on their behalf. Therefore, there is an urgent need for the community, with guidance from the Ministry of Fisheries and Marine Resources (MFMR), to review and update the current registration system. In order to avoid arguments over the fishing grounds and competition for the fishery resources, registration should be restricted to fishermen resident in the area. Tweddle *et al.*, (2011) noted that fishermen from elsewhere have no interest in long-term sustainability of the resource. They are often responsible for the introduction of destructive fishing gear within the host area. In the Barotse floodplain for instance, Zambian fishermen complain about fishermen who come from outside and ignore their traditional agreements on resource ownership (Tweddle *et al.*, 2011). Similarly in the Zambezi Region, the advanced use of destructive seines and drifting monofilament gillnets in the Zambezi River by Zambian fishermen fishing on behalf of businessmen in the area causes serious tension in the local fishing communities.

RECOMMENDATIONS FOR FUTURE STUDIES

While the current study was able to provide some important management recommendation for sustainable utilisation of the Lake Liambezi Fishery in Namibia, a number of gaps in the knowledge base were identified.

1. An assessment of juvenile age and growth of *O. andersonii*, *O. macrochir* and *T. rendalli* must be initiated in order to gain detailed information on the life characteristics of these commercially

important species. This should be linked to the floodplain pulse in the Kavango and Zambezi Regions.

2. A follow-up study on the limnology study conducted by Seaman *et al.* (1978), before the lake dried up, should be initiated as it is well known that great changes might have taken place since it started refilling in 2000. Such a study is important because fish community structure may be determined by the limnological status.

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APPENDIX

Appendix 1: Water level data set from Lake Liambezi between May 2011 and April 2012

Date	Water Level
Jan-11	6.01
Jan-11	6.05
Jan-11	6.1
Jan-11	6.15
Feb-11	6.2
Feb-11	6.2
Feb-11	6.25
Feb-11	6.3
Mar-11	6.32
Mar-11	6.36
Mar-11	6.41
Mar-11	6.47
Apr-11	6.52
Apr-11	6.57
Apr-11	6.68
Apr-11	6.73
May-11	6.73
May-11	6.77
May-11	6.87
May-11	6.82
Jun-11	6.8
Jun-11	6.8
Jun-11	6.76
Jun-11	6.76
Jul-11	6.7
Jul-11	6.64
Jul-11	6.59
Jul-11	6.59
Jul-11	6.59
Aug-11	6.54
Aug-11	6.5
Aug-11	6.5
Aug-11	6.45
Sep-11	6.4

Continued…..

Sep-11	6.35
Sep-11	6.31
Sep-11	6.27
Sep-11	6.22
Oct-11	6.22
Oct-11	6.22
Oct-11	6.17
Oct-11	6.12
Oct-11	6.08
Oct-11	6.03
Nov-11	6.03
Nov-11	5.58
Nov-11	5.58
Nov-11	5.56
Dec-11	5.51
Dec-11	5.46
Dec-11	5.46
Dec-11	5.5
Dec-11	5.55
Jan-12	5.58
Jan-12	5.58
Jan-12	5.56
Jan-12	5.56
Feb-12	5.52
Feb-12	5.55
Feb-12	5.6
Feb-12	5.64
Mar-12	5.68
Mar-12	5.68
Mar-12	5.64
Mar-12	5.6
Mar-12	5.63
Apr-12	5.63
Apr-12	5.59
Apr-12	5.55
Apr-12	5.5

Appendix 2: Monthly water surface temperature data set from Lake Liambezi between May 2011 and April 2012. Empty cells = No data collected due to malfunctioning of the instrument or fewer sampling days.

May-11	Jun-11	Jul-11	Aug-11	Sep-11	Oct-11	Nov-11	Dec-12	Jan-12	Feb-12	Mar-12	Apr-12
22.5	20.1	17.8	19.8	24.6	25.4	28	27.6	24.3	23.8	26.3	23.8
22.5	20.1	17.8	19.8	24.6	25.4	28	27.6	24.3	23.8	26.3	23.8
22.5	20.1	17.8	19.8	24.6	25.4	27.9	27.6	24.3	23.6	26.3	23.6
22.5	20.1	17.8	19.8	24.6	25.4	28.3	27.6	24.3	23.6	26.3	23.6
22.5	20.1	17.8	19.8	24.6	25.4	28.3	27.6	24.3	23.7	26.3	23.7
22.5	20.1	17.8	19.8	24.6	25.4	28.3	27.6	24.3	23.7	26.3	23.7
22.5	20.1	17.8	19.8	24.6	25.4	28.3	27.6	24.3	23.7	26.3	23.7
22.5	20.1	17.8	19.8	24.6	25.4	28.3	27.6	24.3	23.7	26.3	23.7
22.5	20.1	17.8	19.6	24.6	25.4	28.3	27.6	24.3	23.7	26.3	23.7
22.5	20.1	17.8	19.6	24.6	25.4	28.3	27.6	24.3	23.7	26.3	23.7
22.5	20.1	17.8	19.6	24.6	25.4	28.3	27.6	24.3	23.7	26.3	23.7
23	20.1	17.8	19.6	24.6	25.4	28.3	27.6	24.3	23.7	26.3	23.7
23	20.1	17.8	19.6	24.6	25.4	28.3	27.6	26.9	23.7	26.3	23.7
23	20.1	17.8	19.6	24.6	25.5	28.3	27.6	26.9	23.7	26.3	23.7
23	20.1	17.8	19.6	24.6	25.5	28.3	27.6	26.9	23.7	26.3	23.7
23	20.1	17.8	19.6	24.5	25.5	28.3	27.6	26.9	23.7	26.3	23.7
23	20.1	17.8	19.6	24.5	25.5	28.3	27.6	26.9	23.7	26.3	23.7
23	20.1	17.8	19.6	24.5	25.5	28.3	27.6	26.9	23.7	26.3	23.7
23	20.1	17.8	19.6	24.5	25.6	27.7	27.6	26.9	23.7	0	23.7
23	20.1	17.8	19.6	24.5	25.6	27.7	27.7	26.9	23.8	26.5	23.8
23	20.1	17.8	18.8	24.5	25.7	27.7	27.7	26.9	23.8	26.5	23.8
23	20.1	17.8	18.8	24.5	25.9	27.7	27.7	26.9	23.9	26.6	23.9
23	20.1	17.8	18.8	24.5	25.9	27.7	27.7	26.9	23.9	26.6	23.9
23	20.1	17.8	18.8	24.5	25.9	27.7	27.7	26.9	23.9	26.3	23.9
23	20.1	17.8	18.8	24.5	25.5	27.7	27.7	26.9	23.9	26.3	23.9
23	20.1	17.8	18.9	24.5	25.5	27.7	27.6	26.9	23.9	26.3	23.9
23	20.1	17.8	18.9	24.5	25.5	27.7	27.6	26.9	23.9	26.3	23.9
23	20.1	17.8	18.9	24.5	25.5	27.8	27.6	26.9	23.9	26.3	23.9
23	20.1	17.8	18.9	24.5	25.5	27.8	27.6	26.9	23.9	26.3	23.9
23	20.1	17.8	18.9	24.5	25.5	27.8	27.6	26.9	23.9	26.3	23.9

Continued…..

May-11	Jun-11	Jul-11	Aug-11	Sep-11	Oct-11	Nov-11	Dec-12	Jan-12	Feb-12	Mar-12	Apr-12
23	20.1	17.8	19	24.5	25.5	27.8	27.6	26.9	23.9	26.3	23.9
22.4	20.1	17.8	19	24.5	25.4	27.8	27.6	26.9	23.9	26.3	23.9
22.4	20.1	17.8	19	24.5	25.4	27.8	26.5	26.9	23.3	26.3	23.3
22.4	20.1	17.8	19	24.5	25.4	27.8	26.5	27	23.3	26.3	23.3
22.4	20.1	17.9	19	24.5	25.4	28	26.5	27	23.3	26.3	23.3
22.4	20.1	17.9	19	24.5	25.5	28	26.5	27	23.3	26.3	23.3
22.4	20.1	17.9	19	24.5	25.5	28	26.5	27	23.3	26.3	23.3
22.4	20.1	17.9	19	24.5	25.5	28	26.5	27	23.3	26.3	23.3
22.4	20.1	17.9	19	24.5	25.5	27.2	26.5	27	23.3	26.3	23.3
22.4	20.1	17.9	19	24.5	25.5	27.2	26.5	27	23.4	26.3	23.4
22.4	20.1	17.9	19	24.5	25.5	27.2	26.5	27	23.4	26.3	23.4
22	20.1	17.9	19	24.5	25.5	27.2	26.5	27	23.4	26.3	23.4
22	20.1	17.9	19	24.5	25.5	27.2	26.5	27	23.4	26.3	23.4
22	20.1	17.9	19	24.5	25.5	27.2	26.5	27	23.5	26.3	23.5
22	20.1	17.9	19	24.5	25.5	27.2	26.5	27	23.5	26.3	23.5
22	20.1	17.9	19	24.5	25.5	27.2	26.5	27	23.5		23.5
22	20.1	17.9	19	24.5	25.5	27.2	26.5	27	23.5		23.5
22	20.1	17.9	19	24.5	25.5	27.2	28.5	27	23.5		23.5
22	20.1	17.9	19	24.5	25.5	27.2	28.5	27	23.5		23.5
22	20.1	17.9	19	24.5	24.4	27.2	26	27	23.5		23.5
22	20.1	17.9	19	24.5	24.4	27.2	26	27	23.5	0	23.5
22	20.1	17.9	19	24.5	24.4	27.2	26	27	23.5		23.5
22	20.1	17.9	19	24.5	24.4	27.2	27.8	27	23.5		23.5
22	20.1	17.9	19	24.5	24.4	27.2	27.8	27	23.5		23.5
22	20.1	17.9	19	24.5	24.4	27.3	27.8	27	23.2		23.2
22	21.2	17.9	19	24.5	24.4	27.3	27.8	27	23.2		23.2
22	21.2	17.9	19	24.5	24.4	27.3	27.8	27	23.2		23.2
22	21.2	17.9	19	24.5	24.4	27.3	27.8	27	23.2		23.2
22	21.2	17.9	19	24.5	24.4	27.3	27.8	27	23.2		23.2
22	21.2	17.9	19	24.5	24.4	27.2	27.8	27	23.2		23.2

Continued…..

May-11	Jun-11	Jul-11	Aug-11	Sep-11	Oct-11	Nov-11	Dec-12	Jan-12	Feb-12	Mar-12	Apr-12
22	21.2	17.9	18.9	24.5	24.4	27.4	27.8	27	23.2		23.2
22	21.2	17.9	18.9	24.5	24.4	27.4	28.4	27	23.2		23.2
22	21.2	17.9	18.9	24.5	24.4	26.8	28.4	27	23.8		23.8
22	21.2	17.9	18.9	24.5	24.4	26.8	28.4	27	23.8		23.8
22	21.2	17.9	18.9	25.2	24.4	26.8	28.4	27	23.8		23.8
22	21.2	17.9	18.9	25.2	26	26.8	28	27	23.8		23.8
	21.2	17.9	18.1	25.2	26	26.8	28	27	23.7		23.7
	21.2	17.9	18.1	25.2	26	26.8	28	27	23.7		23.7
	21.2	17.9	18.1	24.6	26	26.8	28	27	23.7		23.7
	21.2	17.9	18.1	24.6	26	26.8	28	27	23.7		23.7
	21.2	17.9	18.1	24.6	26	26.8	28	27	23.7		23.7
	21.2	17.5	17.7	24.7	26	26.8	28	27	23.7		23.7
	21.2	17.5	17.7	24.7	26	26.7	28	27	23.7		23.7
	21.2	17.5	17.7	24.7	26	26.7	28	27	23.7		23.7
	21.2	17.6	17.7	24.7	26	26.7	28	27	23.7		23.7
	21.2	17.1	17.7	24.7	26	26.7	28	27	23.7		23.7
	21.2	17.1	17.7	24.7	25.9	26.7	28	27	23.7		23.7
	21.2	17.1	17.7	24.7	25.9	26.7	28	27	23.7		23.7
	21.2	17.1	17.7	24.7	25.9	26.7	28	27	23.7		23.7
	21.2	17.1	17.7	25	25.9	26.7	28	27	23.7		23.7
	21.2	17.1	17.7	25	25.9	26.7	28	27	23.7		23.7
	21.2	17.1	17.7	25	25.9	26.7	28	27	23.7		23.7
	21.2	17.1	17.7	25	25.9	26.7	28	27	23.7		23.7
	21.2	17.1	17.7	24.9	25.9	26.7	28	27	23.7		23.7
	21.2	17.1	17.8	24.9	24.7	26.7	28	27	23.7		23.7
	21.2	17.1	17.8	25	24.7	26.7	28	27	23.7		23.7
	21.2	17.1	17.8	25	24.7	26.7	28	27	23.7		23.7
	21.2	17.1	17.8	25	24.5	26.7	28	27	23.7		23.7
	21.2	17.2	17.8	24.9	24.5	26.7	28	27	23.7		23.7
	21.2	17.2	17.8	24.9	24.5	26.7	28	27	23.7		23.7

Continued…..

May-11	Jun-11	Jul-11	Aug-11	Sep-11	Oct-11	Nov-11	Dec-12	Jan-12	Feb-12	Mar-12	Apr-12
	21.2	17.2	17.8	24.9	24.5	26.9	28	26.7	23.7		23.7
	21.2	17.2	17.8	24.9	25.4	26.9	28	26.7	23.7		23.7
	21.2	17.2	17.8	24.9	25.4	26.9	28	26.9	23.7		23.7
	21.2	17.2	17.8	24.9	25.4	26.9	28	26.9	23.7		23.7
	21.2	17.2	17.8	24.9	25.4	26.9	28	27	23.7		23.7
	21.2	17.2	17.8	24.9	25.4	26.9	28	27.3	23.8		23.8
	21.2	17.2	17.8	24.9	25.4	26.9	28	27.4	23.8		23.8
	21.2	17.2	17.7	24.9	25.4	26.9	28	27.6	23.8		23.8
	21.2	17.2	17.7	24.9	25.4	27	28	27.6	23.8		23.8
	21.2	17.2	17.7	24.9	25.4	27	28	27.6	23.8		23.8
	21.2	17.2	18.1	24.9	25.4	27	28	27.6	23.8		23.8
	21.2	17.2	18.1	24.9	25.4	26.7	28	27.6	23.8		23.8
	21.2	17.2	18.1	24.9	25.4	26.7	28	27.6	23.8		23.8
	21.2	17.2	18.1	24.9	25.4	26.8	28	27.6	23.8		23.8
	21.2	17.2	18.1	24.9	25.4	26.8	28	27.6	23.8		23.8
	21.2	17.2	18.1	24.9	25.4	27.4	28	27.6	23.8		23.8
	20.5	17.2	18.1	24.9	25.4	27.4	28	27.6	23.8		23.8
	20.5	17.2	19.3	24.9	25.4	27.4	28	27.6	23.8		23.8
	20.5	17.2	19.3	24.9	25.4	27.4	28	27.6	23.8		23.8
	20.5	17.2	19.3	24.9	25.4	27.4	28	27.6	23.8		23.8
	20.5	17.2	19.3	24.9	25.4	27.4	28	27.6	23.8		23.8
	20.5	17.2	19.2	24.9	25.4	27.4	28	27.6	23.8		23.8
	20.5	17.2	19.1	24.9	25.4	27.4	28	27.6	23.8		23.8
	20.5	17.2	19	24.9	24.5	27.4	28	27.6	23.8		23.8
	20.5	17.2	19	24.9	26	27.4	28	27.6	23.8		23.8
	20.5	17.2	19	24.9	26	27.4	28	27.8	23.8		23.8
	20.5	17.2	19	24.9	25.9	27.4	28	27.8	23.8		23.8
	20.5	17.2	19	24.9	25.9	27.4	28	27.8	23.8		23.8
	20.5	17.2	19	24.9	25.9	27.4	28	27.8	23.9		23.9
	20.5	17.2	19	24.9	25.9	27.4	28	27.8	23.9		23.9

Continued…..

May-11	Jun-11	Jul-11	Aug-11	Sep-11	Oct-11	Nov-11	Dec-12	Jan-12	Feb-12	Mar-12	Apr-12
	20.5	17.2	19	24.8	25.9	27.4	28	27.8	23.9		23.9
	20.5	17.2	19	24.8	25.9	27.4	28	27.8	23.9		23.9
	20.5	17.2	19	24.8	25.9	27.4	28	27.8	23.9		23.9
	20.5	17.1	19	24.8	25.9	27.4	28	27.8	24		24
	20.5	17.1	19	24.8	25.9	27.4	28	27.8	24		24
	20.5	17.1	19	24.8	25.9	27.4	28	27.8	24		24
	20.5	17.1	19	24.8	25.9	27.4	28	27.8	24		24
	20.5	17.1	19	24.8	25.9	27.4	28	27.8	24		24
	20.5	17.1	19	24.8	25.9	27.4	28	27.8	24		24
	20.5	17.1	19	24.8	25.9	27.4	28	28	24		24
	20.5	17.1	19	24.8	25.9	27.4	28	28	24		24
	20.5	17.1	18.8	24.8	25.9	27.4	28	28	24		24
	20.5	17.4	18.8	24.8	25.9	27.4	28	28	23.7		23.7
	20.5	17.4	18.8	24.8	25.9	27.4	28	28	23.8		23.8
	20.5	17.4	18.8	24.8	25.9	27.4	28	28	23.8		23.8
	20.5	17.4	18.8	24.8	25.9	27.4	28	28	23.8		23.8
	20.5	17.4	18.8	24.8	25.9	27.2	28	26.6	23.8		23.8
	20.5	17.4	18.8	24.8	25.9	27.2	28	26.6	23.8		23.8
	20.5	17.1	18.8	24.8	25.9	27.2	28	26.6	23.8		23.8
	20.5	17.1	18.8	24.8	25.9	27.2	28	26.6	23.8		23.8
	20.5	17.1	18.8	24.8	25.9	27.2	28	26.6	23.8		23.8
	20.5	17.1	18.8	24.8	25.9	27.2	28	26.6	23.8		23.8
	20.5	17.1	18.8	24.8	25.9	27.2	28	26.7	23.8		23.8
	20.5	17	18.8	24.8	25.9	27.2	28	26.7	23.8		23.8
	20.5	17	18.8	24.8	25.9	27.2	28	26.7	23.8		23.8
	20.5	17	19.1	24.8	25.9	27.2	28	26.7	23.8		23.8
	20.5	17	19.1	24.8	25.9	27.7	28	26.7	23.6		23.6
	20.5	17	19.1	24.8	25.9	27.5	28	26.7	23.8		23.8
	20.5	17	19.1	24.8	25.9	27.7	28	26.7	23.8		23.8
	20.5	17	19.1	24.8	25.9	27.4	28	26.7	23.8		23.8

Continued.....

May-11	Jun-11	Jul-11	Aug-11	Sep-11	Oct-11	Nov-11	Dec-12	Jan-12	Feb-12	Mar-12	Apr-12
	20.5	17	19.1	24.8	25.9	27.4	28	26.7	23		23
	20.5	17	19.1	24.8	25.9	27.3	28	26.7	23		23
	20.5	17	19.1	24.8	25.9	27.3	28	26.7	23		23
	20.5	17	19.1	24.8	25.9	27.3	28	26.7	23		23
	20.5	17	19.1	25	25.9	27.2	28	26.7	23		23
	20.5	17	19.1	25	25.9	28	28	26.7	23.1		23.1
	19.4	17	19.1	25	25.9	28	28	26.7	23.1		23.1
	19.4	17	19.1	25	25.9	28	28	26.7	23.1		23.1
	19.4	17	19.1	25	25.7	28	28	26.7	23.1		23.1
	19.4	17	19.1	25	25.7	28	28	26.7	23.1		23.1
	19.4	17	19.1	25	25.7	28	28	26.7	23.1		23.1
	19.4	17	19.1	25	25.7	28	28	26.7	23.1		23.1
	19.4	17	19.1	25	25.7	28	28	26.7	23.1		23.1
	19.4	17	19.1	25	25.9	28	28	26.7	23.1		23.1
	19.4	17	19.1	25	25.9	28	28	26.7	23.1		23.1
	19.4	17	19.1	25	25.9	28	28	26.7	23.1		23.1
	19.4	17	19.1	25.1	25.9	28	28	26.7	23.1		23.1
	19.4	17	19.1	25.1	25.9	28	28	26.7	23.1		23.1
	19.4	17	19.1	25.1	26	28	28	26.7	23.1		23.1
	19.4	17	19.1	25.1	26	28.2	28	26.7	23.1		23.1
	19.4	17	19.1	25.1	26	28.2	28	26.7	23.1		23.1
	19.4	17	19.1	24.8	26	28.2	28	26.7	23.3		23.3
	19.4	17	19.1	24.8	25.9	27.2	28	26.7	23.3		23.3
	19.4	17	19.1	24.8	25.9	27	28	26.7	23.3		23.3
	19.4	17	19.1	24.8	25.9	27.2	28	26.7	23.3		23.3
	19.4	17	19.1	24.8	25.9	27.8	28	26.7	23.3		23.3
	19.4	17	19.1	23.5	25.9	27.8	28	26.7	23.3		23.3
	19.4	17	19.1	23.5	25.9	27.8	28	26.7	23.3		23.3
	19.4	17	19.4	23.5	25.9	27.6	28	26.7	23.4		23.4
	19.4	17	19.4	23.5	25.9	28.6	28	26.7	23.4		23.4

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May-11	Jun-11	Jul-11	Aug-11	Sep-11	Oct-11	Nov-11	Dec-12	Jan-12	Feb-12	Mar-12	Apr-12
	19.4	17	19.4	23.5	25.9	28.6	28	26.7	23.2		23.2
	19.4	17	19.4	23.5	25.7	28.7	28	26.7	23.3		23.3
	19.4	17	19.4	23.5		28.7	28	26.7	23.3		23.3
	19.4	17	19.4	23.5		28.7	28	26.7	22.9		22.9
	19.4	17	19.4	23.5		28.7	28	26.7	23.1		23.1
	19.2	16.8	19.4	23.5		28.7	28	26.7	23.3		23.3
	19.2	16.8	19.3	23.5		28.7	28	26.7	23.4		23.4
	19.2	16.8	19.1	23.5		28.7	28	26.7	23.4		23.4
	19.2	16.8	19.2	23.5		28.7	28	26.7	23.1		23.1
	19.2	16.8	19.4	23.5		28.7	28	26.7	23.1		23.1
	19.2	16.8	19.4	23.5		28.7	28	26.7	23.1		23.1
	19.2	16.8	19.4	23.5		28.7	28	26.7	23.1		23.1
	19.2	16.8	19	23.5		28.8	28	26.7	23.1		23.1
	19.2	16.8	19.1	23.5		28.8	28	26.7	23		23
	19.2	16.8	20	23.5		28.8	28	26.7	23		23
	19.2	16.8	20	23.5		28.8	28	26.7	23		23
	19.2	16.8	20	23.5		28.7	28	26.7	23		23
	19.2	16.8	20	23.5		28.6	28	26.7	23.4		23.4
	19.2	16.8	20	23.5		28.7	28	26.7	23.5		23.5
	19.2	16.8	19.8	23.5		27.1	28	26.7	23.5		23.5
	19.2	16.8	19.8	23.5		27.1	28	26.7	23.5		23.5
	19.2	16.8	19.8	23.5		27.1	28	26.7	23.5		23.5
	19.2	16.8	19.8	23.5		27.1	28	26.7	23.4		23.4
	19.2	16.8	19.8	23.5		27.1	28	26.7	23.4		23.4
	19.2	16.6	19.8	23.5		27.1	28	26.7	23.4		
	19.2	16.6	19.8	23.5		27.1	28	26.7	23.4		
	19.2	16.6	19.8	23.5		27.1	28	26.7	23.4		
	19.2	16.6	19.8	23.5		27.1	28	26.7	23.4		
	19.2	16.6	19.8	23.5		27.1	28	26.7	23.4		
	19.2	17	19.8	23.5		27	28	26.7	23.4		

Continued…..

May-11	Jun-11	Jul-11	Aug-11	Sep-11	Oct-11	Nov-11	Dec-12	Jan-12	Feb-12	Mar-12	Apr-12
	19.2	17	19.8	23.5		27.4	28	26.7	23.4		
	19.2	17	19.8	23.5		27.5	28	26.7	23.4		
	19.2	17	19.8	23.5		27.5	28	26.7	23.4		
	19.2	17	19.8	23.5		27.5	28	26.7	23.4		
	19.2	17	19.8	23.5		27.1	28	26.7	23.4		
		17	19.8	23.5		27.2	28	26.7	23.4		
		17	19.8	23.5		27.2	28	26.7	23.4		
		17	19.8	23.5		27.2	28	26.7	23.4		
		17	19.8	23.5		27.2	28	26.7	27.6		
		17	19.8	23.5		27.2	28	26.7	27.6		
		16.8	19.8	23.5		27.2	28	26.7	27.6		
		17	19.8	23.5		27.2	28	26.7	27.6		
		17	19.8	23.5		27.2	28	26.7	27.6		
		17	19.8	23.5		26.6	28	26.7	27.6		
		17	19.8	23.5		26.6	28	26.7	27.6		
		17	19.8	23.4		26.4	28	26.7	27.6		
		16.9	19.8	23.4		26.4	28	26.7	27.6		
		16.9	19.8	23.4		26.4	28	26.7	27.6		
		16.9	19.8	23.4		26.4	28	26.7	27.6		
		16.9	19.8	23.4		26.4	28	26.7	27.6		
		16.9	19.8	23.4		26.4	28	26.7	27.6		
		16.9	19.8	23.4		26.4	28	26.7	27.6		
		16.9	19.8	23.4		26.4	28	26.7	27.6		
		16.9	19.8	23.4		26.4	28	26.7	27.6		
		16.9	19.8	23.4		26.4	28	26.7	27.6		
		16.9	19.8	23.4		26.4	28	26.7	27.6		
		16.9	19.8	23.4		26.9	28	26.7	27.4		
		16.9	19.8	23.4		26.9	28	26.7	27.4		
		16.9	19.8	23.4		26.9	28	26.7	27.4		
		16.9	19.8	23.4		26.9	28	26.7	27.4		

Continued…..

May-11	Jun-11	Jul-11	Aug-11	Sep-11	Oct-11	Nov-11	Dec-12	Jan-12	Feb-12	Mar-12	Apr-12
		16.9	19.8	23.4		26.9	28	26.7	27.4		
		16.9	19.8	23.4		26.9	28	26.7	27.4		
		16.9	19.8	23.4		26.9	28	26.7	27.4		
		16.9	19.8	23.4		26.8	28	26.7	27.4		
		16.9	19.5	23.4		26.8	28	26.7	27.4		
		16.9	19.5	23.4		26.8	28	26.7	27.4		
		16.9	19.5	23.4		26.5	28	26.7	27.4		
		16.9	19.5	23.4		26.4	28	26.7	27.4		
		16.5	19.5	23.4		26.6	28	26.7	27.4		
		16.5	19.5	23.4		26.7	28	26.7	27.4		
		16.5	19.5	23.4		26.7	28	26.7	27.4		
		16.5	19.5	23.4		26.7	28	26.7	27.4		
		16.7	19.5	23.4		26.7	28	26.7	27.4		
		16.7	19.5	23.4		26.7	28	26.7	27.3		
		16.7	19.5	23.4		26.7	28	26.7	27.3		
		16.5	19.5	23.4		26.7	28	26.7	27.3		
		16.5	19.5	23.4		26.7	28	26.7	27.3		
		16.5	19.5	23.4		26.7	28	26.7	27.3		
		16.5	19.5	23.4		26.7	28	26.7	27.3		
		16.5	19.5	23.4		26.7	28	26.7	27.3		
		16.5	19.1	23.4		26.7	28	26.7	27.3		
		16.5	19.1	23.4		26.7	28	26.7	27.3		
		16.5	19.1	23.4		26.7	28	26.7	27.3		
		16.6	19.1	23.4		26.7	28	26.7	27.3		
		16.6	19.1	23.4		26.7	28	26.7	27.3		
		16.6	19.6	23.4		26.6	28	26.7	27.3		
		16.7	19.6	23.4		26.6	28	26.7	27.3		
		16.6	19.6	23.4		26.6	28	26.7	27.3		
		17.5	19.4	23.4		26.6	28	26.7	27.3		
		17.5	19.4	23.4		26.6	28	26.7	27.3		

Continued…..

May-11	Jun-11	Jul-11	Aug-11	Sep-11	Oct-11	Nov-11	Dec-12	Jan-12	Feb-12	Mar-12	Apr-12
		17.3	19.4	23.4		26.7	28	26.7	27.3		
		17.4	19.4	23.4		26.6	28	26.7	27.3		
		16.5	19.4	23.4			28	26.7	27.3		
		16.5	19.4	23.4			28	26.7	27.3		
		16.5	19.4	23.4			28	26.7	27.3		
		16.5	19.4	23.4			28	26.7	27.3		
		15.4	19.4	23.4			28	26.7	27.3		
		15.4	19.4	23.4			28	26.7	27.3		
		15.4	19.4	23.4			28	26.7	27.3		
		15.4	19.4	23.4			28	26.7	27.3		
		15.4	19.4	23.4			28	26.7	27.3		
		15.4	19.4	23.6			28	26.7	27.3		
		17.6	19.4	23.6			28	26.7	27.3		
		17.6	19.4	23.6			28	26.7	27.3		
		16.5	19.4	23.6			28	26.7	27.3		
		16.5	19.4	23.6			28	26.7	27.3		
		16.5	19.4	23.6			28	26.7	27.3		
		16.5	19.4	23.6			28	26.7	27.3		
		16.5	19.4	23.6			28	26.7	27.3		
		16.5	19.4	23.6			28	26.7	27.3		
		16.5	19.4	23.6			28	26.7	27.3		
		16.1	19.4	23.6			28	26.7	27.3		
		16.1	19.4	23.5			28	26.7	27.3		
		16.1	19.4	23.5			28	26.7	27.3		
		16.1	19.4	23.5			28	26.7	27.7		
		16.1	19.4	23.5			28	26.7	27.7		
		16.1	19.4	23			28	26.7	27.7		
		16.5	19.4	23			28	26.7	27.7		
		16.6	19.4	23			28	26.7	27.7		
		16.6	19.4	23			28	26.7	27.7		

Continued…..

May-11	Jun-11	Jul-11	Aug-11	Sep-11	Oct-11	Nov-11	Dec-12	Jan-12	Feb-12	Mar-12	Apr-12
		16.6	19.4	23			28	26.7	27.7		
		16.6	19.4	23			28	26.7	27.7		
		16.6	19.4	23			28	26.7	27.7		
		16.6	19.4	23			28	26.7	27.7		
		16.6	19.4	23			28	26.7	27.7		
		16.6	19.4	23			28	26.7	27.7		
		16.6	19.4	23			28	26.7	27.7		
		16.6	19.4	23			28	26.7	28.1		
		16.6	19.4	23			28	26.7	28.1		
		16.6	19.4	23			28	26.7	28.1		
		17	19.4	23			28	26.7	28.1		
		17	19.4	23			28	26.7	28.1		
		17	19.4	23			28	26.7	28.1		
		17	19.4	23			28	26.7			
		17	19.4	23			28	26.7			
		17.1	19.4	23			28	26.7			
		17.1	19.4	23			28	26.7			
		17.1	19.4	23			28	26.7			
		17.1	19.4	23.1			28	26.7			
		17.1	19.4	23.1			28	26.7			
		17.1	19.4	23.1			28	26.7			
		17.1	19.4	23.1			28	26.7			
		17.1	19.4	23.1			28	26.7			
		17.1	19.4	23.1			28	26.7			
		17.1	19.4	23.1			28	26.7			
		17.1	19.4	23.1			28	26.7			
		17.1	19.4	23.1			28	26.7			
		17.1	19.4	23.4			28	26.7			
		17.1	19.4	23.4			28	27			
		17.1	19.4	23.4			28	27			

Continued…..

May-11	Jun-11	Jul-11	Aug-11	Sep-11	Oct-11	Nov-11	Dec-12	Jan-12	Feb-12	Mar-12	Apr-12
		16.8	19.4	23.4			28	27			
		16.8	19.4	23.4			28	27			
			19.4	23.4			28	27			
			19.4	23.4			28	26.9			
			19.4	23.4			28	26.8			
			19.4	23.4			28	26.8			
			19.4	23.4			28	26.7			
			19.4	23.4			28	26.7			
			19.4	23.4			28	26.7			
			19.4	23.4			28	26.7			
			19.4	23.4			28	26.7			
			19.4	23.4			28	26.7			
			19.4	23.4			28	26.7			
			19.4	23.4			28	26.7			
			19.4	23.4			28	26.7			
			19.4	23.4			28	26.7			
			19.4	23.4			26	26.7			
			19.4	23.4			26	26.7			
			19.4	23.4			26	26.7			
			19.4	23.4			26.1	26.7			
			19.4	23.4			26.1	26.7			
			19.4	23.4			26.1	26.7			
			19.4	23.4			26.1	26.7			
			19.3	23.4			26.1	26.7			
			19.1	23.4			26.1	26.7			
			19.1	23.4			26.1	26.7			
			19.1	23.4			26.1	26.7			
			19.1	23.2			26.1	26.7			
			19.1	23.2			26.1	26.7			
			19.1	23.2			26.1	26.7			

Continued…..

					24.6							
					24.4							
					24.4							
					24.4							
					24.4							
					24.4							
					24.4							
					24.6							
					24.6							
					24.6							
					24.6							
					24.6							
					24.6							
					24.5							
Average	**22**	**19.2**	**15.4**	**17.7**	**23**	**24.4**	**26.4**	**26**	**24.3**	**22.9**	**26.3**	**22.9**
STDEV	**0.42**	**0.44**	**0.05**	**0.38**	**0.16**	**0.51**	**0.48**	**0.65**	**1.01**	**0.24**	**5.37**	**0.24**

Appendix 3: Secchi depth readings data from Lake Liambezi between May 2011 and April 2012

May-11	Jun-11	Jul-11	Aug-11	Sep-11	Oct-11	Nov-11	Dec-12	Jan-12	Feb-12	Mar-12	Apr-12
1	1.3	1.15	0.9	1.8	0.94	0.8	0.8	1.6	0.6	0.8	0.6
1	1.3	1.15	0.9	1.8	0.94	0.7	0.8	1.6	0.6	0.8	0.6
1	1.3	1.15	0.9	1.8	0.94	0.8	0.8	1.6	0.6	0.8	0.6
1	1.3	1.15	0.9	1.8	0.94	0.75	0.8	1.6	0.6	0.8	0.6
1	1.3	1.15	0.9	1.8	0.94	0.75	0.8	1.6	0.6	0.8	0.6
1	1.3	1.15	0.9	1.8	0.94	0.75	0.8	1.6	0.6	0.8	0.6
1	1.3	1.15	0.9	1.8	0.94	0.75	0.8	1.6	0.6	0.8	0.6
1	1.3	1.15	0.9	1.8	0.94	0.75	0.8	1.6	0.6	0.8	0.6
1	1.3	1.15	1.1	1.8	0.94	0.75	0.8	1.6	0.6	0.8	0.6
1	1.3	1.15	1.1	1.8	0.94	0.75	0.8	1.6	0.6	6.5	0.6
1	1.3	1.15	1.1	1.8	0.94	0.75	0.8	1.6	0.6	6.5	0.6
1.2	1.3	1.15	1.1	1.8	0.94	0.75	0.8	1.6	0.6	6.5	0.6
1.2	1.3	1.15	1.1	1.8	0.94	0.75	0.8	1.6	0.7	6.5	0.7
1.2	1.3	1.15	1.1	1.8	0.91	0.75	0.8	1.6	0.7	0.7	0.7
1.2	1.3	1.15	1.1	1.8	0.91	0.75	0.8	1.6	0.7	0.7	0.7
1.2	1.3	1.15	1.1	1.65	0.91	0.75	0.8	1.6	0.7	0.7	0.7
1.2	1.3	1.15	1.1	1.65	0.91	0.75	0.8	1.6	0.7	0.7	0.7
1.2	1.3	1.15	1.1	1.65	0.91	0.75	0.8	1.6	0.7	0.7	0.7
1.2	1.3	1.15	1.1	1.65	0.98	0.6	0.8	1.6	0.7	0	0.7
1.2	1.3	1.15	1.1	1.65	0.98	0.6	0.8	1.6	0.7	0.8	0.7
1.2	1.3	1.15	1.05	1.65	0.92	0.6	0.8	1.6	0.7	0.8	0.7
1.2	1.3	1.15	1.05	1.65	0.94	0.6	0.8	1.6	0.8	0.6	0.8
1.2	1.3	1.15	1.05	1.65	0.94	0.6	0.8	1.6	0.8	0.6	0.8
1.2	1.3	1.15	1.05	1.65	0.98	0.6	0.8	1.6	0.8	0.6	0.8
1.2	1.3	1.15	1.05	1.65	0.98	0.6	0.8	1.6	0.8	0.6	0.8
1.2	1.3	1.15	1.05	1.65	0.98	0.6	0.8	1.6	0.8	0.6	0.8
1.2	1.3	1.15	1.5	1.65	0.98	0.6	0.8	1.6	0.8	0.6	0.8
1.2	1.3	1.15	1.5	1.65	0.98	0.8	0.8	1.6	0.8	0.6	0.8
1.2	1.3	1.15	1.5	1.65	0.98	0.8	0.8	1.6	0.7	0.6	0.7
1.2	1.3	1.15	1.5	1.65	0.98	0.8	0.5	1.6	0.7	0.6	0.7

Continued…

May-11	Jun-11	Jul-11	Aug-11	Sep-11	Oct-11	Nov-11	Dec-12	Jan-12	Feb-12	Mar-12	Apr-12
1.2	1.3	1.15	1.15	1.65	0.98	0.8	0.8	1.6	0.7	0.6	0.7
1.2	1.3	1.15	1.15	1.65	0.94	0.8	0.8	1.6	0.7	0.6	0.7
1.2	1.3	1.15	1.15	1.65	0.94	0.8	1.2	1.6	0.8	0.6	0.8
1.2	1.3	1.15	1.15	1.65	0.94	0.8	1.2	1.6	0.8	0.6	0.8
1.2	1.3	1.08	1.15	1.65	0.94	0.75	1.2	1.6	0.8	0.6	0.8
1.2	1.3	1.08	1.15	1.65	0.75	0.75	1.2	1.6	0.8	0.6	0.8
1.2	1.3	1.08	1.15	1.65	0.75	0.75	1.2	1.6	0.8	0.6	0.8
1.2	1.3	1.08	1.15	1.65	0.75	0.75	1.2	1.5	0.8	0.6	0.8
1.2	1.3	1.08	1.15	1.65	0.75	0.7	1.2	1.5	0.8	0.6	0.8
1.2	1.3	1.08	1.15	1.65	0.75	0.7	1.2	1.5	0.4	0.6	0.4
1.2	1.3	1.08	1.15	1.65	0.75	0.7	1.2	1.5	0.4	0.6	0.4
1.2	1.3	1.08	1.15	1.65	0.75	0.7	1.2	1.5	0.4	0.6	0.4
1.2	1.3	1.08	1.15	1.65	0.75	0.7	1.2	1.5	0.4	0.6	0.4
1.2	1.3	1.08	1.15	1.65	0.75	0.7	1.2	1.5	0.4	0.6	0.4
1.2	1.3	1.08	1.15	1.65	0.75	0.7	1.2	1.5	0.4	0.6	0.4
1.2	1.3	1.08	1.15	1.65	0.75	0.7	1.2	1.5	0.4	0.6	0.4
1.2	1.3	1.08	1.15	1.65	0.75	0.7	1.2	1.5	0.4	0.6	0.4
1.2	1.3	1.08	1.15	1.65	0.75	0.7	1	1.5	0.4	0.6	0.4
1.2	1.3	1.08	1.15	1.65	0.75	0.7	1	1.5	0.5	0.6	0.5
1.2	1.3	1.08	1.15	1.65	0.75	0.7	1.2	1.5	0.5	0.6	0.5
1.2	1.3	1.08	1.15	1.65	0.75	0.7	1.2	1.5	0.5	0.6	0.5
1.2	1.3	1.08	1.15	1.65	0.75	0.7	1.2	1.5	0.5	0.6	0.5
1.2	1.3	1.08	1.15	1.65	0.75	0.7	1	1.5	0.5	0.6	0.5
1.2	1.3	1.08	1.1	1.65	0.75	0.7	1	1.5	0.5	0.6	0.5
1.2	1.3	1.08	1.1	1.65	0.75	0.63	1	1.5	0.4	0.6	0.4
1.2	1.1	1.08	1.1	1.65	0.75	0.63	1	1.5	0.4	0.6	0.4
1.2	1.1	1.08	1.1	1.65	0.75	0.63	1	1.5	0.4	0.6	0.4
1.2	1.1	1.08	1.1	1.65	0.75	0.63	1	1.5	0.4	0.6	0.4
1.2	1.1	1.08	1.1	1.65	0.75	0.65	1	1.4	0.4	0.6	0.4
1.2	1.1	1.08	1.1	1.65	0.75	0.67	1	1.4	0.4	0.6	0.4

Continued…

May-11	Jun-11	Jul-11	Aug-11	Sep-11	Oct-11	Nov-11	Dec-12	Jan-12	Feb-12	Mar-12	Apr-12
1.2	1.1	1.08	1.15	1.65	0.75	0.89	1	1.4	0.4	0.6	0.4
1.2	1.1	1.08	1.15	1.65	0.75	0.6	0.7	1.4	0.4	0.6	0.4
1.2	1.1	1.08	1.15	1.65	0.75	0.63	0.9	1.4	0.8	0.6	0.8
1.2	1.1	1.08	1.15	1.65	0.75	0.63	0.9	1.6	0.8	0.6	0.8
1.2	1.1	1.08	1.15	2.15	0.75	0.63	0.9	1.6	0.9	0.6	0.9
1.2	1.1	1.08	1.15	2.15	0.97	0.63	0.9	1.6	0.9	0.6	0.9
1.2	1.1	1.08	1.5	2.15	1.05	0.63	0.9	1.6	0.9	0.6	0.9
1.2	1.1	1.08	1.5	2.15	1.05	0.63	0.9	1.6	0.9	0.6	0.9
	1.1	1.08	1.5	1.6	1.05	0.63	0.9	1.6	0.9	0.6	0.9
	1.1	1.08	1.5	1.6	1.05	0.63	0.9	1.6	0.9	0.6	0.9
	1.1	1.08	1.5	1.6	1.05	0.63	0.9	1.6	0.9	0.6	0.9
	1.1	1.32	1	1.6	1.05	0.63	0.9	1.6	0.9	0.6	0.9
	1.1	1.32	1	1.6	1.05	0.65	0.9	1.6	0.9	0.6	0.9
	1.1	1.32	1	1.6	1.05	0.65	0.9	1.6	0.9	0.6	0.9
	1.1	1.29	1	1.6	1.05	0.65	0.9	1.6	0.9	0.6	0.9
	1.1	1.48	1	1.6	1.05	0.65	0.9	1.6	0.9	0.6	0.9
	1.1	1.48	1	1.6	0.95	0.65	0.9	1.6	0.9	0.6	0.9
	1.1	1.48	1	1.6	0.95	0.65	0.9	1.6	0.9	0.6	0.9
	1.1	1.48	1	1.6	0.95	0.65	0.9	1.6	0.9	0.6	0.9
	1.1	1.48	1	2.1	0.95	0.65	0.9	1.6	0.9	0.6	0.9
	1.1	1.48	1	2.03	0.95	0.65	0.9	1.5	0.9	0.6	0.9
	1.1	1.48	1	2	0.95	0.65	0.9	1.5	0.9	0.6	0.9
	1.1	1.48	1	1.6	0.95	0.65	0.9	1.5	0.9	0.6	0.9
	1.1	1.48	1	1.55	0.95	0.65	0.9	1.2	1	0.6	1
	1.1	1.48	1.2	1.55	0.81	0.65	0.9	1.2	1	0.6	1
	1.1	1.48	1.2	2.05	0.81	0.65	0.9	1.2	1	0.6	1
	1.1	1.48	1.2	2.05	0.81	0.65	0.9	1.2	1	0.6	1
	1.1	1.48	1.2	2.05	0.7	0.65	0.9	1.2	1	0.6	1
	1.1	1.17	1.2	1.9	0.7	0.65	0.9	1.2	1	0.6	1
	1.1	1.17	1.2	1.9	0.7	0.65	0.9	1.2	1	0.6	1

Continued…

May-11	Jun-11	Jul-11	Aug-11	Sep-11	Oct-11	Nov-11	Dec-12	Jan-12	Feb-12	Mar-12	Apr-12
	1.1	1.17	1.2	1.9	0.7	0.52	0.9	1.2	1	0.6	1
	1.1	1.17	1.2	1.9	0.75	0.52	0.9	2.5	1	0.6	1
	1.1	1.17	1.2	1.9	0.75	0.52	0.9	2.5	1	0.6	1
	1.1	1.17	1.2	1.9	0.75	0.52	0.9	1.3	1	0.6	1
	1.1	1.17	1.2	1.9	0.75	0.52	0.9	1.3	1	0.6	1
	1.1	1.17	1.2	1.9	0.75	0.52	0.9	1.3	1	0.6	1
	1.1	1.17	1.2	1.9	0.75	0.52	0.9	1.3	1	0.6	1
	1.1	1.17	1	1.9	0.75	0.52	0.9	1.3	1	0.6	1
	1.1	1.17	1	1.9	0.75	0.53	0.9	1.3	1	0.6	1
	1.1	1.17	1	1.9	0.75	0.53	0.9	1.3	1	0.6	1
	1.1	1.17	1.3	1.9	0.75	0.53	0.9	1.3	1	0.6	1
	1.1	1.17	1.3	1.9	0.75	0.6	0.9	1.3	1	0.6	1
	1.1	1.17	1.3	1.9	0.75	0.55	0.9	1.3	1	0.6	1
	1.1	1.17	1.3	1.9	0.75	0.55	0.9	1.3	1	0.6	1
	1.1	1.17	1.3	1.9	0.75	0.55	0.9	1.3	1	0.6	1
	1.1	1.17	1.3	1.9	0.75	1.43	0.9	1.3	1	0.6	1
	1	1.17	1.3	1.9	0.75	1.43	0.9	1.3	1	0.6	1
	1	1.17	0.85	1.9	0.75	1.43	0.9	1.3	1	0.6	1
	1	1.17	0.85	1.9	0.75	1.43	0.9	1.3	1	0.6	1
	1	1.17	0.85	1.9	0.75	1.43	0.9	1.3	1	0.6	1
	1	1.17	0.85	1.9	0.75	1.43	0.9	1.3	1	0.6	1
	1	1.17	0.9	1.9	0.75	1.43	0.9	1.3	1	0.6	1
	1	1.17	0.9	1.9	0.75	1.43	0.9	1.3	1	0.6	1
	1	1.17	1.05	1.9	0.53	1.43	0.9	1.2	1	0.6	1
	1	1.17	1.05	1.9	1.05	1.43	0.9	1.2	1	0.6	1
	1	1.17	1.05	1.9	0.97	1.43	0.9	1.2	1	0.6	1
	1	1.17	1.05	1.9	0.95	1.43	0.9	1.2	1	0.6	1
	1	1.17	1.05	1.9	0.95	1.43	0.9	1.2	1	0.6	1
	1	1.17	1.05	1.9	0.95	1.43	0.9	1.2	1	0.6	1
	1	1.17	1.05	1.9	0.95	1.43	0.9	1.2	1	0.6	1

Continued…

May-11	Jun-11	Jul-11	Aug-11	Sep-11	Oct-11	Nov-11	Dec-12	Jan-12	Feb-12	Mar-12	Apr-12
	1	1.17	1.05	1.55	1.54	1.43	0.9	1.2	1	0.6	1
	1	1.17	1.05	1.55	1.54	1.43	0.9	1.2	1	0.6	1
	1	1.17	1.05	1.55	1.54	1.43	0.9	1.2	1	0.6	1
	1	1.32	1.05	1.55	1.54	1.43	0.9	1.2	1	0.6	1
	1	1.32	1.05	1.55	1.54	1.43	0.9	1.2	1	0.6	1
	1	1.32	1.05	1.55	1.54	1.43	0.9	1.2	1	0.6	1
	1	1.32	1.05	1.55	1.54	1.43	0.9	1.2	1	0.6	1
	1	1.32	1.05	1.55	1.54	1.43	0.9	1.2	1	0.6	1
	1	1.32	1.05	1.55	1.54	1.43	0.9	1.2	1	0.6	1
	1	1.32	1.05	1.55	1.54	1.43	0.9	1.2	1	0.6	1
	1	1.32	1.05	1.55	1.54	1.43	0.9	1.2	1	0.6	1
	1	1.32	1.08	1.55	1.54	1.43	0.9	1.2	1	0.6	1
	1	1.17	1.08	1.55	1.54	1.43	0.9	1.2	0.8	0.6	0.8
	1	1.17	1.08	1.55	1.54	1.43	0.9	1.2	0.8	0.6	0.8
	1	1.17	1.08	1.55	1.54	1.43	0.9	1.2	0.8	0.6	0.8
	1	1.17	1.08	1.55	1.54	1.43	0.9	1.2	0.8	0.6	0.8
	1	1.17	1.08	1.55	1.54	1.34	0.9	1.2	0.8	0.6	0.8
	1	1.17	1.08	1.51	1.54	1.34	0.9	1.2	0.8	0.6	0.8
	1	1.48	1.08	1.51	1.54	1.34	0.9	1.2	0.8	0.6	0.8
	1	1.48	1.08	1.51	1.54	1.34	0.9	1.2	0.8	0.6	0.8
	1	1.48	1.08	1.51	1.54	1.34	0.9	1.2	0.8	0.6	0.8
	1	1.48	1.08	1.51	1.54	1.34	0.9	1.2	0.8	0.6	0.8
	1	1.48	1.08	1.51	1.54	1.34	0.9	1.2	0.8	0.6	0.8
	1	1.11	1.08	1.51	1.54	1.34	0.9	1.2	0.8	0.6	0.8
	1	1.11	1.08	1.51	1.54	1.34	0.9	1.2	0.8	0.6	0.8
	1	1.11	1	1.51	1.54	1.34	0.9	1.2	0.8	0.6	0.8
	1	1.11	0.95	1.51	1.54	1.5	0.9	1.2	0.7	0.6	0.7
	1	1.11	0.95	1.51	1.54	1.4	0.9	1.2	0.8	0.6	0.8
	1	1.11	0.95	1.51	1.54	1.5	0.9	1.2	0.8	0.6	0.8
	1	1.11	0.95	1.51	1.54	1.45	0.9	1.2	0.8	0.6	0.8

Continued…

May-11	Jun-11	Jul-11	Aug-11	Sep-11	Oct-11	Nov-11	Dec-12	Jan-12	Feb-12	Mar-12	Apr-12
	1	1.11	0.95	1.51	1.54	1.45	0.9	1.2	1	0.6	1
	1	1.11	0.95	1.51	1.54	1.45	0.9	1.2	1	0.6	1
	1	1.11	0.95	1.51	1.54	1.45	0.9	1.2	1	0.6	1
	1	1.11	0.95	1.51	1.54	1.45	0.9	1.2	1	0.6	1
	1	1.11	0.95	1.8	1.54	1.3	0.9	1.2	1	0.6	1
	1	1.11	0.95	1.8	1.54	1.4	0.9	1.2	1.4	0.6	1.4
	1.5	1.11	0.95	1.8	1.54	1.4	0.9	1.2	1.4	0.6	1.4
	1.5	1.11	0.95	1.8	1.54	1.4	0.9	1.2	1.4	0.6	1.4
	1.5	1.11	0.95	1.8	1.3	1.4	0.9	1.2	1.4	0.6	1.4
	1.5	1.11	0.95	1.8	1.3	1.4	0.9	1.2	1.4	0.6	1.4
	1.5	1.11	0.95	1.8	1.3	1.4	0.9	1.2	1.4	0.6	1.4
	1.5	1.11	0.95	1.8	1.3	1.4	0.9	1.2	1.4	0.6	1.4
	1.5	1.11	0.95	1.8	1.3	1.4	0.9	1.2	1.4	0.6	1.4
	1.5	1.11	0.95	1.8	1.48	1.4	0.9	1.2	1.4	0.6	1.4
	1.5	1.11	0.95	1.8	1.48	1.4	0.9	1.2	1.4	0.6	1.4
	1.5	1.11	0.95	1.8	1.48	1.4	0.9	1.2	1.4	0.6	1.4
	1.5	1.11	0.95	1.2	1.48	1.4	0.9	1.2	1.4	0.6	1.4
	1.5	1.11	0.95	1.2	1.48	1.4	0.9	1.2	1.4	0.6	1.4
	1.5	1.11	0.95	1.2	1.48	1.4	0.9	1.2	1.4	0.6	1.4
	1.5	1.11	0.95	1.2	1.48	1.49	0.9	1.2	1.4	0.6	1.4
	1.5	1.11	0.95	1.2	1.48	1.49	0.9	1.1	1.4	0.6	1.4
	1.5	1.11	0.95	1.9	1.48	1.49	0.9	1.1	1.4	0.6	1.4
	1.5	1.11	0.95	1.5	1.6	1.98	0.9	1.1	1.4	0.6	1.4
	1.5	1.11	0.95	1.7	1.6	1.8	0.9	1.2	1.4	0.6	1.4
	1.5	1.11	0.95	1.7	1.6	1.98	0.9	0.8	1.4	0.6	1.4
	1.5	1.11	0.95	1.7	1.6	1.35	0.9	0.9	1.4	0.6	1.4
	1.5	1.11	0.95	1.01	1.6	1.35	0.9	1	1.4	0.6	1.4
	1.5	1.11	0.95	1.01	1.6	1.63	0.9	1.2	1.4	0.6	1.4
	1.5	1.11	3.4	1.01	1.6	1.5	0.9	1.2	1	0.6	1
	1.5	1.11	3.4	1.01	1.6	1.6	0.9	1.2	1		1

Continued…

May-11	Jun-11	Jul-11	Aug-11	Sep-11	Oct-11	Nov-11	Dec-12	Jan-12	Feb-12	Mar-12	Apr-12
	1.5	1.11	3.4	1.01	1.53	1.6	0.9	1.2	1.2		1.2
	1.5	1.11	3.4	1.01	1.58	1.9	0.9	1.2	1.4		1.4
	1.5	1.11	3.4	1.01		1.8	0.9	1.2	1.4		1.4
	1.5	1.11	3.4	1.01		1.8	0.9	1.2	0.4		0.4
	1.5	1.11	3.4	1.01		1.8	0.9	1.2	0.4		0.4
	1.3	1.32	3.4	1.01		1.8	0.9	1.2	0.4		0.4
	1.3	1.32	3.9	1.01		1.8	0.9	1.2	0.3		0.3
	1.3	1.32	3	1.01		1.8	0.9	1.2	0.3		0.3
	1.3	1.32	3.05	1.01		1.8	0.9	1.2	0.3		0.3
	1.3	1.32	1.9	1.01		1.8	0.9	1.2	0.3		0.3
	1.3	1.32	1.9	1.01		1.8	0.9	1.2	0.3		0.3
	1.3	1.32	1.9	1.01		1.8	0.9	1.2	0.3		0.3
	1.3	1.32	2	1.01		1.95	0.9	1.2	0.3		0.3
	1.3	1.32	1.95	1.01		1.95	0.9	1.2	0.3		0.3
	1.3	1.32	2.1	1.01		1.95	0.9	0.9	0.3		0.3
	1.3	1.32	2.1	1.01		1.95	0.9	0.9	0.3		0.3
	1.3	1.32	2.1	1.01		1.52	0.9	0.9	0.3		0.3
	1.3	1.32	2.1	1.01		1.7	0.9	0.9	0.4		0.4
	1.3	1.32	2.1	1.01		1.7	0.9	0.9	0.4		0.4
	1.3	1.32	2.17	1.01		0.53	0.9	0.9	0.4		0.4
	1.3	1.32	2.17	1.01		0.53	0.9	0.9	0.4		0.4
	1.3	1.32	2.17	1.01		0.53	0.9	0.9	0.3		0.3
	1.3	1.32	2.17	1.01		0.53	0.9	0.9	0.3		0.3
	1.3	1.32	2.17	1.01		0.53	0.9	0.9	0.3		0.3
	1.3	1.38	2.17	1.01		0.53	0.9	0.9	0.3		
	1.3	1.38	2.17	1.01		0.53	0.9	0.8	0.3		
	1.3	1.38	2.17	1.01		0.53	0.9	0.8	0.3		
	1.3	1.38	2.17	1.01		0.53	0.9	0.8	0.3		
	1.3	1.38	2.17	1.01		0.53	0.9	0.8	0.3		
	1.3	1.27	2.17	1.01		0.55	0.9	1.1	0.3		

Continued….

May-11	Jun-11	Jul-11	Aug-11	Sep-11	Oct-11	Nov-11	Dec-12	Jan-12	Feb-12	Mar-12	Apr-12
	1.3	1.27	2.17	1.01		0.6	0.9	1.1	0.3		
	1.3	1.27	2.17	1.01		0.71	0.9	1.1	0.3		
	1.3	1.27	2.17	1.01		0.71	0.9	1.1	0.3		
	1.3	1.27	2.17	1.01		0.71	0.9	1.2	0.3		
	1.3	1.27	2.17	1.01		0.65	0.9	1.2	0.3		
		1.27	2.17	1.01		0.51	0.9	0.8	0.3		
		1.23	2.17	1.01		0.51	0.9	0.8	0.3		
		1.23	2.17	1.01		0.51	0.9	0.8	0.3		
		1.23	2.17	1.01		0.51	0.9	0.8	0.3		
		1.23	2.17	1.01		0.51	0.9	0.8	0.3		
		1.25	2.17	1.01		0.49	0.9	2.1	0.3		
		1.43	2.17	1.01		0.49	0.9	1.8	0.3		
		1.43	2.17	1.01		0.5	0.9	1.8	0.3		
		1.43	2.17	1.01		0.85	0.9	1.8	0.3		
		1.31	2.17	1.01		0.85	0.9	1.8	0.3		
		1.33	2.17	1.11		0.73	0.9	1.8	0.3		
		1.11	2.17	1.11		0.73	0.9	1.8	0.3		
		1.11	2.17	1.11		0.73	0.9	1.8	0.3		
		1.11	2.17	1.11		0.73	0.9	1.8	0.3		
		1.11	2.17	1.11		0.73	0.9	1.8	0.3		
		1.11	2.17	1.11		0.73	0.9	1.8	0.3		
		1.11	2.17	1.11		0.73	0.9	1.8	0.3		
		1.11	2.17	1.11		0.73	0.9	1.8	0.3		
		1.11	2.17	1.11		0.73	0.9	1.8	0.3		
		1.11	2.17	1.11		0.73	0.9	1.8	0.3		
		1.11	2.17	1.11		0.73	0.9	1.8	0.3		
		1.11	2.17	1.11		0.67	0.9	1.8	0.3		
		1.11	2.17	1.11		0.67	0.9	1.8	0.3		
		1.11	2.17	1.11		0.67	0.9	1.8	0.3		
		1.16	2.17	1.11		0.67	0.9	1.8	0.3		

Continued…

May-11	Jun-11	Jul-11	Aug-11	Sep-11	Oct-11	Nov-11	Dec-12	Jan-12	Feb-12	Mar-12	Apr-12
		1.16	2.17	1.11		0.67	0.9	1.8	0.3		
		1.16	2.17	1.11		0.67	0.9	1.8	0.3		
		1.16	2.17	1.11		0.95	0.9	1.8	0.3		
		1.16	2.17	1.11		0.55	0.9	1.8	0.3		
		1.16	1.85	1.11		0.55	0.9	1.8	0.3		
		1.16	1.85	1.11		0.55	0.9	1.8	0.3		
		1.16	1.85	1.11		0.9	0.9	1.8	0.3		
		1.16	1.85	1.11		0.7	0.9	1.8	0.3		
		1.1	1.85	1.11		0.79	0.9	1.8	0.3		
		1.1	1.85	1.11		0.71	0.9	1.8	0.3		
		1.1	1.85	1.11		0.71	0.9	1.8	0.3		
		1.1	1.85	1.11		0.71	0.9	1.8	0.3		
		1.2	1.85	1.11		0.71	0.9	1.8	0.3		
		1.05	1.85	1.11		0.71	0.9	1.8	0.3		
		1.05	1.85	1.11		0.71	0.9	1.8	0.3		
		1.35	1.85	1.11		0.71	0.9	1.8	0.3		
		1.35	1.85	1.11		0.71	0.9	1.8	0.3		
		1.35	1.85	1.11		0.71	0.9	1.8	0.3		
		1.35	1.85	1.11		0.71	0.9	1.8	0.3		
		1.35	1.85	1.11		0.71	0.9	1.8	0.3		
		1.35	1.12	1.11		0.5	0.9	1.8	0.3		
		1.35	1.12	1.11		0.5	0.9	1.8	0.3		
		1.35	1.12	1.11		0.5	0.9	1.8	0.3		
		1.45	1.5	1.11		0.5	0.9	1.8	0.3		
		1.45	1.5	1.11		0.5	0.9	1.8	0.3		
		1.45	2.15	1.11		0.64	0.9	1.8	0.3		
		1.5	2.15	1.11		0.6	0.9	1.8	0.3		
		1.3	2.15	1.11		0.52	0.9	1.8	0.3		
		1.9	1.48	1.11		0.57	0.9	1.8	0.3		
		1.9	1.48	1.11		0.57	0.9	1.8	0.3		

Continued…

May-11	Jun-11	Jul-11	Aug-11	Sep-11	Oct-11	Nov-11	Dec-12	Jan-12	Feb-12	Mar-12	Apr-12
		1.8	1.48	1.11		0.5	0.9	1.8	0.3		
		2.1	1.48	1.11		0.55	0.9	1.8	0.3		
		1.95	1.48	1.11			0.9	1.8	0.3		
		1.95	1.48	1.11			0.9	1.8	0.3		
		1.95	1.48	1.11			0.9	1.8	0.3		
		1.95	1.48	0.7			0.9	1.8	0.3		
		2.1	1.47	0.7			0.9	1.8	0.3		
		2.1	1.47	0.7			0.9	1.8	0.3		
		2.1	1.47	0.7			0.9	1.8	0.3		
		2.1	1.47	0.7			0.9	1.8	0.3		
		2.1	1.47	0.7			0.9	1.8	0.3		
		2.1	1.47	0.61			0.9	1.8	0.3		
		1.9	1.47	0.61			0.9	1.8	0.3		
		1.9	1.47	0.61			0.9	1.8	0.3		
		1.52	1.47	0.61			0.9	1.8	0.3		
		1.52	1.47	0.61			0.9	1.8	0.3		
		1.52	1.47	0.61			0.9	1.8	0.3		
		1.52	1.47	0.61			0.9	1.8	0.3		
		1.52	1.47	0.61			0.9	1.8	0.3		
		1.52	1.47	0.61			0.9	1.8	0.3		
		1.52	1.47	0.61			0.9	1.8	0.3		
		1.6	1.47	0.61			0.9	1.8	0.3		
		1.6	1.47	0.63			0.9	1.8	0.3		
		1.6	1.47	0.65			0.9	1.8	0.3		
		1.6	1.47	0.65			0.9	1.8	9		
		1.6	1.47	0.6			0.9	1.2	9		
		1.6	1.47	1.02			0.9	1.2	9		
		1.6	1.47	1.02			0.9	1.2	9		
		1.66	1.47	1.02			0.9	1.2	9		
		1.66	1.47	1.02			0.9	1.2	9		

Continued…

May-11	Jun-11	Jul-11	Aug-11	Sep-11	Oct-11	Nov-11	Dec-12	Jan-12	Feb-12	Mar-12	Apr-12
		1.66	1.47	1.02			0.9	1.2	9		
		1.66	1.47	1.02			0.9	1.2	9		
		1.66	1.47	1.02			0.9	1.2	9		
		1.66	1.47	1.02			0.9	1.2	9		
		1.7	1.47	1.02			0.9	1.2	9		
		1.7	1.47	1.02			0.9	1.2	9		
		1.7	1.47	1.02			0.9	1.2	9		
		1.7	1.47	1.02			0.9	1.2	9		
		1.7	1.47	1.02			0.9	1.2	9		
		1.52	1.47	1.02			0.9	1.2	9		
		1.45	1.47	1.02			0.9	1.3	9		
		1.4	1.47	1.02			0.9	1.3	9		
		1.4	1.47	1.02			0.9	1.3	9		
		1.4	1.47	1.02			0.9	1.3			
		1.33	1.47	1.02			0.9	1.3			
		1.45	1.47	1.02			0.9	1.3			
		1.45	1.47	1.02			0.9	1.3			
		1.45	1.47	1.02			0.9	1.3			
		1.45	1.47	0.99			0.9	1.2			
		1.45	1.47	0.99			0.9	1.2			
		1.45	1.47	0.99			0.9	1.2			
		1.45	1.47	0.99			0.9	1.2			
		1.45	1.47	0.99			0.9	1.2			
		1.45	1.47	0.99			0.9	1.2			
		1.45	1.47	0.99			0.9	1.3			
		1.45	1.47	0.99			0.9	1.3			
		1.45	1.47	0.99			0.9	1.3			
		1.45	1.47	0.9			0.9	1.3			
		1.45	1.47	0.9			0.9	1.3			
		1.45	1.47	0.9			0.9	1.3			

	11-May	11-Jun	11-Jul	11-Aug	11-Sep	11-Oct	11-Nov	12-Dec	12-Jan	12-Feb	12-Mar	12-Apr
			1.63	1.47	0.9			0.9	1.3			
			1.63	1.47	0.9			0.9	1.3			
				1.47	0.9			0.9	1.3			
				1.47	0.9			0.9	1.3			
				1.47	0.9			0.9	1.3			
				1.47	0.9			0.9	1.3			
				1.75	0.9			0.9	1.3			
				1.75	0.9			0.9	1.3			
				1.75	0.9			0.9	1.3			
				1.75	0.9			0.9	1.3			
				1.75	0.9			0.9	1.3			
				1.75	0.9			0.9	1.3			
				1.75	0.9			0.9	1.3			
				1.75	0.86			0.9	1.3			
				1.75	0.86			0.9	1.3			
				1.75	0.86			0.9	1.3			
				1.75	0.86			1.4	1.3			
				1.5	0.86			1.5	1.3			
				1.5	0.86			1.5	1.3			
				1.5	0.86			1.6	1.3			
				1.5	0.86			1.6	1.3			
				1.5	1			1.6	1.3			
				1.5	1			1.6	1.3			
				1.55	1			1.6	1.3			
				1	1			1.6	1.3			
				1	1			1.6	1.3			
Average	**1**	**1.0**	**1.1**	**0.85**	**0.6**	**0.53**	**0.49**	**0.5**	**0.8**	**0.3**	**0.6**	**0.3**
STDEV	**0.07**	**0.08**	**0.04**	**0.14**	**0.13**	**0.10**	**0.07**	**0.18**	**0.07**	**0.17**	**0.11**	**0.17**

Appendix 4: Questionnaire used for the catch survey at Shamahuka landing site between May 2011 and April 2012

SECTION A: **Landing site characteristics**

Name of recorder………………………………… Date……………………………………..
Time…………………………………………

Name of Area…………………………………………………….. Name of landing site…………………………………………….

GPS: S:………...…………………………….. E:…………………………………………..

SECTION B: **Number of fishing boats by type**

1. Canoes ☐
2. Fiberglass/plastic boat ☐
3. Engine power boats ☐
4. others ☐

Total ☐

Section C: **Gear type used**

1. Monofilament gillnets ☐
2. Multifilament gillnets ☐
3. Traps ☐
4. Baskets ☐
5. Spear ☐
6. Hook and line ☐
7. other (specify) ☐

Section D: **Mesh size preference**

1. 3 inches ☐
2. 3.5 inches ☐
3. 4 inches ☐
4. 4.5 inches ☐
5. 5 inches ☐
6. other ☐

Section E: **Frequency of fishing activities in a week**

Once ☐ Twice ☐ Trice ☐ Four times ☐ five times ☐ six times ☐ seven times ☐

Total ☐

Appendix 5: Percentage numeric contribution of the most abundant families in Lake Liambezi littoral zone and the Kavango floodplain, sampled between March and October 2011.

	Lake Liambezi	**Kavango floodplain**
Species by families	%N	%N
Alestidae		
Brycinus lateralis	25.5	9.3
Hydrocynus vittatus	-	0.3
Micralestes acutidens	1.3	-
Rhabdalestes maunensis	32.9	5.8
Total	**59.7**	**15.4**
Cichilidae		
Oreochromis andersonii	1.7	7.8
Oreochromis macrochir	4.6	21.6
Pharyngochromis acuticeps	7.5	0.2
Pseudocrenilabrus philander	2.1	8.6
Sargochromis sp.	0.2	-
Sargochromis sp."green bream	0.1	-
Sargochromis giardi	-	-
Serranochromis angusticeps	-	-
Serranochromis macrocephalus	1	-
Tilapia rendalli	6.9	7.8
Tilapia sparrmanii	1.5	22.3
Tilapia ruweti	0.2	4.7
Total	**25.8**	**73**
Cyprinidae		
Barbus afrovernayi	-	0.4
Barbus bifrenatus	0.2	-
Barbus haasianus	-	1.9
Barbus paludinosus	-	0.1
Barbus poechii	9.3	-
Barbus radiatus		0.2
Labeo cylindricus	5.1	-
Total	**14.6**	**2.6**

Continued…

Poecillidae		
Micropanchax hutereaui	-	0.3
Micropanchax katangae	0.1	0.1
Micropanchax johnstoni	0.1	5.5
Total	**0.2**	**5.9**
Others		
Schilbeidae		
Schilbe intermedius	-	2.6
Mormyridae		
Pollimyrus spp	-	-
Clariidae		
Clarias ngamensis	-	0.1
Mochokidae		
Synodontis sp	-	-
Total	-	**2.7**

Appendix 6: Monthly catch data set per canoe per net night recorded from a sample of 602 canoes/days at Shamahuka landing site, on Lake Liambezi between May 2011 and April 2012

DATE	WEIGHT(kg)
18.05.2011	13
18.05.2011	6
18.05.2011	20
18.05.2011	25
18.05.2011	15.5
Average	15.9
SE	3.1

DATE	WEIGHT(kg)/DAY
07.06.2011	63
07.06.2011	20
07.06.2011	39
07.06.2011	30
07.06.2011	63
07.06.2011	34
07.06.2011	47
07.06.2011	33
07.06.2011	52
07.06.2011	39
07.06.2011	43
07.06.2011	39
07.06.2011	107.5
07.06.2011	40.5
07.06.2011	32
13.06.2011	9
13.06.2011	17
13.06.2011	15
13.06.2011	31.5
13.06.2011	12
13.06.2011	76
13.06.2011	19

Continued…..

13.06.2011	30.5
13.06.2011	12.5
13.06.2011	9
13.06.2011	42
13.06.2011	51
13.06.2011	83
15.06.2011	16
15.06.2011	26.5
15.06.2011	47.5
15.06.2011	23
15.06.2011	38
15.06.2011	54
15.06.2011	10.5
15.06.2011	33
15.06.2011	22.5
15.06.2011	32.5
15.06.2011	39.5
Average	36.73
SE	3.4

DATE	WEIGHT(kg)
06.07.2011	35.5
06.07.2011	46.5
06.07.2011	33.5
06.07.2011	69.5
06.07.2011	52
06.07.2011	61.5
06.07.2011	55
06.07.2011	9
06.07.2011	36
06.07.2011	57
06.07.2011	68
06.07.2011	60
06.07.2011	36
06.07.2011	42.5
06.07.2011	51
06.07.2011	24
06.07.2011	39.5
06.07.2011	23
06.07.2011	50
06.07.2011	21
06.07.2011	13
06.07.2011	29
08.07.2011	50
08.07.2011	10
08.07.2011	50
08.07.2011	22
08.07.2011	37
08.07.2011	42
08.07.2011	69
08.07.2011	28

Continued….

08.07.2011	20
08.07.2011	20
08.07.2011	52
08.07.2011	27
08.07.2011	35.5
08.07.2011	42
08.07.2011	27
13.07.2011	12
13.07.2011	21
13.07.2011	15.5
13.07.2011	33
13.07.2011	11
13.07.2011	43
13.07.2011	12.5
13.07.2011	26.5
13.07.2011	42
13.07.2011	3
13.07.2011	31.5
13.07.2011	13
13.07.2011	22
13.07.2011	13.5
13.07.2011	9
13.07.2011	57.5
13.07.2011	15
13.07.2011	12
13.07.2011	8.5
13.07.2011	12
13.07.2011	12
13.07.2011	15.1
13.07.2011	9
13.07.2011	5
13.07.2011	34
13.07.2011	12
Average	30.87
SE	2.3

DATE	WEIGHT(kg)
18.08.2012	30
18.08.2012	20
18.08.2012	66
18.08.2012	26.5
18.08.2012	30
18.08.2012	15
18.08.2012	47
18.08.2012	65
18.08.2012	26.5
18.08.2012	70
18.08.2012	42
18.08.2012	32
18.08.2012	46.5
18.08.2012	49.5
18.08.2012	40
18.08.2012	35
18.08.2012	45
18.08.2012	48
18.08.2012	75
18.08.2012	60
18.08.2012	45
18.08.2012	22.5
18.08.2012	82
18.08.2012	55
18.08.2012	42
Average	44.6
SE	3.5

DATE	WEIGHT(kg)
24.09.2011	17
24.09.2011	20
24.09.2011	62
24.09.2011	59
24.09.2011	52
24.09.2011	22
24.09.2011	10
24.09.2011	23
24.09.2011	61
24.09.2011	19
24.09.2011	38
24.09.2011	10
24.09.2011	17
24.09.2011	17
24.09.2011	19
26.09.2011	34
26.09.2011	40
26.09.2011	13
26.09.2011	94
26.09.2011	24
26.09.2011	25
26.09.2011	60
26.09.2011	19
26.09.2011	32.5
26.09.2011	30.5
26.09.2011	30
26.09.2011	16
26.09.2011	27
26.09.2011	21
26.09.2011	20
26.09.2011	18
26.09.2011	36
26.09.2011	15
26.09.2011	40
27.09.2011	40

Continued…

27.09.2011	10
27.09.2011	17
27.09.2011	23
27.09.2011	43
27.09.2011	38
27.09.2011	30
27.09.2011	20
27.09.2011	33
27.09.2011	13
27.09.2011	21
27.09.2011	31.5
27.09.2011	11
27.09.2011	21
27.09.2011	11
27.09.2011	21.5
27.09.2011	39.5
27.09.2011	16
28.09.2011	12
28.09.2011	25
28.09.2011	20
28.09.2011	19
28.09.2011	21
28.09.2011	15
28.09.2011	16
28.09.2011	36
28.09.2011	18
28.09.2011	35
28.09.2011	13
28.09.2011	20
28.09.2011	43
28.09.2011	32
28.09.2011	14
28.09.2011	40
30.09.2011	16
30.09.2011	3
30.09.2011	12
30.09.2011	18
30.09.2011	60
30.09.2011	32
Average	27.3
SE	1.8

DATE	WEIGHT(kg)
19.10.2011	27
19.10.2011	8
19.10.2011	20
19.10.2011	12
19.10.2011	14
19.10.2011	7
Average	14.67
SE	3.1

DATE	WEIGHT(kg)
01.11.2011	16
01.11.2011	31
01.11.2011	37
01.11.2011	9
01.11.2011	15
01.11.2011	19
01.11.2011	13
01.11.2011	48
01.11.2011	18
01.11.2011	28.5
01.11.2011	38
03.11.2011	37.5
03.11.2011	12
03.11.2011	11.5
03.11.2011	111.5
03.11.2011	12.5
03.11.2011	15
03.11.2011	29
03.11.2011	19
03.11.2011	20.5
03.11.2011	10.5
10.11.2011	12
10.11.2011	66
10.11.2011	6.5
10.11.2011	11
10.11.2011	1
10.11.2011	3
10.11.2011	10.5
10.11.2011	18
11.11.2011	1.6
11.11.2011	28
11.11.2011	6.5
11.11.2011	22
11.11.2011	9
11.11.2011	22
11.11.2011	17.5

Continued…..

11.11.2011	22
14.11.2011	39
14.11.2011	30
14.11.2011	13
14.11.2011	15
14.11.2011	25
14.11.2011	20
14.11.2011	14
14.11.2011	11
14.11.2011	23.5
14.11.2011	18
14.11.2011	8
22.11.2011	4
22.11.2011	38.5
22.11.2011	11
22.11.2011	43.5
22.11.2011	44
22.11.2011	54
22.11.2011	60
22.11.2011	40.5
22.11.2011	18.5
22.11.2011	29
22.11.2011	23
22.11.2011	21
22.11.2011	40
22.11.2011	38
Average	28.3
SE	2.3

DATE	WEIGHT(kg)
07.12.2011	14.5
07.12.2011	18.5
07.12.2011	21
07.12.2011	21
07.12.2011	17
07.12.2011	42
07.12.2011	35
07.12.2011	15
07.12.2011	14.5
12.12.2011	21
12.12.2011	12
12.12.2011	12.5
12.12.2011	14
12.12.2011	40
12.12.2011	30
12.12.2011	40
12.12.2011	30
12.12.2011	16
12.12.2011	63
12.12.2011	5
12.12.2011	19
12.12.2011	14
12.12.2011	21
12.12.2011	41
13.12.2011	16
13.12.2011	55
13.12.2011	60
13.12.2011	37
13.12.2011	21
13.12.2011	50
13.12.2011	15
13.12.2011	35
13.12.2011	17
13.12.2011	42
13.12.2011	30
13.12.2011	20
13.12.2011	43.5
13.12.2011	16
13.12.2011	12
21.12.2011	12
21.12.2011	47

Continued….

21.12.2011	16.5
21.12.2011	36
21.12.2011	73
21.12.2011	46
21.12.2011	16.5
21.12.2011	20.5
21.12.2011	50
21.12.2011	69.5
21.12.2011	15
21.12.2011	5
21.12.2011	35
21.12.2011	15
23.12.2011	10
23.12.2011	17.5
23.12.2011	42
23.12.2011	46.5
23.12.2011	56
23.12.2011	64
23.12.2011	12.5
23.12.2011	21.5
28.12.2011	19
28.12.2011	19.5
28.12.2011	19.5
28.12.2011	89
29.12.2011	4
29.12.2011	8
29.12.2011	92
29.12.2011	19
29.12.2011	19.5
29.12.2011	40
29.12.2011	22
29.12.2011	40
29.12.2011	20
29.12.2011	38
29.12.2011	70
29.12.2011	52
29.12.2011	68
29.12.2011	45
29.12.2011	62
29.12.2011	39.5
29.12.2011	62
Average	31.97
SE	2.3

DATE	WEIGHT(kg)
04.01.2012	22
04.01.2012	38
04.01.2012	52
04.01.2012	41.5
04.01.2012	40
04.01.2012	50
04.01.2012	15
04.01.2012	65
04.01.2012	23
04.01.2012	6
04.01.2012	7
04.01.2012	77
04.01.2012	37
04.01.2012	8
05.01.2012	52
05.01.2012	39
05.01.2012	47
05.01.2012	3
05.01.2012	41
05.01.2012	40
05.01.2012	53
05.01.2012	55
05.01.2012	37.5
05.01.2012	36
05.01.2012	12
05.01.2012	33
05.01.2012	9
05.01.2012	145
11.01.2012	59
11.01.2012	31
11.01.2012	35.5
11.01.2012	17
11.01.2012	34
11.01.2012	63
11.01.2012	5
11.01.2012	3
11.01.2012	4.5
11.01.2012	15
11.01.2012	28
11.01.2012	28
11.01.2012	30
11.01.2012	4

Continued…..

11.01.2012	8
12.01.2012	28
12.01.2012	30
12.01.2012	32
12.01.2012	38
12.01.2012	27
12.01.2012	40
12.01.2012	80
12.01.2012	42
12.01.2012	5.5
12.01.2012	45
12.01.2012	60
12.01.2012	32.5
12.01.2012	34
12.01.2012	36
12.01.2012	28
12.01.2012	30.5
12.01.2012	35
12.01.2012	30.5
12.01.2012	9
12.01.2012	202
12.01.2012	40
22.01.2012	22
22.01.2012	33
22.01.2012	42
22.01.2012	40
22.01.2012	21
22.01.2012	39
22.01.2012	57
23.01.2012	21
23.01.2012	29
23.01.2012	22
23.01.2012	30
23.01.2012	23
23.01.2012	60
23.01.2012	23
23.01.2012	70
27.01.2012	4
27.01.2012	38
27.01.2012	39
27.01.2012	39
27.01.2012	6
27.01.2012	44
27.01.2012	83
27.01.2012	75
27.01.2012	59
Average	37.19
SE	3.0

DATE	WEIGHT(kg)
22.02.2012	76
22.02.2012	51
22.02.2012	37
22.02.2012	23
22.02.2012	38
22.02.2012	27.5
24.02.2012	6
27.02.2012	79
27.02.2012	63
27.02.2012	72
27.02.2012	85
27.02.2012	44
27.02.2012	60.5
27.02.2012	37
27.02.2012	86.5
27.02.2012	40
27.02.2012	33.5
28.02.2012	30.5
28.02.2012	14
28.02.2012	21
28.02.2012	17
28.02.2012	11
28.02.2012	8
Average	41.76
SE	5.3

DATE	WEIGHT(kg)
06.03.2012	38
06.03.2012	39
06.03.2012	116
06.03.2012	66
06.03.2012	26
06.03.2012	40
06.03.2012	39
06.03.2012	30
06.03.2012	40
06.03.2012	37
07.03.2012	10
07.03.2012	57
07.03.2012	39
07.03.2012	25
07.03.2012	33
07.03.2012	73
07.03.2012	45
07.03.2012	2
14.03.2012	37
14.03.2012	32
14.03.2012	17
14.03.2012	53
14.03.2012	59
14.03.2012	26
14.03.2012	8
14.03.2012	20
14.03.2012	40
14.03.2012	46
14.03.2012	12
14.03.2012	40
14.03.2012	30
14.03.2012	38
14.03.2012	16
14.03.2012	15
15.03.2012	174
15.03.2012	13
15.03.2012	56
15.03.2012	73
15.03.2012	24
15.03.2012	76
15.03.2012	35

15.03.2012	31
15.03.2012	62
15.03.2012	36
23.03.2012	55
23.03.2012	70
23.03.2012	16
23.03.2012	60
24.03.2012	55
24.03.2012	50
24.03.2012	21
24.03.2012	57
24.03.2012	62
24.03.2012	36
24.03.2012	55.5
27.03.2012	78
27.03.2012	18
27.03.2012	56
27.03.2012	83
27.03.2012	66
27.03.2012	83
27.03.2012	43
27.03.2012	65
27.03.2012	55
27.03.2012	59
27.03.2012	36
27.03.2012	61
27.03.2012	45
27.03.2012	35
27.03.2012	15
27.03.2012	25
28.03.2012	82
28.03.2012	50
28.03.2012	47
28.03.2012	28.5
28.03.2012	13.5
28.03.2012	57.5
28.03.2012	61
28.03.2012	33.5
28.03.2012	48.5
28.03.2012	40
28.03.2012	72
Average	45.34
SE	2.8

DATE	WEIGHT(kg)
04.04.2012	50
04.04.2012	45
04.04.2012	36
04.04.2012	65
04.04.2012	37
04.04.2012	55
04.04.2012	37
04.04.2012	60
04.04.2012	47
04.04.2012	21
04.04.2012	20
05.04.2012	19
05.04.2012	80
05.04.2012	44
05.04.2012	33
05.04.2012	7
05.04.2012	49
05.04.2012	38.5
05.04.2012	26
05.04.2012	30
05.04.2012	48
05.04.2012	50
05.04.2012	35
12.04.2012	40
12.04.2012	85
12.04.2012	21
12.04.2012	31
13.04.2012	45
13.04.2012	71
13.04.2012	148
13.04.2012	50
13.04.2012	20
13.04.2012	56
13.04.2012	28
13.04.2012	63
17.04.2012	42
17.04.2012	148
17.04.2012	57
17.04.2012	48
17.04.2012	53
18.04.2012	35
18.04.2012	51
18.04.2012	46

Continued…..

18.04.2012	70
18.04.2012	152
18.04.2012	43
18.04.2012	31
18.04.2012	64
27.04.2012	92.5
27.04.2012	47
27.04.2012	129
27.04.2012	31
27.04.2012	87
Average	53.15
SE	4.4