

ASSESSING THE CURRENT STATUS OF LOCAL FLOODPLAIN FISHERIES IN
THE OKAVANGO RIVER, KAVANGO EAST REGION, NAMIBIA.

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MICHAEL KANGAUSARU (201104661)

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Main Supervisor: Dr. Clinton Hay (University of Namibia)

Co-Supervisor: Mr. Francois Jacobs (Ministry of Fisheries and Marine Resources)

ABSTRACT

Globally, floodplains are acknowledged as hydrologically important, environmentally sensitive, and ecologically productive ecosystems that perform several natural functions. They provide both cultural and natural services that are of great value to society (Peel, 2012). Flooding occurs naturally along river's and is an integral part of a healthy watercourse. It is believed that flooding may nurture life in and around rivers as the waters transport nutrient-rich sediments that contribute to a fertile environment for growth of plants that maintain and support biota. Particularly, these nutrient rich areas may perhaps play an important role for many fish species that utilize the floodplain (Hay *et al.*, 2002). It has been suggested that floodplain areas could be used for spawning, nursery, breeding and feeding grounds for many freshwater fish species. A fish survey in the floodplain at Kamutjonga Inland Fisheries Institute (KIFI) was conducted from February to April 2017. Fish sampling was carried out once a week using a seine net. Whereas data from fishermen catches were recorded daily for the flood period. The total area covered was 261 753m² for all sampling events. From the fishermen catches, a total of 12 353 individuals were collected representing 24 species along the floodplain at KIFI. From this, the Cyprinidae and Cichilidae families dominated the fishermen catches with 45.8% and 37.50% respectively according to percentage number (%N). The less common families included the Schilbedae and Cyprinodontidae families which combined made up less than 17% of the caches for the group. The species were ranked based on percentage index of relative importance (%IRI). The five most important fish species accounted for 96% (total IRI) when combined with *Oreochromis andersonii*

(57.8%), *Hydrocynus vittatus* (10.7%), *Serranochromis altus* (10.2%), *Tilapia sparrmanii* (5.1%), and *Pseudocrenilabrus philander* (5.9%). In comparison, the seine net survey resulted in a total of 2915 fish representing 10 families, 17 genera and 31 species sampled from the Kamutjonga floodplain. The five most important fish species according to the percentage index of relative importance (%IRI) were *Oreochromis andersonii* (76.7%), *S. altus* (5.1%), *P. philander* (4.5), *T. sparrmanii* (3.2%) and *Coptodon rendalli* (3.2%) cumulatively contributing to 92.7% of the catch.

According to percentage IRI, Cyprinidae represented 11 species contributing 35.5%, Cichlidae contributed 32.3%, Clariidae and Hepsetidae contributed 6.5% each, Poecillidae, Schilbeidae, Characins, Mochokidae and Mormyridae all contributed 3.2% each. These results suggest that the floodplain at KIFI is not only exploited for subsistence fisheries but is potentially utilized as feeding, nursery grounds and could provide refuge for the Okavango River fish communities. Furthermore, from both the fishermen and experimental gear catches it was observed the species abundance was dominated by *O. andersonii* for the flood period. Species diversity for the different flood prod showed no significant differences for the fishermen catch, however there were significant differences observed for the experimental dragnet catch. There was a statistically significant difference ($P=0.00$) in surface water temperature during the flood rising phase, peak and receding phase in the floodplain and river. The floodplain and the river's conductivity was observed to be significantly different ($P=0.03$) during the different flood phases. There was a significant difference ($P=0.00$) in water clarity during the flood rising, peak and receding phase in the floodplain as well as in the river.

For the sustainability of the fishery seine netting and mosquito netting in the floodplains at KIFI should be discouraged to avoid recruitment overfishing particularly for fish species namely; *O. andersonii*, *H. vittatus* *C. rendalli* that are commercially important species. This management approach will ensure that smaller fish sizes are not harvested before they mature and recruit into the fishery.

Keywords: Okavango, floodplain, spawning, nursery, Kamutjonga, fisheries, hydrology, wetlands.

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DECLARATION

I, Michael Kangausaru, declare hereby that this study is a true reflection of my own research, and that this work, or part thereof has not been submitted for a degree in any other institution of higher education.

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Date:

Michael Kangausaru

Student number: 201104661

1.0 INTRODUCTION

1.1 Orientation of the Study

The Southern African Development Community (SADC) region is regarded as the most arid place in the world facing water-stress, debilitating poverty, increased vulnerability and political instability (Ong'ayo, 2008; Ashton and Turton, 2007). While the region is regarded as one of the world's most food-insecure, it is moreover burdened by malnutrition. In the midst of this, there exists a great imperative for rapid economic growth if its natural resources are appropriately managed (Ascher, 1999; van der Ploeg, 2011; Couzens, 2014). Precipitation in the region is characterized by gradually lowering rainfall totals and Namibia is no exception to this phenomenon (Benhin, 2014). Namibia's rainfall is fundamentally skewed, with the northeast receiving more than the west and south-western parts of the country. This results in flooding of most areas as well as drought in other parts. These seasonally inundated areas form highly productive wetlands and account for much of the species richness as well as the production of an array of thatch-grasses harvested for local community sustenance, an activity that usually stretches from mid-April to December (Sawi, 2016).

Holtzhausen (1991) suggests that the key to productivity of many wetlands may be that they act as nutrient traps, which is thought to support an abundant and constant supply of food for numerous invertebrates. Kolding *et al.*, (2014) elucidate that the reason for the African inland fisheries having a high level of production is that many of the small fishes go unreported into local markets. Productive fisheries are thought to be aimed

toward small fish species that weigh only one to a few grams. The annual flooding of the northern parts of the country locally known as “*Efundja*”, often results not only in damage to infrastructure and loss of life but in particular also provides a thriving freshwater fishery on these floodplains (Adams, 2011; Shifidi, 2014). In Kavango-East region it produces an opportunity for a livelihood that supports a large section of economically underdeveloped population of the country (Welcomme, Brummet and Denny, 2006; Verhoeven and Setter, 2010; Sawi, 2016).

Globally, water is a key agricultural input factor that is high in demand (Benhin, 2014). Its sufficiency or lack thereof is critical for sustainable growth and increase in food availability (Grafton *et al.*, 2015). However, policies for increasing agricultural productivity have been mainly centered on crop cultivation (Pardey *et al.*, 2006;) however, this does not account for fishery products that constitute nearly 20% of animal protein intake in developing countries which are often among limited choices of affordable protein source (Beveridge, 2013; FAO, 2016). It is thought that fish consumption data in developing countries is highly underestimated in regard to the contribution of subsistence fisheries and small-scale fisheries in official statistics (Food and Agricultural Organization, 2014; Pauly, 2016). Longley *et al.*, (2014) are of the view that small sun-dried whole-fish (with heads, bones and organs) are concentrated sources of several essential nutrients. In comparison, larger fish are usually not eaten whole and therefore do not contribute as much to micronutrient intake. The Okavango River system in northern Namibia is one of the most pristine catchments in the world with minor human impact richly endowed with biodiversity. It still has an intact

floodplain river ecosystem and promotes a productive fishery. It is an elemental flood-pulsed wetland that originates from the highlands of central Angola flowing through Namibia and spills onto Botswana's Kalahari sands thereby supporting diverse ecological processes (Mendelsohn and Obeid, 2004; Bethune, 2009; McCarthy et al., 2000).

With good rainfall within the river's catchment area, especially in Angola, water levels rise profoundly. Peak flows are in February for rivers feeding the Cubango sub-Basin, while the highest flows only reach the lower Cuito in June. This rise in water level presages the inundation of extensive areas of land along the river giving rise to floodplains (Hay *et al.*, 2000; Mosepele *et al.*, 2009; Murray, Wolski and Ringrose, 2006). The river experiences peak flooding from March to May, with the 375-km long floodplain extending up to 5 km across. During high water flow periods, many fish species utilize floodplain systems as corridors and spawning grounds, while juvenile fish occupy the associated complex habitats (e.g. open waters, vegetated areas) as nursery grounds. Floodplains also help mitigate the impacts of seasonal flood events by dispersing increased amount of water over large spatial areas. These floodplain areas offer an unparalleled 'race-to-fish' delight of riverine resources for many that fail to harvest sufficient crops that can meet the household demand due to the irregularity of drought and flooding in the country (Newsham and Thomas, 2009). While for the duration of the flood period, friction between competing users is normal in common property resources (Welcomme, 1998).

Rural people have consistently taken advantage of the regular cycles of wetting and drying of floodplains so much so that it has become part of their cultural development (Ligtermoet, 2016). In this instance inland fisheries are a livelihood of last resort for the poor and sometimes malnourished communities (Mosepele, 2014). This has seen fishermen modestly and gradually harvesting the fishery to meet their individual household needs. However, the African person has been socialized into African traditional beliefs which tend to encourage the unregulated harvesting of fish resources (Peel, 2012) and ‘leaving everything to the supreme author of life’ for continued provisions. The role of fish and fishery products in tackling poverty, supporting economic growth and enhancing the effectiveness of growth strategies for poverty reduction has been substantially documented. According to the FAO (2014) it is estimated that fishery resources, particularly in rural Africa, are in a precarious state and nearly 6 million fishermen and women are living in poverty. However, the fish trade generates livelihoods for more than 100 million people (FAO, 2014) and represents a critical source of nutrition. Fishing, therefore in this view, is a very vital industry, as it contributes both to livelihoods and food security, especially in the SADC region. Fish trading is reported to benefit beyond 100 million people and represents a critical source of nutrition (FAO, 2014). From these findings it is crucial to understand the implications of these climatic events and their interface with poverty.

For the populace majority in the Kavango Region, rampant degradation and poverty is the reality whereby the situation is characterized by extremely high levels of poverty and unemployment among rural youth and women (Republic of Namibia, 2008). Namibia’s

high dependence on rain-fed agriculture has left the population vulnerable to food insecurity and high incidence of poverty due to climate change and variability (Benhin, 2014; Grafton *et al.*, 2015). In spite of this, fisheries in the Okavango River and its associated floodplains make critical contributions not only to the lives of the local population residing along the river, but also at a national level by enabling smallholder farmers to engage in fish value chains and thereby increase their profitability (Tvedten *et al.*, 1994; Purvis, 2002 and Turpie *et al.*, 2006). Tockner and Stanford (2002) accentuated that flooding events provide important hydrologic and geomorphic functions that result in sediment deposition, ground water recharge, point bar formation, and scour events which are necessary for the maintenance, recruitment, and growth of riparian forests, as well as directly contributing to local productivity and biotic interactions, this may be similar in the Okavango River and region.

Various types of fishing gears are employed in subsistence fishing within the Okavango River and these include, the use of traditional and modern gear types each with varying effectiveness. Examples of traditional methods include fishing funnels, fish fences, fish coral traps, bow and arrow, spears, scoop baskets whereas the use of modern gear include gillnets, seine nets, angling and wire mesh fykes (Hay *et al.*, 1996). Noting the various fishing gears, mesh sizes and catch per unit effort articulate the fishing intensity and as such are used as a measure which indicates the status of exploitation level in floodplains. The study examines and evaluates the function played by floodplain fishers and how fisheries resources have shaped and influences community livelihood and society at large. The thesis structure initially includes the review of the physical forming

of the floodplains, secondly the fish species composition for the flood period and lastly the fishing intensity on the KIFI floodplain.

1.2 Problem Statement

Despite the regional importance of biodiversity, particularly fishery resources to the local people residing in Kamutjonga village, very little is known concerning the extent of subsistence fishing along the Okavango River with an early emphasis on the fish stocks alone having occurred (Hocutt *et al.*, 1994; Hay *et al.*, 1996; Hay *et al.*, 1997). Today, pressure on this resource is increasing. Peel (2012); Mendelsohn and Obeid (2004) demonstrated that of a total of 73 species which had been previously recorded during biological surveys conducted in the Okavango River between 1992 and 2010 (MFMR,2011) only 41 species, represented by 9 families, 13 cichlids and 28 non-cichlid have recently been observed.

Small scale fisheries are generally undervalued and little is understood as most are consumed locally and go unrecorded in catch statistics. According to Tweddle and Hay (2013) limited information on fish stocks from the Okavango River has consequences on the management of the fishery such as conflicts emanating from diametrically opposed requirements from the utilization of the resource between different stake-holders and predictions are, the situation is likely to affect fish populations and the pristine Okavango ecosystem in the near future (Mosepele *et al.*, 2011). Presently, there is no reliable data available on the subsistence/commercial fishery in the Namibian reach of the river or information from the informal fish markets in this river section (Mosepele,

2013). This challenge has been further exacerbated by various fishing gears incorporated in the harvesting of the resource with different intensities.

1.3 Objectives of the study

The overall objective of the study was to assess the local floodplain fishery of the Kamutjonga floodplains, with the potential to formulate better management practices to conserve the resources in Kavango East region, Namibia.

Specific objectives:

- a) To determine the catch composition per gear type (fishing method).
- b) To determine the catch efficiency of different fishing gears and species diversity.
- c) To determine the fish sizes harvested by the local fishery using different fishing gear (traditional versus modern).

1.4 Research questions

- a) Which fish species are found within the inundated areas of the KIFI floodplain?
- b) Did the catch rates between gears (fishermen and experimental drag-netting) vary during the flood period? If so, what are the differences in the catch rates?
- c) Are there differences in the fish species composition on the KIFI floodplain between the fishermen and experimental gear used? If so, what fish species and during what phase of the flooding period?
- d) Did the fish sizes sampled differ between the fishermen and experimental gear? If so, during what phase of the flood period were there differences?

- e) Does the fish productivity change with the different levels of the flood pulse (rising, peak and receding)?
- f) Is there any association between the fishermen and experimental gear catches for the flood period?

1.5 Significance of the study

Baseline information on the floodplain fishery of the Kavango Region is as limited and so the results generated from this assessment will be the basis for providing management advice to ensure the sustainable use of the fisheries resources on the floodplains and uplifting of livelihood for thousands of people living in poverty (especially women and children) who dwell along the river and are sole dependents of the health of the fish stocks from the Okavango River.

2.0 LITERATURE REVIEW

2.1 Fish species composition in the Okavango River

It has been observed that for both tropical and temperate rivers, fish yields per unit surface area are considerably greater in rivers with flood pulses and associated floodplains as compared to impoundments where flood pulses are fundamentally reduced or generally absent (FAO, 2001). Flooding supports the incorporation of extra-channel allochthonous organic material and terrestrial nutrients into aquatic dimensions of the riverine ecosystem. According to Bills, Skelton and Almeida (2012), the earliest collection of fishes from the Okavango reported in scientific literature date back to 1861. Further studies were carried out by Nichols and Boulton (1927); Trewavas, (1936); Trewavas, (1973)

In particular, the ichthyofauna of the Kavango in the Namibian portion has been documented by many researchers (Jubb and Gaigher, 1971, Skelton *et al.*, 1985, Bruton and Jackson, 1983, Skelton and Merron 1984, 1985, 1987; Merron, 1991; van der Waal, 1987, 1991; Peel, 2012; Simasiku, 2014). From this collection, numerous important species were derived including, *O. andersonii*, *M. lacerda*, *H. vittatus*, *C. ngamensis*, *H. odoe*, and *S. thumbergi*. The fish community consisted of more than 70 fish species each with their specific ecology, forming an integral part of the complex and dynamic Okavango River ecosystem. Fish surveys further along the years continued with various different researchers, including Jubb and Gaigher (1971), Skelton (*et al.*, 1985). Additionally there has been an increase in fisheries and ichthyological research in

Namibia that including the Okavango River by well versed scientists (Mosepele *et al.*, 2009 Kramer *et al.*, 2007, 2011 & 2012). The Ministry of Fisheries and Marine Resources (MFMR) has since 1995 estimated the production in the Okavango River to range between 800 to 1000 tons/year (MFMR, 1995).

Previous research identified 83 fish species from the Okavango River and Delta in Botswana of which five of these were at the time listed as rare (Merron and Bruton, 1995). They broadly divided the regions fish population into different categories namely: resident species, which are longitudinal migrants that move downstream with the floods. These species return when flood waters recede. Then, there are lateral species including those that inhabit the isolated bays and back waters on the floodplains. Merron and Bruton (1995) note that there are usually fifteen to twenty fish species within any one community, and that usually less than four species often comprise the largest proportion of fish biomass within a fish community. In comparison to this research, a study by Hay *et al.* (1996) on the Okavango River revealed 79 non-endemic fish species. Among these, two species were at the time listed on the International Union for Conservation of Nature (IUCN) red data lists (Skelton, 1990), *Clariallabes platyprosopos* and *Aethiomastacembalus vanderwaal*.

According to Peel (2012), the Okavango River is amongst few rivers world-wide with no exotic or introduced fish species. In his study, he chronicled 41 fish species, 13 of which are cichlids. These fish species included the demersal broad-head catfish (*Clariallabes platyprosopos*), the smooth-head catfish (*Clarias liocephalus*). As well as

the naturally occurring benthopelagic fish species comprising the kavango tilapia (*Tilapia ruweti*), hyphen barb (*Enteromius bifrenatus*) and spot-tail barb (*Enteromius afrovernayi*). Native pelagic fish species found in the Okavango River include tigerfish (*Hydrocynus vittatus*) and silver robber (*Micralestes acutidens*). When flooding occurs, many invertebrates and fish species inhabit the inundated areas to take advantage of these allochthonous resources and their products (Winemiller, 1996). The dynamic interface shared between the aquatic and terrestrial dimensions of the ecosystem is exceptionally important because this environment, is limited in time, promotes faunal interactions and rapid nutrient exchanges. In light of this, it is believed that the height and duration of floods may directly influence the fish yields from floodplain river ecosystems (FAO, 2001).

A publication by Simasiku and Mafwila (2017) on the floodplain in Kavango resulted in the synthesis of 24 species representing 8 families. Cichlids represented by 12 species dominated the catches and the least represented fish families were Schilbeidae, Clariidae, and Mochokidae, based on a ranking of percentage index of relative importance. *Oreochromis macrochir*, *O. andersonii*, and *C. rendalli* were the dominating fish species according to %IRI. A study by Hay *et al.*, (2000) recorded 75 species and the three most important species, according to IRI, were all Cichlids; *P. philander*, *T. sparrmanii*, and *C. rendalli*.

The link between flooding and breeding of river fishes is well documented for tropical rivers in Asia, Africa, South America and Northern Australia. Humphries *et al.* (1999)

put forward a notion that in cases where high temperatures and flows do not coincide, temperature will often be the dominant variable that influences the timing of spawning. An example of this is from the Okavango Delta, where for the most part the flood occurs at the coldest time of the year, and so the fish spawn during low water. The highest proportion of sexually mature fish was found during the period from January to March, during the peak of the rainy season (Hay *et al.*, 2000). Although spawning modes of floodplain fishes are diverse, the use of these ecosystems seems for the majority to be initiated by adults (Humphries *et al.*, 1998). Whereby, mature fishes migrate to the floodplain when the flood rises and spawn in a variety of habitats. These fishes place their larvae in diverse optimal habitats, rather than relying on the larvae to get there themselves (Staaterman and Paris, 2014). There may be several reasons for this variation, such as habitat heterogeneity in combination with changes in mobility, schooling behaviour, or habitat during the early ontogeny. Thus, Urpanen *et al.*, (2007) noted that the biological aspects, when and where to collect the samples, need to be considered when optimizing the sampling.

2.2 The fishing methods in the Okavango River

Fish is regarded as a cheap source of food globally (Humphries *et al.*, 1999, Hat *et al.*, 2000, Turpie *et al.*, 2006). Similarly, in southern Africa people have also engaged in fish harvesting by using several fishing methods have been utilized in harvesting the wetlands. Each gear in use is ultimately fit in form and shape for its intended use. Traditional fishing methods are still in practice consisting both active and passive gears, particularly in the floodplains of the upper Zambezi and Okavango Rivers in Namibia

and Botswana (van der Waal, 1991; Hay *et al.*, 2000; Peel, 2012; Simasiku, 2014). It was observed that new entrants into the fishing industry in the floodplain at Kamutjonga, usually juvenile girls engage in the harvesting of the open access resource with traditional fish trapping methods, including wading through the water in small groups to herd fish into mosquito-nets with older well-articulated fishermen using monofilament nets and sometimes hook and line.

Most people harvesting the rivers' resources still utilize traditional gears such as baskets, funnel traps and fish diversion fences constructed of plant material (Munwela *et al.*, 2010). For water transport to the various fishing grounds, traditional dugout canoes locally known as "Wato" made from kiaat (*Pterocarpus angolensis*) or the sausage tree (*Kigelia africana*) dominate the fishery of the Okavango River (Hay *et al.*, 1996). Monofilament gillnet costs on average between N\$250-300 whereas in Zambia one pays N\$500 for the same gear type. Whereby, gillnets are readily available on the open markets in Katima Mulilo and from selected Zambian dealers at a relatively low cost. Low cost of nets and the relative ease with which fish are caught makes fishing in the Okavango River attractive to would-be fishermen (Welcomme, 2001; Tweddle, 2013). Nets are usually set out in a series of two weeks and inspected for fish each morning.

Harvesting of the fisheries resources in the floodplain at KIFI is currently dominated by pap-baited plastic containers and mosquito nets. During periods of low water, fishermen set out a number of perforated pap-baited plastic containers in the different habitats offered by the extensive floodplain area. When the flood water levels are high enough

they change to more sophisticated mosquito nets to increase their catches thereby alternating back to plastic containers when the floods recede. An individual fisherman may have at least five to fifteen containers being the highest number recorded per person. The pap bait attracts the fish to the container being watched by the fisherman who then swiftly jolts it out of the water. Pores at the base of the plastic container permit the water to sieve through the trap leaving the fish behind.

When the floods are at peak phase, they move to more sophisticated gears, mosquito-nets (or gill-nets when floodplain is fully flooded), which are labour intensive. The harvest from these net is equally shared between the participants at the end of the day. Global concern over malaria transmission has led to the mass distribution of insecticide-treated nets (ITN) and long-lasting insecticide-treated nets (LLIN) especially in Namibia. These mosquito nets are intended for malaria protection, but because there is a surplus supply they have been repurposed for alternative uses including crop cover and fishing. This is made possible because they are provided for without charge or at a highly subsidised price. Treated mosquito nets are considered to be the cheapest and most effective measure of prevention in controlling the killer disease in developing countries (Eisele *et al.*, 2010; Bhatia *et al.*, 2004). According to WHO (2014) malaria transmission is among the most severe public health issues with an estimated 198 million cases and 584, 000 deaths globally. In Namibia malaria risk is present throughout the year in the Kunene, Zambezi and Kavango regions. It is predominantly high in the Kavango regions which has recorded the maximum number of malaria cases and deaths in the country (Nembwaya, 2014).

2.3 Global trends in floodplain fishing

It has been observed that rural livelihood systems are directly or indirectly underpinned by the utilization of freshwater resources specifically in highly productive tropical floodplain regions (Tockner and Stanford, 2002). Table 1 below depicts the current status and magnitude of global floodplains. Fish resources are a crucial component of the food web, essential for the processes of nutrient cycling and subsidizing populations of wildlife. At the same time, the megafauna, especially hippo's (*Hippopotamus amphibious*) and elephant's (*Loxodonta africana*), have key interactions with the environment that are essential for maintaining fish populations (Mosepele *et al.*, 2009). Aquatic vegetation such as macrophytes (e.g. water-lilies, duck-weed) has been suggested to possibly promote higher diversity, abundance and species richness, influencing the fish assemblage structure of littoral habitats. Additionally, they provide refuge from predators to young and small adult fish (Avendaño & Ramírez, 2017).

Table 1: Global coverage of floodplains and the major human impacts associated.

(Source: Tockner and Stanford, 2002).

Geographic Region	River System	Floodplain Area (km ²)	Major Impacts
Africa	Nile (Sudd), Zaire, Niger	310 000	Hydrological Change
Europe	Danube & Volga Deltas	40 000	Embankment, Drainage
North America (USA)	50 % in Alaska, Mississippi	240 000	Embankment, Hydrological change, Drainage
South America	Primarily Amazonian basin	1 100 000	Urbanisation
SE Asia (incl. China)	Mekong, Irrawady,	400 000	Urbanisation, Hydrological Change
Australasia	Fly River, Pao Creek & Cooper River	150 000	Hydrological Change
Russia/Central Asia	Lena, Mongolia	??	
Total		2 240 000	

According to Mosepele (2014) there are significant differences between floodplain fisheries from developing and developed countries with emphasis mainly on resource use. Developed countries value floodplains for their recreational value, whereas developing countries are particularly interested in their food value and other natural product provisions. From this a global comparison can be made. Total global floodplain area estimates range from 0.8 to 1.65 10^6 km² as shown in Table 1 above (Tockner and Stanford, 2002). The extent of human impacts on riparian zones is apparent, with the largest remaining flood plains are in South America where about 20% of tropical lowlands are flooded annually. Many large floodplains are still relatively untouched (e.g. Sudd, Congo Basin). However, they are being transformed at an accelerating rate as a result of water management activities, in particular by large-scale irrigation schemes and

the ongoing construction of dams (Thoms and Cullen, 1998; Tockner and Stanford, 2002).

Floodplains are important ecosystems as they provide natural resource services. From this a global comparison on how they influence global livelihoods can be drawn. The fisheries of the Yala swamp (in Kenya) provide a source of income to its riparian community. This is estimated to be four times that from agricultural related activities. In Bangladeshi, floodplain fisheries provide for a dual purpose. They are a seasonal protein source and are additionally an income generating endeavour which underpins the livelihoods of the rural fishing communities. Riparian communities in the extensive course of The Mekong River currently derive food provisions from its utilization thereby supporting the livelihood of an approximate 92 million people from different countries. In the Amazon, subsistence fishing of the floodplains takes precedence over recreational use. It is an important source of animal protein for the riparian community and associated activities provide employment for a substantial number of people.

Table 2: River systems in Namibia and the relative proportion of fish species associated with each floodplain. (Source: Holtzhausen, 1991).

Wetland	Total number of species	Associated with floodplains (%)
Cunene River	54	79.0
Kavango River	73	64.7
Orange River	9	53.9
Eastern Caprivi	59	77.6
Cuvelai System	39	88.6

As the above shows the number of river systems in Namibia and the relative proportions of species found within (Holtzhausen, 1991). Of the combined river systems the Okavango River records the highest number of freshwater fish species followed by the Eastern Caprivi and Cunene rivers in Namibia. Of this, 64.7% of the species are associated with the floodplain areas for the recruitment, growth and survival rates of the fish stock. Okavango River in Namibia (Table 2) also has a high species richness, partly due to its varied habitats, with rapids, backwaters and floodplains (Bethune, 2009). The annual flooding of the Okavango River starts ordinarily in December. These floods reach peak point between March and April and thereby generally going down during the month of May. Albeit it should be noted, rainfall in Angola is predominantly responsible for influencing the intensity and duration of the flood (Hay *et al.*, 2000). River-floodplain systems in the tropical regions support high biological diversity particularly of important fisheries (Welcomme, 1985; 1990; Lowe-McConnell, 1987). High

biological diversity, both taxonomic and functional, is associated with high spatial complexity and the dynamic nature of aquatic, terrestrial and ecotonal habitats (Ward *et al.*, 1999; Tockner & Ward, 2000). However, variability in the size and duration of the flood season affects the productivity of the floodplain. Drought may make people who are already affected by poverty more vulnerable to inequality, health issues and marginalization. For example some specific households may not have any means of earning an income outside of subsistence farming, it is these very homesteads that are solely dependent on natural resources without which their situation becomes dire.

Based on fish behaviour there are two groups into which floodplain fish are often categorized (McCarthy, 2000). There are 'white fish' which have been known to migrate to the main river channel in the late dry season in order to avoid the unfavourable conditions on the floodplain. At the beginning of the monsoon, with the rising of the water level, they spawn either upstream in the main channel or in the floodplain. After spawning in the main channel, the eggs and larvae drift passively downstream towards the inundated floodplain (de Graaf *et al.*, 1999). The main species of white fish comprise Cyprinidae and Schilbeidae. There are those categorized as 'black fish' which have a broad environmental tolerance and can sustain the harsh conditions of the floodplain during the dry season. Black fish include members of the Clariidae, Cichlidae, Siluridae and Ophiocephalidae. On the basis of this classification, a high percentage of white fish is attained in the floodplain at KIFI.

For centuries, populations worldwide have relied on seasonal flooding for their livelihoods. Examples include the Aboriginal and Torres Strait Islander people from Australia that live a primeval lifestyle and heavily rely on utilizing the East Alligator River floodplain region in northern, Indo-Gangetic Basin communities of Bangladesh. Much like these two areas the KIFI floodplain is home to diverse fisheries resources upon which the riparian communities rely on. This dependence has resulted in settlements being built on riverbanks and floodplains in order to utilize the water sources and fluvial soils provided by seasonal floods. Tockner and Stanford (2002) explain that their importance is understated especially when most human societies are listed as threatened by increasing environmental pressures. Some examples include the Lozi ‘Water People’ of the Barotse floodplain; the Tonga communities in the Kafue floodplain and the Ogoni in the Niger delta.

According to Rural Poverty Portal (2010) despite the importance of fish in the diet, consumption is highly variable; from location to location, throughout the year (due to the seasonality of capture fisheries and, to a lesser extent, aquaculture). Fish is among limited choices of affordable protein source. The floodplain at KIFI is a prime example, it is shallow (<2m deep) and characterized by cyclic episodes of filling and drying. When full the floodplain supports a highly productive fishery and when dry it is used for agriculture and grazing purposes. The former situation favours the exploitation of the fishery resources by multiple users using different devices.

Despite there being a general world-wide reduction in food insecurity, Africa's food security and nutrition situation is growing worse. A former study by Hay *et al.*, (2000) elucidates that although Namibia is categorized as a middle-income country, there is income inequality between the rich and poor, one of the most marked in the world with increasing vulnerability. Although the government through various policies has reduced the income inequality from the initial 0.646 Gini coefficient at independence, the initiatives have failed to address one of the major causes of the problem which is rural and informal infrastructure shortages. The long-term growth in income inequality raises not only social and political concerns, but also an economic perspective. In light of this, the government has made worthy progress in addressing the structural problems such as gender parity and access to basic education, yet the situation of imbalance persists.

Albeit a minimal proportion of the total population enjoys considerable wealth, overall the poverty rates are high. In Namibia, about 27.6% of households are classified as poor and 13.8 % as severely poor with poverty especially prevalent in rural areas (Rural Poverty Portal, 2017). Approximately, 70% of the population lives in rural areas, and about 60% are concentrated in the seven northern regions (FAO, 2007). According to a Namibia Statistics Agency report, the then Kavango region, now divided into Kavango East and Kavango West, which had 71% of its inhabitants in rural areas was the region with the highest poverty rate of 53%. The rural poor are generally not educated, with inadequate access to health care, adequate sanitation, gas and electricity supplies. Food shortage is a major problem during years of drought, and nutritional intake is consistently poor. The highest rates of nutritional deficiencies can be found in the north-

east, in the Kavango and Zambezi Region's (Hay *et al.*, 2000; FAO, 2007, Mosepele *et al.*, 2009).

Rural women are traditionally disadvantaged. The poorest of families are those homesteads headed by women. These cumulatively contribute to about 43% and are more likely to be dependent on subsistence agriculture. Traditionally, their access to productive assets and employment opportunities is less secure. Having less control over earnings and property, they bear a heavier burden of agricultural and domestic work. This burden on rural women is further exacerbated by the HIV/AIDS epidemic (Van der Waal, 1991). Other disadvantaged households are those without alternative income sources, those with inadequate access to land, water, and those without livestock that solely rely on harvesting and selling of thatch grass as a means of survival (Sawi, 2016).

2.4 Current trends in fresh water fisheries activity within Namibia

In Namibia, fisheries play an important role for the riparian communities. An approximate 60% of the Namibian population resides in rural areas whereby fish resources presently generate a variety of benefits. These comprise food security and employment, nutrition, livelihoods, foreign currency, and furthermore conservation and biodiversity values that are recognized globally (FAO, 2014). Earlier studies conducted by Tvedten (1994); Purvis (2002) and Turpie *et al.*, (2006) noted an average catch of 350kg per house-hold. Drought is extreme, particularly in rural areas where crops are failing and livestock are dying. Impacts of drought are so severe that there exists a potential conflict over use of the river's water with consequences on the fishery

resources. Welcomme (2001) recognised that fish growth in floodplain environments is highly seasonal. Increased growth rates are noted during the flood season and slowest during the dry season.

Mosepele *et al.*, (2014) recommends that an appreciation of the rivers environmental flow regime is vital to the management of the Okavango as an ecosystem supporting diverse biota. According to findings by Tweddle and Hay (2013) social and economic issues are of major importance in the Okavango fishery, with conflicting expectations on subsistence, commercial, and tourism angling interests, mainly in Botswana. Detailed figures for production of inland fisheries in Namibia are lacking; however as elucidated by Tvedten *et al.* (1994) approximately 2800t/yr is produced. Whereas, harvests from Lake Liambezi yielded approximately 1700t/yr in 2011 and collectively with the Zambezi Region's the floodplains produced 6000t/yr (Tweddle and Hay, 2013).

2.5 Fisheries Management Techniques

Management is defined as the integral process of collecting information, analysis, planning, consultation, decision making, allocation of resources and formulation and implementation of regulations which govern fisheries activities in order to ensure the continued productivity and accomplishment of other fisheries objectives (FAO, 2014). From this definition, two distinguishable views are set forth, both essentially aiming at accomplishing the same objective. One based in-vivo the resources and is advocated by natural scientists and the other is based on the society advocated by socio-economists. Modern management seeks to reconcile the two views, using them as tools to reach

balanced decisions on the resource with the participation of all stakeholders in the fishery (Welcomme, 2001).

In 2003, the government of Namibia gazetted the Inland Fisheries Resources Act No.1 to promote the conservation and protection of aquatic environments and the sustainable development of inland fisheries resources (Ministry of Fisheries and Marine Resources, 1995). Fisheries resources are basically “open access resources” that can be harvested with simple fishing gears. As a solution to mitigate the growing problem of resource over-exploitation, the responsibility of managing the resource is shared between the Government and various user groups. The concept termed as co-management, focuses on the recognition that user groups have to be actively involved in the management regime if the objective is to yield positive results and thereby be both effective and legal (MFMR, 1995).

In the Kavango Region, management approaches include technical measures such as gear restrictions, mesh size regulations, method of capture, and the number and length of gillnets per fisherman (Peel, 2012). A permit system has been established 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. In addition, explosives, poisonous chemicals, intoxicating substances, lighting, scoop nets, jigging, drag netting and fish driving may not be used to catch fish, as stipulated in the Inland Fisheries Resources Act. In Namibia, the Mahango National Park creates a no-fishing zone on the Okavango River at the Namibia-Botswana border. As a result of this, between 1992 and 1999,

experimental catches within the park grew exponentially, approximately five times higher than in heavily-exploited areas upstream (Hay *et al.*, 2002). However there are no direct management measures in place for the complex multi-species multi-gear KIFI floodplain fishery in Namibia such as in other comparable countries.

3.0 RESERACH METHODS

3.1 Study area

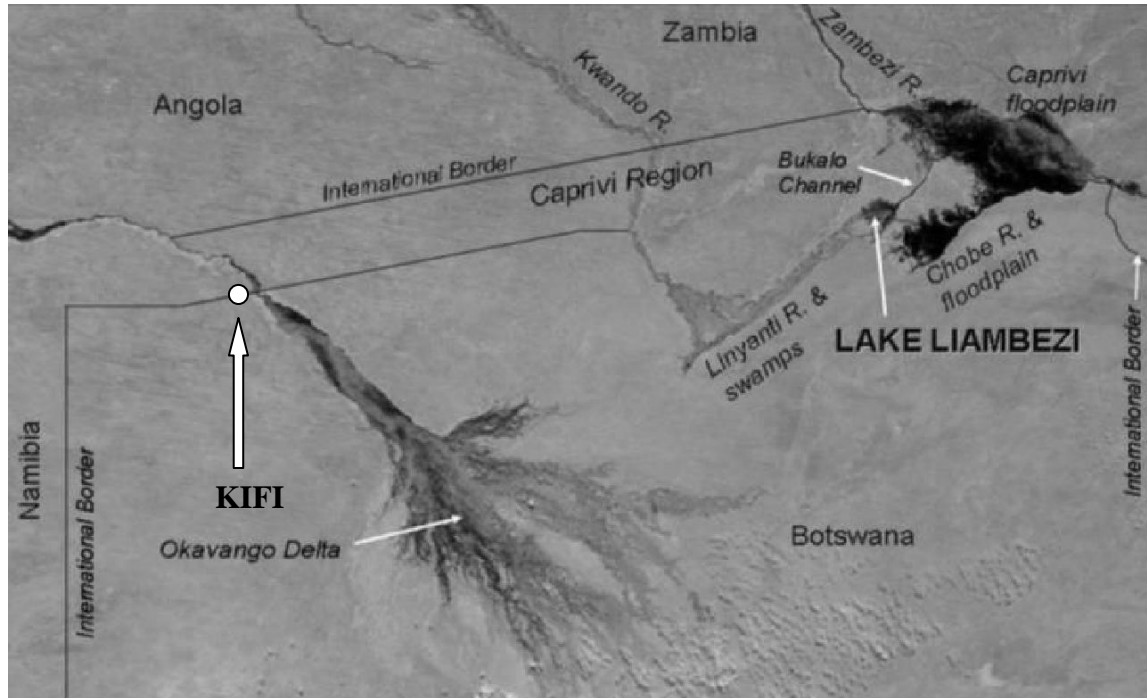


Figure 3: Map of Namibia and the expanded area showing the location of Kamutjonga Inland Fisheries Institute in north-eastern Namibia and bordering countries. (Source: Simasiku, 2014).

The study was conducted on the inundated floodplains at the Ministry of Fisheries and Marine Resources' (MFMR) Kamutjonga Inland Fisheries Institute (KIFI) in the Mukwe constituency. The Okavango River is the fourth-longest river system in southern Africa, running southeastward for 1,600km. It originates in Angola, forms part of the border between Angola and Namibia at Katwitwi. Thereafter, it flows into Botswana, and ultimately drains into the Okavango Delta (Moremi Game Reserve) (Hay *et al.*, 2000).

The Angolan portion provides 94.5 % of the total water runoff in the catchment; Namibia provides 2.9 % and Botswana 2.6% (Simasiku, 2014). It is characterized by a relatively fast-flow and a rocky substrate (Hay *et al.*, 2002; Mendelsohn and Obeid 2004). Before reaching the town of Rundu, the river flows over sandy substrates along a wide floodplain valley through which it meanders and forms numerous backwaters and lagoons lined by dense reeds. Further along, the river flows over a large series of rapids and small waterfalls between Mukwe and Poppa Falls, after which it meanders and spreads out to form the Okavango panhandle, the uppermost reach of the Okavango Delta (Mendelsohn and Obeid 2004).

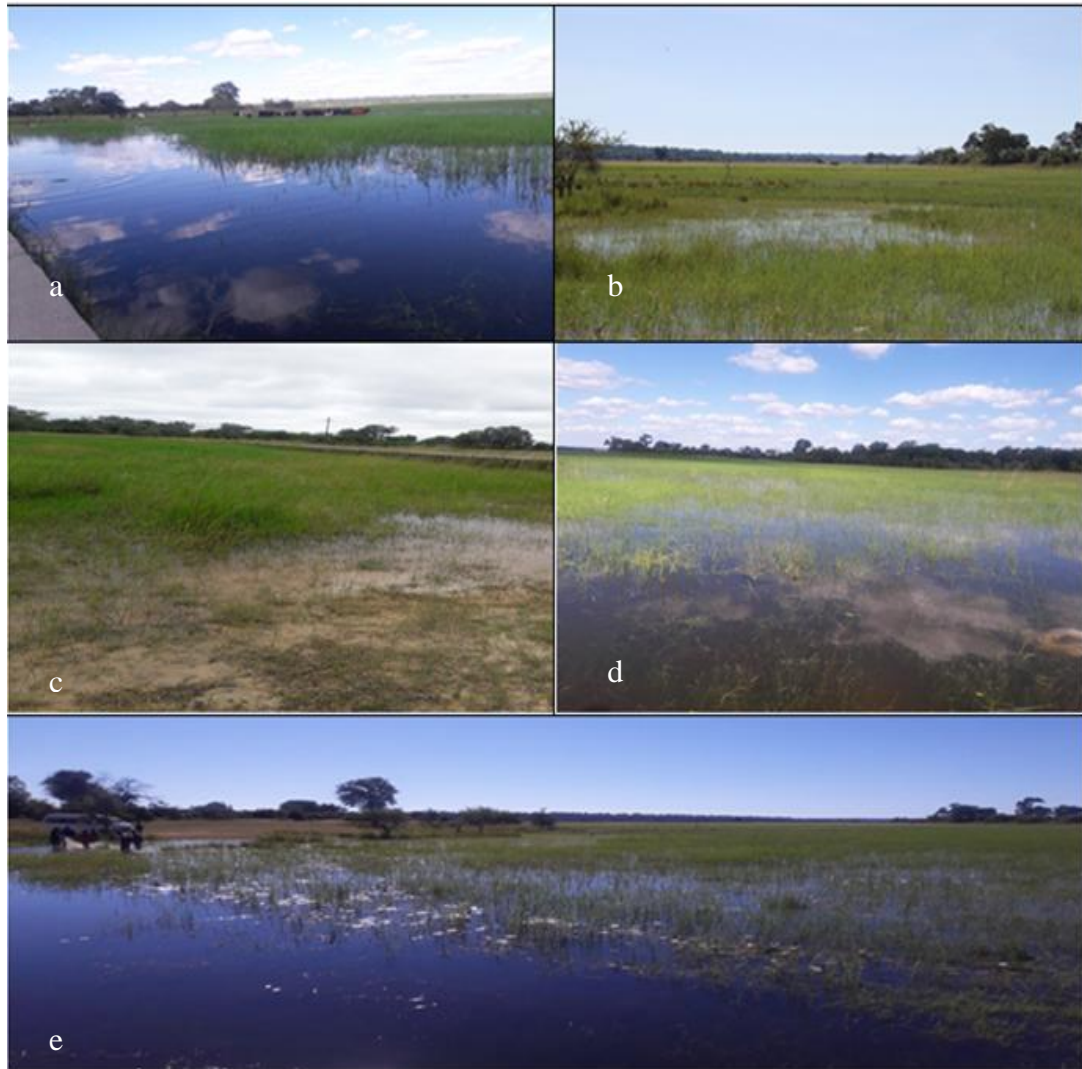


Figure 4: The different habitats provided by the KIFI floodplain (a) open waters (b) dense macrophyte beds (c) flooded marginal grasses (d) patchy distributed vegetation (e) open waters with reeds. (Source: Francois Jacobs, 2017).

The annual flood in the Namibian portion of the Okavango starts during December reaches its peak from March to April and recedes during May (Hay *et al.*, 2000). The floodplain at KIFI is approximately 10 km in length and reaches about 2 km at its widest point reaching a maximum depth of ± 1 m. The floodplain at KIFI and surrounding areas are dominated by a variety of submerged and floating plants. Small scale pastoralism also occurs in the floodplains at KIFI. It borders with the Mahango Game Park where large mammals are protected and commonly occur. Common tree species include the paperbark thorn (*Acacia Sieberian*), camel thorn (*Acacia erioloba*) and is also composed of terrestrial grass species such as pearly love grass (*Eragrostis rotifer*) and devil's grass (*Cynodon dactylon*) (Mendelsohn and Obeid, 2004)

3.2 Sampling procedure



Figure 5: Sampling of the KIFI floodplain using the experimental gear (a) open-waters (b) macrophyte beds (c) patchily distributed vegetation (d) collection of samples from gear (e) sorting (f) grouping (g) measuring (h) data entry. (Source: Francois Jacobs).

Data collection commenced from February when the floodplain was inundated until April during the recede period. This period was divided into different flood levels including the inundation phase, the rising phase, the peak flood phase and the receding phase. The first part of the study involved characterizing community data whereby a biological survey was performed to determine who is fishing and what the fisherman's catches constitute, what gear types are in use as well as the economic importance of the catches. Variables analyzed included water temperature, turbidity, pH and conductivity. Fish length was measured using a measuring board and recorded to the nearest millimetre (mm). Fork length (FL) or total length (TL) was measured depending on the species. Fish weight was measured in the field as wet weight to the nearest gram (g). Fish were identified to species level by assistance from fishermen, supervisors by making use of a handbook by Paul Skelton (2001). Where one species was particularly numerous, a sub-sample was measured and weighed individually and the remainder counted and weighed collectively.



Figure 6: Sampling of the KIFI floodplain by the fishermen (a) fisher-folk (b) mosquito netting (c) juvenile boy showing catches for the day (d) juvenile girls show their catches (e) grouping (f) sorting (g) measuring (h) recording

3.2.1 Fishermen catch survey.

Daily monitoring was performed at 9.00a.m 11.00a.m 13.00p.m and 15.00p.m and recording of the catches from the subsistence fishery was between February and April 2017. This was the period when fishing took place on the floodplains. Fish samples were measured and recorded according to species at the KIFI Bridge. There was a total of 18 fishermen days within the fourteen weeks, from February to April. These eighteen days were divided into four weeks, which relate to the different flood phases stated earlier. Where one species was particularly numerous, a sub-sample was measured and weighed individually and the remainder counted and weighed collectively. Appendix 1 shows the field survey sheet into which data was recorded and then transferred into PASGEAR version 2.3 (Kolding, 1999).

Table 1: The days whereby fishermen catches were observed, illustrating the different flooding periods for KIFI floodplains 2017

Week	Dates	Flood phase	Water level (mm)
1	14 to 19 February	Inundation phase	205
2	10 to 16 March	Rising	352
3	17 to 23 March	Peak	547
4	24 to 4April	Recede	346

3.2.2 Experimental (drag-netting) catch survey

The second part of the study involved the use of a seine net (experimental gear) measuring 10m long x 1.5m deep with a 5mm stretched mesh size with a bunt. Whereby fish samples were collected from the floodplain to assess the fish species that populate the different habitats therein. This was done each Wednesday at 9a.m and was carried out using a beach-seine. The seine net was hauled 10 times per trip and this was sufficient to get a representation of the fish species for the different habitats covered by study area. Samples collected were then separated according to station collected and then taken back to the lab for identification. The total length and weight was measured using a measuring board and a calibrated weighting scale respectively. All recorded data was stored and analyzed in PASGEAR version 2.3 (Kolding, 1999).

Table 2: Days when fishermen and experimental drag netting activity coincided.

Fishermen	Experimental drag-netting
14 – 19 February	15 February
10 – 16 March	15 March
17 – 23 March	29 March
24 – 04 April	05 April

3.3. Data analysis

All recorded data were stored and analysed in PASGEAR version 2.3 (Kolding, 1999). The Index of relative importance (IRI) was applied as a measure of relative abundance or commonness of different species in the catch and was calculated as:

$$\text{IRI} = (\%N + \%W) \times (\%FO)$$

Where, %N denotes percentage contribution of each species by number to the total catch and %W = percentage contribution of each species by weight to the total catch. %FO = percentage frequency of occurrence of each species in the total number of seine hauls.

Catch per unit (CPUE) effort was used to calculate the number and weight of fish caught and was calculated as:

$$\text{CPUE} = C_i / E_i$$

Where; C_i is the catch of species in numbers and E_i is the effort expended to obtain i .

An assessment of the normality of data was carried out using a Kolmogorov-Smirnov test. A Kruskal-Wallis test was used to examine the monthly changes in relative abundance (total CPUE) at 0.05 significance-level. The Shannon-Wiener index of diversity is a measure of species diversity, weighed by their abundances or evenness and was calculated as:

$$H = -\sum p_i \ln p_i$$

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. The Mann-Whitney test was used to test the differences between the species diversity for the fishermen and experimental gear; otherwise for more than two distributions; the Kruskal-Wallis test was used for multiple comparisons using SPSS version 24 (IBM, 2016).

The non-parametric Friedman's test in SPSS was used to test for difference in species composition between each of the four weeks for the fishermen and for the experimental gears. The test was further used to test for differences in species composition between months for each of the gear catches.

The Chi-square non-parametrical statistics test for independence in SPSS was used to test for the null hypothesis whether there was any significant association in the catches between the fishermen and experimental gear. The threshold for significance was selected as $p = 0.05$.

4.0 RESULTS

4.1 Physiochemical properties

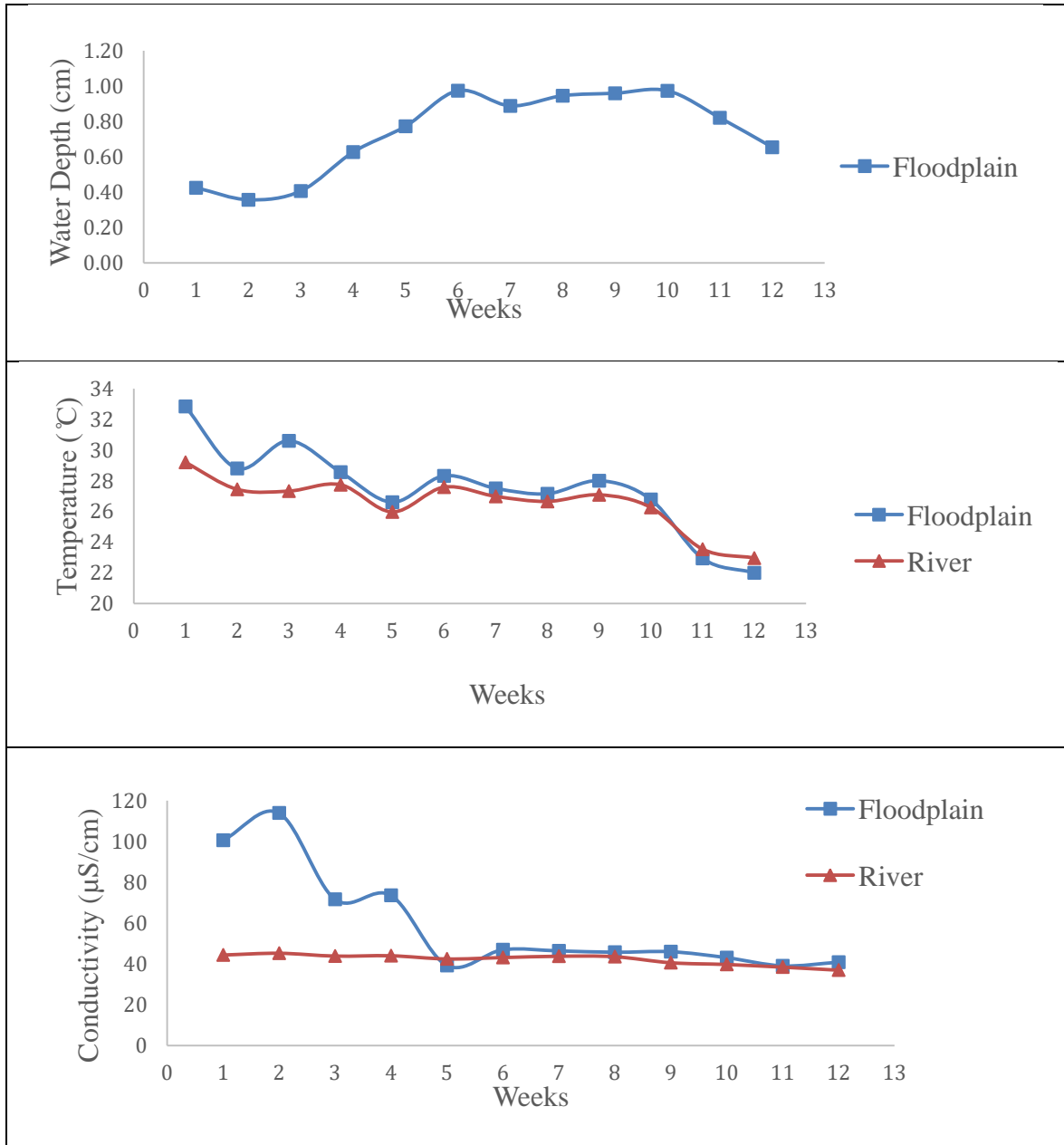


Figure 7: Physiochemical properties of the KIFI floodplain recorded from February to April 2017.

The water quality parameters (turbidity, conductivity & temperature) and depth recorded during the 13week sampling period varied considerably (Fig. 7). Water conductivity was high during the flood inundation and rising period but gradually decreased after the flood reached its peak (week 7). Water temperature was relatively constant throughout the three flood phases. Water transparency changes with increasing depth.

4.2. Catch composition on the Kamutjonga floodplains.

4.2.1. Experimental dragnet catches

A total of 2 915 individuals were collected during the four-week sampling period from February to April 2017. Fishermen catches stopped on 4 April 2017. In total 31 fish species were collected in the floodplain at KIFI. The species were ranked based on percentage index of relative importance (Table 3). The five most important species accounted for 96% (total IRI) when combined with *O. andersonii*, *T. sparrmanii*, *H. vittatus*, *S. altus* and *P. philander* each contributing 57.8%, 5.1% 10.7%, 10.2% and 5.9%.

Table 3: Experimental gear catch composition Number (No.) of fish per species, percentage number (%N), weight (W), percentage weight (%W), frequency of occurrence (%FO) and the percentage index of relative importance (%IRI) of all species sampled in the KIFI floodplain, Namibia, from February to April 2017.

Species	No.	% No.	Weight(kg)	% Weight	IRI	% IRI
<i>Oreochromis andersonii</i>	1393	47.8	3.119	47.8	2867	57.8
<i>Tilapia sparrmanii</i>	343	11.8	0.502	7.7	563	11.4
<i>Hydrocynus vittatus</i>	201	6.9	1.546	23.7	531	10.7
<i>Serranochromis altus</i>	337	11.6	0.523	8	505	10.2
<i>Pseudocrenilabrus philander</i>	250	8.6	0.206	3.2	290	5.9
<i>Coptodon rendalli</i>	94	3.2	0.231	3.5	85	1.7
<i>Pharyngochromis acuticeps</i>	59	2	0.058	0.9	31	0.6
<i>Micropanchax johnstoni</i>	53	1.8	0.012	0.2	22	0.4
<i>Enteromius radiatus</i>	37	1.3	0.062	1	21	0.4
<i>Schilbe intermedius</i>	21	0.7	0.098	1.5	20	0.4
<i>Enteromius poechii</i>	32	1.1	0.032	0.5	10	0.2
<i>Enteromius paludinosus</i>	13	0.4	0.024	0.4	3	0.1
<i>Enteromius unitaeniatus</i>	13	0.4	0.019	0.3	2	0
<i>Enteromius bifrenatus</i>	10	0.3	0.01	0.1	2	0
<i>Clarias gariepinus</i>	9	0.3	0.016	0.2	1	0

Table 3: Experimental gear catch composition...Continued.

Species	No.	% No.	Weight(kg)	% Weight	IRI	% IRI
<i>Enteromius fasciolatus</i>	9	0.3	0.009	0.1	1	0
<i>Sargochromis greenwoodi</i>	4	0.1	0.021	0.3	1	0
<i>Enteromius haasianus</i>	6	0.2	0.001	0	1	0
<i>Serranochromis angusticeps</i>	5	0.2	0.006	0.1	1	0
<i>Hepsetus odoe</i>	3	0.1	0.013	0.2	0	0
<i>Enteromius barnardi</i>	5	0.2	0.003	0.1	0	0
<i>Labeo cylindricus</i>	3	0.1	0.004	0.1	0	0
<i>Enteromius afrovernayi</i>	3	0.1	0.001	0	0	0
<i>Micralestes acutidens</i>	2	0.1	0.006	0.1	0	0
<i>Tilapia ruweti</i>	2	0.1	0.002	0	0	0
<i>Nannocharax multifasciatus</i>	3	0.1	0	0	0	0
<i>Synodontis macrostigma</i>	1	0	0.001	0	0	0
<i>Enteromius kerstenii</i>	1	0	0.001	0	0	0
<i>Sargochromis giardi</i>	1	0	0.001	0	0	0
<i>Clarias ngamensis</i>	1	0	0.001	0	0	0
<i>Petrocephalus catostoma</i>	1	0	0	0	0	0
Total	2915	100	6.528	100	4958	100

4.2.2. Fishermen gear catches

In comparison, fishermen's catches resulted in a total of 12 353 fishes including 24 different species sampled from the floodplain at KIFI (Table 4). The five most important species according to the percentage index of relative importance (%IRI) were *O. andersonii* (76.7%), *S. altus* (5.1%), *P. philander* (4.5), *T. sparrmanii* (3.2%) and *C. rendalli* (3.2%) cumulatively contributing to 92.7% of the catches.

Table 4: Fishermen gear catch composition (Number (No.) of fish per species, percentage numbers (%N), weight (W), percentage weight (%W), frequency of occurrence (%FO) and the percentage index of relative importance (%IRI)) of all species sampled in the KIFI floodplain, Namibia, from February to April 2017.

Species	No.	% Number	Weight(kg)	% Weight	% IRI
<i>Oreochromis andersonii</i>	7483	60.6	17.416	74.1	76.7
<i>Serranochromis altus</i>	919	7.4	1.401	6	5.1
<i>Pseudocrenilabrus philander</i>	761	6.2	0.783	3.3	4.5
<i>Tilapia sparrmanii</i>	459	3.7	0.724	3.1	3.2
<i>Coptodon rendalli</i>	330	2.7	0.868	3.7	3.2
<i>Pharyngochromis acuticeps</i>	811	6.6	0.587	2.5	3.2
<i>Enteromius barnardi</i>	292	2.4	0.211	0.9	0.9
<i>Hydrocynus vittatus</i>	102	0.8	0.561	2.4	0.8
<i>Enteromius radiatus</i>	134	1.1	0.183	0.8	0.6

Table 4: Fishermen gear catch composition...Continued

Species	No.	% Number	Weight(kg)	% Weight	% IRI
<i>Micropanchax johnstoni</i>	416	3.4	0.141	0.6	0.5
<i>Enteromius poechii</i>	74	0.6	0.054	0.2	0.3
<i>Micralestes acutidens</i>	93	0.8	0.168	0.7	0.2
<i>Enteromius fasciolatus</i>	74	0.6	0.05	0.2	0.2
<i>Enteromius afrovernayi</i>	75	0.6	0.043	0.2	0.2
<i>Oreochromis macrochir</i>	218	1.8	0.175	0.7	0.2
<i>Tilapia ruweti</i>	33	0.3	0.092	0.4	0.1
<i>Enteromius unitaeniatus</i>	46	0.4	0.028	0.1	0.1
<i>Enteromius bifrenatus</i>	11	0.1	0.01	0	0
<i>Enteromius paludinosus</i>	4	0	0.007	0	0
<i>Enteromius haasianus</i>	7	0.1	0.002	0	0
<i>Enteromius multilineatus</i>	4	0	0.004	0	0
<i>Schilbe intermedius</i>	2	0	0.001	0	0
<i>Labeo lunatus</i>	3	0	0.003	0	0
<i>Serranochromis angusticeps</i>	2	0	0.003	0	0
<i>Total</i>	12353	100	23.515	100	100

4.3. Species composition according to fish families

4.3.1 Experimental gear catches

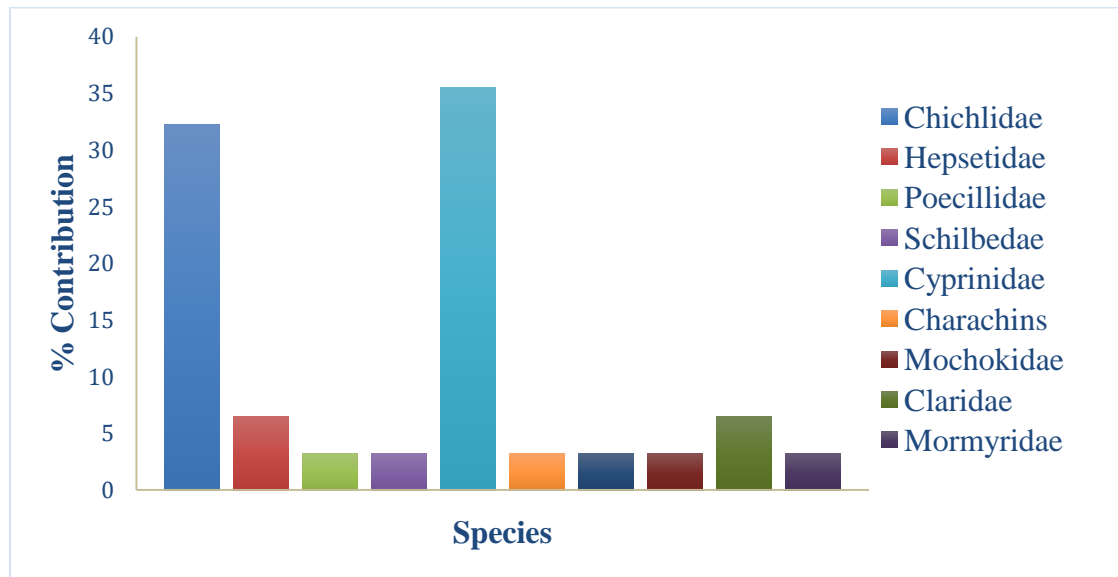


Figure 8: A comparative representation of the fish families sampled on the KIFI floodplain from the experimental gear catches by percentage number (%N) from February to April 2017.

According to percentage number (%N), the family Cyprinidae contributed 35.5%, Cichlidae contributed 32.3%, Clariidae and Hepsetidae contributed 6.5% each. From the above diagram (Fig. 8) the least represented families in the KIFI floodplain for the flood period included the Poecillidae, Schilbeidae, Characidae, Mochokidae and Mormyridae all contributed 3.2% each.

4.3.2 Fishermen gear catches

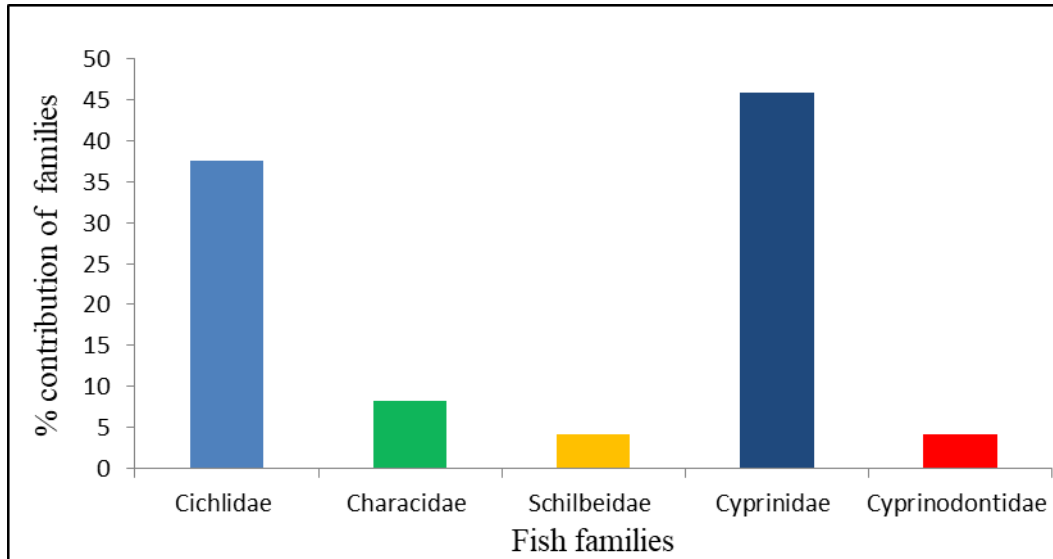


Figure 9: A comparative representation of the fish families sampled in the KIFI floodplain from the fishermen's catches, February to April 2017 by percentage number (%N).

The diagram above (Fig. 9) indicates the different fish families which constituted the fishermen catches. From this, the Cyprinidae family dominated the fishermen catches. This was followed by Cichilidae each with 45.8% and 37.50% respectively according to percentage number (%N). The less represented families included the Schilbeidae and Cyprinodontidae families which combined made up less 17% of the catches for the group.

4.4 Species Abundance

4.4.1 Fishermen gear catches

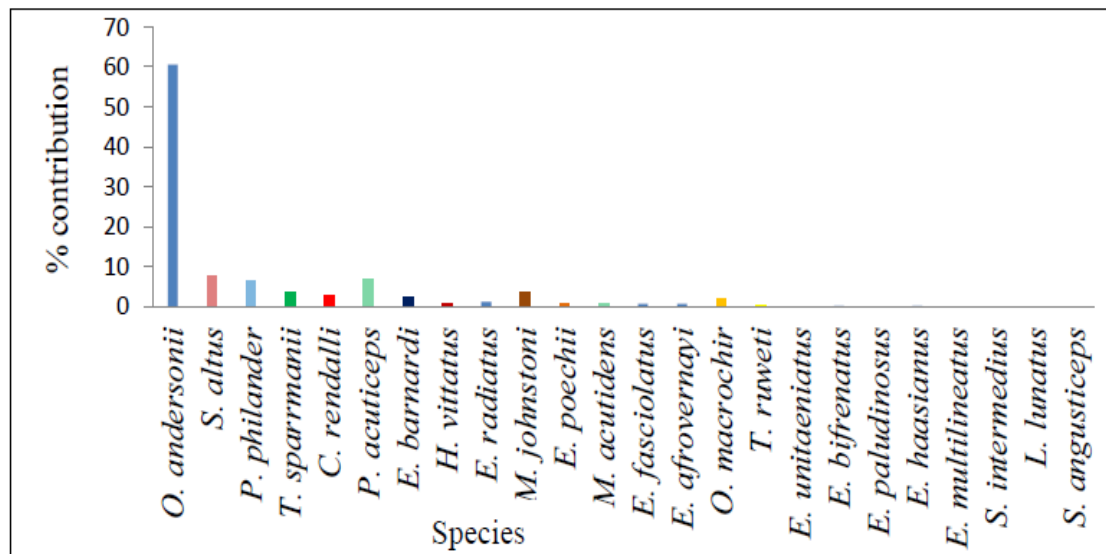


Figure 10: Relative species abundance of fish species sampled by the fishermen from the KIFI floodplain according to percentage number (%N), February to April 2017.

According to percentage number (%N), high species abundance was observed for *O. andersonii* is followed by *S. altus*, *P. acuticeps*, *P. philander* and *T. sparrmanii* each with 60.6%, 7.4%, 6.2% and 3.7% for the fishermen catches (Fig. 10). It was observed that most fish species are rare, (they are represented by a single individual in a community sample) e.g. *Labeo lunatus*, *S. intermedius* and *S. angusticeps* and relatively few species are abundant (represented by a large number of individuals in a community sample). *Tilapia sparrmanii* (11.8%), *S. altus* (11.6%), *P. philander* (8.6%), *H. vittatus* (6.9%). A total of 12 353 fish was recorded for the fisherman catches weighing 23.52kg for the flood period February to April 2017.

4.4.2. Experimental gear catches

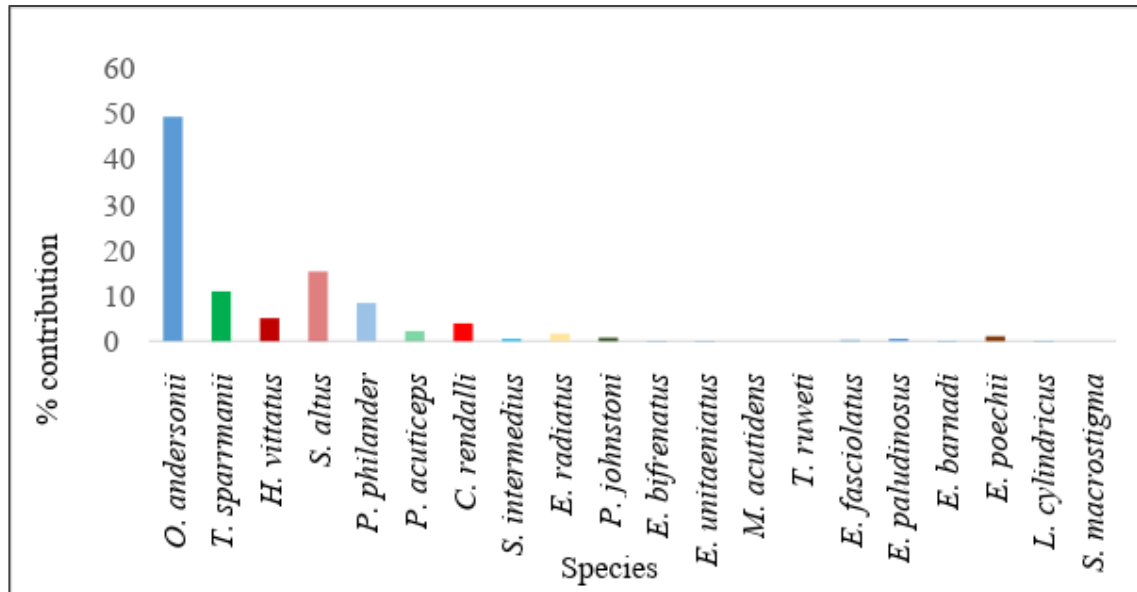


Figure 11. Relative species abundance of fish sampled by the experimental gear from the KIFI floodplain, according to percentage number (%N), February to April 2017.

As represented in the above diagram (Fig. 12), the experimental gear catches composed mostly of *O. andersonii*. *Oreochromis andersonii* (49%) had a high relative species abundance compared to *S. altus* (15.2%), *T. sparrmanii* (10.9%), *P. philander* (8.3%) and *H. vittatus* (5%). Relative species abundances for the experimental gear is parallel to that of the fishermen showing indicating that most fish species are rare in the floodplain. A total of 2 915 fish were recorded weighing 6.53kg for the flood period the experimental gear according to percentage number (%N). Species abundance was higher in regard to *O. andersonii* (60.6%), *P. acuticeps* (6.6%), whereas the minority group consisted of *M. johnstoni* (3.4%), *E. barnardi* (2.4%), *E. fasciolatus* (0.6%).

4.5 Comparison of species composition between catches from the subsistence fishery and catches from the experimental gear from February to April 2017.

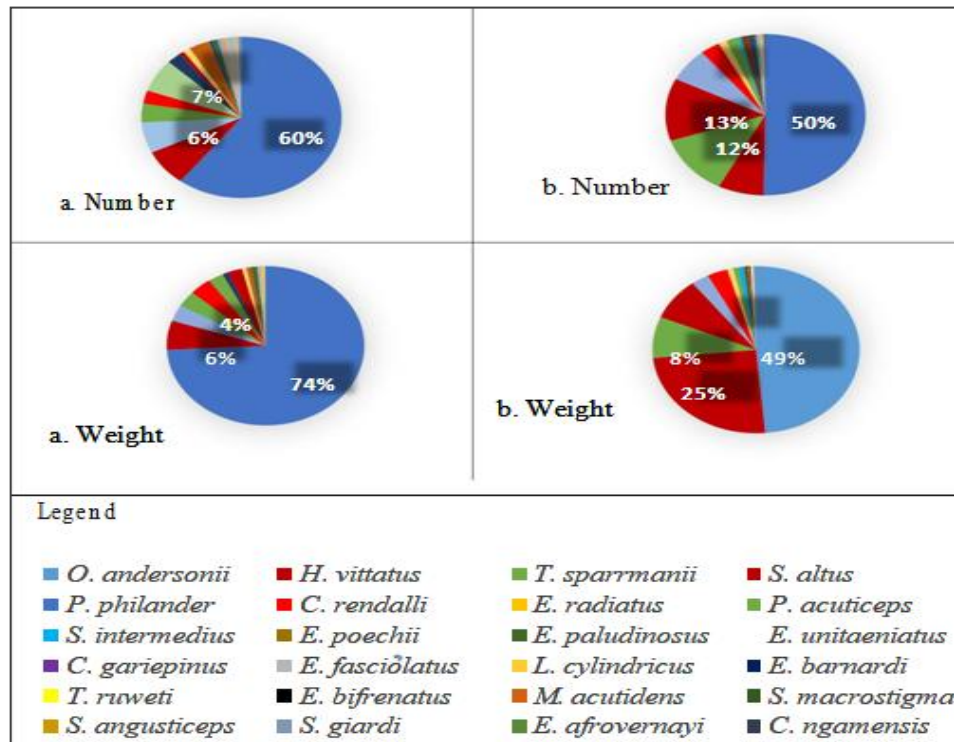


Figure 12. Species composition for (a) fishermen and (b) experimental gear in percentage (%N) and weight (%W), February to April 2017.

Oreochromis andersonii dominated the catches for the (a) fishermen and (b) experimental gear as can be observed from the diagram above (Fig. 12). It represented the fishermen catches at 60% compared to 50% in the experimental gear according to percentage number (%N). Whereas, *S. altus* was the second highest represented fish species according to percentage number, in the fishermen's and experimental gear catches with 7% and 13% respectively. *Pharyngochromis acuticeps* was the third highest in the fishermen's catches as compared to *T. sparrmanii* (12%) in the

experimental gear. In both groups the less common fish species consisted of *H. vittatus*, *S. intermedius* and *C. rendalli*. There was no significant difference (Chi-square test; $P=0.63$; $X^2 =107.199$; $df = 33$) in number of fish species sampled between fishermen and experimental gear.

Similarly, with regard to percentage weight (%W), *O. andersonii* dominated the catches and was represented by 74% and 49% in the fishermen and experimental gear respectively (Fig. 13). The second most represented species were *S. altus* and *H. vittatus* for the fishermen and experimental gear respectively. Species in the minority group for both the fishermen and experimental gear consisted of *C. ngamensis*, *P. catostoma*, *S. angusticeps* and *S. giardi*. There was no significant difference (Chi-square test; $P =0.25$; $X^2 =0.000$; $df =25$) in weight of fish species sampled between fishermen and experimental gear for the flood period.

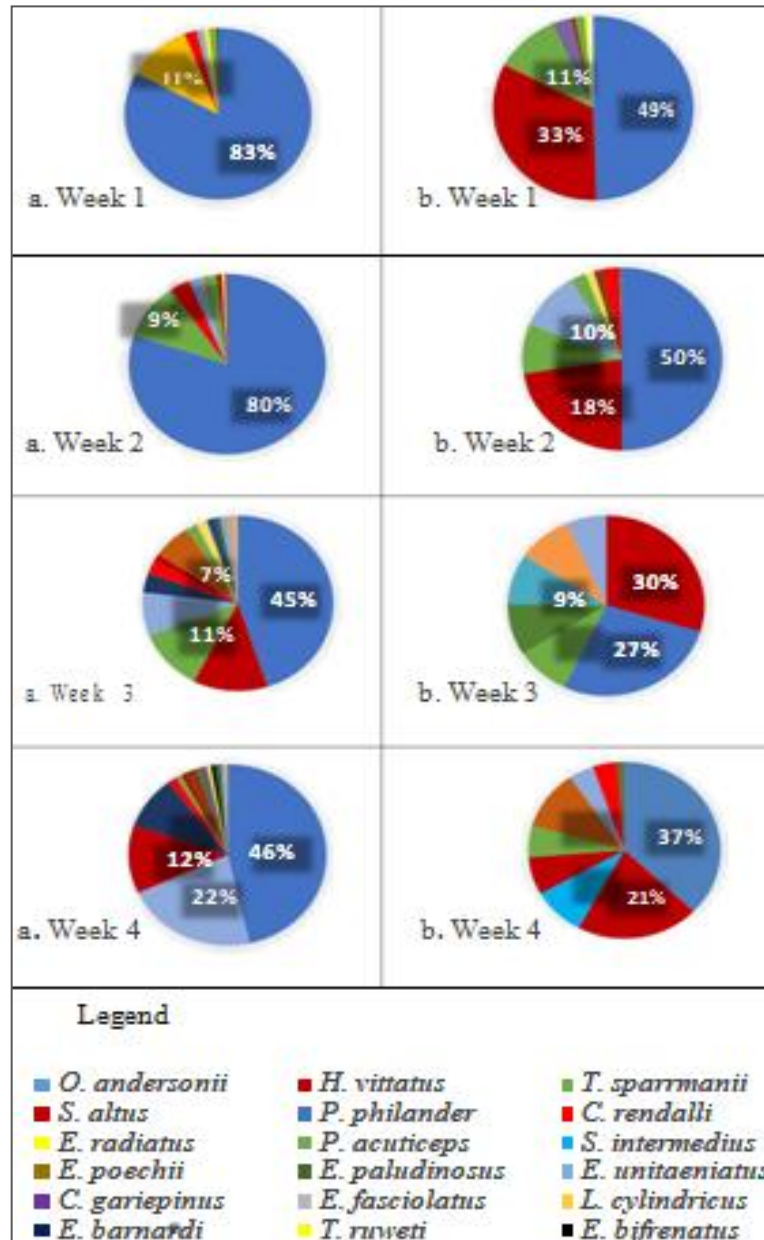


Figure 13. Species composition for (a) fishermen and (b) experimental gear catches by percentage number (%N) for the grouped weeks, February to April 2017.

As the flood waters began to rise, in week one, nine fish species were recorded for the fishermen's catches and this was dominated by *O. andersonii*, *O. macrochir* and *C.*

rendalli with 83%, 11% and 2% respectively (Fig. 13). Whereas, the experimental gear catches were composed of eight fish species. These catches were dominated by *O. andersonii*, *H. vittatus* and *T. sparrmanii* with 49%, 33% and 11% as shown above.

In week 2 during the inundation phase, both groups are dominated by *O. andersonii* but the experimental gear catches had 30% less by percentage number as the floods continue to rise. The second most abundant species is *S. altus* (18%) in the experimental gear but is however represented among the fishermen's less common species with *T. sparrmanii* (10%).

As the flood peaked, week three, *O. andersonii* species composition was the most common in the fishermen's catches and second most abundant in the experimental gear catches, whereas *H. vittatus* species composition is the most abundant in the experimental gear catches and amongst the less common in the fishermen's catches. The second abundant species in the fishermen's catches was *S. altus* however; it was not sampled in the seine-net (experimental catches).

In week four, during the receding phase, both fishermen's and experimental catches are dominated by *O. andersonii* with 46% and 37% respectively (Figure 7). However in the case of fishermen the second highest species composition by %N is *P. philander* followed by *S. altus* with 22% and 12% respectively. Whereas in the experimental gear *S. altus* and *P. johnstonii* with 21% and 11% respectively. The less common species consisted of *H. vittatus*, *T. sparrmanii* and *C. rendalli* as the flood receded. However, there is no significant relationship (Friedmans test; $P=0.616$; $X^2=1.80$; $df= 3$, $N=24$) for

the fishermen catches between the four weeks according to number. With regard to the experimental catches, there is a significant relationship (Friedmans test; $P=0.001$; $X^2=15.56$; $df=3$; $N=20$) between the four weeks.

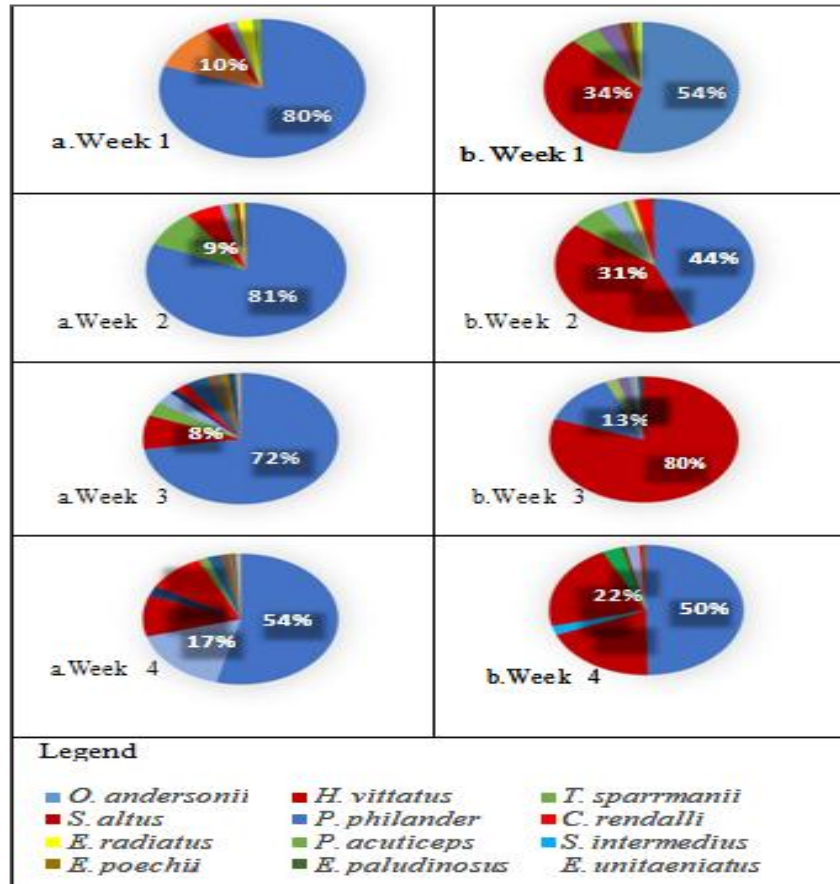


Figure 14: Species composition for fishermen (a) and experimental gear (b) catches by percentage weight (%W), February to April 2017.

Catches from both fishermen and experimental gear were dominated by *O. andersonii* with 80% and 54% respectively according to %W. *Oreochromis macrochir* is the second highest in the fishermen's catches whereas in the experimental gear it is *H. vittatus*, each have 10% and 34% respectively as shown in the diagram (Fig. 13). *Tilapia ruweti* and *T.*

sparrmanii are among the minority groups for week 1. The highest species composition for week two by %W is *O. andersonii* with 81% in the fishermen's catches as compared to 44% in the experimental gear as the floods continued to rise. The second highest is *T. sparrmanii* (9%) in the fishermen's catches as compared to *H. vittatus* (31%) in the experimental gear. *Coptodon rendalli*, *P. philander* and *E. radiatus* are present in both fishermen's catches but in the minority group.

In week 3, flood-peak phase, both the fishermen and the experimental gear are dominated by *O. andersonii* and *H. vittatus* that is, 72% and 80% for respectively by percentage weight. However, the second highest species composition is *S. altus* (8%) and *O. andersonii* 13%. The minority group in both catch groups is composed of species namely *T. sparrmanii*, *S. angusticeps* and *E. fasciolatus*.

The fishermen's and experimental gear catches are dominated by *O. andersonii* with 54% and 50% percentage weight for week 4 during the receding phase. This is followed by *P. philander* (17%) and *H. vittatus* (22%) in the different catch groups respectively as the floods receded. *Serranochromis altus* species is present in both groups with similar percentage weight, that's is 10% and 19% in the fishermen's and experimental gear respectively.

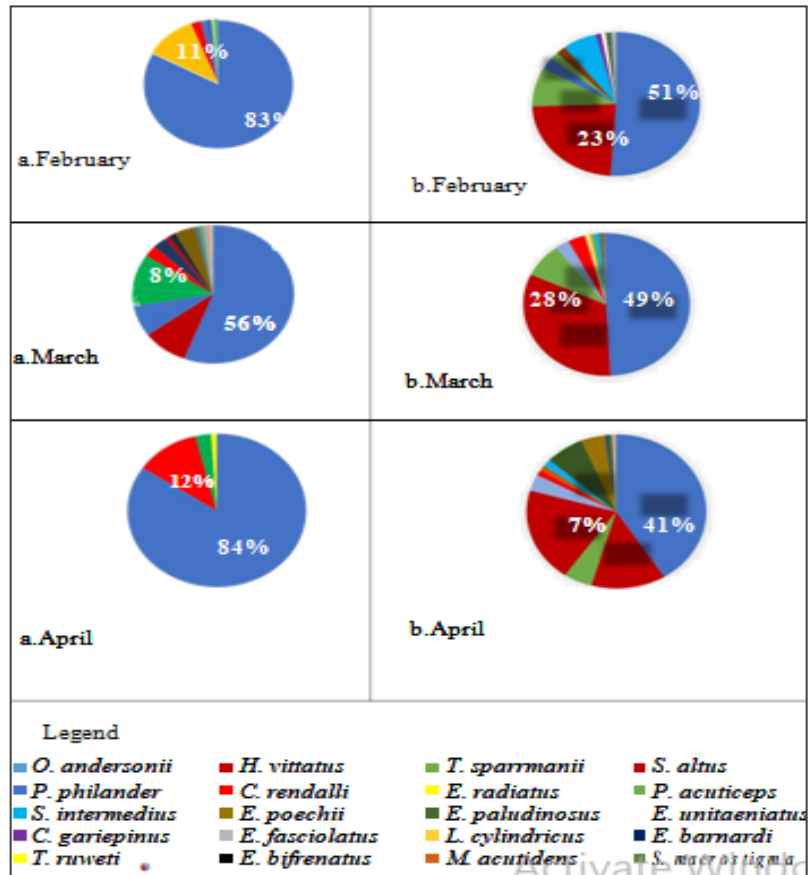


Figure 15: Species composition for (a) fishermen and (b) experimental gear catches by percentage number (%N) for each month, February to April 2017.

The above shows (Fig. 15) the species composition for the fishermen's catches were dominated by *O. andersonii*, *T. ruweti* and *C. rendalli* with 83%, 11% and 1% respectively. *Oreochromis andersonii*, *H. vittatus* and *T. sparrmanii* species composition for the month of February dominated the catches for the experimental gear as the flood season began. Each species contributed 57%, 19% and 11 % respectively by percentage number. The minority group (13%) consisted of fish species namely *C. gariepinus*, *S. intermedius* and *T. ruweti*. An individual *E. kerstenii* fish was sampled during the flood

period and it was only within February when the water started to rise within the floodplain. There was a significant difference in the fish sampled between the fishermen and experimental dragnet catches (Chi-square test; $P= 0.17$; $X^2=447.240$; $df =1122$).

As the floodplain continued rising to peak point, March, the percentage number (%N) contribution of the fish species composition change simultaneously. The fishermen catches were dominated by *O. andersonii*, *P. acuticeps* and *S. altus* with 83%, 8% and 7% respectively. *Oreochromis andersonii*, *S. altus* and *T. sparrmanii* contributed to 87% of the experimental gear with the remaining 13% consisting of *C. rendalli*, *S. intermedius* and declining numbers of *H. vittatus* were encountered. Particularly *L. cylindricus*, *S. macrostigma*, *S. giardi* *S. angusticeps* and *S. greenwoodi* started only being encountered during this month for seine-netting activity. There was a significant difference in the fish sampled between the fishermen and experimental dragnet catches (Chi-square test; $P= 0.006$; $X^2=47.674$; $df =26$).

In April, as the flood receded, the percentage number of the floodplain fishes changed. *Oreochromis andersonii*, *T. sparrmanii* and *S. altus* dominated the experimental gear and each species contributed 23%, 18% and 16% respectively. These three species combined made up more than half of the catches for April by percentage number. The minority group consisted of *M. johnstonii*, *C. rendalli* and *P. philander*. *Petrocephalus catostoma*, *H. cuvieri* and *H. multifasciatus* were sampled only during the receding period. There was a significant difference in the fish species sampled between the

fishermen and the experimental dragnet catches in the month of April (Chi-square test; $P=0.000$; $X^2=94.329$; $df=21$).

For the monthly catches there was no significant difference (Friedmans test; $P=0.095$; $X^2=4.709$; $df=2$) in the catches for the experimental gear. Whereas, for the fishermen there was a significant difference in the monthly catches (Friedmans test; $P=0.000$; $X^2=107.990$; $df=33$) for the flood period.

4.6 Species Diversity

4.6.1 Fishermen Catches

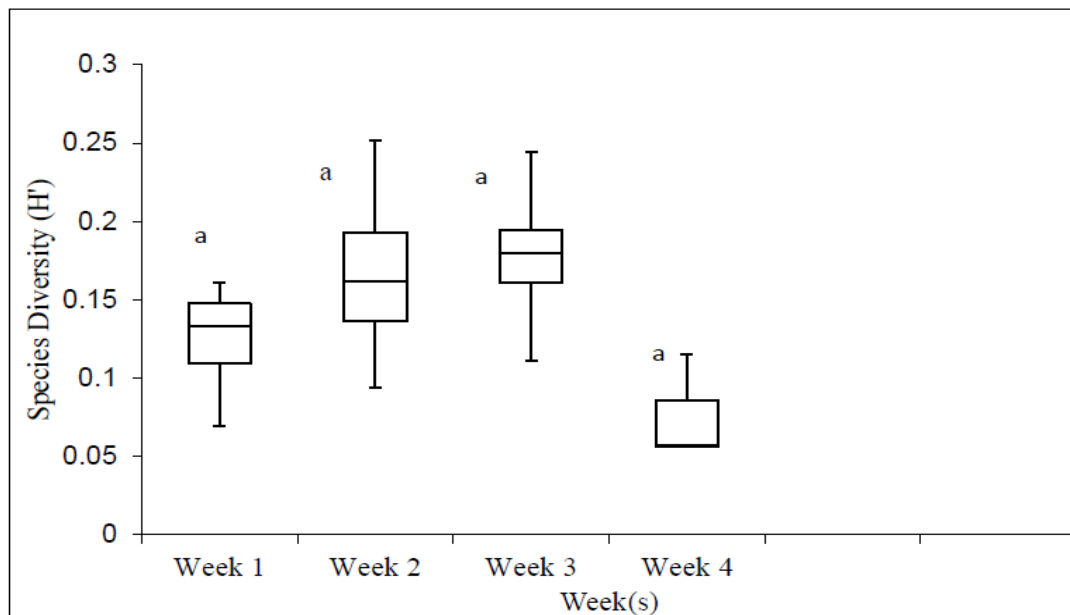


Figure 15. Species diversity from each week for the fishermen catches, February to April 2017. The letters denote significant differences (Kruskal-Wallis test; $df=3$).

The floodplain fish species community structure was compared between weeks at the species level. As shown in the diagram above (Figure 15) all weeks showed similar species diversity. There were no significant differences in the species diversity for fishermen for the different weeks (Kruskal-Wallis test; $H = 5.948$; $P=0.114$; $df =3$).

4.6.2 Experimental gear catches

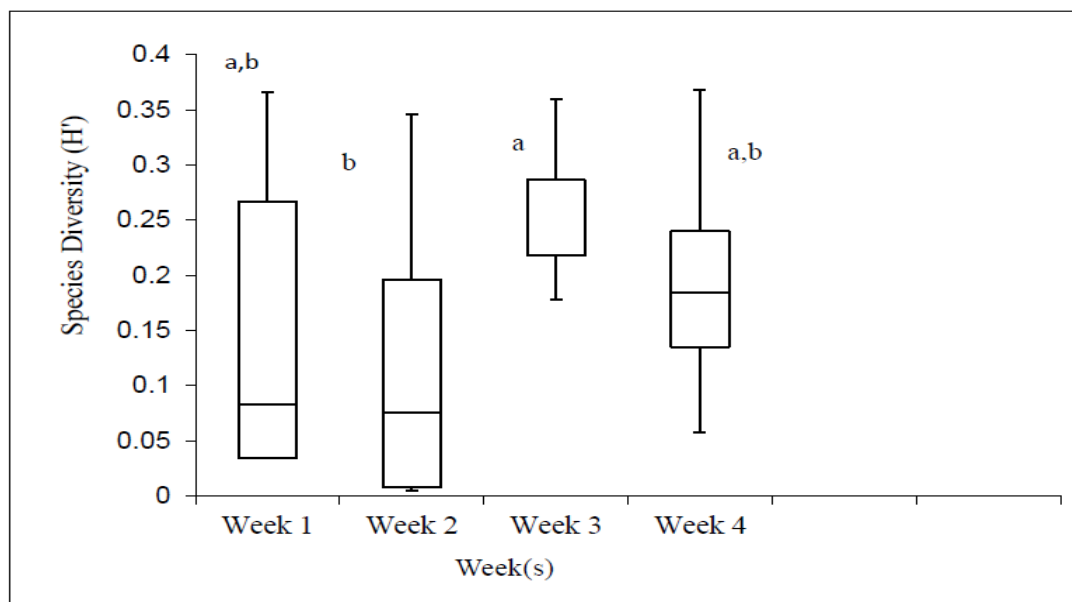


Figure 16. Species diversity for each week from the experimental gear catches, February to April. The letters denote significant differences (Kruskal-Wallis; $df =3$).

There was a significant difference (Kruskal-Wallis test; $H=8.346$; $P =0.044$; $df =3$) in the distribution of species diversity across categories of weeks. There was a significant difference between week two-three ($P=0.05$) as depicted by the diagram above (Fig. 21) that had different species diversities. All other weeks had a similar species diversity. The species diversity index for the four weeks is 0.0825, 0.076, 0.218 and 0.184 respectively.

Between weeks, two-one ($P = 1.000$), two-four ($P = 0.365$); one-four ($P = 1.000$); one-three ($P = 0.628$); four-three ($P = 1.000$) represent a similar species distribution but week three, flood-peak period, shows a higher overall species diversity among the four weeks.

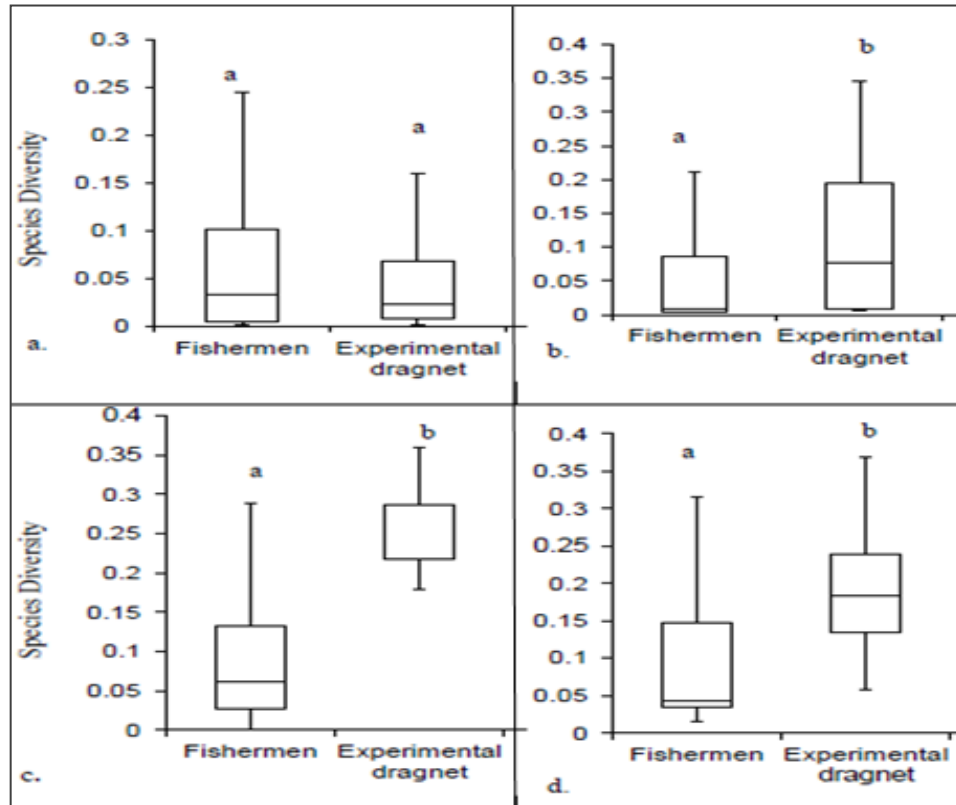


Figure 17. Species diversity between catches from the fishermen and experimental gear for weeks' one (a) two (b) three (c) and four (d). the letters denote significant differences (Mann-Whitney; $df=1$).

There was no difference in the species diversity for week one, but the other three weeks all differed in species diversity between the fishermen and experimental dragnet catches. For week one, flood inundation period, the distribution of species diversity (Fig. 17) (Mann-Whitney = 48; $P = 0.277$; $df = 1$), shows that there was no significant difference

between the catches. However, as the flood continued to rise in week two there is a significant difference in the species diversity (Mann-Whitney = 174.500; $P=0.026$; $df=1$). In week three, flood-peak period, there was significant differences for species diversity (Mann-Whitney $P = 122.500$, $P= 0.002$; $df=1$) between the catches from both groups. Week four shows that there is a significant difference in the distribution of species diversity (Mann-Whitney = 84; $P = 0.035$; $df=1$) between the fisherman and experiment gear catches.

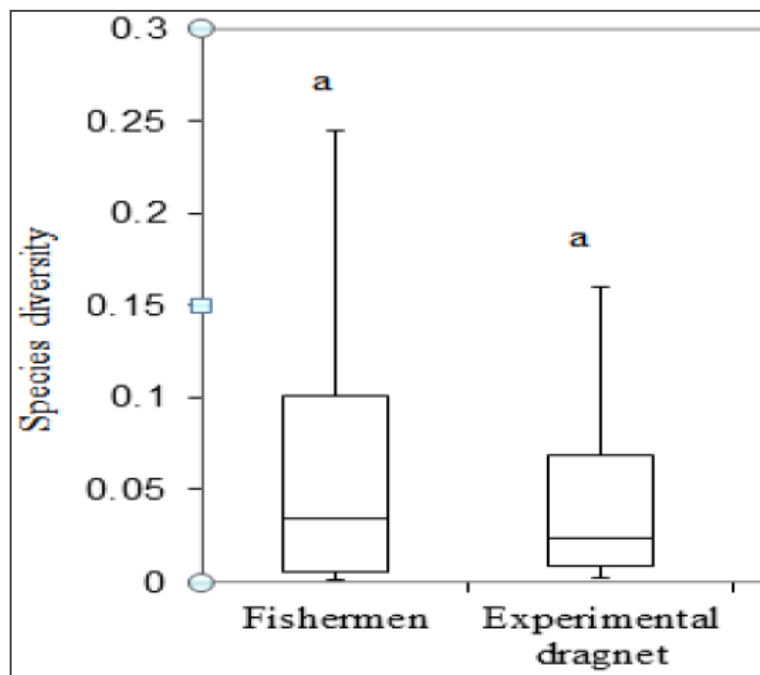


Figure 18. Species diversity between fishermen and experimental gear catches, February to April 2017. The letters denote significant difference (Mann-Whitney test; $df=1$).

As the above diagram shows (Fig. 18), there was no significant difference in species diversity between the catches for the fishermen and experimental gear when combining the data sets for the entire study period. The species diversity for the successive flood phases when the flood was rising, at peak and receded was similar (Mann-Whitney=352; P=0.794; df=1) for the fishermen and experimental gear catches.

4.7 Length-Frequency Distribution

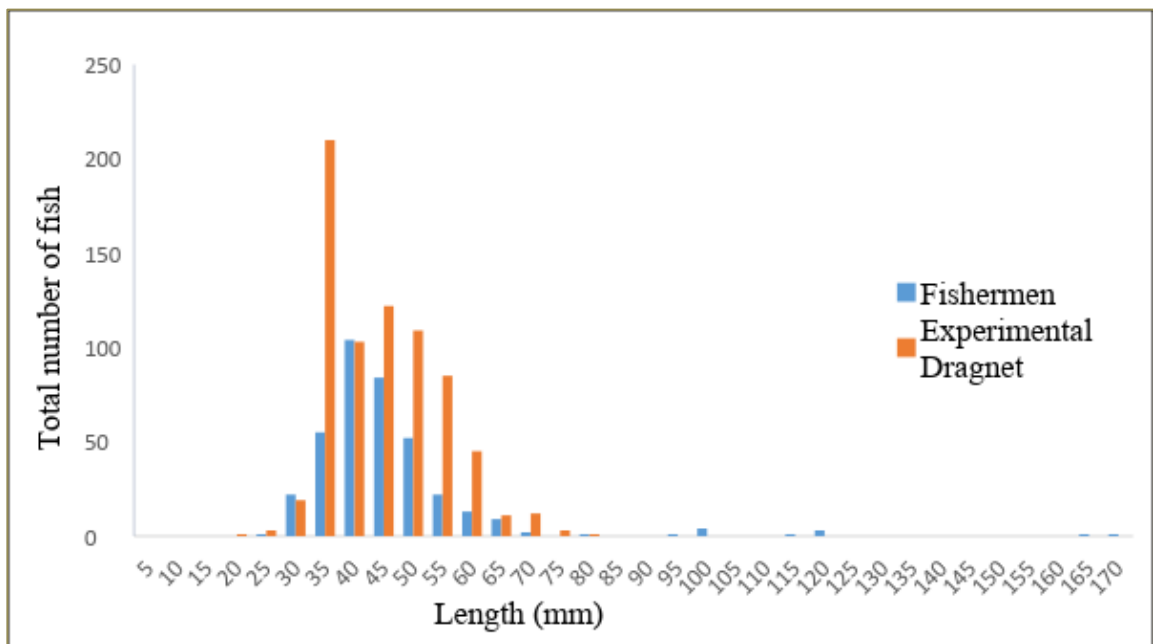


Figure 19. Length-frequency distribution for *O. andersonii* from the catches between the fishermen and experimental gear, February to April 2017.

Fishermen catches had an extensive length range for *O. andersonii*. The smallest and the largest fish size was 30mm and 120mm respectively. In comparison the experimental gear fish size ranged from 25mm to 75mm for the smallest and largest fish respectively. The modal length for the experimental gear catches was at the 35mm length class

compared to 40mm for the fishermen. Equal number of the 40mm sized fish was caught in both groups. Equal numbers of the 40mm fish size was sampled by both fishing groups. There was no significant difference (Mann-Whitney value = 608.5; P= 0.483; df =1) in the fish lengths of *O. andersonii* sampled from the fishermen and experimental gear catches (Fig. 19).

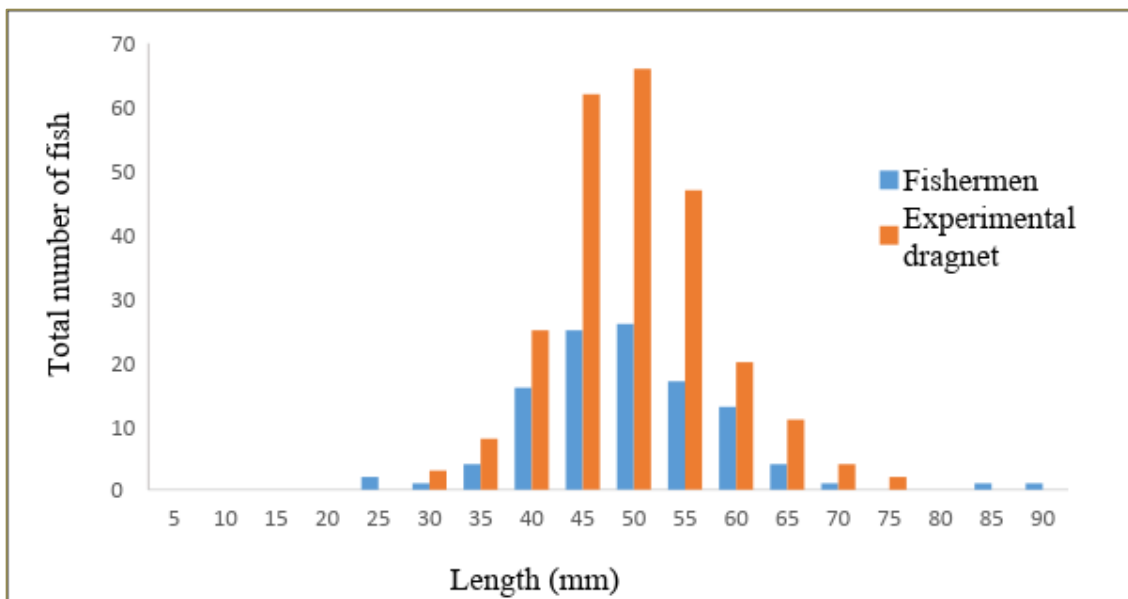


Figure 20. Length-frequency distribution for *S. altus* between the fishermen and experimental gear catches, February to April 2017.

The experimental gear catches had the highest frequency of *S. altus* during the four weeks of the flood period as compared to the fishermen catches. The modal fish length for both catch groups was 50mm, whereas the 25mm and 90mm fish sizes were the minimum and maximum lengths sampled only by the fishermen. There was no significant difference in the length sizes of *S. altus* sampled in the flood period between

the fishermen and experimental dragnet (Mann-Whitney value= 170; P= 0.815; df =1) in the fish lengths sampled from the fishermen and experimental gear catches (Fig. 20).

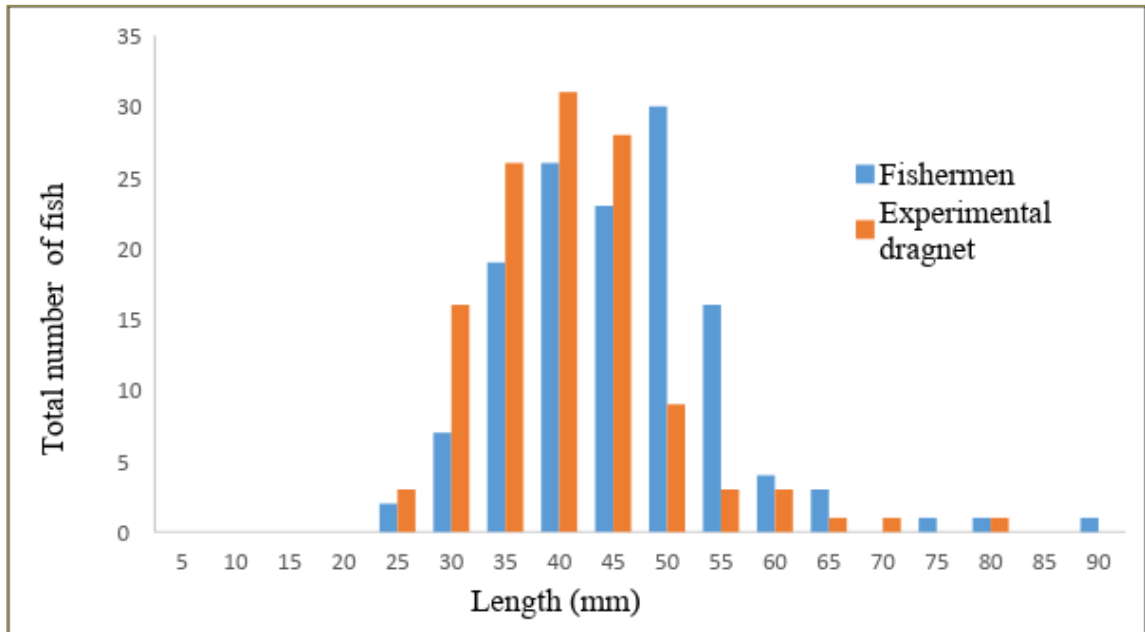


Figure 21. Length-frequency distribution for *T. sparrmanii* between fishermen and experimental gear catches, February to April 2017.

A similar trend in fish sizes caught from both groups is observed as depicted by the diagram above (Fig. 21). However, fishermen catches had a modal length class of 50mm in comparison to 40mm recorded for the experimental gear catches. The smallest length size (25mm) was recorded for both the fishermen and experimental gear whereas the maximum fish length (90mm) was only recorded for the fishermen catches. Equal numbers of 80mm size fish was recorded for both fishing groups. There was no

significant difference (Mann-Whitney value= 153; P= 0.385; df =1) in the fish lengths sampled during the flood period between the fishermen and the experimental gear .

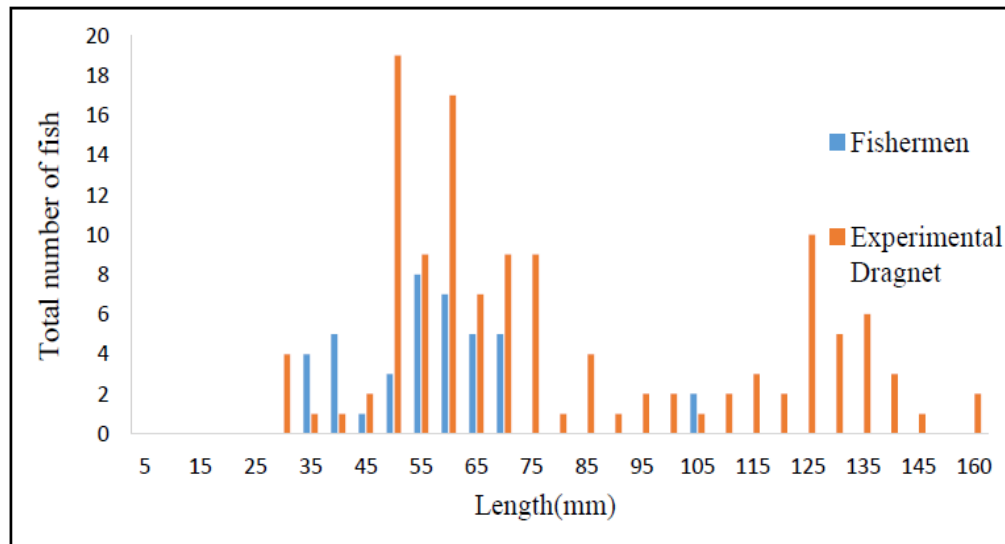


Figure 22. Length-frequency distribution for *H. vittatus* between fishermen and experimental gear catches, February to April 2017.

Various fish sizes of *H. vittatus* were caught during the flood season, with a length distribution ranging from 30mm to 160mm. The above diagram (Fig. 22) shows a bimodal length frequency distribution for the experimental gear catches with modal lengths at 50mm and 125mm. The experimental gear show an extensive fish length distribution as compared to the fishermen catches. The modal length for the fishermen is 55mm. All large sized fish were caught by the experimental gear with exception of two 105mm sized fish. Consequently, the experimental gear catches recorded both the smallest and largest fish sizes for the period that is 30mm and 160mm respectively. There was a significant difference (Mann-Whitney value = 714; P=0.036; df =1) in the

fish sizes caught by the fishermen and experimental gear catches for the February to April flood period.

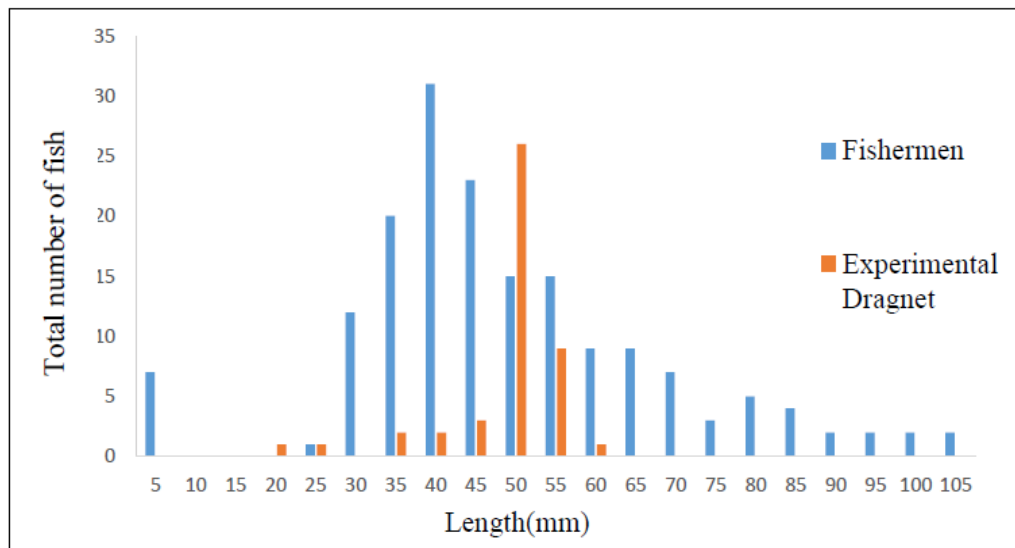


Figure 23. Length-frequency distribution for *C. rendalli* between fishermen and experimental gear catches, February to April 2017.

Coptodon rendalli fish length distribution ranged from 5mm to 105mm. Fishermen catches spread over an extensive range with the 40mm being the modal fish size. Whereas, experimental gear catches ranged from 20 to 60mm representing the smallest and largest fish size for the flood period. The 50mm was the modal fish size for the experimental gear catches. Both the minimum and maximum fish sizes were sampled only by the fisher with 5mm and 105mm respectively. There was a significant difference (Mann-Whitney value = 84.50; P= 0.000; df =1) in the length sizes of *C. rendalli* sampled between the fishermen and experimental gear catches for the flood period (Fig. 23).

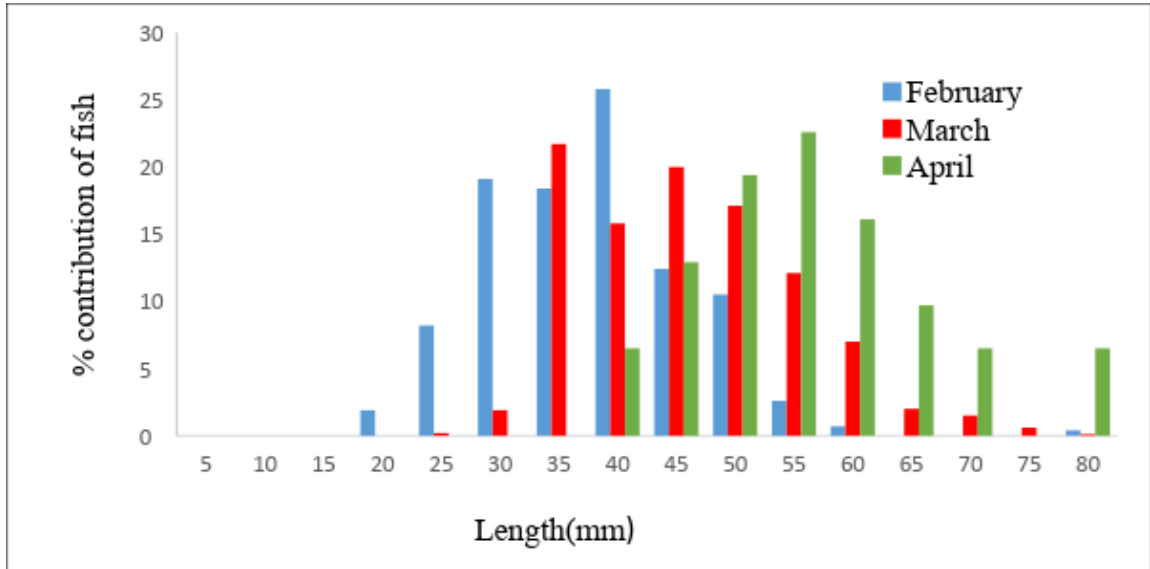


Figure 24. Length-frequency distribution for *O. andersonii* for the experimental gear by percentage number (%N), each month separately, February to April 2017.

As the floods started to rise in February, *O. andersonii* species composition by percentage number had an extensive length distribution from 20mm to 60mm. Only one 80mm fish length was recorded. As represented by the above diagram (Fig. 24) the modal length for February was 40mm, whereas for March, flood-peak, it was 35mm and 55mm for April as the floods recede. The length range for March is 30mm to 75mm whereas for April, fish lengths ranging from 40mm to 80mm. from the diagram above, it is observed that during the flood peak, March, and when the flood recedes (April) there are larger sized fish as compared to the onset of the flood period during February. March and April catches have high frequency for length sizes 45-70mm with larger fish being recorded in April at 80mm as compared to February and March. There was a significant difference ($Kruskal-Wallis = 6.754$; $P = 0.034$; $df = 2$) in the fish lengths sampled for the

flood period. April and March ($P=0.028$) show significant differences in the length sizes of *O. andersonii* sampled, however, there are no significant differences between February-March ($P=0.689$) and February-April ($P=0.489$).

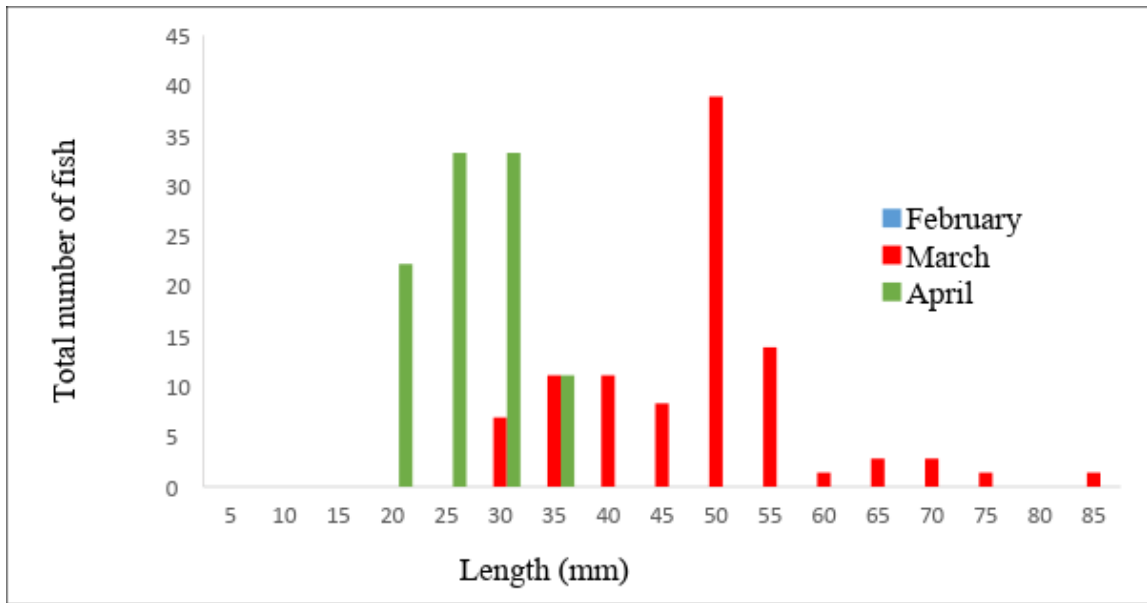


Figure 25. Length-frequency distribution for *C. rendalli* from the experimental gear catches, each month separately, February to April 2017.

In February, as the flood began to rise, there was no *C. rendalli* sampled from the experimental gear. However in alternative months *C. rendalli* was documented coming into the floodplain. The smallest fish size recorded was in April and the largest being in March each with 20mm and 85mm respectively by percentage number. A unimodal distribution is depicted in the above diagram for the month of March for the 50mm fish size. Whereas, in comparison a bimodal distribution is observed from the above diagram

(Fig. 25) for the month of April, for fish sizes 25mm and 30mm. The size distribution is extensive during the flood peak period, with larger fish, that is, 30-85mm. However, the 50mm fish size had the highest frequency for the period overall. Increasing number of 30mm fish sizes were caught in April as compared to March and equal numbers of the 35mm length class were caught in the two months. The small sized fish were recorded during the flood receding period, that is, the 20mm and 25mm fish sizes were recorded only in April whereas the 40-85mm fish sizes were only recorded in March during the flood peak period. There was a significant difference (Mann-Whitney 78.50; $P=0.022$; $df =1$) in the length sizes of *C. rendalli* sampled for March and April from the experimental dragnet.

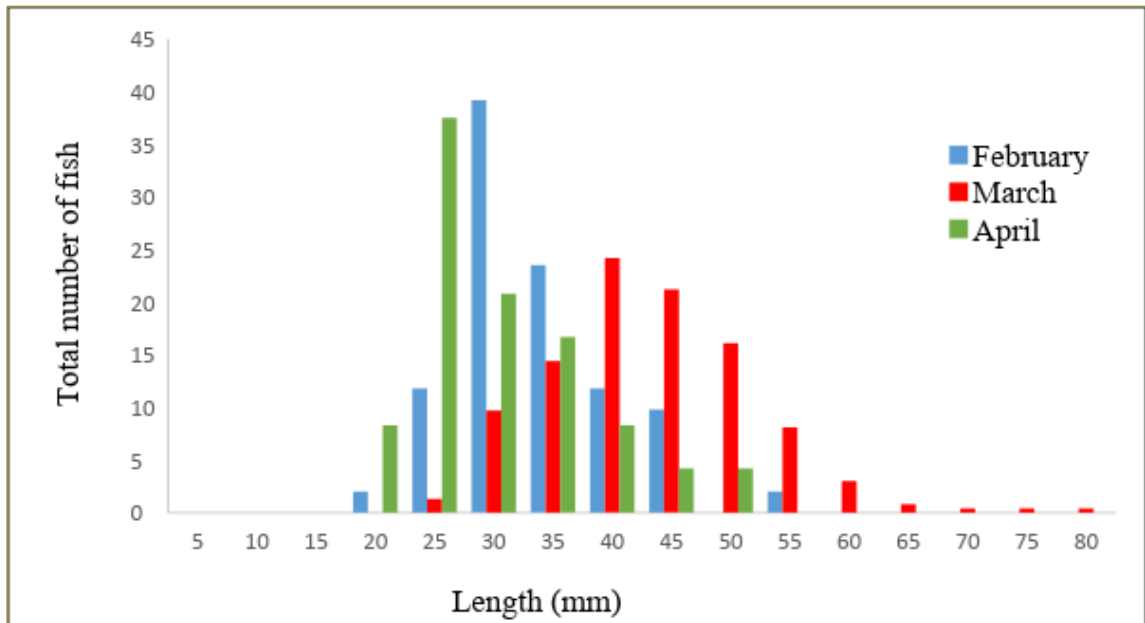


Figure 26. Length-frequency distribution for *T. sparrmanii* from the experimental gear each month separately, February to April 2017, Kruskal-Wallis, $df =2$).

For the flood period the fish sizes ranged from 20mm to 80mm. the diagram above (Fig. 26) shows that small size fish were recorded in February as the flood began to rise. Whereas the largest fish was recorded in March during the flood peak period, measuring 80mm. The modal length was 30mm for February, 40mm for March and 25mm for April. Fish lengths greater than 55mm were only sampled in March. There is no significant difference in *T. sparrmanii* length-frequency distribution (Kruskal-Wallis, $P=0.587$; $df =2$) for experimental gear catches between the different months.

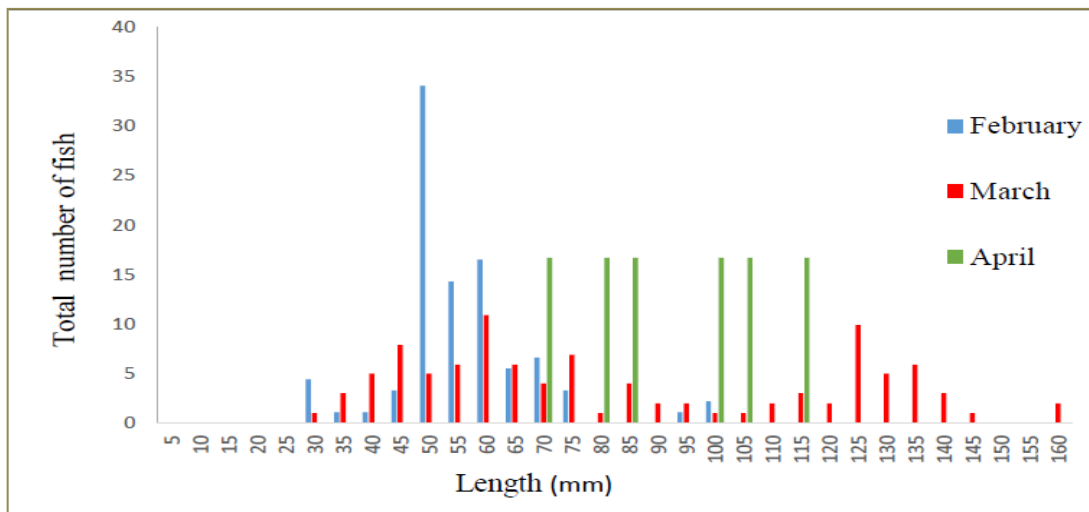


Figure 27. Length-frequency distribution of *H. vittatus* from the experimental gear each month separately, February to April 2017, Kruskal-Wallis, $df =2$.

Hydrocynus vittatus length size ranged from 30mm to 160mm for the flood period February to April. The modal length for February was 50mm as seen from the above diagram (Fig. 27). A bimodal distribution is observed for March for lengths 60mm and 125mm recorded for the flood peak period. The smallest fish were recorded in both February and March at 30mm, whereas the largest fish size was 160mm recorded only

March, during the flood peak period. The length-frequency distribution for March is largely extensive in comparison to the other two months with a major mode at the 60mm fish size. When months are compared, there were significant differences in the distribution of *H. vittatus* fish distribution for the experimental gear catches (Kruskal-Wallis test; $P=0.02$; $df= 2$) from February to April 2017. There was a significant difference between February and March (Kruskal-Wallis, $P=0.03$; $df=2$) and March and April (Kruskal-Wallis, $P=0.002$; $df= 2$).

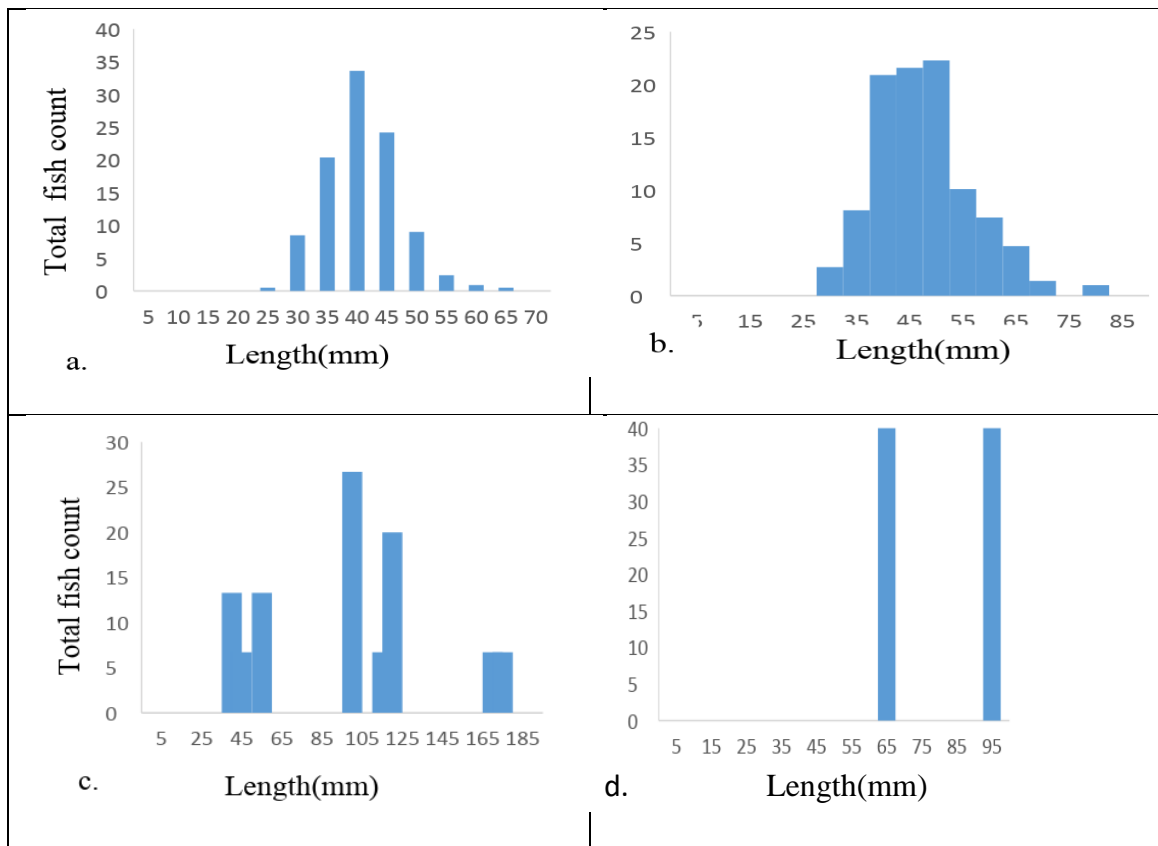


Figure 28. Length-frequency distribution of *O. andersonii* for weeks one (a) two (b) three (c) four (d) from the fishermen catches, February to April 2017.

As flooding progressed larger size fish were encountered. As the above shows (Fig. 28), in week one, rising period, *O. andersonii* fish sizes ranged in (a.) from 25mm to 65mm showing a modal length of 40mm the largest fish recorded was 65mm. In week two (b.) as the floods continue to rise, the fish lengths ranged from 30mm to 80mm and the modal length of 50mm. In week three (c.), the flood peak phase, the modal length was 100mm and as the floods receded, there was no modal length for the lengths 65mm and 95mm as they had equal representation. The fish sizes ranged from 40mm to 175mm. In week four (d.), during the flood receding phase, equal number of *O. andersonii* were sampled, that is for fish sizes, 65mm and 95mm. There was a significant difference (Kruskal-Wallis, $P= 0.000$, $df= 3$) in the distribution of length across the weeks with the exception for week one and week two (Kruskal-Wallis, $P=1.000$) for *O. andersonii*. There was no significant difference between week one-two ($P=1.000$); week three-four ($P=1.000$) however there was a significant difference between week one-three ($P=0.008$), week two-three ($P=0.007$), week one-four ($P=0.002$), week two-four ($P=0.002$) week two-four ($P=0.002$).

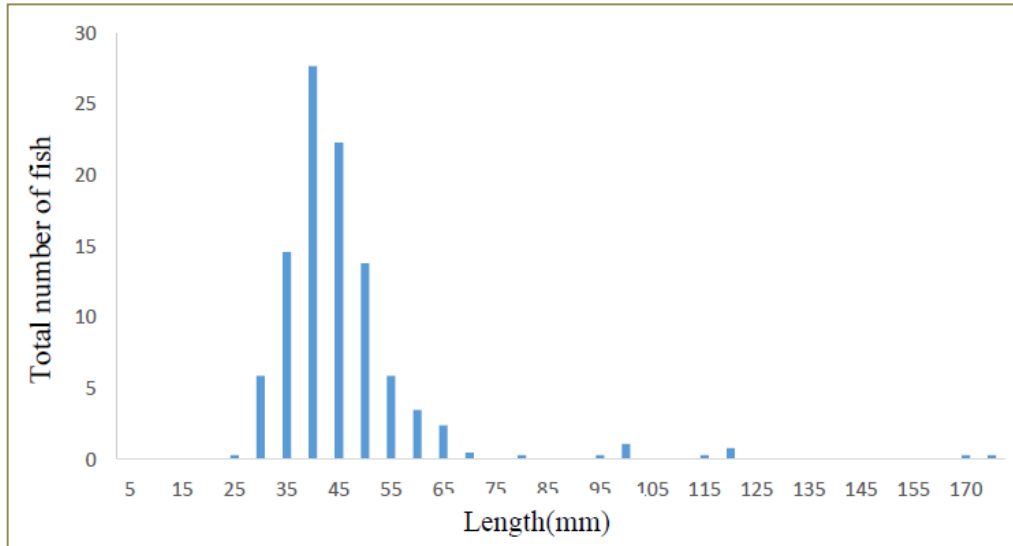


Figure 29. Length-frequency distribution for *O. andersonii* from the fishermen’s catches when all months are combined, February to April 2017.

For the flood period February to April (rising, peak and receding) the fish sizes ranged from 25mm to 175mm from the fishermen catches as shown above (Fig. 29). The modal fish length was 40mm. And the largest fish recorded was 175mm in week three, flood peak period. The minimum fish was 25mm recorded only in week one (a.) of the flood period. The second highest frequency was recorded for the 45mm fish length and this was from the beginning to the peak of the flood period.

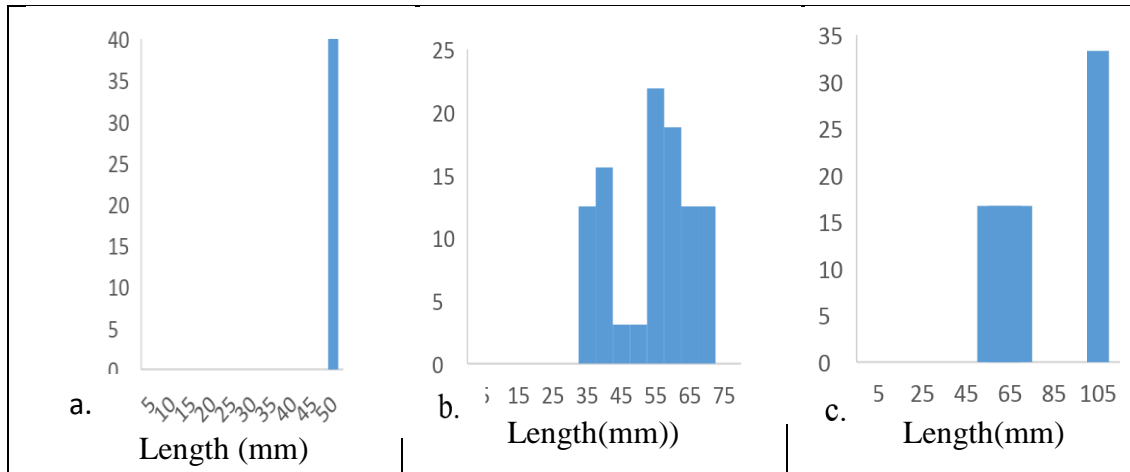


Figure 30. Length-frequency distribution for *H. vittatus* from the fishermen catches each week separately from February to April 2017.

As the floods began, no *H. vittatus* was present, that is in (a.) week one. However, in consecutive weeks as the floods continue to rise, *H. vittatus* fish species are encountered by the fishermen. Increasing numbers of *H. vittatus* were caught in week 3 (peak period) according to percentage number as the above diagram depicts. The fish sizes ranged from 35mm to 70mm during the flood peak phase as the above shows (Fig. 30). The modal fish length was 55mm. Equal numbers were caught for the 45mm and 50mm as well as for the 65mm and 70mm sized fish by percentage number. In week four as the floods receded, the fish sizes ranged from 55mm to 105mm. The modal fish length was 105mm and equal numbers for the sizes, 50- 70mm were recorded by the fishermen during the flood receding period. There was a significant difference (Kruskal-Wallis, $P = 0.012$, $df=2$) in the fish lengths between weeks two-three ($P=0.025$), weeks three-four

($P=0.034$) but however there was no significant difference between weeks two-four ($P=1.000$).

5.0 DISCUSSION

5.1 Floodplain species composition and catch variations

In total there were 34 different fish species occupying the KIFI floodplain for the 2017 flood period. In consideration of the fishes that contribute to fish communities sampled from fishermen and experimental gear according to %IRI, there are nine common species between catch methods. These are *O. andersonii*, *H. vittatus*, *T. sparrmanii*, *C. rendalli*, *M. johnstoni*, *P. acuticeps*, *P. philander*, *E. radiates* and *S. altus*. Differences are observed on the tenth species, *S. intermedius* is only in the experimental gear catches whereas *E. barnardi* in the fishermen catches according to %IRI. The difference in fish totals and species diversity between the fishermen and the experimental gear catches can be attributed to the intensification (effort) of harvesting by the former group. More fishermen hours were spent fishing; as compared to drag-netting-activity which was done once a week for no more than two hours. The results obtained are similar to a preliminary survey conducted during the previous year by Jacobs and Libala (2016), whereby *O. andersonii* was found to be the most dominant species both in number and weight in the KIFI floodplain by the MFMR. It was present throughout the flood period, February to April and thus is a floodplain resident fish species. Whereas, some fish species were encountered only in the beginning of the flood period, namely *O. macrochir*, *T. ruweti* and *L. cylindricus*. This could be as result of fish migrations e.g. *H. vittatus*. It is thought that species of Cyprinidae from Asia, Africa and Europe and Characoidei in Africa and South America are reticent members of this group, which at times undertake extensive movements thereby dispersing into productive floodplain

habitats with good water quality to exploit abundant resources thereby spawn (Graham and Harris, 2004).

5.2 Fishing Gears used by fishermen on the KIFI Floodplain

Various fishing gears were encountered in the study area included mostly modern types such as mosquito nets, hook and line, fishing baskets whereas some others were unique for the particular locality especially the baited plastic containers. Commonly operated gears were the mosquito net and plastic containers. This confirms previous findings by Hay *et al.* (2000) on the use of modern gear type employed in the harvesting the fishery. As the low lands flooded, usages of these gears increased. The fishing effort and fishing duration varied with the type of gear. However, there was no significant differences (Chi-squared test; $X^2=107.199$; $P=1.000$; $df=33$) in the fish sampled between the fishermen and experimental gear.

5.3 Species Abundance

Species abundance was higher at the beginning of the sampling period particularly in March but decreased as the flood receded. This may be the result that, as the flood rises; different fishes migrate onto the floodplain in response to increased food availability thereby increasing the productivity of the floodplain. However, as the flood recedes fish move to find refuge in other habitats (Avendaño & Ramírez, 2017) thus either leaving the floodplain forthwith or into isolated pools whereby mortality increases as a result of crowding, competition, predation and fishing mortality. The presence of predatory fish species namely *C. gariepinus*; *C. ngamensis*; *H. odoe* and *H. vittatus* (Jackson, 1961)

and could have been the resulting cause of variation in other juvenile fish abundance in the KIFI floodplain as the floods continued to rise to peak. Cichlids from the Kafue floodplain have been known to be prey species that constitute almost 19% of the food diet of *H. odoe* (Carey, 1971). In week three, *O. andersonii* species composition was the most common in the fishermen's catches and second most abundant in the experimental gear catches. *Hydrocynu. vittatus* composition is the most abundant in the experimental gear catches and is amongst the less common species in the fishermen's catches for the flood period. This therefore could be as a result that *H. vittatus* occupied the floodplain in response to increased food availability.

Species abundance decreased also as a result of fishing by the riparian community who depend on the fish from the floodplain river for protein and income. Species unique to the experimental gear catches are *H. multifasciatus*, *S. macrostigma*, *E. kerstenii*, *S. giardi*, *C. ngamensis*, *P. catostoma*, *L. cylindricus*, *H. cuvieri*, *S. greenwoodi* and whereas *O. macrochir*, *E. multilineatus* and *L. lunatus* are unique to the fishermen catches. Both of which are common species but its abundance (*L. lunatus*) fluctuates extensively relative to the magnitude of inundation (Tweddle *et al.*, 2004). *Labeo lunatus* is reported to coexist with *L. cylindricus* in rocky habitats, preferably inhabiting the main river channel where it was found broadly throughout the wetland system (Tweddle *et al.* 2004). It grazes on algae and detritus and is a known summer breeding fish (IUCN, 2017) It has been suggested that it may probably breed in flooded marginal habitats as its juveniles are mostly caught in fish weirs set across waters draining from floodplains (Marshall and Tweddle, 2007). The highest abundance of *O. andersonii*, *T.*

sparrmanii and *P. philander* were observed in March. Juvenile Cichlids (*O. andersonii* and *O. macrochir*) from the north-eastern regions of Namibia have been documented by numerous authors (Van der Waal, 1985; Hay *et al.*, 2000; Weyl and Hecht, 1998; Peel, 2012, Simasiku, 2014) to have sustained reproductive activity from September to April. Sexually mature females have been observed in August – March. These findings support the presence of high abundance of juvenile schools of *O. andersonii* and *C. rendalli* during the summer period. Previous study by Simasiku (2014) on the Okavango and Zambezi floodplains, enumerated high concentration of nesting activities of *C. rendalli* were observed between November and March. Fish species, *T. sparrmanii*, *P. acuticeps* and *P. philander* were most abundant in March and these observations track their reported breeding season.

Tilapia ruweti was much less common in its distribution than *T. sparrmanii*, representing less than 1.0% of the total catches for the experimental dragnet catches. These results are similar to findings from Hay *et al.*, 2000; Peel, 2012; Jacobs and Libala, 2016 Simasiku and Mafwila 2017 and seem to suggest that *T. ruweti* only inhabits the floodplain later when the environmental is conducive The fishermens gear catches had higher numbers of individuals sampled as compared to the experimental catches each with 33 and 2 respectively. Welcomme (1985) observed that *T. ruweti* is generally rare, but locally or seasonally common. The genus *Oreochromis* was represented in the study area by the *O. andersonii* and *O. macrochir*. Of the two species, *O. andersonii* was more common and present from February through April for both catch groups. However, *O. macrochir* was rare, with only 218 individuals collected from

the fishermen catches for the sampling period. This scarcity in *O. macrochir* may be related to an annual shift or to gear selectivity. Hay *et al.* (2000) reported a much higher relative abundance of the fish species in the Okavango River.

Two Cichlids of the genus *Serranochromis* were collected along the floodplain, that is, predators; *S. altus* and *S. angusticeps* being somewhat prominent in the flood peak and receding period. These coincides with the presence of increased numbers of different species namely *L. cylindricus*, *T. ruweti*, *B. unitaeniatus* and *P. philander*. Both these species were found in more than half the samples taken for both groups and constituted 66.7% and 10.2% for the fishermen and experimental dragnet catches respectively. *Hydrocynus vittatus* was the third most important species in the experimental dragnet catches, but ranked eighth in the fishermen's catches during the surveys (according to % IRI) this may be a result of gear selectivity that results in this variation. According to Winemiller 1991 *S. altus* feeds primarily on nocturnal mormyrid and schilbeid fishes whereas *S. angusticeps* ambushes small characids and cyprinids. This seems to suggest that they are likely to utilize the floodplain when there is an high species abundance upon which they can prey on and this is during the flood peak period.

Munwela, Hay, and Hamutenya, (2010); Peel, (2012); Simasiku (2014); Simasiku and Mafwila (2017) documented that the Okavango fish community is abundant with juvenile fish species. This is in line with the findings from this study and evidence from Hay *et al.*, 2000; Næsje *et al.* (2004) supports the theory that most of the fish caught may mature early. Van der Waal (1991); Hay, Van Zyl and Steyn (1996); Welcomme

(1998); Tweedle and Hay (2013); Næsje *et al.*, (2004); Hay *et al.*, (2000) reviewed the fish of the upper Zambezi River system, and their checklists of fish included the Okavango River. The latter work, particularly, parallels the research reported here in that seasonal shifts in abundance and diversity of the floodplain fish communities. With increasing fishing pressure, fish populations may undergo a series of changes in size, species composition and abundance as well as maturing early (Miethe *et al.*, 2010).

The Namibian annual rain cycle divides the year into periods of high fish productivity during the flood season, and relative inactivity and hardship during the dry season. However, Tockner and Stanford (2002) suggested that the flow regime is significant in determining the magnitude of ecological process and the temporal variability in floodplain communities and ecosystem process. So important is the hydrology regime of floodplains that it alters the diversity of not only fish but also some bird species. Minuscule changes in relative water sources may considerably alter the species composition and diversity.

According to Ward *et al.*, (2002) there is a direct correlation between fish catches and the maximum inundation of the floodplains in African rivers. Bruton and Kok (1980) in their findings, acknowledge that the dynamics regarding wetland fish communities is largely dependent on the continuous and periodically changing abiotic factors. This is marked particularly by water temperature and water level variations. Changes in these two factors may have several important functions that result in pulses of nutrient input and fish abundance. Biotic factors, such as food availability, diseases and symbiotic

relations are likewise crucial factors that affect species abundance. The decline in fish densities observed in April as the flood waters recede, marks the onset of the dry season. This decrease in fish populations may be the result that juvenile fish species migrate from the ephemeral floodplain habitats into deeper main channels and lagoon habitats as environmental conditions become unfavourable (Hocutt *et al.*, 1994).

5.4 Species Diversity

There were no significant differences (Kruskal-Wallis; $P=0.114$) in the catches for fishermen for the different weeks with regard to the experimental catches. However, there was a significant difference in species diversity (Kruskal-wallis test; $P =0.044$) between week two and three as shown (Fig. 21). From the fishermen catches five fish species had a high species diversity index value, that is *O. andersonii*, *T. sparrmanii*, *S. altus*, *P. philander* and *H. vittatus* each with 0.353, 0.249, 0.252, 0.211 and 0.184 respectively. The species diversity showed an increasing trend from week one to week three (highest species diversity index value) when the flood was at peak level and the number of fish was also the highest. This could be as a result of fish food availability on the floodplain and or serve as a refuge for several small aquatic species. In week four the trend started declining. In comparison the experimental gear had *O. andersonii*, *S. altus*, *P. acuticeps* *P. philander* and *T. sparrmanii* with diversity index values of 0.304,0.193, 0.179 0.172, and 0.122 respectively. Difference in species diversity in weeks between the fishermen and experimental gears is probably due to gear selectivity.

5.5 Body Length Distribution

These results reflect that the KIFI floodplain fish community is dominated by relatively small species (immature) and individuals. Two fish species were recorded with a body length over 80mm and these were *H. vittatus* (105mm) and *C. rendalli* (85mm) whereas *P. philander*, *M. johnstoni* and *P. acuticeps* were among the small size fish species sampled by the fishermen and experimental gear catches with individuals sampled less than 50mm. This confirms the finding by Hay *et al.*, (2000) that the Okavango River particularly in fishing communities is endowed with small fish species with some species identified to be sexually mature at a relative early stage in the life cycles such as e.g. *P. philander*. According to % IRI *P. philander* was the third dominant species in the fishermen catches whereas it was the sixth most dominating species in the experimental catches each with 4.5% and 5.9% respectively. The modal length was 40mm for both fishermen and experimental dragnet catches. Findings from Hay *et al.*, (2000) documented that at this length most of *P. philander* sampled had reached maturity. There was no *H. vittatus* fish species observed in February and April, for the fishermen and experimental gear respectively. However, in March (flood peak period) there was some fish sampled and the lengths ranged from 35mm to 105mm. The modal length for the distribution was 55mm (still immature) fish size and the second highest frequency for the distribution was 60mm with the largest fish recorded being 105mm. *Serranochromis altus* was another species that was not observed for the months of February and April, flooding rising and receding periods. However, samples were collected in March, flood peak period, and the fish lengths ranged from 25mm to 90mm

(all immature). The modal fish length was 50mm with the second highest length was 45mm and the overall largest for the distribution being 90mm. *Hydrocynus vittatus* was only observed in March during flood peak period and usually in deep waters of the floodplain hunting in like size shoals, this could be that it relies on other fish as its staple diet for most of its life.

The observation that there were different sized species over the period could be a result of rapid growth during the flood season which has been correlated with periods of increased food availability, high temperatures and reduced density-dependant competition, conditions which are reversed during the dry season (Welcomme, 2001). Furthermore it was observed by Dudley, (1974); Merron, (1991); Weyl & Hecht, (1998); van der Waal, (1985) that for some fish species namely *O. andersonii*, *O. macrochir* and *C. rendalli* have an extended spawning season which generally extends throughout the summer period. Within this period multiple broods may be raised. However there was no significant difference in fish size for *O. andersonii*, *T. sparrmanii* and *S. altus* for the fishermen and experimental gear catches observed showing that the fishermen catches were not selective for large sized fish species such as these. For *C. rendalli* (Mann-Whitney value = 84.50; P= 0.000; df =1) and *H. vittatus* (Mann-Whitney value = 714; P=0.036; df =1) there were significant differences in the fish size recorded for the flood period. Findings for variation in growth are, however, often inconsistent or contradictory between different species and systems (Welcomme, 1985, 2001) and in addition to intra-annual variation, fishes often show inter-annual variation in growth in floodplain systems. It is believed that growth rates may also vary substantially within and between

populations of conspecifics and this is usually the result of different environmental conditions experienced by individuals or populations (Booth *et al.*, 1995; Oliveira, Ferreira, & Ferreira, 2002; Shephard & Jackson, 2006; Weyl & Hecht, 1998).

5.6 Floodplain Hydrology and Fish Migrations

Established fish ecology information includes as floodwaters draw-back, many fishes migrate back to the river channel, but some juveniles in particular, may occupy structurally complex aquatic habitats of the floodplain where current velocity is lower (Winemiller, 1996). Water flows are the primary orientation cues for migration due to fish's natural rheotactic tendency. According to Schiemer *et al.*, (2013) some fishes avoid deteriorating conditions on the floodplain by undergoing migration to the main river channel and frequently by more extensive movements in the river beyond the floodplain area. This might be the case for *O. macrochir*, *T. ruweti*, *L. cylindricus* which were only sampled during the inundation phase for the flood period Simasiku and Mafwila (2017) observed *O. macrochir* and *O. andersonii* juveniles in late April which seems to suggest that they have a long breeding period. These fishes are collectively grouped as “Piracema” or “Subienda” species in Latin America, whereas in the Mekong they are termed “white” fishes, and in other river systems may be classified as rheophilic (World Bank, 2001). In this view, the migration of any fishery is important to note. Prime examples include two noteworthy migratory fish species that occupy floodplains; the *L. victorianus* in the Nzoia River and that for *Labeo altivelis* in the Luapula which have collapsed due to over-exploitation (Welcomme, 1985). A decline in fish densities maybe justified by the fact that juvenile fish migrate from the ephemeral floodplain

habitats into deeper main channels and lagoon habitats when faced with harsh environmental conditions (Hocutt *et al.*, 2001)

Many Cichlids have been documented to respond to the annual flooding cycle by migrating from dry refuges to habitats that are more productive and favourable for feeding (Welcomme, 1985; Junk & Welcomme, 1990). Furthermore habitat diversity is postulated to be highest in the floodplain sections, with flooded grasslands, flooded forests, small and large river channels, and permanent and temporary lakes and pools. Scientists have hypothesized that this species migrate during the rains to spawn(seasonal), that is, they congregate at river mouths (ovulation occurs during the subsequent upstream migration) whereas some have been noted to be less seasonal (periodic) and is apparently tied to rain and/or temperature cycles (Munroe *et al.*, 1990). Many fish species have been documented by numerous authors performing their characteristic migration patterns throughout the year. Jackson, (1961) observed juvenile *O. macrochir* in Lake Mweru migrate between the lake edges into open after attaining an advantageous size for predator escape. Juveniles of *L. capensis* and *E. anoplus* have been noted to migrate from marginal areas into offshores leaving smaller sized individuals in the inshore. In the reverse, Ellender *et al.*, (2008) observed *O. mossambicus* juveniles migrate offshore into deep estuary channels after attaining an average size of 80 mm. Each of these habitats is thereby used by different fish species for their essential life processes, including spawning and feeding (FAO, 2014). This survey revealed that the peak fishing time for the 2017 flood period was during the rising phase of the flood and during peak water periods when the fish were abundant, i.e.

from mid-February to the end of March. In March, during the peak flood, the floodplains support an abundance of small insects, crustaceans and plankton upon which it can feed on in open waters. Some aquatic vegetation such as macrophytes may support higher fish diversity, abundance and species richness, influencing the fish assemblage structure.

According to past observation (Hay *et al.*, 2000) and the results of the present study, the juveniles of cichlids for instance *O. andersonii*, *T. sparrmanii* *H. viattaus*, were abundant at the rising and the peak of the flood. However, as the flood receded they were encountered less frequently. This might have been due to increased fishing intensity (increases in number of fishermen and fisher-hours) that depicts the onset of floodplain harvesting. Sustained harvesting pressure can lead to a decrease in number of fish found in floodplains. This was discussed in previous studies done by Hay *et al.* (2000); Peel (2012), Mosepele *et al.* (2009); Tweddle and Hay (2013) increasing catch rates are decreasing fishing communities whereby larger and more valuable fish species are being replaced by smaller less valuable species. This results in impoverished rural fishing communities which have become trapped in a cycle of declining individual catches resulting from increased effort and the use of environmentally destructive fishing gears that catch the scanty remaining small fish species.

Many fish species have been documented to migrate back to the river channel when water levels fall within the floodplain. According to Dutterer *et al.*, (2013) some juveniles can remain in structurally complex aquatic habitats of the floodplain where current velocity is lower. As the floods start to recede *H. vittatus* is encountered less.

Whereby, *H. odoe* species starts being encountered as the floods recede. This is thought to be as a result of *H. vittatus* preying on *H. odoe* and the species compete for similar food resources. *Hepsetus odoe* spawning season is speculated to vary depending upon the region. With some researchers suspecting that the spawning season usually begins after the flood season has begun and that flood waters may possibly stimulate the gonads of the species namely *H. odoe* (Merron and Bruton, 1994). Merron and Bruton (1988) suggested that many floodplain breeders spawn during periods when relatively higher temperatures are experienced from September to December. Whereas, during cold water periods are known to result in significant fish mortalities, particularly in shallow waters. Some researchers are of the view that Cichlids may spawn instinctively before flooding occurs. This period is simultaneous with two factors, that is, increased day length and temperature which are thought to be the primary cues (Chimatiro, 2004; Merron, 1991; Weyl and Hecht, 1998; Winemiller, 1996; Van der Waal, 1985).

5.7 Fish Yield in the KIFI Floodplain

For the fishermen observed a total of 178 pap-baited plastic containers were employed in the fishery from February to April. The total catch was estimated at 0.101kg/day for 18 fishermen days. A total of 7.754kg of fish was calculated for the entire flood period. There were a total of 16 mosquito-nets in use during this period and this resulted in an estimated 1.980kg of fish per day. For the sampling period this was estimated to be 49.654kg of fish. From these findings the floodplain at KIFI is estimated to produce an estimated 3.94kg/ha. However, according to research, the Okavango Delta ecosystem is projected to support an annual fish yield of 5000-8000 tonnes (FAO, 2003). At present,

the catch figures from this study are very low. This is in regard to the production from an overall floodplain area estimated at over 250ha, thus there is minimal impact on the fishery from harvesting done by the local fishermen.

6. CONCLUSION

The KIFI floodplain fishery is exploited by subsistence fishermen, mainly women and children particularly those people who do not possess production assets. They engage in fishing year to year and their efforts are intensified during the flood-periods so as to catch more fish by making use of relatively cheap and simple gears which may reduce the overall number of immature individuals within a species. In light of this, it is evident that, floodplain fisheries are an important renewable resource in Namibia. Therefore, the traditional rights of rural communities who derive sustenance from this resource should be safe-guarded though they may be contravening legislation. The present catches by the local fisher-folk consists mainly of small species (mainly juveniles of large sized species) with a relatively low commercial value which only provide for subsistence.

Populations of fish increase through the flood season reaching a maximum at peak floods thereby declining both numerically and by weight during the receding period. Although, some fish species may be preferred as food (*H. vittatus*; *C. rendalli* and *O. andersonii*), the fishermen seem to spend more effort on increasing the quantity of fish (and thereby food supply) rather than selectively catching specific species although it ultimately leads to selective fishing by the fishermen. When total catches in small scale fisheries are falling, it is associated with decreased amounts of water or deteriorating water quality and aquatic habitats. Another example is from the observed decrease in the size of fish caught (as described above), which is general interpreted as a sign of overfishing (Kolding *et al.*, 2014). A decrease in size, as in the common “fishing down process”, may be a sign of fishing, but not necessarily a sign of overfishing. It may also

be interpreted as a healthy sign of a redistribution of fishing effort over larger parts of the fish community and thereby keeping the structure intact (Kolding et al., 2014). In assessing the current status of the KIFI floodplain ecology, the present contribution has produced an up to date archive of the fish database by validating and supplementing previously referenced and established fish database,. This will also enable researchers to compare these findings against future derived database from the Kamutjonga areas as well from other sources for northern Namibia fishery.

Catching small fish, which are sun-dried and consumed whole, is the most high-yielding, eco-friendly and nourishing way of utilizing the natural food that aquatic ecosystem provides. In some instances, maintaining healthy aquatic ecosystems is more important than the traditional fishery management scheme. Furthermore, it is evident from this study that the KIFI floodplain is rich in biodiversity particularly fresh water fish species including commercially important species hence management initiatives should ascertain that harvesting is regulated in such a manner that does not only work to restrict the populous that rely on the resource, but it should enable and promote the sustainable utilisation of the resources. The results from this study will help provide an improved understanding of past extreme precipitation events that are required for scientists, practitioners, policymakers and civil society to better compare and otherwise refer to.

7. RECOMMENDATIONS

- Promote and invest in development of infrastructure in Namibia's rural areas especially a fish market such as in the Zambezi region.
- Sensitization of the community towards the need to promote a 'healthy' floodplain ecosystem. In terms of operations, the KIFI floodplain may established into a Fish Protected Area as gazetted by MFMR maybe be a liable option.
- Due caution to be practiced with regard to small or large scale anthropogenic changes to rivers regime.
- Further research in the KIFI floodplain should be carried out in relation to breeding, nursery habitats, flow, depth requirements for sensitive species in the floodplain is required.
- Further monitoring of the effects of tsetse fly spraying activities on fish species and populations in various habitats is needed.
- Research into transmission of emerging infectious diseases from wildlife that may threaten biodiversity and human health should be carried out.

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