

FISH SPECIES COMPOSITION, FISH SIZES AND DIVERSITY IN THE KAMUTJONGA
FLOODPLAIN, KAVANGO RIVER, NAMIBIA

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ABSTRACT

Floodplains are amongst the most productive aquatic environments on earth providing valuable ecosystem services to communities such as being a valuable protein source for marginalized communities. This study ultimately aims to provide information on the fish species composition, fish sizes and species diversity in the Kavango River's Kamutjonga floodplain as a basis to provide management advice to ensure the sustainable use of the fisheries. The fish species composition and relative abundance were assessed in the Kamutjonga floodplain along the Kavango River between February and April 2017, February to June 2018 and February to June 2020. Fish sampling was carried out once weekly using a seine net. A total of 2924 fishes were collected in 2017, 1678 fishes in 2018 and 4461 in 2020. The catch per unit effort (CPUE) by number was higher in 2017, followed by 2018 and lastly 2020. 31 fish species from 10 families, 37 species from 11 families and 31 species from 9 families were identified in 2017, 2018 and 2020 respectively. The Cyprinidae family was most prominent in the catches in 2017 and 2020, whereas the Cichlidae family dominated the catches in 2018. According to the index of relative importance, the most important species according to number in 2017, 2018 and 2020 were *Oreochromis andersonii* comprising of 47.7%, 27.1% and 49.6% of the total catches, respectively. The total weight of fishes collected in 2017, 2018 and 2020 were 6.404 kg, 5.963 kg and 11.456 kg respectively. The two most important fish species according to weight throughout the sampling period were *O. andersonii* (2.990 kg in 2017, 2.300 kg in 2018 and 6.273 kg in 2020) followed by *Hydrocynus vittatus* (1.546 kg in 2017, 1.915 kg in 2018 and 1.076 in 2020). The highest weight of fish was found in 2020, however, the catch per unit effort (CPUE) by weight was highest in 2018, followed by 2017 and then 2020. The majority of *Oreochromis andersonii* sampled were between the length classes 41 mm to 50 mm (n = 489) in 2017, 61 mm to 70 mm (n=89) in 2018

and 31 mm to 40 mm (n=606) in 2020. The majority of *Coptodon rendalli* sampled were found between the length classes 51 mm to 60 mm in 2017, 21 mm to 30 mm, 41 mm to 50 mm in 2018, and 41 mm to 50 mm in 2020. The majority of *Hydrocynus vittatus* sampled were found between the length classes 51 mm 59 mm (n = 54 mm) in 2017, 71 mm to 80 mm (n = 48) in 2018 and 31 mm to 34 mm (n = 68 mm) in 2020. This study found no significant difference in fish species diversity between years. The water level of the Kamutjonga floodplain had an influence on the catch rates, however, the water temperature did not affect the catch rates (catch per unit effort by number) in all the three years of sampling.

Key words: Floodplain, Kamutjonga, Kavango River, species composition, diversity, relative abundance, catch per unit effort.

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DECLARATION

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1. INTRODUCTION

1.1 Background of the study

Globally, floodplain fisheries are considered an important source of protein to sustain livelihoods (FAO, 2016). Floodplains are defined as flat land areas adjacent to rivers which become inundated by lateral water overflows from river channels, during high-flow periods (Welcomme, 1975). Floodplains cover about 2×10^6 km² globally and are some of the most productive renewable biological resources worldwide (Tockner, 2002). The aim of this study was to assess the fish species composition, fish sizes and species diversity on the Kamutjonga floodplain. This study will contribute to the current knowledge on floodplain fish species, their biology, behaviour and the influence of environmental factors such as temperature on the catch per unit effort in floodplains such as the Kavango River's Kamutjonga floodplain.

Floodplains are considered important habitats for biodiversity, which includes aquatic invertebrates, fish and wildlife (Høberg et al., 2002; Welcomme, 1979; Junk, 1989). Moreover, floodplains are of great importance in terms of providing fertile environments for agricultural purposes such as cultivation, grazing grounds for livestock and reeds for building traditional houses (Lindholm, 2007). The nutrients released from soil, detritus and faeces during the transition from terrestrial to aquatic systems make floodplains fertile (Høberg et al., 2002). The most important service of floodplains is arguably the production of protein for riparian communities as they can support large fisheries (Welcomme, 1979). The fisheries associated with floodplains are regarded as key sources of food security and employment for riparian communities (Weyl et al., 2010). In many countries, floodplains are a key livelihood resource in terms of providing services

to the rural poor, especially at household levels in times of crop failure or during drought periods (Mitchell, 2013).

Inland fisheries in Africa

Africa has a population of about one billion people of which over 200 million people use fish from inland fisheries for consumption (FAO, 2018). Fish is the main source of animal protein and the fisheries provide a direct source of livelihood to over 10 million Africans (FAO, 2016). In this continent, many people that are fully dependent on freshwater ecosystem services are living in rural areas where there is a high richness of freshwater biodiversity including healthy fish stocks (Darwall et al., 2011). People depend upon biodiversity for survival, such as for the foods and materials for building homes. The global fish production from inland fisheries in 2018 was 12 million tonnes of which 25% is from Africa (FAO, 2020).

In 2011 the estimated added value of inland fisheries to the GDP of Africa was 0.33%. According to de Graaf and Garibaldi (2014) there are approximately 6.1 million fishers of which 3.4 million women are employed in the fisheries sector in Africa. It is suggested that there are five steps linked to the fisheries value chain through processing, preservation, transport, marketing, production and maintenance of boats and gear (Welcomme, 2011; Youn et al., 2014). Abbott et al. (2015) emphasize that the fisheries value chain may be underrated and the importance of small fish in Africa for sustainable and healthy livelihoods, especially during disasters, is poorly understood because the small-scale artisanal fisheries are seldom monitored. These catches from small-scale fisheries are either consumed locally or sold in informal markets and as such go unrecorded in the catch statistics (Kolding et al., 2016).

Inland fisheries in Namibia

Namibia is considered an arid country with a climate characterized by hot and dry conditions and occupies an area of 824 290 km² of which about 5 000 km² is under water (FAO, 2018). In the north-east part of the country, the amount of rainfall received is between 500 to 600 mm per year (Ward, 1992), and the mean annual rainfall is estimated to be 285 mm of which 83 percent of the total rainfall evaporates, 14 percent is used by vegetation, 2 percent becomes runoff and only 1 percent goes underground (Aquastat survey, 2005).

The north-eastern Namibia has diverse wetland habitats such as perennial rivers and their associated floodplains which has great species richness compared to other parts of the country (Curtis, et al., 1998). The five perennial rivers in Namibia are the Lower Orange River, Kunene River, Kavango River, Upper Zambezi River, Chobe River and Kwando River and are shared with neighbouring countries. In Namibia, approximately 51% of the population lives in urban areas and 49% of the population lives in rural areas where the majority of the people are situated around or near wetlands.

The overuse of wetlands and agricultural activities has resulted in deforestation, overgrazing and overfishing (Hay et al., 2000). Floodplain fisheries provide a major source of protein and income to these riparian communities (Purvis, 2001). The poor people that are found in the northern part of Namibia are a good example of people who are more dependent on fish as a source of food (Hay et al., 2000). As a newly independent country, Namibia is concerned about conserving its biodiversity by maintaining viable populations of species at all levels to preserve, maintain and sustainably use, restore and enhance the natural environment for the present and future generations (Curtis et al., 1998). In Namibia, there are 114 freshwater fish species with five endemics including

the Caprivi Killifish (*Nothobranchius capriviensis*), the Cave Catfish (*Clarias cavernicola*) and Otjikoto Tilapia (*Tilapia guinasana*) (Holtzhausen, 1991).

There have been some baseline investigations conducted on fish stocks of the Namibian rivers. The maximum sustainable yields for Zambezi / Kwando Rivers and Kavango River has been estimated even though the data on MSY is unreliable because management of these complex systems should be based on time series data from monitoring programmes (Tvedten et al., 1992). The annual biological surveys conducted by the ministry of fisheries and marine resources in Namibia has indicated a decline in catch rates (Tweddle et al., 2015). This agrees with the report by Ortmann, (2009) there is a decline in the catch rates due to various factors particularly over-fishing. Despite this decline in fish stocks, communities in rural areas continue to fish because they do not have other alternative livelihoods (Tweddle et al., 2015).

The Kavango River fishery

The Kavango River also known as the Cubango in Angola originates in the highlands of Angola (Johnson & Hocutt, 2001). It is shared between Namibia, Angola and Botswana (Hay et al., 2000). According to Bethune (1991), the Kavango River contains low concentrations of nutrients, phytoplankton, zooplankton, microphytes and suspended solids. It has been recorded that 78% of freshwater fish found in the Namibian section of the Kavango River are floodplain dependent for larval and juvenile stages, and therefore they are dependent on migration between floodplains and the main river (Barnard, 1998).

Munwela (2010) states that there are approximately 202 000 people in the Kavango region and about 82% of the population resides up to about 3 to 5 kilometers from the river in rural areas. The fishing methods that they use include traditional gears such as baskets and fences as well as modern

gears such as gill nets, seine nets, hook and line as well as mosquito-nets which are environmentally destructive (Munwela, 2010). According to Hay et al. (2000) fish is an important source of subsistence and income in the majority of the households in the Kavango region and any changes in the ecosystems such as lower flood levels new methods of fishing or the destruction of habitats can cause the fishery in the Kavango River to be modified. In addition, an increase in population in the region results in increased fishing activities which might end up leading to conflicts between fishermen that are fishing for different purposes on the Kavango River (Hay et al., 2000).

Dynamics of the floodplain fisheries

The timing and duration of flooding determine the growth, recruitment and survival rates of fishes on floodplains (Holtzhausen, 1991). The inundation of floodplains has been thought to improve fish recruitment by providing a suitable environment for fish spawning (Siziba et al., 2013) or enhancing larval and the survival of juveniles by providing them with abundant food (King et al., 2003). In addition, fish consume some organic matter that has accumulated on the floodplain in the form of nutrients, phytoplankton, zooplankton and macrophytes. Floodplain river fishes spawn before or during the inundation of temporary wetlands and raise their juveniles within these habitats (Merron, 1991; Welcomme, 2001).

Temporal floodplains provide important habitats for juvenile fish and support large populations of small sized fish species (Siziba et al., 2011). The *Enteromius* spp are some of the fish species that occupy the floodplain habitats. The high productivity on the floodplain which is due to the terrestrial vegetation and other organic matter results in the fast growth of these fish species. According to Høberg et al. (2002), there are 80 fish species in the Okavango Delta with a fish

production of approximately 10 000 tonnes which in turn serves as a source of food for other organisms.

The size and duration of the floods have an impact on not only the structure and function of the floodplain, but also on the water chemistry as well as the productivity of the biota on the floodplain (Lindholm et al., 2007). Several studies have suggested that there is a close relationship between flooding patterns and the general dynamics of a floodplain that leads to variations in the abundance and diversity of aquatic biota (Hocutt and Johnson, 2001; Høberg et al., 2002; Lindholm, 2007; Mosepele, 2001).

Although floodplains are highly valuable, they are also vulnerable ecosystems (Curtis et al., 1998). Floodplains are becoming highly threatened due to anthropogenic activities such as water abstraction, overgrazing and overfishing (Siziba et al., 2011). Changes in these anthropogenic activities are among the factors that threaten the survival of aquatic biota in floodplain wetlands (Curtis et al., 1998). Moreover, floodplains have also been degraded by river and flow management (Tockner et al., 2008). Floodplains are also used by an increasing human population for many ecosystem services such as providing water for human activities for instance irrigation, drinking water and power production (Curtis et al., 1998; Hay et al., 2000).

Flood pulse concept

The flood pulse concept describes an ecological response to flood pulsed hydrology (Junk et al., 1989). The flood pulse concept focuses on the lateral exchange of water, nutrients and organisms between the river channel and the connected floodplain (Junk et al., 1989). According to Junk et al. (1989) the flood pulse supports rich nutrient cycling between the floodplain and the river which is considered the most vital driver for biological productivity in floodplains. According to Junk et

al. (1989) nutrients from the terrestrial sources such as vegetation and detritus accumulates on the floodplain at the beginning of the flood season resulting in the movement of fish onto the floodplain to make use of the increased food availability as well as making use of the floodplain for spawning and as a nursery. The life cycles of biota inhabiting the floodplain are related to the flood pulse in terms of its annual timing, magnitude and duration (Johnson & Hocutt, 2001). The longer the floodplains are inundated, the higher the survival rates of the juveniles and the higher the fish production (Junk et al., 1989). However, as soon as the flood recedes, fish move out of the floodplain to find refugia and mortality increases due to crowding and predation (Junk et al., 1989). Bayley (2005) stated that the flood pulse enhances biological productivity and controls the adaptation of biota on the floodplain while maintaining diversity in the system. The effect of the flood pulse concept is often suggested as being a major driver for fish population dynamics in systems that are regularly inundated (Junk et al., 1989). According to Johnson & Hocutt (2001) the flood pulse concept implies that the rate of rising and falling, the magnitude and duration of the flood are reflected in the ecological character of the associated biota. Research investigating the influence of the flood pulse on fish populations throughout the world has been conducted with a variety of results and much of this research shows that these relationships are complex (Mosepele, 2011; Hocutt & Johnson 2001).

Fishing patterns on rivers and floodplains

There is increasing concern on the impact of fishing on ecosystems and fish production throughout the world as the growing need for food security increases (Garcia et al., 2012). The traditional and modern gears used in the diverse habitats of rivers and their associated floodplains by the local communities and fishers have impacted the fish communities differently (Hay et al., 2000). A

management approach such as gear restrictions, mesh and fish size limits may increase catches in some gears or reduce catches in others. In addition, this may influence the distribution of catches and income among fishers and local communities (Hay et al., 2000). The principle of balanced harvest has been suggested to steady increase total catches in many African fishery systems (Kolding et al., 2015). For instance, in Mozambique the fishing pattern has shifted to focus more on productive smaller organisms (Tilley et al., 2020). Garcia et al. (2012) asserts that fish are adapted to high juvenile mortality because juveniles have low survival rates therefore preserving large fish will lead to limited ecological effects. The popular notion of growth overfishing which involves the harvesting of juvenile fish and the selective removal of adult fish from fish populations might result in the reduced catch rates or even the depletion of stocks (Kolding et al., 2015).

1.2 Statement of the problem

Previous fisheries research activities in the Kavango River have mainly focused on the main river fisheries and less on the understanding of dynamics of the floodplains and its fisheries. There is a need to better understand the dynamics of the floodplains and their intrinsic value to riparian human communities. This in order to develop an improved and sustainable management plan for the Kavango River and its associated floodplains which support the local people with valuable protein. Presently, there is no reliable data on fish species dynamics that can serve as a basis for providing management advice on the sustainable use of the fishery resource found on the Kamutjonga floodplain which support the local people with valuable protein. Women and children in particular have been observed each flooding year on the Kavango River's Kamutjonga floodplain fishing with different fishing gears such as mosquito nets targeting smaller fishes which

may result in adverse consequences of growth overfishing and place a detrimental impact on the ecosystem.

1.3 Objectives of the study

The objectives of this study are to assess the fish species composition, fish sizes, species richness and diversity of the Kamutjonga floodplain, Kavango River as well as the influence of environmental parameters such as water temperature and water level on the catch per unit effort.

Specific objectives:

- a) To assess the fish species composition of the Kamutjonga floodplain during the flood period of 2017, 2018 and 2020.
- b) To determine the species richness and diversity on the Kamutjonga floodplain between the years 2017, 2018 and 2020.
- c) To determine the seasonal and annual catch per unit effort of the dominant fish (*Oreochromis andersonii*, *Coptodon rendalli* and *Hydrocynus vittatus*) in Kamutjonga floodplain during the flood phases of 2017, 2018 and 2020.
- d) To determine the variations in the length frequencies of the dominant species (*Oreochromis andersonii*, *Coptodon rendalli* and *Hydrocynus vittatus*) in the Kamutjonga floodplain between the years 2017, 2018 and 2020.
- e) To determine the relationship between catch per unit effort and environmental parameters (water level and water temperature) in the Kamutjonga floodplain.

1.4 Hypotheses

- a) There was no significant difference between species diversity on the Kamutjonga floodplain between the years 2017, 2018 and 2020.
- b) There was no significant difference in the monthly and annual catch per unit effort by number of all fish species of the Kamutjonga floodplain between years 2017, 2018 and 2020.
- c) There was no significant difference in the catch per unit effort by weight of the most dominant fish species in the Kamutjonga floodplain between years.
- d) There was no correlation between catch per unit effort and water parameters (water level and temperature).

1.5 Significance of the study

As the ministry of fisheries and marine resources continues with laudable efforts in seeking solutions to sustainably manage the fishery of the Kavango River and its floodplains, there is a need to better understand the fish species composition, fish sizes and diversity in these complex and variable floodplain ecosystems. The results will serve as baseline data that will be provided to the fisheries managers in order to enable them to make informed decisions regarding the management of the Kamutjonga floodplain. The information from the study will also be provided to the local community in order to encourage them to sustainably manage the Kamutjonga floodplain.

1.6 Limitations of the study

The results are based on only data collected by only one gear (a seine net). The seine net targets only inshore species. In terms of catch sizes, the seine net targets juveniles and the small sized classes fish species. Vegetation in floodplains does influence the sampling protocol. However, all these limitations were reduced by ensuring that the same area was covered during sampling each year. Gillnets were not used because they cannot be set in shallow littoral zones, less than 500 cm.

2. LITERATURE REVIEW

2.1 Fish species composition in the Kamutjonga floodplain

The Kavango River contains high species richness, it supports over 76 fish species (Hay et al., 2000) due to its different habitats which include mainstream, backwaters and rapids as well as floodplains (Bethune, 1991; Siziba et al., 2011). Castelnau (1861) investigated the earliest collection of fish species from the Okavango swamp Lake Ngami (Jubb & Gaigher, 1971; Simasiku, 2014). Since then there has been a series of fish surveys on the Kavango River. A study by Hay et al. (1996) in the Okavango River revealed 79 fish species of which the three most important species, according to the Index of Relative Importance (IRI), were all Cichlidae; *Pseudocrenilabrus philander*, *Tilapia sparrmanii* and *Coptodon rendalli*. Mosepele (2011) stated that most of the studies in the Okavango Delta indicate that the Cichlidae is the most dominant family. The abundance of cichlids on floodplains highlight the importance of floodplains as a major source of food and promote high fish production for the livelihood of people.

According to Simasiku (2017) the Kavango floodplain contains fish species of commercially importance such as *Oreochromis macrochir*, *Oreochromis andersonii* and *Coptodon rendalli*.

Hocutt and Johnson (2001) conducted the first seasonal survey on the fish species of the Kavango River floodplain along the Namibia /Angola border. They collected 57 fish species representing 14 families and 29 genera during the sampling periods of February (rising), May and June (peak), September (receding) and November (low flow conditions) in 1992. A 1.5 m high and 3.2 m long small seine net with 5 mm mesh, wire mesh fish traps as well as rotenone were used. The results from that study indicate that the total annual catch was dominated by cichlids and cyprinids to a lesser extent. The most abundant species was the southern mouthbrooder (*Pseudocrenilabrus philander*) followed by the redbreast tilapia (*Coptodon rendalli*) and the banded tilapia (*Tilapia sparrmanii*) (Johnson & Hocutt, 2001). The Cyprinidae family was the most speciose family. This family includes the *Enteromius* spp. and *Labeo cylindricus* (Johnson & Hocutt, 2001). Simasiku et al, (2021) examined the effects of water level and water quality on small-sized and juvenile fish assemblages in littoral zones of the Zambezi / Chobe floodplain and discovered that cichlids were the most prevalent during the peak flood phase whereas cyprinids were abundant during the recession flood phase, in addition, water level, oxygen and conductivity had an influence on fish species assemblages. There are past studies on the fish composition in Kavango River (Peel, 2012; Simasiku 2014; Johnson & Hocutt, 2001), however, these studies did not include the influence of water parameters on catch rates. This current study is not only assessing the species composition and species diversity of the Kamutjonga floodplain, it also included the effects of environmental factors such as water temperature and water level on the catch per unit effort.

2.2 Fish sizes on the floodplain

During high flood period there is increased food availability from sources such as leaves, seeds and insects which lead to increased feeding intensity and subsequently fish growth (Welcomme,

1975). It has been noted that there might be changes in the growth of fish on the floodplain during flooding due to changes in the abundance of food, habitats and temperature (Welcomme, 1975). Dudley (1972) suggested that some fish species complete major part of their growth during the flood season; for instance, it was noted that 75% of the expected first year's growth in length of juveniles *Oreochromis andersonii* and *Oreochromis macrochir* happened within six weeks of the peak flood on Kafue River (Welcomme, 1975). According to Peel (2012) the combined length at 50% maturity for male and female *O. andersonii*, *O. macrochir* and *C. rendalli* was 238 mm TL, 184 mm TL and 195 mm TL respectively. Furthermore, Peel (2012) affirms that the explanation for the seasonal variations in growth between different species and systems are inconsistent and contradictory. There are also inter-annual variations in growth on floodplains which depend on the intensity and duration of flooding (Welcomme, 1975). Results from previous studies (Dudley 1972, 1974; Kapetsky, 1974; Welcomme, 1975) indicate that fish growth is positively correlated with the intensity of flooding and that severe decline in environmental conditions lead to poor fish growth.

2.3 Flooding phases, fish productivity and the influence of water level on catch rates

The seasonal flooding of floodplains in the Kavango River lasts for six months (Lindholm, 2007) is due to a pulse of water that is caused by rainfall in the highlands of Angola. These seasonal floodplains which are subject to limnological extremes are also unpredictable and vary in timing and magnitude from one year to the next (Høberg et al., 2002). In addition, oxygen concentrations, nutrient concentrations and predation on fish and fish fry are driven by these variations (Ramberg et al., 2010). According to Welcomme (1975) nutrients in the form of animal dung and vegetation accumulate on the plain and then get dissolved by flood waters as soon as flooding begins. Furthermore, the main river also transfers dissolved nutrients onto the floodplain. This leads to

high production and supports many forms of aquatic biota (Bayley, 2005). Consequently, such productivity will provide conditions that are very favourable for fish to reproduce, feed and grow on the floodplains (Welcomme, 1975).

The influence water levels on catch rates has been investigated by various throughout the world for instance Merona and Gascuel (1993) found that there was an association between catch rates and water level which was possibly due to recruitment and competition in the Amazon floodplain. Simasiku et al., (2021) investigated how fish species such as *Oreochromis andersonii*, *Coptodon rendalii*, *Tilapia ruweti* and *Pseudocrenilabrus philander* respond to a change in the water level during different flooding phases and found that *O. andersonii* was abundant during the receding phase whereas *C. rendalii* was more abundant during the peak flooding phase. The highest catch rates of *T. ruweti* and *P. philander* was found during low flooding phase (Simasiku et al., 2021). These differences in catch rates underscores the fundamental role of flooding on fish productivity.

2.4 Fish migrations on floodplains

Fish species undergo longitudinal migrations along the main river and lateral migrations on and off the floodplains as a result of seasonal flooding (Lowe-McConnell, 1989). It is through these migrations that nutrients from sources such as vegetation, soil, detritus and grazer's dung are transported from floodplains to river systems resulting in high primary productivity (Lindholm et al., 2007; Junk et al., 1989). Floodplain fishes are known to respond to annual flooding by migrating from the main channel during the dry season and move into the floodplain's productive habitats favourable for feeding, spawning, nursery and to find refuge from predation (Siziba et al., 2011; Welcomme, 1979; Junk et al., 1989).

It has been noted that the migration of fish species on and off the floodplain is not random, fish move on the floodplain in a distinguished manner. According to Welcomme (1975) adult Tilapia females tend to migrate early onto the floodplain followed by adult males. Moreover, small fish species such as *Enteromius* migrate onto the floodplain as soon as it gets inundated and when the flood recedes the adult fish and juveniles that are sensitive to deoxygenated conditions tend to also migrate out of the floodplain to look for favorable environments (Welcomme, 1975), this happens before the connection with the main river system ends and others are consumed by predators (Winemiller & Jepsen, 1998).

The variations in migratory movements of fish species during low and high-water seasons result in different fish communities. According to Hay et al., (2000) there is limited information available to determine how fish migrate in the Kavango River. *Hydrocynus vittatus* is one of the fish species whose migration pattern has been studied by various authors (Økland et al., 2005) and the conclusion is that Tigerfish in general indicate opportunistic movement patterns that are related to feeding, spawning and the temperature of the water (Økland, 2005).

2.5 Fish feeding on floodplains

Floodplains are known as high productive ecosystems which serve as areas for feeding during seasons of inundation. During inundation, the floodplain gets strongly enriched with inorganic nutrients, rapid growth of vegetation, organic debris such as seeds, young shoots, leaves, detritus from decayed macrophytes and mammalian feces resulting in high productivity of phytoplankton and zooplankton for fish fry to feed on (Hoberg et al., 2002; Welcomme, 1975). In addition, the juveniles feed on small insects and mollusks, zooplankton and periphyton whereas the adult fish feed on the floodplain feed on macroinvertebrates, plankton and even other fish species (Welcomme, 1975). According to Welcomme (1979) fish feeding on the floodplain is linked to

food supply and population density because during the flood, there is high amount of food availability, low density of fish populations and an increase in the feeding activity for many fish species. However, the limited availability of nutrients results in limited feeding intensity and a high population density during the falling flood season (Welcomme, 1979). The variation in the feeding intensity is due to the flood regime (Welcomme, 1975).

2.6 Fish breeding on floodplains

Reproduction in floodplains corresponds with the early phase of the flood and is highly seasonal because the floodplain is dry in some parts of the year (Welcomme & Merona, 1988). The fish species which inhabit the floodplain for breeding have different breeding strategies and the degree of their parental care also differ (Welcomme & Merona, 1988). Some fish species on the floodplain are referred to as partial spawners and others have a prolonged breeding season resulting in many broods (Welcomme & Merona, 1988). According to Johnson and Hocutt (2001) the reproductive strategies of the fish in Kavango River were in advance of flooding when the water was still low but by the second month of flooding, they become juveniles. It was observed that piscivorous species such as *Serranochromis* spp. have late reproductive maturity with low number of offspring whereas others such as Cyprinids and Mormyrids have early reproductive maturity, with high number of small size offspring. When fish have spawned on the floodplain and the water temperature have increased, juveniles are placed in more productive areas by their parents (Økland et al., 2005). The embryos hatch within a few days and become larvae which feed on abundant zooplankton (Mosepele et al., 2009). Furthermore, the juvenile fish use the vegetation cover for protection before they move out of the floodplain to deep waters as they grow larger (Thorstad et al., 2003).

The reproductive strategy of fish species such as *Hepsetus cuvieri* in Okavango Delta have been investigated and according to observations, temperature initiates spawning, and when eggs have hatched, the embryos suspend themselves into a foam of nest which is guarded by the parents from predators until they have fully developed (Merron et al., 1990). It has been illustrated that there are most likely two peak flood seasons in a year which allows some fish species to have two breeding seasons. However, this is determined by the biology and behaviors of different fish species (Welcomme, 1969). In Malawi's Shire River it has been observed that the breeding season of fish species such as the *Enteromius*, *Clarias* or *Alestes* is very much discreet compared to some Cichlids such as *Oreochromis andersonii* which breeds entirely outside the breeding season (Welcomme & Merona, 1988). It has been observed that the tilapia males are more aggressive, brightly coloured and larger than female tilapias during the breeding period (Turner, 2000).

2.7 Fish recruitment on floodplains

Recruitment is defined as the survival of a fish to a reference time in the life cycle (King et al., 2003). Inundation of the floodplain has been suggested to enhance fish recruitment by providing a suitable environment for fish spawning and enhancing the availability of food as well as diversification of habitats for larva (King et al., 2003). The relationship between flooding and recruitment suggests that flooding improves recruitment by directly stimulating spawning and indirectly enhancing larval and juvenile survival on the floodplain (King et al., 2003). Merron (1991) suggested that fish recruitment in the Okavango Delta predominantly occurs in temporary wetlands called floodplains.

The timing, duration and the extent of inundation are the main factors which determine the importance of floodplain's successful fish recruitment (Welcomme, 1979, 1985; Bayley, 1991 and

Konrad et al., 2011). However, as the water recedes, crowding, predation, and competition for the availability of food are some of the factors that will determine the survival of the young fish and therefore the recruitment success (Konrad et al., 2011). Winemiller (2008) dismisses the idea that the flood pulse alone controls the success of the fish recruitment. He suggests that not all fish species are equally affected by habitat complexity and temperature in floodplains.

Fish species have different life history strategies and hence the survival chance and recruitment success for the young fish varies (Konrad et al., 2011). These life history strategies involve opportunistic species which have life history traits such as early maturation whereby species are continuously spawning. Moreover, opportunistic species such as *Lacustricola* are flexible and are able to colonize new floodplain habitats resulting in successful recruitment (Paugy, 2001). Furthermore, some species have delayed maturation whereby they can only adapt when there are variations in environmental conditions while others are equilibrium strategists whereby the survival of eggs and larva is depended on the condition of adult fish (Konrad et al., 2011).

According to a study conducted on fish recruitment in large temperate floodplains, a shorter flood duration resulted in a decrease in the extent of flooded terrestrial habitats and a decrease in productivity consequently affecting recruitment negatively (Konrad, et al., 2011). Lindholm (2007) emphasized on the importance of the size and duration of the flooding and concluded that, small floods result in low fish reproduction, increased methane production as well as high productivity as a result of limited circulation following the low on the floodplains. In contrast, large floods result in the dilution of nutrients, reduction in the production of methane and anoxia Lindholm (2007). Konrad et al., (2011) stated that low temperature at the beginning of flooding in

large temperate floodplains and the reduced time window at which flooding provided a suitable habitat at an appropriate water temperature could result in a long-term decrease in the recruitment success. Similarly, Junk et al., (1989) stressed that high flows and rising temperature are important for successful fish recruitment in temperate systems. According to Konrad et al., (2011) abiotic processes for instance anoxia and desiccation as well as biotic processes such as predation and competition could lead to unsuccessful spawning which could further result in recruitment not to be successful.

Despite the lack of direct evidence showing that the impact of flooding and temperature on the recruitment of juveniles also affects the abundance of adult fish on floodplains, past data has indicated higher catches in years preceding large flood years. This indicates that the young fish that recruited in the year with a large flood had a higher survival and growth resulting in a higher catchable biomass the following year (Konrad et al., 2011). Therefore, good recruitment is expected when the rise in water level and temperature are linked and conversely poor recruitment occurs when the flood period is shortened (King et al., 2003).

3. RESEARCH METHOD

3.1 Study area

The Kavango River basin is 530 000 km² and 1600 km in length. The Kavango River and its catchment provides a rich assemblage of vegetation especially reed beds which acts as landscape engineers causing water to flow slowly (Jacobson, 1995). The vegetation responds to the variations in the type and depth of the soil from the riverbed to the sand plateau and between the valley bottom and top sand plateau (Strohbach, 2013). The eastern Kavango region falls into the “Woodlands of the northern Kalahari sensu” or the “Zambesian *Baikiaea* Woodlands” (Strohbach, 2013). The rainfall in the Kavango River is variable with the minimum annual rainfall of 600 mm year⁻¹ (Curtis et al., 1998). The Kavango River flows south from its origin in the central highlands of Angola where it is known as the Rio Cubango in Angola. The Kavango River turns east to form the 415 km long boarder between Namibia and Angola. The river then turns southeast at Mukwe for another 35 km before reaching Botswana and then terminates into the 15 000 km² Okavango Delta (Hay et al., 2000). The Okavango Delta is considered a large ecologically remote wet land which receives strong annual flood pulse (Johnson & Hocutt, 2001). Moreover, the Okavango delta is characterized by semi - arid climate (Mosepele et al., 2015). The water that flows through the Delta during exceptionally wet periods fills the sump lake known as Lake Ngami in the southwestern end of the Delta (Mosepele et al., 2009). The Kavango River is estimated to be ca 65 million years old (Mendelsohn & Obeid, 2004; Strohnbach, 2013). The Kavango River forms three extensive floodplains known as the western floodplains from west of Tondoro towards Nkurenkuru, the floodplain at Cuito and the eastern floodplains below the Popa falls which forms the Panhandle of the Okavango Delta (Hay et al. 1996; Mendlsohn and Obeid, 2003). This river

floods from the months of December to July each year with up to 6 m maximum above low flows and an average discharge of $10\,500 \times 10^6 \text{ m}^3$ annually at the Botswana border (Johnson & Hocutt, 2001). Flooding decreases in September and the minimum flow is usually in November (Johnson & Hocutt, 2001). The study was conducted on the Kamutjonga floodplain, which is situated 20 km southeast of Divundu in the Kavango East Region. The floodplain's first inlet is located near Ngepi Camp and extends approximately 17 km to the south and joins the river in the Mahangu Game Park (Figure 1).

The floodplain has numerous inlets from the main river channel and is approximately 2 km at its widest during peak flow periods. This floodplain has a bridge in the middle which starts from the Kamutjonga inland fisheries institute all the way to the main river. The Kamutjonga floodplain is usually inundated from February and reaches its peak in March and April and recedes in June or July depending on the rainfall in the highlands of Angola. The Kamutjonga floodplain is subject to fluctuations in habitats and flood levels from year to year. This floodplain has sandy substrates, rocky outcrops, abundant aquatic vegetation shrubs papyrus beds (*Cyperus papyrus*), grass fields, and trees. The habitats of the floodplain change as the flood season progresses and are covered with macrophyte beds, primary grasses, open water vegetation and patchy distributed vegetation at the end of the flood season, open water with reeds (polyphyletic species) (Figure 2). According to Welcomme (1979a) the Kavango River floodplains are considered fringing floodplains, lying between river valley walls. It has been noted that this river can be separated into higher ground levees which appear like islands and the flats which are considered as areas that are of higher productivity. The Kamutjonga floodplain was selected for this study because of its importance to the local community especially women and children dependent on it for food.

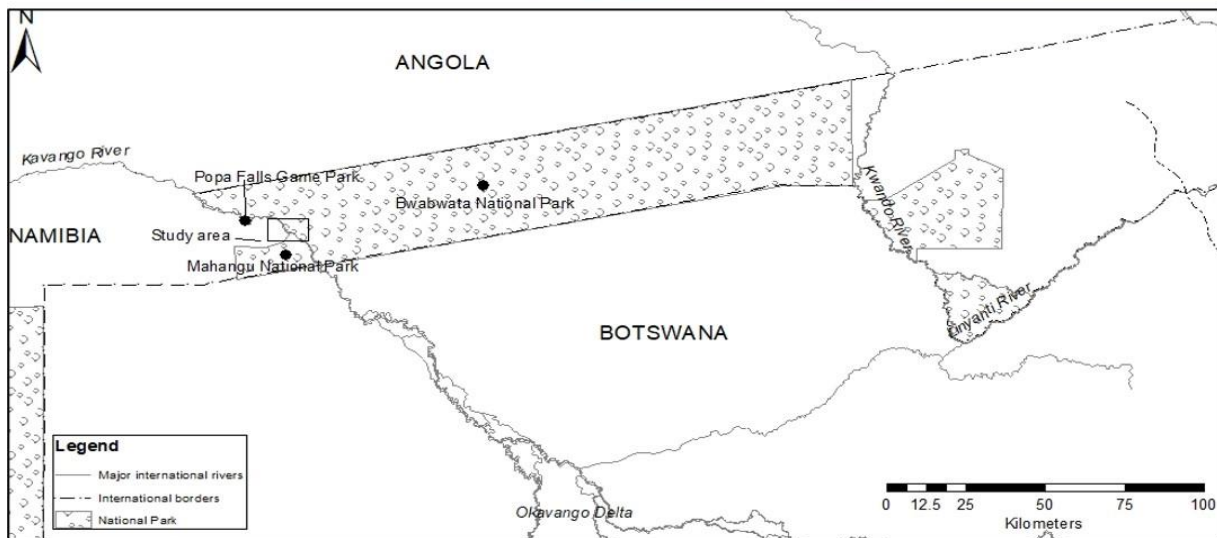
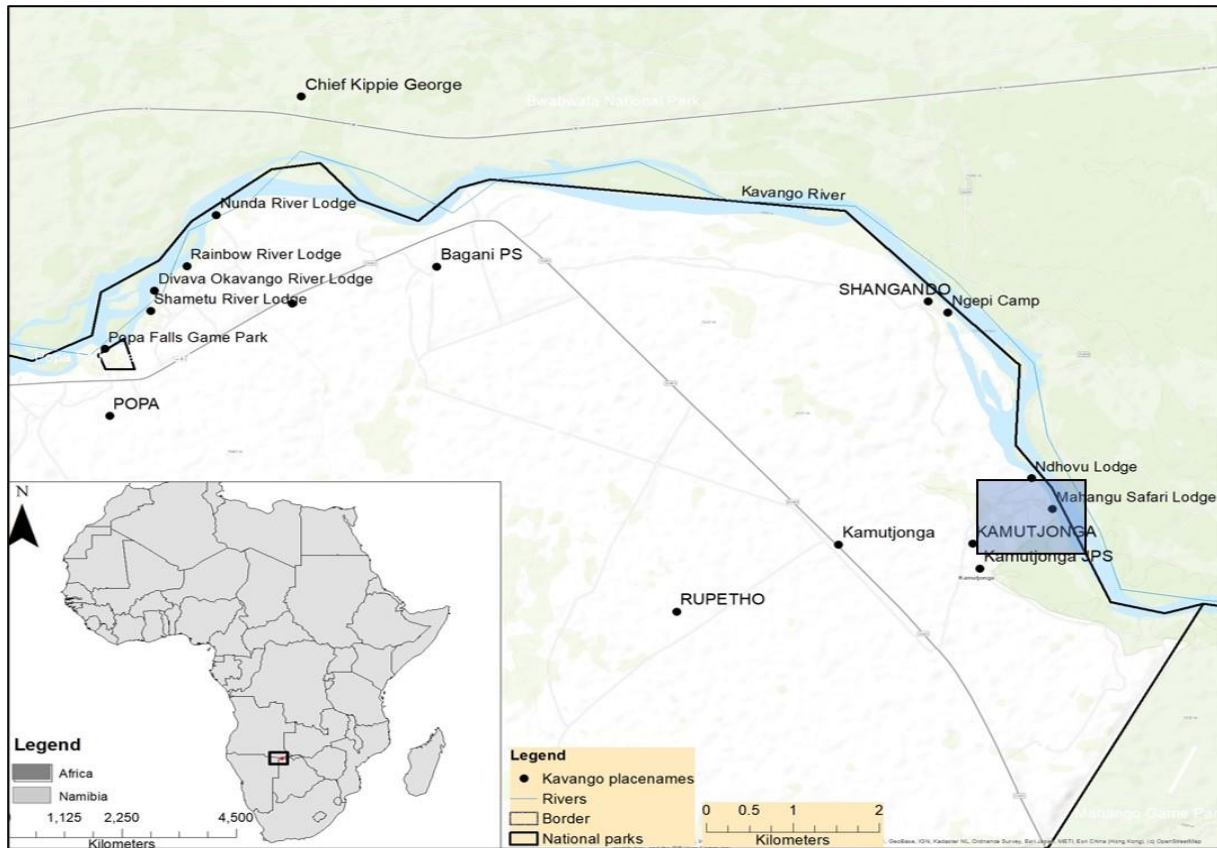


Figure 1 Map showing the location of Kamutjonga floodplain, Divundu, Kavango East Region.

(Source: F.J Jacobs)

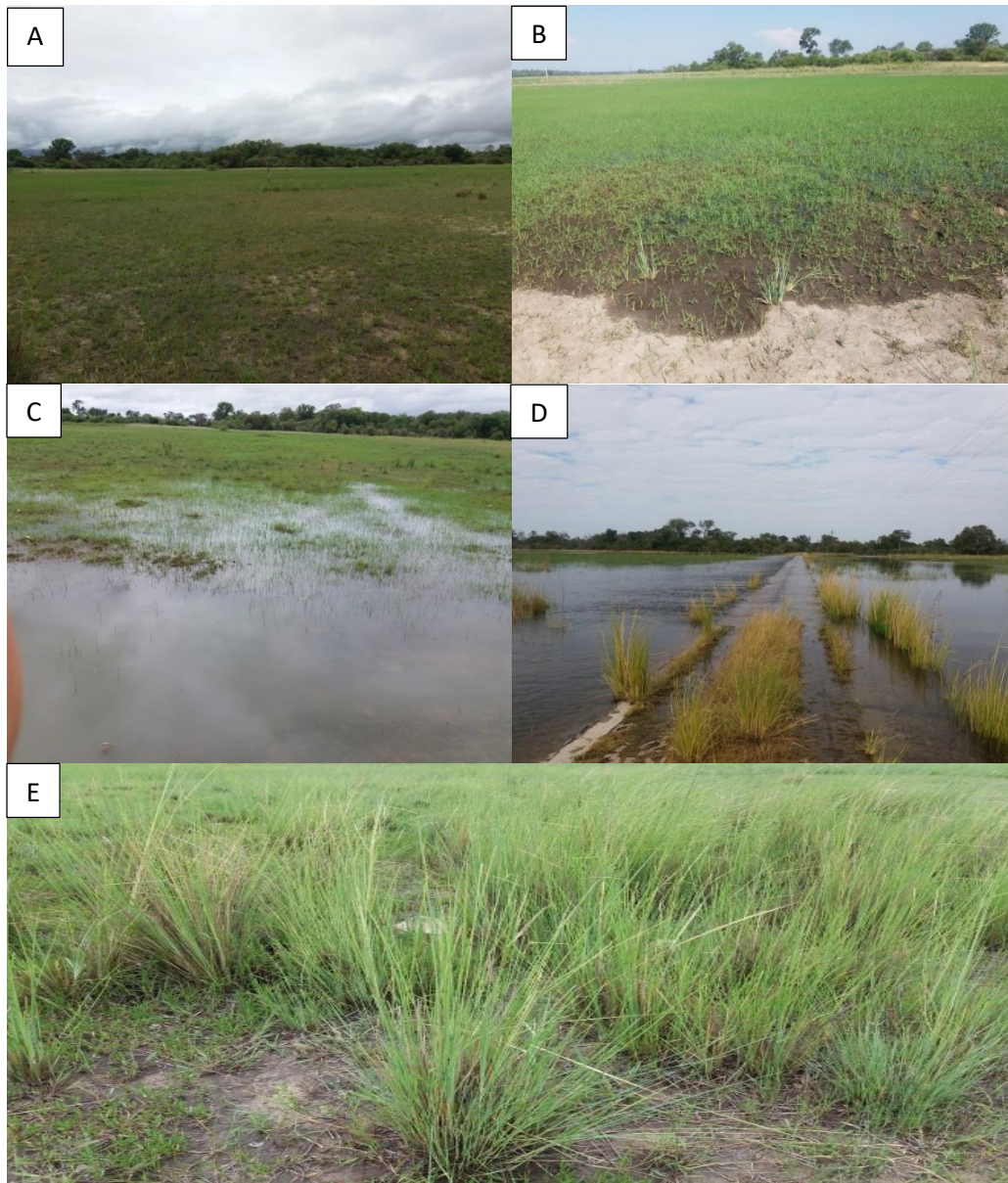


Figure 2 Changing habitats on the Kamutjonga floodplain during the flood season. Macrophyte beds just before the floodplain gets inundated (A), Primary grasses during the incoming flood (B), open water vegetation with the bridge in the middle of the floodplain during rising flood period (C), open water with reeds at the peak of the flood (D), Patchy distributed vegetation at the end of the flood season (E).

3.2 Physicochemical water parameters

At all occasions before fish sampling, physicochemical water parameters including water temperature were measured using a Hach multi-meter. However, not all water parameters were recorded each sampling year due to a faulty multi-meter. In one year, oxygen, pH, conductivity and transparency measurements were taken, and the other years, the multi-meter was not functioning which posed a huge challenge in monitoring the water quality. For this reason, only the water temperature which was consistency in all years was considered. The records for pH, conductivity and oxygen were omitted from this study. The water level was measured using a measuring pole which was put on the floodplain before the floods arrived to indicate the level of water as the flood was rising. Readings were taken from the measuring pole on each sampling day.

3.3 Fish sampling

A 10 m long x 1.5 m deep seine net with 2 mm stretched mesh size was hauled at different sampling sites

Figure 3 A). Sampling was from February to April in 2017, February to June in 2018 and February to June in 2020. The overlap between months depending on water level. On each day of sampling, a net was pulled once at each sampling site. Some days, ten sites were sampled and other days twenty sites were covered depending on how much water was on the floodplain. The length and width of each haul was measured, and the proportion of vegetation in the haul area estimated. All the fish caught were kept in an aerated container with water and taken to the laboratory at KIFI for identification to species level. Fish length was measured using a measuring board to the nearest mm total length (TL) or fork length (FL) depending on the species (

Figure 3D). Fish were anaesthetised using 2-phenoxy ethanol. The weight of the fish was measured to the nearest gram (g) using a calibrated weighing scale (

Figure 3 D). After identification and measuring the fish, all specimens were kept in labelled ziplock bags and stored in the deep freezer.



Figure 3 Sampling of the KIFI floodplain using a seine net (A) and taking water quality measurements (B), collection of fish from the seine net on top of the bridge (C) and (D), Fish identification (E), length and weight measurements (F).

Table 1 Sampling design of the Kamutjonga floodplain

Years	Number of sampling sites	Total Number of hauls	Habitats	Number of samples
2017	129	129	Swallow flooded vegetation	2924
2018	175	175	Shallow flooded vegetation	1678
2020	181	181	Shallow flooded vegetation	4461

3.4 Data analysis

3.4.1 Species composition

To determine the catch composition, all the recorded data were stored 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:

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

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.

3.4.2 Catch per unit effort

Catch per unit (CPUE) effort was defined as the number or weight of fish caught per meter square (m²) and was calculated as:

$$CPUE = C_i / E_i$$

Where; C_i is the catch of species i by number or weight and E_i is the effort expended to obtain the catch. The catch per unit effort was standardized as number or weight of fish per square meter. This was obtained by dividing the CPUE obtained from Pasgear by the Relative Effort (length of the net multiplied by the size of the dragged area in meters).

Effort is defined as the number of hauls or pulls per each dragged surface area. Effort depended on how much water covered the floodplain. The number of sampling sites and number of drags on each site are depicted in Table 1.

3.4.3 Species diversity

Species diversity is defined as the variety and relative abundance of species (Simasiku, 2014). Species diversity can be divided into species evenness and species richness (Peel, 2012). 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 Wiener index assumes that individuals are randomly sampled from an ‘indefinitely large’ population, and that all species are represented in the sample. Shannon’s index considers the evenness of the abundance of species, but the ratio of observed diversity to maximum diversity was used to

calculate the index of evenness as follows: $J' = H/H_{\max}$, where $H_{\max} = \ln H'$

Where J' is constrained between 0.0 and 1.0, a value of 1.0 means all species are equally abundant in the area. Both H' and J' assume that all species in the area are accounted for in the sample.

3.4.4 Statistical analyses

An assessment of the normality of data and homogeneity of variance was carried out using a Kolmogorov - Smirnov test and Levene’s test in SPSS. The data was not normally distributed and hence the Kruskal - Wallis test was used to examine the monthly and yearly variations in relative abundance (total CPUE) as well as to compare the diversity among the years. A 95% confident level was selected as a threshold. The average length of the most important fish species was obtained in excel and the Kruskal - Wallis tests was used to test for any variations in sizes.

4. RESULTS

4.1 Fish species composition of the Kamutjonga floodplain.

The list of all fish species sampled from the Kamutjonga floodplain between February to April 2017, February to June 2018 and between February to June 2020 were ranked based on the index of relative importance (IRI) (Kolding, 1999) (

Table 2). The number of individuals of fish sampled from the Kamutjonga floodplain between February and April 2017, February to June 2018 and between February to June 2020 were 2924, 1698 and 4461 respectively. *Oreochromis andersonii*, *Tilapia sparrmanii*, *Hydrocynus vittatus*, *Serranochromis altus*, *Serranochromis angusticeps*, *Pseudocrenilabrus philander* and *Coptodon rendalli* were among the most important fish species both according to the index of relative importance (IRI) and in terms of number as well as weight in all the years of sampling (

Table 2). The total weight of all the fish caught in 2017 was 6.404 kg, 5.619 kg in 2018 and 11.456 kg in 2020. The fish caught were juveniles and small sized fish species.

Table 2 Percent Index of relative importance (IRI) for all species sampled from Kamutjonga floodplain between February 2017 to April 2017, February 2018 to June 2018 and February and February 2020 to June 2020

Species	2017				2018				2020			
	%Nr	%W	%FRQ	IRI	%Nr	%W	%FRQ	IRI	%Nr	%W	%FRQ	IRI

<i>Oreochromis andersonii</i>	47.7	46.7	29.2	2758	27.1	40.9	45.5	3095	49.6	54.8	64.0	6681
<i>Coptodon rendalli</i>	3.3	3.6	12.3	85	8.8	4.2	21.9	285	9.1	14.5	46.6	1101
<i>Tilapia sparrmanii</i>	11.7	7.9	27.7	554	10.4	0.5	14.0	63	12.1	6.1	53.4	968
<i>Serranochromis altus</i>	11.6	8.0	25.1	413	0.1	0.1	0.6	0	0.9	2.0	10,6	31
<i>Serranochromis angusticeps</i>	0.2	0.1	2.1	1	10.2	10.5	35.4	733	-	-	-	-
<i>Pseudocrenilabrus philander</i>	8.5	3.3	24.1	284	6.9	1.2	20.2	164	7.1	2.2	21.2	197
<i>Pharyngochromis acuticeps</i>	2.1	0.8	10.3	30	0.2	0.1	1.1	0	0.7	2.8	9.5	33
<i>Oreochromis macrochir</i>	0.1	0.3	1.5	1	0.6	1.1	3.9	7	-	-	-	-
<i>Tilapia ruweti</i>	0.1	1.0	1.0	0	0.5	1.0	3.4	5	<0.1	0.5	15.3	48
<i>Serranochromis altus</i>		-		-	0.9	2.0		0.3	<0.1	0.6	10.6	31
<i>Sargochromis greenwoodi</i>	-	-	-	-	0.2	0.1	2.2	1	-	-	-	-
<i>Sargochromis giardi</i>	0.0	0.0	0.5	0	-	-	-	-	-	-	-	-
<i>Enteromius fasiolatus</i>	0.3	<0.1	2.1	1	-	-	-	-	0.3	0.1	3.2	1
<i>Enteromius barnardi</i>	0.2	<0.1	2.1	0	0.9	0.1	5.1	5	0.2	0.1	2.1	0

<i>Enteromius radiatus</i>	1.3	1.0	9.2	21	1.8	0.5	12.4	29	0.5	0.4	4.8	5
<i>Enteromius poechii</i>	1.1	0.6			2.1	10.1	10.1	25	0.5	0.5	4.8	5
<i>Enteromius bifrenatus</i>	0.3	0.2	3.1	2	4.9	1.0	14.0	82	0.6	0.2	4.8	4
<i>Enteromius paludinosus</i>	0.4	0.4	4.1	3	0.4	0.2	3.4	2	0.8	1.0	7.4	14
<i>Enteromius unitaeniatus</i>	0.4	0.3	3.1	2	0.5	0.2	3.9	2	0.6	0.5	4.8	5
<i>Enteromius afrovernayi</i>	0.1	<0.1	1.5	0	0.4	<0.1	1.7	1	-	-	-	-
<i>Enteromius kerstenii</i>	<0.1	0.4	0.5	0	-	-	-	-	<0.1	0.3	-	-
<i>Enteromius haasianus</i>	0.2	<0.1	2.6	1	0.1	0.1	0.6	0	-	-	-	-
<i>Labeo cylindricus</i>	0.1	0.1	1.7	1	0.1	0.3	1.5	0	-	-	-	-
<i>Hepsetus cuvieri</i>	0.1	0.2	1.5	0	0.1	0.3	0.6	0	-	-	-	-
<i>Micralestes acutidens</i>	0.1	0.1	1.0	0	2.4	0.3	6.2	18	0.5	0.5	6.3	6
<i>Hydrocynus vittatus</i>	0.2	24.1	16.9	525	14.4	34.1	30.3	1472	6.2	9.4	27.0	421
<i>Rhabdalestes maunensis</i>	-	-	-	-	0.2	0.1	0.6	0	-	-	-	-
<i>Brycynus laterelis</i>	-	-	-	-	0.3	0.1	2.2	1	-	0.1	0.5	0
<i>Synodontis spp</i>	0.1	0.4	-	-	-	-	-	-	<0.1	<0.1	0.5	5

<i>Lacustricola hutereaui</i>	-	-	-	-	-	-	-	-	<0.1	<0.1	0.5	0
<i>Lacustricola johnstoni</i>	1.9	0.2	10.8	23	-	-	12.4	134	0.7	0.1	8.5	6
<i>Schilbe intermedius</i>	0.7	1.5	8.7	20	0.8	0.2	4.5	4	2.1	1.0	1.1	1
<i>Clarias gariepinus</i>	0.3	0.2	2.1	1	0.1	<0.1	1.1	0	0.1	0.2	3.2	1
<i>Clarias ngamensis</i>	<0.1	<0.1	0.5	0	0.1	<0.1	0.6	0	-	-	0.5	0
<i>Nannocharax machadoi</i>	-	-	-	-	0.6	0.1	1.1	1	-	-	-	-
<i>Nannocharax multifasciatus</i>	0.1	<0.1	0.5	0	0.4	<0.1	1.1	0	-	-	-	-
<i>Petrocephalus okavangoensis</i>	<0.1	<0.1	0.5	0	0.1	0	1.1	0	0.2	0.1	2.6	1
<i>Mormyrus lacerda</i>	-	-	-	-	0.1	1.1	1.1	0	0.1	0.1	-	-
<i>Marcusenius altisambesi</i>	-	-	-	-	0.1	0.6	0.6	0	0.2	0.2	3.2	3
<i>Pollimyrus castelnaui</i>	-	-	-	-	0.1	<0.1	0.6	0	-	-	0.5	0

Rare fish species in this study were considered those that were represented by only one or two individuals in a sample. In 2017, *Synodontis macrostigma* (1), *Enteromius kerstenii* (1), *Sargochromis giardi* (1), *Clarias ngamensis* (1) and *Petrocephalus okavangoensis* (1) were least represented fish species (

Table 2). The five least important species in 2018 in terms of number were *Marcusenius altisambesi* (1), *Pollimyrus castelnaui* (1), *Synodontis macrostigma* (1), *Clarias ngamensis* (1) and *Enteromius haasianus* (1) (Table 1).

The least represented fish species according to number in 2020 were *Synodontis* spp (1), *Clarias ngamensis* (1), *Pollimyrus castelnaui* (1) and *Lacustricola hutereaui* (1).

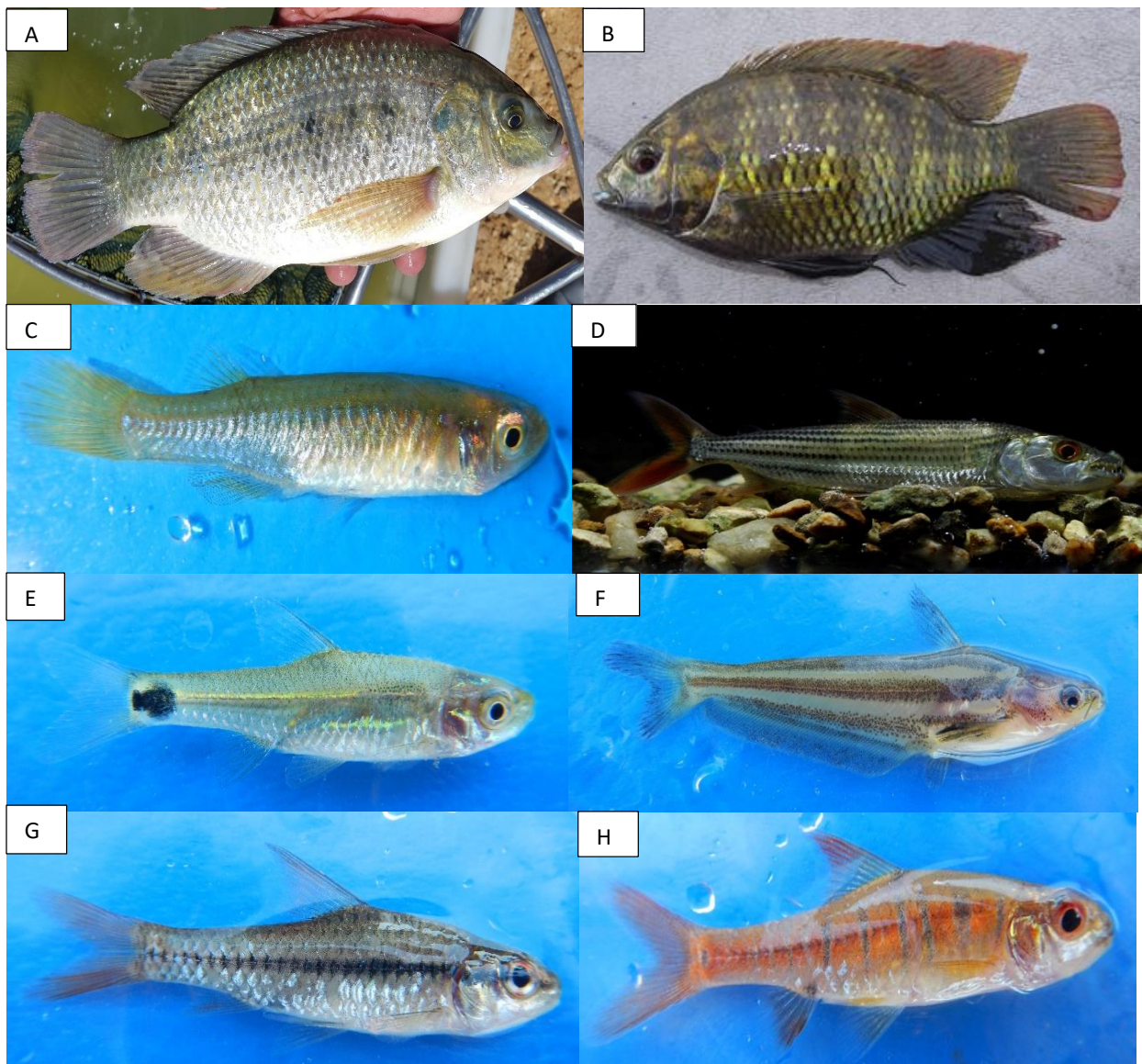


Figure 4: Some fish species found in the Kamutjonga floodplain from February 2017 to June 2020, *Oreochromis andersonii* (A), *Tilapia sparrmanii* (B), *Lacustricola johnstoni* (C), *Hydrocynus vittatus* (D), *Enteromius afrovernayi* (E), *Schilbe intermedius* (F), *Enteromius radiatus* (G), *Enteromius fasciolatus* (H).

4.2 Species richness and diversity of the Kamutjonga floodplain

The species richness was higher in 2018 (37 fish species) compared to 2017 (31 fish species) and 2020 (30 fish species). Ten fish families were registered in the floodplain catches in 2017. The Cyprinidae was the most dominating family comprising of 36% and 11 species of the total catch, followed by the Cichlidae family (32%; n = 10). Thereafter the Clariidae (7%; n = 2) and Alestidae (7%; n = 2) followed. The fish families with the least number of species were Cyprinodontidae, Schilbeidae, Hepsetidae, Distichodontidae, Mochokidae and Mormyridae (3%; n = 1) (Figure 5). Eight fish families were registered in the floodplain catches in 2018. As in 2017 two families dominated the catches. The Cichlidae family comprised 30% and 11 of the species in the total catches followed by the Cyprinidae (27%; n=10), Mormyridae (11%; n=4) and Alestidae family (8%; n=3). The least represented families were the Distichodontidae and Clariidae (5%; n=2 each), followed by Hepsetidae, Schilbeidae, Mochokidae and Cyprinodontidae (3%; n=1 each) (Figure 5). In 2020 there were 10 fish families registered in the floodplain catches with Cyprinidae being the most dominant family comprising 30% and 9 fish species followed by Cichlidae comprising 25% and 8 fish species, Mormyridae comprising 9% and 3 fish species, Mochokidae, Cyprinodontida, Clariidae and Alestidae 6% and 2 fish species each, Schilbeidae comprised 3% and 1 fish species (Figure 5).

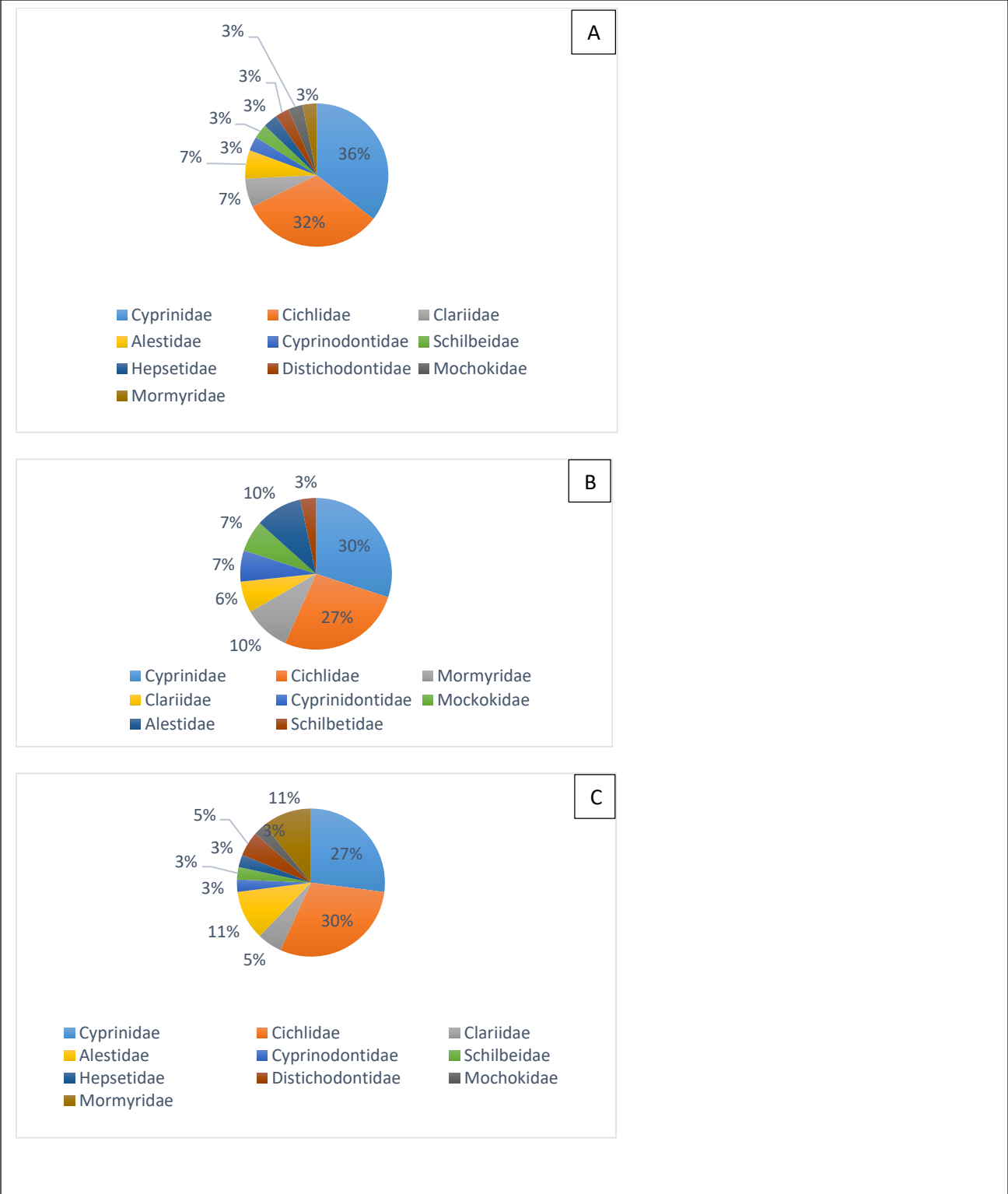


Figure 5: Fish families (in percentages) sampled from the Kamutjonga floodplain between February 2017 to April 2017 (A), February 2018 to June 2018 (B) and February 2020 to June 2020 (C).

The species diversity which includes the total number of fish species and evenness of species was calculated using the Shannon-Wiener index and are depicted in (Table 3). There was no significant difference in the species diversity among years (Kruskal - Wallis test; $F= 0.459$, $P = 0.795$, $DF = 2$) and the evenness index indicated that the number of individuals were not evenly distributed among species, and the distribution did not differ among years (Table 3).

Table 3: Shannon-Wiener diversity (H') and evenness (J') indices for 2017, 2018 and 2020.

Years	2017	2018	2020
H'	1.851	2.431	1.837
J'	0.54	0.64	0.55

4.3 Catch per unit effort of all fish species by number of the Kamutjonga floodplain

4.3.1 Monthly and annual catch per unit effort by number and weight of all species

In 2017 there was an increase in the mean monthly catch per unit effort by number from February to March and a decline in the month of April. The catch rates were higher in the month of March (rising flood phase) and lowest in the month of April (receding flood phase) (Figure 6). In 2018 the mean monthly CPUE by number increased as the flood progressed from the rising phase in February to April and declined between the months of May and June as the flood was receding. The highest catch per unit effort by number was found in April (rising flood phase) whereas the lowest was found in June (receding flood phase) (Figure 6). In 2020 the catch per unit effort by number was high in February as the flood was rising then declined between the months of March

and April before increasing slightly as the flood was receding between May and June. The highest catch per unit effort by number was found in April and lowest in June (Figure 6).

The mean monthly catch per unit effort by weight was high in February 2017 during the rising phase then declined as the flood receded from March to April (Figure 7). In 2018, the catch per unit effort by weight was high as the flood was rising from February to April and as the flood progressed, there was a reduction in weight from April to May followed by a slight increase in weight during the month of June as the flood was receding (Figure 7). In 2020, there was no significant difference in the monthly catch per unit effort by weight of fish caught on the Kamutjonga floodplain (Figure 7). The statistical results of all the monthly catch per unit effort by number and weight are depicted in Table 3.

There was a significant difference in catch per unit effort by number (Kruskal - Wallis test; $F = 236.714$, $DF = 4$, $P = 0.000$ and weight (Kruskal - Wallis test; $F = 279.353$, $DF = 4$, $P = 0.000$) between years being highest in 2020 and lowest in 2017 (Figure 8).

Table 4 Mean monthly Catch per unit effort by number and weight in 2017, 2018 and 2020 (Kruskal-Wallis test).

	Year	F	DF	P	Result
CPUE by number	2017	9.192	2	0.010	Significance difference in CPUE.
	2018	31.199	4	0.000	Significance difference in CPUE.

	2020	10.085	4	0.035	Significance difference in CPUE.
CPUE by weight	2017	18.556	2	0.001	Significance differences in CPUE.
	2018	31.417	2	0.001	Significance differences in CPUE.
	2020	3.247	4	0.517	No significance difference.

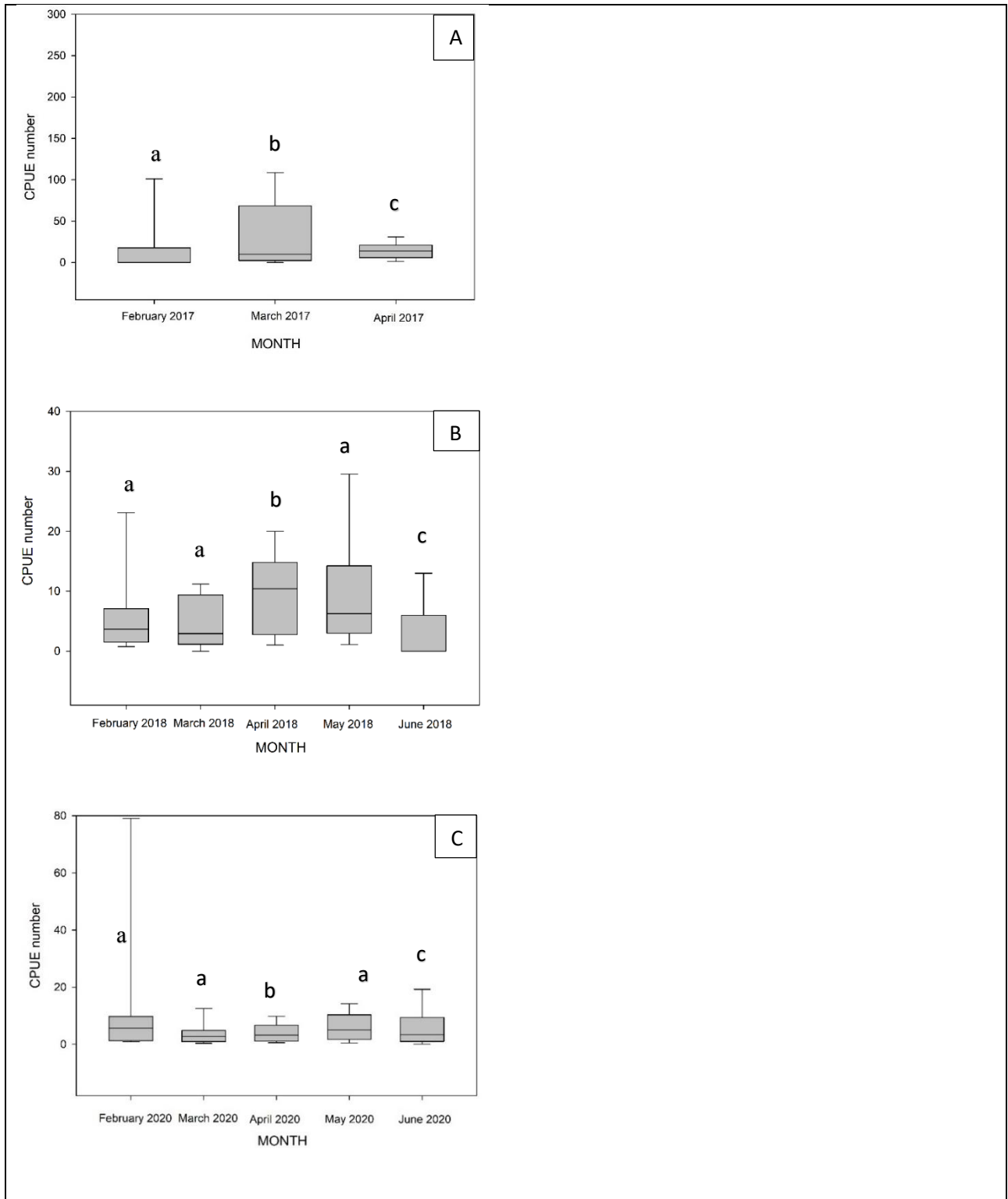


Figure 6 Box and whisker plots for mean monthly CPUE by number in 2017 (A), 2018 (B) and 2020 (C) on the Kamutjonga floodplain, Kavango River. Boxes represents median and the upper

and lower quartiles and whiskers represent the minimum and maximum. Superscripts denote significant differences ($P > 0.05$).

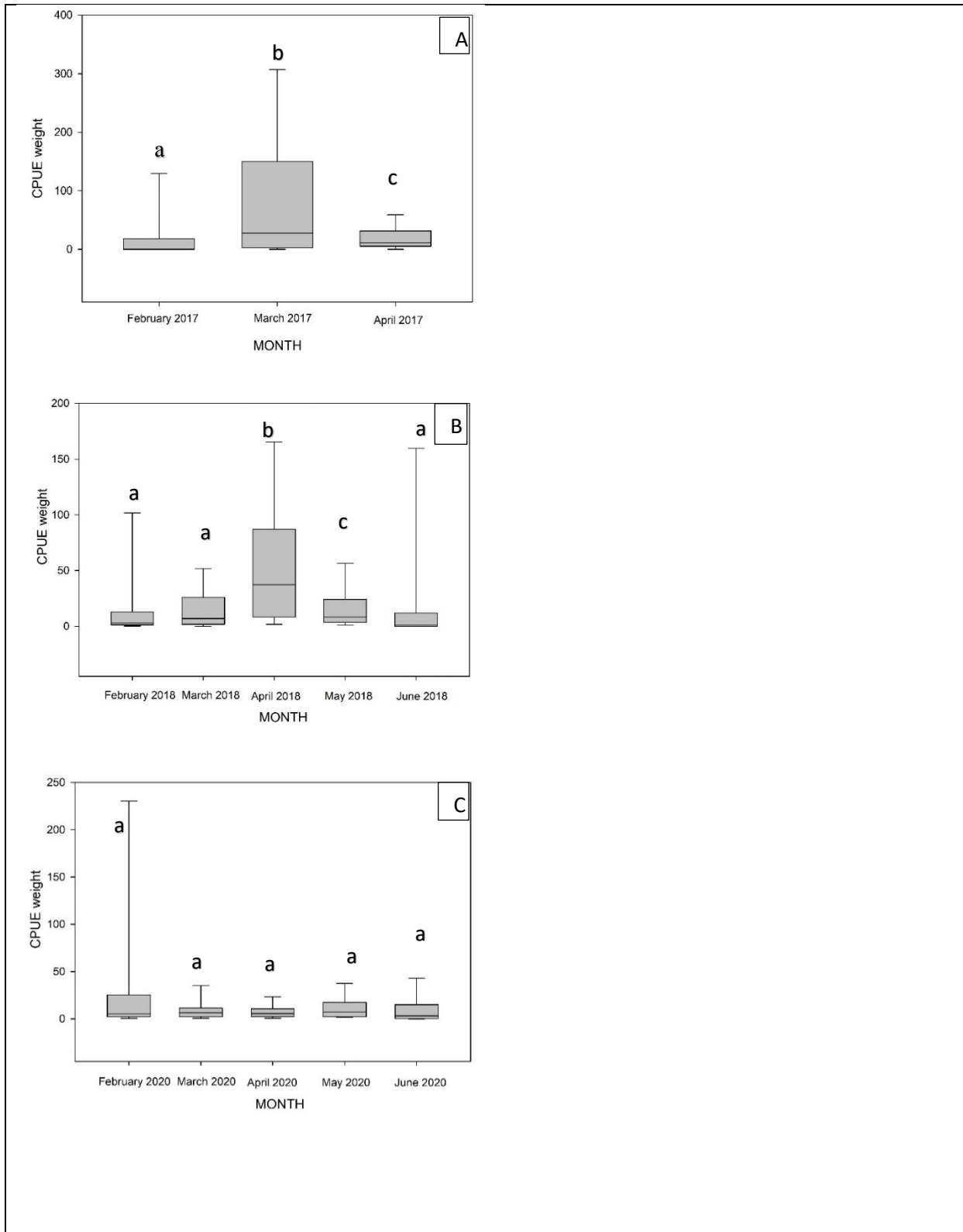


Figure 7 Box and whisker plots for the mean monthly CPUE by weight in 2017(A), 2018 (B) and 2020 (C) on the Kamutjonga floodplain, Kavango River. Boxes represents median and the upper

and lower quartiles and whiskers represent the minimum and maximum. Superscripts denote significant differences ($P > 0.05$).

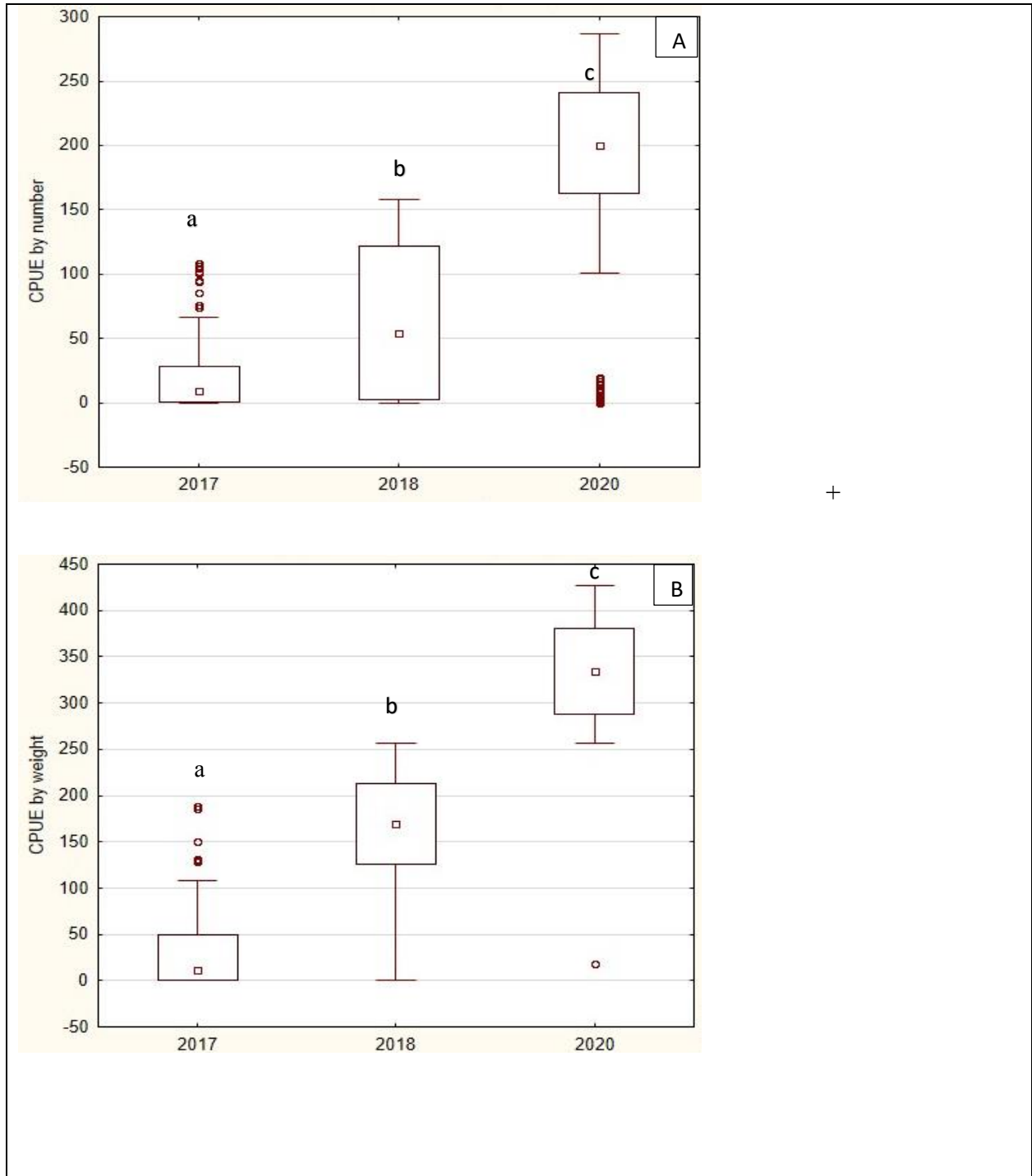


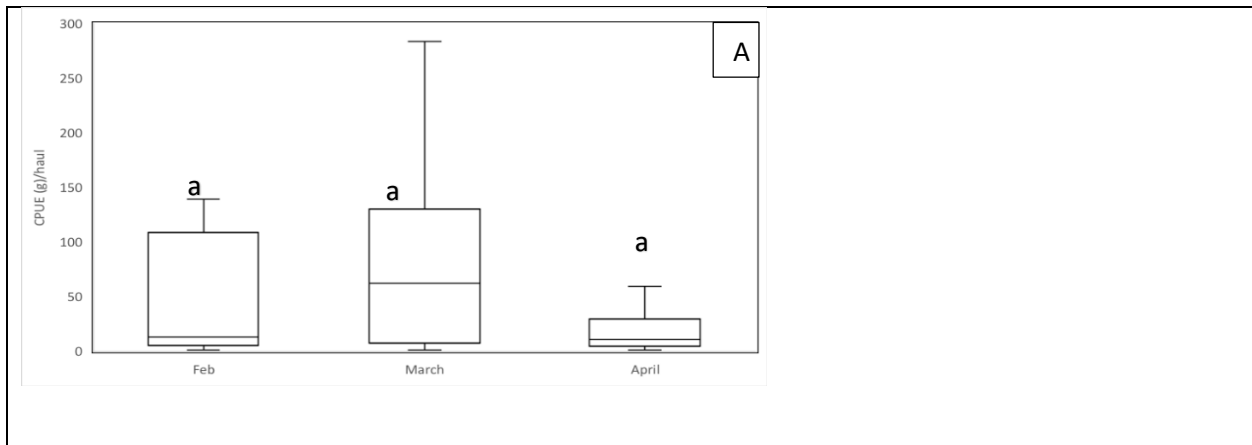
Figure 8 Box and whisker plots of the mean yearly CPUE by number (A) and weight (B) for all fish species sampled in the Kamutjonga floodplain, Kavango River sampled from February to

April 2017, February to June 2018 and February to June 2020. Boxes represent the upper and lower quartiles and whiskers represent the minimum and maximum. Superscripts denote significant differences ($P > 0.05$).

4.3.2 Catch per unit effort by weight of the most dominant fish species

Oreochromis andersonii

There was no significant difference in the catch per unit effort by weight of *Oreochromis andersonii* between months in the year of 2017 (Kruskal - Wallis test, $F = 5.167$, $DF = 2$, $P = 0.075$) (Figure 9). However, there was a significant difference in the catch per unit effort by weight of *Oreochromis andersonii* in 2018 (Kruskal - Wallis test, $F = 16.486$, $DF = 4$, $P = 0.002$). The catch per unit effort by weight for *Oreochromis andersonii* was highest in the month of May and lowest in the month of February (Figure 9). In 2020 There was no significant difference in the catch per unit effort by weight of *Oreochromis andersonii* between months (Kruskal - Wallis test, $F = 3.775$, $DF = 3$, $P = 0.287$) (Figure 9).



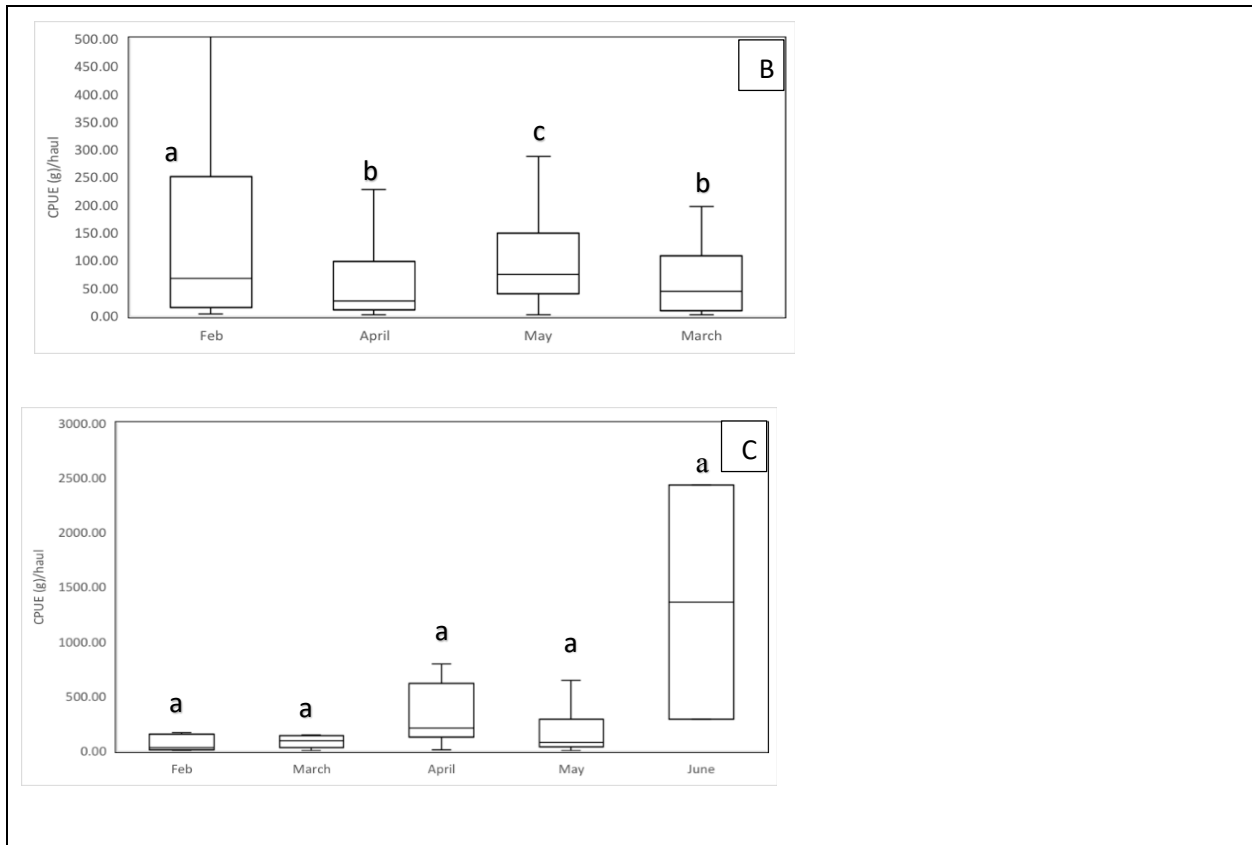


Figure 9 Box and whisker plots for the monthly CPUE by weight for *Oreochromis andersonii* sampled in Kamuntjonga floodplain from February to April 2017 (A), February to June 2018 (B) and February to June 2020 (C). Boxes represents median and the upper and lower quartiles and whiskers represent the minimum and maximum. Superscripts denote significant differences ($P > 0.05$).

Coptodon rendalli

There was a significance difference in the monthly catch per unit effort by weight of *Coptodon rendalli* in 2017 (Kruskal - Wallis test, $F = 18.516$, $DF = 2$, $P = 0.000$). The catch per unit effort by weight for *Coptodon rendalli* was highest in March and lowest in April (Figure 10). There was no significance difference in the monthly catch per unit effort by weight of *Coptodon rendalli* in

2018 (Kruskal - Wallis test, $F = 7.738$, $DF = 4$, $P = 0.102$) and 2020 (Kruskal - Wallis test, $F = 6.441$, $DF = 4$, $P = 0.166$) (Figure 10).

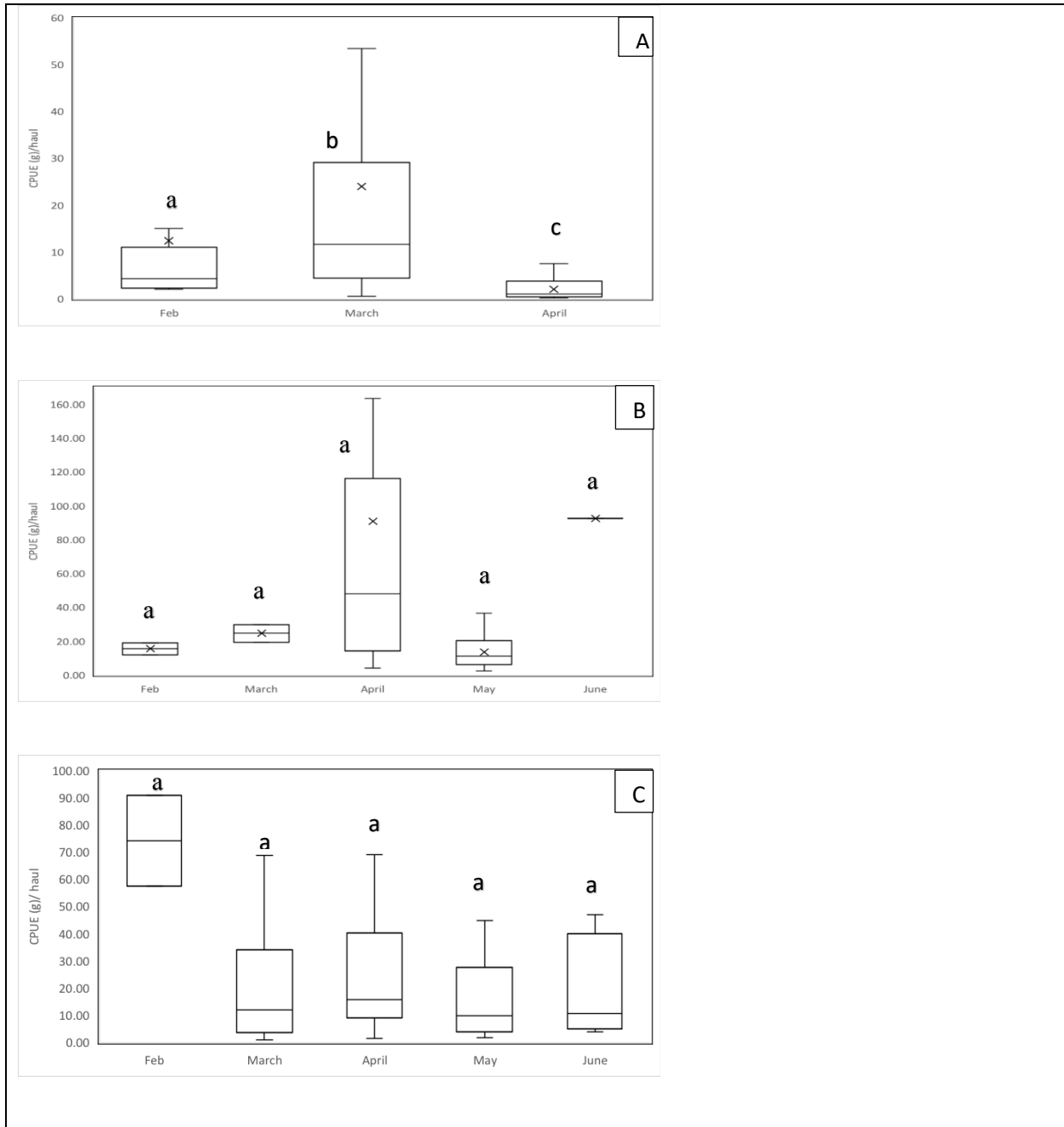
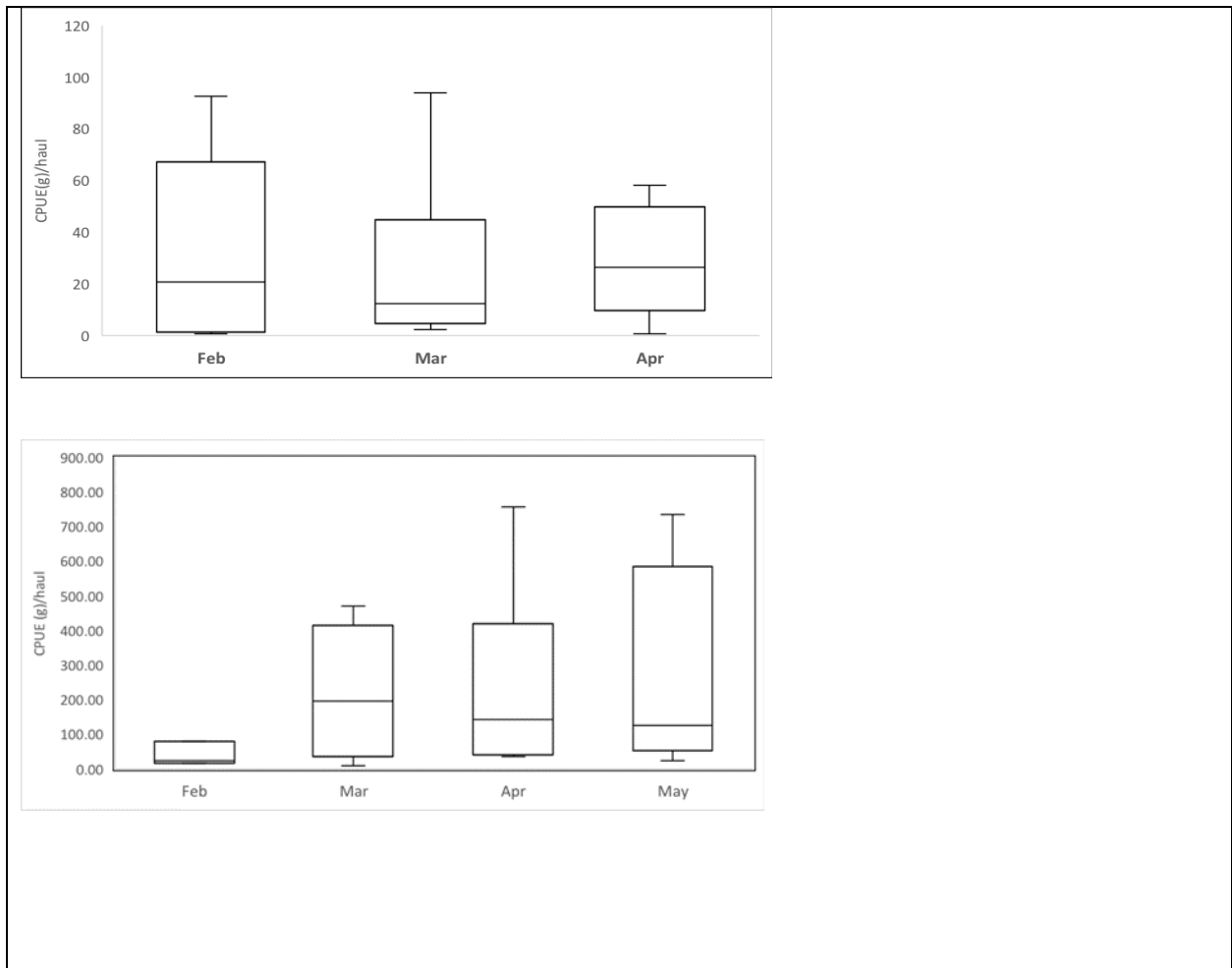


Figure 10 Box and whisker plots for the monthly CPUE by weight of *Coptodon rendalii* sampled in Kamuntjonga floodplain from February to April 2017, February to June 2018 and February to

June 2020. Boxes represents median and the upper and lower quartiles and whiskers represent the minimum and maximum. Superscripts denote significant differences ($P > 0.05$).

Hydrocynus vittatus

There was no significant difference in the catch per unit effort by weight of *Hydrocynus vittatus* in 2017 (Kruskal - Wallis test, $F = 0.157$, $DF = 2$, $P = 0.924$), 2018 (Kruskal - Wallis test, $F = 0.578$, $DF = 2$, $P = 0.901$) and 2020 (Kruskal - Wallis test, $F = 3.125$, $DF = 4$, $P = 0.537$) (



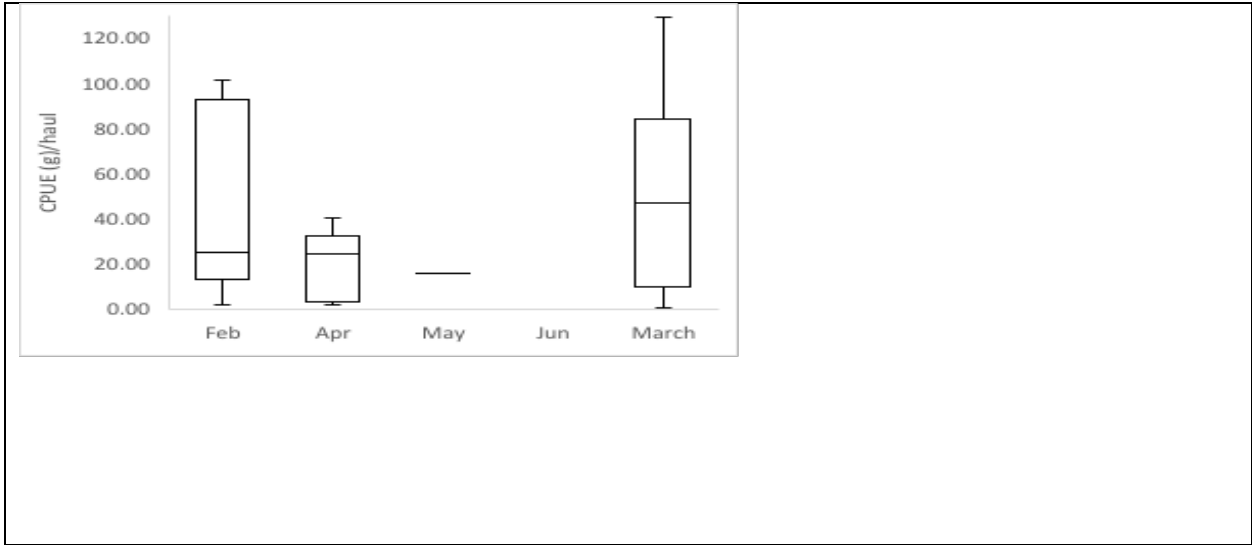
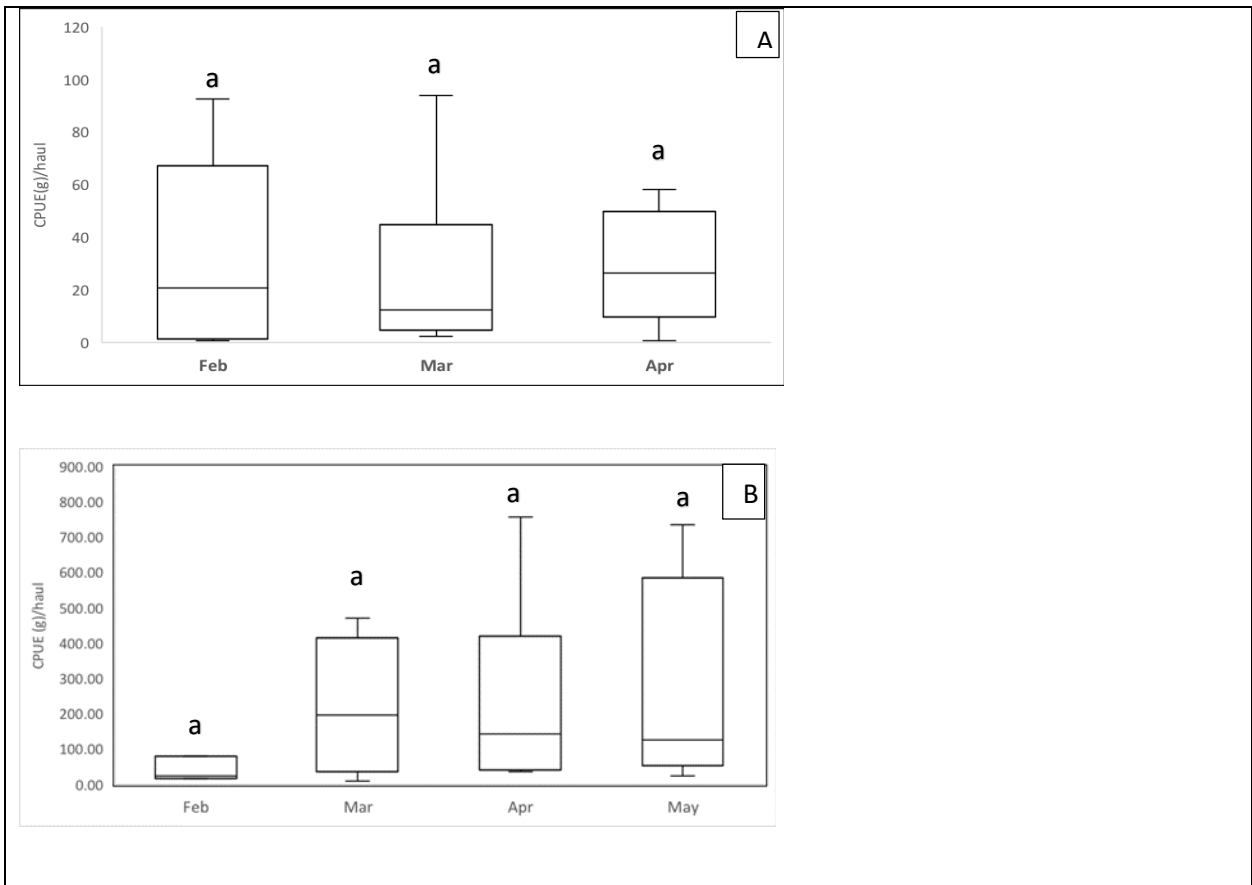


Figure 11).



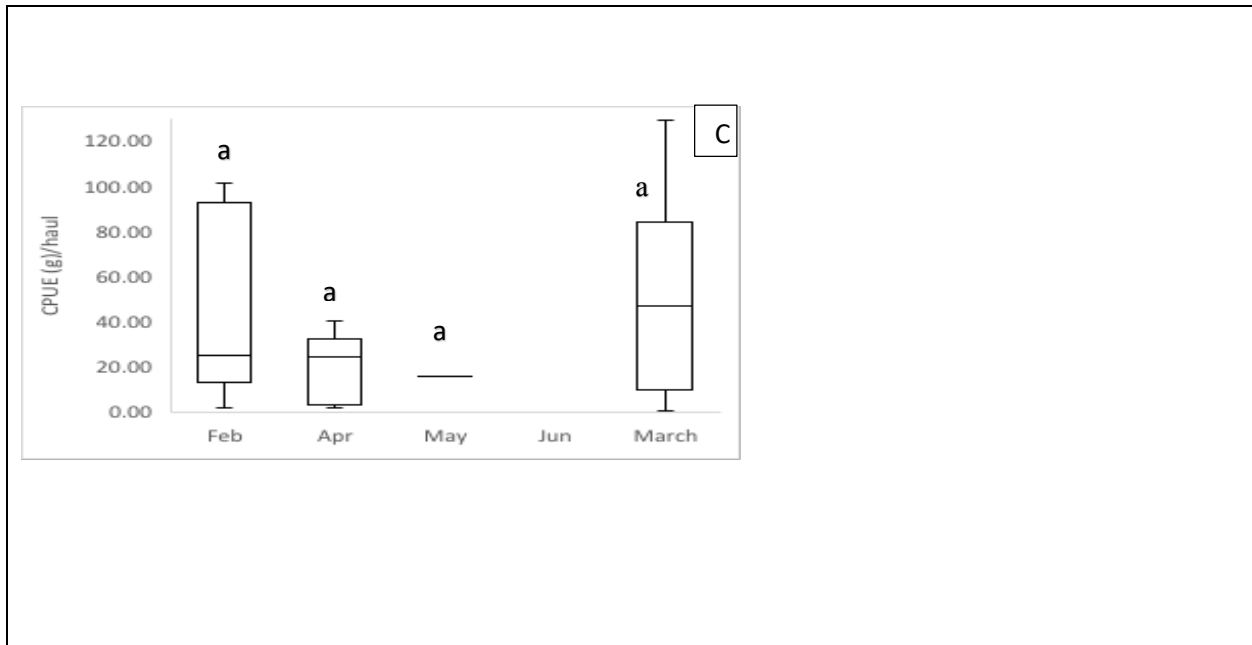


Figure 11 Box and whisker plots for the monthly CPUE by weight *Hydrocynus vittatus* sampled in Kamuntjonga floodplain from February to April 2017 (A), February to June 2018 (B) and February to June 2020 (C). Boxes represents median and the upper and lower quartiles and whiskers represent the minimum and maximum. Superscripts denote significant differences ($P > 0.05$).

4.4 Length frequencies of the most dominant fish species

Oreochromis andersonii

Oreochromis andersonii was numerously caught in the seine net samples throughout the sampling period. The mean body length of this species in 2017 was 46.7 mm \pm SD 17.79 (n = 1211), 52.4 mm \pm SD 25.02 (n = 460) in 2018 and 43.4 mm \pm SD 18.25 (n=2135) in 2020. The majority of fish caught in numbers were between the

length classes 41 mm to 50 mm (n = 489) in 2017, 61 mm to 70 mm (n=89) in 2018 and 31 mm to 40 mm (n=606) in 2020. The size at which most *Oreochromis andersonii* vacated the floodplain was between the length classes of 71 mm to 80 mm throughout the sampling period (

Figure 12). This is their maximum attainable size observed while on the floodplain. This suggest that the fish vacated the floodplain at this particular size when they were active enough to escape predation.

Coptodon rendalli

The body length of *Coptodon rendalli* varied between 23 mm and 100 mm with a mean length of 46.30 mm \pm SD 20.19 throughout the sampling period. The mean length of *Coptodon rendalli* was 47.7 mm \pm SD 17.84 (n = 97) in 2017, 52.40 mm \pm SD 25.11 (n=149) in 2018 and 44.97 mm \pm SD 18.62 (n = 408) in 2020. The majority of fish sampled in numbers were found between the length classes 51 mm to 60 mm in 2017, 21 mm to 30 mm as well as 41 mm to 50 mm in 2018, and finally 41 mm to 50 mm in 2020. The largest size at which the majority of *Coptodon rendalli* left the Kamutjonga floodplain was between the length classes of 81 mm to 90 mm in all years (

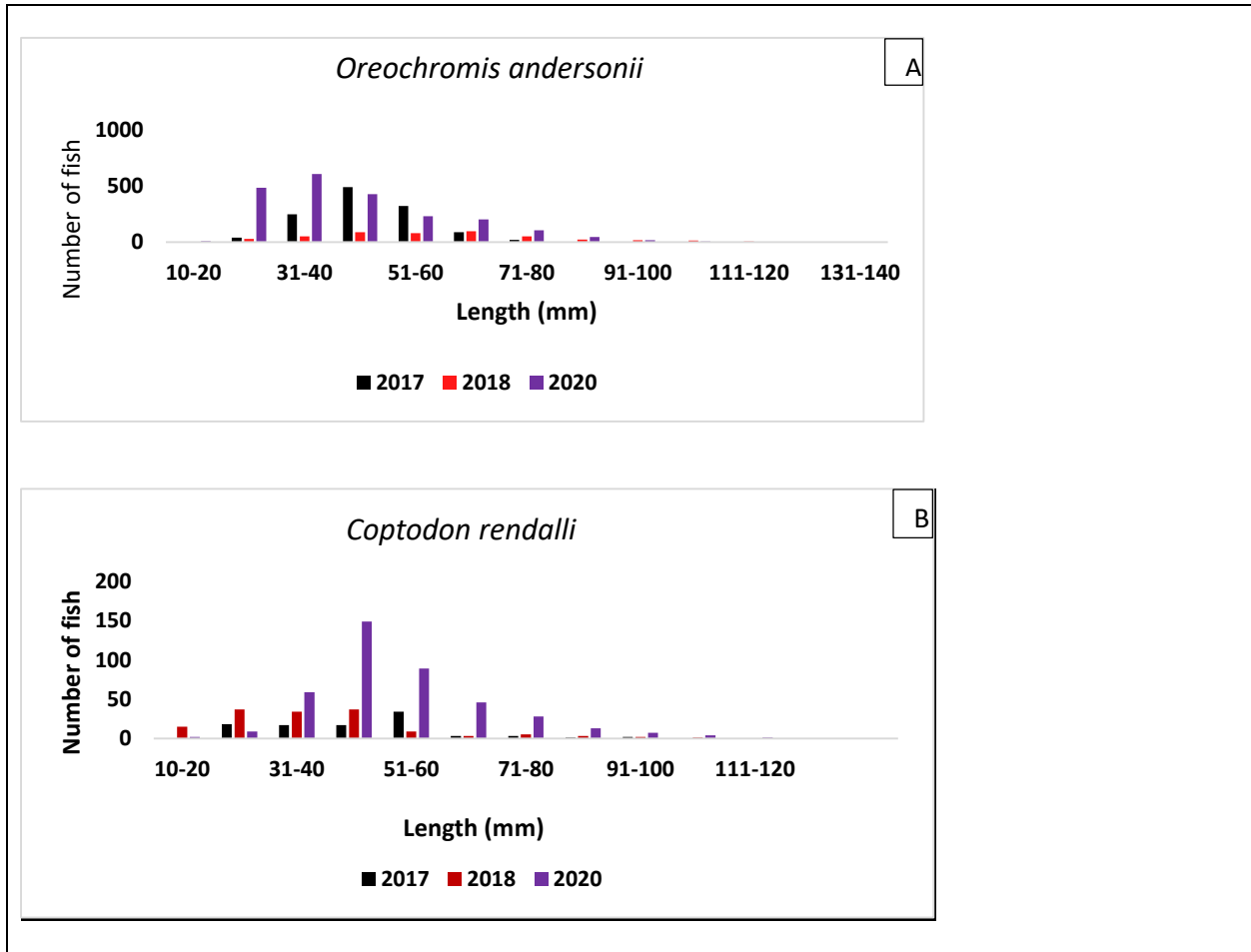
Figure 12).

Hydrocynus vittatus

The length of *Hydrocynus vittatus* recorded varied between 20 mm and 195 mm with the average length of 46.20 mm \pm SD 20.09 during the three-year sampling period. The mean length of *Hydrocynus vittatus* was 47.20 mm \pm SD 17.73 (n = 201) in 2017, 54.07 mm \pm SD 23.97 (n = 245) and 44.78 mm \pm SD 18.57 (n= 277) in 2018 and 2020 respectively. The majority of fish sampled

in numbers were found between the length classes 51 mm 59 mm (n = 54 mm) in 2017, 71 mm to 80 mm (n = 48) in 2018 and 31 mm to 34 mm (n = 68 mm) in 2020. This species vacated the Kamutjonga floodplain at the length classes of 131 mm to 140 mm (

Figure 12).



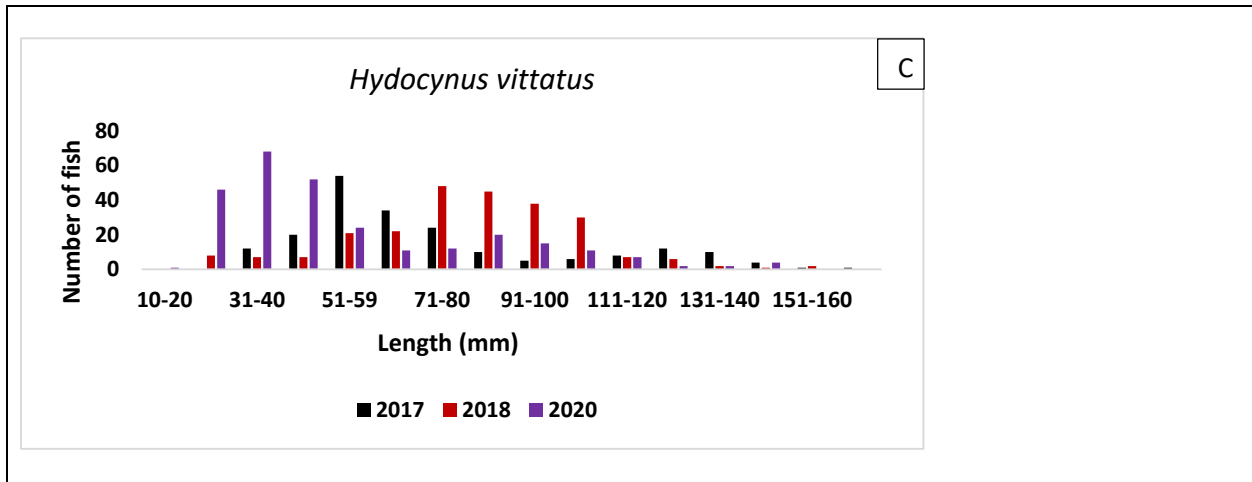


Figure 12 Length frequencies of *Oreochromis andersonii* (A), *Coptodon rendalii* (B) and *Hydocynus vittatus* (C) from 2017, 2018 and 2020.

4.5 Relationship between water level and catch per unit effort by number of all species combined

The results for water depth measured to the nearest cm throughout the sampling period are depicted in

Figure 13.

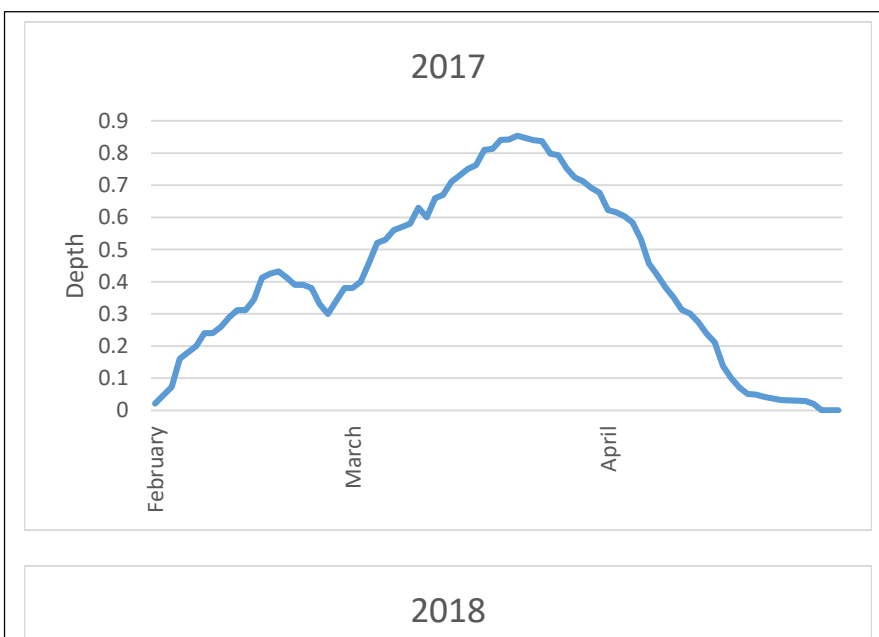
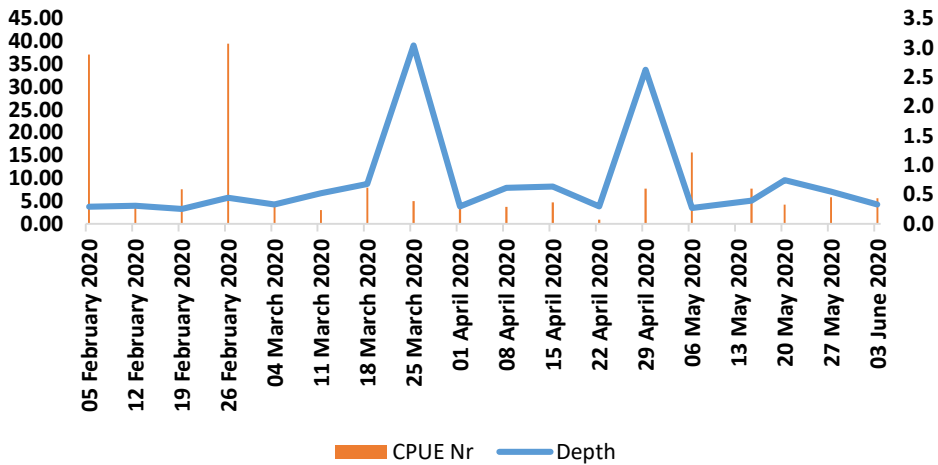
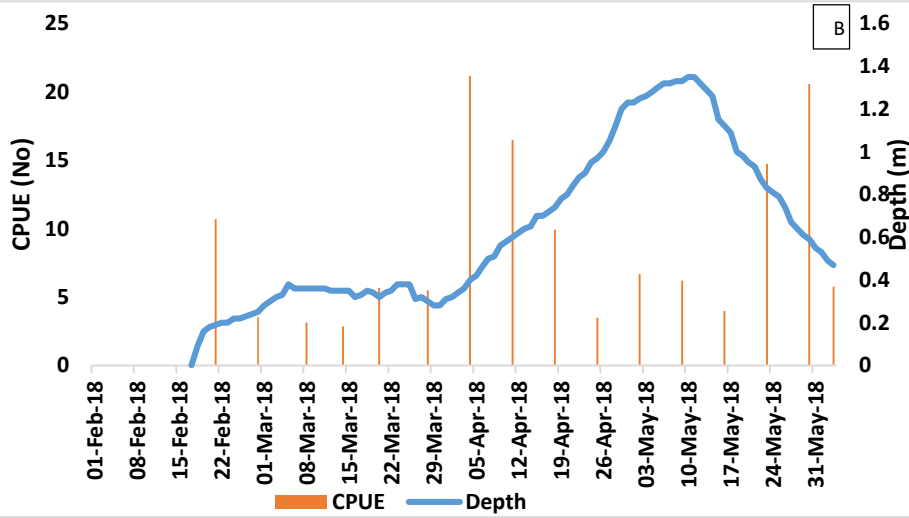
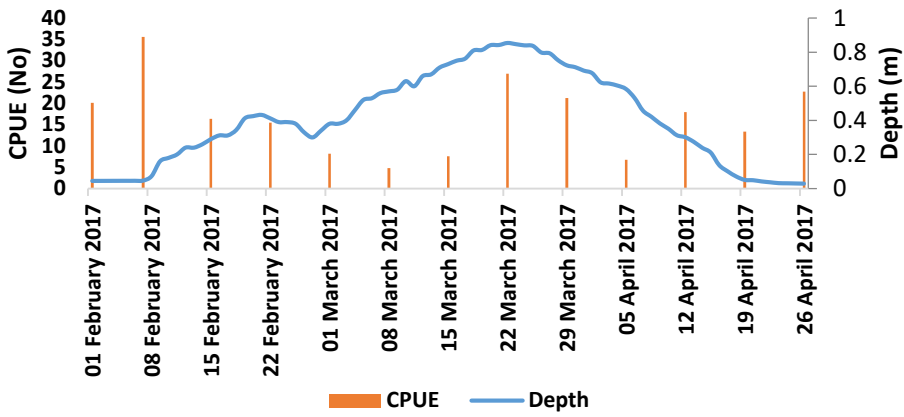


Figure 13 Water level (depth) of the Kamutjonga floodplain from February to April 2017, February to June 2018 and February to June 2020.

There was a negative but not significant correlation between water level (depth) and catch per unit effort in 2017 ($P = 0.05$) Figure 14). There was a negative and significant relationship between the water level and catch per unit effort by number in 2018, ($r^2 = 0.40$) and no significant correlation between water level and catch per unit effort in 2020 on the Kamutjonga floodplain (Figure 14).



c

A

Figure 14 CPUE by number verses water level (Depth) in Kamutjonga floodplain in 2017 (A), 2018 (B) and 2020 (C).

4.6 Correlation between water temperature and catch per unit effort by number

The monthly average temperatures in Kamutjonga floodplain were recorded from the beginning of the sampling period in February 2017 to the end of the sampling period in June 2020 and are depicted in Table 5. The average temperature in 2017 was 25.5 °C, the minimum and maximum water temperatures were 21.9 °C and 28.3 °C. In 2018, the minimum and maximum water temperature were 15.27 °C and 28.03 °C respectively with the average temperature of 23.80 °C. The average temperature in 2020 was 25.06 °C, with the minimum and maximum water temperatures of 16.98 °C and 28.48 °C. There was no significant difference in monthly average temperatures between years (Kruskal-Wallis test, $F = 5.148$, $DF = 2$, $P = 0.217$). Water temperature in all years combined had no significant correlation on the catch per unit effort by number (Spearman's rho correlation, $r^2 = 0.00144$, $P = 0.148$).

Table 5 Water temperature of Kamutjonga floodplain between February to April 2017, February to June 2018 and February to June 2020

Year	Average temp (°C)	Standard deviation (SD)	Minimum temp (°C)	Maximum temp (°C)
2017	25.53	1.70	21.86	28.30
2018	23.83	3.45	15.27	28.03

2020	25.16	3.13	16.98	28.48
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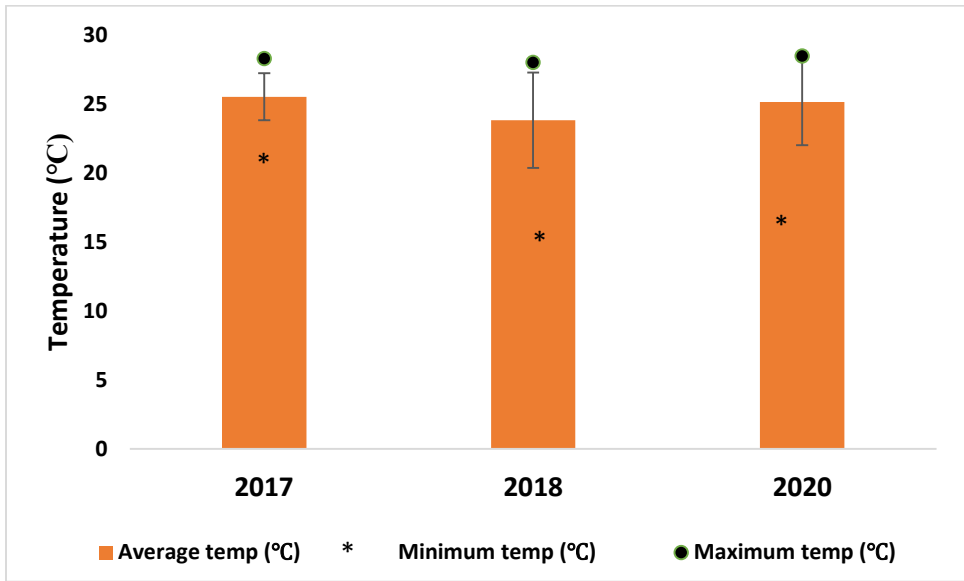


Figure 15 Average water temperature and standard deviation of Kamutjonga floodplain from February to April 2017, February to June 2018 and February to June 2020. ● represents maximum length, * represents minimum length.

5. DISSCUSION

5.1 Species composition of the Kamutjonga floodplain

The fish species composition found in the Kamutjonga floodplain included juveniles of the commercially important fish species such as *Oreochromis andersonii*, *Tilapia sparrmanii*, *Coptodon rendalli* and *Hydrocynus vittatus*. In addition, small sized species such as *Pseudocrenilabrus philander*, *Lacustricola johnstoni* and some *Enteromius species* (*E. radiatus*, *E. bifrenatus* and *E. poechii*) were also sampled. The results of this study also illustrated that the Kavango River's Kamutjonga floodplain is an important habitat for juvenile cichlids. These observations are in line with the findings of Hay et al., (2000), Peel (2012) and Simasiku (2014) who reported that the newly inundated areas of the Kavango are dominated by juvenile cichlids (e.g. *Oreochromis andersonii*, *Tilapia sparrmanii* and *Coptodon rendalli*) and cyprinids (e.g. *E. bifrenatus* and *E. barnardi*) during the first month of flooding. The majority of fish species were similar in all the years of sampling during this study. Mosepele (2019) also noted the presence of these species in the Okavango delta. Floodplains are utilized by these fish species for feeding, reproduction and shelter. The abundance of Tilapiine cichlids is attributed to the habitat preference of this species. This proves the preference of these fish species for slow-flowing or standing waters such as floodplain lagoons (Skelton, 2001; Thorstad et al., 2003). This agrees with Skelton (1993) who stated that juveniles of cichlids prefer to remain inshore among vegetation while some of the adults occupy open waters. Most of the fish species were observed hiding next to the bridge during sampling. As noted by Økland et al., (2005), fish species have adapted to the flood cycle

by spawning during the rising phase and placing their juveniles in more protective areas of the floodplain. It was also observed during this study that the vegetation, as well as the bridge on the Kamutjonga floodplain played an important role in providing protection for juveniles. During sampling, most fish species were witnessed hiding in these two habitats. The results of this study showed that the majority of fish species were frequently encountered in all years of sampling especially cichlids except species such as *Serranochromis angusticeps*, *Oreochromis macrochir*, *Sagochromis greenwood* which was not encountered in 2020.

5.2 Species richness and species diversity

The species richness in Kamutjonga floodplain during the first (2017) and third year (2020) of sampling were almost the same. In addition, these two years of sampling had the same number of fish families represented even though there were differences in the duration of the flooding season, being a shorter flood period during the first year of sampling and a longer flood period during the third year of sampling. On the other hand, the second year of sampling (2018) which was also one of the years that had a longer flooding period was found to be the highest in species richness. However, the number of recorded fish families and individual number of the most frequent species were equally low during that year. Flood duration has been suggested to influence fish diversity and density (Agostinho et al., 2001). Long floods have been proven to increase diversity because of the protective function of flooding and by allowing more species to spawn (Agostinho et al., 2001).

The current study found no significant difference in species diversity on the Kamutjonga floodplain between the three sampling years. The Cyprinidae and Cichlidae were the two most dominating families throughout the sampling period. The cyprinids are the largest fish family in

Southern Africa with 80 species some of which are economically important in fisheries and aquarium trade for instance *Enteromius poechii* which is also used as a bait for *Hydrocynus vittatus* (Hay et al., (2000). The Cichlidae is the largest fish family in Africa with about 900 species described (Skelton, 2001) and in this study, 25% to 32% of cichlids species were sampled on the Kamutjonga floodplains. This included *O. andersonii*, *C. rendalli*, *S. altus* and *T. sparrmanii* among others. The prevalence of fish families such as cyprinids and cichlids on the Kamutjonga floodplain supports the study of Hoberg et al., (2000) and Siziba et al., (2011) who reported a high incidence of juvenile cichlids and cyprinids in the temporary floodplains of the Kavango River. In addition, Hocutt and Johnson (2001) and Hay et al., (2000) reported a high incidence of Cyprinidae and Cichlidae families in Kavango River.

It has been suggested that the diversity of fish in freshwater systems is related to habitat structural complexity (Peel, 2002). Species diversity is expected to be higher in the river than it is in floodplains due to complex habitats found in the main river as compared to floodplains with changing structures of habitats. The number of fish species recorded in this study was less than what was recorded by Hay et al., (2000) in the Kavango River (76 fish species) and Siziba et al., (2011) in the temporary floodplains of the Okavango Delta but higher than the 24 fish species recorded by Simasiku and Mafwila (2017) in the lateral zone of the Kavango floodplain. These variations are due to the different aquatic habitats, sampling equipment, sampling design and the effort employed in different studies (Simasiku et al., 2021). It is important to note that the type of gear used as well as the size of the area sampled will always determine the number of species sampled from a specific area. This may explain why certain fish species were not encountered in this study and the scarcity of other fish species.

5.3 Catch per unit effort (CPUE) of fish species on the Kamutjonga floodplain

5.3.1 Monthly and annual catch per unit effort by number and weight of all fish species

The catch per unit effort by number and weight was higher in the last year of sampling when the flood season was longest and lowest during the first year of sampling where the flood season was the shortest. In this study, the flood duration was highest in 2020 (18 weeks of flooding) followed by 2018 (15 weeks of flooding) and shorter in 2017 (13 weeks of flooding). The catch per unit effort by number and weight were highest in 2020 followed by 2018 and lowest in 2017. This could have been because there was no sampling done in 2019 because of the absence of flood exacerbated by drought that particular year. This indicates that perhaps the lack of flood the previous year allowed the floodplain to accumulate nutrients which increased fish productivity in 2020. Furthermore, the duration of the flood in 2020 lasted longer followed by the 2018 and 2017 flood cycles. This observation was supported by Junk et al. (1989) who suggested that the longer the floodplain is inundated, the higher the survival rates of juveniles and the higher the fish production on the floodplain. It has been noted that, the years of high flooding result in a higher abundance of catchable fish and consequently, an increase in the catch per unit effort. These annual variation in the catch per unit effort were expected because of the annual differences in the duration and extent of flooding. The results of this study are in accordance to the findings of Hocutt and Johnson, (2001) that productivity in floodplains depend on the magnitude of flooding. Moreover, it has been reported that the catch per unit effort in years with high flooding is inferred to reflect high fish abundance which might be due to high recruitment and the survival of the young-of-the-year fish (De Graaf, 2003).

The high catches during the receding flood phase supports what was proved by Peel (2012) that low water period results in an increase in fish densities. This is in agreement with the data from three African Rivers reported by Welcomme (1975) that the catches are higher during years of good floods and poor during years of poor floods.

The results from this study indicate that there were monthly and annual fluctuations in catch rates. The high catch per unit effort by number and weight during the rising flood period was due to abundant food resources provided by the nutrient rich floodplain environment. This agrees with the findings by Winemiller and Jepsen (1998) that the high number of fish on the floodplain at the beginning of flooding is a result of longitudinal migrations of fish in association with nutrient availability. Different fish species migrated from the main river to the newly inundated floodplains for feeding opportunities, spawning and refugia thereby increasing the productivity of floodplains as described by previous research (Junk et al., 1989; Winemiller, 1996; Siziba et al., 2011). As the water level continued to increase, there was a decline in catch rates. This was observed especially in the year 2020 whereby the decline in the number of fish sampled when the water reached the peak was due to an increase in the availability of habitats which allowed fish not to be concentrated in one area but to become more dispersed by moving to different habitats on the floodplain such as open water, dense vegetation and most juveniles moved towards the bridge. This is similar to what was stated by Siqueira-Souza et al. (2016), that there is a reduction in the population density of many fish species during high water. According to Peel (2012) and Welcomme (2001) prey species use the vegetation on the floodplain for refuge.

The reduction in the catch per unit effort by number during receding flood period was also due to mortality. During the low flood period, spawning habitats get reduced and nursery areas become extremely shallow (Lindholm M, 2007). Consequently, fish became crowded and more

congregated in pools and channels on the floodplain making them easier to catch. Moreover, they became more vulnerable to fishing mortality by the local communities, particularly women and children who spent most of their time fishing on the Kamutjonga floodplain. During the months of receding, there is a reduction in water volume and thus there a high counter rate between predator and prey, hence increased abiotic interaction. Equally, the water condition becomes hypoxic, and unsuitable for sensitive species such as cichlids. Usually such species will always leave the floodplain towards the recession phase of the flooding season.

5.3.2 Catch per unit effort by weight of the dominant fish species

There was no variation in the catch per unit effort by weight of *Oreochromis andersonii* during the first year of sampling in 2017 and the last year of sampling in 2020 on the Kamutjonga floodplain. However, variations in CPUE by weight of this species were observed in the second year of sampling in 2018. According to the results of this study, the catch per unit effort by weight of *O. andersonii* was the highest in June and lowest in February 2018. This might be because at the beginning of inundation on the floodplain (February), *O. andersonii* migrates on the floodplains for feeding and breeding in response to favourable conditions (food availability and many different habitats) (Simasiku et al., 2021). From this period to the end of the flood season in June, based on the frequent samples *O. andersonii* might have successfully spawned and used the available food resources to enhance recruitment. This might have contributed to the increased catch per unit effort by weight in June 2018. Similarly to *O. andersonii*, the high catch per unit effort of *Coptodon rendalli* in March during the 2017 sampling year, follows their biology, coinciding with their breeding periodicity from August to March (Peel, 2012). This agrees with the high abundance of *C. rendalli* observed by Simasiku et al., (2021) in the Zambezi / Chobe floodplain. *Hydrocynus vittatus* was one dominant fish species without any significant difference

in the catch per unit effort by weight. Mosepele et al., (2009) suggested that the contraction period (decreasing inundation) results in increased activities by predatory fish species such as *Hydrocynus vittatus*. This fish species preys on whatever is most abundant (Skelton, 2001).

5.4 Length frequencies of the dominant fish species

Oreochromis andersonii is a large species with a total length above 500 mm (Trewavas, 1983). In this study, the length of *O. andersonii* ranged from 19 mm to 132 mm. The reported length of *O. andersonii* at 50% maturity was 240 mm (Peel, 2012). The obtained minimum, maximum and mean lengths of *O. andersonii* in this study are below the 50 % maturity length reported by Peel (2012). The majority of fish caught in numbers were found within the length classes 41 mm to 50 mm, 61 mm to 70 mm and 31 mm to 40 mm in 2017, 2018 and 2020 respectively. According to the findings of this study, *O. andersonii* obtained from the Kamutjonga floodplain were immature. The abundance of juveniles *O. andersonii* in the Kamutjonga floodplain is because of the species preference for standing or flowing waters such as floodplains where juveniles remain among the vegetation while adults occupy open waters (Skelton, 2001). The reported size at which *Oreochromis andersonii* left the Kavango River's Kamutjonga floodplain was between 71 mm to 80 mm. This agrees with what was reported by Simasiku and Mafwila (2017) that juvenile *O. andersonii* left the marginal zone of the Kavango River at an average size of 80 mm to 90 mm (TL). Similarly, Simasiku et al., (2021) found that this species left the littoral zone of the Zambezi Chobe floodplain at an average size between 70 mm to 80 mm.

Coptodon rendalii (Redbreast tilapia) reaches maturity at the length of 110 and prefers quiet and well vegetative water along the river floodplains, littorals or backwaters (Hay et al., 2000). The minimum maturity length of this fish species observed by Hay et al., (2000) was between 110 mm

and 140 mm for males and females respectively. (Hay et al., 2000). In this study the majority of *Coptodon rendalli* sampled were between the length classes of 51 mm to 60 mm in 2017, 21 mm to 30 mm and between 41 mm to 50 mm in 2018 and 2020. The fish species caught were immature fish. The expected response of fish to unsuitable conditions during low water is to move into the main stream and therefore the juvenile *Coptodon rendalli* left the Kamutjonga floodplain before the connection between the floodplain and the main river could end during the receding flood period at the length classes of 81 mm to 90 mm. This agrees with the reported average size of 70 mm to 80 mm at which the juvenile *C. rendalli* vacated the littoral zone into the main river channel of the Zambezi / Chobe floodplain (Simasiku et al., 2021).

Hydrocynus vittatus (Tigerfish) is a popular species in commercial and subsistence fisheries, as well as for angling and targeted for fishing competitions. It prefers warm, well-oxygenated water where it breeds during summer and adults migrate up or downstream to suitable spawning sites along flooded areas where the hatched larvae are carried to the main water body (Skelton, 2001). It is a predatory species which is endemic to Africa (Jacobs et al., 2019). The maturity length for the male is 300 mm to 400 mm whereas that of females exceeds 400 mm (Skelton, 2001). In Kavango, were found to be 180 mm and 270 mm for males and females with the length at 50% maturity being 200 mm and 280 mm respectively (Hay et al., 2000). The majority of fish species caught in numbers were within the length classes 51 mm to 59 mm in 2017, 71 mm to 80 mm in 2018 and between 31 mm to 40 mm in 2020. In this study, *H. vittatus* caught on the Kamutjonga floodplain throughout the study period were juveniles. The size of *H. vittatus* obtained in this study confirms what was stated by Skelton (1993) that *H. vittatus* spawns on the floodplain. This was also stated by Skelton (1993) who suggested that *H. vittatus* migrates downstream or upstream (longitudinal migration) to suitable spawning sites during flooding. Hay et al., (2000) also reported

that *H. vittatus* spawns in shallow flooded areas. The absence of larger sizes of this species in this study might be explained by its preference for larger, fast-flowing water bodies such as open waters in rivers or lakes (Merron, 1995; Hay et al., 2000). This species shows opportunistic migration patterns related to spawning, feeding and water temperature based on the conditions where it reside (Thorstad et al., 2002). The results of this study also confirm previous findings (Merron and Bruton, 1995; Merron, 1995; Mosepele, 2017) that the population distribution and abundance of *H. vittatus* is regulated by the flood pulse.

The results obtained in this study agree with what was stated by Hay et al., (2000) that the fish community of the Kavango River is dominated by small fish species. The sizes observed for different fish species are due to rapid growth resulting from food availability and a reduction in density dependent competition (Welcomme, 2001). This was proved by the results of this study. The year 2018 had the lowest number of fish species as compared to 2017 and 2020. However, this was the year which had the highest size of fish. This proves that the reduced number of fish results in reduced competition for food resources. Moreover, the variation in fish sizes might also be due to environmental conditions experienced by different fish species (Booth et al., 1995).

5.5 The influence of water level and catch per unit effort by number of all species

The results of this study indicate that, the relationship of water level on the catch per unit effort by number was inversely related in 2018. The decline in catches during the rising phase of the flood is attributed to fish becoming more dispersed and the prey species using the vegetation on the floodplain for refuge (Peel, 2012; Welcomme, 2001). In this study, the chances of catching fish during high water levels were limited due to an increase in the habitats of choice as the floodplain expanded which allowed fish to find refugia in different habitats. This is due the dilution effect (Junk et al., 1989).

5.6 Correlation between water temperature and catch per unit effort by number of all species

The results of this study indicate that the water temperature of the Kamutjonga floodplain did not influence the catch rates (catch per unit effort by number). The results from this study agree with the findings by Simasiku et al., (2021) that temperature showed no relationship to the fish species community assemblages in Zambezi / Chobe floodplain (Lowe-McConnell, 1987. According to Lowe-McConnell (1987), the temperature is constant in tropical streams and is considered to have less influence on fish behaviour than in temperate streams.

6. CONCLUSION

The Kamutjonga floodplain is a unique, productive and diverse ecosystem which supports a range of aquatic biota. This floodplain has proven to be essential for breeding, feeding and nursery. The findings of this present study have shown the fish species composition that colonize the Kamutjonga floodplain, their habitat preference and utilization. The Kamutjonga floodplain is used as a nursery area for by Namibia's commercially important and subsistence fish species such as *Oreochromis andersonii* and *Coptodon rendalli*. This was observed based on the high abundance of juvenile fish species that were captured as the flood season was progressing. Furthermore, the fish species which inhabit this floodplain uses the floodplain as a refuge area, they move out from the main river onto the floodplain in order to find protection from a high risk of predation faced in the mainstream. The vegetation and the bridge on the Kamutjonga floodplain provided protection from predators for these juveniles. This was observed during sampling where they would move towards the dense vegetation as well as the bridge where the seine net could not reach.

According to the findings of this study, the catch rates in Kamutjonga floodplain are influenced by the flood duration. The years with a longer flood period (2020) had the highest catch rates as compared to the year with a short flood period (2017). On the other hand, the years which got inundated early (2018) had the high number of species families. This suggests that the timing of the flood plays a role in fish species abundance. This study has shown that, the size and duration of flooding are the key determinant factors in the floodplain fish community structure.

This study has shown the importance of flooding for recruitment and how climate change (i.e drought) is likely to reduce recruitment. The length frequency results indicated that the majority

of being harvested on the Kamutjonga floodplain were immature. These juveniles are harvested before they could spawn and contribute to the fish stock of the Kavango River. This study has shown no significant difference in the species diversity.

Water level was also another key important factor in shaping catch rates of fish in the Kamutjonga floodplain. The findings of this study have indicated that water level is responsible for fish distribution and abundance. Cichlids are also important for subsistence and their decline will negatively impact livelihood. On the other hand, the water temperature of the Kamutjonga floodplain had no influence on catch rates.

In conclusion, the Kamutjonga floodplain represents an important habitat for different fish species, particularly juvenile cichlids and small-sized fish species. Lack of regulation or monitoring of this particular floodplain, might negatively affect the fish species composition and species diversity. Moreover, juveniles may be prevented from recruiting into adult populations which could contribute to the fish stock in the Kavango River.

7. Recommendation

The results from this study show that over 30 fish species inhabit the Kamutjonga floodplain. The high abundance of juveniles and small sized fish species in the Kamutjonga floodplain proves that this floodplain is an important habitat for fish breeding, feeding, reproduction and recruitment. It is therefore recommended that continuous monitoring of this particular floodplain should continue as this floodplain has proved to be an important habitat for commercially important fish species.

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Appendix 1



ETHICAL CLEARANCE CERTIFICATE

Ethical Clearance Reference Number: SOS-0001 Date: 13 October 2021

This Ethical Clearance Certificate is issued by the University of Namibia Ethics Committee (REC) in accordance with the University of Namibia's Research Ethics Policy and Guidelines. Ethical approval is given in respect of undertakings contained in the Research Project outlined below. This Certificate is issued on the recommendations of the ethical evaluation done by the ethics committee.

Title of Project: ANNUAL VARIATION IN FISH SPECIES COMPOSITION AND DIVERSITY IN THE KAMUTJONGA FLOODPLAIN, KAVANGO RIVER, NAMIBIA

Student: NAUMI STELLA LIBALA

Student Number: 200813234

Supervisor(s): Dr. Clinton Hay (University of Namibia);
Dr. Tor Naesje (Norwegian Institute for Nature Research);
Dr. Francois Jacobs (Ministry of Fisheries and Marine Resources)

Centre for Research Services

Take note of the following:

1. Any significant changes in the conditions or undertakings outlined in the approved Proposal must be communicated to the ethics committee. An application to make amendments may be necessary.
2. Any breaches of ethical undertakings or practices that have an impact on ethical conduct of the research must be reported to the ethics committee
3. The Principal Researcher must report issues of ethical compliance to the ethics committee (through the Chairperson) at the end of the Project or as may be requested by the ethics committee
4. The ethics committee retains the right to:
 - i) Withdraw or amend this Ethical Clearance if any unethical practices (as outlined in the Research Ethics Policy) have been detected or suspected,
 - ii) Request for an ethical compliance report at any point during the course of the research.

The ethics committee wishes you the best in your research.

A handwritten signature in black ink, appearing to read 'Zivayi Chiguvare', is written over a horizontal line.

Dr. Zivayi Chiguvare (Chairperson Ethics Committee)

A handwritten signature in black ink, appearing to read 'Davis Mumbengegwi', is written over a horizontal line.

Prof. Davis Mumbengegwi (Head, Multidisciplinary Research)