

THE SPATIAL, TEMPORAL AND VERTICAL FISH SPECIES COMPOSITION OF
THE KAMUTJONGA FLOODPLAIN, KAVANGO RIVER, NAMIBIA.

A THESIS SUBMITTED IN FULFILMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF SCIENCE (BIOLOGICAL SCIENCES)

OF
THE UNIVERSITY OF NAMIBIA

BY

VILIO TUUTILENI MUUNDA

201610508

OCTOBER 2023

MAIN SUPERVISOR: Dr Clinton Hay (Department of Environmental Science,
University of Namibia)

CO-SUPERVISORS: Dr Francois Jacobs (Ministry of Fisheries and Marine Resources)

Dr Tor Naesje (Norwegian Institute for Nature Research)

ABSTRACT

The present study investigated the variations in fish species composition on a floodplain during a flood pulse on the floodplain along Kavango River, Namibia. Specifically, the study aimed at comparing the species composition, the catch per unit effort, and the body length of two selected species (*Pseudocrenilabrus philander* and *Tilapia sparrmanii*) across periods during the flood, across depth intervals and sites on the floodplain. Further, the study also aimed at determining any correlation between the catch per unit effort and the physio-chemical parameters of the water. A throw trap net was used to sample six (6) sites along the peripheries of the Kamutjonga floodplain during its inundated period (20 February 2020 to 09 June 2020), with each site subdivided into three depth intervals – 0-29 cm, 30-59 cm and 60-99 cm. Three flooding periods (early, middle and late) were identified during the flood pulse. A total of 48 throws were cast at each site per flooding period, with each depth interval sampled 16 times per site. A total of 30 species were recorded on the floodplain, with the highest number of species (17) recorded during the early flooding period, in the deepest section sampled (60 – 99 cm) (21 species) and at site 2 (20 species). Cichlids dominated the floodplain, with *Oreochromis andersonii* and *Pseudocrenilabrus philander* being the most important species during the early and late flooding period, respectively. Few but large specimens were on the floodplain during early flooding, whilst a lot of small (by weight) specimens were during the late flooding periods. More specimens, yet large (by weight) were found on the shallow section (0 – 29 cm) of the floodplain. The findings uphold the significance of the peripheries of newly inundated areas, which are documented to serve as breeding, nursery and forage grounds for most riverine species. A large proportion (83%) of individuals such as those of *P. philander* were above sexual maturity during the early flooding period, which coincided with the highest number of small-sized specimens during the late flooding period – further hinting at the use of the floodplain as a breeding ground.

Keywords: Floodplain, fisheries, Kavango River, Kamutjonga, Throw-trap net, fish species composition, Spatio-temporal, Namibia

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LIST OF ABBREVIATIONS AND ACRONYMS

CPUE -	Catch per Unit Effort
FPC -	Flood Pulse Concept
GPS -	Geographic Position System
IRI -	Index of Relative Importance
KIFI -	Kamutjonga Inland Fisheries Institute
m a s l -	Meters above sea level
PVC -	Polyvinyl Chloride
SPSS -	Statistical Software Package for Social Science

ACKNOWLEDGEMENT

I would like to thank God Almighty for blessing me with the potential to undertake this research and the diligence to complete it to the best of my abilities. My deepest gratitude goes out to my supervisors, Dr Hay Clinton, Dr Francois Jacobs and Dr Tor Naesje, for their invaluable guidance and their overall supervision offered during my research project.

I would like to thank Mr Renier Burger and the entire staff members of the Kamutjonga Inland Fisheries Institute (KIFI) for making my stay at KIFI memorable – during the challenging times of the COVID-19 global pandemic. From housing, orientation, and data collection, the staff members of KIFI have always been keen to lend a helping hand.

A vote of thanks goes to the Namibian Chambers of Environment and the Norwegian Institute for Nature Research for providing the financial support that enabled me to complete this study. I would further like to acknowledge and thank my colleagues Phillipus Tshimwandi and Nghilifavali Mwatilifange for their assistance offered during the field data collection. Much appreciation to my mother, Sevelia Daniel, and aunt, Helen Nghishiti, for your prayers and support.

My friends and family members along with anybody who may have contributed directly or indirectly to this study, I thank and appreciate you.

“And whatever you do, whether in word or deed, do it all in the name of the Lord Jesus, giving thanks to God the Father through Him”

Colossians 3:17

DEDICATION

This thesis is dedicated to my grandmother, Teresia Hamutenya, whose kind words of encouragement have laid a strong foundation for my self-belief and self-esteem, ensuring that I achieve all that I set my sight on. To this day, her favourite Oshiwambo phrase “ino nyengwa koshiima ihashi popi” (which loosely translates to “do not be defeated by what does not speak”) still plays a determinant role in how I approach tasks.

DECLARATION

I, Vilio Tuutileni Muunda, hereby declare that this study is my own work and is a true reflection of my research and that this work or any part thereof has not been submitted for a degree at any other institution.

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Mr. Vilio Tuutileni Muunda



October 2023

Name of Student

Signature

Date

CHAPTER 1: INTRODUCTION AND LITERATURE REVIEW

1.1. General introduction

In Namibia, the characteristic annual inundation of the low-lying areas adjacent to the Kavango River results in many fish species migrating into the floodplain for, but not limited to, breeding and shelter from predation. This river/floodplain interaction is important for maintaining the ecological integrity of the river, as postulated in the Flood Pulse Concept -FPC- (Junk *et al.*, 1989). The FPC states that a significant proportion of the composition, productivity and interaction of a river's biota is derived from the adjacent low-lying areas, rather than being transported from upstream, as advocated in the River Continuum Concept (Vannote *et al.*, 1980). As the river inundates its floodplains, nutrients are discharged from the soil and added to the water. This accrued availability of nutrients suggests that floodplains may directly enhance the recruitment of fish, and hence, indirectly alter the fish species composition and productivity of both the river and its floodplains (Bayley, 1995; King *et al.*, 2003).

The floodplain areas provide suitable spawning and nursery habitats, because the fish may evade predators by escaping into the surrounding vegetation and shallow waters.

Furthermore, some fish species and juvenile fishes may also feed on the suspended algae in the water, as documented in Bayley (1995) and Junk *et al.*, (1989). Unlike large-sized fish, small-sized fish on floodplains are an important source of vital nutrients for rural communities, because they are usually consumed whole (with guts, bones and heads) (Kolding *et al.*, 2016). This underpins the importance of temporal subsistence fishery in floodplains and associated wetlands such as iishanas, ensuring food security and a source

of income generation to over 50% of rural communities in northern Namibia throughout the flood cycle (Bene, 2003). It is reported that the majority (75-85%) of fish offspring die before they reach maturity, and only a few individuals need to survive from each spawning female to maintain the population (Welcomme, 1975). Hence, in theory, a fishery that exploits the surplus production of fish is not harmful to the fish populations and will support and provide important and easily accessible protein to people.

Floodplain fisheries have been a source of food security for poor rural communities globally (Bennett *et al.*, 2018; Funge-Smith & Bennett, 2019; Taylor *et al.*, 2011), and its significance in Namibia is also great where it serves as a critical source of proteins and daily relish for communities living along the floodplains. A recent study on the Kamutjonga floodplain revealed that community fishers frequently used mosquito nets and plastic containers as their main fishing gear during the flooding season, mainly catching juveniles and small fish species between 25 – 50 mm in length (Tiyeho, 2022). Noting the: a) nutritional significance of juveniles and small fishes, which are predominantly caught by community fishers, b) the increasing demand for juveniles and small fishes, and c) the critical yet urgent need to better understand the variation of fish species composition on floodplains to aid management; the present study aims to provide a focused and detailed analysis of where and when the small, but highly nutritious fishes are located on the Kamutjonga floodplain.

In general, the fish species composition has been noted to vary in both time and space in Rivers and associated floodplains (Castro *et al.*, 2002; Ngor *et al.*, 2018). Within the same floodplain, anthropogenic factors such as the construction of bridges have the potential to form fragments of unique species composition in the same floodplain (Skelton, 1993). In

addition, depth, and physiochemical parameters such as temperature and the availability of forage are among some of the factors that influence the distribution of fish over time (Castro *et al.*, 2002; Ngor *et al.*, 2018; Skelton, 1993).

1.2. Defining floodplains

Floodplains are intricate ecosystems, with a great degree of temporal and spatial plasticity. There are several definitions for “floodplain”, although some definitions are more ecologically-relevant than others. To highlight the ecological relevance, a floodplain definition must acknowledge that flooding impacts the biological components of the water that will subsequently react according to the flooding. Equally important, it must state that the response of the biota is not affected by the source of the pulsing water and that there exists a wide range of ecological similarities between the adjacent water source and the floodplain. Moreover, it must take into account the wide-ranging hydrological spectrum of the duration and timing of the flood. Such was Junk *et al.* (1989)’s ecological definition of a floodplain. They defined a floodplain as an area that is periodically inundated by the lateral overflows of adjacent rivers/lakes, or by direct precipitation or groundwater; and the subsequent physiological characteristics cause the biota to acclimatize by altering their morphological, anatomical, physiological, phenological and/or ethological traits, producing unique community structures (Junk *et al.*, 1989).

Floodplains are generally considered to be transition zones between the aquatic (riverine) and the terrestrial realm. Extending from the low to the high-water line, these ecotones consist of terrestrial vegetation that is influenced by the sudden availability of water and associated nutrients (Jain *et al.*, 2008; Suchara, 2018; Tockner & Stanford, 2006). Junk *et*

al. (1989) also termed the floodplain areas the “Aquatic /Terrestrial Transition Zone” because it alternates between aquatic and terrestrial environments. During the flooding seasons, the floodplain may be overwhelmed by aquatic biota, which migrates back into the river (or die on the floodplain) when the water recedes, creating a niche for terrestrial plants and animals to dominate the floodplain.

1.3. Life-history cycles and survival tactics of common fishes in the Kavango River

There are wide variations in the life cycles of most riverine fish species all over the world and specifically along the stretches of the Kavango River. Some species, such as those belonging to the *Enteromius* genus, have relatively simple life cycles, which begin with the fertilisation of one of the numerous eggs scattered in submerged vegetation. The embryo takes about two days to hatch into a small larva that would continue to develop for another two days while feeding on micro-planktons before the fish becomes a fully formed juvenile. Over the next few months, the fish will mature and start the cycle over again. Other species have life cycles that are slight variations of this, becoming more complex with each species (Skelton, 1993). Some cycles involve migrations between the River and the floodplain. Threespot tilapia, like several other cichlids - excavates nests and breed in the River before flooding. After hatching, threespot tilapia then migrates from the River onto the floodplain to nurse the fries that were bred in the River. On the floodplain, their chances of survival are increased as there is reduced predation due to the cover provided by thick vegetation, while the feeding habitats are also increased (Bruton *et al.*, 2018).

Certain fishes of the Kavango River, such as the Okavango tilapia, tigerfish and the threespot tilapia have very specific habitat requirements, which vary according to the stages of the life cycle. When they migrate onto the floodplain during a flood pulse, it is done following behavioural survival mechanisms that prevent them from getting stranded when the water recedes. Specifically, as the flood water recedes, floodplain fishes migrate into the main River channel and survive the dry season on the vegetated reeds of the river (Bruton *et al.*, 2018). The catfishes (both bluntfoot and sharptooth) can breathe air, enabling them to survive habitat desiccation and even use their pectoral fins as “legs” to cross moist grounds in search of new habitats (Bruton *et al.*, 2018; Skelton, 1993)– i.e. migrating from the drying floodplain onto the main River channel.

1.4. River-floodplain systems

Most floodplains have biological characteristics that are similar to those of the river/ water source. However, the relationship between the river and its floodplain extends further than the supply of water from the river to the floodplain. Floodplains serve as grounds for spawning, nursery, protection and food for fish. In return, the floodplains replenish the river with nutrients and a large number of matured fishes (Kangausaru, 2018). The interdependence between the two is so well-defined that it is regarded as an inseparable unit because they utilize the same water, sediments and organic budget (Junk *et al.*, 1989). This unit is termed a river-floodplain system.

In concert with the Flood Pulse Concept (Junk *et al.*, 1989), the water from the river connects and transverses the entire floodplain. The peripheral water column that transverses the floodplain is called the “moving littoral” (Junk *et al.*, 1989). This mobile

water column is responsible for wetting the floodplain during flooding. Moreover, the moving littoral is one of the key sources of river-derived nutrients that get fluxed into the floodplain, resulting in high floodplain productivity (Keizer *et al.*, 2014). This zone is rife with biological and chemical activities. During inundation, organic nutrients in the form of dissolved solids and particulate matter the minerals that were mineralised during previous flooding events are dissolved into the water and made accessible for biological uptake or chemical reactions (Junk *et al.*, 1989). During drawback, however, excess dissolved nutrients are dissolved back into the floodplain, which will eventually be availed for the succeeding flooding event (Bayley, 1995; Tockner *et al.*, 2000).

The best way to visualize and relate to the river-floodplain system is through Junk *et al.* (1989)'s perception of this ecosystem as analogous to a highway. Since the life history characteristics of fish in the river and the floodplains are moderately studied in Namibia and all over the world (Hay, 1990; Hay *et al.*, 2008; Jacobs, 2017; Mims *et al.*, 2010; Næsje *et al.*, 2004), their movement and distribution have been likened with that of the movements of vehicles on a highway (Junk *et al.*, 1989). The vehicles (fish) move up and down the highway (river) in different directions in search of resources. However, together with their symbiotic occupants (nutrients), they have to exit the highway for sustenance into areas of high productivity (floodplains), where they accumulate the fuel (nutrients/food, spawning, protection) required. The energised vehicles then return to complete the journey down the highway (river/downstream).

The river-floodplain system retains many ecological benefits, with some, such as the maintenance of biological diversity, being more evident than others. Bayley (1995) highlighted that enhanced production is a significant, but less obvious, benefit of the river-

floodplain system. There exists an optimal rate of inundation within whose upper and lower extremes production of aquatic biota is limited (Bayley, 1991). Fish yields from multi-species fisheries can be viewed as a homogenization of heterogeneous aquatic and terrestrial production processes (Bayley, 1995). Given that the total surface area of rivers is small compared to the average inundated area of associated floodplains (Bayley, 1995), and that the majority of riverine biota (especially fish) depend on floodplain resources (Junk *et al.*, 1989; Woods *et al.*, 2012), the remaining minority of fish that do not readily depend on the floodplain cannot have a significant influence on production.

1.5. Temporal riverine fish dynamics

Fish species composition on the floodplain has been reported to vary between seasons all over the world. On the right margin of Porto Rico Island in the upper Paran  River, Brazil, the temporal distribution and composition of ichthyoplankton were assessed on Leopoldo's Inlet (Castro *et al.*, 2002). In this inlet, the research demonstrated a variation in the temporal distribution of larvae on the floodplain, with the densities recorded ranging from 36.79 larvae/10 m³ to 0.05 larvae/10 m³. Albeit with significant dominance of one species (*Apareiodon afinis*) throughout the flooded period, there were structural shifts in the fisheries communities, with up to seven species dominating the inlet in the summer (February) of 1991, as opposed to the full dominance of *A. afinis* in winter (July) of 1991 (Castro *et al.*, 2002).

In South-eastern Asia, a study by Chan *et al.* (2017) documented that different fish functional groups occupied the water during different periods of flooding. In addition, the catch rates increased with the level of flooding water, and its fluctuations (Chan *et al.*,

2017). This functional and structural response to flooding has long been reported, including for Namibian river systems, where Hocutt and Johnson (2001) reported a significantly higher catch per unit effort and diversity during months of peak flooding, and the lowest during the month of least flow. Further, Simasiku and Mafwila (2017) revealed a shift in species dominance and mean length over the flooding period. At the beginning of the flood, *Oreochromis andersonii* dominated the floodplains during the rising phase of the flood (March-April) while *Tilapia sparrmanii* and *Pseudocrenilabrus philander* dominated the floodplain towards the end receding phase of the flooding (July-October) (Simasiku & Mafwila, 2017). Variations in fish abundances and composition between sampling months were attributed to the warm, wet season during the flood pulse and general seasonal variations, water level and life stages of the fisheries on the floodplain (Röpke *et al.*, 2015; Simasiku & Mafwila, 2017).

1.6. Spatial and vertical riverine fish dynamics

Fish species composition, community structure and diversity are fluid, with natural variations expected within and between systems due to internal and external dynamic aspects of the system itself. In South-East Asia's largest tropical flood pulse system, the Tonle Sap River and Lake, Ngor *et al.* (2018) reported distinct spatial abundance distribution patterns throughout the flood pulse-fed lake, with high diversity reported in the middle whilst low diversity was reported towards the peripheries of the lake. These spatial distribution patterns were attributed to the higher degree of inundation which tends to increase habitat connectivity and availability (Ngor *et al.*, 2018). Similar findings in tropical river-lake floodplain systems revealed that water depth and sufficient surface

cover were key drivers associated with high spatial fisheries diversity and composition (Fernandes *et al.*, 2010; Hoeinghaus *et al.*, 2003).

In Namibia, Simasiku (2019) conducted littoral surveys on the Zambezi/Chobe and recorded a total of 31 species during a single flooding event from March 2017 to February 2018. These systems were dominated by species of the Cichlidae and Cyprinidae families, with *Rhabdalestes maunensis*, *Pharyngochromis acuticeps* and *Enteromius paludinosus* all dominating the floodplains during different flooding periods (Simasiku, 2019). A similar pattern of family dominance was earlier reported along the Kavango River floodplains where Hocutt and Johnson (2001) recorded a total of 57 species from 1991 to 1993 with the majority from Cichlidae family: *Pseudocrenilabrus philander* (14.9%), *Tilapia rendalli* (11.6%), *T. sparrmanii* (10.0%) and Cyprinidae species such as *Enteromius poechii* (7.0%) (Hocutt & Johnson, 2001). The spatial dominance of similar species in different systems was accredited to reproductive periodicity and the general strategies, with r-selected species (mainly from the family Cyprinidae) forming a major component of the catch throughout the flooding cycles (Hocutt & Johnson, 2001; Simasiku, 2019).

Freshwater systems such as floodplains are typically restricted and well-defined in the extent they cover, often not directly connecting and merging with other systems, hence the fishes in these systems tend to be unique. In addition to this natural factor limiting the spatial distribution of fish, physical barriers (e.g. dams), physio-chemical tolerance (e.g. temperature), and biological barriers (e.g., alien species) are some of the factors that may hinder the spatial distribution of fish in freshwater systems (Skelton, 1993). An inadequate

effort has been extorted towards understanding the intra-floodplain spatial variations in fish species composition during a flooding event.

1.7. Kavango River and floodplain fish species richness

The Kavango River and its floodplains have received significant scientific attention in the past decade or so, particularly due to their immaculate contribution to sustaining the livelihoods of communities living along the floodplain. On the floodplain, various fishing methods are permitted by law, while only the gill nets are allowed for fishing in the Kavango River's main channel (on the Namibian section of the River). The type of gear used can influence the catchability and hence the reported number of fish species recorded in a system. During 1992 – 1999, Hay *et al.* (2000) identified 47 species from gill net catches from the Kavango River. Further, Peel (2012) recorded a total of 41 species in the Kavango River, whilst records dating back to the mid-1990s found up to 83 species in the Kavango River (Kangausaru, 2018; Peel, 2012).

Along the floodplains, the number of fish species may also vary from time to time and with the type of gear used to sample. During five seasonal sampling periods on the floodplains of the Kavango River in 1991, Hocutt and Johnson (2001) recorded a total of 57 species, although this was relatively fewer than those previously cited in the literature, with some researchers reporting as many as 65 species (Hocutt & Johnson, 2001). In recent studies, Kangausaru (2018)'s experimental dragnets recorded 31 species on the Kamutjonga floodplain, of which *Oreochromis andersonii* was one of the most important species on the floodplain with 57.8% of the total Index of Relative Importance. Before that, Simasiku and Mafwila, (2017) compiled a checklist of species on the floodplain and

recorded 24 species in the same floodplain. Tiyeho (2022), who assessed the catches of local fishers utilising various gears on the Kamutjonga floodplain parallel to this study, found a total of 23 species in 2020 (Tiyeho, 2022).

1.8. Problem statement

Although floodplains are areas with high diversity and productivity, there is a well-defined structural and functional response of fish communities to the alternating flood and drought conditions (Hocutt & Johnson, 2001; Junk et al., 1989; Kangausaru, 2018; Peel, 2012). Be that as it may, current management approaches in the Kavango River and its associated floodplains do not cater for intra-flood spatiotemporal variations in fish species composition. This makes it difficult to make informed management decisions and hence threatens the sustainable utilization of these floodplains and river resources. Therefore, in an attempt to provide much-needed scientific research on the detailed understanding of which species occupy the floodplain at various periods, depths and sites on the floodplain, in conjunction with other research that focused on other aspects of the floodplain, this study will be valuable information to the directorate of inland fisheries and aquaculture and the community members in their efforts to better manage the floodplain fish resources.

1.9. Aim and objectives of the study

The main goal of the study was to document the composition of fish species occupying different sites, depth intervals and at different periods of flooding on the Kamutjonga floodplain during the 2020 flooding cycle. Specifically, the study focused on:

- a) Determining the overall fish species composition on the Kamutjonga floodplain;

- b) Determining the correlation (if any) between catch per unit effort and the physiochemical parameters of the flood water;
- c) Comparing the fish species composition at varying depths, flooding periods and sampling stations on the Kamutjonga floodplain;
- d) Comparing the catch per unit effort of fish at varying depths, flooding periods and sampling stations on the Kamutjonga floodplain, and
- e) Comparing the lengths of selected species at varying depths, flooding periods and sampling stations on the Kamutjonga floodplain.

1.10. Null hypotheses

The following were the null hypotheses for the study:

- a) This is an exploratory objective, no hypothesis needed;
- b) There is no significant relationship between the various environmental variables measured and the catch rate
- c) There is no difference in the relative importance (IRI) of each species across the three levels of depth intervals, the three levels of flooding periods and the six levels of sampling sites;
- d) There are no significant differences in the catch per unit effort across the three levels of depth intervals, the three levels of flooding periods and the six levels of sampling sites;
- e) There are no significant differences in the body lengths of the selected species across the three levels of depth intervals, the three levels of flooding periods and the six levels of sampling sites;

1.11. Significance of the study

Floodplains serve as an important source of protein for the local fishers, who particularly target small-sized fishes on the peripheries of the floodplain (Tiyeho, 2022). Hence it is critical to understand the fish species composition of the small-sized fishes on the floodplain, particularly given the current increasing demand for fish. Hocutt and Johnson (2001) highlighted the significance of the variability in the degree and timing of a flooding cycle, therefore the same variability can be expected in the fish species composition of the Kamutjonga floodplain (Hocutt & Johnson, 2001). Floodplain habitats provide refuge and nursing grounds to juveniles before they return to the main river (Bayley, 1991; Junk *et al.*, 1989; Simasiku & Mafwila, 2017). However, concerns over declining frequencies of larger fishes were noted to be a cause of concern for the Kavango River fishes, which are dependent on its floodplains (Jacobs *et al.*, 2022). Therefore, a more comprehensive understanding of the floodplain dynamics could help with the management of the Kavango River fish, whilst providing effective bases for decisions regarding regulating fisheries on the floodplain.

With data from this study, used in conjunction with other aligned findings, relevant authorities can use it to make informed decisions regarding the duration, timing and localities to carry out subsistence fisheries on the floodplain, amongst other management-related decisions. Having credible science-based data on the spatial, temporal and vertical fish species composition during a flood pulse will not only offer the best opportunities for optimal management of fish resources by community members and government alike but will also enable sustained and insured food sources for thousands of community members that rely on floodplain fisheries for self-sustenance.

1.12. Limitations of the study

In general, the size of the research team (3 persons), and working under extreme environmental conditions were some of the mitigating factors to sampling. The following are further some of the possible limiting factors that could have (actually or potentially) affected the accuracy and the efficiency of the collected data during the sampling period.

a) The magnitude and extent of the flood

The flood cycle in 2020 lasted for nearly 5 months, with sampling starting on the 20th of February to the 9th of June 2020. The inundation period directly influenced the sampling period, because, beyond the said date, the floodplain became muddy and highly vegetated for sampling. In addition, when the flood peaked, the water level on the floodplain exceeded 2 m (200 cm), making it potentially dangerous for sampling due to the frequent sighting of hippos and crocodiles in the floodplain. Therefore, the sampling depth limit was set at less than 1 m because 1) below this water level the researchers could easily spot hippos on the floodplain and 2) increase the efficiency of the net. However, this possibly excluded fish communities that have a preference to inhabit deep waters.

Further, as the water level on the floodplain increased, it pushed the peripheries of the floodplain into the surrounding standing perennial vegetation, limiting the number of available places where the net can be cast within the 1 m water level. Consequently, the number of sampling days in April (peak flood) was the lowest compared to any other sampling month.

b) Extreme environmental conditions

Sampling was carried out under the scorching sun of the Kavango West Region, whilst frequent heavy rainfall downpours made data collection more difficult for the 3-men sampling team. Therefore, sampling started early in the day (around 07h00 a.m.) so that the team can escape the afternoon's high temperatures, which at times reached 39.9 °C. However, sampling only in the early hours of the day may have limited the researchers from accessing fishes that are active during the night and/or during other periods.

c) Gear selectivity

Most fishing gears are selective towards species of a certain size and/or those that exhibit a certain behaviour. The throw-trap net (sampling gear used in the current study) is known to be most effective in shallow waters, catching small-sized fishes (either juvenile or larger fishes or matured small fishes) on the floodplain (Pelicice *et al.*, 2005; Simasiku & Mafwila, 2017). As noted by Junk, Bayley and Sparks (1989), matured and juveniles of small-sized fishes occupy the shallow peripheries of the floodplains for forage, protection and spawning; whilst the larger fishes often occupy the deeper sections of the floodplain. This study targeted these specimens in the shallow peripheries of the Kamutjonga floodplain.

CHAPTER 2: MATERIALS AND METHODS

2.1. Study area

2.1.1. Location and extent

The study was conducted in the Kavango East Region (Namibia), Mukwe Constituency, along the Kavango River, at the Ministry of Fisheries and Marine Resources' Kamutjonga Inland Fisheries Institute (KIFI) (Figure 1). The Kamutjonga floodplain is found at 18°08'51.99" S and 21°40'48.02" E, 23 km south-east of Divundu, accessible by a combination of the tarred road (17 km) and a gravel road (6 km). The floodplain is bordered on one side (West) by the Kamutjonga Village and by the Kavango River on the other (East). The floodplain area has an average elevation of 1000 m above sea level (asl), with the highest point in the floodplain only having an elevation of 1002 m asl. The section studied, the Kamutjonga floodplain, is part of a long (\pm 17 km) stretch of disconnected floodplains along the Kavango River.

The Kamutjonga floodplain, which is located along the Namibian section of the Kavango River, is fed primarily by the lateral overspill of the River during high-flow periods and supplemented by the direct precipitation from rainfall; resulting in numerous fish species migrating from the River onto the floodplain (Simasiku & Mafwila, 2017). During dry periods, however, the surrounding communities harvest thatch from the floodplain and also use the floodplain as a grazing area for their livestock.

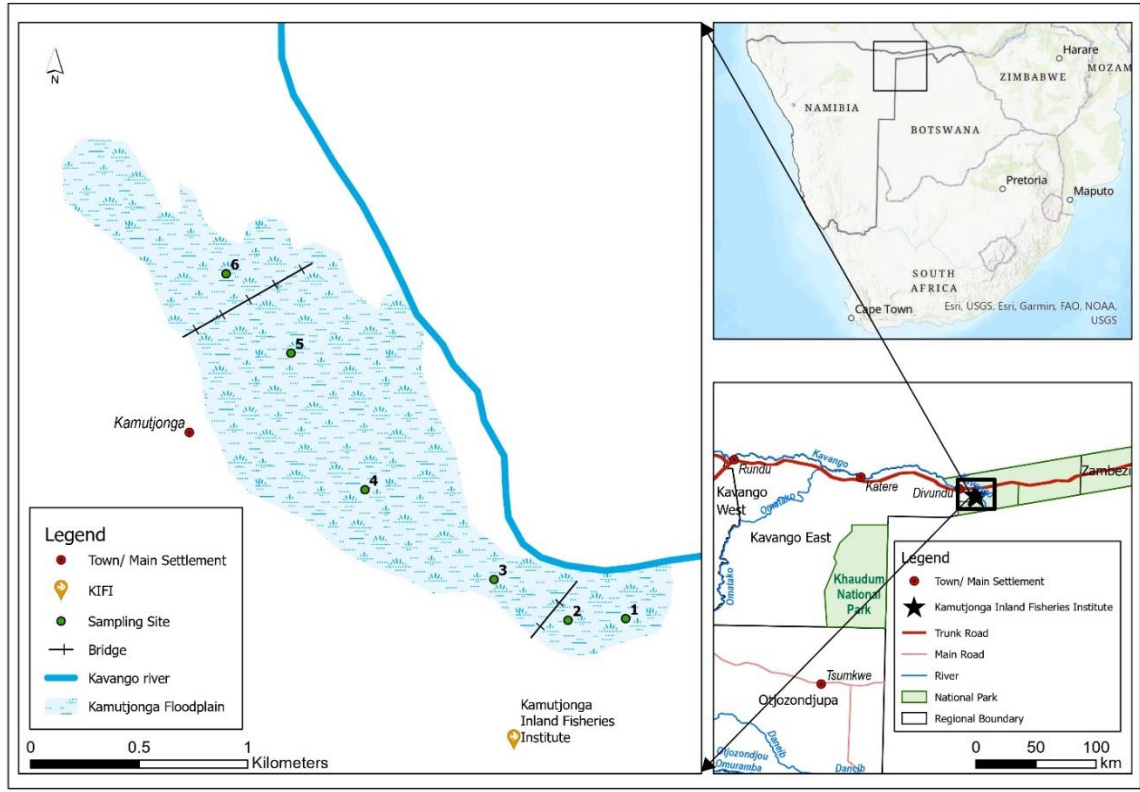


Figure 1: Map of southern Africa showing the location and extent of the Kamutjonga floodplain in Namibia as well as the sampling sites on the floodplain.

2.1.2. Climate

The north-eastern areas of Namibia received about 6.0 – 6.2 kilowatt-hours per square meter per day (kWh/m²/day) of solar radiation, which is relatively less than the north-central parts of Namibia due to significant cloud cover in the north-east during summer months (Mendelsohn *et al.*, 2002). Temperatures are usually lowest in the winter month of July when daily temperatures have been reported to be as low as 6°C. The highest temperatures, during summer, can reach 40°C in some places (Hocutt & Johnson, 2001; Mendelsohn *et al.*, 2002). Albeit Namibia is a semi-arid country, the north-east receives some significant amount of rainfall during the rainy season, with an average of 550-600

mm of rain annually; and an average of at least 45 days (annually) with 1 mm or more of rain and some of the least rainfall variabilities between years (Mendelsohn *et al.*, 2002).

2.2. Sampling stations

A total of 6 sampling stations were selected to be representative of the different parts along the entire length of the floodplain, bordered by the Kamutjonga Village and the Kavango River. Site 1 was located far east of the floodplain, adjacent to the fence of the Mahango Game Park. In terms of the flow of water in the floodplain, this site is downstream of the floodplain, closest to the confluence of the floodplain and the Kavango River. Between the river and the floodplain, there is a dividing fence designed to block the movement of large-bodied animals, hence it does not hinder the free movement of fish to and from the floodplain. Sites 2 and 3 were located on either side of a bridge, which permits the passage of people and vehicles from KIFI and surrounding areas over the floodplain onto the banks of the Kavango River during high flow periods. The bridge was made of meshed wires interlocked with concrete blocks, making it impossible for riverine fauna to go through, except when the floodwaters submerged the bridge.

Site 2 was downstream of the KIFI Bridge, and it is where the majority of the local community members frequently used varying types of fishing gear such as mosquito nets, bottle traps, spears, hook-and-line and other means of traditional fishing methods. In nature, fish must expend energy to swim against the current to easily filter out suspended food particles as well as to prevent being swept downstream (Boyar, 1967). Site 3 was located upstream of the KIFI bridge. Site 4 was located in the middle of the floodplain, sandwiched by two bridges, and there was a depression in the floodplain at site 4, which

was beyond the sampling depth for the current study. Sites 5 and 6 were located on either side of the Mahango Bridge, which had a designated section to allow for water (and fish) to flow under the bridge.

2.3. Flooding periods

Although the floodplain was sampled from 20 February 2020 to 9 June 2020, sampling efforts were not always equal due to various factors such as the availability of sampling spaces at sites (water level pushed into vegetation) or receding of the flood (no water at certain sites). Temporal comparison among sites and depth intervals were therefore done in three comparable “Flooding Periods” within the broader period of inundation (20 February to 9 June 2020). Henceforth, the term flooding period in this thesis shall refer to these three selected periods when the floodplain was fully inundated.

During these flooding periods, equal sampling effort was afforded per site and depth interval. During each period, all sites on the floodplain were sampled in no more than 10 days. Each of the six sites was sampled once per day, with 48 throws administered per site (16 throws per depth interval), once during each flooding period. A total of 288 throw trap nets were cast during each flooding period, equally divided among sites (48 per site). The duration of the flooding periods were as follows: The “Early flooding period” was from 03 – 09 March 2020; the “Mid-flooding period” was from 28 March to 4 April 2020, and the late flooding period was from the 14th to the 23rd of May 2020 (Figure 2).

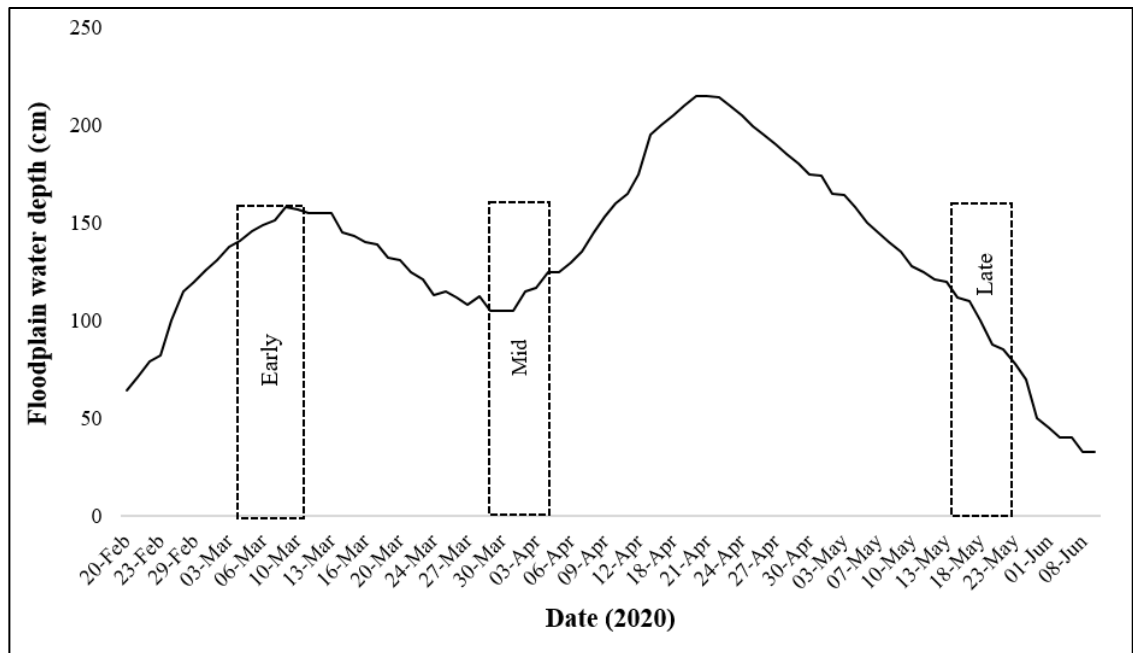


Figure 2: The hydrograph of the Kamutjonga floodplain during the 2020 flooding cycle. Vertical dotted bars indicate sampling periods for this study.

2.4. Sampling procedures

Sampling started when the floodwaters started filling the sampling sites on the floodplain, with the first site sampled on the 20th of February 2020. Sampling lasted for about 5 months, ending on the 9th of June 2020 when floodwater receded and sampling sites were covered in thickets of vegetation. Whenever possible, sampling was done in a sequence from one site to another, with a single site sampled per day. Throws were cast randomly per site and within each depth interval. During each sampling day, efforts were carried out equally between three depth intervals: 0 – 29 cm; 30 – 59 cm; and 60 – 99 cm (Figure 3). Sampling beyond the depth of 100 cm was discouraged on safety grounds, and general sampling was done with extreme caution because the floodplain was linked to the main river through a wide channel, posing significant threats from hippos and crocodile attacks

(Figure 5). A daily target of 48 throw trap nets was cast, divided equally between depth intervals (16 throws per depth interval).

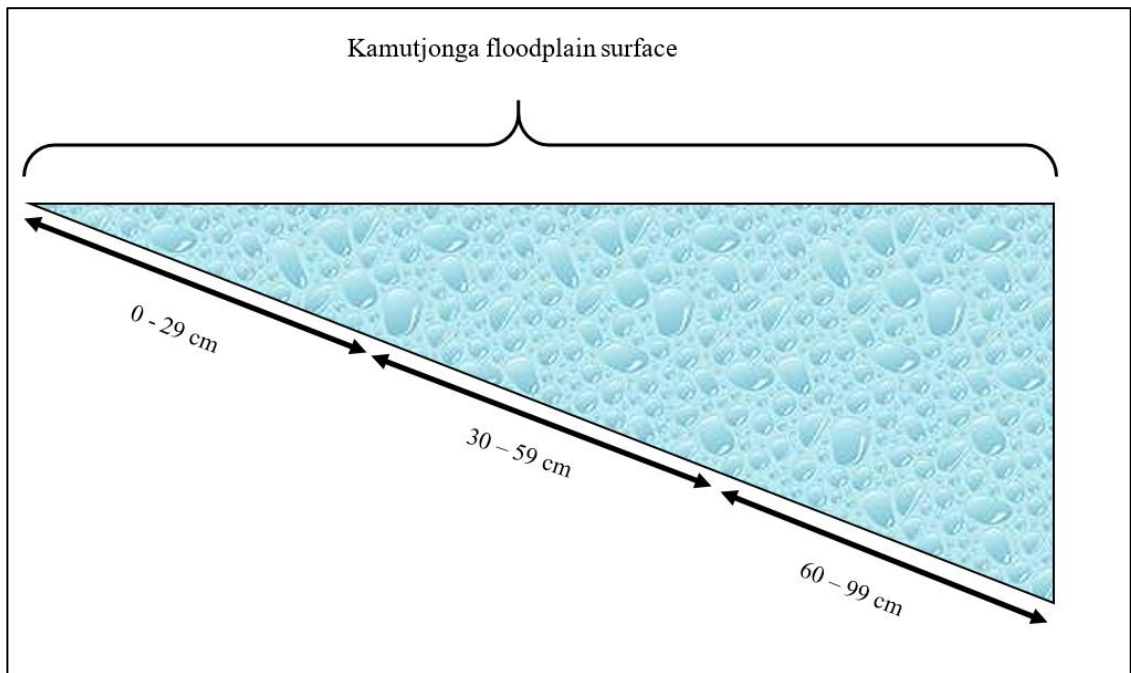


Figure 3: The depiction of the three depth intervals (0 – 29 cm; 30 – 59 cm and 60 – 99 cm) demarcated on the Kamutjonga floodplain during the study period (20 February to 9 June 2020).

For each cast net, a suite of physicochemical parameters of the water was measured *in situ*. This included temperature (°C) and dissolved oxygen (mg/L), measured with a Sperm Scientific Dissolved Oxygen Pen Meter 850045; sampling depth (cm); and vegetation cover (%). In addition, the water level on the floodplain was monitored at a single pole located at site 2 – the readings on this pole were recorded every morning from the start to the end of the flood cycle. The GPS coordinates for every sampling point (every throw trap-net cast) were recorded using a Garmin eTrex® 30x GPS. All specimens handled humanly and were anaesthetized by placing them on ice during sampling, before

identification, to species level, at the KIFI wet specimen laboratories – using diagrams and thorough descriptions by Skelton (1993); counted, individually weighed (0.01g) and measured (total or fork length, depending on the species) (Figure 4). Specimens that could not be identified to the species level were identified to the lowest level possible, mainly genus or in some cases family level. After identification and measurements, all the specimens were preserved in 70% ethanol solution and stored at University of Namibia's Main Campus in Windhoek.

Species with forked tails (i.e. those of the Mochokidae, Alestidae, Mormyridae, Cyprinidae and Schilbeidae family) had their lengths measured as Fork Length (FL) – which is the distance from the tip of the snout to the end of the mid-caudal rays. Species with rounded tails (i.e. those of the Cichlidae, Procatopodidae and Clariidae family) had their lengths taken as Total Length (TL) – the distance from the tip of the snout to the furthest tip of the caudal fin.



Figure 4: The researchers measured the length, weight and recorded the sampled fish specimens. On the left, one of the researchers is preparing a 70% ethanol solution to preserve the specimens.



Figure 5: Sampling on the floodplain was done under extreme caution due to frequent sightings of hippopotamus and crocodiles. The researchers in the photograph are seen scanning the surrounding areas for possible dangers.



Figure 6: Sampling with a throw trap net: a) Researcher hauling trapped fishes with a scoop net, b) measuring the physio-chemical parameters of the water, and c) measuring the depth of the water inside the net.

2.5. Sampling gear: Throw-trap net

A hollow throw-trap net was used to sample the floodplain. The net was constructed with two frames, one made of lightweight PVC piping and the other of a heavy metallic (steel) frame. The two frames had a diameter of 1.2 m and are separated by a 1.2 m high, 1 mm mesh-sized net covering all laterals. The (throw-trap) net is deployed by two people by throwing it approximately 5 m away into either vegetated or open water on the floodplain. Upon landing, the heavy metallic part sinks to the bottom whilst the light PVC frame floated on top of the water, trapping all within the net. All the trapped fish were then hauled out using a scoop net.

Throw trap nets are widely used to address the limitations of other fish sampling gears such as gill nets and seine nets that are rendered ineffective in shallow and vegetated parts of the floodplain (Pelicice *et al.*, 2005; Siziba *et al.* 2011). As a modification from Siziba *et al.* (2011) who used a pole to dislodge the net from the edge of the floodplain, in the current study, the net was deployed by two people holding it side-by-side (Figure 7). This enabled sampling in deep waters (up to 99 cm depth), past the 40 cm depth limit experienced by Siziba *et al.* (2011); whilst ensuring longer throw distances.

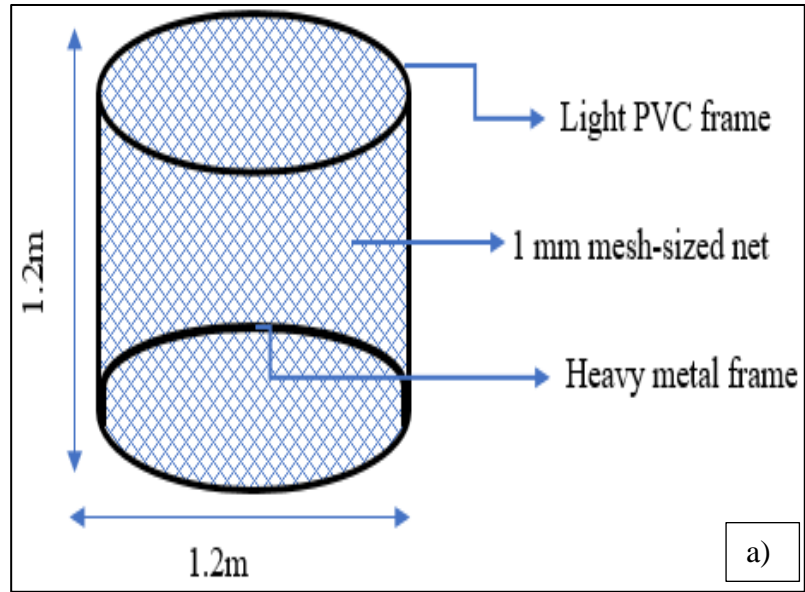


Figure 7: The (a) Schematic diagram of the throw-trap net and (b) its in-field deployment technique used.

2.6. Flooding pattern of the floodplain

All the sampling sites on the floodplain were not fully (or at all) inundated from the start of the flooding. Site 1, which linked the lowest point of the floodplain to the Kavango River, was the first to be flooded, followed by the adjacent sites 2 and 3. Sites 2 and 3 are separated by a bridge traversing the floodplain (Figure 1). The bridge, which is made of compacted concrete stones, does not have a dedicated channel underneath, hence blocking the movement of fish from one site to the next during periods before the water level overruns the 150 cm high bridge – the water level first went over the bridge on the 8th of March 2020 during the rising water and went below the 150 cm mark when the flood was receding on the 6th of May 2020. As the volume of water in the river increased, a second channel opened up -during the first week of flooding- between the river and the floodplain, close to site 5. The furthest sites (4 – 6) were the last to get fully inundated.

Further, only the 0 – 29 cm and 30 – 59 cm depth intervals were inundated during the initial stages of flooding, as the depth of the floodplain was merely over 60 cm deep. For example, during the first day of sampling (20th February 2020), there were no 60 – 99 cm depth intervals at site 2; whilst only the 0 – 29 cm depth interval was present at site 3 (Table 2).

2.7. Data set

A total of 1 827 throws were cast during the flood cycle, resulting in 1721 specimens collected, during 41 days of sampling between the 20th of February and the 9th of June 2020 (Table 2). Albeit the researchers targeted 48 throws per sampling day, limited sampling areas at the beginning (late February and early March 2020) and end (late May

and early June 2020) of the flooding ensued a reduced number of throws (Table 2). Similarly, as sites were not inundated and drained at the same rate, the water level was not deep enough to sample a depth interval of 60 – 99 cm at the beginning and end of flooding (Table 2). Between sampling sites, the number of throws cast ranged between 264 at site 1 and 344 at site 4. The net was cast 684 times in the 0 – 29 cm depth interval, followed by the 30 – 59 cm depth interval 623 times, whilst 520 throws were cast in the 60 – 99 cm 520 depth interval (Table 2).

Noting that the sampling effort was not the same throughout, three “flooding periods” were identified within the broader sampling period: The early flooding period (03 – 09 March 2020); the middle flooding period (28 March – 04 April 2020) and the late flooding period (14 – 23 May 2020). During these flooding periods, the number of throws per sampling day was identical per site (48), with 16 throws per each of the three depth intervals. During each flooding period, all sites were sampled no more than ten (10) days apart. In total, 288 throws were cast per flooding period. During the three flooding periods, all sites, and depth intervals were sampled equally, with a total of 864 throws resulting in 872 specimens collected during the three sampling periods (Table 1). In general, the water temperature was the highest during the late flooding middle flooding period ($28.16\text{ }^{\circ}\text{C} \pm 1.91\text{ SD}$) and this coincided with the lowest dissolved oxygen recorded ($6.00\text{ gm/L} \pm 1.31\text{ SD}$). The coolest temperatures and highest level of dissolved oxygen were recorded during the late flooding period, $21.72 \pm 2.13\text{ }^{\circ}\text{C}$ and $7.05 \pm 1.12\text{ mg/L}$, respectively.

The data from all the efforts during the inundated flood pulse (20 February – 9 June 2020) were used to determine the overall species composition (objective “a”) and whether the

catch rates were correlated to any physiochemical parameters of the water (objective “b”). Objectives “c”, “d” and “e” were addressed using combined data from the three flooding periods which were identified within the broader flood pulse. *Pseudocrenilabrus philander* and *Tilapia sparrmanii* were the two species selected, whose length distributions were compared across flooding periods, depth intervals and sampling sites. They were selected because 1) they were in high abundance enough for comparisons and 2) had some sexually matured individuals based on their respective minimum lengths at maturity.

Table 1: The number of throw trap net samples, the number of fish caught, average fish weight and average dissolved oxygen (mg/L) in the depth intervals sampled (0 – 29 cm, 30 – 59 cm and 60 – 99 cm), during the early, middle and late flooding period at the six (1 – 6) sites sampled on the Kamutjonga floodplain during 20 February and 9 June 2020.

	Number of throws	Number of fish caught	Average fish weight (g ± SD)	Average temperature (°C ± SD)	Average dissolved oxygen (mg/L ± SD)
Vertical					
0 - 29 cm	288	603	0.94 ± 2.56	24.14 ± 3.34	7.03 ± 1.13
30 - 59 cm	288	147	0.76 ± 3.18	25.03 ± 3.41	6.48 ± 1.17
60 -99 cm	288	122	0.30 ± 1.03	24.50 ± 2.99	5.93 ± 1.03
Temporal					
Early Flooding	288	249	1.31 ± 3.01	25.16 ± 1.85	6.61 ± 0.97
Mid flooding	288	160	0.19 ± 0.70	28.16 ± 1.91	6.00 ± 1.31
Late flooding	288	463	0.67 ± 2.65	21.72 ± 2.13	7.05 ± 1.12
Spatial					
Site 1	144	205	1.08 ± 4.09	25.79 ± 3.92	7.67 ± 1.12
Site 2	144	174	0.40 ± 0.98	25.93 ± 2.12	6.68 ± 1.04
Site 3	144	109	0.95 ± 2.01	25.76 ± 2.43	6.86 ± 1.26
Site 4	144	196	0.65 ± 1.67	22.50 ± 2.24	6.54 ± 0.89
Site 5	144	97	0.52 ± 2.17	22.24 ± 2.73	6.21 ± 1.08
Site 6	144	91	0.93 ± 2.61	24.49 ± 3.55	5.57 ± 0.70
Overall	864	872	0.75 ± 2.48	24.44 ± 3.30	6.64 ± 1.20

Table 2: The number of fish caught and the effort expended to catch them at each sampling station's (Site 1 – 6) depth interval (0 – 29 cm, 30 – 59 cm and 60 – 99 cm) on the Kamutjonga floodplain, 2020. * indicates sampling days for the early flooding period; ** middle flooding period and *** the late flooding period.

Sampling station	Site 1			Site 2			Site 3			Site 4			Site 5			Site 6			Total Catch	Total Effort																
	0-29 cm	30-59 cm	60-99 cm	0-29 cm	30-59 cm	60-99 cm	0-29 cm	30-59 cm	60-99 cm	0-29 cm	30-59 cm	60-99 cm	0-29 cm	30-59 cm	60-99 cm	0-29 cm	30-59 cm	60-99 cm																		
Depth class	Catch	Effort	Catch	Effort	Catch	Effort	Catch	Effort	Catch	Effort	Catch	Effort	Catch	Effort	Catch	Effort	Catch	Effort																		
Date (2020)																																				
20-Feb					73	12	78	13											153	37																
21-Feb	29	12	15	12	28	12													72	36																
22-Feb													3	12	0	12	0	12	3	36																
23-Feb															2	12	2	12	4	24																
27-Feb					11	12	10	12	9	12									30	36																
28-Feb											2	12	3	12	4	12			9	36																
29-Feb	5	12	4	12	0	12													9	36																
01-Mar													13	12	7	12	0	12	20	36																
02-Mar															24	16	21	15	45	31																
03-Mar*																		1	16	36	64															
04-Mar*													6	16	3	16	5	16	14	48																
05-Mar*																			31	48																
06-Mar*										39	16	13	16	1	16				53	48																
07-Mar*					50	16	7	16	9	16									66	48																
09-Mar*	42	16	4	16	4	16													50	48																
10-Mar																	8	16	9	48																
16-Mar															2	16	5	16	10	48																
24-Mar													6	16	5	16	1	16	12	48																
28-Mar**																			16	48																
30-Mar**	10	16	39	16	20	16													112	96																
31-Mar**					22	16	10	16	11	16									23	48																
02-Apr**															3	16	3	16	6	48																
04-Apr**																			3	48																
09-Apr																			31	48																
30-Apr					85	16	30	16	2	16									117	48																
07-May																			19	48																
08-May															13	16	6	16	31	48																
09-May													4	16	13	16	27	16	44	48																
14-May***																			40	48																
15-May***					23	16	13	16	29	16									65	48																
18-May***	61	16	17	16	8	16													86	48																
21-May***																			33	48																
22-May***																			77	48																
23-May***																			162	48																
28-May					37	16	13	16	0	16									50	48																
30-May											11	16	2	16	0	16			13	48																
01-Jun	7	16	1	16	0	16													8	48																
05-Jun																			32	96																
06-Jun																			48	48																
08-Jun					17	16	0	16	0	16									65	96																
09-Jun	14	16	0	16	0	16					48	16	0	16	0	16			14	48																
Total	168	104	80	104	60	104	318	120	161	121	60	108	169	120	29	108	14	108	237	120	45	120	125	124	60	123	31	112	95	96	22	96	6	96	1721	2004

2.8. Data analysis

2.8.1. Species composition

The Index of Relative Importance (IRI), a standard methodology for measuring species composition since the early 1970s, has been lauded to reduce biases in ecological studies (Hart *et al.*, 2002). This calculation was applied in the current study to assess the ecological relative importance of each species' per flooding period, depth interval and site based on the species' frequency of occurrence, weight contribution, and contribution to the total number of samples. The IRI was calculated as:

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

Where %N is the percentage contribution of each species by number to the total/overall catch; %W is the percentage contribution of each species by weight to the total catch and %FO represented the percentage frequency of occurrence of each species.

2.8.2. Catch per Unit Effort (CPUE)

The Catch per Unit Effort (CPUE) was used to indicate the relative fish abundance and was expressed in weight (g/throw) and numbers (No. /throw), as the average catch per sampling event. It was calculated as:

$$CPUE = \frac{Ci}{Ei}$$

Where “*C_i*” is the total catch in numbers or weight (g) at a particular level under considerations (e.g depth interval, flooding period, or site) and “*E_i*” is the number of throw trap nets cast to obtain the catch (*C_i*) at that level. CPUE is given as a) the number of fish/throw or (b) the weight of fish (g)/throw.

2.8.3. Statistical analysis

Statistical analyses were carried out using the Statistical Package for Social Sciences (SPSS) version 27 and SigmaPlot 14.0. The significance level for all statistical tests was set at 0.05 (95% confidence level). All data were checked for normality, using the Shapiro-Wilk test, which guided the type of statistical test to be used. Before using non-parametric tests, data were first log (10) transformed and tested for normality again – if still not normally distributed, a non-parametric test was applied to the original data. If the data were normally distributed after transformation, then a parametric test would have been applied to the transformed data. A Spearman-ranked correlation test was applied to test whether there was a significant correlation between the catch per unit effort by numbers and temperature, dissolved oxygen, average sampling depth and the level of water on the floodplain. A Kruskal Wallis test was applied to test for differences in the catch per unit effort (CPUE) across a) sites, b) depth intervals and c) flooding periods. In addition, the Kruskal Wallis tested for differences in the lengths of *Tilapia sparrmanii* and *Pseudocrenilabrus philander* across (a) sampling site, (b) depth interval and (c) flooding period.

CHAPTER 3: RESULTS

3.1. Environmental variables

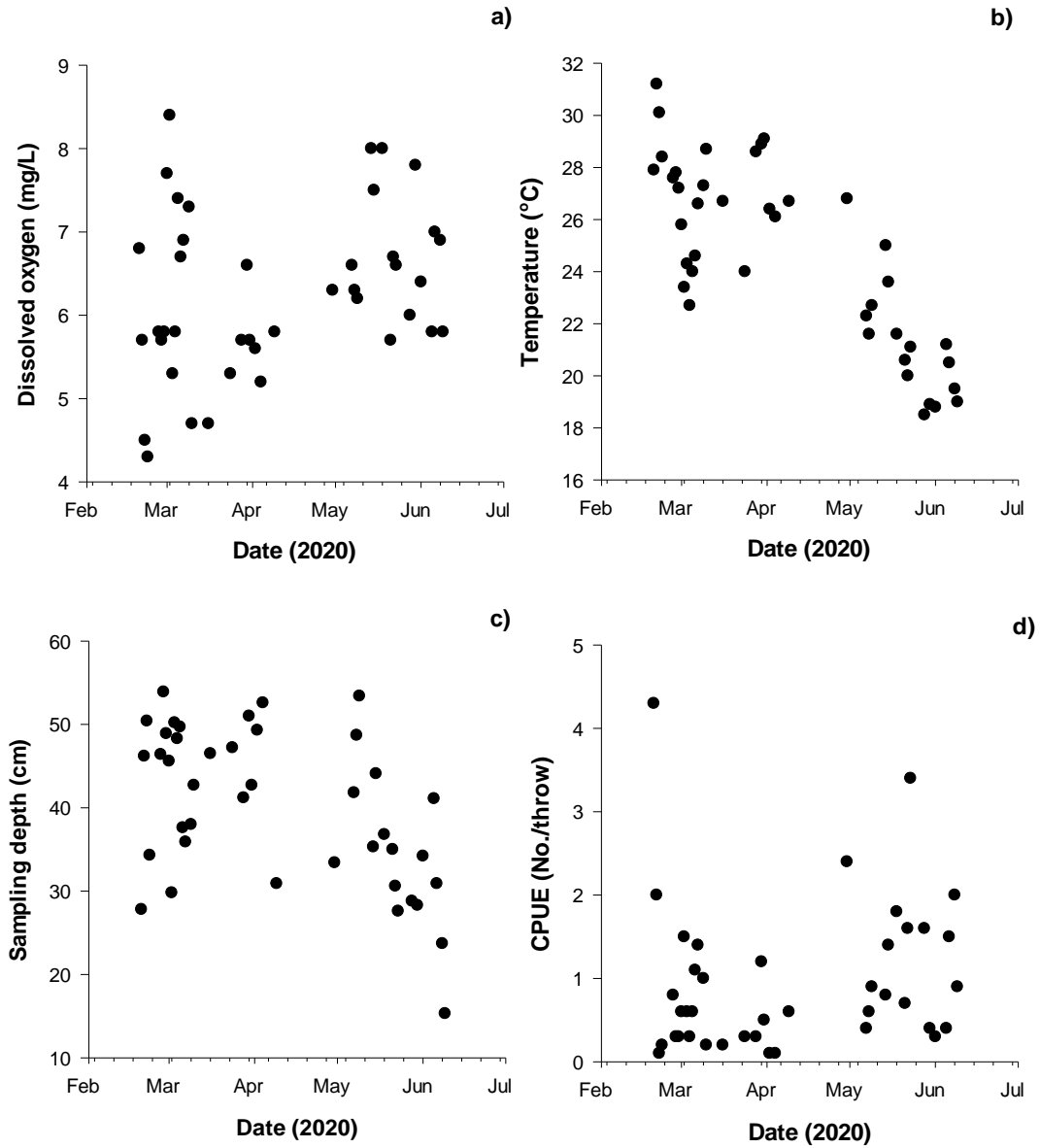


Figure 8: Daily average levels of a) the dissolved oxygen in the water, b) water temperature, c) sampling depth and d) Catch per Unit Effort (CPUE) by numbers during the 2020 flood pulse on the Kamutjonga floodplain.

The number of specimens per throw (CPUE) on the floodplain increased with increasing concentration of dissolved oxygen (mg/L) in the water (spearman rho = 0.635, $p < 0.001$) (Figure 8). The mean oxygen concentration was 6.6 mg/L, which ranged from 3.5 mg/L to 10.7 mg/L. The mean surface temperature of the water on the floodplain (24.4 °C), which ranged from 18.1 °C to 39.9 °C, was not correlated with the catch (spearman rho = -0.256, $p < 0.105$) (Figure 8). The average depth for each sampling point was correlated with the catch per unit effort, with more specimens caught at shallow sampling points (spearman rho = -0.543, $p < 0.001$) (Figure 8). However, the depth of water on the floodplain, measured at one central point, was not correlated to the number of specimens caught (spearman rho = -0.201, $p < 0.206$).

3.2. Overall species composition

Sampling the floodplain from the 20th of February 2020 to the 09th of June 2020 resulted in 1721 fish specimens collected, weighing a combined total of 2716.7 g (Table 3). These belonged to nine (9) families and 30 species, although three groups of specimens could not be identified to specific epithets (Some individuals of the Cichlidae family; *Enteromius* spp.; and *Synodontis* spp.). Cyprinidae (n = 10) and Cichlidae (n = 8) were the most speciose families on the floodplain. In terms of numbers, *Pseudocrenilabrus philander* was the most numerous on the floodplain (562), whilst *Oreochromis andersonii* contributed half (1359 g) of the total fish weight (Table 3). Of the nine fish families recorded on the floodplain, Cichlidae dominated the catches, accounting for 1400 specimens (81%) of the total number of fish collected. *Oreochromis andersonii* (45.7%), *P. philander* (41.6%) and *Tilapia sparrmanii* (7.2%) were the most important species on

the floodplain based on the total Index of Relative Importance (IRI%), which measures the relative contribution of each species based on relative weight contribution, relative number and relative frequency of occurrence (Table 3). Cichlidae was the most important family, contributing 98.4% of the total IRI on the floodplain.

Table 3: The number, weight (g) and the Index of Relative Importance (%) of species sampled on the Kamutjonga floodplain during the study period (20th of February to the 9th of June 2020). The shading represents the three most important species in each category.

Taxon	Number	Weight (g)	%IRI
Alestidae			
<i>Brycinus lateralis</i>	2	0.8	0.0
<i>Hydrocynus vittatus</i>	15	20.0	0.0
<i>Micralestes acutidens</i>	5	0.7	0.0
Cichlidae			
Cichlidae spp.	140	22.4	2.1
<i>Coptodon rendalli</i>	55	362.5	1.6
<i>Oreochromis andersonii</i>	373	1359.0	45.7
<i>Pharyngochromis acuticeps</i>	9	10.0	0.0
<i>Pseudocrenilabrus philander</i>	562	288.2	41.6
<i>Serranochromis altus</i>	10	58.9	0.0
<i>Tilapia ruweti</i>	36	47.4	0.2
<i>Tilapia sparrmanii</i>	215	194.5	7.2
Clariidae			
<i>Clarias gariepinus</i>	26	73.4	0.2
<i>Clarias ngamensis</i>	3	102.6	0.0
Cyprinidae			
<i>Enteromius barnardi</i>	77	22.6	0.7
<i>Enteromius bifrenatus</i>	44	17.6	0.2
<i>Enteromius fasciolatus</i>	6	2.1	0.0
<i>Enteromius haasianus</i>	11	1.1	0.0
<i>Enteromius paludinosus</i>	23	27.0	0.1
<i>Enteromius poechii</i>	17	6.4	0.0
<i>Enteromius radiatus</i>	13	15.2	0.0
<i>Enteromius</i> spp.	13	1.7	0.0
<i>Enteromius unitaeniatus</i>	19	12.8	0.1

<i>Labeo cylindricus</i>	1	2.3	0.0
Distichodontidae			
<i>Nannocharax multifasciatus</i>	2	0.6	0.0
Mochokidae			
<i>Synodontis</i> spp.	3	1.0	0.0
Mormyridae			
<i>Marcusenius altisambesi</i>	8	53.5	0.0
<i>Pollimyrus marianne</i>	2	3.3	0.0
Procatopodidae			
<i>Lacustricola hutereaui</i>	4	0.6	0.0
<i>Lacustricola johnstoni</i>	21	3.0	0.0
Schilbeidae			
<i>Schilbe intermedius</i>	6	5.6	0.0
Total	1721	2716.7	100.0

3.3. Catches during flooding periods

3.3.1. Temporal species composition

A total of 872 specimens were collected during the three flooding periods, representing 8 families and 26 species. Of the 872 specimens collected during the three flooding periods, 249 (29%) of the specimens – representing 17 species - were sampled during the early flooding period. The combined weight of all specimens was highest (586.0 g) in the early flooding period. *Oreochromis andersonii* (82.3%), *T. sparrmanii* (9.2%) and *P. philander* (4.0%) were the most important species during the early flooding period in terms of their total IRI (Table 4). In terms of numerical (106) and weight (346.9 g) contribution, *O. andersonii* contributed the highest during the early flooding period.

The lowest number of specimens were collected during the middle flooding period (160 specimens – 18% of the total number of specimens during all the flooding periods), representing 16 species. *Pseudocrenilabrus philander* (37.5%), *T. sparrmanii* (20.4%) and *Clarias gariepinus* (5.4%) were the most important species during the middle

flooding period in terms of their total IRI contribution (Table 4). It is noteworthy that the unidentified (due to their small size) group of Cichlidae species contributed 30.2% to the total IRI, but the researchers could not directly accredit it to being the second-most important single “species” on the floodplain because this could have been an aggregation of many cichlid species. *Enteromius unitaeniatus* (Cyprinidae) and *Lacustricola johnstoni* (Procatopodidae) were joint third most abundant species on the floodplain during the middle flooding period, with nine specimens of each species collected (Table 4). In terms of numbers, *P. philander* (36) contributed the highest during the middle flooding period, whilst in terms of weight *C. gariepinus* (20.6 g) contributed the total highest weight (Table 4). The highest number of specimens (n = 463) were collected during the late flooding period (53%), where a total of 15 species were recorded (Table 4). *Pseudocrenilabrus philander* alone contributed 95.8% of the total IRI, demonstrating its high importance during the late flooding period in terms of its relative numbers, weight and frequency of occurrence (IRI%). *Tilapia sparrmanii* (2.6%) and *T. ruweti* (0.9%) were the next most important species during the late flooding period (Table 4). In terms of both the number of specimens (n = 337) and the weight of all specimens of an individual species (164.6 g), *P. philander* contributed the highest during the late flooding period (Table 4).

Table 4: The number, weight (g) and the Index of Relative Importance (%) of species sampled on the Kamutjonga floodplain during the early (3 – 9 March), middle (28 March – 4 April) and late (14 – 23 May) flooding periods. The shading represents the three most important species in each category. * represents the contribution of a group of unidentified species.

Taxon	Early flooding period			Mid flooding period			Late flooding period		
	Number	Weight (g)	IRI%	Number	Weight (g)	IRI%	Number	Weight (g)	IRI%
Alestidae									
<i>Brycinus lateralis</i>	1	0.1	0.0						
<i>Hydrocynus vittatus</i>	1	1.5	0.0						
Cichlidae									
Cichlidae spp.	32	9.3	3.2	43*	2.7	30.2*	14	1.6	0.1
<i>Coptodon rendalli</i>	19	114.8	4.0	2	9.3	0.7	5	30.1	0.1
<i>Oreochromis andersonii</i>	106	346.9	82.3	1	1.9	0.1	5	16.7	0.1
<i>Pharyngochromis acuticeps</i>	1	0.2	0.0	3	0.6	0.2	1	0.2	0.0
<i>Pseudocrenilabrus philander</i>	6	4.7	0.1	36	16.4	37.5	337	164.6	95.8
<i>Serranochromis altus</i>	4	20.6	0.2	2	1.5	0.2			
<i>Tilapia ruweti</i>	4	3.0	0.1				26	34.8	0.9
<i>Tilapia sparrmanii</i>	46	52.2	9.2	28	10.1	20.4	48	45.9	2.6
Clariidae									
<i>Clarias gariepinus</i>	10	27.4	0.7	7	20.6	5.4			
<i>Clarias ngamensis</i>							3	102.6	0.2
Cyprinidae									
<i>Enteromius barnardi</i>	1	0.1	0.0	8	2.1	1.5	3	0.4	0.0
<i>Enteromius bifrenatus</i>	3	0.5	0.0	3	0.5	0.2	11	5.0	0.1
<i>Enteromius fasciolatus</i>							1	0.3	0.0
<i>Enteromius haasianus</i>	6	0.5	0.1						
<i>Enteromius poechii</i>				2	0.5	0.1	1	0.3	0.0
<i>Enteromius</i> spp.				3	0.0	0.1	3	0.5	0.0
<i>Enteromius unitaeniatus</i>				9	3.1	2.1			
<i>Labeo cylindricus</i>	1	2.3	0.0						
Mochokidae									
<i>Synodontis</i> spp.	3	1.0	0.0						
Mormyridae									
<i>Marcusenius altisambesi</i>							4	14.3	0.0
<i>Pollimyrus marianne</i>							1	0.5	0.0
Procatopodidae									
<i>Lacustricola hutereaui</i>				3	0.4	0.2			
<i>Lacustricola johnstoni</i>	5	0.9	0.1	9	0.7	1.4			
Schilbeidae									
<i>Schilbe intermedius</i>				1	0.3	0.0			
Total	249	586.0	100	160	70.9	100.0	463	417.7	100

3.3.2. Temporal catch per unit effort

There was a difference in the median Catch per Unit Effort (CPUE) between the early, middle and late flooding period, in both CPUE by numbers ($H_{(2)} = 22.908$, $p < 0.001$) and by weight ($H_{(2)} = 25.607$, $p < 0.001$) (Figure 9). The median CPUE in numbers during the late flooding period (1.6 fish/throw) significantly differed from the median CPUE during the early flooding period (0.7 fish/throw) ($p < 0.001$) and the middle flooding period (0.6 fish/throw) ($p < 0.001$). In terms of CPUE in weight, the median CPUE during the middle flooding period (0.1 fish/throw) significantly differed from the median CPUE during the early flooding period (1.5 fish/throw) ($p < 0.001$) and the late flooding period (1.1 fish/throw) ($p < 0.001$). During the early flooding periods, there were fewer but large-sized fishes per throw on the floodplain, as opposed to numerous but small-sized (weight) fishes per throw on the floodplain during the late flooding period (Figure 9).

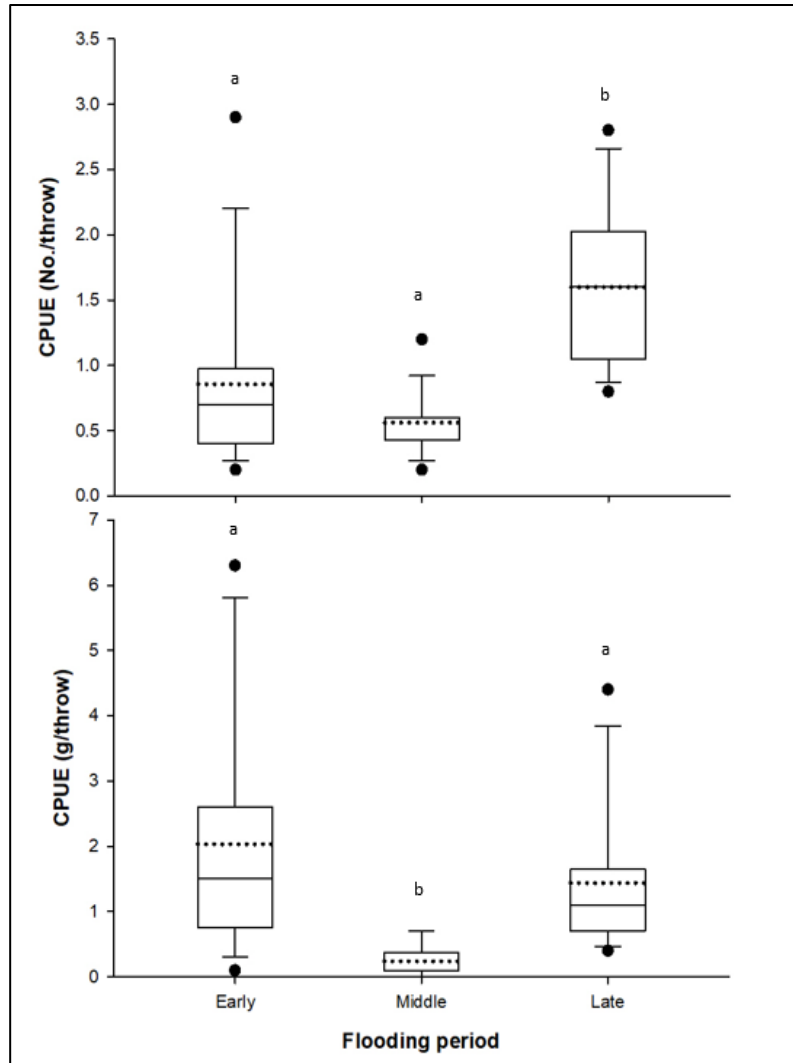


Figure 9: The Catch per unit effort (CPUE) in numbers (number of fish/throw) and weight (g/throw) of species sampled on the Kamutjonga floodplain during the early (3 – 9 March), middle (28 March – 4 April) and late (14 – 23 May) flooding periods. Different letters denote significant differences (Kruskal-Wallis; Pairwise comparison, $p \leq 0.05$). The dotted line indicates the mean.

3.3.3. Temporal length distribution of *Tilapia sparrmanii* and *Pseudocrenilabrus philander*

The body length of the 122 specimens of *T. sparrmanii* sampled on the floodplain significantly differed across flooding periods during the flood cycle ($H_{(2)} = 21.912$, $p < 0.001$). Of the total specimens, 46 (38%) were sampled during the early flooding period, with their body length ranging between 10 to 59 mm. The modal body length interval, 30 – 40 mm, accounted for 38% of the total catch during the early flooding period (Figure 10). The mean body length of *T. sparrmanii* during the early flooding period was 37 ± 10 mm (Figure 11). During the middle flooding period, 28 (23%) specimens of *T. sparrmanii* were recorded, with the body length ranging from 19 to 44 mm, and 50% of the specimens in the modal length interval of 20 -30 mm (Figure 10). The mean body length of the specimens during the middle flooding period was 27 ± 8 mm (Figure 11). During the late flooding period, where 48 (39%) of the 122 specimens were sampled, the body length ranged from 15 to 80 mm, with 29% of specimens in the modal 20 – 30 mm body length interval (Figure 10). The mean body length of *T. sparrmanii* during the late flooding period was 33 ± 11 mm (Figure 11), with only two specimens (4%) above the reported minimum length at maturity of 61 mm (Hay et al., 2000).

Similarly, the 379 specimens of *P. philander* significantly differed across the flooding periods ($H_{(2)} = 12.617$, $p < 0.002$) (Figure 11). Only six (6) specimens (2%) were sampled during the early flooding period, with the body length ranging between 30 and 43 mm (Figure 10). Three of the six specimens (50%) were in the modal body length interval of 30 – 40 mm. The mean body length of *P. philander* during the early flooding period was 38 ± 5 mm, with five of the six specimens (83%) above the reported 30 mm minimum

length at maturity for *P. philander* (Figure 11) (Hay et al., 2000). During the middle flooding period, 36 (9% of the total catch) *P. philander* specimens were sampled, ranging between 12 to 45 mm, with 25 (69% of the total catch in the flooding period) in the modal body length interval of 20 – 30 mm (Figure 10). The mean body length for *P. philander* during the middle flooding period was 27 ± 7 mm, with six of the 36 specimens (17%) above minimum length at maturity (Figure 10, Figure 11). During the late flooding period, 337 of the 379 total number of *P. philander* (89%) were recorded, with body lengths ranging from 11 to 68 mm (Figure 10), of which 152 (45%) belonged to the modal body length interval of 20 – 30 mm (Figure 10). The mean length of *P. philander* during the late flooding period was 29 ± 7 mm, with some 118 specimens (31%) above the minimum length at maturity (Figure 10, Figure 11).

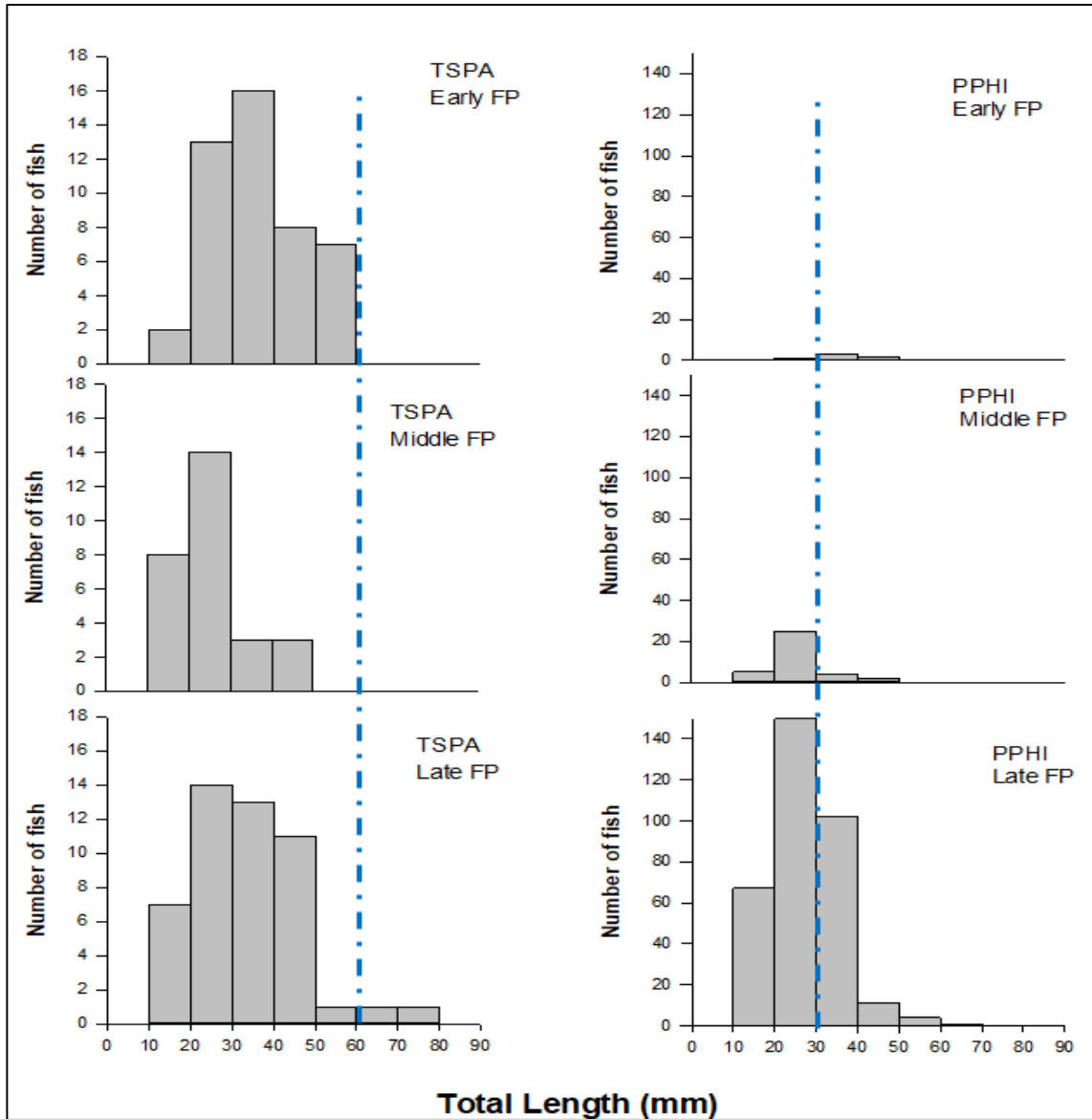


Figure 10 Length frequency distributions of *Tilapia sparrmanii* (TSPA) and *Pseudocrenilabrus philander* (PPHI) on the Kamutjonga floodplain 2020, grouped by periods during the flood cycle - early, middle and late flooding period (FP). Blue dotted vertical lines indicate the respective minimum length at maturity (Hay *et al.*, 2000).

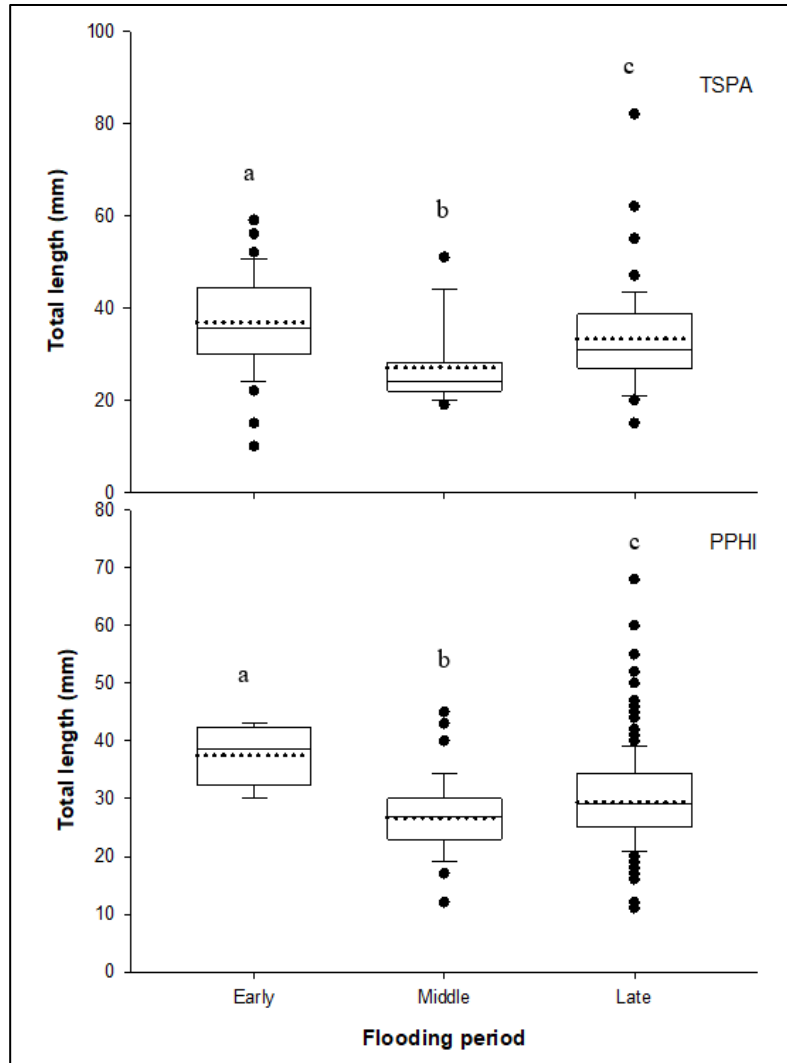


Figure 11 Body length of *Tilapia sparrmanii* (TSPA) and *Pseudocrenilabrus philander* (PPHI) grouped by flooding periods during the 2020 flood pulse on the Kamutjonga floodplain. Different letters denote significant differences (Kruskal-Wallis; Pairwise comparison, $p \leq 0.05$). The dotted line indicates the mean.

3.4. Catches at depth intervals

3.4.1. Vertical species composition

When sampling, each site was subdivided into three depth intervals: 0- 29 cm, 30 – 59 cm and 60 – 99 cm (Figure 3), and the sampling effort in each depth interval was the same. Across depth intervals, Cichlidae was the most important family, with cichlids accounting for at least 72% of the total IRI at each depth interval. In the 0 – 29 cm depth interval, a total of 603 (69%) of the total number of specimens (872) were recorded, belonging to 19 species. *Coptodon rendalli* (21.4%) was the most important single species on the floodplain in terms of IRI and contributed the third-highest weight in the 0 – 29 cm depth interval (Table 5). *Clarias gariepinus* (16.6%) and *C. ngamensis* (9.6%) were the next most important species in the 0 – 29 cm depth interval based on their IRI contributions. *Oreochromis andersonii* contributed the highest weight (250.0 g) and the third highest number of specimens (91), while *P. philander* contributed the highest number of specimens (n = 277) and the third highest weight (129.8 g). A group of Cichlidae specimens that could not be identified to species level due to its small size contributed 46.8% to the IRI but since this is (likely) an aggregate of species, it was not shaded as the most important single species in Table 5.

In the 30 – 59 cm depth interval, a total of 147 specimens (17% of the total number of specimens – 872) were recorded, belonging to 17 species. *Pseudocrenilabrus philander* (51.7%) was the most important species based on its IRI in the 30 – 59 cm depth interval and contributed the highest number of specimens (50). *Oreochromis andersonii* (26.0%) was the next most important species based on its IRI and contributed the highest weight

(250.0 g) and the joint-second highest number of specimens with *T. sparrmanii* (n = 19). *Tilapia sparrmanii* was the third most important species in the 30 – 59 cm depth interval (IRI = 8.4%). *Clarias ngamensis* and *C. rendalli* contributed the second and third highest weight, 62.4 g and 23.0 g, respectively. A group of Cichlidae specimens that could not be identified to species level due to its small size contributed 9.1% to the IRI but since this is (likely) an aggregate of species, it was not shaded as the most important single species in Table 5.

In the 60 – 99 cm depth interval, a total of 122 (14% of the 872 total specimens) were recorded. This was the most speciose depth interval, with 21 species. *Pseudocrenilabrus philander* was the most important species in the 60 – 99 cm depth interval (IRI = 81.8%), and it also contributed the highest number of specimens (n = 52) and weight (34.0 g) in this depth interval. *Tilapia sparrmanii* was the next most important species in the 60 – 99 cm depth interval (IRI = 7.9%) and contribute the second-highest number of specimens (n = 12) and weight (22.1 g). *Enteromius bifrenatus* was the third most import species in the 60 – 99 cm depth interval (IRI = 1%) and contributed the third highest number of specimens (6). *Coptodon rendalli* contributed the third-highest weight in the depth interval (9.6 g). A group of Cichlidae specimens that could not be identified to species level due to its small size contributed 5.3% to the IRI but since this is (likely) an aggregate of species, it was not shaded as the most important single species in Table 5.

Table 5: The number, weight (g) and the Index of Relative Importance (%) of species sampled on the Kamutjonga floodplain during the early (3 – 9 March), middle (28 March – 4 April) and late (14 – 23 May) flooding periods at 0 – 29 cm, 30 – 59 cm and 60 – 99 cm depth interval. The shading represents the three most important species in each category.

Taxon	0 - 29 cm			30 - 59 cm			60 - 99 cm		
	Number	Weight (g)	IRI (%)	Number	Weight (g)	IRI (%)	Number	Weight (g)	IRI (%)
Alestidae									
<i>Brycinus lateralis</i>							1	0.1	0.0
<i>Hydrocynus vittatus</i>	1	1.5	0.1						
Cichlidae									
Cichlidae spp.	50	9.0	46.8*	23	1.5	9.1*	16	3.2	5.3*
<i>Coptodon rendalli</i>	20	121.6	21.4	4	23.0	1.1	2	9.6	0.5
<i>Oreochromis andersonii</i>	91	250.0	1.8	19	113.2	26.0	2	2.3	0.2
<i>Pharyngochromis acuticeps</i>	1	0.3	0.0	3	0.5	0.2	1	0.2	0.0
<i>Pseudocrenilabrus philander</i>	277	129.8	0.8	50	21.8	51.7	52	34.0	81.8
<i>Serranochromis altus</i>	2	7.7	0.1	1	7.2	0.1	3	7.1	0.6
<i>Tilapia ruweti</i>	26	34.6	0.3	2	1.3	0.1	2	2.0	0.1
<i>Tilapia sparrmanii</i>	91	72.5	0.9	19	13.7	8.4	12	22.1	7.9
Clariidae									
<i>Clarias gariepinus</i>	8	33.0	16.6	4	12.3	0.7	5	2.8	0.7
<i>Clarias ngamensis</i>	1	40.2	9.6	2	62.4	1.2			
Cyprinidae									
<i>Enteromius barnardi</i>	3	0.3	0.2	4	0.8	0.3	5	1.5	0.6
<i>Enteromius bifrenatus</i>	6	2.0	0.7	5	0.8	0.5	6	3.1	1.0
<i>Enteromius fasciolatus</i>							1	0.3	0.0
<i>Enteromius haasianus</i>	4	0.3	0.3	1	0.1	0.0	1	0.1	0.0
<i>Enteromius poechii</i>	2	0.6	0.1	1	0.2	0.0			
<i>Enteromius</i> spp.				5	0.2	0.4	1	0.3	0.0
<i>Enteromius unitaeniatus</i>				3	1.7	0.2	6	1.4	0.8
<i>Labeo cylindricus</i>				1	2.3	0.0			
Mochokidae									
<i>Synodontis</i> spp.	3	1.0	0.0						
Mormyridae									
<i>Marcusenius altisambesi</i>	2	7.8	0.1				2	6.5	0.3
<i>Pollimyrus marianne</i>							1	0.5	0.0
Procatopodidae									
<i>Lacustricola hutereaui</i>	2	0.3	0.1				1	0.1	0.0
<i>Lacustricola johnstoni</i>	13	1.2	0.2				1	0.4	0.0
Schilbeidae									
<i>Schilbe intermedius</i>							1	0.3	0.0
Total	603	713.6	100	147	263.0	100	122	97.9	100

3.4.2. Vertical catch per unit effort

The CPUE in numbers (number of fish/throw) and weight (g/throw) sampled between the 0 – 29 cm, 30 – 59 cm and 60 – 99 cm depth intervals are presented in Figure 12 below. The median CPUE in numbers ($H_{(2)} = 32.006$, $p < 0.001$) and weight ($H_{(2)} = 20.960$, $p < 0.001$) varied between depth intervals. The median CPUE in numbers between 0 – 29 cm (1.7 fish/throw) and (a) 30 – 59 cm (0.5 fish/throw) ($p < 0.001$) and (b) 60 – 99 cm (0.4 fish/throw) ($p < 0.001$) were significantly different (Figure 12). Similarly, the median CPUE in weight between the 0 – 29 cm (1.6 g/throw) significantly varied with the 30 – 59 cm (0.3 g/throw) ($p < 0.001$) and the 60 – 99 cm depth interval (0.3 g/throw) ($p < 0.001$) (Figure 12).

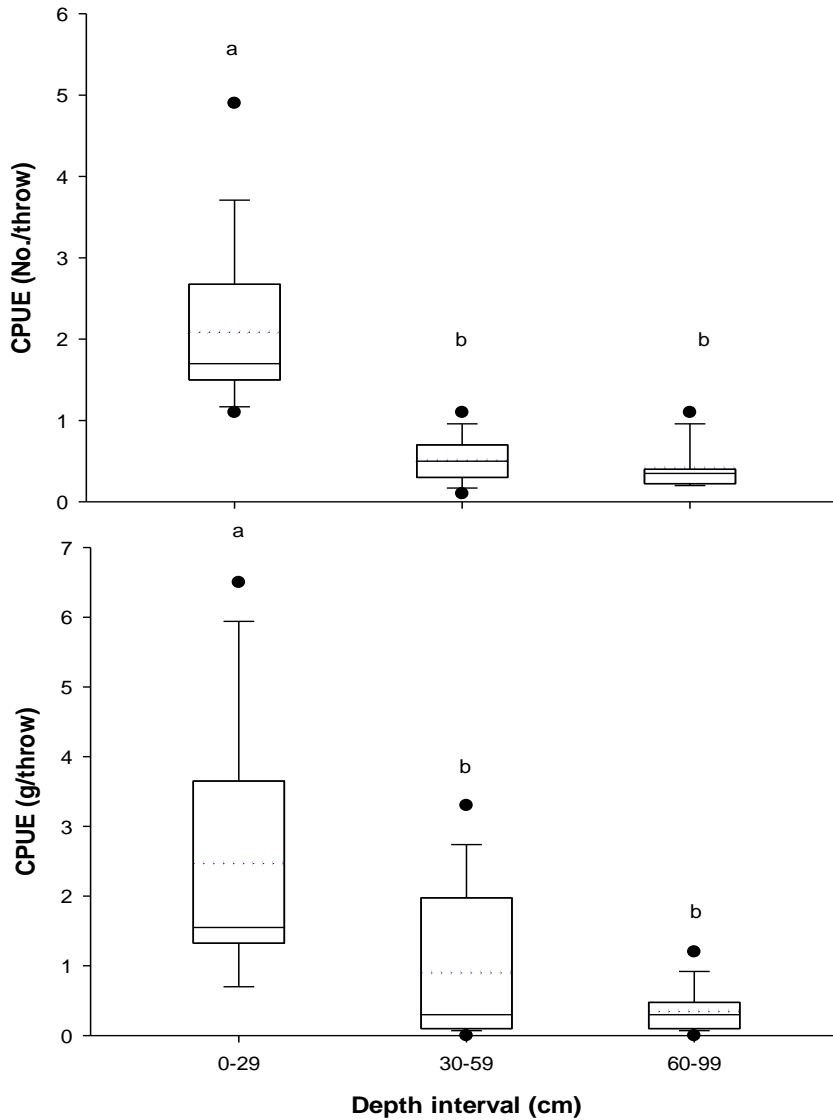


Figure 12: The Catch per unit effort (CPUE) in numbers (number of fish/throw) and weight (g/throw) of species sampled on the Kamutjonga floodplain at the 0 – 29 cm, 30 – 59 cm and 60 – 99 cm depth interval during the early (3 – 9 March), middle (28 March – 4 April) and late (14 – 23 May) flooding periods. Different letters denote significant differences (Kruskal-Wallis; Mann-Whitney U-test comparison, $p \leq 0.05$). The dotted line indicates the mean.

3.4.3. Vertical length distribution of *Tilapia sparrmanii* and *Pseudocrenilabrus philander*

The body length of the 122 *T. sparrmanii* specimens collected did not vary significantly across the three depth intervals on the floodplain ($H_{(2)} = 0.066$, $p < 0.967$) (Figure 14). Of the total, 91 specimens (75%) were collected in the shallowest section (0 – 29 cm depth interval), with body length ranging between 10 – 59 mm (Figure 13). Of the 91 specimens, 41 (45%) had body length between 20 – 30 mm, the most of any length group (Figure 13). The mean body length of *T. sparrmanii* in the 0 – 29 cm depth interval was 33 ± 10 mm (Figure 14), with none of the specimens above the 61 mm reported minimum length at maturity (Hay et al., 2000). In the 30 – 59 cm depth interval, a total of 19 specimens were collected, with body lengths ranging between 19 and 50 mm. The modal length group the 40 – 50 mm, with six (32%) of the 19 specimens recorded (Figure 13). The mean length of *T. sparrmanii* in the 30 – 59 cm depth interval was 32 ± 10 mm, with none of the specimens above the 61 mm reported minimum length at maturity (Figure 13, Figure 14) (Hay et al., 2000). In the 60 – 99 cm depth interval, 12 specimens ranged from 15 to 80 mm, with the 30 – 40 mm length being the modal group (Figure 13). The mean length of *T. sparrmanii* in the 60 – 99 cm depth interval was 36 ± 18 mm, with two (17%) specimens above the reported 61 mm minimum length at maturity (Figure 13, Figure 14) (Hay et al., 2000).

The body length of the 379 specimens of *P. philander* also did not vary across depth intervals ($H_{(2)} = 4.040$, $p < 0.133$) (Figure 14). In the 0 - 29 cm depth interval, where 277 (73%) of the specimens were sampled, the body length ranged between 12 and 47 mm, with the modal body length group 20 – 30 mm accounting for 163 (59%) of the total

specimens in the depth interval (Figure 13). The mean length *P. philander* in the 0 -29 cm depth interval was 29 ± 7 mm, with 98 (35%) of the specimens above the 30 mm minimum length at sexual maturity (Figure 13, Figure 14) (Hay et al., 2000). In the 30 – 59 cm depth interval, a total of 50 *P. philander* specimens were sampled (13%), with body lengths ranging from 17 to 60 mm. The 20 – 30 mm length group was the modal group, accounting for 26 (52%) of the specimens (Figure 13). The mean body length of *P. philander* in the 30 – 59 cm depth interval was 28 ± 8 mm (Figure 14), with 12 (24%) of the specimens having lengths above the 30 mm minimum length at maturity (Figure 13) (Hay et al., 2000). In the 60 – 99 cm depth interval, a total of 52 (14%) specimens were sampled, with body lengths ranging between 11 and 68 mm. The modal length group was 20 – 30 mm, with 24 (46%) of the 52 specimens (Figure 13). The mean length of *P. philander* in the 60 – 99 cm depth interval was 30 ± 10 mm (Figure 14), with 19 (37%) specimens having lengths above the reported 30 mm minimum length at sexual maturity (Figure 13) (Hay et al., 2000).

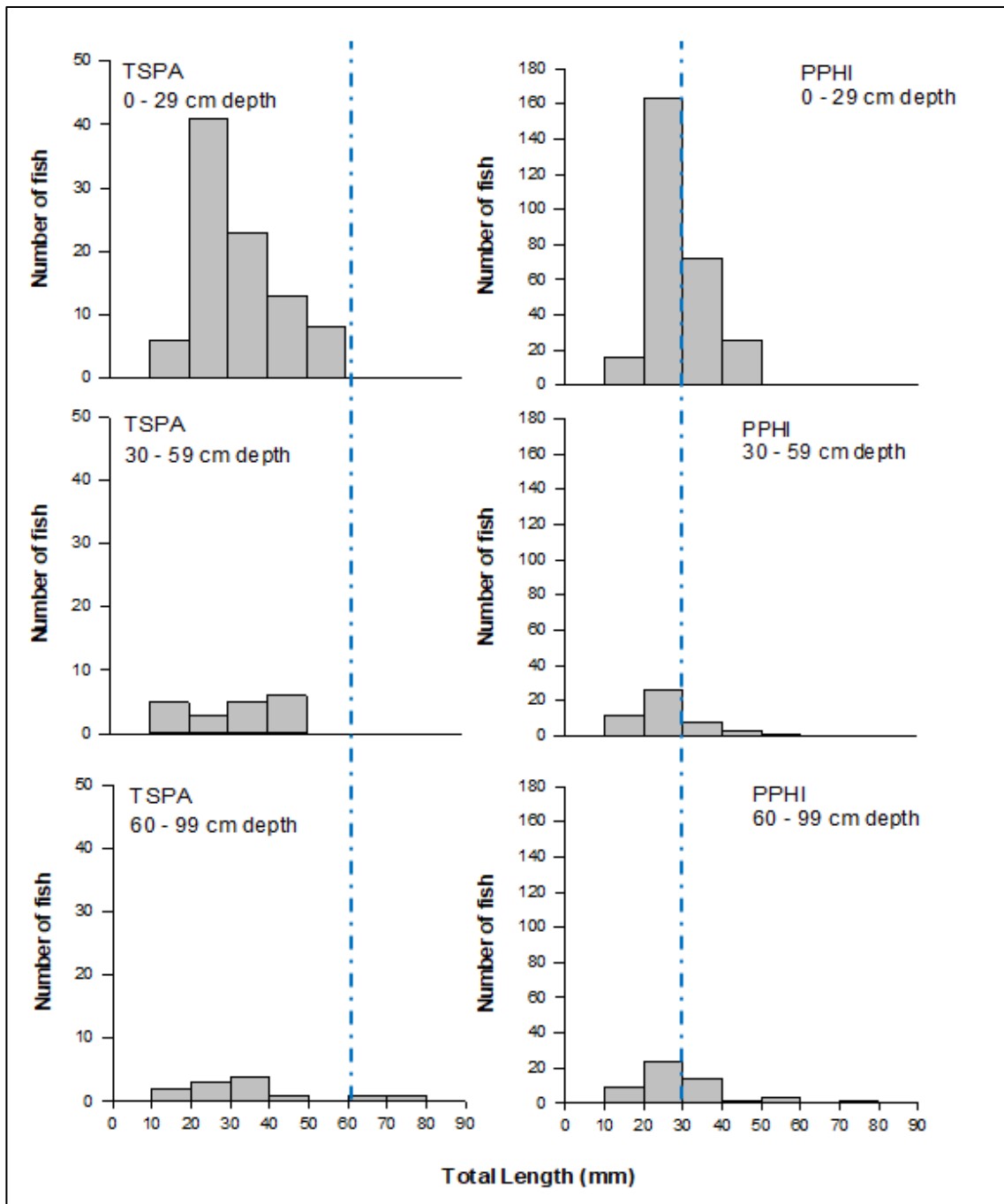


Figure 13 Length frequency distributions of *Tilapia sparrmanii* (TSPA) and *Pseudocrenilabrus philander* (PPHI) on the Kamutjonga floodplain 2020, grouped by depth intervals. Blue dotted vertical lines indicate the respective minimum length at maturity (Hay *et al.*, 2000).

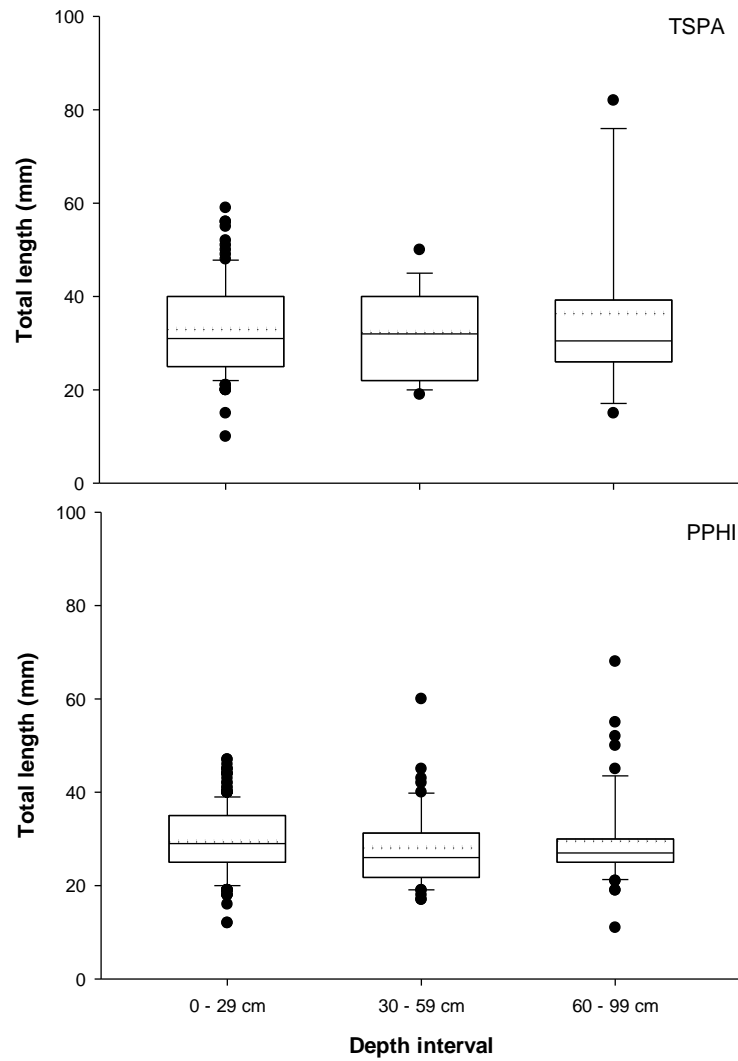


Figure 14: Body length of *Tilapia sparrmanii* (TSPA) and *Pseudocrenilabrus philander* (PPHI) grouped by depth intervals during the 2020 flood pulse on the Kamutjonga floodplain. The dotted line indicates the mean.

3.5. Catches at sampling sites

3.5.1. Spatial species composition

From the samples collected during the flooding periods on the floodplain, specimens from the Cichlidae family dominated at least 93% of the total Index of Relative Importance (IRI) at all sampling sites (Table 6). Of the total 872 specimens (which combined to 1074.5 g) collected on the floodplain, 205 (24%) specimens (total weight of 293.6 g) were collected at site 1 – which was the highest proportion of specimens across sampling sites. Further, a total of 16 species were recorded at site 1, with *P. philander* (73.2%), *T. sparrmanii* (12.1%) and *O. andersonii* (4.5%) the most important species in terms of their numerical and weight contribution, as well as the frequency of occurrence at site 1. In terms of numbers, *P. philander* (91 specimens), *T. sparrmanii* (31) and *O. andersonii* (19) contributed the highest number of specimens at site 1, whilst in terms of weight *Clarias ngamensis* (102.6 g), *Coptodon rendalli* (55.8 g) and *P. philander* (40.4 g) contributed the highest weight (Table 6).

At site 2, a total of 174 specimens (20%) of the total number of specimens were recorded, contributing a combined 101.5 g. Site 2 was the most speciose site, with 20 species recorded. *Pseudocrenilabrus philander* (52.5%), *T. sparrmanii* (11.3%) and *O. andersonii* (5.8%) were the most important species in terms of their relative IRI. Coincidentally, the same species contributed the highest number of specimens and weight (Table 6). A group of Cichlidae specimens that could not be identified to species level due to its small size contributed 23.7% to the IRI but since this is (likely) an aggregate of species, it was not shaded as the most important single species in Table 6. At site 3, a total

of 109 specimens (13% of the total number of specimens) were recorded, weighing up to 195.3 g. A total of 13 species were recorded at site 3, with *O. andersonii* (61.0%), *T. sparrmanii* (30.6%) and *P. philander* (3.8%) contributing the highest IRI. In terms of numbers, *T. sparrmanii* (35), *O. andersonii* (33) and *P. philander* (13) contributed the highest number of specimens in that order, whilst in terms of weight *O. andersonii* (121.7 g), *T. sparrmanii* (22.9 g) and *Serranochromis altus* (12.7 g) (Table 6).

At site 4, 22% (196) of the total number of specimens, belonging to 9 species were recorded. In terms of both numbers (133), weight (82.4 g) and IRI (93.0%), *P. philander* dominated the catches, followed by *T. sparrmanii* which contributed the second highest number of specimens (n = 24), and IRI (3.5%). *Oreochromis andersonii* contributed the second-highest weight (23.2 g) and *T. sparrmanii* contributed the third-highest weight (21.5 g). *Tilapia ruweti* was the third most important species at site 4 (IRI = 1.7%) (Table 6).

At site 5, a total of 97 specimens (11% of the total number of specimens) were recorded, weighing 106.7 g. These specimens belonged to 8 species, with *P. philander* being the most important species in terms of IRI (88.8%) and contributing the highest number of specimens (n = 66). *Oreochromis andersonii* was the second most important species in terms of IRI (7.8%), contributing the highest weight (62.2 g) and joint-highest number of specimens with *T. ruweti* (8 specimens). *Tilapia ruweti* was the third most important species (IRI = 2.1%) and contributed the third highest weight (10.0 g). At site 6, a total of 91 specimens were recorded (10% of the total number of specimens), belonging to 10 species. *Oreochromis andersonii* was the most important species at site 6 (IRI = 69.1%), contributing the highest number of specimens (27) and weight (118.6 g). The next most

important species at site 6 was *P. philander* (IRI = 17.1%) which also contributed the second-highest number of specimens (n = 22). *Tilapia sparrmanii* was the third most important species at site 6 (IRI = 5.2%) and also contributed the third highest number of specimens (n = 12). *Clarias ngamensis* (26.4 g) and *C. rendalli* (24.1 g) contributed the second and third highest weight at site 6, respectively (Table 6).

Table 6: The number, weight (g) and the Index of Relative Importance (%) of species sampled on the Kamutjonga floodplain during the early (3 – 9 March), middle (28 March – 4 April) and late (14 – 23 May) flooding periods at sites 1 - 6. The shading represents the three most important species in each category. * represents the contribution of a group of unidentified species.

Taxon	Site 1			Site 2			Site 3			Site 4			Site 5			Site 6		
	Number	Weight (g)	IRI (%)	Number	Weight (g)	IRI (%)	Number	Weight (g)	IRI (%)	Number	Weight (g)	IRI (%)	Number	Weight (g)	IRI (%)	Number	Weight (g)	IRI (%)
Alestidae																		
<i>Brycinus lateralis</i>				1	0.1	0.0												
<i>Hydrocynus vittatus</i>							1	1.5	0.0									
Cichlidae																		
Cichlidae spp.	28*	1.7	5.5	39	9.9	23.7*	10	0.9	1.9				7*	0.2	0.8	5	0.8	0.8
<i>Coptodon rendalli</i>	6	55.8	1.8	7	5.0	1.2	5	24.0	1.7	3	37.4	0.4	1	7.9	0.1	4	24.1	1.9
<i>Oreochromis andersonii</i>	19	23.6	4.5	13	16.3	5.8	33	121.7	61.0	12	23.2	1.3	8	62.2	7.8	27	118.6	69.1
<i>Pharyngochromis acuticeps</i>	1	0.2	0.0	3	0.6	0.1	1	0.2	0.0									
<i>Pseudocrenilabrus philander</i>	91	40.4	73.2	52	23.9	52.5	13	5.5	3.8	135	82.4	93.0	66	25.5	88.8	22	8.0	17.1
<i>Serranochromis altus</i>	2	6.2	0.1	1	0.9	0.0	2	12.7	0.3	1	2.3	0.0						
<i>Tilapia ruweti</i>	2	6.5	0.1				4	3.0	0.4	16	18.4	1.7	8	10.0	2.1			
<i>Tilapia sparrmanii</i>	31	38.1	12.1	19	20.9	11.3	35	22.9	30.6	24	21.5	3.5	1	0.2	0.0	12	4.7	5.2
Clariidae																		
<i>Clarias gariepinus</i>	2	11.6	0.1	1	0.8	0.0	1	2.1	0.0	1	6.5	0.0	5	0.6	0.4	7	26.4	4.2
<i>Clarias ngamensis</i>	3	102.6	1.5															
Cyprinidae																		
<i>Enteromius barnardi</i>	8	2.1	0.5	3	0.4	0.1	1	0.1	0.0									
<i>Enteromius bifrenatus</i>				11	5.0	2.3	1	0.2	0.0				1	0.0	0.0	4	0.8	0.5
<i>Enteromius fasciolatus</i>				1	0.3	0.0												
<i>Enteromius haasianus</i>	1	0.1	0.0	1	0.1	0.0										4	0.4	0.5
<i>Enteromius poechii</i>				1	0.3	0.0	2	0.5	0.1									
<i>Enteromius spp.</i>	1	0.0	0.0							1	0.0	0.0				4	0.5	0.5
<i>Enteromius unitaeniatus</i>	7	2.7	0.4													2	0.5	0.1
<i>Labeeo cylindricus</i>				1	2.3	0.1												
Mochokidae																		
<i>Synodontis spp.</i>										3	1.0	0.0						
Mormyridae																		
<i>Marcusenius altisambesi</i>	1	1.7	0.0	3	12.6	0.8												
<i>Pollimyrus marianne</i>				1	0.5	0.0												
Procatopodidae																		
<i>Lacustricola hutereaui</i>				3	0.4	0.1												
<i>Lacustricola johnstoni</i>	2	0.5	0.0	12	1.1	1.8												
Schilbeidae																		
<i>Schilbe intermedius</i>				1	0.3	0.0												
	205	293.6	100	174	101.5	100	109	195.3	100	196	192.6	100	97	106.7	100	91	184.8	100

3.5.1. Spatial catch per unit effort

The Catch per Unit Effort (CPUE) in numbers (number of fish/throw) and weight (g/throw) between sites 1 – 6 are presented in Figure 15 below. The median CPUE in numbers differed between sites ($H_{(5)} = 22.754$, $p < 0.001$), but the CPUE in weight did not differ between sites ($H_{(5)} = 9.237$, $p < 0.100$) (Figure 15). Between sampling sites, the median CPUE in numbers varied between sites 1 and 3 ($p = 0.006$), sites 1 and 5 ($p < 0.002$); and sites 1 and 6 ($p < 0.001$). Further, the median CPUE at site 4 (1.2 fish/throw) was significantly higher than that of site 3 ($p < 0.008$), site 5 ($p < 0.003$) and site 6 ($p < 0.001$). The median CPUE in numbers between sites 2 (0.9 fish/throw) and 6 (0.7 fish/throw) also differed significantly ($p < 0.038$).

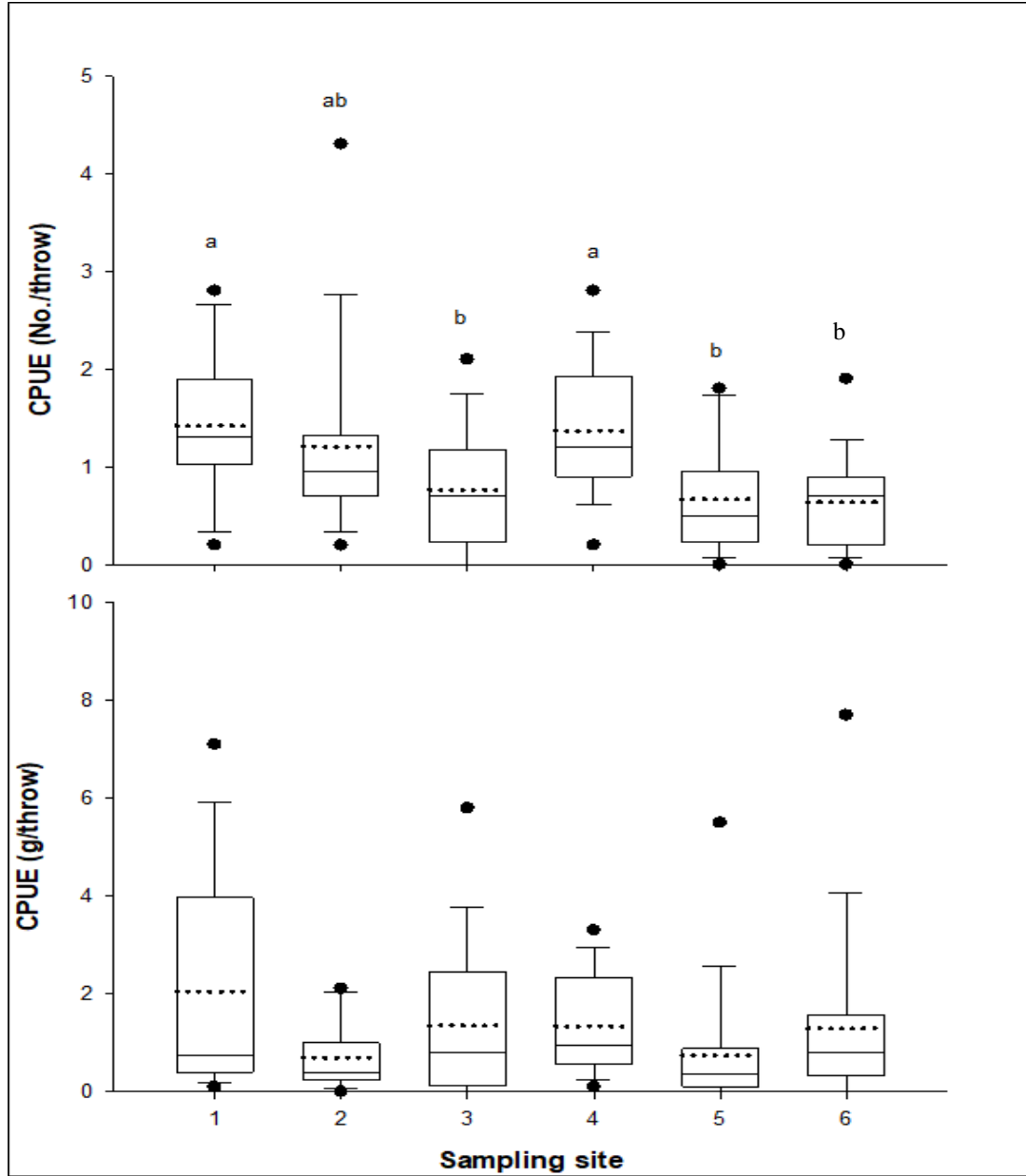


Figure 13: The catch per unit effort (CPUE) in numbers (number of fish/throw) and weight (g/throw) of species sampled on the Kamutjonga floodplain at sites 1 - 6 during the early, middle and late flooding periods. Different letters denote significant differences (Kruskal-Wallis; Mann-Whitney U-test comparison, $p \leq 0.05$). The dotted line indicates the mean.

3.5.2. Spatial length distribution of *Tilapia sparrmanii* and *Pseudocrenilabrus philander*

The body length of the 122 specimens of *T. sparrmanii* sampled varied across sampling sites on the floodplain ($H_{(5)} = 18.597$, $p < 0.002$) (Figure 17). Of the 122 total *T. sparrmanii* specimens, 31 (25%) were found at site 1, with the body length ranging between 19 and 59 mm. The 30 – 40 mm length group was the most frequent, accounting for 31% (10 specimens) of the number of specimens at site 1 (Figure 16). The mean body length of *T. sparrmanii* at site 1 was 38 ± 11 mm (Figure 17), with none of the specimens above the reported 61 mm minimum length at maturity (Figure 16) (Hay et al., 2000). At site 2, there were 19 (16%) of the specimens were found, with body lengths ranging between 20 and 80 mm (Figure 17). Specimens with lengths between 20 – 30 mm were the most frequent, accounting for 74% (14 specimens) of the total *T. sparrmanii* catch at site 2. The mean length of the specimens at site 2 was 33 ± 14 mm (Figure 17), with one of the specimens (5%) having the 80mm length, which is more than the reported 61 mm length at minimum sexual maturity (Figure 16) (Hay et al., 2000).

The highest number of specimens were sampled at site 3, with 35 *T. sparrmanii* specimens ranging between 15 and 62 mm. Most of the specimens (18 of 35) had lengths between 20 – 30 mm length groups (Figure 16). The mean length of specimens was 30 ± 10 mm (Figure 17), with one more specimen above the minimum length at maturity (Figure 16). The 24 specimens sampled at site 4 ranged between 10 and 55 mm, with 13 (54%) of the specimens having lengths between 30 – 40 mm (Figure 16). The mean length of specimens at site 4 was 35 ± 9 mm, with none of the specimens above the reported 61 mm minimum length at maturity (Figure 16) (Hay et al., 2000). At site 5, only one specimen was

sampled, with a length of 23 mm (Figure 16). At site 6, a total of 12 *T. sparrmanii* specimens were sampled, with body lengths ranging between 20 and 51 mm, and 8 of the 12 specimens (67%) having lengths between 20 – 30 mm (Figure 16). The mean length of the specimens at site 6 was 28 ± 9 mm (Figure 17).

Similarly, the length of the 379 specimens of *P. philander* sampled differed across sampling sites on the floodplain ($H_{(5)} = 14.342$, $p < 0.014$) (Figure 17). At site 1, there were 94 specimens (25%) of *P. philander*, with body lengths ranging from 12 to 60 mm (Figure 16). Nearly half of the specimens at site 1 had lengths between 20 and 30 mm – accounting for 44 (47%) (Figure 16). The mean length of *P. philander* at site 1 was 28 ± 8 mm (Figure 17), with 26 (28%) having lengths above the reported 30 mm minimum length at maturity (Figure 16) (Hay et al., 2000). At site 2, where 52 (14%) *P. philander* specimens were sampled, the body length ranged between 12 and 43 mm (Figure 16). Thirty-two of the specimens (62%) had lengths between 20 – 30 mm. The mean length of the *P. philander* specimens at site 2 was 28 ± 7 mm (Figure 16), with 10 (19%) of the specimens having lengths above the reported 30 mm minimum length at maturity for *P. philander* (Figure 11, Figure 12) (Hay et al., 2000). The lowest number of specimens per site (13) was recorded at site 3, where specimens had body lengths ranging from 11 to 47 mm (Figure 16). Seven of the 13 specimens (54%) had lengths between 20 – 30 mm. The mean length of specimens at site 3 was 28 ± 9 mm, with 38% (5 specimens) having lengths above the reported 30 mm minimum length at maturity (Figure 16, Figure 17).

The highest number of specimens (132) was recorded at site 4, with body lengths ranging from 18 to 68 mm, while 52 (39%) of the specimens had lengths between 30 – 40 mm (Figure 16). The mean length of *P. philander* at site 4 was 31 ± 8 mm, with nearly half of

the specimens (64 specimens – 48%) having lengths above the reported minimum length at maturity (Figure 16, Figure 17). At site 5, a total of 66 specimens were recorded, with body lengths ranging from 18 to 46 mm (Figure 16). At site 5, 42 specimens (64%) had lengths between 20 – 30 mm. The mean length at site 5 was 29 ± 5 mm, with 20 of the specimens (30%) having lengths above the reported 30 mm minimum length at maturity (Figure 16, Figure 17). At site 6, a total of 22 specimens were sampled, ranging from 19 to 41 mm in length. Of the 22 specimens, 15 (68%) had lengths between 20 – 30 mm (Figure 16). The mean length of *P. philander* at site 6 was 27 ± 6 mm, with four of 22 (18%) having lengths above the reported minimum length at maturity (Figure 16, Figure 17) (Hay et al., 2000).

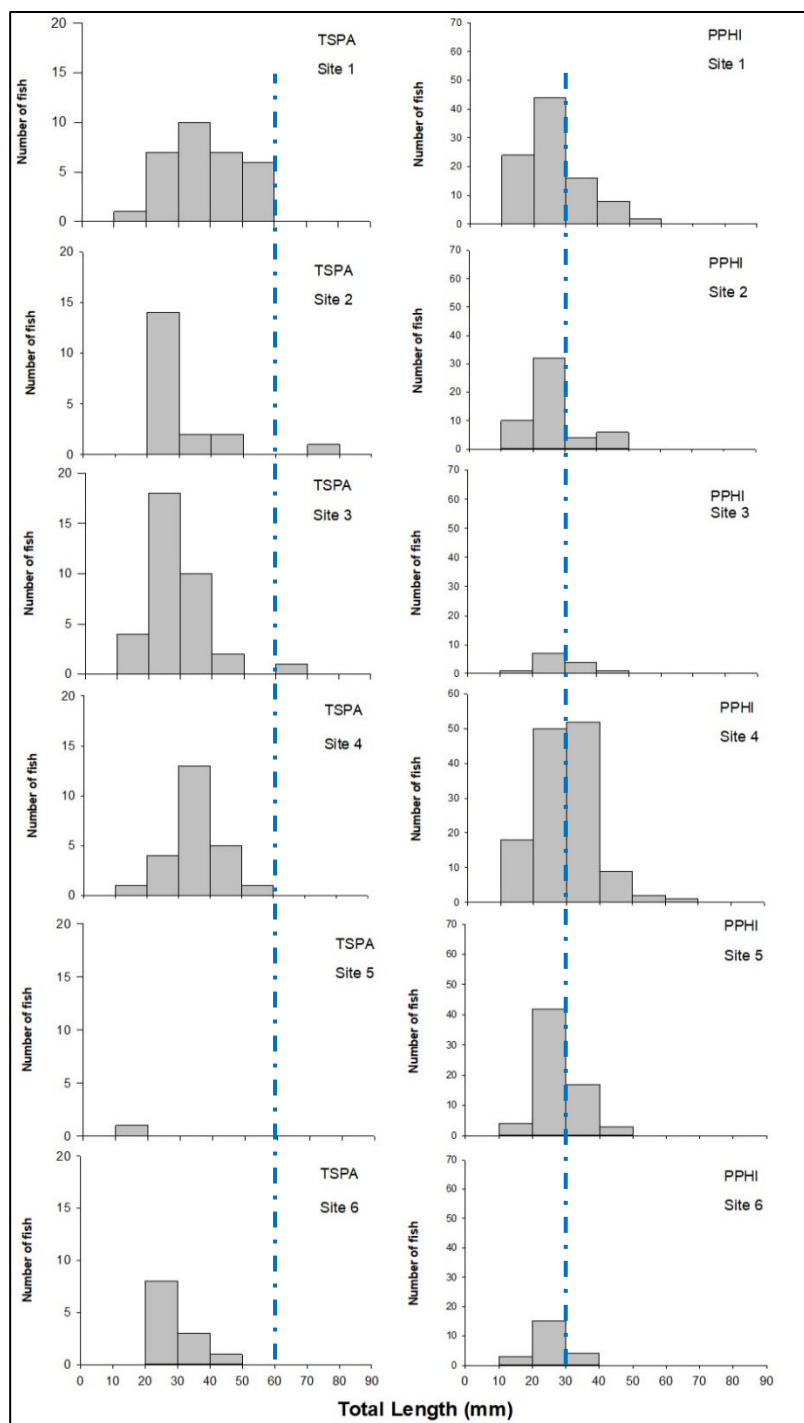


Figure 16: Length frequency distributions of *Tilapia sparrmanii* (TSPA) and *Pseudocrenilabrus philander* (PPHI) on the Kamutjonga floodplain 2020, grouped by sampling sites. Blue dotted vertical lines indicate the respective minimum length at maturity (Hay et al., 2000).

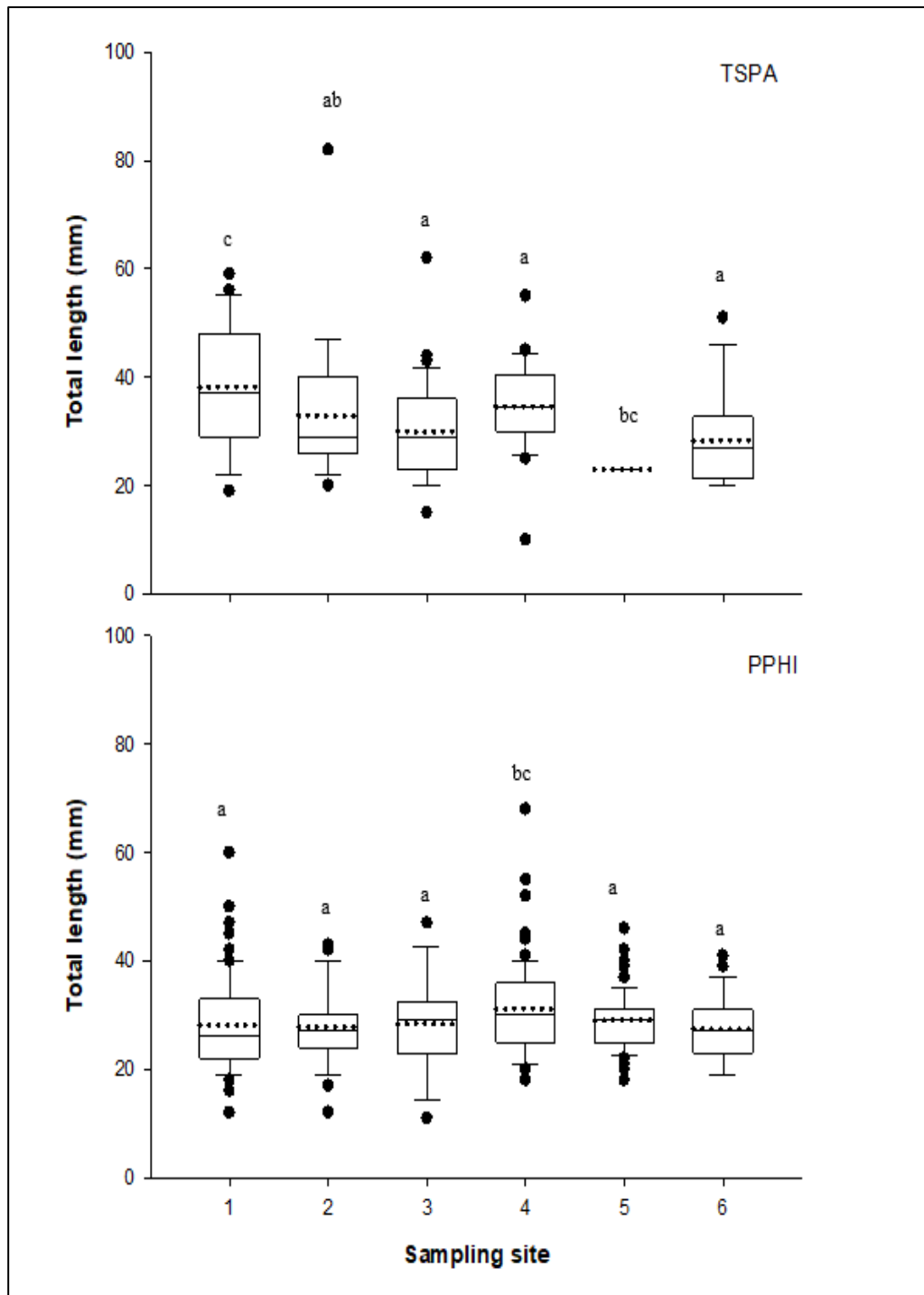


Figure 17: Body length of *Tilapia sparrmanii* (TSPA) and *Pseudocrenilabrus philander* (PPHI) grouped by flooding periods during the 2020 flood pulse on the Kamutjonga floodplain. Different letters denote significant differences (Kruskal-Wallis; Pairwise comparison, $p \leq 0.05$). The dotted line indicates the mean.

CHAPTER 4: DISCUSSION

4.1. Composition of fish during sampling periods

When comparing the catch between the early, middle and late flooding periods on the Kamutjonga floodplain, more species ($n = 17$) were recorded during the early periods of flooding, from 249 specimens. During the late flooding periods, the highest number of specimens were recorded ($n = 463$) but with the fewest number of fish species ($n = 13$), of which one species (*P. philander*) contributed 73% ($n = 337$) of the total number of specimens in the late flooding period. The results from the current study tie well with the finding of other researchers who found differences in fish species composition during flooding cycles on floodplains along the Kavango River and its Delta (Hocutt & Johnson, 2001; Mosepele *et al.*, 2022; Tiyeho, 2022). Hocutt and Johnson (2001) documented that although there is variability in the degree and timing of the annual flood cycle, fish productivity on the floodplain remains primarily dictated by the flooding cycle with a) fish communities timing their peak productivity with flood cycle and b) cichlids dominating the on the floodplain.

Cichlids dominated the catches on the floodplain during all flooding periods, with all cichlid species contributing to at least 99% of the total IRI during the early and late flooding periods on the Kamutjonga floodplain (Table 4). Cichlids such as *P. philander*, *O. andersonii*, *T. sparrmanii* and *C. rendalli*, and catfishes (*C. gariepinus*, *C. ngamensis*), and barbs (*E. unitaeniatus*) were some of the most dominant species. A few years prior, a study revealed similar results on the same floodplain, with cichlids altogether contributing about 94.4% of the total IRI (Simasiku & Mafwila, 2017). In the Okavango Delta in Botswana, and along the Kavango River with data from as far back as 1992, juveniles of

the same cichlid species as in the current study dominated the catches in the newly inundated areas (Hay *et al.*, 2000; Mosepele *et al.*, 2022). Cichlids dominate the peripheries of the floodplains because they can occupy three different trophic levels (piscivore, herbivore and invertivore), allowing them to have a range of feeding options at any given time and enabling them to outcompete species from other families. Further, cichlids also occupy the full spectrum of reproductive strategies (from r- through K-selection), with their ability to optimize either at the carrying capacity or alter their growth rate strategies, advantaging them in how they compete with species from other families on the floodplain (Hocutt & Johnson, 2001). During flooding, there is a reported boom in zooplankton and primary producers in the newly inundated areas, which serve as abundant food sources for the cichlid species (Hocutt & Johnson, 2001; Siziba *et al.*, 2013).

Pseudocrenilabrus philander, also a cichlid, dominated the catches in the late flooding period, with an increased abundance in the number of specimens caught during the late flooding period (n = 337) as opposed to only six specimens during the early flooding period (Table 4). Inversely, specimens of *O. andersonii*, another cichlid, dominated the catches during the early flooding periods (106 specimens), while only five specimens were sampled during the late flooding periods (Table 4). Tropical fish time their reproductive cycles, and hence their dominance in a particular system, with seasonal flooding, with species such as *O. andersonii* known to spawn pre-flooding and their fingerlings are then nursed on the floodplain (Hocutt & Johnson, 2001; Skelton, 1993).

The finding from the current study suggests *P. philander* spawns during the early to middle of the flooding cycle. This is evidenced by the presence of few (only 6) specimens, but large in size (mean length 38 ± 5 mm), during the early flooding period; whilst a total

of 337 specimens were present during the late flooding period. In addition, 83% of the six specimens recorded early in the flooding period were above the minimum length at maturity for *P. philander*, which likely bred on the floodplain through the middle flooding period hence the number of specimens during the late flooding period was highest as there was a lot of small (mean length 29 ± 7 mm), sexually immature specimens (with only 35% above maturity length) on the floodplain. Bruton *et al.* (2018) and Skelton (1993) have both reported that *P. philander*, a species which prefers vegetated floodplains, breeds from early spring to late summer in the Okavango Delta (Bruton *et al.*, 2018; Skelton, 1993).

Tilapia sparrmanii, a highly adaptable small cichlid, is known to spawn throughout the warm months, and is very tolerant to low temperatures (Bruton *et al.*, 2018). These are nest guarders which make sand-scrape nests, preferably in the river, and the breeding pairs guard the nest (Bruton *et al.*, 2018; Skelton, 1993). The findings of the current study are coherent with those of previous researchers, with considerably a lot of small-sized *T. sparrmanii* specimens found throughout the flooding cycle. During the early and middle flooding periods, none of the 74 *T. sparrmanii* specimens was above the 61 mm minimum length at maturity, while only 4% of the 48 were above sexual maturity during the late flooding period. This hints that the *T. sparrmanii* specimens came from the breeding ground (River) onto the nursery ground (floodplain), where their chances of survival for the fingerlings are enhanced by the cover provided by the vegetation on the floodplain (Junk *et al.*, 1989; Skelton, 1993; Tockner *et al.*, 2000).

A cichlid species that were common in the catch composition on the floodplain in previous studies, *Oreochromis macrochir* (greenhead bream) was not recorded in the current study. In an earlier study on the Kamutjonga floodplain, *O. macrochir* was the most important

species on the floodplain, contributing 40.3% to the total IRI (Simasiku & Mafwila, 2017) and it is known to reach lengths of 325 mm – hence it should be identified with ease on the floodplain if it were present (Hay *et al.*, 2000). *Oreochromis macrochir*'s breeding period (between February and March) overlaps with the flooding of the Kamutjonga floodplain (Jere *et al.*, 2021). During the middle flooding period, which started towards the end of March in the current study, there were about 43 cichlid specimens that could not be identified to species level due to their small size; and 14 specimens during the late flooding period – it can be speculated that *O. macrochir* has been one of the few cichlids that could not have been identified to species level. However, other factors such as gear selectivity could equally account for the absence of *O. macrochir* on the floodplain. *Oreochromis machrochir* is classified as a vulnerable species on the IUCN Red List of freshwater fishes from Southern Africa (Bruton *et al.*, 2018), raising further concerns about its absence on the floodplain about its population size and status.

The diet and feeding ecology of most floodplain fish species is related to the flood pulse and the volume of water on the floodplain (Mosepele *et al.*, 2012), with fish growing fast during rising water levels and the period at the maximum area on the floodplain is flooded to take advantage of the abundantly available food (Bayley, 1988). This way, the fish will be grown enough to avoid being stranded in isolated pools when the water retreats. However, evidence from the current study suggested that there is no relationship between the volume of water on the floodplain and the catch rate. Although the volume of water may be high, the fish will prefer the shallow peripheries of the floodplain, which may be pushed further inland when the water level is high, where there are abundant newly

availed food sources and safe from piscivores predation in the deep section of the floodplain (Junk *et al.*, 1989; Simasiku & Mafwila, 2017).

4.2. Composition of fish at depth intervals

The number of specimens decreased with increasing sampling depth on the floodplain, whilst the deepest sampling interval on the floodplain recorded the highest number of fish species. Water depth is a documented factor altering the composition of fish in rivers and associated floodplains (Negi & Mangain, 2013; Skelton, 1993). Bayley (1991), for instance, reported that the abundance and productivity of fish decreased with increasing depth, where a tenfold increase in depth only predicted a twofold in abundance and catches by local fishers in floodplains and lakes less than 4 m in depth (Bayley, 1991). Further, the pattern from the current study hints at upholding longstanding prepositions that the peripheries of the newly flooded areas serve as a nursery ground for most riverine species (Junk *et al.*, 1989; Simasiku & Mafwila, 2017; Thorstad *et al.*, 2003; Tockner *et al.*, 2000), with nearly 70% of all specimens found in the shallowest depth interval (0 – 29 cm) on the floodplain (Table 5).

In addition, the shallow depths were predominately covered by emergent vegetation, whilst the deep section of the floodplain was mainly open waters with little to no submerged vegetation growth (Pers. obs. 2020). The limited vegetation, coupled and in conjunction with the that the deep section has been under water or flooded for longer periods than the shallow section, enabled few individuals of most species to adapt to the stable conditions in deep waters, unlike in the shallow section where the water level (and hence habitats) constantly changed. The vegetated shallow depths which were not

inundated for longer periods (relative to the deep sections), which suited dominance by cichlids such as *P. philander* and *O. andersonii* that prefers vegetated shallow and well-oxygenated waters (Skelton, 1993). It was, however, not logistically possible to quantify the fluctuation of oxygen levels within a water column for the current study.

The catchability of fish tends to decline with increasing depth, particularly due to various factors such as the sheer volume of water being sampled and light intensity. Buijse *et al.* (1992) reported that increased water clarity can lead to zero catches and subsequently diminish the effectiveness of sampling procedures, especially in deep sections (Buijse *et al.*, 1992). In the deep section of the floodplain, there is more volume of water allowing the fish to easily see the approaching net and evade capture. Findings from the current study reveal that 93% of the specimens sampled in the 0 – 29 cm depth interval have lengths less than 60 mm. Large fishes on the floodplain prefer deep calm waters whilst juveniles occupy the shallow peripheries for feeding and escaping predation from larger fish in the deep waters (Hay *et al.*, 2000; Junk *et al.*, 1989; Simasiku & Mafwila, 2017; Skelton, 1993). Therefore, one is likely to have a low density of fish (likely large fish) in the deep section, and a high density in the shallow section where there are a lot of small-sized fish – that is the pattern observed in the current study.

4.3. Composition of fish at sampling sites

The fish species composition varied between sampling sites on the Kamutjonga floodplain, with site 1, which was near the junction between the river and the floodplain, recording the highest number of specimens across the floodplain, whilst the nearby site 2 had the most species. The distribution of fish in freshwater systems such as floodplains is usually uneven spatially (Skelton, 1993). Although there have been several research studies on the Kamutjonga floodplain's fishes, intra-floodplain spatial comparisons of fish species composition are non-existent, with previous researchers focusing on holistic floodplain fish species composition, selected species, and composition over time (Kangausaru, 2018; Peel, 2012; Simasiku & Mafwila, 2017; Tiyeho, 2022).

All over the world, the distribution of fish on floodplains is said to vary between sites within the aquatic system, especially where anthropogenic barriers such as bridges and weirs exist (Baumgartner, 2004; Baumgartner *et al.*, 2018; Miranda *et al.*, 2005; Skelton, 1993). Within the first week of sampling, all sites were fully connected and submerged, while the KIFI Bridge still formed as a barrier against fish migration between sites 2 and 3 until the 8th of March 2020 when the water level was above 150 cm on the floodplain. Such physical boundaries on the floodplain are the most obvious factors limiting the distribution of fish across the floodplain. The construction of bridges serves as an effective blockage of nutrients in the floodplain, creating an area of high nutrient concentration and pile up of particulate and matter, therefore attracting fish to forage (Cisowska & Hutchins, 2016). Fish also tend to swim against the current, hence more species accumulated downstream of the semi-permeable KIFI bridge, whilst the lowest number of species were recorded at the porous Mahangu Bridge.

The ability of small fish species to maintain a suitable physiochemical environment around them plays a critical role in avoiding predators or aiding their ability to feed on food sources in the surrounding habitats (Liao, 2007). Some fish employ behavioural patterns such as actively swimming towards and accumulating at areas of desired physiochemical tolerance (Liao, 2007; Skelton, 1993). Physiochemical parameters of water such as the level of dissolved oxygen in the water influenced the relative abundance of fish caught in the current study. Site 1, which had the highest mean level of dissolved oxygen (7.67 ± 1.12 mg/L), consequently also recorded the highest mean weight of fish (2.0 ± 2.3 g). Inversely, site 2, where the lowest average weight of fish (0.7 ± 0.7 g) was recorded, also recorded the highest mean temperatures (25.93 ± 2.12 °C), evidencing the role physiochemical parameters such as temperature and level of dissolved oxygen as a determinant factor in determining how fish are spread across sites, as previously reported by Mallya (2007).

A thorough inspection of site 4 revealed a deep depression in the middle of the site, beyond the 1 m range of our sampling depth. With 48% of the most abundant species on the floodplain (*P. philander*) found at site 4 deemed to be sexually matured based on their lengths (> 30 mm TL), the depression at site 4 could have harboured matured specimens which then easily bred and their fingerlings sought refuge in the shallow section of site 4. The highest mean length of *P. philander* (31 ± 8 mm TL) was at site 4. Further, as depicted in Figure 13, the highest proportion of matured *P. philander* (37%) and *T. sparrmanii* (17%) were in the deepest sampling interval (60 – 99 cm), hinting to site 4 as a refuge for large specimens on the floodplain.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

This research was the first study to document the variations in species composition of fish occupying a floodplain at different periods during the flood pulse, different sites along the same floodplain and at different depth intervals. Based on the results from the study, there were few but large (by weight) fish specimens on the floodplain at the beginning of the flood pulse, as opposed to a lot of smaller fish specimens towards the end of the flood pulse. Be that as it may, the number of fish species on the floodplain was highest at the beginning and fewest at the end of the flood pulse, with one species (*Pseudocrenilabrus philander*) dominating the catches during the late flooding period. Across depth intervals, most of the species harboured the deepest section sampled, where the catch rate and the number of specimens were lowest; while nearly 70% of all the specimens were found in the shallowest section (0 – 29 cm) of the floodplain. Spatially, most of the specimens, and the biggest specimens based on mean weight, were found at site 1, which was the site linking the floodplain and the protected section of the Kavango River and was also inundated the longest (first to get flooded). Most of the species were, however, located at the adjacent site, site 2, which was downstream of a manmade bridge traversing the floodplain.

5.2. Recommendations

Although the Kamutjonga floodplain is fast becoming one of the most researched floodplains along the Kavango River in Namibia, the need for further research is evident. For instance, this was the first study detailing the composition of the floodplain across various stations within the floodplain, as well as between varying depths. The findings from the current study are only limited to one flooding season, hence we are guided against making broad extrapolations. Be that as it may, these findings can be used as a baseline by fisheries managers when executing programmes and policies that would ensure optimal and sustainable utilisation of fisheries resources on the Kamutjonga floodplain. Continued research to better understand the fish species dynamics of the floodplain during the flooding cycle is recommended as well as exploring the nutritional value of these abundantly available specimens on the floodplain.

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APPENDICES

Appendix 1: Ethical clearance certificate issued by the University of Namibia Ethics Committee to carry out the study.



ETHICAL CLEARANCE CERTIFICATE

Ethical Clearance Reference Number: SOS-0002 **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: ASSESSMENT OF FISH PRODUCTIVITY OF THE KAMUTJONGA FLOODPLAIN ALONG THE KAVANGO RIVER, NAMIBIA

Student: MUUNDA VILIO TUUTILENI

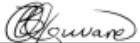
Student Number: 201610508

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)

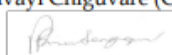
Centre for Research Services
Take note of the following:

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.



Dr. Zivayi Chiguvare (Chairperson, Ethics Committee)



Prof. Davis Mumbengegwi (Head, Multidisciplinary Research)

Appendix 2: Screenshot of the data entry form for the study.

Date	Site code	Gear	Gear code	Habitat (gear 3 only)	Relative effort (m)	Volume (m ³)	setting Hours (H)	Mesh size	Phase	Depth class	Effort	Pole depth (cm)	Depth 1 (cm)	Depth 2 (cm)	Depth 3 (cm)	Average depth (m)	Water Temp	DO (mg/l)	Coordinate s (S)	Coordinates (E)	Species Code Name	Freq	Length (mm)	Weight (g)
20/02/2020	2	1	A	0	1.13	24.11	0	1	1	1	3	64	21	22	21	21.33	29.6	7.3	18.15398	21.68926	OAND	1	32	0.72
20/02/2020	2	1	A	0	1.13	24.11	0	1	1	1	3	64	21	22	21	21.33	29.6	7.3	18.15398	21.68926	OAND	1	42	1.52
20/02/2020	2	1	A	0	1.13	24.11	0	1	1	1	3	64	21	22	21	21.33	29.6	7.3	18.15398	21.68926	OAND	1	42	1.98
20/02/2020	2	1	A	0	1.13	24.11	0	1	1	1	3	64	21	22	21	21.33	29.6	7.3	18.15398	21.68926	OAND	1	44	1.67
20/02/2020	2	1	A	0	1.13	24.11	0	1	1	1	3	64	21	22	21	21.33	29.6	7.3	18.15398	21.68926	OAND	1	35	1.25
20/02/2020	2	1	A	0	1.13	24.11	0	1	1	1	3	64	21	22	21	21.33	29.6	7.3	18.15398	21.68926	OAND	1	33	0.90
20/02/2020	2	1	A	0	1.13	24.11	0	1	1	1	3	64	21	22	21	21.33	29.6	7.3	18.15398	21.68926	OAND	1	37	1.16
20/02/2020	2	1	A	0	1.13	24.11	0	1	1	1	3	64	21	22	21	21.33	29.6	7.3	18.15398	21.68926	OAND	1	38	1.55
20/02/2020	2	1	A	0	1.13	24.11	0	1	1	1	3	64	21	22	21	21.33	29.6	7.3	18.15398	21.68926	OAND	1	30	0.69
20/02/2020	2	1	A	0	1.13	24.11	0	1	1	1	3	64	21	22	21	21.33	29.6	7.3	18.15398	21.68926	OAND	1	27	0.48
20/02/2020	2	1	A	0	1.13	24.11	0	1	1	1	4	64	19	19	19	19.00	28.3	7.4	18.15397	21.68926	OAND	1	46	1.94
20/02/2020	2	1	A	0	1.13	21.47	0	1	1	1	4	64	19	19	19	19.00	28.3	7.4	18.15397	21.68926	OAND	1	38	1.19
20/02/2020	2	1	A	0	1.13	21.47	0	1	1	1	4	64	19	19	19	19.00	28.3	7.4	18.15397	21.68926	OAND	1	37	1.06
20/02/2020	2	1	A	0	1.13	20.34	0	1	1	1	5	64	16	17	21	18.00	28.7	7.0	18.15292	21.68925	OAND	1	44	1.60
20/02/2020	2	1	A	0	1.13	20.34	0	1	1	1	5	64	16	17	21	18.00	28.7	7.0	18.15292	21.68925	OAND	1	48	2.10
20/02/2020	2	1	A	0	1.13	20.34	0	1	1	1	5	64	16	17	21	18.00	28.7	7.0	18.15292	21.68925	OAND	1	39	1.01
20/02/2020	2	1	A	0	1.13	20.34	0	1	1	1	5	64	16	17	21	18.00	28.7	7.0	18.15292	21.68925	OAND	1	37	1.29
20/02/2020	2	1	A	0	1.13	20.34	0	1	1	1	5	64	16	17	21	18.00	28.7	7.0	18.15292	21.68925	OAND	1	30	0.67
20/02/2020	2	1	A	0	1.13	20.34	0	1	1	1	5	64	16	17	21	18.00	28.7	7.0	18.15292	21.68925	OAND	1	16	0.20
20/02/2020	2	1	A	0	1.13	20.34	0	1	1	1	5	64	16	17	21	18.00	28.7	7.0	18.15292	21.68925	BPOE	1	21	0.29
20/02/2020	2	1	A	0	1.13	19.21	0	1	1	1	6	64	17	17	17	17.00	28.1	8.5	18.15386	21.68936	OAND	1	82	1.06
20/02/2020	2	1	A	0	1.13	19.21	0	1	1	1	6	64	17	17	17	17.00	28.1	8.5	18.15386	21.68936	OAND	1	40	1.35
20/02/2020	2	1	A	0	1.13	19.21	0	1	1	1	6	64	17	17	17	17.00	28.1	8.5	18.15386	21.68936	OAND	1	42	1.71
20/02/2020	2	1	A	0	1.13	19.21	0	1	1	1	6	64	17	17	17	17.00	28.1	8.5	18.15386	21.68936	OAND	1	41	1.35
20/02/2020	2	1	A	0	1.13	19.21	0	1	1	1	6	64	17	17	17	17.00	28.1	8.5	18.15386	21.68936	OAND	1	37	1.26
20/02/2020	2	1	A	0	1.13	19.21	0	1	1	1	6	64	17	17	17	17.00	28.1	8.5	18.15386	21.68936	OAND	1	38	1.07
20/02/2020	2	1	A	0	1.13	19.21	0	1	1	1	6	64	17	17	17	17.00	28.1	8.5	18.15386	21.68936	OAND	1	34	0.99