

FEEDING ECOLOGY OF THE AFRICAN TIGERFISH *HYDROCYNUS VITTATUS*
CASTELNAU, 1861 IN THE FLOODPLAINS OF THE KAVANGO RIVER,
NAMIBIA.

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Abstract

The feeding ecology of the African tigerfish *Hydrocynus vittatus* was investigated in the floodplains of the Kavango River, Namibia. A total of 275 samples of tigerfish were caught, using a seine and an experimental multifilament gillnet, during the annual flooding period between February and May 2020. The result of the study shows a significant ontogenetic dietary shift ($P < 0.05$) between size classes of tigerfish. The study also find a significant different ($P < 0.05$) in the diet composition of different size classes of tigerfish, where small size class tigerfish (20 mm -149 mm) fed predominately on aquatic macro invertebrates, which contributed by percentage number 94.5 % (N%), feeding mainly prey on the group of Corixidae 42.5%, Notonectidae 25.5% and Letophlebiidae 18.2%. Medium size class tigerfish (150 mm – 190 mm) fed on both portions of fish (*Enteromius* spp) and aquatic macro invertebrates (Trichoptera and Libellulidae)and the large size class tigerfish (200 mm - 585 mm) were predominately piscivorous (68.2 % N), feeding mainly on Cichlidae 34.9% and *M. altisambesi* 15.9 %. Overall, the results of the study show that tigerfish did not consume prey larger than 150 mm in total length (TL), and the predator - prey length ratio was approximately 23%. The study findings show that tigerfish on the Kamutjonga floodplains feed predominately on aquatic macro-invertebrates when in the early stages of life and are piscivorous in the adult stage life. The study results provide important information in understanding the dietary requirement of tigerfish in the Kamutjonga floodplains. Such information is important in conservation measure of tigerfish. Henceforth, the study recommended multi-species modeling studies based on predator-prey interactions, in order to better understand, resource use and partitioning among species on the Kamutjonga floodplain.

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DEDICATION

This thesis is dedicated to my son, **Petrus “Munondumbo” J. Tshimwandi**, who is the reason for my drive in life.

DECLARATION

I, Sheehama F Tshimwandi, 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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1. Introduction

1.1 Background of the study

Hydrocynus vittatus (Castelnau 1861) commonly known as the African tigerfish, is a predatory fish species and a member of the Characiformes (Jackson, 1961; Matthes, 1968; Kenmuir, 1973; Skelton, 2001). This species is widely distributed across African drainage basins, but are restricted to relatively warm and oxygen-rich habitats in rivers and lakes (Jackson, 1961; Skelton, 2001; Goodier et al., 2011). *Hydrocynus vittatus* is one of five recognized tigerfish species endemic to the African continent (Goodier et al., 2011).

In Namibia, tigerfish occurs in the Zambezi, Kwando-Linyanti-Chobe, and Kavango River systems (Holtzhausen, 1991; Skelton, 2001). These rivers are all associated with large seasonal grassland floodplains (Jackson, 1961; Skelton, 2001; Jacobs, 2017). These floodplains consist of complex food webs, in which the tigerfish is considered an apex predator (Jackson, 1961; Kenmuir, 1973; Winemiller & Jespsen, 1998), and an important contributor to the transfer of energy from the floodplains into the main river (Jackson, 1961; Winemiller & Jeaaspsen, 1998). Tigerfish prefer open flowing water, however, they also migrate to the floodplain during the annual flood (Winemiller & Kelso-Winemiller, 1994; Winemiller & Jespsen, 1998; Økland et al., 2005). As top predator they contribute in functioning of riverine ecosystems, maintaining the biodiversity and community structures of fish species within rivers and transfer energy acquired from their prey in the floodplains back to the river (Winemiller & Jespsen, 1998).

Namibian floodplain rivers experience annual change in hydrology, low water level during dry seasons and high water levels during and after the rainy season (Hocutt & Johnson,

2001). These floodplain areas are among the most productive wetlands in the world and provide nutrients essential for maintaining biological productivity (Jackson, 1961; Winemiller & Kelso-Winemiller, 1994; Winemiller & Jespsen, 1998). Various fish species make use of these floodplains during the flooded period for reproduction, feeding and growth, including apex predators such as the tigerfish and catfishes (Mosepele et al., 2009). It has been suggested that predation by tigerfish has a direct influence on fish migration/distribution and the abundance of prey populations in the environment (Jackson, 1961; Winemiller & Welcomme, 2004). Although tigerfish prefer main river channels, they move to floodplains during the rising and peak phase of flooding (Winemiller & Jespsen, 1998). Their local distribution in these freshwater systems depends on the magnitude of the flooding regime (Winemiller & Welcomme, 2004; Mosepele et al., 2009; Mosepele, 2016).

Tigerfish is regarded as an important recreational fish species, and form an important part of artisanal fisheries and contribute to food security particularly in riparian communities (Tweddle et al., 2015; Cooke et al., 2016). Recreational angling is a popular and important activity in the northeast of Namibia, generating an estimate of 70% of revenue through local lodges in the riparian community, these lodges are the most important contributor to the economy in terms of providing jobs for the local people (Tweddle et al., 2015; Cooke et al., 2016). However, the impact of pollution in rivers and lake ecosystems as well as overfishing have resulted in low catch rates of this species, e.g. in the Zambezi River and Lake Kariba (Steyn et al., 1996; Cooke et al., 2016) and it is likely to affect the tourism industry which in turn may impact on the livelihoods of local fishing communities (Tweddle et al., 2015).

Floodplain fisheries have intrinsic value to the livelihood of riparian communities and support their way of life (Thorstad et al., 2002; Mosepele, 2016; Jacobs, 2017). Globally, these wetlands produce at least 15% of fish production, and inland fisheries provide a vital and cheap source of protein (Mosepele, 2016). In Namibia, about 60% of the rural population are living close to floodplains, where these communities attain variety of benefits from the floodplains, ranging from water, agriculture use and inland fishery that provide food security, income, employment, revenue from tourism and livelihoods (Tweddle & Hay, 2013). Therefore, there is a need to manage floodplain fisheries, in order to maintain the socio-economic development of riparian communities (Mosepele et al., 2009; Tweddle & Hay, 2013; Mosepele, Kolding & Bokhutlo, 2017).

As the riparian population increases, so are the fishing activities. This put pressure on the inland fisheries, which in turn gives rise to resource conflicts between local, commercial and the recreational fishery (Hay et al., 2000; Tweddle & Hay, 2013). Therefore, management of rivers and floodplains are of utmost importance to ensure sustainable utilization of inland fisheries and maintaining its economic spinoffs from these resources, which, in return safeguard the livelihoods of the riparian community, especially deprived people that are depending on inland fisheries (Hay et al., 2000; Thorstad et al., 2002; Jacobs, 2017).

Predation by tigerfish especially on the juvenile fish species of commercially importance may have a significant impact on the fish population's natural mortality, and such information is vital for formulating fish stock assessment models (Mhlanga, 2003)(Mhlanga, 2003). Little is known about the feeding ecology of tigerfish on the floodplains of the Kavango River.

Such information on the feeding ecology of fish are important to provide an understanding of resource use and partitioning among species (Jackson, 1961; Winemiller & KelsoWinemiller, 1994; Dalu et al., 2012; Simasiku et al., 2017b). Understanding the feeding ecology of tigerfish can assist in setting up floodplain fishery management guidelines. Therefore, this study aims to determine the feeding ecology of tigerfish in the floodplains of the Kavango River by looking at the food composition and ontogenetic dietary shifts between different size classes.

1.2 Statement of the problem

Despite the economic and ecological value of tigerfish, limited information exists on the feeding ecology of tigerfish in the floodplains of the Kavango River. For this reason, the effects of predation on the dynamics of the fish populations are not known, particularly on the commercially important fish species. In order, to sustainably manage, preserve and conserve fisheries resources, it requires a clear understanding of the feeding requirements of this species and the impacts that it might have on other fish species.

1.3 Research objectives

The main objective of the study is to determine the food composition of different size classes of tigerfish in the Kamutjonga floodplains, Kavango River. Specific objectives are to:

- a) determine the ontogenetic dietary shift in tigerfish.
- b) determine the food composition of tigerfish, by analyzing food items in the stomachs.
- c) determine the predator-prey length relationship.

1.4 Hypothesis

- a) There is no significant dietary shift between the size classes of tigerfish.
- b) There is no significant difference in the food compositions of tigerfish with respect to their size classes.
- c) There is no significant relationship between the predator length and prey length.

1.5 Significance of the study

Studies on the feeding ecology of fish provide important information on the fish feeding patterns, and resources partitioning. This information further aids the understanding of important ecological components such as fish habitat use, behavior, condition, species interaction as well as energy intake. As a result, understanding the ecological components associated with feeding ecology can provide useful fisheries management guidelines.

1.6 Limitation of the study

The study can be affected by annual rainfall in the highlands of Angola, and is dependent on the annual flooding regime which regulates the flow of water in the Kavango River. Moreover, the availability and size distribution of the tigerfish has been known change with change in flooding regime (Winemiller & Kelso-Winemiller, 1994), which may affect the study.

1.7 Delimitation of the study

The study will focus on the feeding ecology of tigerfish in the Kamutjonga floodplains of the Kavango River, Namibia.

2. Literature review

2.1 The African tigerfish

Jacobs et al., (2017), describes the African tigerfish (Castelnau 1861) as one of the fiercest and most charismatic fish species found in freshwater ecosystems. Tigerfish are noticeable by a set of 8 large razor sharp, protruding teeth on each jaw and a series of black longitudinal parallel strips and a black adipose fin (Skelton, 2001). Tigerfish can grow up to 700 mm in length and largest fish weighed 16 kg (International Game Fish Association IGFA world record), caught in Lake Kariba, Zimbabwe (Jackson, 1961; Matthes, 1968).



Figure 2.1 The African tigerfish *Hydrocynus vittatus* from the Kamutjonga floodplains.

Hydrocynus spp, are one of the widely distributed species across the African drainage basins, but restricted to relatively warm and oxygen-rich habitats in rivers and lakes (Jackson, 1961; Skelton, 2001; Goodier et al., 2011). *Hydrocynus vittatus* is one of the five (*H. forskahlii*, *H. brevis*, *H. goliath* and *H. tanzaniae*) recognized species of tigerfish in the African fresh water system, that are biogeographically isolated (Goodier et al., 2011). *Hydrocynus forskahlii* (Cuvier 1819) and *H. brevis* (Günther 1864), are distributed along western Africa in the Khartoum and Nile rivers, while the *H. goliath* (Boulenger, 1898) is distributed on the tropical region and it is endemic to the Congo system. *Hydrocynus tanzaniae* (Brewster, 1986), are found in the Ruvu and Rufiji-Ruaha system in Tanzania and finally *H. vittatus* (Castelnaud, 1861), occupies the southern African fresh water systems (Goodier et al., 2011).

2.2 Tigerfish feeding ecology

Their teeth are designed for biting and holding prey, before swallowing its prey whole (Jackson, 1961; Skelton, 2001). Due to its nature of feeding, the effect of predation can negatively impact commercially important fish species (Jackson, 1961; Kenmuir, 1973). It is suggested that tigerfish may have been responsible for poor recruitment of tilapia populations (e.g. *Oreochromis macrochir*) in Lake Kariba (Matthes, 1968) and *Coptodon rendalli* in Malilangwe reservoir (Dalu et al., 2012). Matthes (1968) has found that tigerfish in lake Kariba, prey predominantly on Cichlidae and Characidae, and further postulated that the rare catches of *Oreochromis mossambicus* (Peters, 1852), ranging from 120 to 260 mm, is linked to heavy predation by tigerfish in lake Kariba. Similarly, the decline of *C. rendalli* in Malilangwe reservoir is associated with an introduction of the tigerfish in the reservoir (Dalu et al., 2012).

Tigerfish is also regarded as an opportunistic predator that changes its diet, depending on the environment and available prey (Dalu et al., 2012; Jacobs, 2017; Jackson, 1961; Kenmuir, 1973). In the Olifants and Letaba Rivers scarcity of fish prey as a result of low water levels led adult tigerfish to prey predominantly on aquatic macro-invertebrates (Gagiano, 1997). Jacobs et al., (2017), observed tigerfish feeding on a carcass of *Hippopotamus amphibious* (Linnaeus 1758) in the Kavango River. Similarly, Jackson (1961) reported tigerfish attacking the wounds of a dead Nile crocodile *Crocodylus niloticus* (Cuvier, 1802) that have been shot in the head in the Sanyati River, Middle Zambezi system. Matthes (1968) observed tigerfish feeding on flying termites that landed on water in Lake Kariba. In the Incomati River and Lake Kariba the tigerfish have shown to be cannibalistic as potential food prey declines, (Jackson, 1961; Gaigher, 1970; Matthes, 1968). O'Brien et al., (2014) observed tigerfish actively feeding on barn swallows *Hirundo rustica* in flight in Schroda Dam, because their natural prey in the dam was believed to be depleting.

2.3 Tigerfish spawning and early development

Tigerfish are known as potamodromous, this means that they migrate to specific areas, that are not usually used for other functions, during the year, to spawn (Roux, 2012). The spawning migration for tigerfish is believed to be connected to a combination of chemical and physical factors associated with the flooding events which inundates nutrient rich floodplains (Kenmuir, 1973). Jackson (1961) states that fish of the superorder Ostariophysi, such as tigerfish, have a short spawning period, and like most freshwater fish they might move to floodplains to spawn during flood periods (Kenmuir, 1973). In the Okavango the spawning period of tigerfish have been suggested to take place before the flooding period

to ensure that juveniles optimize the flooded area for both food and protection (Jacobs et al., 2017). Flooding cover large grassland and forests which provide suitable environments for spawning for many fish, including tigerfish. Juveniles tigerfish make use of these floodplains area to ensure survival, thus, spawning usually taking place at the beginning of the flooding period (Kenmuir, 1973). However, Jackson and Rogers, (1976), found a two-month juvenile tigerfish in the Zambezi River during early November before flooding period, suggesting early spawning.

Juveniles of about 50 mm fork length (FL) move up in the water masses and mostly occupy the littoral area and shallow pools where they feed on zooplankton (Steyn et al., 1996; Skelton, 2001). Larger juveniles of about 50 - 60 mm FL become almost entirely ichthyophagous and supplement their diets with aquatic macro-invertebrates molluscs and crustaceans in Lake Kariba (Matthes, 1968; Kenmuir, 1973). Tigerfish of similar size (<150 mm) hunt and roam in shoals, unlike the adult tigerfish, which are more solitary (Jackson, 1961; Skelton, 2001). These shoals of tigerfish are often seen in feeding frenzies as they hunt in packs and prey on cichlids, *Micralestes acutidens*, *Brycinus lateralis* and *Enteromius* spp (pers. obs. F. Tshimwandi; Skelton, 2001; Jacobs, 2017). Therefore, as an apex predator, tigerfish impact on the ecology of river systems may play an important role on the health of ecosystems that maintain a functional biodiversity of the ecosystem (Kenmuir, 1973). Food requirements of predatory fish species are known to change during their lifetime. As a result, the interaction between predators and prey, play an important role in the fish population structure and functionality of the ecosystem (Kenmuir, 1973).

2.4 Kavango River floodplains

The flooding of the Kavango river is predominately influenced by the rainfall in highlands of Angola, about 1700 m a.s.l (Hocutt et al., 1994). It forms the border between Angola and Namibia as it enters at Katwitwi. Along the Namibian section of the river, it is characterized by rocky outcrops, sandy substrates and abundant aquatic vegetation. The river flow for about 460 km within Namibia, before it enters Botswana and evaporates in the swamps of the Okavango Delta (Hay et al., 2000). The flooding of the floodplains may start in January / February, depending on the increase in the water discharge. In Namibia the Kavango River is known to reach its flooding peak between March - April and recedes during May. These floodplains are highly productive, complex, and closely link terrestrial and aquatic ecosystems. This connection supports diverse fish communities (Winemiller & Welcomme, 2004; Jackson et al., 2012; Mosepele, 2016). During the first month of flooding, the Kavango floodplains are dominated by juvenile cichlids (e.g. *Tilapia sparrmanii*, *Oreochromis andersonii*, and *Coptodon rendalli*), *Clarias gariepinus*, and cyprinids (e.g. *Enteromius* spp) supported by an increase of primary producers such as phytoplankton and abundant secondary producer such as zooplankton (Mosepele, 2016; Kanguasaru, 2018).

During the flooding period the primary consumers and juvenile fish species make use of the floodplain by feeding on the enriched food supply during the inundation of the floodplain and in this time of period many juveniles' fish turn to fall prey to tigerfish. Mosepele (2016) observed tigerfish dominating fish assemblages during the peak discharge of the flood and suggested that the floodplain feeding ecology are flood-pulse driven. Ecologically, tigerfish is an important piscivorous in the African freshwater

ecosystem and sometimes regarded as an indicator species for water quality, as they are very sensitive to water pollution (Smit et al., 2013). Additionally, they connect the terrestrial floodplain environment with that of the aquatic ecosystem (rivers and lakes), therefore, maintaining the ecosystem functionality (Winemiller & Jespsen, 1998). In the Zambezi River, top floodplain predators such as *Hepsetus cuvieri* (Castelnau 1861) (African pike) and *Schilbe intermedius* (Ruppell, 1832) (silver catfish), mainly occupy the edges of river, those that inhabit the main river get preyed upon by tigerfish (Winemiller & Jespsen, 1998).

3. Materials and methods

3.1 Study area

The Kavango River originates from the series of headwater streams in the central highlands of Angola (Hocutt et al., 1994). In southern Africa, the Kavango River is the fourth-longest river system, shared by three countries, Angola, Namibia and Botswana (Hay et al., 2000). According to Hocutt et al., (1994) the river is divided into four zones, from the highlands of Angola it crosses the border of Namibia at Katwitwi. The first zone stretches from Katwitwi to Kasivi, this area is characterized by developing floodplains with sandy, rocky substrates and submerged vegetation. Zone two is characterized by well-developed floodplains as the river flows from Kasivi to Mbambi in some areas the floodplains are covering up to five kilometers at the widest point. In this section the river becomes wider and is characterized by sandy substrates with back bays and oxbow ponds. It flows eastward passing wide sandy floodplains before reaching Rundu. Zone three, the river flows towards Popa falls, in this area the floodplains start to decrease in size. These

floodplains are characterized by wooden islands with smaller channels surrounding them, the substrates include gravel, large boulders, and bedrock associated with rapids. Finally, the fourth zone stretches from Popa Falls to the Namibia/Botswana border. In this area the floodplains are characterized by woody, grassland floodplains and backwater system. The kamutjonga floodplains where the study took place is located in zone four. The study was conducted in the floodplains of Kamutjonga, along the Kavango River, near the Kamutjonga Inland Fisheries Institute (KIFI), Ministry of Fisheries and Marine Resources (MFMR).

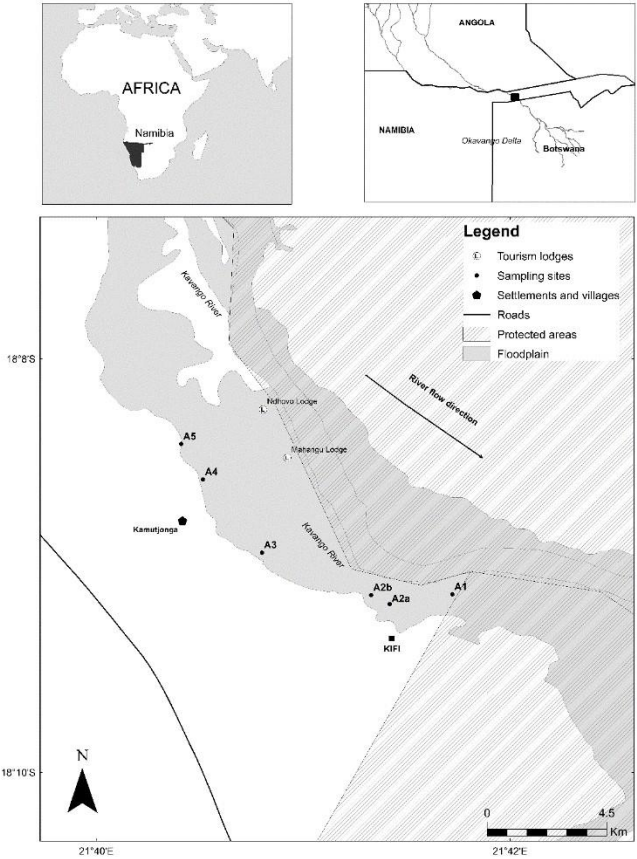


Figure 3.1 A map of the study area, Kamutjonga floodplain in the Kavango River.

Generated by Kheabeb using ArcGIS 9.3 software.

The Kamutjonga floodplain is situated in the Mukwe constituency, Kavango East Region, about 24 km from the Divundu. The floodplain is about 10 km long and 2 km at the widest point (Kanguasaru, 2018) reaching a maximum water depth of ± 2 m. It is characterized by clay, gravel and sandy substratum, with open waters and patchy vegetation (Figure 3.2). The floodplain is dominated by a variety of terrestrial grass, floating (*Nympaea nouchalia* var. *coerule*) and submerged aquatics plants (*Utricularia stellaris*, *Potamogeton pectinatus*, etc.) and woodland.



Figure 3.2 Types of habitats found in the Kamutjonga floodplains, Kavango River. **a)** vegetated area **b)** open water **c)** margin of vegetated area.

3.2 Environmental parameters

The water temperature of the Kamutjonga floodplain ranged between 18.9 °C to 31.3 °C and dissolved Oxygen ranged between 4.0 mg/L to 8.2 mg/L, between February and May 2020. The study area, had a maximum depth of 215 cm. The depth at which tigerfish samples were collected ranged between 20 cm to 215 cm with a mean of 83.3 cm, \pm SD = 55.6 cm (table 4.1).

Table 3.1 Monthly environmental variables (Water depth, temperature and Dissolved Oxygen DO) where tigerfish samples were collected, at the Kamutjonga floodplain during the annual flooding period between February and May 2020.

	March			April			May		
	Tem p (°C)	DO (mg/ L)	Dept h (cm)	Tem p (°C)	DO (mg/ L)	Dept h (cm)	Tem p (°C)	DO (mg/ L)	Depth (cm)
Mean	26.2	5.8	132.2	25.4	5.8	177.2	21.6	6.1	146.2
Standard Deviation	1.9	0.8	18.8	1.3	0.8	32.7	1.5	0.3	18.4
Minimum	23.7	4.3	105	23.9	4.3	115	18.9	5.6	123
Maximum	29.9	7.1	158	28.3	8.1	215	23.5	6.9	174

3.3 Sampling

Sampling was done using two sampling gears, a seine net and an experimental multifilament gillnet (Hay et al., 2000). Tigerfish were collected at six selected sites, which represent the study area within the Kamutjonga floodplains from February to May 2020. The sites were selected based on the three types of habitats provided by the Kamutjonga floodplains (Figure 3.2). A seine net, of one millimeter mesh size was used to target the littoral habitats of the floodplains (Table 3.1). While an experimental multifilament gillnet was used to sample deeper habitats (>100 cm), (Table 3.1). Each site was sampled once a week using an experimental multifilament gillnet and seine net, for the duration of the flooding period (February to May 2020).

Different size classes of the same species may play different ecological and functional roles such as prey selection, habitat selection etc. Therefore, for comparison purposes, the tigerfish were grouped into three major size classes, from; 20 - 150 mm is small size class, 150 – 199 mm is medium size class and > 200 mm large size class. The size classes of tigerfish were determined based on the life history and biology of tigerfish (Skelton, 2001), and also on the bases of previous study, on the feeding ecology of tigerfish (Mhlanga, 2003; Simasiku et al., 2017b).

Table 3.2 Number of tigerfish caught per fishing gear during the sampling period in the Kamutjonga floodplain between February and May 2020.

Types of Fishing Gear	Small (< 150 mm)	medium (150 -199 mm)	Large (>200 mm)
Multi-filament gillnet	49	26	121

Seine net	78	1	0
Total	127	27	121

3.2.1 Seine netting.

A seine net of mesh size one millimeter (10 m long by 1.5 m high), was dragged at each of the six selected sites to collect tigerfish on the Kamutjonga floodplain (Figure 3.1). At each site, a total of 10 drags was made to assure representative sampling effort per site. The seine net was deployed in the littoral area of the floodplain (Figure 3.3), at depths less than a meter to target small tigerfish (Table 3.1). Each drag was made approximately 10 m away from the previous, to avoid scaring fish. The habitats sampled at each site were open water, margin of vegetated area and vegetated area, and sampling was done once at each station per week (Figure 3.3).

Fish caught were first anaesthetized and euthanized using 20 mg/l of clove oil according to Fernandes and others (2017), then put in a zip lock bag with a unique label and chilled on ice before transporting the samples to the KIFI laboratory.



Figure 3.3 Seine netting at the littoral part of the Kavango river floodplain between February and May 2020 .

3.2.2 Gill netting.

During the high flood, when water level reached a depth of greater than 100 cm, an experimental multifilament gillnet was used to collect fish samples from the Kamutjonga floodplain from 28th February to 13th May 2020 (Figure 3.4). The experimental multifilament gillnet consists of five randomly distributed panels with a stretched mesh of 22, 35, 73, 118 and 150 mm, each panel 10 m long by 1.5 m high. The nets were set in 3 habitats, vegetated water, margin of vegetated area and open water. The setting of the experimental multifilament gillnet was done overnight for about 12 to 13 hours, from evening 18h00 to 19h00 and retrieved in the morning from 06h00 to 07h00.



Figure 3.4 Gill netting in the Kamutjonga floodplain, Kavango River between February and May 2020 flooding period.

Most fish caught by experimental multifilament gillnet died, gillnets are known destructive sampling method, but effective and unbiased methods. However, live samples were first anaesthetized and euthanized using 20 mg/l of clove oil (Fernandes et al., 2017), then chilled on ice before transported to the KIFI laboratory. In the laboratory the fish samples were sorted and grouped according to species and mesh size. The tigerfish samples were then measured, fork length (FL) measured to the nearest millimeter (mm) and weighed to the nearest gram (g).



Figure 3.5 Identification of fish and measurement.

3.2.3 The collection of stomach contents

After recording the biological data (length and weight) tigerfish were dissected, using a blunt nose stainless steel scissor to avoid damage of the stomach content. The insertion was made from the anus of the tigerfish. After the insertion was made, the stomach was carefully removed and placed in a jar containing 70% ethanol. The jars containing preserved stomach content were labeled and stored for 48 hours (Hopkin, 1980). This was done to allow for the removal of excess water in the stomach of tigerfish (Hopkin, 1980), before stomach content analysis.

3.3 Diet analysis

After 48 hours, the stomach content was carefully removed from the jar containing 70% ethanol and placed on a white tray (Hopkin, 1980). The stomach was then split using a pair of pointed stainless steel scissors and its content spread in the tray with water for identification. The items in the stomach were then identified to the lowest taxonomic level possible, using Skelton (2001) and Gerber & Gabriel (2002). Prey item that could be identified was counted and measured (full length) to the nearest millimeter.

To assess ontogenetic dietary shifts of the tigerfish, prey items were first categorized into broader taxonomic prey categories such as fish, invertebrates and others item (amphibian, plant material etc.).

3.3.1 Statistical analysis

The data were tested for normality using Shapiro-Wilk test, using SPSS (IBM SPSS Statistics 23). A Chi-square Test of Association was used to determine if there was any significant dietary shift in the diet of the tigerfish, relative to the size class and also to determine the food composition of tigerfish (Kim, et al., 2020). A simple linear regression was performed to determine the predator-prey length relationship using SPSS program (IBM SPSS Statistics 23).

To determined food composition of tigerfish, prey items were calculated by frequency of occurrence and the number method according to Hyslop (1980). Frequency of occurrence refers to the number of stomachs containing individuals of each food category and expressed as a percentage of all stomachs with content. Formula:

$$\%FOi = \frac{Ni}{N} \times 100$$

Where % **FOi** is the frequency of occurrence of given food item *i*, **N_i** is the number of stomachs containing prey item *i* and **N** is the total number of stomachs with content. Number method accounts for the amount of prey items in the gut content. The individuals of each prey category in each stomach were counted and expressed as a proportion of the total prey items in stomachs examined and expressed as:

$$\%Ni = \frac{Ni}{Nt} \times 100$$

Where, %**Ni** – is the percentage number of *i* prey item, **Ni** – is the number prey items *i* and **Nt** – is the total number of prey items.

4. Results.

4.1 Tigerfish catches

A total of 275 tigerfish were caught during the study between February and May 2020, in the Kamutjonga floodplains, using a seine and experimental multifilament gillnets. Seine netting caught a total of 79 tigerfish. Of the total caught, 78 were in the small size class (20 – 149 mm) and one in the medium size class (150 – 199 mm). The experimental multifilament gillnet caught a total of 196 of tigerfish, of which, 49 were in the small size class, 26 in the medium size class and 121 large size class tigerfish (Table 3.1).

The majority of small size class of tigerfish (< 150 mm) were caught mostly in the open water habitats. While the medium size class tigerfish were caught in open water and

vegetated areas (Figure 4.1). The large size class (200 mm – 585 mm) tigerfish were caught mostly in the vegetated area and margin of the vegetated area (Figure 4.1).

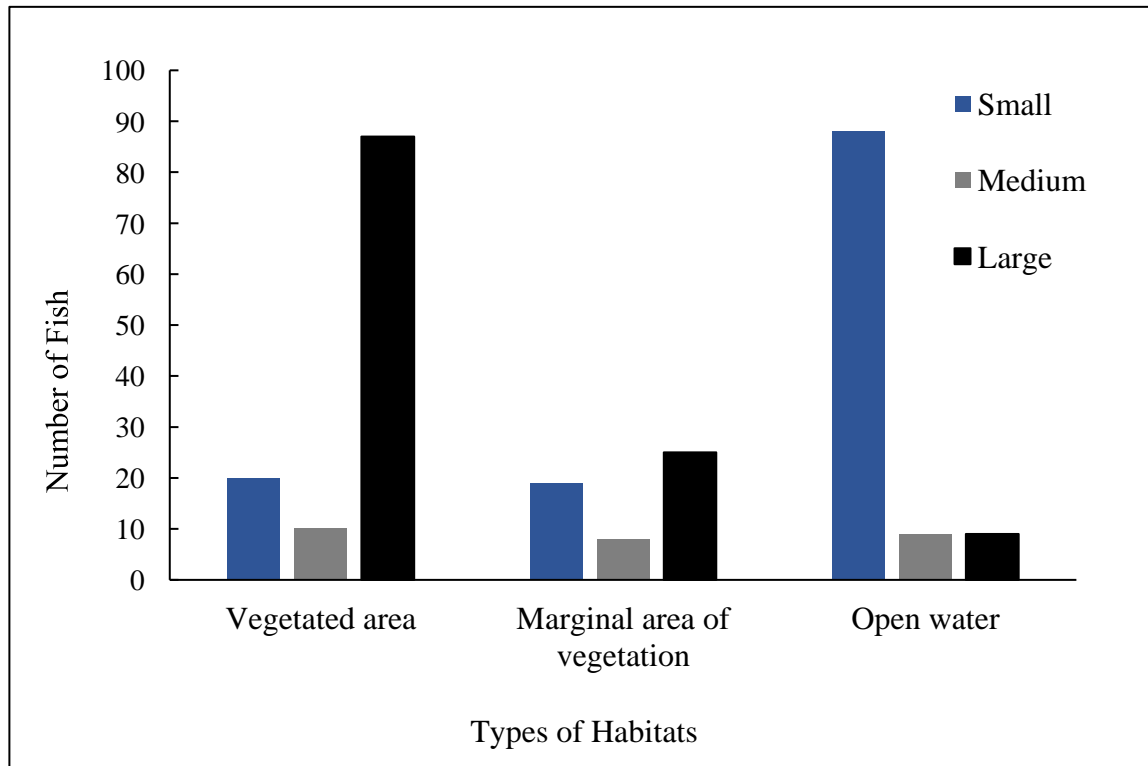


Figure 4.1 Number of *Hydrocynus vittatus* per length classes, caught in three types of habitats in the Kamutjonga floodplain during February to May 2020.

To estimate the relationship between the fish weight in grams (g) and Fork length FL in millimeter (mm), the length-weight equation $W = a L^b$ was used. Where W = fish weight in grams, L =fish length FL (mm) a is an intercept and b is the slope of the relationship. The length (mm) and weight (g) of all tigerfish caught ranged between 20 to 585 mm and 0.07 to 3334 g, respectively (Figure 4.2). The average length and weight of tigerfish caught were 221.4 ± 140.8 mm and 358.9 ± 527.0 g, respectively.

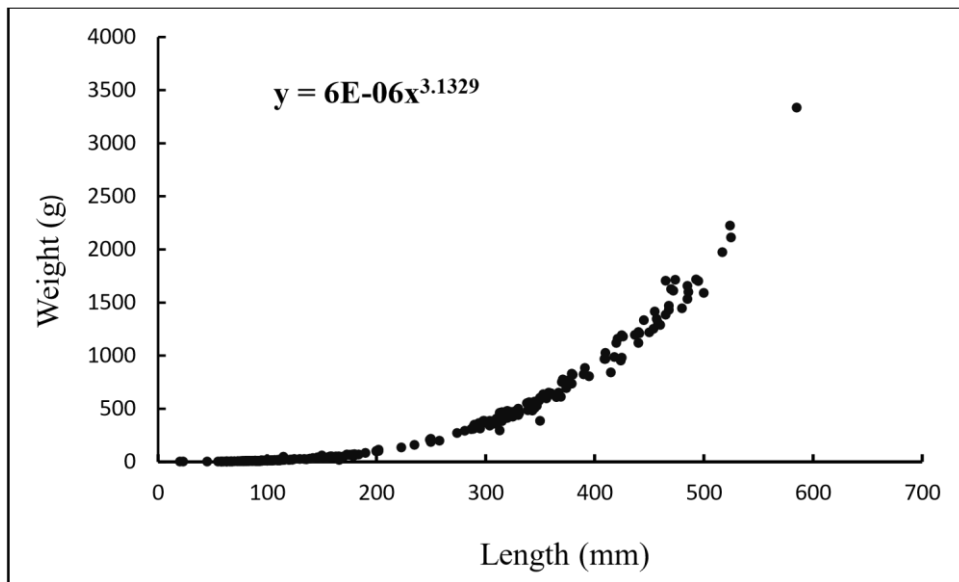


Figure 4.2 Length/weight relationship of *Hydrocynus vittatus* sampled from Kamutjonga floodplain, Kavango River.

4.2 Dietary shift and food composition of tigerfish

Out of the 275 tigerfish sampled, 183 (100 small tigerfish, 14 medium tigerfish and 69 larger tigerfish) had food items in their stomachs. Tigerfish were grouped into three major length (FL) classes to determine the dietary shift between the size classes of tigerfish (Table 4.3). Overall, a total of 764 prey items were identified and categorized into 34 prey item groups (Table 4.3).

According to the frequency of occurrence (FO %), there is a significant shift in the diet of tigerfish relative to the size classes, ($X^2 (4) = 111.463, p = 0.001$). The small size class of tigerfish fed mainly on aquatic macro-invertebrates, they constitute of 86.4% (FO %). Fish prey represented less than 5% of the prey items by FO %. The aquatic macro-invertebrates

in the group of Corixidae 33.90% (FO %), Notonectidae 14.41% (FO %), Letophlebiidae 15.5% (FO %) and Gerridae 10.17% (FO %) contributed the most in the diet of the small size class of tigerfish (Table 4.2).

Table 4.1 Percentage frequency of occurrence and number of all prey items consumed by *Hydrocynus vittatus* of the three size classes (small, medium and large) from the floodplains of Kamutjonga from February to May 2020.

Size class of tigerfish	small	medium	Large	small	medium	Large
	%FO	%FO	%FO	%N	%N	%N
<i>Micralestes acutidens</i>	0.85			0.2		
Enteromius spp	1.69	4.76		0.4	3.0	
<i>Enteromius bifrenatus</i>		4.76			3.0	
<i>Enteromius radiatus</i>			1.67			1.6
Cichlidae			34.99	1.2		34.9
<i>Clarias</i> spp		4.76	1.67		3.0	1.6
<i>Marcusenius altisambesi</i>				0.2	3.0	15.9
<i>Hydrocynus vittatus</i>	0.85	4.76	13.33			
<i>Hydrocynus vittatus</i>			3.33			3.2
<i>Pollimyrus castelnaui</i>	0.85	4.76		0.2	3.0	
<i>Schilbe intermedius</i>		4.76	6.67		3.0	7.9
<i>Synodontis</i> spp			3.33			3.2
<i>Coptodon rendalli</i>		4.76			3.0	
<i>Tilapia sparrmanii</i>	0.85			0.6		
Aeshnidae	0.85		1.67	0.2		1.6
Baetidae				0.8		

Coleoptera	0.85			0.4	
Corixidae	33.90			42.5	
Diptera	0.85			0.2	
Dragon fly (odonata)		4.76	1.67		3.0
Dytiscidae			3.33		3.2
Ephemeroptera	4.24	14.29	1.67	1.6	9.1
Gerridae	10.17			3.6	
Gomphidae			1.67		1.6
Leptophlebiidae	15.25			18.2	
Libellulidae	4.24	23.81	11.66	1.2	15.2
Nematode			1.67		3.2
Notonectidae	14.41			25.5	
Odonata	0.85		1.67	0.2	1.6
Simuliidae	0.85			0.2	
Spider (araneae)			1.67		1.6
Trichoptera		23.81			51.5
Green algae	3.39			0.8	
Grass	2.54		6.67	0.6	3.1
Jelly Tots	2.54		1.67	1.2	0.8

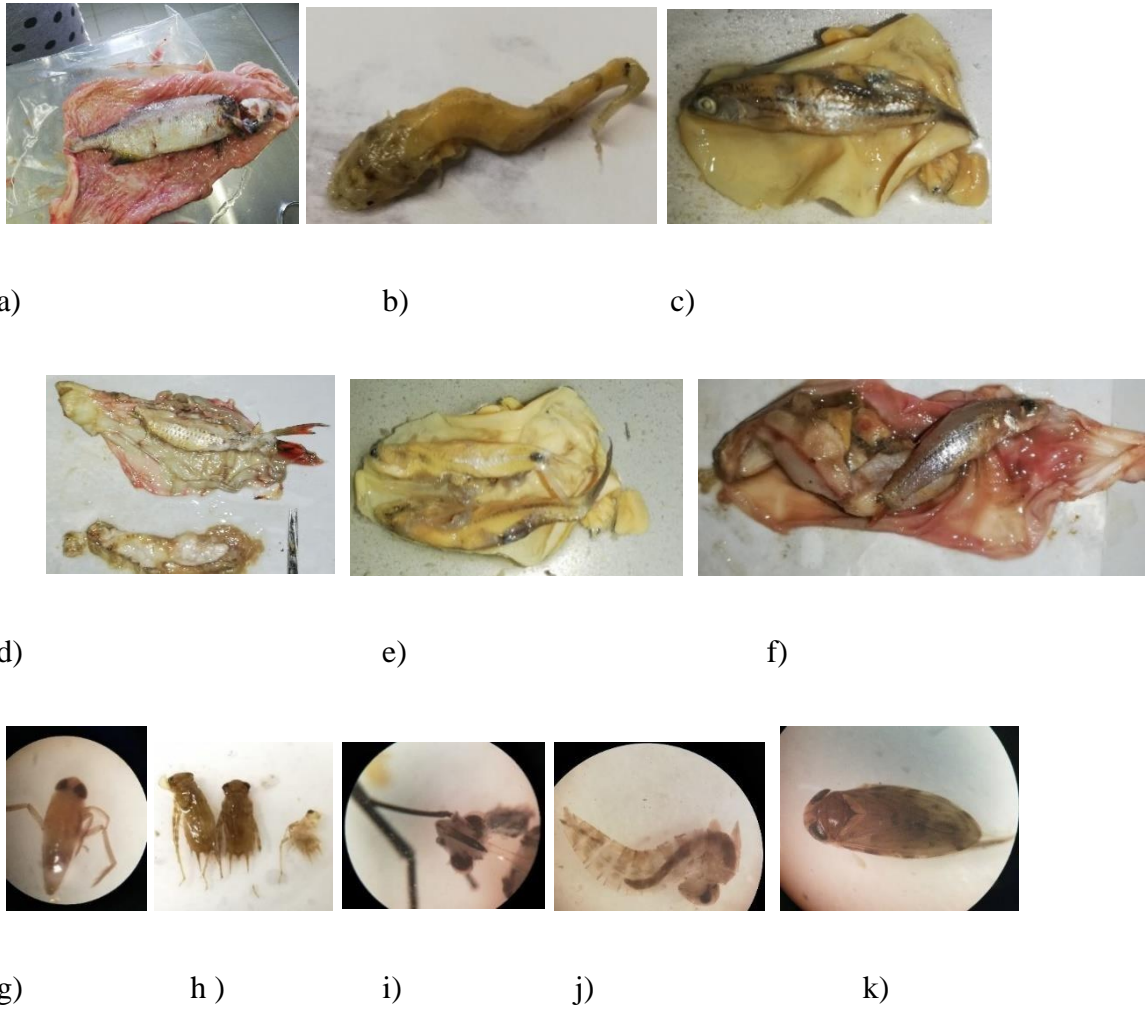


Figure 4. 3 Prey items found in the stomach of *Hyrocynus vittatus* collected from the floodplain of Kavango river, Kamutjonga (February to May 2020). a) *Marcusenius altisambesi* b) *Clarias* spp c) *Enteromius bifrenatus* d) *Hydrocynus vittatus* e) *Enteromius* spp f) *Enteromius radiatus* g) Corixidae h) Odonata i) Gerridae j) Phemeroptera k) Notonectidae.

The medium size class of tigerfish fed on both aquatic macro-invertebrates and fish prey which contributed on an overall 66.6% and 33.3 % FO % respectively. The aquatic macroinvertebrates in the group of Trichoptera 23.81 % FO %, Ephemeroptera 23.18 % FO % and Libellulidae 14.29 % FO %, and fish prey in the group of *Enteromius* spp 9.5%

FO % were the most important prey group in the diet of the medium size class. Large size class of tigerfish were almost entirely piscivorous and fish prey contributes 65.0% (FO %). Cichlidae 34.9% (FO%) and *M. altisambesi* 13.3 % (FO%) form an important part in the diet of large size class while fish prey in the group of *Enteromius radiatus*, *Clarias* spp and *Synodontis* spp contributed less than 20 % (FO%), cannibalism was also observed 3.3% (FO%) (Figure 4.3, Table 4.2).

Based on the percentage number method there is a significant difference in the diet composition of tigerfish with respect to the 3 size classes (small, medium and large), ($X^2(4) = 101.483, p = 0.001$). The small size class feed mainly on aquatic macro invertebrates and contributing a total of 94.5 % (N %). The medium size class feed on both aquatic and macro invertebrates, while large size class feeds predominantly on fish.

Table 4.2 Percentage contribution of major prey item categories consumed by all size classes of tigerfish in the Kamutjonga floodplains between February and May 2020.

size classes	Frequency of occurrence (%)			Number method (%)		
	fish prey	Aquatic macro-invertebrates	Other prey	Fish prey	Aquatic macroinvertebrates	other prey
small	5.08	86.44	8.47	2.81	94.59	2.61
medium	33.33	66.67	0	21.21	78.79	0
lager	65	26.67	8.34	68.25	28.56	3.94

4.3 Predator-prey length relationship

Out of 183 tigerfish, 79 (43.2 %) tigerfish had stomachs with some food that could be identified and measured. The result show that tigerfish consume fish prey less than 150 mm in total body length (TL) (Figure 4.5). The overall length ratio between the predator length (FL) and prey length (TL) is averaged at 23%. The fit relationship (r^2) is 0.44 which means the relationship is not great despite significances (Figure 4.5. The results show that there is a positive significant difference between the predator length and prey length ($F, (1, 68) = 54.4, P = 0.001$) with $r^2 = 0.44$. The size of the prey increases with increase in predator size, the results also show that small size class (20 -149mm) and medium size class (150 -199 mm) of tigerfish fed on much larger fish prey, while large size class (> 200 mm) of tigerfish fed on a wide range of fish prey size (Figure 4.2).

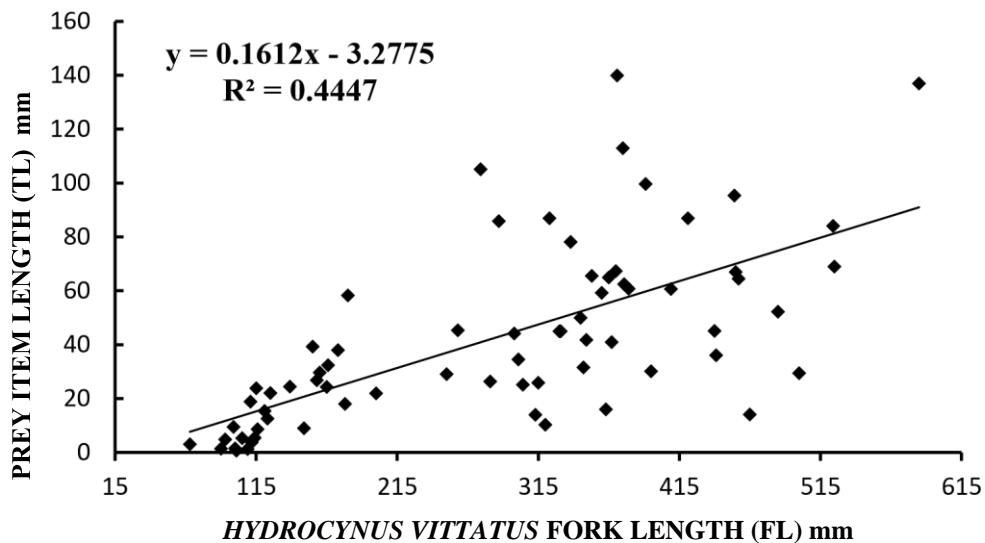


Figure 4. 4 The relationship between fish prey (TL) and predator full length (FL) from the Kamutjonga floodplains, Kavango River from February to May 2020.

5. Discussion

The feeding habits of many African inland water predatory fish have been studied with aim to determine their dietary requirements in their natural habitats (Dalu et al., 2012). Feeding ecology studies provide vital information on resource partition and feeding patterns of fish understanding these information help in identifying potential food prey and foraging area of these fish along the Kavango River. These information may be incorporated in to fisheries management measures (Kenmuir, 1973). The results from this study provide important understanding into the food consumption of the tigerfish especially in the Kamutjonga floodplains. Based on the Ministry of Fisheries and Marine Resources (MFMR) data the catch per unit effort CPUE of tigerfish have been declining for the past 10 years (un-published data). As a result, such information on the feeding ecology may be incorporated in the conservation measure of tigerfish and may aid in modeling ecosystem food webs, which in turn aid in understanding species/population interactions in the Kamutjonga floodplain.

The study results show high number of catches of small sized tigerfish in the shallow open water area of the floodplain. Generally tigerfish are considered to be rheophilic group of species that prefer open water areas (Jackson, 1961), which may explain in this study the high number of catches of the small size class of tigerfish in the open water area. Furthermore, these small size class of tigerfish were observed (pers. obs. F. Tshimwandi) hunting in groups, on *Enteromius* spp and groups of Cichlidae species in the open water area of Kamutjonga floodplain. Suggesting that, open water areas may provide suitable environment for small size class hunting frenzies. Similarly, Skelton, (2001) observed small tigerfish < 150 mm in the Okavango Delta, occupying clear shallow pools and

hunting in packs of similar sized fish, hunting mainly on slender bodied shoaling fish species. Additionally, tigerfish are known to be social hunters especially at the smaller stage of their life (Skelton, 2001).

The results of this study show a significant shift in the ontogenetic diet of tigerfish relative to size classes, where small size class of tigerfish feed predominately on aquatic macro invertebrates, medium size class of tigerfish feed on both portions of fish and aquatic macro invertebrates and the large size class of tigerfish are predominately piscivorous. The findings of the study agree with Simasiku et al., (2017a) on the study of feeding ecology of tigerfish in the Kalimbeza Channel on the Zambezi River, noted early dietary shift between small size class and medium size classes of tigerfish, as they shift from insects based diet to fish based diet, feeding mainly on *Enteromius* spp and Cichlidae. It is commonly known, that most predatory tropical fish species go through early ontogenetic dietary shifts (Matthes, 1968; Kenmuir, 1973; Skelton, 2001). Early shifts in the diet of predatory fish are known to have significant impacts on individuals, population natural mortality (Mhlanga, 2003). The dietary shift for tigerfish may also be linked to mouth size as proposed by Winemiller and Winemiller (1994). The mouth size of the small tigerfish is limited, thus only able to capture fairly small size prey, such as larva of aquatic invertebrates (Kenmuir, 1973, 1975). Additionally, switch to piscivory is associated with increase in growth and survival and individual preference as suggested by (Gaigher, 1970). The high portion of fish in the diet of large tigerfish, indicates that the tigerfish is a piscivorous predator. It is known that, the bigger a fish gets, the more energy it needs, so it targets more profitable prey (ie larger prey – more energy for less effort).

The study shows that tigerfish in the Kavango floodplains have a variety of prey items that mainly comprises of fish and aquatic macro-invertebrates. The study results finds a significant different in the food composition of tigerfish, relative to the size classes. With an exception of small size class tigerfish, the data show that the tigerfish feed predominately on fish prey in the group of Cichlidae and *M. altisambesi*, additionally the results show that tigerfish from the Kamutjonga flood appear to be cannibalistic. In a similar study, Mhlanga (2003), reported tigerfish fed mostly on *Limnothrissa miodon* (55%), cichlids (20%), other fish prey that occurred less frequent and include *Clarias* spp and *Synodontis* spp in Lake Kariba. Dalu et al., (2012) showed that tigerfish in Malilangwe Reservoir feeds mainly on Cichlids (35%) and fish prey in the group Gobiidae, Cyprinidae and Clariidae consumed in different proportions. It seems like the diet of tigerfish does not follow a strict feeding regime, but it mainly related to the abundance of what is in the environment, and is dictated by the local assemblage.

The study finds a positive relationship between the predator length and prey length. Tigerfish fed on fish less than 150 mm, in this study. These means fish above 150 mm maybe less likely to be preyed upon by the tigerfish. In similar studys, Dalu et al., (2012) found tigerfish to feed on fish between 30mm - 170 mm while, Simasiku et al., (2017a) reported tigerfish to feed on fish between 50 mm – 170 mm. The ratios between predator length and prey length averaged at 23%. The results of the studies agrees with Jackson (1961) on the study of the impact of predation, by the tigerfish. Tigerfish (small and medium sizeclass) between 68 and 200 mm feed on much larger prey in relation to size, while larger (< 200 mm) tigerfish, that fed on a wide range of prey (Figure 4.5), the study findings agrees with (Kenmuir, 1973) on the nature of the same study.

6. Conclusions

The main aim of the study was to determine the feeding ecology of tigerfish in the Kamutjonga floodplains. This study showed that tigerfish in the Kamutjonga floodplain have a wide range of prey selection. Although all size classes consume on both fish and aquatic macro invertebrates prey item, the overall finding of the study is that tigerfish in the Kamutjonga floodplain prey mostly on aquatic invertebrates in the early stage of life and shift to piscivorous from medium size class to large size class. The study finds ontogenetic shifts in the diet of tigerfish, where small size class of tigerfish feed mostly on aquatic macro-invertebrates, medium size class tigerfish feed on both fish and aquatic macro invertebrates and large size class of tigerfish feed mostly on fish. Early switch to piscivory maybe be associated with increase in growth and survival. The study results show that tigerfish predate on fish prey less than 150 mm TL, and the predator- prey length ratio average at 23 %. The result of the study showed that tigerfish have a high availability of prey selection in the Kamutjonga floodplains.

Dietary data are important and widely used in ecosystem modeling as well as stock assessment models (Mhlanga, 2003). Hence, to ensure sustainability of fishery resource there is a need to better understand the long term interaction of prey and other groups of predators, such as African pike, catfish species etc., hence, a follow up study is recommended. Data from this study may aid in setting up multi-species modeling based on predator-prey interactions, including the development of ecosystem models and food webs, which may help in understanding species interactions with regards to predation and its impacts on fish population dynamics in the floodplain of Kavango River.

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Appendices

Appendix 1: Ethical clearance certificate.



ETHICAL CLEARANCE CERTIFICATE

Ethical Clearance Reference Number: SOS-0022 Date: 25 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: FEEDING ECOLOGY OF THE AFRICAN TIGERFISH
(HYDROCYNUS VITTATUS CASTELNAU 1861) IN THE
KAMUTJONGA FLOODPLAIN KAVANGO RIVER, NAMIBIA

Student: FILIPPUS S. TSHIMWANDI


Student Number: 201209176

Supervisor(s): DR. CLINTON HAY (University of Namibia);
DR. TOR NAESJE (Norwegian Institute for Nature Research);
DR. FRANCOIS JACOBS (Min. 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 Mumbengewi (Head, Multidisciplinary Research)

Appendix 2: Research permission letter.

CENTRE FOR RESEARCH SERVICES

Office of the Pro-Vice Chancellor: Research, Innovation & Development

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RESEARCH PERMISSION LETTER

Date: 04/11/2021

Student Name: Filippus S Tshimwandi

Student Number: 201209176

Programme: Master of Science in Biodiversity Management

Approved Research Title: Feeding Ecology of The African Tiger Fish (*Hydrocynus Vittatus Castelanau 1861*) In the Kamutjonga Floodplain in The Kavango River Namibia.

TO WHOM IT MAY CONCERN:

I hereby confirm that the above-mentioned student is registered at the University of Namibia for the programme indicated. The proposed study met all the requirements as stipulated in the University guidelines and has been approved by the relevant committees.

The proposal adheres to ethical principles as per attached Ethical Clearance Certificate. Permission is hereby granted to carry out the research as described in the approved proposal.

Best Regards

A handwritten signature in black ink, appearing to read "AEE Shikongo".

Dr. AEE Shikongo
Head: Postgraduate Research Support Services
Tel: +264 61 206 3129
E-mail: aeshikongo@unam.na

