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The feeding habits of an introduced piscivore, *Hydrocynus vittatus* (Castelnau 1861) in a small tropical African reservoir

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Abstract. The diet of the tigerfish, *Hydrocynus vittatus* (Castelnau 1861) from a small impoundment (Malilangwe reservoir) was investigated. The tigerfish is an introduced piscivorous fish in this reservoir. Stomach contents analysis indicated that the adult size classes were almost entirely piscivorous and showed diet shifts with size changes. Approximately 35% of the tigerfish diet consisted of cichlid fishes and also included large numbers of Gobiidae (31%), Cyprinidae (29%) and Clariidae (28%). Small size classes of tigerfish fed heavily on macroinvertebrates, in particular, the taxa Pleidae (18%), Chironomidae (13%), *Chaoborus* sp. (11.5%), Corixidae (7.7%), Baetidae (4%) and Notonectidae (7%). They later shifted to a diet of cichlids. *Hydrocynus vittatus* predator-prey length ratio averaged approximately 0.21. The study showed that *H. vittatus* has a varying food composition probably due to changes in food abundances and distributions within the reservoir. Thus it does not have a strict food regime and this gives it a better chance of survival.

Key words: tigerfish, stomach contents, cichlid, macroinvertebrates, introduced

Resumo. Hábitos alimentares de um piscívoro introduzido, *Hydrocynus vittatus* (Castelnau 1861) em um pequeno reservatório tropical africano. A dieta do peixe-tigre *Hydrocynus vittatus* (Castelnau 1861) foi estudada a partir de uma pequena represa (reserva de Malilangwe). O peixe-tigre é uma espécie piscívora introduzida nesta reserva. A análise do conteúdo estomacal indicou que as classes de tamanho adultas foram quase completamente piscívoros e mostrou mudanças na dieta com relação ao tamanho. A dieta do peixe-tigre consistiu em peixes ciclídeos em aproximadamente 35% e também incluiu uma grande porcentagem de Gobiidae (31%), Cyprinidae (29%) e Clariidae (28%). Classes de tamanho menores se alimentaram basicamente de macroinvertebrados, em particular, Pleidae (18%), Chironomidae (13%), *Chaoborus* sp. (11,5%), Corixidae (7,7%), Baetidae (4%) e Notonectidae (7%). Posteriormente, eles mudaram para uma dieta de ciclídeos. A relação do comprimento predador-presa para *Hydrocynus vittatus* teve uma média de cerca de 0,21. O estudo mostrou que *H. vittatus* tem uma dieta variada, devido a mudanças na abundância dos alimentos e à sua distribuição dentro da reserva. Deste modo, a espécie não tem um regime alimentar rigoroso, o que representa uma vantagem para sua sobrevivência.

Palavras chave: peixe-tigre, conteúdo estomacal, ciclídeos, macroinvertebrados, introduzida

Introduction

The introduction of *Lates niloticus* into Lake Victoria in the 1950s led to extinction of hundreds of endemic haplochromine species and it shows an ontogenic change in diet (Ogari 1988). Largemouth bass *Micropterus salmoides* (Lacepede) and *Serranochromis robustus* (Boulenger) were introduced into Zimbabwe in 1932 and early 1960s respectively and have caused the decline in *Barbus* spp. diversity and abundance in streams (Gratwicke & Marshall 2001). In Zimbabwe, the impact of these introduced predators such as tigerfish, *Hydrocynus* *vittatus* (Castelnau 1861) is generally ignored or overlooked.

The tigerfish constitutes about 8.2% of the fish biomass in the reservoir (Dalu *et al*. 2011 *unpub. data*). This species is a member of the Alestiidae, a piscivorous and pelagic predator that is widely distributed in Zimbabwean inland waters, (Thorstad *et al.* 2002, Marshall 2011). Tigerfish can grow up to 70 cm in fork length and 15 kg in weight, although such large specimens are rare (Marshall 2011). The populations of tigerfish have declined in many rivers due to pollution, water extraction and migration barriers, such as weirs and dams (Skelton 2001). Tigerfish is also one of the most popular angling species and was introduced into the Malilangwe reservoir for that sole purpose.

Little is known about the feeding ecology of introduced tigerfish in small lakes and reservoirs with most studies having been done in large lakes such as Lake Kariba (Matthes 1968, Marshall 1987, Ogari 1988, Mhlanga 2003). This paper considers the food composition of *H. vittatus* in Malilangwe reservoir in an attempt to determine how much dietary overlap there was between different size-classes. It was hypothesised that the greatest overlap would be amongst small individuals, but the overlap would decrease amongst larger individuals because of a tendency to specialise on certain food items.

Study area

Malilangwe Reservoir is located in Malilangwe Wildlife Reserve, in the Chiredzi District, south-eastern Lowveld of Zimbabwe (20°58’ 21°02’ S, 31°47’ 32°01’ E) (Figure 1). Mean annual rainfall collected is 562 mm. Temperatures are high with most daily maxima in excess of 32 °C throughout the year and peak temperatures during hot spells in the summer often over 45 °C (Davy 2005, Traill 2006). The annual average evaporation has been estimated at *c*. 2000 mm (Kelly & Walker 1976). Malilangwe Reservoir arises from an impounded river formed in 1964 and is used for water supply in the reserve. It is a gravity section masonry dam with a surface area of 211 hectares with maximum volume of 1.2×10^7 m^3 at full capacity. Flanked by rocky hills on most of its sides, the impoundment has a rocky substrate with few sandy bays. The reservoir is poorly vegetated with few marginal plants including *Azolla filiculoides, Ludwigia stolonifera, Panicum repens, Schoenoplectus corymbosus, Potamogeton* sp., *Phragmites mauritianus* and *Cyperus* sp. (Barson *et al.* 2008). The fish communities include *H. vittatus, Oreochromis placidus, O. macrochir, O. mossambiccus, Tilapia rendalli, Glossogobius giuris, Clarias gariepinus* and *Labeo altivelis* (*unpublished data* Dalu *et al*. 2011).

Methods

Fish survey and analysis

Sampling was carried out monthly for 6 months (May to October 2011). The sampling program was done using three types of fishing gear: fyke nets, seine net and gill nets. Fyke nets were used in the shallow parts (<1 m) while gill nets were set in the deeper sections (>1.5 m) of the dam. Three double fyke nets with a stretched mesh size of 24 mm connected by a 12.5 m long net giving a total length of 18 m were set overnight at randomly selected sites. A fleet of cotton multifilament nets stretched meshes of 7, 12, 20, 30, 40, 50, 60 and 72 mm were used throughout the sampling period and all nets were set overnight for 12–14 hrs. A Seine net with mesh size of 18 mm was also used only in June 2011. Gill nets were used more extensively compared to the other fishing gears. Fish were identified using Skelton (2001) and Marshall (2011). Fish standard lengths (SL) were measured to the nearest centimetres (cm).

Fish stomachs were dissected out and preserved in 70% alcohol for 24 hrs to allow fixation of tissues. The contents of each stomach were examined under an inverted microscope according to Mhlanga 2003 and Zengeya & Marshall 2007. Each item in the diet was identified to the lowest possible taxonomic level and counted. The diet was first determined by the frequency of occurrence method, which records the percentage of stomachs containing a particular food item out of the total stomachs containing food (Zengeya & Marshall 2007). The food items were then combined into broader taxonomic categories for quantitative comparisons. The percentage of empty stomachs was determined.

In order to determine whether there was a change in food composition among the different size groups, the fish were separated into several standard length (SL) size classes; 15-29.9, 30-34.9, 35-39.9, 40-44.9 and 45-49.9. The size class 15-19.9 and 20-24.9 had single individuals hence were combined to form size class 15-29.9. Kruskal-Wallis analysis ($p < 0.05$) a non-parametric test was carried out to test the differences in stomach contents plus food items between (i) individual study months, and (ii) fish of different size classes (H_0: no differences in diets between individual months and also fish size classes). The analysis was done for the whole study period and size classes using SysStat 12 for Windows version 12.02.00 (Systat, 2007). The dietary overlap between size classes for the tigerfish was calculated according to Colwell & Futuyma (1971):

$$C_{ih} = 1 - 0.5 \sum_{j=i}^{n} (|P_{ij} - P_{hj}|)$$

Where C_{ih} = overlap coefficient of length groups **i** and ***j***, P_{ij} = proportional occurrence of prey type ***j*** in length group **i** and P_{hj} = proportional occurrence of prey type **j** in length group **h**. For the index, values may range near 0 (specialized diet or almost no overlap) to 1.0 (even use of food resources or complete overlap).

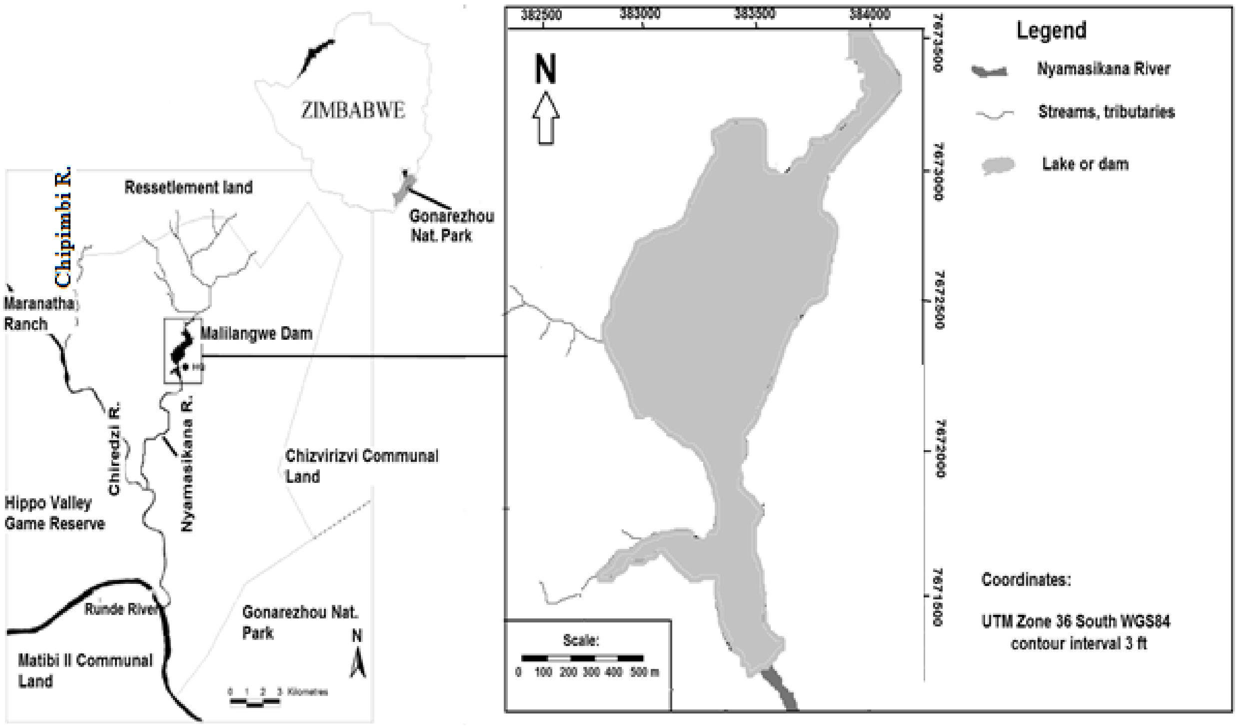

Figure 1. Location of the study area, Malilangwe Reservoir, south eastern Lowveld, Zimbabwe.

Results

A total of 155 tigerfish specimens were collected during the survey. The number of tigerfish caught decreased from May (68 specimens) to September and October (3 specimens each). Out of 155 stomachs examined, only 34 (21.9%) had food in the stomach. The trend for the proportion of empty stomachs increased from May (76.5%) to September and October (100%) (Figure 2). Using Kruskal-Wallis test, we observed that there was a significant ($p < 0.05$) change in diet from May to October, with $p = 0.021$.

Tigerfish in the 15–29.9 SL size class fed on *Oreochromis mossambiccus, Labeo altivelis* and *Oreochromis placidus* (food proportion = 0.7) while those from the 30–44.9 SL size group fed on fish (65%); *Oreochromis placidus, O. mossambicus, Glossogobius giuris, Clarias gariepinus* and *Labeo altivelis*. Tigerfish in the 35–39.9 SL size group fed on fish (78%); *Glossogobius giuris, Labeo altivelis* and *Oreochromis placidus.* Macroinvertebrates formed a small proportion of the diet of tigerfish in the 35–39.9 SL (0.24) and 40–44.9 SL (0.16). Tigerfish in the 40–44.9 SL size group fed on fish *Glossogobius giuris, Clarias gariepinus* and *Oreochromis mossambiccus* (Figure 4, Table I). Tigerfish in the 25–29.9 and 30–34.9 SL size group also fed on fish (0.64 & 0.37) and macroinvertebrates (0.35 & 0.58 respectively). There were no significant ($p > 0.05$) differences in diet between the size classes with $p = 0.869$ whilst there were significant differences ($p = 0.044$) within size classes for the proportion of food items namely Baetidae, Chaoborus sp., Corixidae, Pleidae, *O. mossambiccus* and *L. altivelis*. The distribution of prey items by size class (SL) of *H. vittatus* shows that *Chaoborus* sp. and cichlids were the major prey items (Table I).

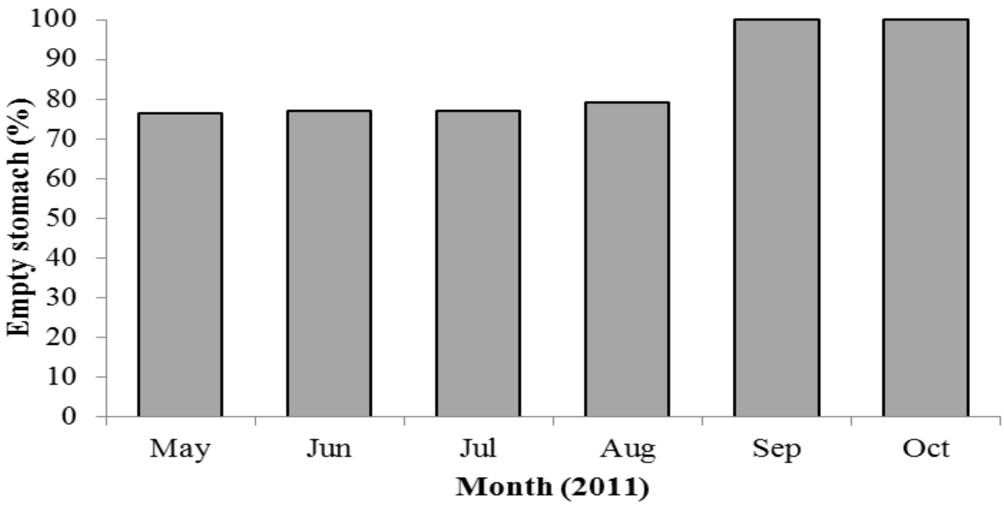

Figure 2. Incidence of empty stomachs in 155 specimens of *Hydrocynus vittatus* in Malilangwe reservoir from May to October 2011 varied from 76.5-100%.

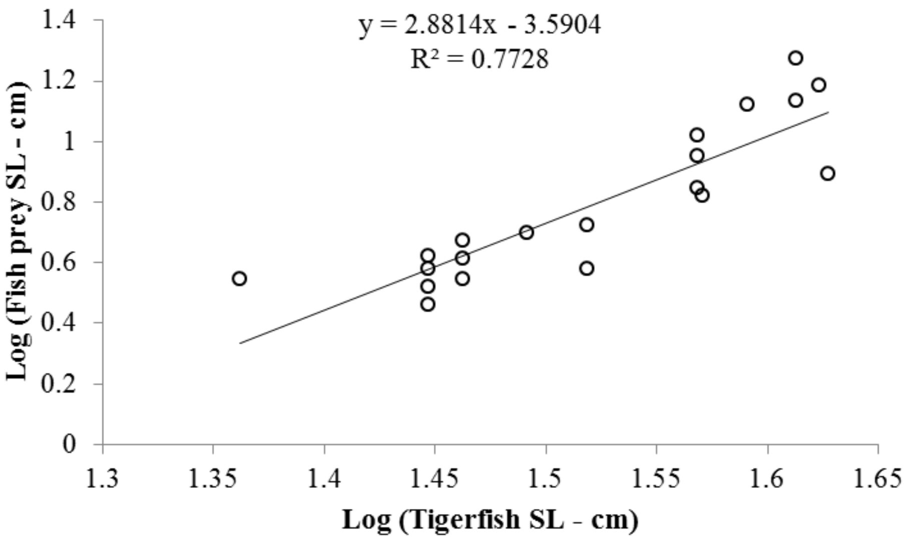

Figure 3. Relationship of prey standard length and predator standard length of *Hydrocynus vittatus* sampled in Malilangwe reservoir from May to October 2011.

The prey length in relation to the predator length for *H. vittatus* is shown in Figure 3. For 20 Tigerfish with measurable prey in their stomachs, the predator length to prey length ratio ranged from 10.4 to 46.1% with a mean of 20.5%. The graph shows that small tigerfish consumed prey (fish) from small size SL classes but larger predators took a wider range of prey sizes and most of the prey items consumed were 3–17 cm SL (Figure 3).

Size related dietary shift among different standard length (SL) size classes are shown in Table 2. Stomach contents analyses by standard length size class indicated a high degree of dietary overlap over all standard length size classes. Juveniles or fry were absent in the catch survey due to the selective nature of the sampling gear that was used (Table II). We observed a diet shift ($p < 0.05$) in tigerfish, as they consumed a large proportion of cichlids during May to June and then shifted to mainly the Cyprinidae, Gobiidae and Clariidae during July to August.

Table I. Frequency of occurrence (%) of different prey items by standard length size class in stomachs of *Hydrocynus vittatus* sampled in Malilangwe reservoir from May to October 2011.

Standard length (cm) size class	**15-29.9**	**30-34.9**	**35-39.9**	**40-44.9**
Weight range (g)	0.23-0.37	0.36-0.62	0.32-0.8	0.92-1.22
Number	9	10	7	8
Fish scales/vertebra	0.01	0.05		0.01
Baetidae		0.07		0.01
Chaoborus sp.	0.17	0.07	0.01	0.15
Pleidae		0.25	0.11	
Corixidae	0.05	0.06	0.12	
Chironomidae		0.13		
Notonectidae	0.05			
Aeshnidae	0.02			
Glossogobius giuris			0.30	0.30
Oreochromis mossambiccus	0.35	0.22		0.25
Clarias gariepinus				0.28
Labeo altivelis	0.20		0.29	
Oreochromis placidus	0.15	0.15	0.17	
Relative fullness	**45.3**	**36.5**	**57.4**	**45**

Table II. Size related dietary shift among the different standard length size classes of *Hydrocynus vittatus* sampled in Malilangwe reservoir (May to October 2011).

SL group (cm)	**20 - 24.9**	**25 - 29.9**	**30 - 34.9**	**35 - 39.9**	**40 - 44.9**
15 - 19.9	0.92	0.85	0.85	0.89	0.92
20 - 24.9		0.93	0.93	0.98	1.00
25 - 29.9			1.00	1.00	1.00
30 - 34.9				1.00	1.00
35 - 39.9					1.00

Discussion

The results of the stomach analyses indicated a high incidence of empty stomachs (78.9%). It was noted that all fish caught in September and October had empty stomachs. These observations are similar to *H. vittatus* studies done by Matthes (1968) and Mhlanga (2003) in Lake Kariba were they observed high percentage incidences of empty stomachs ranging between 50% and 90%. It is common to find high proportion of empty stomachs in piscivorous fishes and also in nocturnal species as shown by studies done by Arrington *et al.* (2002). The high percentage incidence of empty stomachs can be attributed to post-capture digestion which resulted in 5% of stomachs analysed to contain fish scales or vertebra. The empty stomachs during September and October can be attributed to high temperatures (mean 30°C) which resulted in low dissolved oxygen levels (≤ 4.5 mgl^{-1}) throughout the water column. This might have resulted in the tigerfish feeding less as they slowed down their metabolism with decline in dissolved oxygen levels causing a significant reduction in food conversion and growth amongst the species. A similar scenario was observed in *Gambusia affinis* fry (Wurtsbaugh & Cech 1983) and Handeland *et al.* (2008) in the Atlantic salmon post-smolts. Also the effect of temperature on fish metabolism could also account for the high numbers of empty stomachs since higher temperature implies higher digestion rate (He & Wurtsbaugh, 1993). Thus fish caught overnight on gill nets would digest the food in their stomachs faster under higher temperatures (He & Wurtsbaugh, 1993).

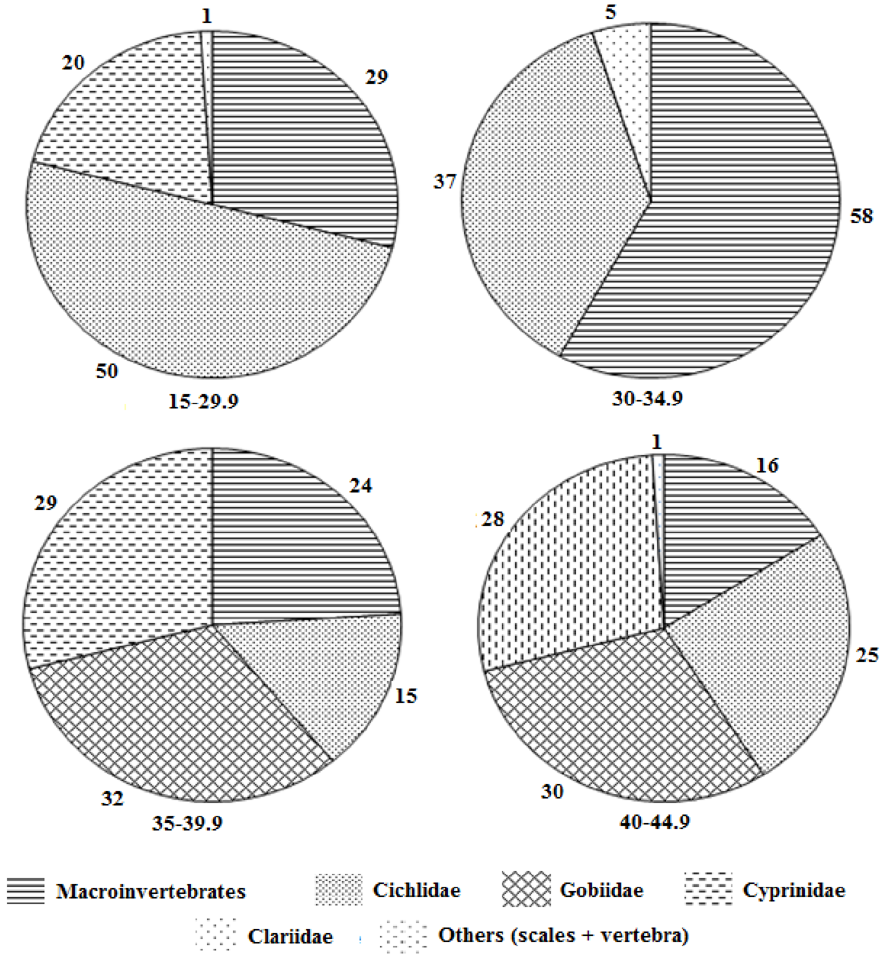

Figure 4. Frequency occurrence of prey items in stomachs of *Hydrocynus vittatus* sampled in Malilangwe reservoir from May to October 2011.

The tigerfish in the reservoir were shown to undergo ontogenetic diet shifts during early life-history stages (Jensen *et al*. 2004). These shifts had large implications for the individuals, populations and communities which eventually resulted in piscivory as observed with the tigerfish in the reservoir. This switch to piscivory is viewed as favourable to individuals because of the associated increase in growth and survival (Jensen *et al*. 2004, Graeb *et al*. 2005). Most of the tigerfish caught fed primarily on fish with macroinvertebrates forming a smaller percentage of their diet and this can be explained by optimal foraging theory which suggests that early switching to piscivorous diet result in faster growth because they derive higher energetic returns from fish prey than alternative prey such as macroinvertebrates (Graeb *et al*. 2005).

Hydrocynus vittatus stomach content analysis showed that it feeds extensively on fish and the results observed in this study agree with other previous studies on the nature of its diet. The study also showed that Cichlids (35%) are currently the major prey item in the diet of *H. vittatus* with Gobiidae (31%), Cyprinidae (29%) and Clariidae (28%) being consumed in different proportions. Mhlanga (2003), showed that tigerfish in Lake Kariba fed primarily on Clupeidae (*Limnothrissa miodon*) (55%), cichlids (20%), other fishes (including Clariidae (catfish), Mochokidae (squeaker fish) and macroinvertebrates) (12%) and Alestiidae (*Brycinus* spp.) (<5%) while Winemiller & Kelso-Winemiller (1994) showed that *Hydrocynus forskahlii* fed primarily on cichlids (over 50%) in the Zambezi River floodplain suggesting that cichlids were consumed more by Tigerfish. Therefore cichlids were consumed by the tigerfish compared to other fish groups. Tigerfish fed primarily on fish less than 20 cm SL, a similar finding to that of Winemiller & Kelso-Winemiller (1994) where it fed on fish less than 25 cm SL. In this study the prey was less than 50% predator length and only in exceptional cases was the ratio greater than 40%.

Diet overlap was higher for the different SL size groups (>0.85) and this suggests that food resource partitioning may occur as environmental conditions and resource densities change with season. Within the different age groups a diet shift was observed and the seasonal diet differences could be more derived from differences in relative prey availability in the resident habitats rather than prey selection by the tigerfish.

The predation on juvenile fish species by Tigerfish has a significant impact on population natural mortality, as it an important parameter in stock assessment models (Mhlanga 2003). A follow-up study investigating interactions between the different prey and predator groups is recommended to better understand the long-term effects of introducing exotic species into a closed ecosystem such as Malilangwe reservoir. The decline in *Tilapia rendalli* in the reservoir can be linked to the introductions of tigerfish but more studies are required to confirm this. The study showed that *H. vittatus* has a varying food composition as a result of changes in food abundances and distributions probably due to differences in months. Thus it does not have a strict food regime and this gives it a better chance of survival.

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