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Fish species composition in the littoral zone of the Kavango floodplain river, Namibia

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Abstract
Littoral fishes in the marginal zones of the Kavango floodplain were sampled using a seine net between March and October 2011. Juveniles of the three commercially important species; *Oreochromis macrochir* (40.3%), *Oreochromis andersonii* (19.3%), and *Tilapia rendalli* (10.2%) were among the five most important species in the littoral zones. This demonstrates the potential use of the littoral zone as a nursery ground for feeding and refuge. Juvenile fish densities of *O. macrochir, O. andersonii,* and *T. rendalli* showed spatiotemporal variation across seasons. Juvenile fish densities were relatively low in winter (June–August) and during the dry seasons (September–October). The attributing factors for these observations were linked to relatively low water temperatures (17 ºC) during winter and high recruitment off the floodplain into the main river channel as the fish grew to mean length of about 70 to 80 mm in size. For the sustainability of the fishery for *O. macrochir, O. andersonii,* and *T. rendalli* which are commercially important species, seine netting in littoral of the Kavango floodplains should be discouraged to avoid recruitment overfishing. This management measure will ensure that fish are not caught at a smaller size before they mature and recruit into the fishery.

Keywords: Kavango floodplain, seine net, juvenile fishes, catch-per-unit-effort

1. Introduction

The Kavango River is characterized by a seasonal hydrology in which water levels rise and fall somewhat gradually, yet continuously, throughout the year [1-3]. At the landscape-scale, these events drive numerous critical ecological processes. Many fish species either seasonally (low water) or consistently occupy main channel habitats (e.g. deep channel, shifting sandbanks, snag complexes). The main channel fishes of the Kavango River have been studied by a number of investigators dating back to pioneering work by Castelnau, who in 1861 described the first species from the Okavango swamp region of Lake Ngami collected by Daviaud [4]. A synthesis of the collection by Peel, (2012) culminated in the most recent checklist of the Kavango River fish species. We shift our focus from the main channel / highway analogy to the moving littoral as a dynamic habitat template. The moving littoral is a land-water ecotone occurring along main river channel margins and extending onto the floodplain during high water [5]. The littoral zone provides different microhabitats with varying degrees of complexity, including the presence or absence of aquatic vegetation. Aquatic vegetation such as macrophytes can promote higher fish diversity, abundance and species richness, influencing the fish assemblage structure of littoral habitats [6-9]. Additionally, they provide refuge from predators to young and small adult fish [10, 11].

Local habitat templates in the moving littoral are disposed to disturbance triggered by seasonal variation patterns of drying and inundation [12]. For example, when the Zambezi River breaches its banks during the annual flood pulse, fishes disperse into productive floodplain habitats with good water quality to exploit abundant resources and to spawn. As water levels gradually fall, many fishes disperse back to the river channel, but juveniles in particular can remain in structurally complex aquatic habitats of the floodplain where current velocity is lower [13]. The aim of this paper was to assess the temporal dynamics of the littoral fish communities in the Kavango River floodplains, as a contribution to the understanding of the importance of the littoral zones.

2. Materials and Methods

2.1 Sampling

Seine net surveys in the Kavango floodplains were conducted between March and October 2011. The Kavango floodplains were sampled at the Ministry of Fisheries and Marine Resources (MFMR)'s Kamutjonga Inland Fisheries Institute (KIFI) in the Mukwe constituency, Namibia (Fig. 1). On each sampling day, the littoral ichthyofauna was sampled using a 20 m long x 1.5 m deep beach-seine with 5 mm stretched mesh size with a bunt. Clear marginal zones between 20 and 40 m wide were randomly selected as the prime sites for seining. The net was laid out and hauled from a distance of 20m offshore. Fish were herded into the net by disturbing the vegetation or substratum that might provide refuge. Preliminary trials on the floodplains with a seine net indicated that five consecutive hauls per trip were sufficient to get a good representation of the fish families within the study area. As a result, five hauls were made per trip. The catch per haul within a towed distance of 20 m was used as an index of relative abundance. This assumed that: (1) the seine efficiency remained uniform in all the areas since there were no modifications to the net over time and (2) that the net was effective at collecting a representative sample of the littoral fish fauna. After sorting by species, all fish species were measured to the nearest mm total length (TL) and weighed to the nearest gram (g). In cases where the catch of a species was large, the catch was sub-sampled.

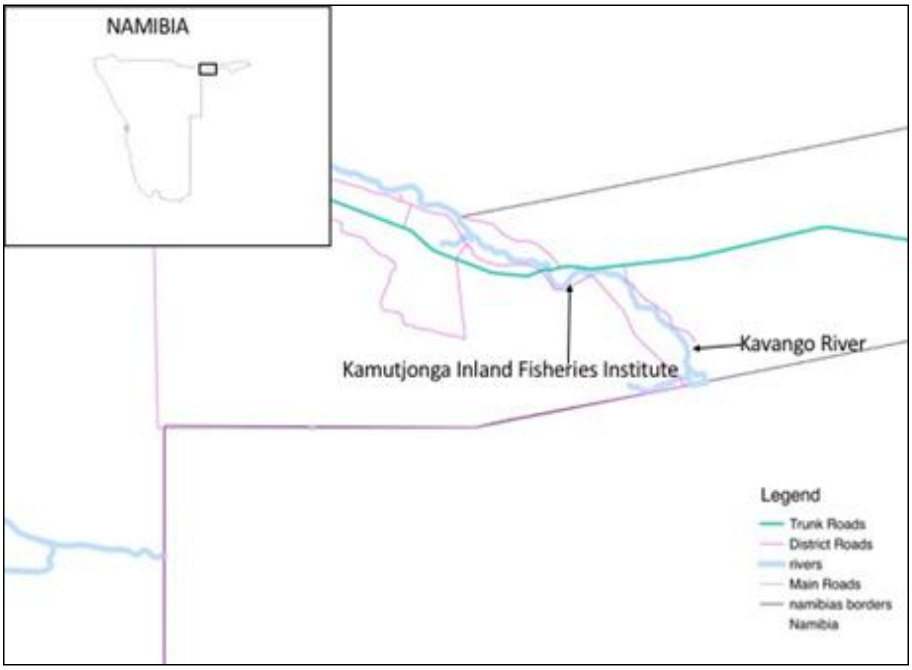

Fig 1: Map of Namibia (insert) and the expanded area of the north-eastern Namibia showing the location of KIFI institute and water bodies in the Okavango River basin during the high waters.

2.2 Data analysis

All recorded data were stored and analysed in PASGEAR. Index of relative importance was applied as a measure of relative abundance or commonness of different species in the catch and was calculated as: IRI = (%N + %W) X (%FO) where %N = Percentage contribution of each species by number to the total catch; %W = Percentage contribution of each species by weight to the total catch; and %FO = Percentage frequency of occurrence of each species in the total number of seine hauls [14]. Seine net CPUE was defined as the number of fish caught per haul. CPUE was calculated as: CPUE = C_i/E_i, where C_i is the catch of species i (in numbers) and E_i is the effort expended to obtain i [14]. The Kruskal-Wallis one-way analysis of variance (ANOVA) test was used to examine for seasonal changes in relative abundance (total CPUE).

3. Results

3.1 Littoral catch composition in the Kavango floodplain

A checklist of all species sampled from the Kavango floodplain between March and October 2011, is depicted in Table 1. A total of 2053 fishes, representing 8 families and 24 species were sampled from the littoral zone of the Kavango floodplain. The species were ranked based on the Index of Relative Importance (IRI). The five most important species accounting for 90.7% of the IRI were *O. macrochir* (40.3%), *O. andersonii* (19.3%), *T. sparrmanii* (17%), *T. rendalli* (10.2%), and *Pseudocrenilabrus philander* (3.9%) (Weber, 1897) [15]. Cichlids represented by 12 species dominated seine catches accounting for 73% (IRI) to the total catch of small fishes by number (Fig. 2 and Table 1). The banded tilapia, *Tilapia sparrmanii* and *Oreochromis microchir* were the most numerous species accounting for 22.3% and 21.6% respectively of the total catch, while the green head bream *O. macrochir* (47.1%) and *O. andersonii* (15.9%) contributed the highest weight (Fig. 2 & Table 1). The least represented fish families were Schilbeidae, Clariidae, and Mochokidae (Table 1).

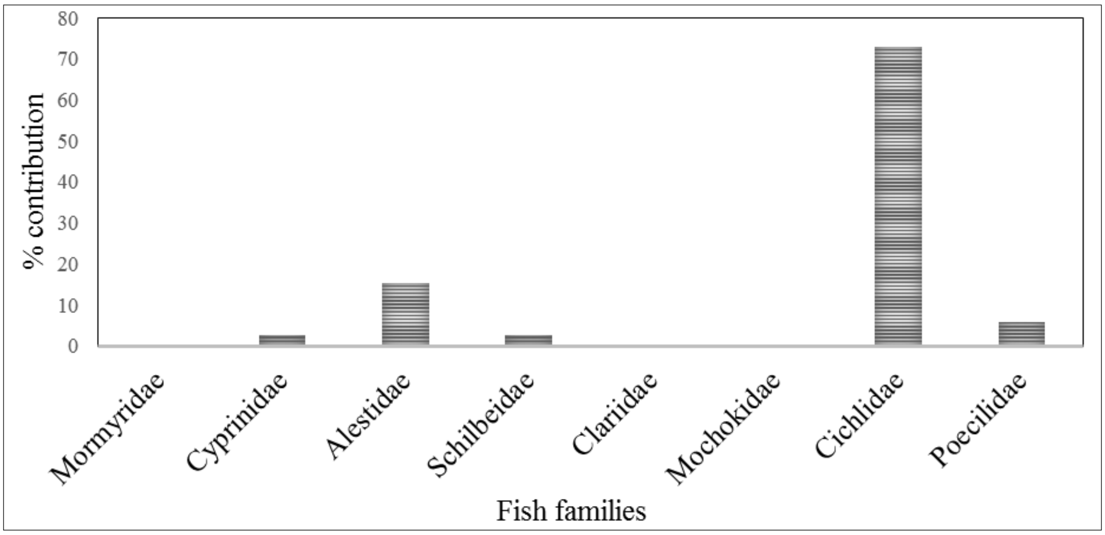

Fig 2: Relative % numerical contribution of fish families to the total caches of all species sampled in the Kavango floodplain, Namibia, between March and October 2011.

Table 1: Seine net catch composition in percent numbers (%N), percent weight (%W) and percent frequency of occurrence (%FO) and the percent index of relative importance (%IRI) of all species sampled in the Kavango floodplain, Namibia, between March and October 2011.

	Kavango floodplain (n = 2053)			
Species	%N	%W	%FO	%IRI
Mormyridae				
Pollimyrus spp	0	0	5	0
Cyprinidae				
Barbus afrovernayi	0.4	0.1	15	0.1
Barbus bifrenatus	0	0	5	0
Barbus paludinosus	0.1	0	15	0
Barbus poechii	-	-	-	-
Barbus radiatus	0.2	0.1	5	0
Barbus haasianus	1.9	0.3	20	0.4
Labeo cylindricus	-	-	-	-
Alestidae				
Brycinus lateralis	9.3	4.1	10	1.2
Hydrocynus vittatus	0.3	2.5	15	0.4
Micralestes acutidens	-	-	-	-
Rhabdalestes maunensis	5.8	1.5	10	0.7
Schilbeidae				
Schilbe intermedius	2.6	3.2	30	1.6
Clariidae				
Clarias ngamensis	0.1	0.3	10	0
Mochokidae				
Synodontis spp.	0	0	5	0
Cichlidae				
Oreochromis andersonii	7.8	15.9	90	19.3
Oreochromis macrochir	21.6	47.1	65	40.3
Pharyngochromis acuticeps	0.2	0.2	15	0.1
Pseudocrenilabrus philander	8.6	2.2	40	3.9
Sargochromis sp.	-	-	-	-
Sargochromis sp. "Green bream"	-	-	-	-
Sargochromis giardi	0	0.1	5	0
Serranochromis angusticeps	0	0.1	5	0
Serranochromis macrocephalus	-	-	-	-
Tilapia rendalli	7.8	9.5	65	10.2
Tilapia sparrmanii	22.3	10.4	60	17.7
Tilapia ruweti	4.7	1.8	50	2.9
Poecilidae				
Micropanchax hutereaui	0.3	0.1	10	0
Micropanchax katangae	0.1	0	10	0
Micropanchax johnstoni	5.5	0.4	25	1.3

3.2 Seasonal abundance of the common littoral species

The eight most abundant species in the littoral zone of the Kavango floodplain were *O. andersonii*, *O. macrochir*, *T. rendalli*, *T. sparrmanii*, *P. acuticeps* (Steindachner, 1866), and *P. philander*, *R. maunensis* (Fowler, 1935) and *B. lateralis* (Boulenger, 1900) [15].

The highest numbers of *O. andersonii* and *O. macrochir* were observed in March and April 2011 but lowest from June to October 2011, however no seasonal difference in CPUE were detected for both species (Kruskal Wallis test, df =7, *P*>0.05) (Fig. 3). The highest CPUE for *T. rendalli* was observed in March and lowest in October 2011 (Fig. 3) whereas *T. sparrmanii* was more prominent in September and lowest in March and June 2011(Figure 3). These differences were not found significant for both *T. rendalli* and *T. sparrmanii* (*P*>0.05). The highest abundance of *P. acuticeps* was in October and *P. philander* were most abundant in September 2011 (Fig. 2). These differences were not found significant for both species (*P*>0.05). The highest numbers of *R. maunensis* and *B. lateralis* were observed in June and July 2011. Both species were least abundant in October 2011. These differences were however not significant for both species (*P*>0.05).

3.3 Length frequency of the common littoral species

Higher frequencies of larger *O. andersonii*, *O. macrochir* and *T. rendalli* were observed between March and April 2011 and crushed to low levels between May and November that year (Figure 3). These differences were significant for *O. andersonii* (Kruskal Wallis test, df = 4, *P*<0.05), *O. macrochir* (Kruskal Wallis test, df = 6, *P*<0.05), and *T. rendalli* (Kruskal Wallis test, df = 6, *P*<0.05). High length frequencies of larger *T. sparrmanii* were observed in July 2011 followed by a decline between August and November (Fig. 4). These differences were significant (Kruskal Wallis test, df = 6, *P*<0.05) *P. acuticeps, P. philander*, *R. maunensis* and *B. lateralis* are small sized species, which can rarely grow to a larger size.

Higher frequencies of larger *R. maunensis* and *B. lateralis* were observed in June and October 2011, (Fig. 4). These differences were found significant (Kruskal Wallis test, df = 3, *P*<0.01) for *B. lateralis*. A slight difference in length frequencies of *P. philander* was observed between May and October 2011 (Fig. 4). These differences were found significant (Kruskal Wallis test, df =5, *P*<0.05).

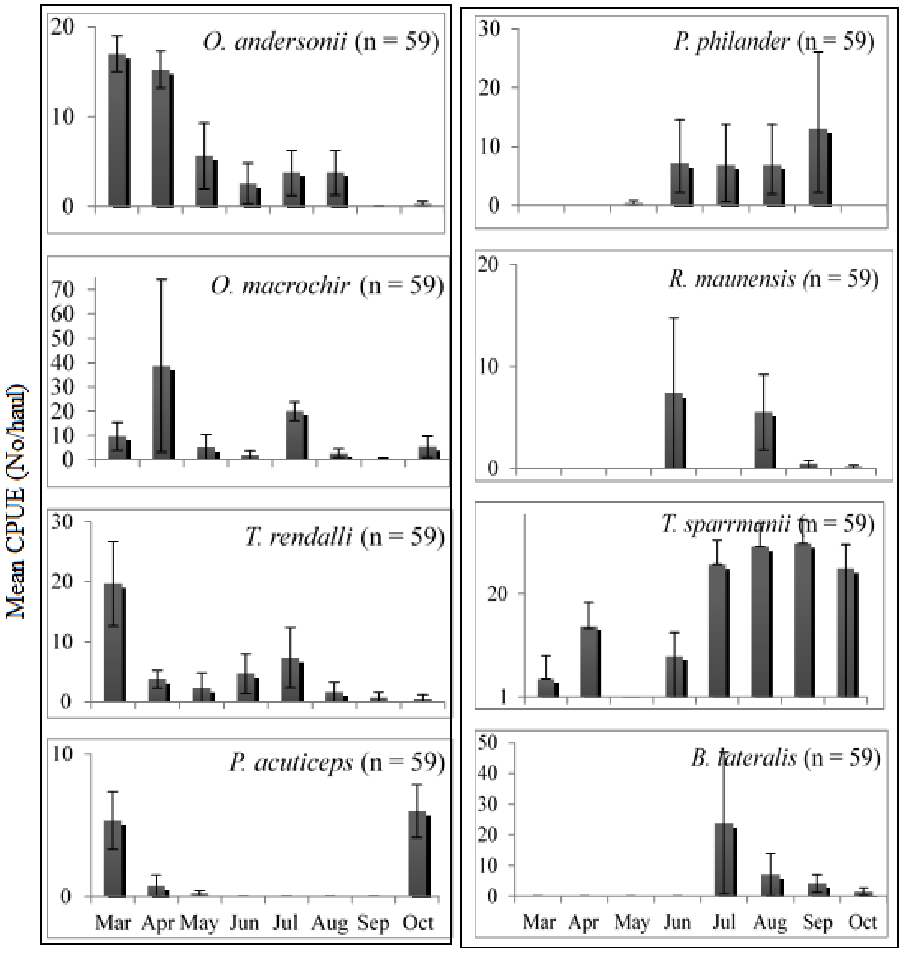

Fig 3: Mean CPUE for *O. andersonii, O. macrochir, T. rendalli, T. Sparrmanii, P. acuticeps, P. philander, R. maunensis,* and *B. lateralis*, in the Kavango floodplain sampled between March – October 2011; n= the total number of hauls conducted.

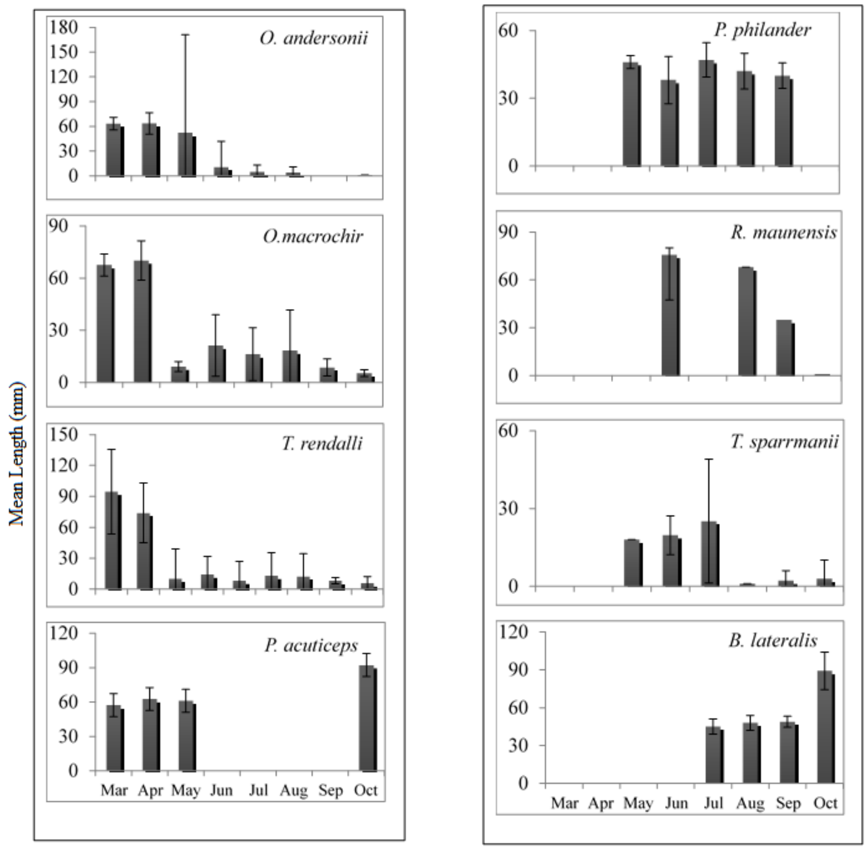

Fig 4: Mean total length (TL) + (SE) for *O. andersonii, O. macrochir, T. rendalli, T. sparmanii, P. acuticeps, P. philander, R. maunensis,* and *B. laterals,* in littoral zone of the Kavango floodplain sampled between March–October2011.

4. Discussion

The evidence from present study suggests that annual inundation of flooded patches of the Kavango River supports large numbers of small fishes as previously reported by Lindholm *et al.* (2007) [16]. Cichlidae, represented by 10 species was by far the most species rich family in the littoral zone of the Kavango floodplain. The ichthyofaunal species were dominated by juveniles' fishes of the economic importance such as *O. andersonii, O. macrochir* and *T. rendalli* as observed by other studies on the Okavango delta [17]. The large quantities of macrophytes within the floodplain might have attracted high populations of cichlids [18]. Cichlid are known to respond to annual flooding by migrating from dry refuges to more productive macrophytes habitats favorable for feeding and spawning [19-22].

Seasonal fish abundance expressed as catch per unit effort (CPUE) of the eight most abundant littoral taxa varied significantly between sampling month. *O. andersonii* and *T. rendalli* bred earlier than *O. macrochir,* with their juveniles being most abundant in March 2011 whereas juvenile *O. macrochir* were apparent later in April 2011. *O. andersonii, O. macrochir* and *T. rendalli* are the three commercially important species in the Zambezi region [23]. Peaks in CPUE of these three species coincided with the warm, wet season (March – April 2011). These observations are essentially in agreement with numerous authors. For instance, Peel, 2012 in Simasiku, 2014 [24] investigated the biology of cichlids in the Kavango and Zambezi Regions and observed breeding peaks during the warm wet season between January – March, with reproductive activity throughout summer, (September – April). Similarly, in Lake Liambezi, *O. andersonii* and *O. macrochir* had long breeding season with ripe females' observed in August – March [23]. On the Zambezi floodplain, high concentration of nesting activities of *T. rendalli* were observed between November and March [23]. Similarly Weyl & Hecht, (1998) [25] observed high abundance of juvenile schools of *T. rendalli* and *O. mossambicus* in the marginal areas of Lake Chicamba during summer. Individual *T. sparrmanii*, *P. acuticeps* and *P. philander* were most abundant in September - October and these observations tracks their reported breeding season in accordance to van der Waal, 1985 [23]. Seasonal peaks in CPUE of the two small sized characins, *R. maunensis* and *B. lateralis* were in synchrony with the peak flood (June – July 2011). Seasonal flooding may contribute positively to the small fish population peaks in two ways: firstly, the inflowing water is likely to bring nutrients from the river and flooded agricultural land into the floodplain. These nutrients will trigger an increase in phytoplankton production and consequently zooplankton productivity, which is crucial as a source of food. Secondly, the floodwaters may also inoculate the flooded floodplain with riverine species.

Juvenile mean body length and fish densities of the large growing cichlids *O. andersonii, O. macrochir* and *T. rendalli*) crashed to low levels during the cold season (June – July) and the dry season (June - October 2011). These observations may be attributed to the influence of seasonal variation, water levels and life stage. Cichlid fish are reproductively inactive during the cold season (June – August) and this may account for low metabolism, slow growth and low abundances of fish in winter [26]. A decline in fish densities during the dry season (September – December 2011) may be justified by the fact that juvenile fish vacate the ephemeral floodplain habitats into deeper main channels and lagoon habitats when faced with harsh environmental conditions (Hocutt *et al*., 2001) or at a particular size [26]. During harsh conditions characterised with reduced water level and dissolved oxygen, fish are likely to be trapped in higher concentrations in isolated pools, where they are subjected to heavy predation and intense biotic competition.

Larger *Labeo capensis* juveniles migrated out of the marginal area of the Hendrik Verwoerd dam into offshores leaving smaller sized individuals in the inshore [27]. *Barbus anoplus* vacates the marginal habitat before they are 190 mm in size [27]. Ellender *et al.*, (2008) [26] observed juvenile *O. mossambicus* moving offshore into deep estuary channels after attaining an average size of 80 mm (SL). Jackson, (1961) [28] reported that juvenile *O. macrochir* in Lake Mweru live along the swampy edge of the lake and enter the open water at a length between 180 mm and 200 mm when they are active enough to escape from fish predators such as *H. vittatus*. This may further confirm the findings of this study. The majority of the large growing species in this study vacated the littoral zone after attaining an average body size between 60 and 90 mm. Alternatively, variation in juvenile fish abundance in the Kavango floodplain may also be attributed to predator prey effect induced by Catfishes (*C. gariepinus* and *C. ngamensis*) and the African Pike (*Hepsetus cuvieri*) on small fish. *Clarias gariepinus* is an ecologically adaptable species [29]. It has a broad diet spectrum and occupies habitats ranging from the offshore to the littoral areas in lakes, to floodplains and to river channels upstream. Both *C. gariepinus* and *C. ngamensis* feed predominantly on fish, especially juvenile cichlids [29]. Carey, (1971) [30] reported that cichlids constituted up to 19% of the food diet of *H. cuvieri*, and this may be assumed to have contributed to a regulatory effect on small fish in the Kavango floodplain.

5. Conclusion

The littoral zone in the Kavango floodplain formed a crucial habitat for juveniles of the commercially important species. The present study findings have important implications for the management and conservation of fishes of the Kavango floodplain. Based on these findings of this study, we recommend that caution should be taken against the use of seine and mosquito netting in these crucial habitats as this may result in growth overfishing. Management measures towards the management of the seine and mosquito netting should be devised and be put in place. Moreover, public awareness campaign and public education on the impacts of seine and mosquito netting in the littoral zones could be implemented.

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