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# An assessment of fish assemblages between protected and non-protected areas on the Zambezi /Chobe River

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**Abstract**
The fisheries of the Zambezi are currently experiencing an alarming decline due to an increasing fishing pressure. With increasing fishing pressure, fish populations may undergo a series of changes in size, species composition and abundance. As a result, scientists and managers are deemed to seek for alternative measures to protect and conserve fish stocks. One such option is the use of fish protected areas (FPAs). Two recently established FPA's on the Zambezi/Chobe River are the Kalimbeza and Kasaya Channels. However, accrued benefits of these FPAs have never been assessed. Comparative experiments using gillnets of different mesh sizes (12 mm – 150 mm) were conducted between FPA's (Kalimbeza channel) and non-FPA's (Hippo channel) between March and December 2016 to test the hypothesis that, FPA's would yield high fish abundance (CPUE) than non- FPAs. Experimental fishing trials showed a high CPUE by weight and number ($p<0.05$) of the five dominant species (*Hydrocynus vittatus, Schilbe intermedius, Pharyngochromis acuticeps, M. acutidens* and *Brycinus lateralis*) in the FPA than non-FPA. Two among the five dominant species *Schilbe intermedius* and *Pharyngochromis acuticeps* showed higher mean sizes ($p<0.05$) in the FPA than non-FPA. Our findings confirmed the importance of the protected areas in conserving fish resources in the Zambezi Region.

**Keywords**; Zambezi River, Fish Protected Areas, experimental gillnets, CPUE.

## Introduction

Globally, the integrity of freshwater ecosystems is deteriorating due to a range of threats, including habitat alteration via processes such as contamination (e.g. eutrophication), hydrological manipulations (e.g. dam construction), and overharvesting of commercially and or recreationally valuable species [1]. Most recently, the fisheries of the Zambezi have seen increased fishing pressure because of increasing human population [2]. With increasing fishing pressure, fish populations may undergo a series of changes in size, species composition and abundance [3]. This is because multi-species fisheries initially target the few largest or most economically valuable species in a fish community [4]. As a result of these factors, the loss of biodiversity in freshwater is assumed to surpass that observed in both terrestrial and marine environments [5]. In view of the above, scientists and managers are deemed to seek for alternative measures to protect and conserve the fish stocks in their natural environment. One such option is the designation of Fish Protected Areas (FPAs). FPAs are defined as "clearly defined aquatic areas developed to protect spawning areas, spawning time periods, and nursery sites where juveniles can mature and disperse from [6]. However, FPA's are a recent development in the Zambezi Region, Namibia. Two recently established FPA's on the Zambezi/Chobe River are the Kalimbeza and Kasaya Channels. The main aim is to retain and maintain a high species richness and abundance through recruitment under reduced disturbance and act as source populations for depleted populations through adult and larval migrations [7]. It is argued that in many cases FPA's are not fulfilling their targets [1]. Presently, they are a few assessments on performance of FPAs in Africa [8] with none conducted in Namibia. Hence, the aim of this study was to improve our understanding about the performance of FPA's in Namibia and whether they are achieving their intended aims by addressing the following questions: (1) is there a difference in fish composition and diversity between FPA and non-FPA's? (2) Is there a difference in fish abundance, expressed as Catch Per Unit Effort between the two areas; and (3) If fish mean lengths differ between FPA's and non-FPA? Our expectations were that FPA's will have higher fish diversity, densities and mean fish sizes.

## Material and Methods

### Study area
The Zambezi region borders on Botswana in the south, Angola and Zambia in the north and Zimbabwe in the east (Fig 1). The area is home to two perennial rivers, namely the Kwando/Linyanti in the west and the Zambezi Chobe in the east. The study was carried out in two section of the Zambezi River; one sections of 5 km stretch within Hippo channel (non-FPA) (Fig. 1A) and the second section of 12 km stretch belonged to a downstream Kalimbeza channel (FPA) (Fig. 1B). The surrounding land in Kalimbeza area is protected for conservation purposes and is composed of grasslands, deep forest, terrestrial wild animals and marshy lowlands (pers.obs.). The unprotected sites around Hippo channel were mainly composed of agricultural land use patterns and rural hamlets (pers. obs.).

### Field sampling
Sampling was conducted from March to December 2016. Fish were collected using a fleet of three brown multifilament nylon nets with stretched mesh sizes of 12, 16, 22, 28, 35, 45, 57, 73, 93, 118 and 150 mm. Each fleet was 110 m long and 2.5 m deep with eleven randomly distributed 10 m mesh panels. Gillnet sampling was conducted in each area for two nights per month, summing up to a sampling effort of 66 capture nights. Gillnets were laid along the shoreline overnight, from around 1700 to 0600 hrs (soaking time of 13 hrs). Specimens were identified using the classification system of Skelton, 2001 [9], measured body length (mm), weight (g) and the mesh size in which the fish were caught were recorded. Water properties measurements (Temperature $^{o}$ C), Dissolved oxygen (mg/L), Conductivity (µS/cm) and pH) were also recorded monthly at each sampling site using an Hq 40 d multi-meter.

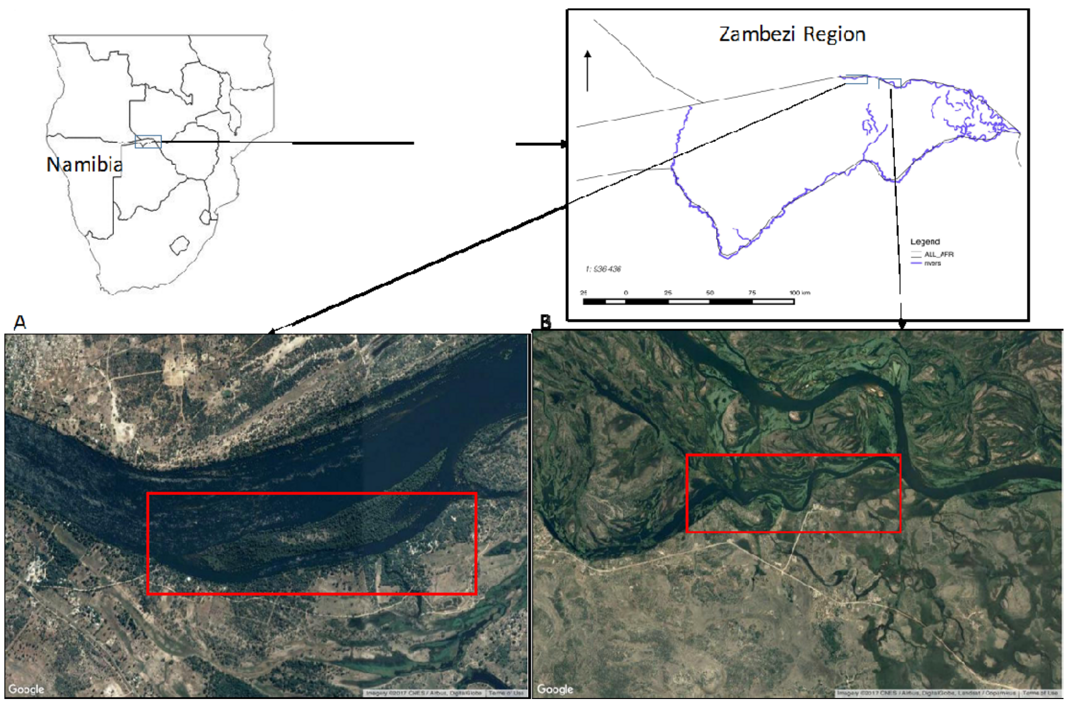


**Fig 1:** Map of the Zambezi Region (A), showing the Hippo Channel, and (B) Kalimbeza Channel on the Zambezi River where gillnets were set during the study. (Map produced S.K.Mafwila using QGIS software version 3.2 wih Google map addin).

## Data Analysis

### Catch composition
The index of relative importance (IRI) was used to determine the most important species in gillnet catches by number, weight and frequency of occurrence, and was calculated as IRI= (%N + %W) x (%FO), where %N is the percentage by number contribution of each species to the total catch of each site, %W is the percentage by weight and %FO is the percentage frequency of occurrence of each species in the total number of net settings.

To ascertain differences in fish composition between the two sampling areas the Sorensen dissimilarity index based on species presence–absence data was calculated as QS = $(b+c)/(2*a+b+c)$, where $a$ is the number of shared species in two sites, whereas $b$ and $c$ are the numbers of species unique to each site [10].

### Species diversity
Species diversity per site was determined using the Shannon-Wiener Diversity Index in Passgear and was calculated as: $H' = -\sum p_i \log p_i$, where $H'$ is the diversity index and $p_i$ is the proportion of individuals found in the $i$th species.

### Catch per unit effort (CPUE)
Relative fish abundance per site was expressed as catch per unit effort (CPUE), and was presented in numbers and in weight per gillnet set. CPUE was calculated as $CPUE = \frac{C_i}{E_i}$, where $C_i$ is the catch of species $\boldsymbol{i}$ (in numbers or weight) and $\boldsymbol{E_i}$ is the effort expended to obtain $\boldsymbol{i}$.

### Statistical analysis
Data on CPUE and fish sizes by site and mesh sizes were first checked for normality and homogeneity of variances using Kolmogorov–Smirnov procedure and Levene's test, respectively. To improve on assumptions of normality and homogeneity of variances, data were log10 transformed. In case where transformation failed to normalize the data, non-

parametric tests were employed. The independent t-test was then applied to compare species diversity indices, CPUE and fish mean sizes between sampling sites. In cases when data failed to meet the normality assumption, the nonparametric Mann-Whitney U-test was employed to determine differences in diversity indices, CPUE and fish sizes between sites. Analysis were only carried out on the most five abundant species among the two areas. All analyses were carried out in Passgear, R version 3.1.3 and SPSS Inc 2015 statistical packages.

## Results

### Physicochemical environment

Table 1 presents the annual average values of water quality properties in both FPA and non-FPA. The average annual conductivity was significantly higher in the protected area than in the non-protected area (t-test, p=0.04). However, dissolved oxygen was significantly lower in the protected area than in the non-protected area (t-test, p=0.01). Recorded water pH was similar between the protected areas (t-test, p=0.12). Likewise, similar values of mean temperature were observed in the protected area and non-protected areas (t-test, p=0.12).

**Table 1:** Average water quality parameters in Kalimbeza channel and Hippo channel between March and December 2016.

| Site | Conductivity (µS/cm) | Dissolved $O_2$ (mg/L) | pH | Temperature (°C) |
|---|---|---|---|---|
| Kalimbeza channel | 74.17 ± 25.37 | 6.17 ± 1.31 | 7.32 ±0.63 | 24.9 ± 3.26 |
| Hipoo channel | 70.0 ± 21.61 | 6.97 ± 0.5 | 7.57 ± 075 | 25.96 ± 3.04 |

### Species composition by sampling areas

Catch composition and %IRI for each species in each area are depicted in Table 2. A total of 12204 fishes representing 10 families and 37 species were sampled in both between March and December 2016. The Sorensen index of similarity detected a 63% similarity in species composition, indicating a higher degree of similarity in species composition between the FAP and non-FAP. However, fish species in both areas differed in terms of importance (as per %IRI, %N, %W, Table 2). In the FPA, 9150 fishes representing 10 families and 34 species were sampled in (48 net nights Table 2). The most numerous species were *Hydrocynus vittatus* (14.3%) and *Schilbe intermedius* (14.3%) while the large predatory characin, *Hydrocynus vittatus* contributed the most weight (35.6%). In turn, in the non FPAs- 3054 fishes representing 10 families and 28 species were sampled in (48 net nights Table 2). The silver catfish *Schilbe intermedius* (25.7%) dominated the catch by number while the large predatory characin, *Hydrocynus vittatus* contributed the most weight (43.1%).

**Table 2:** Experimental gillnet catch composition expressed in percentage number (%N), percentage weight (%W) and percentage frequency of occurrence (%FO) and the percentage index of relative importance (%IRI) of all fish species sampled at Kalimbeza and Hippo channel.

| | Kalimbeza | | | Hippo | | |
|---|---|---|---|---|---|---|
| | % No | % Weight | % IRI | % No | % Weight | % IRI |
| **Mormyridae** | | | | | | |
| *Marcusenius altisambesi* | 3.4 | 2.2 | 1.6 | 0.3 | 0.1 | 0 |
| *Petrocephalus catostoma* | 3.2 | 0.6 | 0.8 | 0.3 | 0.1 | 0 |
| *Cyphomyrus cubangoensis* | 0.3 | 0.2 | 0 | 0.7 | 0.2 | 0.1 |
| *Pollimyrus castelnaui* | 0.3 | 0.1 | 0 | 0 | 0 | 0 |
| *Mormyrus lacerda* | 0 | 0.2 | 0 | - | - | - |
| **Cyprinidae** | | | | | | |
| *Enteromius poechii* | 10.3 | 1.3 | 3.8 | 3.2 | 0.8 | 1 |
| *Enteromiusradiatus* | 0.5 | 0.1 | 0.1 | 1 | 0.4 | 0.1 |
| *Enteromius unitaeniatus* | 0.1 | 0 | 0 | 0.4 | 0 | 0 |
| *Enteromius eutaenia* | 0.1 | 0 | 0 | 0.4 | 0 | 0 |
| *Enteromius fasciolatus* | - | - | - | 0.1 | 0 | 0 |
| *Enteromius bifrenatus* | - | - | - | 0 | 0 | 0 |
| *Labeo lunatus* | 1.8 | 2.3 | 0.8 | 1.4 | 1.1 | 0.4 |
| *Labeo cylindricus* | 1 | 0.8 | 0.2 | 0.3 | 0.1 | 0 |
| *Labeo spp* | 0.2 | 0.2 | 0 | - | - | - |
| *Opsaridium zambezense* | 0.1 | 0 | 0 | 0.5 | 0.1 | 0 |
| **Characidae** | | | | | | |
| *Hydrocynus vittatus* | 14.3 | 35.6 | 40.1 | 14.1 | 43.1 | 40.7 |
| *Brycinus lateralis* | 25 | 10.2 | 17.9 | 15.3 | 6 | 7.7 |
| *Micralestes acutidens* | 10.1 | 1 | 2.9 | 29.8 | 2.5 | 16.3 |
| **Hepsetidae** | | | | | | |
| *Hepsetus cuvieri* | 0.1 | 0.8 | 0 | 0 | 0.1 | 0 |
| **Claroteidae** | | | | | | |
| *Parauchenoglanis ngamensis* | 0.1 | 0.1 | 0 | 0 | 0.2 | 0 |
| **Schilbeidae** | | | | | | |
| *Schilbe intermedius* | 14.3 | 14.7 | 18.5 | 25.7 | 28.4 | 30.4 |
| **Clariidae** | | | | | | |
| *Clarias gariepinus* | 0.1 | 14.4 | 0.6 | 0.1 | 5.6 | 0.1 |
| *Clarias ngamensis* | - | - | - | 0 | 1.4 | 0 |
| **Mochokidae** | | | | | | |
| *Synodontis sp.* | 7.3 | 10.3 | 8.5 | 2 | 6.7 | 1.8 |
| *Synodontis nigromaculatus* | 0.1 | 0.3 | 0 | - | - | - |
| **Cichlidae** | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| *Pharyngochromis acuticeps* | 5.9 | 3.1 | 3.9 | 3.4 | 1.6 | 1.3 |
| *Hemichromis elongatus* | 0.2 | 0.3 | 0 | 0.5 | 0.5 | 0 |
| *Tilapia sparrmanii* | 0.4 | 0.2 | 0.1 | - | - | - |
| *Serranochromis macrocephalus* | 0.2 | 0.4 | 0 | 0.1 | 0.3 | 0 |
| *Coptodon rendalli* | 0 | 0 | 0 | 0.3 | 0.5 | 0 |
| *Sargochromis carlottae* | 0.1 | 0.2 | 0 | 0.1 | 0.3 | 0 |
| *Pseudocrenilabrus philander* | 0.1 | 0 | 0 | - | - | - |
| *Oreochromis macrochir* | 0 | 0.1 | 0 | - | - | - |
| *Serranochromis altus* | 0 | 0.1 | 0 | - | - | - |
| *Sargochromis codringtonii* | 0 | 0 | 0 | - | - | - |
| *Ctenopoma multispine* | 0 | 0 | 0 | - | - | - |
| **Distichodontidae** | | | | | | |
| *Nannocharax sp.* | 0.1 | 0 | 0 | 0 | 0 | 0 |

**Species richness and diversity**

Species richness by family in both areas is illustrated in Table 2, with FPAs being the most species rich (n=34) than non-FPAs areas (n= 28). Cichlidae (11 species) and Cyprinidae (8 species) were the most species rich families in the FPAs, whereas the most speciose rich families in the non-FPAs, were the Cyprinidae (9 species) and Cichlidae being second with 5 species. Species diversity on the other hand, was similar between FPAs (2.28) and non-FPAs areas (1.92), (Mann-Whitney, P>0.63).

**Catch per Unit Effort (CPUE) by sampling area**

Overall CPUE by number was significantly higher in the FPAs (1.97 ±0.096 fish /net. night) than in the non-FPAs (1.45±0.09 g/ set) (Mann-Whitney, P= 0.001). CPUE by weight also differed significantly between areas (Mann-Whitney, P=0.003) with higher CPUE by weight in the FPAs (4817.06 ± 755.5 g/ net. night) than in non-FPA (1948.3 ± 329.5 g/ net. night). Figure 2 & 3 shows the monthly mean catch trend for the FPA and non-FPAs respectively. Both areas showed a fluctuation in monthly catch rates. Monthly catch rates (CPUE) by number showed a sharp decline in July in the FPAs and in August in the non-FPAs (Figure 2). CPUE by weight showed a decline in April & July in the non-FPAs and in October in the FPAs (Figure 3).

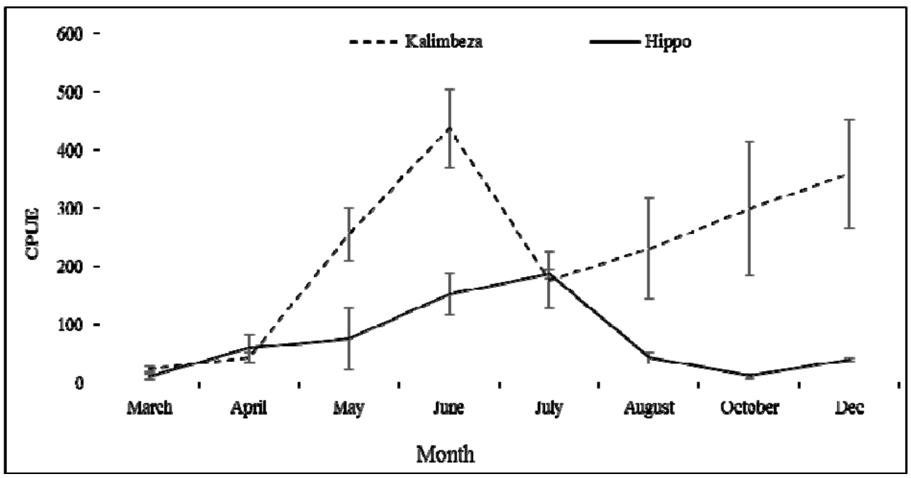


**Fig 2:** Monthly catch per unit effort ± standard error by number in experimental gillnet catches between Kalimbeza (FPAs) and Hippo channel (non-FPAs), sampled between March 2016 - December 2017

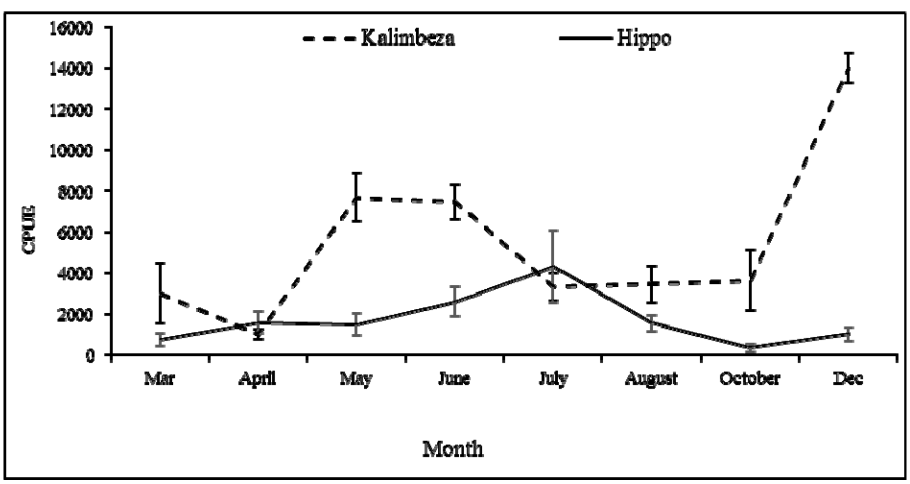


**Fig 3:** Monthly catch per unit effort ± standard error by weight (b) in experimental gillnet catches between Kalimbeza (FPAs) and Hippo channel (non- FPAs, sampled between March 2016 - December 2017

**CPUE by mesh size groups**

Catch per unit effort by number per mesh size group (12-16 mm); (22-28); (35-45); (57-73) & (93-150) is illustrated in Table 3. CPUE by number in both FPA and non- FPAs was highest in mesh group (22-28). CPUE by number differed significantly between areas for mesh groups; (22-28, t-test, P = 0.01), (35-45, Mann-Whitney, P=0.002), (57-73, Mann-Whitney, P=0.003) and (93-150) (Mann-Whitney, P=0.001), being higher in the FPA than non-FPAs (Table 3). No significant differences in CPUE by number were detected for small the mesh group (12-16) between FPAs and non-FPAs (t-test, P=0.23). In the FPAs, mesh group 35-45 had the highest CPUE by weight while 93-150 accounted for highest weight in the non-FPAs (Table 4). CPUE values by weight also differed significantly between sampling areas for mesh groups (22-28, t-test, P=0.01), (35-45, Mann-Whitney, P=0.002), & (57-73, Mann-Whitney, P=0.003), with higher CPUE observed in the FPAs than non-FPAs. No significant differences were detected in CPUE by weight for the smaller mesh group (12-16, t-test, P=0.23) (Table 4).

**Table 3:** CPUE by number per mesh group in Kalimbeza channel (FPAs) and Hippo channel (non- FPAs).* Denotes significant difference.

| Mesh size (mm) | Kalimbeza/SE | Hippo/SE | P value |
|---|---|---|---|
| 12-16 | 34.0±12.0 | 20.2±6.8 | 0.23 (t-test) |
| 22-28 | 127.0±24.5 | 29.0±7.0 | 0.01* (t-test) |
| 35-45 | 43.7±9.0 | 15.5±4.4 | 0.002* (Mann-Whitney-u test) |
| 57-73 | 2.4±0.5 | 1.4±0.3 | 0.003* (Mann-Whitney-u test) |
| 93-150 | 29.1.0±5.9 | 9.4±1.9 | 0.001* (Mann-Whitney-u test) |

**Table 4:** CPUE by weight per mesh group in Kalimbeza channel (FPAs) and Hippo channel (non- FPAs).* Denotes significant difference.

| Mesh size (mm) | Kalimbeza/SE | Hippo/SE | P value |
|---|---|---|---|
| 12-16 | 111.0±30.4 | 46.2±15.2 | 0.23 (t-test) |
| 22-28 | 1549.9±254.2 | 465.2±126.5 | 0.01* (t-test) |
| 35-45 | 1740.8±312.3 | 710.2±161.3 | 0.002* (Mann-Whitney-u test) |
| 57-73 | 408.7±89.7 | 261.3±69.4 | 0.003* (Mann-Whitney-u test) |
| 93-150 | 1713.9±323.1 | 838.9±186.0 | 0.004* (Mann-Whitney-u test) |

**CPUE of the most abundant species by area**

Catch per unit effort by number of the five most abundant species in the study area are illustrated in Table 5 & 6. These are species which were collected in sufficient numbers in both areas. *Hydrocynus vittatus* was the only commercially and recreationally important species. In the FPAs, CPUE by number was dominated by the small characin *Brycinus lateralis* while *Micralestes acutidens* accounted for the highest CPUE by number in the non-FPAs (Table 5). CPUE by number differed significantly between sampling areas for four out of five species; *H. vittatus* (Mann-Whitney, P=0.01), *Schilbe intermedius* (t-test, P=0.03), *Brycinus lateralis* (t-test, P=0.004) and *Pharyngochromis acuticeps* (t-test, P=0.012) with higher CPUE's recorded in the FPAs than non-FPAs. CPUE by numbers for *M. acutidens* was similar between FPAs and non-FPAS ($P>0.05$), (Table 5). Similarly, CPUE by weight differed significantly between sampling areas for *H. vittatus* (Mann-Whitney, P=0.01), *S. intermedius* (t-test, P=0.02), *B. lateralis* (t-test, P=0.016) and *P. acuticeps* (t-test, P=0.002) with higher CPUE observed in the FPAs than non FPAs (Table 6). There was no significant differences in CPUE by weight detected between FPAs and non-FPAs for *M. acutidens* (Table 6).

**Table 5:** CPUE by number per species by species in Kalimbeza and Hippo channel. * Denotes significant difference.

| Species | Kalimbeza/St error | Hippo/St error | P value |
|---|---|---|---|
| *Hydrocynus vittatus* | 29.1±5.91 | 9.4±1.9 | 0.01* (Mann-Whitney -u test) |
| *Schilbe intermedius* | 29.0±6.6 | 17.1±6.2 | 0.03* (t-test) |
| *Brycinus lateralis* | 50.9±10.7 | 10.1±3.4 | 0.004* (t-test) |
| *Micralestes acutidens* | 20.6±9.1 | 19.8±7.5 | 0.89 (Mann-Whitney -u test) |
| *Pharyngochromis acuticeps* | 12.0±3.6 | 2.2±0.9 | 0.012* (t-test) |

**Table 6:** CPUE by weight per species by species in Kalimbeza and Hippo channel. * Denotes significant difference.

| Species | Kalimbeza/St error | Hippo/St error | P value |
|---|---|---|---|
| *Hydrocynus vittatus* | 1713±323.1 | 839±186.4 | 0.01* (Mann-Whitney -u test) |
| *Schilbe intermedius* | 706±166.2 | 17.1±197.0 | 0.02* (t-test) |
| *Brycinus lateralis* | 489±108.0 | 10.1±44.0 | 0.016* (t-test) |
| *Micralestes acutidens* | 48±18.8 | 19.8±19.4 | 0.67 (Mann-Whitney -u test) |
| *Pharyngochromis acuticeps* | 12.0±23.7 | 2.2±20.7 | 0.002* (t-test) |

**Fish mean sizes of the most abundant species by area**

Statistical analysis on fish size of the most abundant species is illustrated in Table 7. Fish mean length differed significantly between sampling areas for *S. intermedius* (Mann-Whitney, P=0.05), *B. lateralis* (t-test, P=0.018), *M. acutidens* (Mann-Whitney, P=0.012) and *P. acuticeps* (t-test, P=0.001). *Schilbe intermedius* and *P. acuticeps* displayed large mean sizes in the FPAs than non-FPAs. The mean size for *B. lateralis* (P=0.018), and *Micralestes acutidens* (P=0.12), were often significantly higher in the non-FPAs. Mean size for the commercially target species *Hydrocynus vittatus* was similar between FPAs and non-FPAs.

**Table 7:** Statistics on size per species in Kalimbeza and Hippo channel. *Denotes significant difference.

| Species | Kalimbeza/St error | Hippo/St error | P value |
|---|---|---|---|
| *Hydrocynus vittatus* | 402.56 ±26.77 | 334.47±46.34 | 0.11 (Mann-Whitney -u test) |
| *Schilbe intermedius* | 192.01±5 | 191±16.0 | 0.05* (Mann-Whitney -u test) |
| *Brycinus lateralis* | 79.2±0.76 | 84.13±1.04 | 0.018* (t-test) |
| *Micralestes acutidens* | 53.13±0.91 | 53.91 ±0.81 | 0.012* (Mann-Whitney -u test) |
| *Pharyngochromis acuticeps* | 89.24±1.189 | 82.53±3.33 | 0.001 * (t-test) |

**Discussions**

To date, the use of closed areas designed to shield freshwater biota from natural and anthropogenic disturbances has been quite slow relative to the marine environment [11-13]. It fills an urgent gap in knowledge on whether FPAs as a management strategy is meeting its objectives of minimizing the over exploitation of fish species in the Zambezi River. Parallel experiments in the Zambezi River revealed that, 34 different species were caught in the protected area (Kalimbeza channel) relative to 28 species which were caught in non-protected areas (Hippo channel). These results indicate that fish may have benefited from protection in the protected channel compared to non-protected areas. While we lack a benchmark on species richness for the FPAs prior its declaration, it is speculated that the current observed richness is a consequence of 4 years of the undisturbed habitat structure within the protected areas [14]. It is generally accepted that vegetation enhances refuge from predation particularly for the young fish, increases structural complexity and availability of food and forms nursery beds [13]. This is further affirmed by Lubbus *et al*. (1990) [15] who showed that fish abundance, biomass and species richness were significantly allied to high macrophytes structure in the Chesapeake Bay (USA). Fish species composition and diversity indices were surprisingly similar between areas. This observation may be explained by the high connectivity between the FPA and the non-FPAs on the Zambezi River. Zambezi River is typically lotic, and permitted exchange of water and fish between the FPA and the non-FPAs. The pattern of connectivity between geographically close environments is fundamental to their high similarity [16].

As expected, fish densities and biomass were significantly higher in the FPA areas than in the non-FPAs. This is in agreement with our initial hypotheses and in general agreement with conclusions from other studies [16, 17, 18]. For instance, FPAs designed to protect nesting black bass (*Micropterus spp*.) from angling during the brood guarding stage have resulted in both an increase of angler catch-per-unit effort and population-level reproductive success [16]. Similarly, the establishment of FPA's has played a large role in increasing the abundance of commercially exploited fish species in Lake Mutirikwi, Zimbabwe (Manika, 2014) [17] and the rehabilitation of exploited lake trout (*Salvelinus namaycush*) populations in both Lake Huron and Lake Superior [18]. Kocovsky & Carline, (2001) [19] documented that an unexploited walleye (*Sander vitreus*) population in Pennsylvania exhibited greater population density and greater adult size relative to other exploited populations. Protection affected individual species differently. Catch Per Unit Effort (CPUE) of the five abundant species *H. vittatus, S. intermedius*, *B. lateralis*, *M. acutidens* and *P. acuticeps* declined in non-protected areas. One interesting observation pertains to the no difference in CPUE of *M. acutidens* between areas. A possible explanation for this observation would be that, *M. acutidens* has the capacity to rapidly increase in numbers and might have occupied the vacant predatory niche left by other commercially cropped species such as *Hydrocynus vittatus* in the non-protected areas (Skelton, 2001) [9], (Peel, 2012) [20], and result in even distribution between FPAs and non- FPAs. Additionally, *M. acutidens* like other small sized but mature fish species are not selected commercially in the minimum legal mesh size of 76 mm. Similar observations were made on the Kwando River where *Schilbe intermedius* was reported to have occupied the vacant predatory niche left by *H. vittatus* [20]. Likewise, in the Kariba system, Zimbabwe, *Synodontis zambezensis* showed the ability to rapidly expand and occupy the habitats left vacant by other commercially cropped fish species [8]. This ecological phenomenon would have resulted in the establishment of fish stocks that are of low value in the non-protected area which would eventually destroy the fishery [21].

Mean fish sizes on individual species varied considerably between sampling areas with higher mean sizes observed in the protected area for *S. intermedius,* and *P acutiiceps*. However these differences were not significant for *H. vittatus*. The large home range migratory behavior of *H. vittatus* could compromise positive results being found for the protected areas (Pelletier *et al*. 2008) [22], implying that species that exhibit a large home-range (i.e. *H. vittatus*), may not be efficiently conserved in FPAs [23]. Another possibly reason for this inconclusiveness is that Kalimbeza Channel (FPA) has only been in existence for four years. Although, recovery of the fish stocks is expected to be faster given the protection status, due to recharge of the of channel and recruitment, it is likely that fish communities including fish sizes are yet to stabilize. The age, use, and level of compliance of a protected zone is important for achieving long-term conservation goals. Older effective reserves show better results than younger reserves, with densities of fish increasing by approximately 5% per year in protected areas compared to unprotected areas [24].

Despite some inconsistence features, an increasing trend in fish densities and mean length of some species in this study (i.e. *H. vittatus, S. intermedius*, *B. lateralis*, *M. acutidens* and *P. acuticeps*) in the protected area, provide promising results regarding the future benefits of the Fish Protected Areas in the Zambezi River. High abundance of juvenile *H. vittatus* (mean size 29.1mm) in the protected areas, suggests that Kalimbeza channel could serves as an ecologically or biologically significant areas for the protection of the fish nursery grounds, and conserve juveniles by limiting their exploitation and ensure successful recruitment. The high abundance of juveniles within the protected areas would also imply that, Kalimbeza FPA serves as a breeding area thus the area is expected to have bigger fish that are sexually mature and able to spawn and give rise to many other individuals [25]. A key aspect that may contribute towards FPAs and non-FPAs to retain high species diversity is habitat quality. In this study with the exception of conductivity, all other water parameters monitored in both FPA and non-FPAs were within the recommended values for healthy aquatic systems by Swingle, (1969) [26]. Our findings confirmed the importance of the protected areas in conserving fish resources in the Zambezi River. However, the benefits of the FPA's for fisheries enhancement and conservation of biodiversity could be realized in a long-term provided the law enforcement and compliance is maintained.

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