Fish Abundance and Species Composition between Fished and Non-fished Areas of Lake Chivero, Zimbabwe

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Abstract: ***The main objectives of this study was to compare fish abundance, species composition and fish mean lengths between fished and non-fished (protected) area of Lake Chivero, Zimbabwe. Biological data (species, weight and length) for individual fish sample collected from fished and non fished areas using gillnets of different mesh sizes were recorded. Mean Catch per Unit Effort (CPUE), Species diversity (H'), species richness (S), species evenness and mean fish lengths were determined for each area. A total of eleven fish species from five fish families were caught during the entire study period. The findings revealed that there were significant differences in fish abundance between fished and non-fished areas (P< 0.005) and a non-significant difference in fish species composition and fish mean lengths between the two areas (P> 0.005). This suggests almost equal levels of resources exploitation and disturbances within the two areas or high levels of fish migration from protected areas to re-colonize depleted stocks in fished areas.***

Keywords: Species Abundance, Species Composition, protected area, Lake Chivero

1. Introduction

The world is currently experiencing very high rates of loss of biodiversity estimated at 100-1000 times the extinction rates pre-human levels [13]. Conservationists are alarmed by this loss and are actively engaged in activities designed to protect as much of the remaining diversity as possible. Freshwater is an essential resource for all life and an indispensable component of socio-economic development. Freshwater ecosystems are exceptionally diverse, and face a multitude of threats, from both freshwater and terrestrial land use. However, freshwater conservation efforts generally lag behind those for terrestrial and marine [16]. Protected areas (PAs) selected, designed and managed for freshwater biodiversity are only a recent development. Freshwater protected areas are especially dedicated to the protection, maintenance and restoration of freshwater biodiversity through legal and other effective management instruments [4]. Biodiversity can be monitored through constant reviews of species abundance and species composition with protected areas serving as control areas in terms of biodiversity [18].

Species composition and relative abundance of different species has long been a key measure for evaluating biological communities. Fish abundance as defined by [19], is the parameter estimated to monitor fish populations. There are several methods used to estimate fish abundance and species composition but the traditional approach to estimating fish abundance involves choosing sites or sampling units within a water body and then count fish from catches within the chosen sites. Previous studies by [17] on Lake Kariba reviewed that protected areas had significantly higher abundance as well as higher species diversity in comparison to open fishing areas.

Species diversity and abundance are affected by various factors which includes; heavy harvest, anthropogenic activities like dam construction, habitat destruction, biological and chemical pollution as well as diseases [11]. It is assumed that species diversity decreases with increase in level of exploitation and thus protected areas or areas with no or minimum disturbances are expected to show higher species diversity than heavily fished areas [17]. According to [20], fishing is a complex process that depends on many factors; including the type of vessel and gear used, target species, stock density, time and areas fished. Fishing changes the structure of fish communities [2].

2. Methodology

Study Area

Lake Chivero is located 37km Southwest of Harare on the central Zimbabwean Plateau at an altitude of 1368.59 metres above sea level and extending from 17^o 52’59.25” South to 30^o 46’22.71” East. The lake is found in agro-ecological region IIa under the Northern Highveld Plateau with a mean annual rainfall of between 750 – 1000 mm. Temperatures can be described as mild in winter and hot in summer and ranges between 13.1^oC and 26.3^oC respectively [12].

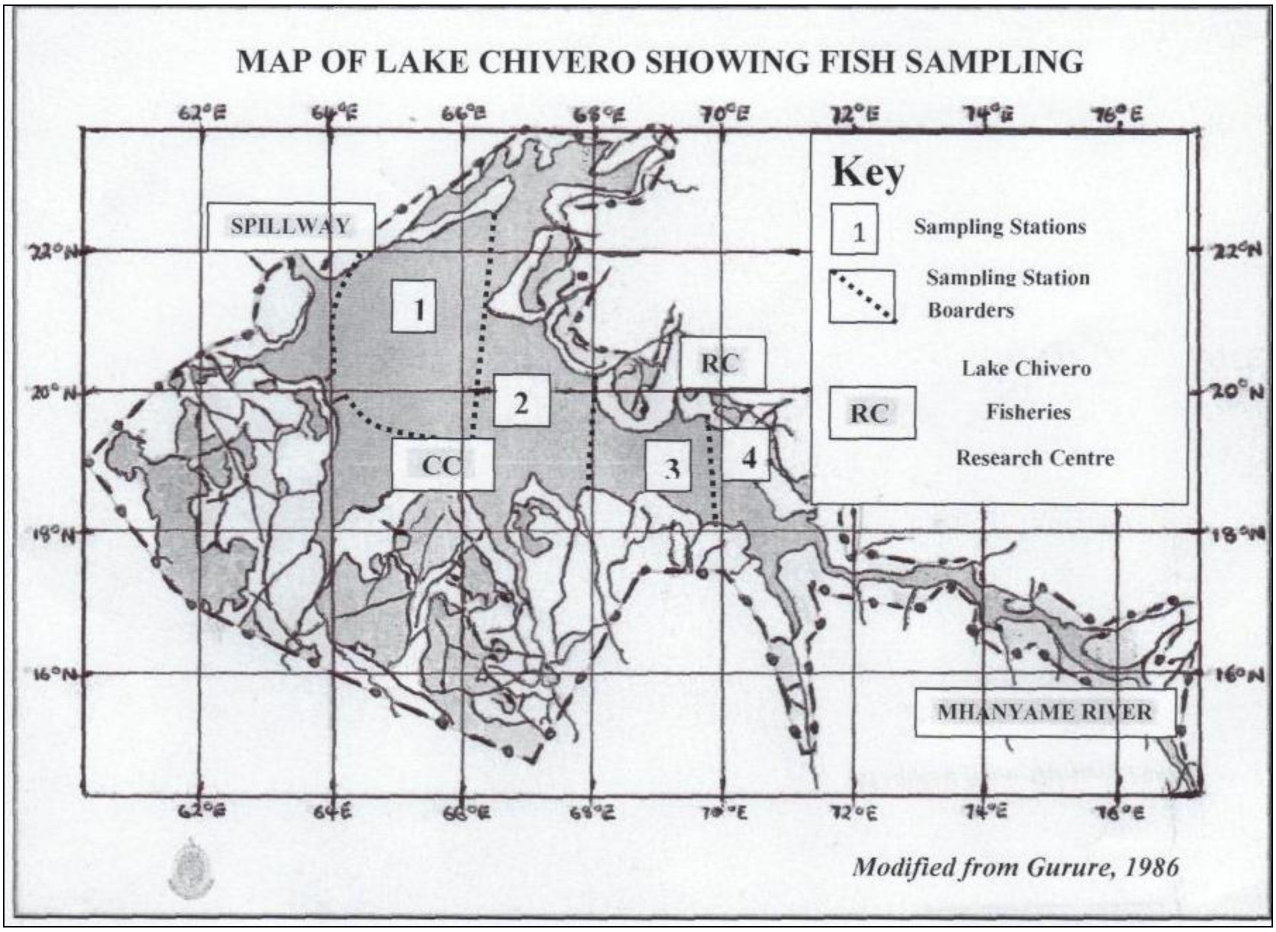

Figure 1: Map of Lake Chivero showing fish sampling stations

Lake Chivero has a dam wall height of 36.5m, a capacity of 250.4 x $10^6 m^3$, a maximum depth of 27m and a mean depth of 9.4m. It has a total surface area of 2630 ha (26,3km^2), a maximum length of 35,7km and a maximum breath of 8km. The catchment's area is 2136 square kilometres [21]. Annual fluctuation in water level is between 2 and 4m. The dam has an ordinary type of spill-way and there are no fish ladders incorporated in the dam wall structure thus completely providing a barrier for potamodromous fish species such as the redeye labeo (*Labeo cylindricus*) [6]. Lake Chivero is highly eutrophic and is infested by aquatic macrophytes such as the water hyacinth (*Eichhornia crassipes*) and spaghetti weed (*Hydrocotyle americana*) [12].

Experimental Design

The study was done using a Completely Randomised Design (CRD) with two treatments.

Data Collection

During the entire sampling period, a 50 horsepower motorised boat and a manual dinghy belonging to Lake Chivero Fisheries Research Station were used. Sampling was carried out from January 2010 to December 2010. A fleet of monofilament gillnet survey nets of different mesh sizes ranging from 2" to 6" (stretched mesh) were used for this research. The different mesh sizes used were 2", 2.5", 3", 3.5", 4", 4.5", 5", 5.5" and 6". These nets were arranged into panels of 100 meters each making cumulatively a total length of 900 metres net length.

Two sites were chosen, one protected (Miller's Creek), where fishing is strictly prohibited and the other one, an open fishing area (Carolina Bank). Nets were laid in these two areas on the sampling night once a month. Gillnets were laid either along the shoreline or perpendicular to the shoreline but uniformity between the two sampling sites was maintained. Where nets were laid perpendicular to the shoreline, nets were arranged in order of their mesh sizes starting with the smallest, increasing chronologically to the largest. Small meshed nets were laid closer to the shore and larger meshed nets stretched further away from the shore into deeper waters.

The catch in each gillnet was considered as a single sample and one gillnet fished one night from 1600hrs to 0600hrs of the next morning allowing a soak time of 14 hours. Catch from each gillnet was sorted according to species, and each species was counted and weighed separately. For each species, length (mm), weight (g) and the mesh size of which the fish were caught were recorded. All measurements were done on site in the morning whilst fish samples were still fresh. Species identification was done using protocols described by [18].

The data was captured into a computer using Microsoft Excel Package (2007 edition).

Data Analysis

Analyses of data for the differences of means in CPUE and fish mean length were done using the Student-T test from Minitab Version 13.31 at 95% confidence Interval.

1. Catch per Unit Effort (CPUE) was used to estimate relative abundance and it was calculated using the formula;

C/F = qN, and therefore **N = (C/F)/q**

Where **C** = the catch
F = the fishing effort, (to be measured in terms of fishing days)
q = catchability coefficient,
N = the number of fish in the population or CPUE, [8].

2. The species diversity was calculated using the Shannon – Weaver index of diversity as follows;

$$H' = -\sum_{i=1}^{S} [(n_i/n).\ln (n_i/n)]$$

Where; **S** = total number of species in the sample,

n_i = is the number of individual belonging to the *i*th position of S species in the sample,

n = is the total number of individuals in the sample, [19].

3. Species Evenness was calculated using the Shannon – Weaver index of species evenness as follows;

E = Species Diversity / lnS

Where **Species diversity** = the Shannon – Weaver diversity index of an area. **S** = species richness of an area.

4. Results

Fish Species Diversity

Eleven different species of five fish families were caught during the sampling (Table 1). Of the eleven species collected, only *Cyprinus carpio* was not recorded in the fished area.

Species Diversity

Both areas had low species diversities on a Shannon-Weaver diversity scale of one to six with one representing an area with very low species diversity and six representing an area with high species diversity. Both areas also had just below average Shannon –Weaver species evenness on a scale zero to one as shown in Table 2.

Table 1: List of Lake Chivero Fish Species caught during the study

Family	Scientific Name & Authority	Common Name
Centrarchidae	*Micropterus salmoides* [Lacepéde, 1802]	Large mouth black bass
Cichlidae	*Oreochromis macrochir* [Boulenger, 1912] *Oreochromis niloticus* [Linnaeus, 1758] *Pharyngochromis darlingii* [Boulenger, 1911] *Serranochromis robustus* [Günther, 1864] *Tilapia rendalli* [Boulenger, 1896] *Tilapia sparrmanii* [A. Smith, 1840]	Green head tilapia Nile bream Zambezi happy Nembwe Red-breasted tilapia Banded tilapia
Claridae	*Clarius gariepinus* [Burchell, 1822]	Sharptooth catfish
Cyprinidae	*Cyprinus carpio* [Linnaeus, 1758] *Labeo cylindricus*[Peters, 1852]	Common carp Redeye labeo
Mormyridae	*Marcusenius macrolepidotus* [Peters, 1852]	Bulldog

Table 2: Species diversity and evenness indices for Fished area and protected area

Area	Fished Area	Protected Area
Shannon – Weaver Index	1.007	1.015
Species Evenness	0.437	0.423

Relative Abundance

Figure 2 shows the annual mean catch trend between fished and protected areas. There was a sharp decrease in mean catch in April and between June and August. Both areas showed decreases in annual catch rates as shown by the trend line, linear equations and the R^2 values (0.093 and 0.005). The R^2 value is greatest in the fished area indicating that the decrease in annual catches is greatest in this area than in the protected area.

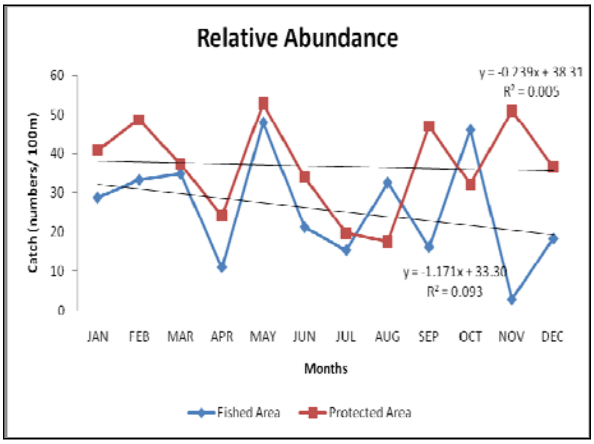

Figure 2: Annual catch trends in fished and protected areas

There was a significant difference in relative abundance between the two areas (P = 0.046) and the statistics for the mean CPUE (Relative Abundance) for the two areas. The mean relative abundances were 25.5 fish per 100 metres and 36.7 fish per 100 metres for the fished and protected areas respectively (Table 3).

Table 3: Statistics describing differences in Relative Abundances

Treatment	Abundance	StDev	Se-mean	P - Value
Fished Area	25.5	13.8	4.0	0.046
Protected Area	36.7	11.9	3.4	

95% CI for difference (- 22.04, - 0.19)

Relative Biomass

The overall relative biomasses (mean CPUE in terms of weight) of the two areas were 830 grams per 100 metres and 1479 grams per 100 metres of the net length for the fished and protected areas respectively. There was a significant difference in relative biomass between the two areas (P = 0.005), with the protected area having larger fish biomass than the fished area.

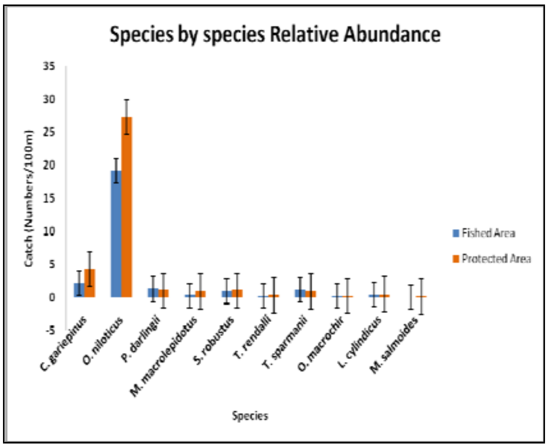

Figure 4: Species by species relative abundance

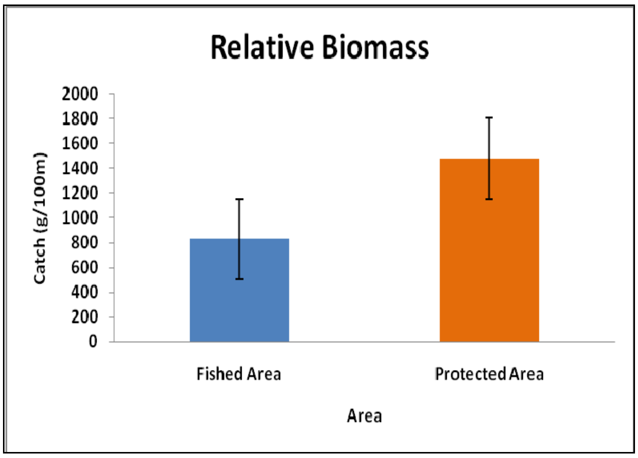

Figure 3: Relative biomass between fished and protected areas

The protected area had larger mean biomass compared to fished area (P = 0.005) indicating that there was a significant difference in mean biomass between the two areas.

Table 4: Mean Relative Biomass of the fished and protected areas

Treatment	Abundance	StDev	Se-mean	P-Value
Fished Area	830	464	134	0.005
Protected Area	1479	551	159	

95% CI for difference (- 1081, - 216)

Relative Abundance of Different Species

For the 10 fish species caught in the studied areas, fished area and protected area, 9 species had a relative abundance of less than 5 fish catch per 100m as indicated in Figure 4.2. *C. carpio* was only present in the protected area. *O. Niloticus* showed the highest relative abundance of 18 and 27 catch per 100m in the fished and protected area respectively.

Fish Mean Lengths.

All the ten species showed that there was no significant difference in fish mean lengths between the two areas, fished and non fished as shown in Figure 5.

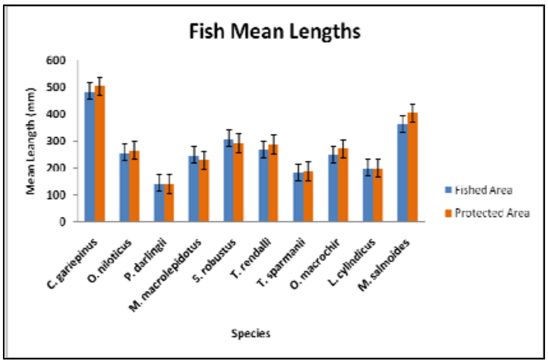

Figure 5: Fish mean lengths

5. Discussion

Species Diversity

Both areas under study showed very low fish species diversity indices and species evenness indices of both areas were just below average. The protected area (Miller's Creek) was expected to exhibit a higher species diversity index than the fished area (Carolina Bank) on the Shannon – Weaver species diversity scale. However, the similarities in species diversity indices of the two areas could be attributed to a number of factors which include;

(a). Pollution in the catchment area; Lake Chivero is highly polluted by raw sewage from the City of Harare and Town of Chitungwiza and many species do not thrive in polluted lakes. The two protected areas of Lake Chivero are adjacent to the Mhanyame (Hunyani) - Marimba River mouths (Figure 3.0), which are the major inlets of untreated sewage thus causing these areas to be the most polluted areas on the lake. Pollution might have decreased the species richness or might have caused local extinction of some species and out-migration of many species which are not tolerant to polluted waters. [15], postulated that species distribution is a result of different tolerances and responses of organisms to physiochemical conditions of the environment.

(b). Heavy poaching activities in the protected area as well as licensed operators' encroachment into protected areas. Poaching and zone encroachment could have simulated commercial exploitation in the protected area and could have also caused out-migrations of sensitive species and disturbances in fish spawning sites. [2], stated that fishing changes the structure of fish communities.

The absence of *C. carpio* in the fished area could be attributed to the general scarcity of the species in the area and also to the fact that *C. carpio* is a riverine cyprinid, [17] and this might explain its appearance in the protected area which is adjacent to the major river mouths and not in the fished area suggesting that the currents in the protected area are stronger than in the fished area which is further away from the major river mouths and in the deeper parts of the lake.

Relative Abundance and Biomass

Heavy fishing removes the larger animals and does not give young fish a chance to grow to their potential size and very few individuals reach sexual maturity [1], thus resulting in a non significance difference in terms of numbers between the two areas.

However, two out of ten species showed significant differences in relative biomass between the two areas. This could be resulting from the fact that protected areas on Lake Chivero were set aside as breeding areas thus the areas are expected to have bigger fish that are sexually mature and can give rise to many other individuals, [4]. Of the two species *C. gariepinus* is a potamodromous species which moves upstream for spawning purposes, [10], and this explains the presence of large sized fish of this species in the protected area which is next to the Mhanyame (Hunyani) and Marimba River mouths. The other species *O. niloticus* is a cichlid; portions of Lake Chivero were set aside in the interest of protecting cichlids which makes the greatest contribution to the commercial catches. The presence of larger sized fish of the family Cichlidae shows that protected areas are important in providing insurance against overexploitation through the provision of refuge for large biomass of sexually mature adults that can give rise to many individuals, [4].

The dominance in abundance of *O. niloticus* over other species in both areas can be attributed to quite a number of factors which includes;

1. Diet: *O. niloticus* is a microphytophagus species (feeds on phytoplankton such as blue-green algae). Of all the microphytophagus fish species of Lake Chivero, *O. niloticus* is the most efficient species in digesting blue-green algae, [14], which is abundant on Lake Chivero due to high nutrient load from the degradation of organic matter and fertilisers leached from adjacent farms, [6]. This ensures a readily available food source and encourages proliferation of the microphytophagus species in which *O. niloticus* has an edge over all other species on the entire lake.

2. Breeding Behaviour: *O. niloticus* is a mouth-brooder, [7]. When female *O. niloticus* senses danger, it picks-up the eggs or fry fish from the nest into their mouth and quickly eludes the areas. This results in high juvenile survivability rates, [10], leading to increased proliferation rates and fast colonisation of foreign systems where there are no natural enemies to control their population growth rates, [3].

3. Hybridization: *O. niloticus* has a tendency of breeding with other closely related species of the same genus such as *O. macrochir* and *O. mossambicus* forming hybrids, [3], that closely resemble *O. niloticus* than the other species. Due to high proliferation rates of *O. niloticus*, the species quickly out numbers other species and repeated cross breeding of *O. niloticus* and its hybrids eventually swamps genes of the other species leading to local extinction of the native species of the same genus,[4].

4. Invasive Species: *O. niloticus* is an exotic species and its proliferation can be attributed to the absence of natural enemies on the lake, [3].

Fish Mean Lengths

The insignificant difference in mean length of the species can be a result of fishing pressure exerted on the protected area by poachers and encroaching licensed commercial operators. This could have homogenised the entire lake in terms of the degree of exploitation. They could also be large amount of movements such that the depleted fished area is quickly re-colonised by fish from the protected area [5] and also the position of protected area in relation to the source of pollution could have caused unpredictable migrations between the two areas as [15], attributed species distribution to be a result of different tolerances and responses of organisms to physiochemical conditions of the environment.

6. Conclusion

The findings revealed that protected areas are essentially effective fish management tools which act as nurseries for depleted areas through adult and larval migrations, and as such, these areas should be dedicated to the protection, maintenance and restoration of biodiversity for the continual existence of fisheries resources.

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