# PROTECTED AREA CONCEPT EFFECT ON SPECIES COMPOSITION AND ABUNDANCE
# A CASE OF LAKE MUTIRIKWI, ZIMBABWE

**MIDLANDS STATE UNIVERSITY**

**A thesis submitted in partial fulfillment for the requirements of the Bachelor of Science Honours Degree**

**of**

**BSc (Hons) Livestock and Wildlife Management,**

**BY**

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## ABSTRACT

A study to investigate the concept of protected areas in the conservation of targeted fish species was carried out on Lake Mutirikwi, Zimbabwe. The research was aimed at establishing differences in fish species composition, abundance and catch per unit effort (CPUE) on different sites of the lake and to enhance conservation and management of targeted fish species through better understanding on the concept of protected area.The study was done using a Completely Randomised Design (CRD) with two treatments and no blocking factor. Biological data (species, count and weight) for individual fish samples were collected from two sampling stations, one protected and the other fished using monofilament gillnets. Species composition, species diversity (H'), species evenness and CPUE were determined in each station.A total of 1310 specimens belonging to 7 species (*Tilapia rendalli, Oreochromis niloticus*, *Oreochromis macrochir, Serranochromis robustus, Micropterus salmoides*, *Clarius gariepinus, and Mormyrus longirostris*) representing 4 families (Cichlidae, Centrachidae, Clariidae, and Mormyridae) were recorded in the 10 sampled stations. All statistical analysis was performed with GenStat Version 14 software. The findings reviewed no significant difference in fish species composition ($F = 0.581$; $p > 0.05$), a significant difference in fish abundance ($F = 0.018$; $p < 0.05$); in terms of biomass ($F = 0.019$; $p < 0.05$) and catch per unit effort (CPUE) ($F = 0.019$; $p < 0.05$) between the protected areas and fished areas. The results add to a growing body of evidence that, populations of commercially exploited fish species can rise considerably within protected areas given time and adequate protection. It is therefore strongly recommended that the Zimbabwe Parks and Wildlife Management Authority is to put in place strong law enforcement and stiff penalties to minimise poaching activities and zone encroachment within the protected areas and also to establish closed fishing seasons, regular monitoring of mesh sizes, and prohibiting fishing activities in littoral zones so as to realise the value of protected areas.



**Key words:** *Abundance, Composition, Fish,Lake Mutirikwi, Zimbabwe.*

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## DECLARATION OF THESIS

I hereby declare that this thesis is composed of work carried out by myself unless otherwise acknowledged and that this thesis is of my own composition. The research was carried out during the period of January 2013 to June 2013. This thesis has not in whole or in part been previously submitted for any other degree or professional qualification.

**Sallymah E. Manika**

**…………………….**

DATE

**16/05/2014**

## CERTIFICATION OF THESIS

I the undersigned, certify that Sallymah E. Manika, a candidate for the degree of Bachelor of Science (Honours) Livestock and Wildlife Management has presented this thesis with title:

***Protected area concept effect on species composition and abundance***

***A case of Lake Mutirikwi, Zimbabwe***

That this thesis is accepted in form and content and that a satisfactory knowledge of the field covered by the thesis was demonstrated by the candidate through an oral examination held on the **12$^{th}$of May 2014**.

Major Supervisor

Mr. J.V. Muzvondiwa

**Signature**…………………………

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# Chapter One

## 1.0 Background Information

Freshwater is an essential resource for all life hence acts as a necessary component of socio-economic development.Fresh water ecosystems are diverse and in most cases are under threats usually from activities carried out in water bodies as well as those done on land. Understanding fish species abundance in freshwater ecosystems is important for wildlife management since reservoirs are not constant systems, a phenomenon reflected by the distribution of fishes within them (Marshall, 1994). The world is currently experiencing very high rates of loss of biodiversity and they have been estimated at 100-1000 times the extinction rates pre-human levels (Convention for Biological Diversity, 2008). Conservationists are alarmed by this loss and are actively engaged in activities designed to protect as much of the remaining diversity as possible.

Rozas & Minello (1997) postulated that knowledge on fish species abundance, density and mobility may provide insight on levels of disturbance, for example poaching in protected areas. Norris *et al* (1995) are of the view that diversity of species present in an ecosystem can be used as a gauge for the health of that ecosystem. Fisheries management options world over are emphasizing property rights over the fisheries that enhance collective responsibility and restricting the total output from the fisheries.

Freshwater protected areas are areas especially dedicated to the protection, maintenance and restoration of freshwater biodiversity through legal and other effective management instruments, (Williamson, 2009). Biodiversity can be monitored through constant reviews of species abundance and composition with protected areas serving as control areas in terms of biodiversity (McClanaham & Kaunda-Arara, 1996).In Zimbabwe, fish are managed under legislation governing wildlife and other natural resources (Parks and Wildlife Act 1996). The Act aims at sustainable utilization of the fishery resource while ensuring that there is no loss of biological diversity.However due to other limiting factors, capture fisheries of Zimbabwe and similar developing world aquatic systems have remained largely open access. Controlmeasures have been based on limiting gear types and mesh sizes but the overall fishing factors have continuously increased. Due to other limiting factors such as difficulties in surveillance and monitoring, the gear restrictions imposed have been largely ineffective.

Species composition and relative abundance of different species are considered as a key aspect for evaluating biological communities (McClanaham & Kaunda-Arara, 1996). Fish abundance as stated by Thomson (2000) 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 Sanyanga (1995) on Lake Kariba reviewed that protected areas had significantly higher abundance as well as higher species diversity on comparison to open fishing areas.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(Sanyanga, 1995). Sanyanga (1995) reviewing the works of Fox (1986) is of the view that fishing success (catch per unit effort) is lower in a fished zone than in an un-fished zone and this is a possible difference expected to be found between protected areas and fished areas.

### 1.1 Limitations of the Study

- Some parts of the Lake is infested by the oxygen weed (*Lagarosiphon major)*, which is a submerged weed and sometimes swept gillnets leaving them hanging on the weeds hence reducing their effectiveness and in the worst cases gillnets could be torn apart.

### 1.2 Problem Statement

Understanding the exploitation and mortality dynamics of the target species is a priority in the face of possible over fishing and collapse of the fishery. The fishery currently lacks proper management practices which is partly attributed to lack of basic biological and ecological information on fish species needed to guide management. Commercial fishermen have a tendency of casting out gillnets and rod and line on restricted (protected) areas. Commercial fishermen often use excessive fishing effort which is way more than the stipulated yardage and some practice fish drive which is not permitted under the set regulations of the permit. This may lead to overexploitation situations, (Walther *et al,* 2003) which might lead to depleted fisheries stocks. The ability to monitor adherence to the stipulated effort among so many players including poaching is extremely daunting for the Zimbabwe Parks and Wildlife Management Authority which is the regulatory authority. As a result the capture fishery is threatened by increasing illegal fishing activities. The apparent staggering fishing pressure may then imply there is over exploitation of the fishery resource. Also commercial fishing operators often complain and raise alarms about what they term “decline in catches” and strongly argue for the legalisation of some fishing methods like fish drive to increase their catchability. On the other hand water level in Lake Mutirikwi is prone to fluctuations annually. It has recently dropped to 15% in December 2012 with irrigation purposes being the major withdrawal. However it is unclear what effect changes in lake level might have on the relative abundance of fish species. Gasith and Gafny (1992) argued that water level fluctuations, either man made or natural affect habitat availability in Lakes.

This scenario leaves gap as far as basic biological information of targeted fish species necessary for the management of Lake Mutirikwi is concerned since natural systems are dynamic and vary in time and space due to changes in biotic and abiotic factors.

## 1.3 Justification

Protected areas are advocated as an essential management tool so as to achieve sustainability in the use of natural resources by providing insurance against over-exploitation and through the provision of refuge for large biomass of sexually mature adults that can give rise to many other individuals (Roberts & Hawkins, 2003). The management systems in place are failing to meet the requirements of fresh water bodies in terms of maintenance of productivity and biological diversity in these ecosystems. To the knowledge of the researcher there is scarce documented data on the fish fauna of Lake Mutirikwi. It is therefore necessary to evaluate the effectiveness of protected areas and also to evaluate the impact of gill-netting on fish species as a way of assessing the conservatory strategies set aside on the Lake and to provide some useful information hence making some recommendations for the sustainable management of Lake Mutirikwi.

## 1.4 Broad Objective

- ❖ To assess the effectiveness of protected area concept on Lake Mutirikwi.

### 1.4.1 Specific Objectives

- To compare fish species composition between commercial fishing areas and experimental (protected) areas of Lake Mutirikwi.
- To compare fish species abundance between commercial fishing areas and experimental (protected) areas of Lake Mutirikwi.
- To compare catch per unit effort (CPUE) between commercial fishing areas and experimental (protected) areas of Lake Mutirikwi.

## 1.5 Study Hypotheses

- **$H_0$:** There is no significant difference on composition of targeted fish species in commercial fishing areas and experimental (protected) areas.
- **$H_0$:** There is no significant difference on abundance of targeted fish species in commercial fishing areas and experimental (protected) areas.
- **$H_0$:** There is no significant difference on catch per unit effort (CPUE) in commercial fishing areas and experimental (protected) areas.

## 1.6 Assumptions

Protected areas serves as fish reserves that can colonize depleted areas through adult and larval migrations.

# Chapter Two: Literature Review

## 2.0 Introduction

During the past decades, consumption of natural resources has increased substantially. Such patterns of increasing consumption are unsustainable for many natural resources. Over 70% of the world's commercially targeted fish species are described by FAO as fully fished, overexploited, depleted or slowly recovering (FAO, 1999). Many fisheries catches across the globe has now leveled off and shows signs of declining as a result of overexploitation (Williamson, 2009) for example *Oreochromis karongae* is one of the most valuable food fishes in Malawi, but populations collapsed in the 1990s due to overfishing, and it is now assessed as Endangered(FAO, 1999). The fisheries resource provides essential nutrition, employment and income for many communities in Africa (FAO, 1999).

The most important commercial fish stocks exploited by fishers in Zimbabwe are within five reservoirs namely Kariba, Chivero, Manyame, Mutirikwi and Mazvikadei(FAO, 1999). The largest fishery in Zimbabwe is on Lake Kariba. These reservoirs supports an open water semi-industrial fishery that exploits commercially important fish species and an artisanal inshore fishery restricted to the shallow inshore water where exploitation is through gillnet.

## 2.1 Threats to Freshwater Biodiversity across the Globe

Natural systems are dynamic and fluctuate in time and space hence freshwater biodiversity is being endangered by a number of key factors that include overfishing, pollution, flow alteration as well as water abstraction, devastation of habitat, and negative impacts of invasive alien species (Millennium Ecosystem Assessment, 2005). In addition to these threats is the impact of global climate change as well as changes in precipitation and runoff patterns (Dudgeon *et al.,*2006). Information of up-to-date and anticipated threats to species and of the areas where they are likely to be most severe is of great importance in enlightening conservation ideologies, policy improvement and developing planning process. Biodiversity assessment process permits for the chief threats to species within regions to be recognized and mapped. Using freshwater fishes as an example and since its one of the most extensively assessed of the freshwater species, the level, nature as well as distribution of major threats can be located or identified. According to Millennium Ecosystem Assessment (2005) Southern African region have 17% of threatened endemic freshwater fish species of the globally endangered species.

However the forms of threats acting upon species can be analysed hence used to warn conservation and development planners. In the instance of freshwater fish, threats identified in different regions essentially reflect the nature as well as the scale of past and present human development activities.

Most ecosystems are under increasing stress, chiefly freshwater hence one fourth of the freshwater fish species are on the margin of getting extinction (IUCN, 1994). Habitat and species loss due to land use change, installation of dams, pollution, overfishing, associated changes in runoff and impact of climate change is relatively far greater in freshwater ecosystems.

**2.2 Challenges in Management of Lake Mutirikwi**

The fishery currently lacks proper management practices which is partly attributed to lack of elementary biological and ecological information on fish species needed to guide management. The ICBD inspires parties to ascertain and monitor activities that may be detrimental to biodiversity and guard biodiversity through different measures such as conception of protected areas and implementation of regulations and motivations aimed at warranting sustainable use.The capability to monitor adherence to the stipulated effort among so many players including poaching is extremely daunting for the Zimbabwe Parks and Wildlife Management Authority which is the regulatory authority at Lake Mutirikwi. Therefore the capture fisheries in Lake Mutirikwi remained basically open access. Control measures have mostly been directed on limiting gear types and mesh sizes but the overall fishing factors have unceasingly increased. Even the gear restrictions imposed have been fundamentally unsuccessful due to difficulty in monitoring and surveillance.

As a result the capture fishery is threatened by increasing illegal fishing activities. Poachers encroach in fish spawning sites that are set aside to protect the interest of cichlids which are the most dominant commercially important fish species on Lake Mutirikwi. Also commercial fisheries operators have a tendency of using fishing effort which is way more than the stipulated yardage which may result in overexploitation of the fisheries resource hence leading to reduced fish catches or biodiversity loss in the long run if no vigorous action is done to keep commercial fishermen and poachers out of these areas (Walther *et al*, 2003). These fishing operators also often encroach into protected areas in the bid to increase their catch and they sometimes seine net in protected areas. The apparent staggering fishing pressure may then imply there is over exploitation of the fishery resource. On the other hand water level in Lake Mutirikwi is prone to fluctuations annually. It has recently dropped to 15% in December 2012, (Annual Report, Lake Mutirikwi Fisheries, 2012). The major withdrawal of water in Lake

Mutirikwi is the irrigated farming lands on the lowveld to the southwest of Triangle town, where sugar cane has been the main crop. However it is indistinct what consequence in lake level changes might have regarding relative abundance of fish species. Gasith and Gafny (1992) are of the view that water level variations due to the influence of human activities or natural processes, affect the availability of habitat in Lakes. Sloman *et al* (2001) and Imre *et al* (2002) indicated that seasonal variations in the water level define the presence or absence of any fish species in a short term inundated area and also inflame complicated alterations in the community structure. Sloman *et al* (2001) established that unstable environmental conditions considerably altered supremacy structure of trout population that was stable under normal constant environmental conditions.

### 2.3 Parameters for Monitoring Fish Populations

A fish population is well-defined as a group of entities of the equivalent species or subspecies that are genetically, spatially, or demographically detached from other groups (Wells and Richmond, 1995). A population will have an exceptional set of dynamics for instance growth, recruitment, and mortality that influence its current and future status. Population assessment and stock assessment are usually used interchangeably by some fishery managers. Thomson (2000) postulated that stock assessment refers to that fraction of the fish population that is utilisable or harvestable by a fishery and also abundance as the parameter estimated to monitor fish populations. Biologists usually do not examine all the fish as population hence base their inferences on a sample of individuals from the population. However, where, and when the samples are drawn has a remarkable influence on the data quality and validity of inferences. The checklists of the total fish fauna present in an area can be made from a variety of sources, including landings by commercial fleets, research vessel catches, angler reports, sightings and sport fishing records, providing a relatively complete picture of the fauna, (Thomson, 2000). Population estimates can be made using indices such as catch per unit effort (CPUE) as a measure of relative abundance which is a relative quantity of the size of a population or subpopulation, and is usually measured in terms of weight as well as the number of fish caught per standard unit of fishing effort (Mark, 1999).

Fish abundance and species composition can be used in fisheries science, economics and management to determine the type of fishery to set up, target species to explore, exploitation method and the type of fishing gear to use (Hannesson, 1998). This information is essential for the establishment of maximum sustainable exploitation levels and mesh size restrictions which may prevent the fishery from crushing(McClanahan and Kaunda-Arara, 1996). Thomson (2000) described population dynamics as basically the understanding of changes in fishery patterns and concerns such as habitat destruction as well as predation and sustainable harvesting rates.

**2.4 Species Composition**

Species richness may be defined as the number of different species presented in an ecological community, region or landscape (Shannon, 1948). Gaston and Spicer (2004) defined species richness as the number of different species in an ecosystem and proposed that species richness is the essential unit to assess the homogeneity of an ecosystem. Species richness may be simplified as a count of species, and it does not take into account the species abundances or their relative abundance distributions. In contrast, species diversity considers both species richness and species evenness. Species evenness articulates how evenly the entities in the community are distributed over the different species (Shannon, 1948).

Monitoring of species composition (assemblage structure) is important to evaluate species trends, species interactions, and status of rare species. Knowledge of assemblage structure over time, and cognisance of the natural variation of fish populations and their reactions to short-term disturbance events and long-term habitat or biological change is the basis for understanding dynamics of the fish assemblage, for example its stability, persistence, and resilience (Roberts, 1997). A common measure of biodiversity is the number of species recorded in that area; however, whether less common species are recorded depends largely on sampling effort, (Turchin, 2003). Depths of simple species richness are linked to area size, and are also affected by sampling intensity (Gulland, 1969). When moderately small numbers of samples are taken from a given area, the numbers of species identified will be relatively lower as compared to a sample size that is relatively large (Gaston and Spicer, 2004).

**2.5 Species Diversity Indices**

Species diversity that is relatively higher indicates a greatly complex community, hence the greater the variety of species the larger the array of species interaction. In most instances population interaction comprising energy transfer (food webs) competition, predation and niche allotment are theoretically more complex and diverse in a community of great species diversity. Lowe-McConnell (1982) is of the view that great species diversity links with community stability; which is the ability of a community organisation to resist disturbance of its components and remain unaffected. Simpson index and Shannon-Weiner index are common measures of species diversity index commonly used (Lowe-McConnell, 1982). The Simpson index is used as a measure of diversity and it takes into cognisance the number of species as well as the evenness of individual occurrence of various species. Shannon-Weiner Index is a popular index which is widely used.

The Shannon index is again an expression of how many equally abundant species would have diversity equal to that in the experimental assemblage. In a sampling event, the Shannon index measures the degree of uncertainty. This means that when the diversity is low, the certainty of catching a particular species is high. On the other hand if diversity is relatively high, then it will be challenging to predict the identity of an individual picked at random. It is calculated as follows;

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

S = being the sum of species in the sample

$n_i$= being the number of individuals belonging to the *i*th position of S species in sample

n = being the sum of individuals in the sample

**2.6Aquatic Biodiversity Dynamism**

Fish diversity and distribution is influenced by several natural factors such as depth, temperature, oxygen and rainy season movements. Abiotic factors include artificial barriers like dam walls and weirs, siltation, introduction of exotic species, commercial fishing, poaching and pollution. McClanaham and Kaunda-Arara (1996) argued that the variation in species richness are a consequence of differences in ecological time, evolutionary time, climatic liability, climatic stability, spatial heterogeneity, productivity, constancy of primary production, predation, competition and disturbance.

Variables that can be used to predict species richness patterns depend largely on the scale of the study. Habitat heterogeneity, total habitat area (and connectivity) and net primary productivity are useful predictors of species richness in marine, freshwater and terrestrial ecosystems at regional level and at local level, (Williamson, 2009), suggested that regional-scale processes may be assumed to affect a local environment in a reliable way, yet there are often remarkable differences in species richness patterns over distances of a few meters, or even centimeters, depending on the body sizes and mobility of the taxonomic group involved. Williamson (2009) also attributed habitat complexity to be a very useful predictor of species richness at local scales in a number of different ecosystems, whilst, Holsinger (2007) added disturbance events as variables that may also affect local species richness and tropical marine examples include pollution and hurricanes. Fish abundance and species composition can also be affected by various factors such as activities in the catchment area, introduction of invasive alien species and pollution (Gasith *et al*., 1992; and Paucer, 2010).

### 2.7 Effects of Damming on Diversity of Riverine Fish Species

There are many different motivating factors that lead to creation of dams in major rivers that include creation of reservoir for hydroelectricity power, creation of reservoir to preserve fresh water stock, creation of recreational fishery and also as a measure to prevent flooding downstream. However, there are several factors that lead to loss in biodiversity in fish after construction of a dam.

The nutrient concentration, water temperature, water chemistry and sediment profile will all likely be altered by the installation of a dam. Segmentation of fish population due to dams without a fish ladder is yet another major problem that is faced due to damming since dam walls provide barriers that may confine movements of migratory fish species and may cause a decline in population of these species (Wells, 1995). Some fish species may fail to reach their original spawning grounds due to damming which will be acting as a barrier hence this may lead to a major decline or extinction of species that have very specific spawning environments. The overall result will be generation of separate populations with less genetic diversity. Marshall (1994) argues that some species such as the predator fish *M. salmoides* and *S. robustus* will have a conducive environment since they favour pelagic environments unlike some of the native species which will be reduced in their population sizes due to their adaptability to riverine conditions.

### 2.8 Pollution and Fish Species Abundance

Water pollution refers to the water contamination by a variety of chemical substances or eutrophication triggered by several nutrients and fertilizers (Turchin, 2003). The pollutants may be materials leached out and transported from land by water percolating through the soil and running off the surface to aquatic systems (Nhapi, 2004). Aquatic systems are the major recipient of an extensive array of wastes produced by man. However these wastes under the influence of bacterial action deplete the dissolved oxygen by consuming it through biochemical oxidation reactions (Paucer, 2010) hence this may suffocate the fish and other aquatic animals (Nhapi, 2004). Studies by Paucer (2010) reviewed that pollution from sewage leads to increased sexual hormones in fish water habitat and lowers fish reproduction rates. Nitrates results in the overgrowth of aquatic algae and reduces oxygen content in water (Paucer, 2010). Suspended solids from pollutants or silt also interfere with fish respiration and may clog or damage fish gills and suffocate eggs and juveniles or may submerge fish habitat resulting in lowered reproduction rates and emigration of species (Paucer, 2010).

Many species cannot abide lower levels of dissolved oxygen for instance <$4mgL^{-1}$ and thus species richness decreases as the concentrations fell below this level hence the air breathing species *C. gariepinus* are the only one to remain at the most polluted sites, (Paucer, 2010). Roberts(1997) said species distribution is a result of different tolerances and responses of organisms to physiochemical conditions of the environment.

**2.9 Effects of biotic factors on Fish Species Abundance**

Hybridisation has the effect of reducing fish biodiversity. Zimbabwe has two groups of *Tilapine* fishes namely the substrate spawners of the genus *Tilapia*and the mouth brooders of the genus *Oreochromis*(Marshal, 1994). The increase in occurrence of *O. niloticus* can cause serious threats to indigenous cichlids through competition and crossbreeding. This species is known to crossbreed with two indigenous cichlids *O. mortimeri* and *O. mossambicus*. Inter-breeding will result in a reduction of the abundance of pure stocks resulting in loss of biodiversity. Since *O. niloticus* was introduced in Lake Mutirikwi only isolated insignificant numbers had persisted in the fish yield records at the station all along but recently commercial gillnet yields from 2010, 2011 and 2012 point out to very significant annual yields of 7.08%, 8% and 10.5% respectively of this species (Annual Report, Lake Mutirikwi Fisheries Research, 2012). *Oreochromis niloticus* is a successful invader which poses great risk to the extent of extinction of commercial and ecological important indigenous species.

**2.10 Effects of Exotic Fish Species on Native Fish Species**

Fish species are commonly introduced by humans, either deliberately or unknowingly into waters to which they are not native. Deliberate introductions are typically made to improve local fish faunas. However in most cases they often have the opposite effect, causing declines in fisheries endangered species and headaches for management agencies. Introduced species are usually most successful in environments that have been altered by humans, where the native species are already stressed or reduced in numbers. Zambrano *et al* (2006) are of the view that introduced species may be the direct cause of the disappearance of native forms through predation, competition, diseases, and hybridisation. Studies carried on the Africa's Lake Victoria show that the introduction of the Nile Perch leads to a massive extinction of numerous fish species despite the increase in revenue generated from fisheries after its introduction (Masai *et al.*, 2001). Lauck*et al*, (1998) proposed that reductions in native species may be due to direct interaction with nonnative fish species, or may result from enlarged fishing pressure or changes in land use put forth by the existence of newly established species.

### 2.11 Overfishing and Fish Abundance

Fishing changes the structure of fish communities, (Walther *et al*, 2003). Higher fishing pressure result in fall in numbers of the larger fish and does not provide the juveniles chance to grow up to their potential. On the other hand fishing pressure that is relatively low on the inshore fish stocks allows more fish to grow to their potential maturity age. Holsinger (2007) classified two main classes of overfishing which leads to fisheries crushing or reduced in productivity as recruitment overfishing and growth overfishing.

Fish recruitment refers to the proportion of new juveniles in a given year that enter a population (Lowe-McConnell, 1982). Fish populations can vary by orders of magnitude as time moves on. According to Holsinger (2007) recruitment overfishing occurs when the adult populations are exposed to heavy fishing pressure that the proportion of spawning biomass is reduced to the point whose capability to replenish itself will be limited. When fishes are harvested at an average size that is smaller than the size that would produce the maximum yield per recruit it results in growth overfishing (Holsinger, 2007). However, growth overfishing is mostly common as compared to recruitment overfishing, but does not obtain the response given to recruitment overfishing since it does not result in some serious threats to the sustainability of the fishery resource (Holsinger, 2007).

### 2.12 Role of Protected Areas in Fishery Resource Management

In conservation of biological diversity, protected areas are significant cornerstones of sustainable development ideologies. They are the critical tools in conservation of biodiversity in the face of global crisis of species extinction and gradual decrease of the world's natural capacity to upkeep different forms of life (CBD, 2008). Unfortunately, the importance of protected areas remains poorly understood and undermined despite their substantial monetary and non-monetary values. Many fisheries are now on the edge of collapsing hence fishery managers are looking to protected areas as essential tools in their rescue (Roberts & Hawkins, 2003). Hannesson (1998) postulated that protected areas offer direct protection to the proportion of the total assemblage of fish stock within its margins since fish migration would be restocking depleted areas hence attaining sustainability. However the extent and range of the spillover of fish to the depleted areas depends on the dispersal characteristics of the fish populations that reside in the reserve. Protected areas with stabilized fish populations within their boundaries might as well provide a comparable function in bordering areas if the spill over is significantly effective. This would reduce some variations in species composition as well as their abundance in the long run (Lauck *et al.* 1998).

Protected areas also increase the market value of a fishery by boosting its species composition and increasing catchability. According to Williamson (2009) time closures are done to provide and safeguard the breeding stocks so as to enhance market value by altering selectivity. Sanchirico (2000) is of the view that protected areas provides researchers with undisturbed areas hence forming new breaks for scientific researches and offering evade against management slip ups.

### 2.13 Fish Migration

The major three purposes which had been traditionally linked to fish migration are; feeding, refuge and spawning (Binder *et al,* 2011). However, for juveniles that have relatively low energy reserves and susceptible to predators, the chief reasons for movement are far more essential to survival and growth than is for larger fish. According to Pullin & Lowe-MaConnell (1982) fish migrations seem to have evolved as a mechanism to place adult fish in favourable feeding places and to place larval and juvenile fish in favourable places for survival. Roughly 2.5% of all fish species undertake migrations (Binder *et al*, 2011). However the scale of migrations is greatly variable hence can range from hundreds of meters, as in stream dwelling fishes and some coastal and also up to thousands of kilometers for instance *Anguilla bengalensis labiata* (Binder *et al*, 2011). The migration timing typically takes place on a seasonal scale, although some species show synchronized regular movements for instance vertical or tidal migrations.

Fish migrations are characteristically grouped into categories, based subjectively on their association to the freshwater or seawater boundary. Migrations that takes place exclusively within freshwater are classified as potamodromous (Binder *et al*, 2011). Potamodromous migrations can occur solely in lakes for instance lake trout, *Salvelinusnamaycush*, in rivers and streams for instance brook lampreys, or can span both lake and fluvial habitats. Migrations that cross the freshwater or seawater boundary are categorized as diadromous (Binder *et al*, 2011).

### 2.14 Use of Gillnets in Surveys

Gill netting is a commonly known method which is usually used by commercial as well as artisanal fisherman in marine as well as freshwater systems (Sutherland, 2000). The use of gill nets in commercial fisheries is managed and regulated by enforcement agencies since they are subject to misuse (Krebs, 1989).Gillnets are also used by fishery scientists to monitor fish populations (Roberts, 1997). Along the upper lining of the gill nets is usually a float line and a lead line on the bottom lining, (Sutherland, 2000). Catch per unit effort is usually used to express gillnet catches for census purposes and the effort is obtained by multiplying net length with time for which the net is set (Roberts, 1997).

Gillnets, like most passive gear, have an advantage because they are simple in their design and construction. They can be repaired relatively easily and at a low cost, this is all important when used in lakes where large numbers of alligators live. Alligators can make large holes in the nets, destroying the net's effectiveness, nothing is worse than trying to remove a live, mad alligator from a net.

Several methods may be used when laying or setting nets in the water. A few nets can be tied together to make one long net which is laid parallel to the Lake shore or separately laid at random point near the shore, preferably an area that is relatively weed free, as excessive amounts of weeds decrease the efficiency of the gillnet. Another way is to use the nets singularly and lay them at right angles to the shore line. Nets may also be laid in a semi-circle from the shore hence several nets may have to be joined and the fish driven or chased into the net.

### 2.15 Gillnet Gear Selectivity

Usually the use of gill nets is for a specific targeted size of fish hence the size of mesh openings determine the size of the targeted fish by preventing backward movement once their gills are entangled by the net and also allowing the juveniles to pass through (Krebs, 1989). Gillnets provide a “passive” capture method that works by entanglement in the net. Fish are caught as they attempt to swim through the opening in the mesh and get stuck. The gear is called “passive” because fisheries personnel do not actively move the nets once they are laid in the intend location. Gillnets are the most selective of all the types of fishing nets because mesh size determines exactly the body diameter (body depth) of fish that will be caught rather than just size as for the other nets, however, according to Sutherland (2000) where a general survey using gillnets is required and selectivity in not an important factor, the use of nets with variable mesh sizes can be as effective as other non-selective survey nets. The selectivity of gillnets is skewed towards fishes which are medium in size as compared to active gears for instance trawling where the proportion of fish caught in net increases with length.

### 3.0 Study Area

Lake Mutirikwi, formerly known as Lake Kyle is the second largest expanse of open water in Zimbabwe after Kariba. It lies in south eastern Zimbabwe, south of Masvingo.

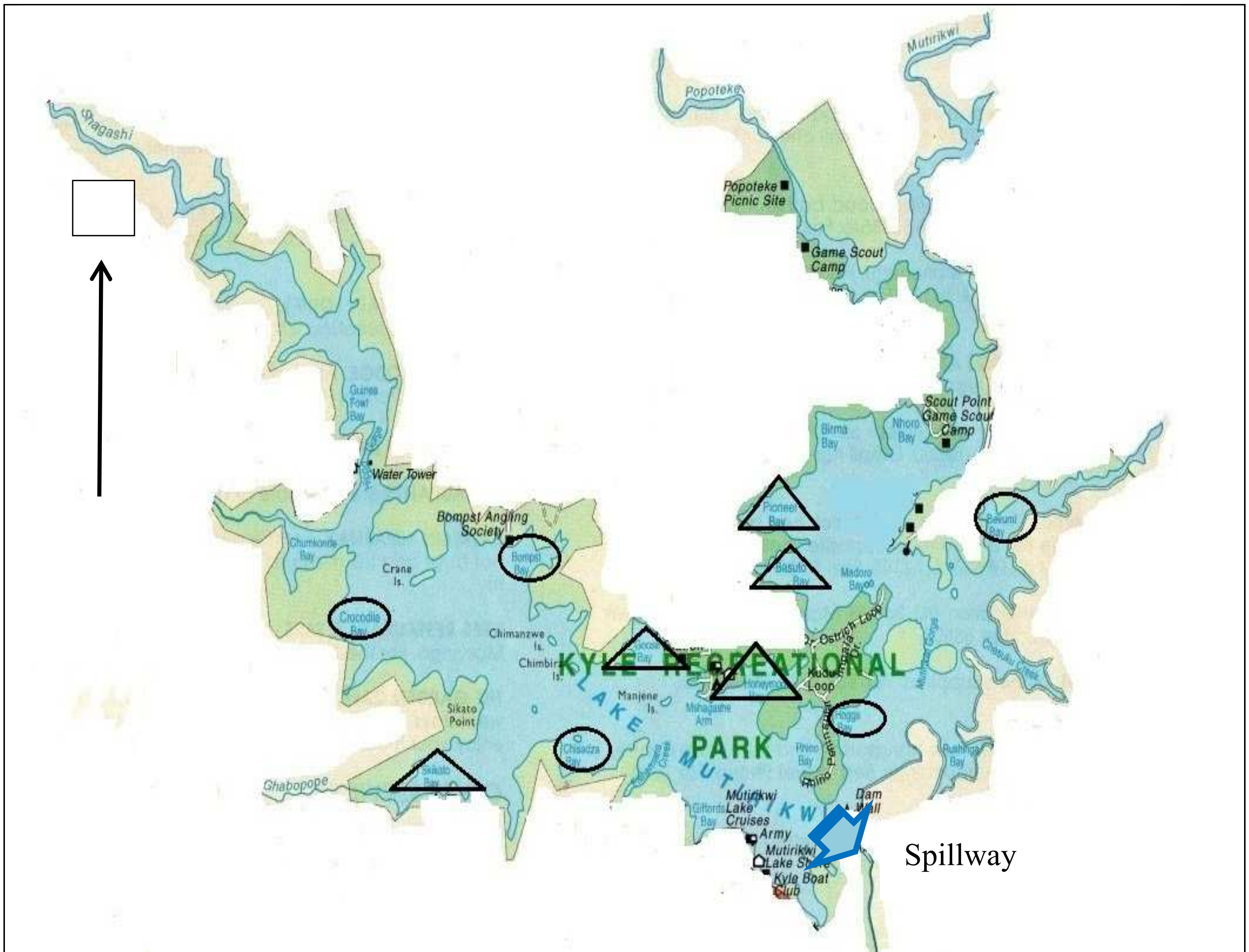


**Figure 1**: Geographical map of Lake Mutirikwi showing fish sampling stations. Marked by triangles △ are protected bays and those marked by circles ○ are fished bays.

Thelake is found in agro-ecological region four. Lake Mutirikwi area has a long term (1899-2000) average annual rainfall of 635mm. Summer rains November to April often fall sporadically and long dry spells are common. The mean maximum daily temperature ranges from 21°C in June to 29°C in October and the mean daily minimum temperature ranges from 5°C in July to 17°C in January

(Masocha, 2009). The Lake covers about 90Km² and was created in 1960 with the impoundment of Mutirikwi river on the confluence of Mutirikwi and Mshagashe River (Zimbabwe National Water Authority, 2010). At full supply level (F.S.L) the Lake has a surface area of 9 069 hectares, a capacity of 1 285 576 million cubic metres (Zimbabwe National Water Authority, 2010). It is 56m deep at its deepest point, with a mean depth of 16m at F.S.L (Zimbabwe National Water Authority, 2010). The Lake lies 1040m above sea level, between latitude 20°15'S and longitude 31°0'E. The Lake is dendritic, with a shoreline of 238Km at F.S.L, and has two main arms, caused by the valleys of the Mshagashe and Mutirikwi rivers (Vincent and Thomas, 1960). Some parts of the lakeshore are steep and rocky and covered by open woodland. The major tributaries of Lake Mutirikwi include the Mbebvi River, Matare River, Pokoteke River, Umpopinyani River, Makurumidzi River and Mshagashe River. The dam wall 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 diadromous fish species such as the redeye labeo (*Labeo cylindricus*), (Magadza, 1997).

### 3.1 The Lake Management

Commercial fishing industry on Lake Mutirikwi is controlled by the State through Parks and Wildlife Management Authority which limits access, closes areas to fishing and set restrictions on the fishing gear. Inshore commercial fishery in the littoral and sub-littoral zone of Lake Mutirikwi started in 1961, a year after the completion of the dam wall. At that time the legal operators were allowed to use passive gillnets for gillnetting, and seine net for seining. Fishing operators are also regulated by annual permits with 10 year lease agreements depending on compliance with regulations. The legal operators are allowed to use passive gillnets for gillnetting, with a minimum mesh size of not less than 3″/76mm (stretched mesh) and a daily total yardage of not more than 1600m. Operators are not allowed to fish in closed / protected areas and from within 150m of developed areas, (Annual Report, Lake Mutirikwi Fisheries Research, 2010) In turn each commercial fishery is entitled to submit catch returns for the gill nets per month to Fisheries Research Office for resource monitoring. Currently 6 commercial fishing co-operatives are operating in the Lake. Illegal gillnetting is extensively done with a third of the total annual production estimated to be harvested by poachers and to lesser degree anglers. An herbivorous cichlid, *Tillapia rendalli* presently dominates the commercial fisheries sector with *Oreochromis mossambicus* and *Oreochromis macrochir* lagging behind. *Oreochromis niloticus* became the fourth most dominant species as observed on the fisheries return sheets in 2011 and has risen to be the third most dominant fish species in 2012. *Clarius gariepinus*, *Marcuseniusmacrolepidotus*, *Mormyrus longirostris*, *Labeo cylindricus*, *Serranochromis robustus jallae, Micropterus salmoides* and *Barbus holubi* also inhabit the lake (Annual Report, Lake Mutirikwi Fisheries Research, 2012). The lake still has great aesthetic value as its waters are still clear and devoid of massive unsightly weeds or massive algae associated with eutrophic waters.

## 3.2 Experimental Design

The study was done using a Completely Randomised Design (CRD) with two treatments and five sampling sites per treatment (10 experimental units).

## 3.3 Data Collection

Fish samples were collected monthly from January up to June 2013 using gill nets. A fleet of monofilament gillnet survey nets of different mesh sizes ranging from 3.5" to 4.5" (stretched mesh) were used for this research. The different mesh sizes used were 3.5", 4" and 4.5". All the nets were 4 meter long deep nets and were arranged into panels making cumulatively a total length of 363 metres net length. During the study, a manual dinghy belonging to Lake Mutirikwi Fisheries Research Station was used.

Ten sites were chosen, five protected (Goose bay, Basuto bay, Pioneer bay, Sikato bay and Honeymoon bay), where fishing is strictly prohibited and the other five which are open fishing areas (Bompst bay, Hoggs bay, Crocodile bay, Chisadza bay and Bevumi bay). Nets were laid in these areas on daily basis except on weekends during the sampling period. Gillnets were laid either along the shoreline or perpendicular to the shoreline but uniformity within the 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 large meshed nets stretched further away from the shore into deeper waters.

The catch on all gillnets for a particular fishing area was considered as a single sample and all gillnets fished one night from 1600hrs to 0600hrs of the next morning allowing a soak time of 14 hours. Catches from all gillnets was sorted according to species, and each species was counted and weighed separately. For each species, weight (g) and total number of fish caught were recorded. All recordings were done on site in the morning whilst fish samples were still fresh.Species identification was done using protocols described by Skelton, (1994). The data was captured into a computer using Microsoft Excel Package (2010 edition).

### 3.4 Data Analysis

Two way ANOVA design was used for analysing the differences of means in CPUE.

- Estimation of relative abundance was done using Catch per Unit Effort (CPUE) as shown in the formula below;

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

**C** = being the catch

**F** = being the fishing effort, (measured in terms of fishing days)

**q** = being the catchability coefficient

**N** = being the number of fish in the population (Marshall and Maes 1994)

- Shannon Weaver index of diversity was used to calculate the species diversity as shown below;

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

**S** = being the sum of species in the sample

**n*i*** = being the number of individual belonging to the *i*th position of **S** species in the sample

**n** = being the sum of individuals in the sample, (Thomson, 2000).

- Shannon Weaver index of species evenness was used to calculate species evenness as shown below;

$$\mathbf{E} = \frac{\textbf{Species Diversity}}{\textbf{InS}}$$

Where Species Diversity = the Shannon WeaverDiversity index of an area.

S = being the species richness of an area.

# Chapter Four: Results

### 4.0Fish Species Composition

A total of 1310 specimens belonging to 7 species (*Tilapia rendalli, Oreochromis niloticus*, *Oreochromis macrochir, Serranochromis robustus, Micropterus salmoides*, *Clarius gariepinus, and Mormyrus longirostris*) representing 4 families (Cichlidae, Centrachidae, Clariidae, and Mormyridae) were recorded out of the 10 sampled stations.The family Cichlidae was represented by *Tilapia rendalli, Oreochromis niloticus*,*Oreochromis macrochir andSerranochromis robustus.* The family Centrachidae was represented by *Micropterus salmoides*, whilst*Clarius gariepinus*was representing the family Clariidae and lastly*Mormyrus longirostris* representing the family Mormyridae.**Table 1** below shows the list of commercially important fish species identified according to their families and common names.

**Table 1:** Fish Species Caught in Fished and Protected Areas of Lake Mutirikwi

| Family | Common name | Scientific name |
|---|---|---|
| **Cichlidae** | Red breasted bream | *Tilapia rendalli* (Boulenger, 1896) |
| **Cichlidae** | Greenhead tilapia | *Oreochromis macrochir* (Boulenger, 1912) |
| **Cichlidae** | Nile tilapia | *Oreochromis niloticus* (Linnaeus, 1758) |
| **Cichlidae** | Yellow belly bream | *Serranochromis robustus* (Gunther, 1864) |
| **Centrachidae** | Largemouth bass | *Micropterus salmoides* (Lacepede, 1802) |
| **Clariidae** | Sharptooth cat fish | *Clarius gariepinus* (Burchell, 1822) |
| **Mormyridae** | Eastern bottlenose | *Mormyrus longirostris* (Peters, 1852) |

### 4.1 Fish Species Diversity and Evenness

Using species diversities on a Shannon-Weaver diversity scale protected area had an index of 1.63 and fished area having an index of 1.70. Therefore the protected area and fished area both showed low species diversities with reference to Shannon-Weaver diversity indexwith the scale of one representing an area with low species diversity and six representing an area with higher species diversity.The protected area had a species evenness of 0.84 with fished area having species evenness of 0.87. Hence both areas had relatively fair species evenness with reference to Shannon-Weaver species evenness scale of zero to one as shown in **Table 2**below.

**Table 2:** Diversity and Species Evenness Indices for Protected and Fished Areas

| Area | Protected Area | Fished Area |
|---|---|---|
| **Shannon – Weaver Index** | 1.6305 | 1.7015 |
| **Species Evenness** | 0.8379 | 0.8744 |

### 4.2Relative Abundance of Fish Species by Count

The most abundant family in the total catch, both in terms of number and weight was Cichlidae(57.71%) followed byMormyridae (21.37%); Centrachidae (12.98%) and lastly Clariidae (7.94%). The dominant speciewas *T.rendalli* (31.98%) followed by *M.longirostris* (21.37%); *O.niloticus* (18.32%); *M.salmoides* (12.98%); *C.gariepinus* (7.94%); *S.robustus* (6.95%); and lastly *O.macrochir* (0.46%).The most widely distributed cichlid speciein both fishing areas was*Tilapia rendalli*with a relative abundance of 22.37% in protected area and 9.62% in fished area. The second most abundant was *M.longirostris*with a relative abundance of 15.42% in protected area and 5.95% in fished area.*Oreochromis macrochir*was the rare of the family Cichlidae in both areas with a relative abundance of 0.15% in protected area and 0.31% in fished area.However in order to satisfy parametric assumptions of a normal distribution the abundance was log transformed. The two way ANOVA revealed that the abundance of fish species in terms of count differed significantly ($F = 0.018$; $p < 0.05$) between the protected area and fished area. The relative abundance of the fish species caught during sampling is shown in **Figure 2** below.

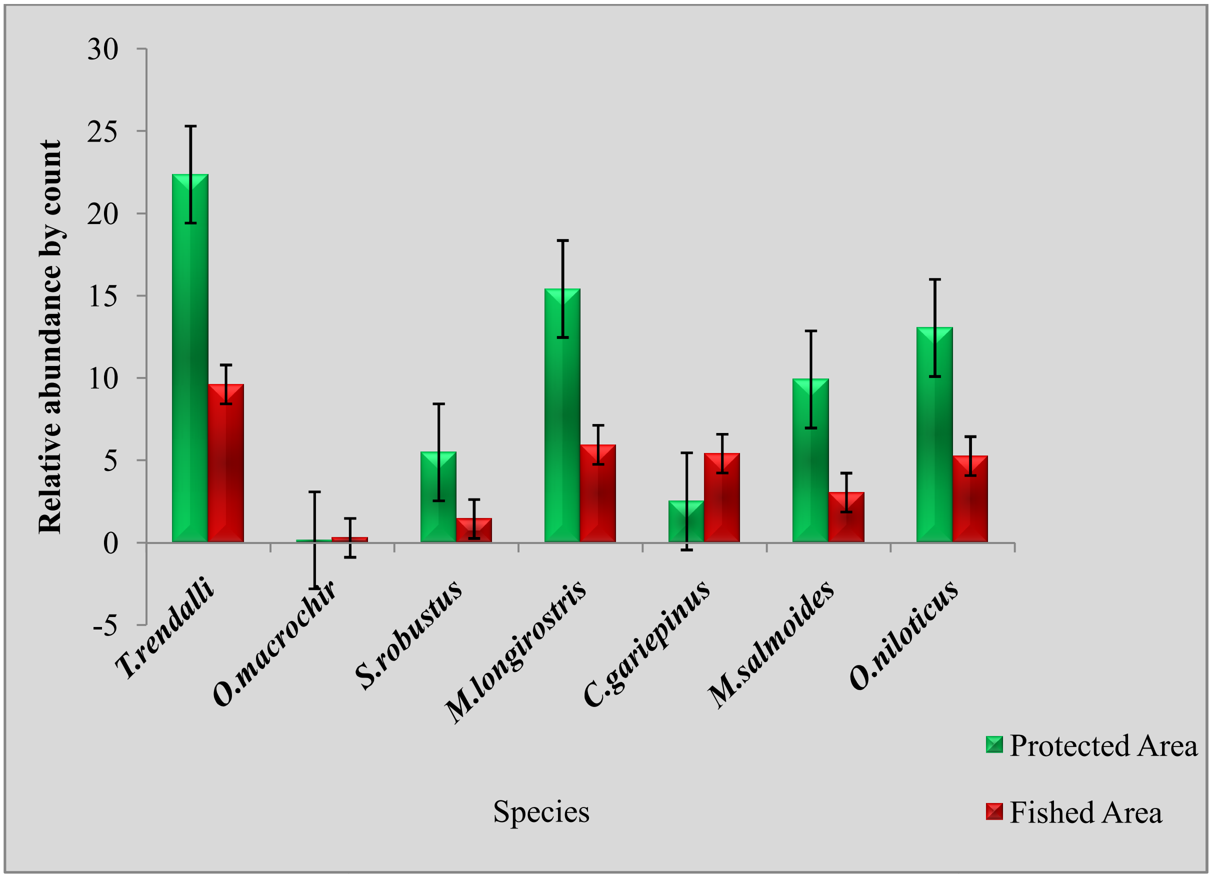


**Figure 2:**Relative abundance of fish species by count over the period of six months between protected and fished areas

### 4.3 Relative Abundance of Fish Species by Biomass

With respect to both protected area and fished area, members of the family Cichlidae was the most dominantin terms of biomass accounting for53.4%,followed by Mormyridae (22.3%);Clariidae (13.6%) and lastly Centrachidae (10.2%).The fish species with the most dominant biomass in both fishing areas was*T.rendalli* with a relative abundance of 22.44% in protected area and 7.36% in fished area. The second most abundant was *M.longirostris* with a relative abundance of 17.77% in protected area and 4.52% in fished area.*Omacrochir* was the rare in both areas accounting for 0.12% in protected area and 0.18% in fished area.The abundance was log transformed in order to satisfy parametric assumptions of a normal distribution. The two way ANOVA revealed that the abundance of fish species in terms of biomass differed significantly ($F = 0.019$; $p < 0.05$) between the protected area and fished area. The relative abundance of the fish species biomass caught during sampling is shown in **Figure 3**below.

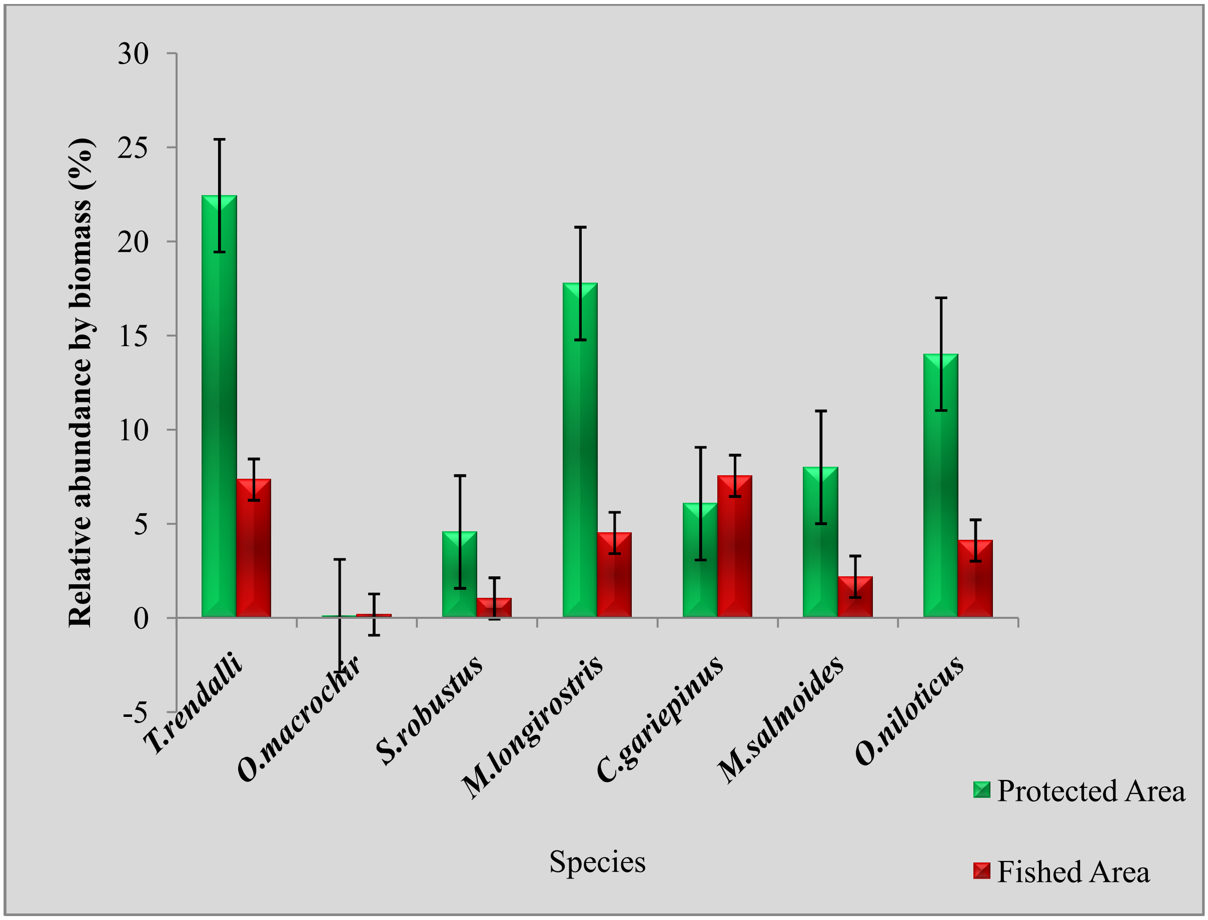


**Figure 3:**Relative biomass between protected and fished areas.

### 4.4 Catch Per Unit Effort (CPUE)

The overall catch per unit effort was higher in protected area with 3909g100m$^{-1}$ whilst the fished area recorded 1444g100m$^{-1}$. The CPUE was also log transformed in order to satisfy parametric assumptions of a normal distribution.Using the two-way ANOVA catch per unit effort (CPUE) in terms of biomass differed significantly ($F = 0.019$; $p <0.05$) between the two areas.The overall CPUE in biomass of all the species caught during the survey are shown in **Figure 4**below.

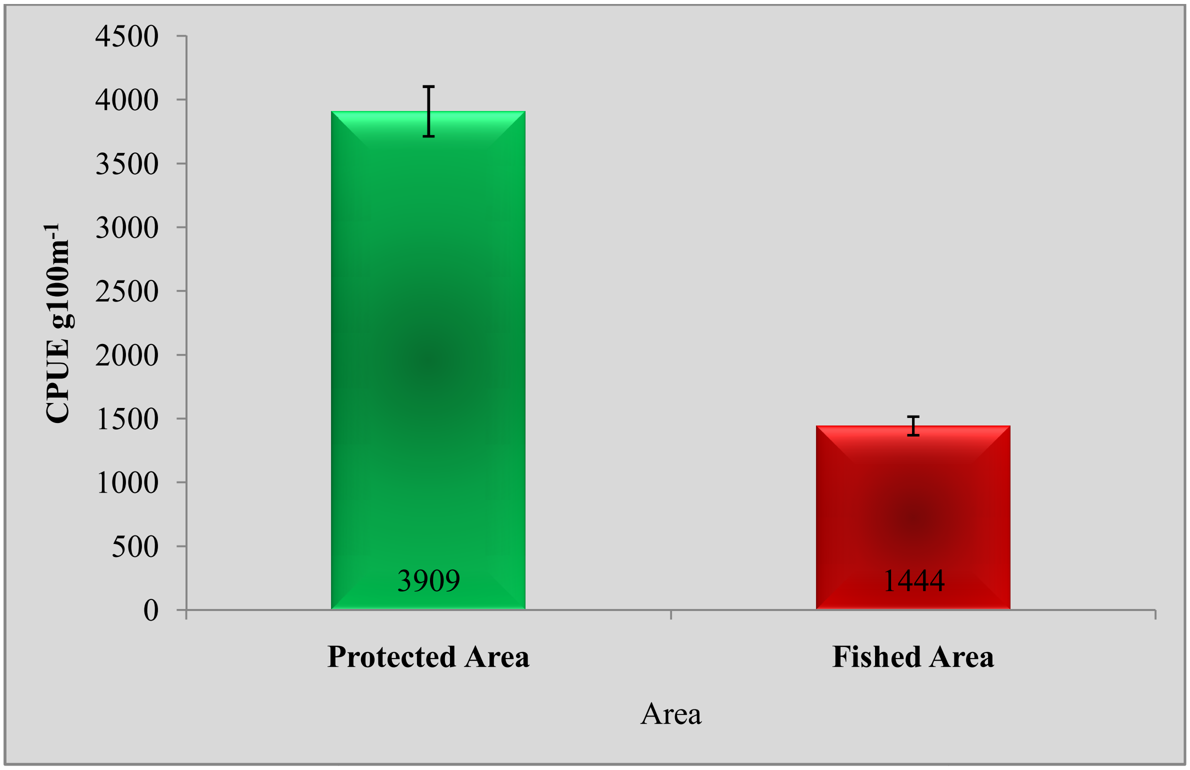


**Figure 4:**Catch per Unit Effort (CPUE) in g100m$^{-1}$ between protected and fished areas.

# Chapter Five: Discussion

### 5.0Fish Species Composition

There was no difference in terms of fish species composition in both areas under study. The two areas showed low species diversities with reference to Shannon-Weaver diversity index. The similarities in species composition of the two areas could be attributed bymany factors. It is expected that protected areas in aquatic ecosystems function to maintain or enhance fishery yields through recruitment subsidies to fished areas from improved populations within the protected areas (spillover effect).It is driven by a buildup of fish species population density and biomass and thus increased competition for space and resources within the protected areas.This general effect of management zoning is consistent with work presented byWilliamson (2009) regarding fishery effects and benefits of marine protected areas within the Great Barrier Reef Marine Park.

Also heavy poaching activities that were observed in the protected areas could have matched the area to an open fished area coupled with fishing pressure from licensed commercial operators frequently caught encroaching into protected areas. Poaching in protected areas could have also caused out-migrations of sensitive species and disturbances in fish spawning sites. Iudicello*et al* (2003) are of the view that fishing changes the structure of fish communities.

The decline and disappearance of some species may have been attributed by the absence of the fish ladder on the dam wall.

Pollution in the catchment area canalso be suggested as one of the possible factors that had led to decline of fish species composition of Lake Mutirikwi in previous years. The gradual increase in abundance of *O.niloticus* may have been associated with gradual rise in pollution levels most likely from Mshagashe River hence this may have caused a negative impact on other fish species.

Seasonal lake level fluctuations can also be suggested as another factor which had led to decline in fish species composition. This seasonality in lake level has potential effects on the lake limnochemistry and the primary productivity.Roberts (1997) postulated that species distribution is a result of different tolerances and responses of organisms to physiochemical conditions of the environment. Also shifts in lake levels exposes the nests of some fish species in the spawning sites hence affecting the size of the hatchery. Physio-chemical events, such as drying up of lakes (as has occurred for Lake Rukwa, Lake

Chilwa and much of Lake Chad) have decimated tilapia populations from time to time (Pullin & Lowe-MaConnell, 1982). This affects the population structures of several fish species in the long run.

**5.1 Relative Abundance of Fish Species by Count and Biomass**

There was a significant difference in fish abundance both in terms of count and biomass between protected areas and fished areas. Protected areas showed more fish count as well as biomass than the fished area.This supports the concept of protected area to be fundamental tool in achieving sustainable management of fishery resource. Sanchirico (2000) postulated that protected areas are effective in protecting critical habitats, as spatial havens for targeted and intensely exploited species, as sources of stock for adjacent areas, and as potential buffers against management blunders.

Since fishing effort is not regularly and efficiently monitored due to the absence of effective methods of regulating fishing effort, low fish abundance and low fish catches which were being experienced by artisanal and licensed commercial fishing operators are assumed to be a result of frequent use of excessive fishing effort by commercial fishermen coupled with fishing pressure resulting from heavy poaching activity on the lake. Also low catches could be a result of overexploitation as high fishing effort reduces the average size of fish in the fishery, a condition known as biological overfishing (Murawski, 2000). It can also be assumed that low catches in fished areas particularly in January and February could be expected since a proportion of the fish populations inside those zones would had moved to spawning aggregation sites in areas other than the survey sites.

However, for all the species caught in protected and fished areas,*Tilapia rendalli* was the most dominant species. The dominance in abundance of *T.rendalli* over other species in both areas can be attributed to quite a number of factors. *Tilapia rendalli* is a species that is characterised by rapid breeding rate. Pullin and Lowe-MaConnell (1982) postulated that *T.rendalli* reproduce throughout the year and only slows down reproduction during the cold dry season (May - July) and an intense activity during the rainy season. They also guard their young ones until they are able to swim. Guarding the young increases considerably the survival of the juveniles and reproductive success (Pullin & Lowe-MaConnell, 1982).

The relative abundance of a single species denotes its dominance in the ecosystem and its ability to use resources and *T.rendalli* is a macrophyte feeder in which the adults feed preferentially on filamentous algae, aquatic macrophytes and vegetable matter of terrestrial origin. Of all the fish species that consume macrophytes of Lake Mutirikwi, *T.rendalli* is the most efficient species in digesting aquatic macrophytes and vegetable matter for instance *Lagarosiphon major* (Oxygen weed) which is abundant on Lake Mutirikwi. Structural adaptation to this diet are the long, coiled intestine, which may be up to fourteen times the body length, the bicuspid and tricuspid teeth used to prepare the food by shredding the coarser materials and breaking some of the cell walls before passing it on to the stomach (Pullin & Lowe-MaConnell, 1982).

# Chapter Six: Conclusion and Recommendations

## 6.0 Conclusion

The research has confirmed persistent and widespread concept of protected area in protection of targeted fish species population in Lake Mutirikwi. Fish species abundance in terms of count and biomass were consistently higherwithin protected areas than on the fished areas. Also catch per unit effort (CPUE) was higher in protected areas as compared to the fished areas hence we reject the null hypothesis and conclude that the protected area concept is effective.

Overall, the results add to a growing body of evidence that, populations of commercially exploited fish species can rise considerably within protected areas given time and adequate protection.

## 6.1 Recommendations

- Further researches should be carried out to examine the impact of seasonal environmental changes on the distribution and habitat utilisation so as to recommend to the management the specific nursery habitats that require protection. This will enhance the supply recruits of the adult stock hence ensuring sustainability of particular fish species.
- Fishery resourcemanagement through Parks and Wildlife Management Authority shouldcontrol fishing especially through strict monitoring of mesh sizes used by commercial fisheries and also closed fishing seasons should be instituted especially during peak breeding seasonsso as to protect the spawning stock biomass from being fished.
- Strong law enforcement and stiff penalties should be put in place to minimise poaching activities and zone encroachment within the protected areas to minimise disturbances to spawning sites.
- Fishing activities should be prohibited in the near littoral zones and vegetated covers since these are critical habitats for fish. Such areas should be gazetted as protected or conservation areas for fish spawning grounds.

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# APPENDICES

**Appendix A:** Information on fish species caught at protected area used to calculate diversity and evenness

| Family | Common name | Scientific name | Number | (Pi) | InPi | Pi(InPi) |
|---|---|---|---|---|---|---|
| **Cichlidae** | Red breasted bream | *Tilapia rendalli* | 293 | 0.3245 | -1.1255 | -0.3652 |
| **Cichlidae** | Greenhead tilapia | *Oreochromis macrochir* | 2 | 0.0022 | -6.1193 | -0.0135 |
| **Cichlidae** | Nile tilapia | *Oreochromis niloticus* | 171 | 0.1894 | -1.6641 | -0.3151 |
| **Cichlidae** | Yellow belly bream | *Serranochromis robustus* | 72 | 0.0797 | -2.5291 | -0.2017 |
| **Centrachidae** | Largemouth bass | *Micropterus salmoides* | 130 | 0.144 | -1.9382 | -0.2791 |
| **Clariidae** | Sharptooth cat fish | *Clarius gariepinus* | 33 | 0.0365 | -3.3092 | -0.1209 |
| **Mormyridae** | Eastern bottlenose | *Mormyrus longirostris* | 202 | 0.2237 | -1.4975 | -0.335 |
| **TOTAL (∑)** | | | **903** | | | **-1.6305** |

Therefore to calculate species diversity of area: Shannon's index (H) = - [∑ (pi*logpi)]

= - (-1.6305)

= **1.6305** species

Species evenness = [(species diversity)/ (In S)] = 1.6305/ (In7) = **0.8379**

**Appendix B** Information on fish species caught at fished areas used to calculate diversity and evenness

| Family | Common name | Scientific name | Number | (Pi) | InPi | Pi(InPi) |
|---|---|---|---|---|---|---|
| **Cichlidae** | Red breasted bream | *Tilapia rendalli* | 126 | 0.3096 | -1.1725 | -0.363 |
| **Cichlidae** | Greenhead tilapia | *Oreochromis macrochir* | 4 | 0.0098 | -4.6225 | -0.0453 |
| **Cichlidae** | Nile tilapia | *Oreochromis niloticus* | 69 | 0.1695 | -1.7747 | -0.3009 |
| **Cichlidae** | Yellow belly bream | *Serranochromis robustus* | 19 | 0.0467 | -3.064 | -0.1431 |
| **Centrachidae** | Largemouth bass | *Micropterus salmoides* | 40 | 0.0983 | -2.3199 | -0.228 |
| **Clariidae** | Sharptooth cat fish | *Clarius gariepinus* | 71 | 0.1744 | -1.7461 | -0.3046 |
| **Mormyridae** | Eastern bottlenose | *Mormyrus longirostris* | 78 | 0.1916 | -1.6521 | -0.3166 |
| **TOTAL (∑)** | | | **407** | | | **-1.7015** |

Therefore to calculate species diversity of area: Shannon's index (H) = - [∑ (pi*logpi)]

= - (-1.7015)

= **1.7015** species

Species evenness = [(species diversity)/ (In S)] = 1.7015/ (In7) = **0.8744**

**Appendix C** Analysis of variance for Biomass (kg)

| Source of variation | d.f. | s.s. | m.s. | v.r. | F pr. |
|---|---|---|---|---|---|
| **Area** | 1 | 2195.6 | 2195.6 | 5.81 | 0.019 |
| **Species** | 6 | 4403.0 | 733.8 | 1.94 | 0.086 |
| **Area.Species** | 6 | 1788.9 | 298.2 | 0.79 | 0.581 |
| **Residual** | 70 | 26447.1 | 377.8 | | |
| **Total** | 83 | 34834.7 | | | |

Variate: Biomass (kg)

| d.f. | s.e. | cv% |
|---|---|---|
| 70 | 19.44 | 55.1 |

**Appendix D** Analysis of variance for CPUE ($g100m^{-1}$)

| Source of variation | d.f. | s.s. | m.s. | v.r. | F pr. |
|---|---|---|---|---|---|
| **Area** | 1 | 2.6034 | 2.6034 | 5.81 | 0.019 |
| **Species** | 6 | 5.2211 | 0.8702 | 1.94 | 0.086 |
| **Area.Species** | 6 | 2.1214 | 0.3536 | 0.79 | 0.581 |
| **Residual** | 70 | 31.3604 | 0.4480 | | |
| **Total** | 83 | 41.3062 | | | |

Variate: CPUE

| d.f. | s.e. | cv% |
|---|---|---|
| 70 | 0.6693 | 55.1 |

**Appendix E** Analysis of variance for Fish Count

| Source of variation | d.f. | s.s. | m.s. | v.r. | F pr. |
|---|---|---|---|---|---|
| **Area** | 1 | 2928.8 | 2928.8 | 5.91 | 0.018 |
| **Month** | 5 | 14602.4 | 2920.5 | 5.89 | <.001 |
| **Area. Month** | 5 | 12821.7 | 2564.3 | 5.17 | <.001 |
| **Residual** | 72 | 35679.4 | 495.5 | | |
| **Total** | 83 | 66032.2 | | | |

Variate: Fish Count

| d.f. | s.e. | cv% |
|---|---|---|
| 72 | 22.26 | 42.7 |

**Appendix F** List of fish species found on Lake Mutirikwi

| Family | Scientific Name & Authority with Date of Original Publication | Common Name |
|---|---|---|
| **Anguillidae** | *Anguilla bengalensis labiata* (Peters, 1852) | **African mottled eel** |
| **Centrachidae** | *Micropterus salmoides* (Lacepede, 1802) | **Large mouth black bass** |
| **Cichlidae** | *Oreochromis macrochir* (Boulenger, 1912) | **Green head tilapia** |
| | *Oreochromis mossambicus* (Peters, 1852) | **Mozambique tilapia** |
| | *Oreochromis niloticus* (Linnaeus, 1758) | **Nile bream** |
| | *Serranochromis robustus* (Gunther, 1864) | **Yellow belly bream** |

| | | |
|---|---|---|
| | *Tilapia rendalli* (Boulenger, 1896)<br>*Tilapia sparrmanii* (A. Smith, 1840) | **Red-breasted tilapia**<br>**Banded tilapia** |
| **Clariidae** | *Clarius gariepinus* (Burchell, 1822) | **Sharptooth catfish** |
| **Cyprinidae** | *Barbus marequensis* (A. Smith, 1841)<br>*Barbus paludinosis*(Peters, 1852)<br>*Barbus radiatus* (Peters, 1853)<br>*Barbus trimaculatus* (Peters, 1952)<br>*Labeo cylindricus*(Peters, 1852) | **Large scale yellow fish**<br>**Straight fin barb**<br>**Beira barb**<br>**Three spot barb**<br>**Redeye labeo** |
| **Mormyridae** | ***Marcusenius macrolepidotus* (Peters, 1852)**<br>***Mormyrus longirostris* (Peters, 1852)** | **Bulldog**<br>**Eastern bottlenose** |

(Source: Mangwaya, 1997)

**Appendix G** Location of Lake Mutirikwi in Zimbabwe