# RELATIONSHIPS BETWEEN ABUNDANCE OF ZOOPLANKTON AND PHYSICO-CHEMICAL PARAMETERS IN LAKE MWERU-WANTIPA, ZAMBIA

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**A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN MANAGEMENT OF NATURAL RESOURCES FOR SUSTAINABLE AGRICULTURE OF SOKOINE UNIVERSITY OF AGRICULTURE. MOROGORO, TANZANIA.**

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# ABSTRACT

This study was conducted in Lake Mweru-wantipa aimed at assessing abundance of zooplankton and its relationships with physico-chemical parameters. Four sampling stations were selected, two on each side of the Lake; the National Park and settlement. Five physico-chemical parameters including, temperature, turbidity, salinity, pH and dissolved oxygen were measured monthly using portable instruments concurrently with collection of duplet zooplankton samples at each sampling point at depths between 0.1m and 0.5m. All physico-chemical parameters were significantly different between the two sites ($p<0.05$) with the exception of temperature and pH. A total of 13 genera of zooplankton were identified belonging to four groups namely; rotifers, cladoceran, copepods and ostracods. The cladoceran had the highest number of species (6) followed by copepods (4) in both sides. However, the copepods had the largest contribution in terms of abundance in both sides. The diversity *H'* was high in settlement areas but the National park had higher species richness. There was significant difference in species diversity between the two sites ($t=3.96$; $p=0.001$).The most abundant group was the cyclopoid in both sides of the lake followed by the *Moina on* the settlement site and the *daphnia* sp on the National park site. The densities of *Molina*, *Simocephalus*, *Ceriodaphinia* and *Cypris* were significantly different between the two sites ($p<0.05$). With the exception of copepods all groups were significantly different between the two sites ($p<0.05$). Generally, the total zooplankton density was not significantly different between the two sites ($t=0.73$; $p=0.06$).The results showed that the zooplankton abundance was clearly influenced by turbidity in settlement areas and pH in National park areas. Agroforestry practices should be promoted in the lake's catchment area in order to reduce sedimentation in the lake and on land deforestation.

**DECLARATION**

I, Aongola Anamunda, do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work and has not been submitted to any other University.

_____________________________ _________________________

Aongola Anamunda Date

(M.Sc Student)

The above declaration is confirmed

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Dr. H. A. Lamtane Date

(Supervisor)

# COPYRIGHT

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Finally, I thank my Wife for her care and the greatest support rendered to me.

## DEDICATION

I dedicate this Master's of Science Degree Dissertation to my Late Parents, for the greatest roles they played in my life and may their great souls rest in eternal peace. I also make it a special dedication to my lovely wife and our two sons for being on my side throughout the duration of studies.

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## LIST OF ABBREVIATIONS AND SYMBOLS

| | |
|---|---|
| Turb | Turbidity |
| Temp | Temperature |
| pH | Expression of Acidity and Alkalinity |
| DO | Dissolved Oxygen |
| NTU | Nephelometric Turbidity Units |
| PPT | Parts Per Thousand |
| S | South |
| N | North |
| E | East |
| M | Meter |
| $^{o}C$ | Degrees Celsius |
| mg/l | milligram/liter |
| NP | National Park |
| STDEV | Standard Deviation |
| USEPA | United States Environmental Protection Agency |
| ZCSO | Zambia Central Statistical Office |
| NEMS | National Environmental Monitoring Standards |
| GPS | Geographical Positioning System |

# CHAPTER ONE

## 1.0 INTRODUCTION

Zooplankton consists of macro and microscopic animals, comprising representatives of almost all major taxa particularly the invertebrates (Gosswami, 2004). Zooplankton can also be categorised as herbivorous and carnivorous zooplanktons based on their nature of feeding, and in turn makes up an important food item to other aquatic animals in the higher trophic levels (Haven, 2002). The zooplankton is an important water quality indicator due to their shorter life spans combined with their different tolerance levels towards physico-chemical parameters (Gajbhiye, 2002). Research has also shown that zooplankton species have different tolerance limits towards the physico-chemical parameters. Balakrishna *et al*. (2013) reported changes of zooplankton species densities as affected by changes in physico-chemical parameters in different seasons. According to Waikato Environmental Technical Report (2008) in New zealand, presence of rotifers can be used to grade eutrophic status of the lakes.

Understanding the patterns of variability of zooplanktons both temporally and spatially provides a good source of information on the processes affecting them. Physico-chemical parameters have been reported as one of the source of the variations in species composition, abundance, diversity and distribution of zooplankton e.g. Imaobong (2013) reported zooplankton species abundance and distribution was determined by levels of eutrophication in lakes of Nigeria. Variations in seasonal abundance and diversity as a result of changes in physico-chemical parameters were also reported by Keder *et al.* (2008). Similar studies on the relationship between zooplankton and physico-chemical parameters have been conducted elsewhere (e.g. Goswami and Mankodi, 2012; Moshood, 2009) in India and Nigeria respectively.

Lake Mweru-wantipa is one of the small lakes found in Zambia located in an isolated part of the country. The lake is a swampy and muddy and has no water outlet though having a number of small streams flowing into it. The lake's boundary lies entirely within the Mweru-wantipa National park. Over the past decade, encroachments have been tolerated and these have increased to a level where many permanent settlements on the eastern sides of the lake established. The lake is the main supplier of fish to the residents of remote districts of Nsama and Kaputa. The settlers apart from fishing have diversified into other activities such as agriculture, logging and charcoal production within the immediate catchment of the lake. Despite these stressors developing around it, the lake has received very little attention from researchers. Lake Mweru-wantipa is also known to have displayed  a series of fluctuations in water levels in the past, which has not really been explained by variations in rainfall levels and has also been known to have dried out almost completely at some time in 1916 (Brelsford,1954). The only known study on Lake Mweru-wantipa was on the biology and exploitation of small pelagic fishes by Mubamba (1989). There is a little information if any on the zooplankton abundance as well as water quality of Lake Mweru-wantipa. Therefore, the present study aimed at assessing some physico-chemical parameters of water and its relationship with the abundance of zooplankton in the Lake Mweru-wantipa.

**1.1 Problem statement and study justification**

The two districts Nsama and Kaputa sharing Lake Mweru-wantipa are homes to two National parks namely Nsumbu and Mweru-wantipa bordering them on either side. Tsetse fly infestation from these National parks and proximity to homesteads made the rearing of larger livestock impossible. This made Lake Mweru-wantipa as the main supplier of animal protein in form of fish to these districts.  The growing number of human population around the lake has not just brought about over fishing but also increasingly large areas close to the lake being opened up for agriculture purposes thus leading to deforestation in the catchment area of the lake. These have increased siltation in the lake as evidenced by the poor transparency of the lake. Studies on the relationship between zooplankton and physico-chemical parameters have been done in the nearby lakes (e.g. Nkotagu and Athuman, 2007) in the Lake Tanganyika but there is limited information on zooplankton of Mweru-wantipa. A zooplankton study and its relationship to physico-chemical parameters will provide an insight into the current limnological status of Lake Mweru-wantipa which has never been done. This will be very valuable baseline information for researchers and government agencies interested in the management of the lake.

## 1.2 Objectives

### 1.2.1 Main Objective

The overall objective of the study was to investigate species composition, abundance, diversity of zooplankton and their relation to physico-chemical parameters in Lake Mweru-wantipa, Zambia.

### 1.2.2 Specific Objectives

(i) To determine dissolved oxygen, temperature, turbidity, salinity and pH of the Lake.

(ii) To determine species composition, abundance and diversity of zooplankton in the lake.

(iii) To determine the relationship between the physico-chemical parameters and abundance of zooplankton in the lake.

## 1.3 Hypothesis;

i. There is significant difference in species composition, diversity and abundance of zooplankton between the settlement and the National park sides of the lake.

ii. There is a significant relationship between zooplankton abundance and the selected physico-chemical parameters in the lake.

# CHAPTER TWO

## 2.0 LITERATURE REVIEW

### 2.1 Biology and Ecology of Zooplankton

Zooplanktons are microscopic animals found in both marine and freshwater ecosystems and their sizes may range from a few microns to a millimeter or more (Goswami, 2004). The major zooplankton groups found in most tropical fresh water Lakes are the rotifers, cladoceran, copepods and ostracods (Witty, 2004). The zooplanktons play a very important role in the aquatic system due to their link between phytoplankton and higher trophic levels (Gajbhiye, 2002). Their composition of proteins, minerals, fatty acids, lipids provides an important source of feed for fish (Kribia *et al*., 1997 in Khalid, 2012). The zooplankton responds to different types of stresses in different ways, therefore they are increasingly used as biological indicators in aquatic ecosystems (Wanessa *et al*., 2008) and Okorafor *et al.* (2013).

Rotifers are distinguishable by their elongated body, head, and trunk and have ciliated parts on the corona that direct food into the mouth, while their food consists of particulate organic detritus, protozoan and algae (Glime, 2013). Their mode of reproduction is asexual through cyclical parthogenesis, though a few exhibit sexual reproductions (Glime, 2013). Rotifers have widely been used as biological indicators in studies due to their sensitivity to different levels of water quality parameters (Radix *et al.,* 2002).

Unlike rotifers, copepods and cladoceran have segmented bodies with an exoskeleton which has jointed appendages (Shiel, 1995). Apart from smaller zooplanktons both cladoceran and copepods feed on a wide range of organisms including algae and reproduce sexually though, cladoceran predominantly reproduce asexually (Forro *et al*., 2008).

Copepods are one group of crustacean that passes through a series of nauplius and copepodid stages before becoming adults (Marten and Reid, 2009).

Copepods unlike other zooplanktons have a much wider adaptation to unfavorable climate (Reid and Williamson, 2010) and are also reported to be the most abundant members of the zooplankton population. Cladoceran on the other hand are reported to be the most abundant in freshwater (Forro *et al.,* 2008). Many small copepods feed on phytoplankton, while some larger ones may be predators and feed on detritus or bacteria. Both copepods and cladoceran's abundance is much dependent on availability of enough variable foods and favourable temperature (Sharma *et al*., 2013).

Ostracods are found in almost all aquatic environments such as marine, brackish waters and fresh water (Martens *et al*., 2008). They are mainly benthic and also occur in semi-terrestrial environments (Pieri *et al*., 2009). Their bodies are flat on either side with a hinged bivalve chitinous shell and have a smooth, thin calcified bean shaped carapaces with a body not clearly distinguished in to segments like the other crustaceans (Gobert, 2012). Ostracods reproduce sexually and also asexually depending on the environmental conditions and pass through several growth stages to the final adult stage. They feed on a variety of feeds such as detritus, bacteria and diatoms (Pieri *et al*., 2009). Unlike other crustaceans, the outer shell of ostracods is hard and easily fossilfied and hence are known to have the most complete fossil record and because of this are increasingly being used as paleo-environmental indicators (Rodriguezi and Ruiz, 2012)

**2.2 Species Composition, Diversity and Abundance of Zooplankton**

Zooplankton species composition varies from one area to another within the same geographical areas (Jonathan *et al*., 2000). These are also known to vary from one season to another influenced by the physico-chemical and biological factors (Perumal *et al*., 2009). The interactions and effects which these have on different zooplankton species ultimately determine the zooplankton structure in a given niche within a geographical area (Sorsa, 2008). Seasonal variations of physico-chemical water parameters can have a significant effect on zooplankton species composition, due to different tolerances exhibited by different zooplankton species towards the seasonal changes in water parameters (Olasehinde and Abeke, 2012) in Ikere gorge, Nigeria.

Within a given water body, certain zooplankton species may be predominantly found in certain areas and may be less or absent in another areas. For example, Kapusta and Kapusta (2013) reported that, cladoceran preferred macrophytes rather than open waters to get away from heated waters and copepods are also known to graze in open waters while the rotifers prefer the littoral zones. Nan and Run (2014) reported large densities of rotifers in littoral zones than open waters most previous studies. In addition, dominance of certain zooplankton species was reported to be due to naturally varying flows of water and sediment in aquatic systems (Ezekiel *et al*., 2011).

The abundance and diversity is also affected by the changes in physico-chemical and biological factors in different seasons. A study on the abundance and diversity of zooplankton by Jadobendro *et al*. (2013) showed that there is positive correlation in zooplanktons populations with water temperatures. Such a positive correlation means that zooplankton species abundances would increase in density during high water temperatures. According to Mzime *et al*. (2010) in African tropical lakes, environmental factors particularly the physico-chemical parameters including the thermal stratification in deeper lakes greatly affect primary and secondary production. In most tropical lakes, differences, due to high temperatures, light and nutrients occurring throughout the year, zooplankton populations remain fairly the same throughout the year with little variations (Papa *et al*., 2011). In addition to environmental factors, in sites prone to drying during some months of the year it is most likely going to have lower zooplankton levels (Krylov *et al*., 2011).

Depth of water bodies affects productivity of zooplankton (Bartram and Balance, 1996). Vadeboncoeur *et al*. (2008) also reported that poor light penetration leads to lower phytoplankton production resulting into lower zooplankton abundances. Zooplankton species abundances and diversity are also shaped by biological factors e.g. Villa *et al*. (1997) reported that interactions between the phytoplankton and zooplankton have a direct influence on the zooplankton abundances. According to Heidi and Peter (2010) species preference and size of phytoplankton by the zooplankton affects the zooplankton distribution, species composition, abundance and diversity.

Interspecific and intraspecific interactions between zooplankton species have an effect on their abundance, diversity and species composition (Declerck *et al*., 2003). Cladoceran and rotifers strongly compete for same limited resources and thus limiting the abundance of rotifers (Kirk and Gilbert, 1990). Animals in higher trophic levels were found to negatively affect zooplankton populations (Nicolle *et al*., 2011). The introduction of *Limnothrissa miodon* in the Lakes of Kariba and Cahora Bassa, were such examples where it has been reported that there is an effect on the zooplankton populations of the lakes (Marshall, 1991). A similar report has been given by Isumbisho *et al*. (2006) on Lake Kivu.

### 2.3 Relationships between Zooplankton and Water Quality Parameters.

Studies in zooplankton abundance and diversity have traditionally been done alongside the physico-chemical parameters (Chapman *et al*., 1996). Ramachandra *et al*. (2006) in Bangalore Lakes, India, found that different zooplankton species respond differently to different physico-chemical parameters outside their tolerant limits. The shorter life span, short generation time and species sensitivity to different levels of physico-chemical parameters have made zooplankton an ideal biological indicator (Ferdous and Muktadir, 2009) in India.

The relationship between the zooplankton and physico-chemical parameters has been found to be responsible for the differences in species composition, abundance and diversity (Anago *et al*., 2013). Basu *et al*. (2013) and Sharma (2011) in India reported positive correlations between zooplankton abundance and water transparency. Since different zooplankton species respond differently to different physico-chemical parameters and within their tolerant limits, the populations of zooplankton species tend to be shaped in part by these water quality parameters. This is so because zooplankton species tend to perform better within their optimum ranges of water quality parameters. For example, cladoceran tend to be highly sensitive against even to very low concentrations of pollutants while copepods are the most tolerant towards pollution (Ramachandra *et al*., 2006). Such relative tolerances towards these stressors e.g. excess nutrient input in aquatic ecosytem lead to sparse and temporal variations of zooplankton species, composition and diversities. Qin *et al*. (2013) reported that eutrophication reduces zooplankton diversity in aquatic systems. Omowaye *et al.* (2008) and Shashikanth and Vijagkumar (2009) reported that abundance and distribution among zooplankton communities can be due to variations in water quality parameters. Some researchers have demonstrated that specific water quality parameters have effects on certain zooplankton species (e.g. Koenigs *et al*., 1990). These authors demonstrated that turbidity can be directly responsible for reduced survival in *Daphnia*.
Anthropogenic activities have been found to be responsible for many acute changes in the water quality parameters of many water bodies including eutrophication due to nutrients drained from agricultural and or municipalities (Kraemer *et al*., 2001). Excess inorganic

nutrients have been responsible for many drastic changes that have been observed in zooplankton structures in affected water bodies. Arimoro and Oganah (2010) and Gammanpila (2010) reported that anthropogenic activities strongly influenced the abundance of zooplankton.

In environments without external influences, zooplanktons are distributed according to environmental preferences and are further regulated by changes in climatic condition. For example, Veerendra *et al*. (2012) reported that species richness of aquatic system is due to the prevailing environmental conditions. Uzma *et al*. (2012) reported that zooplankton abundance and species distribution depends on favourable climatic conditions.

# CHAPTER THREE

## 3.0 MATERIALS AND METHODS

### 3.1 Description of the Study Area

The research was conducted in Lake Mweru-wantipa located in the Northern Province of Zambia. The lake is located between coordinates 8$^{o}$ 10'S to 9$^{o}$10'S and 29$^{o}$00'E to 30$^{o}$ 00'E. The size of the lake is 73 km long, 43 km width and has an average depth of two meters (Frame Survey Report, 2004).

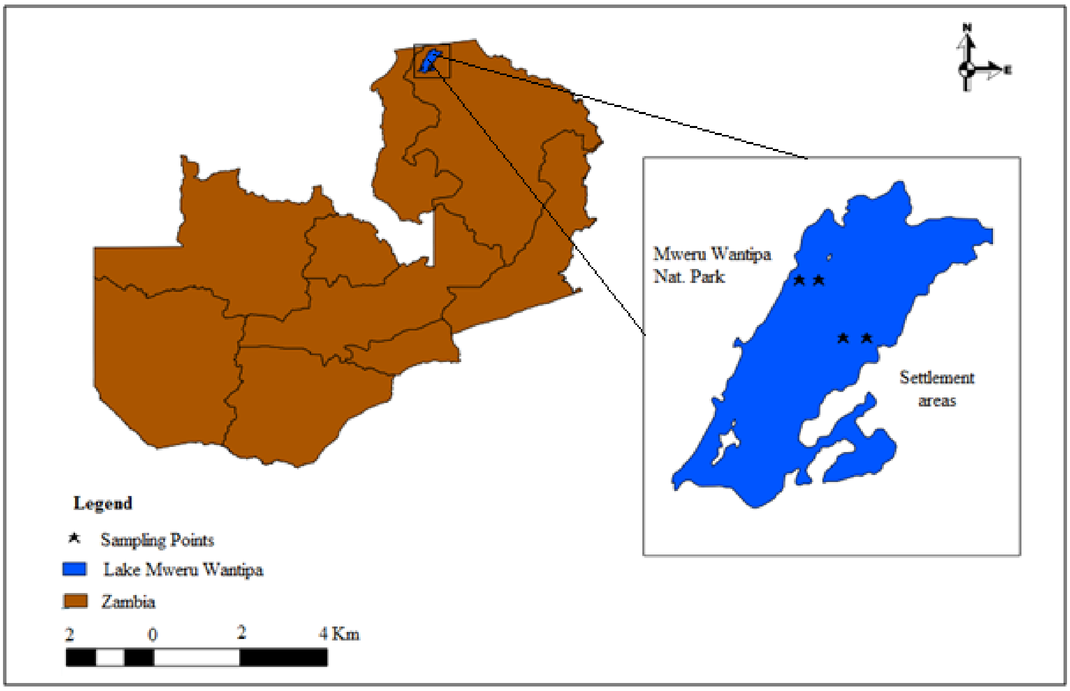


**Figure 1**: The Map of Lake Mweru-wantipa showing settlements and National park

Though, the lake has a number of inlets that bring in water, it has no outlet. The western side is boarded by National park (Fig. 1). The lake is shared by two districts namely Nsama and Kaputa whose main source of livelihoods is fishing and agriculture. The area falls within agro ecological zone (III) which is characterized by humid subtropical climate with warmest temperature of about 32$^{o}$C in October and coolest temperatures of about 5$^{o}$C in July (Chabala *et al*., 2013). The districts normally experiences two seasons yearly which are dry and wet seasons; the dry season normally starts in May and runs through October while the wet season starts from November to April. The region receives an average rainfall of 1000 – 1500 mm and has strong acidic soils with low nutrients caused by high rainfall (Paul, 2008).

### 3.2 Sampling Design

Four sampling stations were chosen across the midsection of the lake, two on the western side of the lake nearer to the National Park, and two on the eastern side of the lake nearer to the human settlements. The sampling points were identified and marked using a geographical positioning system (GPS).

**Table 1**: Zooplankton sampling points on the Lake Mweru-wantipa, Zambia

| | National | Park | Settlement | areas |
|---|---|---|---|---|
| Sampling stations | 1 | 2 | 3 | 4 |
| GPS coordinates | 08°36’0”S, | 08°37’54.3”S, | 08°40’19.8”S, | 08°41’23.0”S, |
| | 029°40’04.1”E | 029°42’03.7”E | 029°44’37.3”E | 029°47’03.3”E |
| Water depth | 0.64m | 0.95m | 2.0m | 2.3m |

Table 1 shows the coordinates of the sampling stations and the depths of the water columns respectively. The water samples were collected at the first week of each of the three sampling months, in the mornings between 08hrs and 12hrs, to ensure that sampling is equally spaced as possible. The physico-chemical parameters were measured at sampling sites concurrently with collection of zooplankton water samples below the water surface. The first sampling took place at the first week of November 2013 and the last sampling was done during the first week of January 2014.

## 3.3 Data Collection

### 3.3.1 Zooplankton Sampling

A graduated 10 liter bucket with a mouth diameter of 20 cm was used to sample zooplankton just below the water surface at depths between 0.1 to 0.5m. One scope of the bucket was taken vertically each time and filtered through 100 µm zooplankton net. Samples were collected in duplicates. The zooplankton samples were stored in 100ml plastic bottles preserved with 4% formaldehyde. The bottles were kept in cooler boxes and transported to the laboratory of the Department of fisheries located at Lake Tanganyika in Mpulungu, Zambia.

### 3.3.2 Water Quality Parameters

Five physico-chemical parameters were measured during sampling using electronic portable instruments. Dissolved oxygen (DO) and salinity were measured using instrument YSI Model 54 ABP, model 54 ARC and Salinometer HI 8033 respectively. Turbidity was measured with a Hach turbidity meter model 2100A with precision ± Nephelometric Turbidity Units (NTU). pH was measured using a pH meter (WTH 323), while temperature was measured using a Hanna temperature probe (HI 9143).

### 3.3.3 Zooplankton Laboratory Analysis

A Labovert FS Microscope with a magnification x40 was used in examination of the zooplankton. The zooplankton identification was done using identification guides by Utzugi and Mazingaliwa (2002) and Scourfield and Harding (1966). Standard Operating Procedure for Zooplankton Analysis guidelines by the United States Environmental Protection Agency (USEPA, 2010) were used to analyze the zooplankton in the laboratory. Samples were thoroughly mixed and a 1ml subsample was withdrawn with a pipette. One ml subsamples with much fewer organisms were discarded until consistent high zooplankton numbers was achieved in the subsamples. A zooplankton counting chamber was used for counting the identified zooplankton species. Zooplanktons were identified up to generic level.

### 3.4 Data Processing and Analysis

A Student *t*-test was used to determine the difference between the means of the zooplankton density and physico-chemical parameters on the two sides of the lake. The biodiversity index used to determine the species diversity of zooplankton was Shannon - Weaver (1949) in Spellerberg and Fedor (2003). The Hutchingson (1970) *t*-test was used to determine the difference between the diversities between the two sides of the Lake. Pearson's correlation (r) analysis was used to investigate whether there is a relationship between physico-chemical parameters to zooplankton abundance. A multiple regression analysis was used to investigate the cause and effect between the zooplankton abundance physico-chemical parameters. The regression model used was $Y_i = \beta_o + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + e_i$

#### 3.4.1 Species Diversity

Species diversity was calculated using the Shannon Weaver Index (1949).

The following formula was used;

$H' = -\sum (Pi * In (Pi))$ where $Pi = ni/N$

In = the natural log

Pi = Proportion of total sample belonging to the $i^{th}$ specie

ni = total number of individuals in a specie

N = total number of individuals

$E = H'/H\max$ where $H\max = In(S)$ measures the species evenness

(S) = the total number of individual distinct peaks within a profile (Species richness)

*E* = measures the species evenness

*H*max = measures the maximum evenness the community can have, the closer is this to one, means the community is optimally even.

*E*exp *H* = Effective Number of Species

**3.4.2 Density Estimation**

Population density was calculated from known densities using the following formula by Lackey (1938); Tonapi, (1980) in Gajanan & Satish (2014).

Density = (n) (v) ⁄ V

Where;

Density = Total no. of organization ⁄ litre of water filtered

n = Average number of organisms in a 1ml plankton sample

v = Volume of concentrate plankton sample (ml)

V = Volume of total water filtered through (L)

# CHAPTER FOUR

## 4.0 RESULTS

### 4.1 Physico-chemical Parameters

#### 4.1.1 Temperature

There was slightly difference in temperature between the two sampling sites (Table 2). However, there was no significant difference in water temperature between the study sites (t=0.586; $p$=0.559).

#### 4.1.2 Turbidity

The mean and range of turbidity recorded from settlement side and National park are presented in Table 1. The highest turbidity value of 2.7 NTU was recorded on the settlement side while the lowest value of 0.4 NTU was recorded on the National park side. The difference in turbidity between the two sides of the lake was significant (t=-5.61; $p$=0.001).

#### 4.1.3 Water Salinity

The lowest (3.5 ppt) and highest (4.6 ppt) salinity were recorded from the settlement and National park sides respectively. There was significant difference in salinity between National Park and settlement (t=12.569; $p$=0.001).

#### 4.1.4 pH

The highest pH value (9.9) during the study was recorded from both sides of the lake, while the lowest (9.2) on the settlement side (Table 2). There was no significant difference in pH values between the two studied sites (t=-2.91; $p$=0.06).

### 4.1.5 Dissolved Oxygen

The lowest and highest dissolved oxygen concentration was 1.2mg/l and 12.1mg/l measured from the National park and settlement side of the lake respectively (Table 2). The oxygen concentrations on the settlement side were significantly higher than the National park side (t=-3.66; $p$=0.001).

**Table 2: Summary of water quality parameters in Lake Mweru-wantipa, Zambia**

| Parameters | National Park | | Settlement areas | |
|---|---|---|---|---|
| | Mean | Range | Mean | Range |
| Depth (m) | 0.8 ± 0.2 | 0.6 – 0.1 | 2.1± 6 | 2.0 – 2.3 |
| Temperature ($^oC$) | $27.8 \pm 3.7^a$ | 19.8 -31.4 | $27.4 \pm 0.79^a$ | 26.5 -28.8 |
| Turbidity (NTU) | $1.4 \pm 0.6^a$ | 0.4 – 2.2 | $1.95 \pm 0.5^b$ | 1.4 – 2.7 |
| Salinity (ppt) | $4.1 \pm 0.3^a$ | 3.9 – 4.6 | $3.6 \pm 0.2^b$ | 3.5 – 4.0 |
| pH | $9.5 \pm 0.2^a$ | 9.2 – 9.9 | $9.6 \pm 0.3^a$ | 9.2 – 9.9 |
| D O (mg/L) | $5.6 \pm 3.1^a$ | 1.2 – 9.4 | $7.6 \pm 2.6^b$ | 4.4 – 12.1 |

Note: Means within the same row with different superscript letters differ significantly at $p$<0.05, DO = dissolved oxygen

### 4.2 Zooplankton Species Composition and Abundance

A total of 13 zooplankton genera from four major groups namely; cladoceran, copepods, ostracods and rotifers were recorded during the present study (Table 3). The National Park side of the lake had the highest number of genera compared to the settlement side. In both sides of the lake, the cladoceran had the highest number of individual group followed by copepods. Rotifers were absent from settlement side of the lake.

**Table 3: Zooplankton groups composition in the Lake Mweru-wingtip, Zambia**

| Taxonomic group | Total no. of taxa | | Percentage composition | |
|---|---|---|---|---|
| | NP | ST | NP | ST |
| Cladocera | 6 | 5 | 46 | 56 |
| Copepoda | 4 | 3 | 31 | 33 |
| Rotifer | 2 | 0 | 15.4 | 0 |
| Ostracoda | 1 | 1 | 7.6 | 11 |
| **Total** | **13** | **9** | **100** | **100** |

NP = National park, ST = settlement areas

Table 4 shows that the cyclopoids had the highest relative abundance in both sides of the lake followed by *Moina* on the settlement sides and *Daphnia* on the National park side. The *Moina* ranked third on the National park side. The lowest relative abundance recorded was rotifers.

**Table 4: Zooplankton composition in percentages of Lake Mweru-wantipa in Zambia**

| Taxa | Genus | Settlements | National park |
|---|---|---|---|
| Cladocera | *Moina* | 20 | 12.1 |
| | *Daphnia* | 11.1 | 10.3 |
| | *Simocephalus* | 2.5 | 0.4 |
| | *Ceriodaphnia* | 2.5 | 1 |
| | *Crystallina* | 1.6 | 1.2 |
| | *Chydorus* | 0 | 0.2 |
| Copepoda | Cyclopoid | 38.8 | 46.6 |
| | Calanoid | 11.8 | 14 |
| | *Ergasilus* | 4.7 | 4.3 |
| | *Angusilus* | 0 | 0.2 |
| Rotifer | *Branchionus* | 0 | 1 |
| | *Conochilus* | 0 | 0.2 |
| Ostracoda | *Cypris* | 6.8 | 8.4 |

### 4.3 Species Diversity

**Table 5: Diversity, species richness and evenness of zooplankton in Lake Mweru-wantipa, Zambia**

| Diversity Index parameter | SAMPLING STATIONS | |
|---|---|---|
| | National Park | settlement |
| Species diversity (*H)*' | 1.50 | 1.76 |
| Species richness | 13 | 9 |
| Species evenness (*E)* | 0.58 | 0.76 |
| Effective Number of Species | 5 | 6 |

*H*'= is the Shannon weaver diversity index

Shannon weaver diversity index indicated a higher diversity of zooplankton on the settlement side. A Hutcheson *t*-test showed that there was a significant difference in zooplankton species diversity (t=3.96; $p$=0.001) between the two study sites. The species richness was higher on the National park compared to the settlements. The species evenness and the effective number of species were greater on the settlements (Table 5).

### 4.4 Density of Zooplankton in Lake Mweru-wantipa, Zambia

**Table 6: Density of zooplankton species in the Lake Mweru-wantipa, Zambia**

| Taxa | Genus | Settlement | National park |
|---|---|---|---|
| Cladocera | *Moina* | $46.7 \pm 16.86^a$ | $20.67 \pm 15.63^b$ |
| | *Daphnia* | $25.4 \pm 5.55^a$ | $28.8 \pm 3.51^a$ |
| | *Simocephalus* | $6.25 \pm 6.25^a$ | $1.67 \pm 1.64^b$ |
| | *Ceriodaphinia* | $5.84 \pm 3.67^a$ | $2.08 \pm 2.1^b$ |
| | *Crystallina* | $3.75 \pm 2.45^a$ | $2.5 \pm 2.49^a$ |
| | *Chydorus* | - | 0.5±0.42 |
| Copepod | Cyclopoid | $90.4 \pm 12.16^a$ | $88.75 \pm 21.18^a$ |
| | Calanoid | $27.5 \pm 12.06^a$ | $27.5 \pm 7.1^a$ |
| | *Ergasilus* | $10.84 \pm 5.65^a$ | $10 \pm 4.08^a$ |
| | *Angusilus* | - | 0.5±0.42 |
| Rotifer | *Branchionus* | - | 2.08±1.63 |
| | *Conochilus* | - | 0.4±0.42 |
| Ostracod | *Cypris* | $20.9 \pm 7.19^a$ | $17.16 \pm 7.56^b$ |

Means within the same row with different superscript letters differ significantly at $p<0.05$

With the exception of *Moina*, *Simocephalus*, *Ceriodaphnia* and *Cypris*, all other species densities were not significantly different between the study sites (Table 5).

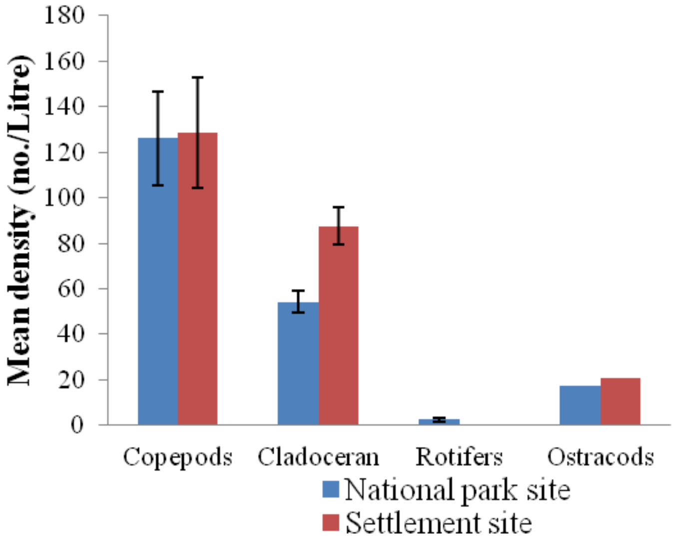


**Figure 2: Mean densities of major zooplankton groups from studied sites in Lake Mweru-wantipa, Zambia.**

The copepods had the highest densities on both sampling sites followed by cladoceran. The least density was rotifers recorded from both sites (Figure 2). *T-tests* showed that the densities of all the groups were significantly different between the sites except copepods ($p$=0.78). Generally the settlement had higher zooplankton densities compared to National park site (Figure 3). However, there was no significant difference on total zooplankton density between the two sites (t=-0.729; $p$=0.06).

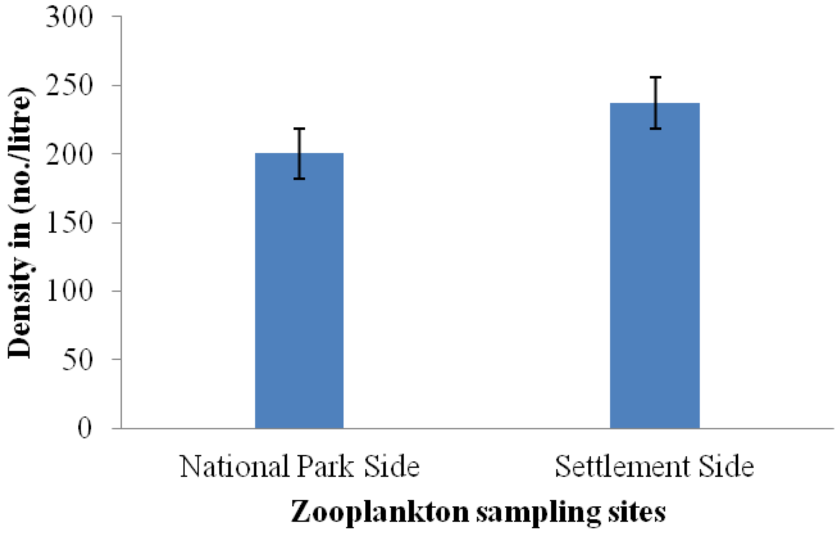


**Figure 3: Density of zooplankton in sampling sites in Lake Mweru-wantipa, Zambia**

**4.5 Relationships between Zooplankton and Physico-chemical Parameters**

Table 6 shows the relationships between the zooplankton and physico-chemical parameters. Temperature, salinity and pH showed negative relationship with zooplankton abundance. Generally, with the exception of turbidity and pH, there was no significant correlation between zooplankton abundance and physico-chemical parameters.

**Table 7: The Pearson coefficient of correlation of total zooplankton and physico-chemical parameters in Lake Mweru-wantipa, Zambia**

| Particulars | Co-efficient of correlation (r) | P value | Remarks |
|---|---|---|---|
| Turbidity | 0.380 | 0.000 | S |
| Temperature | -0.046 | 0.63 | NS |
| pH | -0.327 | 0.000 | S |
| Dissolved oxygen | 0.151 | 0.115 | NS |
| Salinity | -0.149 | 0.121 | NS |

NS = Not Significant, S = Significant

There were significant relationships between total zooplankton and turbidity on the settlement and pH on the National park (Tables 8 & 9).

**Table 8: Regression analysis for zooplankton and physico-chemical parameters on the settlement area in Lake Mweru-wantipa, Zambia**

| Predictor | Coefficients | P-value | Remark |
|---|---|---|---|
| Constant | -77.7 | 0.47 | S |
| Turbidity | 11.86 | 0.04 | S |
| Temperature | 0.37 | 0.81 | NS |
| pH | 6.08 | 0.49 | NS |
| Dissolved oxygen | -0.33 | 0.51 | NS |
| Salinity | -0.40 | 0.96 | NS |

S = Significant, NS = Significant

**Table 9: Regression analysis for zooplankton and physico-chemical parameters on the National park area in Lake Mweru-wantipa, Zambia**

| Predictor | Coefficient | P-value | Remark |
|---|---|---|---|
| Constant | 200.70 | 0.06 | NS |
| Turbidity | 2.70 | 0.64 | NS |
| Temperature | 0.89 | 0.47 | NS |
| pH | -23.59 | 0.04 | S |
| Dissolved oxygen | 0.61 | 0.57 | NS |
| Salinity | 0.08 | 0.99 | NS |

S = Significant, NS = Not Significant

# CHAPTER FIVE

## 5.0 DISCUSSION

### 5.1 Physico-chemical Parameters

Lake Mweru is a shallow and smaller lake, bordered by a National park on the western side, while the eastern, southern and northern sides of the Lake's are settlement areas. The major economic activities in the settlement areas are agriculture and fishing. The fisheries frame survey report of Lake Mweru-wantipa by Zambia Central Statistical Office (Frame Survey Report, 2004) showed that there has been an immense increase in the number of fishing villages around the Lake. Improper agriculture practices and deforestation lead to land degradation and alteration of physico-chemical parameters of the Lake. Yorke and Margai (2007) in Ayivor and Gordon (2012) reported that population growths and developmental activities along water bodies in many sub Saharan countries have been responsible for negative changes in water quality parameters.

Marginal differences in water temperature recorded on the two studied sides of the lake were probably due to shallowness of the lake (Table 2). The depth of water bodies has potential to effect variations in physico-chemical parameters including temperature and dissolved oxygen. Shallow waters generally warm easier and quicker compared to deeper lakes. Stefanidis and Papastergiadou (2012) conducted a study in the Greek lakes and reported that variations in some water quality parameters can be due to morphometric measurements of water bodies. The homogeneity in temperature in shallow lakes has been achieved through regular mixing and stirring. This phenomenon has been recorded in other shallow lakes including Edward and George in Uganda (Otim, 2005).

The higher turbidity recorded from settlement side of the lake is probably due to improper agriculture practices and deforestation. Agricultural activities along the catchment of the lake lead to erosion and hence high turbidity in the lake from the runoff. High turbidity has been reported in Birim river basin in Ghana (Ansah and Asante, 2000) and in Lake Victoria (Scheren *et al.,* 2001) due to improper agricultural activities. Conversion of land to agriculture has been reported as one of the drivers to deterioration of aquatic systems (e.g. Rucha *et al*., 2011; Yorke & Magai, 2007) in India and Ghana respectively. The loose soils as a result of removal of vegetative cover are washed into aquatic systems may create turbid and eutrophic conditions.

Relatively lower water depth on the national park side was the contributing factor towards high salinity (Table 2). Shallow areas are generally more prone to drying up due to evaporation, and then the salts become concentrated as the water drops. As the lake recedes, the dried salt looks like white patches on the dried shore line. Saravanakumar *et al*. (2007) in India reported that changes in salinity can be due to loss of water through evaporation and rainfall. Surprisingly, salinity levels recorded in the present study (Table 2) were similar to those in brackish waters reported along the estuaries in Sri lanka (Gammanpila, 2010). However, salinity levels below 5.0 ppt are within the fresh water range (USEPA, Standard Operating Procedures, 1986). Lakes are considered saline when they have salinity above 3 ppt (Robert *et al*., 2008).

The stirring and mixing of the lake and its small size could also be attributed to the uniformity in pH values across the lake. Small size, low depth and wind have been reported as parameters promoting water mixing (Omondi *et al*., 2014) in small water bodies of Kenya. The present findings on pH values (Table 2) were similar to those obtained by Otim (2005) on Nile basin in Uganda. However, the mean pH values obtained in the present study (Table 2) were slightly above the optimum aquatic range of 6.5 to 9.0 (USEPA, 1986). The higher pH values could probably explained in part as a result of higher primary production. Green colour was observed on the entire surface of the lake during the sampling period. Tucker and Dabramo (2008) Waters with high algae content results into intense photosynthesis during the day, thereby, carbon dioxide is used up in the process resulting in high pH values. A similar finding was reported by Savala *et al.* (1999) in the Lake Tanganyika. In contrast, lower pH values (6.3 to 6.9) were reported in Lake Bangweulu, Zambia (Kolding, 2011). Higher pH levels (>10) is harmful as they increase ammonia toxicity to fish and other organisms in aquatic systems (Rossana, 2013)

Significant differences in dissolved oxygen between the study sites might have been due to a number of biotic and abiotic factors in the Lake. Occasional short duration winds that swept the water surfaces have been observed to take place several times in a day during sampling period. These could lead to spatial differences within shorter distances. Probably the differences in depth of water could also contribute to differences in dissolved oxygen levels since photosynthesis is one of the major sources of dissolved oxygen. The National Environmental Monitoring Standards (NEMS, 2013) reported that dissolved oxygen is negatively affected by salinity thus, the lower oxygen levels on the National park could have been also due to the significant higher salinity observed in the present study (Table 2). The present findings are similar to those obtained in Lake Tanganyika by Savala *et al.* (1999). The dissolved oxygen levels recorded in the present study (Table 2) were within limits of natural background level of 5.0 to 7.0 mg/l that supports aquatic life.

**5.2 Zooplankton Species Composition and Diversity**

In the present study, the cladoceran dominated in terms of species number followed by copepods. This concurs with the findings of Abubakar (2013) in Nguru Lake, Nigeria. Ghidini *et al.* (2009) conducted a similar study in Brazil and concluded that since most cladoceran species are herbivorous and phytoplankton feeders, they are able to develop in many fresh water environments. Kishe – Machumu *et al.* (2008) reported that cladoceran are more vulnerable to predation owing to their large size, conspicuous eyes and their mode of movement making them more attractive prey easy targets for capture. Low transparency of Lake Mweru-wantipa could have led to less predation making cladoceran to flourish.

The dominance of copepods among zooplankton in fresh water has been also reported in Lake Victoria (Ngupula, 2013; Ajounu, 2011). In the present study, the cyclopoids (Table 6) showed higher relative abundance compared to other zooplankton. Similar findings have been reported by Silva (1998) in Patricio *et al*. (2010); Waya and Mwambungu (2004) in Chilean inland waters and Lake Victoria respectively. Cyclopoids can survive in most kinds of fresh water habitats in the Neotropics. This can be explained by their feeding behavior; they are grasping feeders that generally eat variety of food than other zooplankton (Irvine & Waya, 1992), while the calanoids are limited by their selective and herbivorous nature. The ostracods are not so commonly captured in many zooplankton studies due to their benthic nature (Martens *et al*., 2008). Contrary to the present study (Table 6) Devaraju (2015) found four taxa of ostracods 14 taxa in a major tropical lake of Mandya district Karnataka. Rotifers constituted the lowest contribution among all zooplankton in the present (Table 4). In contrast, rotifers were among dominant taxa in Lake Victoria Basin with 18 species (Waya & Chande, 2004). Rotifers appear to be protected from predation owing to their diminutive size, which offer low caloric value as prey besides being not easily visible to the predators.

Shannon Weaver diversity index showed higher diversity of zooplankton on the settlement side, and the Hutcheson *t*-test showed a significant difference between the two sides. The diversity difference probably could be due to the high species evenness on the settlement side (Table 5). Also higher salinity on the National park could have been responsible for low diversity of zooplankton. Nielsen *et al*. (2003) reported that zooplankton diversity has been reduced at salinities between 1 to 5 ppt. Low species richness on the settlement side (Table 5) could be a reflection of the high turbidity compared to National park areas. Ghidini *et al.* (2009) in the study of eutrophic shallow reservoir in Brazil reservoirs made a similar observation. The species richness in the present study (Table 5) was generally poor compared to other studies conducted elsewhere; e.g. Ezekiel *et al*. (2011) in a tropical lake in Nigeria found 17 species belonging to six taxonomic groups, Brazil. However, similar results have been found by other workers, e.g. Omuwaye *et al.* (2011) in Nigeria, reported only 11 species belonging to three groups of zooplankton.

**5.3 Zooplankton Density**

Differences in zooplankton densities were observed between the two studied sites (Table 6). These could have been due to the differences in physico-chemical parameters and to depth between the two sites (Table 2). The lower densities of rotifers on the National park side and absence on settlement areas compared to other groups could be attributed to higher turbidity in the lake which was significantly high in settlement areas and to salinity and pH which were significant higher in settlement areas. These factors are well known in limiting the abundance and diversity of zooplankton (Harris and Vinobaba, 2012). Contrary to the present findings (Table 6), Gammanpila *et al.* (2010) in a Sri lankan lagoon reported higher proportions of rotifers (11% to 37%) compared to other groups of zooplankton. However, similar results of zooplankton total densities in studied sites have been reported by Gammanpila *et al*. (2010) in Sri lanka, whose densities were in the range of 87 to 298/l. The higher copepod density compared to other zooplankton has been reported by Ekwu and Sikoki (2005) found crustacean compositions of 74% (copepod 17 taxa & cladocera 11taxa) in lower estuary in Nigeria. The highest density of cyclopoids in freshwater has also been reported by other workers elsewhere e.g. Ngupula (2013) reported that cyclopoids had dominated by 73%. In contrast to the present findings (Table 6) the highest contribution of *Moina* has been reported by Abubakar (2013) in Nguru Lake, the crustaceans were composed of 65% of which 41% were cladocerans dominated by *Moina*.

**5.4 Relationships between Zooplankton, Abundance and Physico-chemical Parameter**

The regression analysis revealed that there was positive and significant relationship between turbidity and zooplankton on the settlement side (Tables 7 & 8). This positive significant relationship may have been contributed by higher significant abundance of *Moina*, *Ceriodaphnia* and *Cypris* in the settlement areas (Table 6), which had also high significant turbidity (Table 2).This could be explained partly by the reduction of the ability of the visual predators to see prey (zooplankton) in turbid waters, thus allowing larger zooplankton to flourish. This was also observed in small lakes in Lake Victoria basin that low transparency makes these lakes to support high abundance of zooplankton than in Lake Victoria with higher transparency (Moss, 1998 in Waya, 2004 and (Ngupula, 2013). However, in the present study (Table 7) an opposite relationship was observed between zooplankton and pH. This suggests that high pH contribute to the lower densities of zooplankton. However, contrary to the present findings, Beenamma and Sadanand (2011) in India, reported positive relationship between zooplankton and pH. In addition, Tenner *et al.* (2005) in Dhembare (2011) reported that pH values ranging from 6 to 8.5 are associated with medium productivity.

# CHAPTER SIX

## 6.0 CONCLUSION AND RECOMMENDATIONS

### 6.1 Conclusion

Turbidity, salinity and dissolved oxygen were significantly different between the two studied sites. A higher diversity index was recorded from the settlement, compared to National park site. With the exception of *Moina*, *Simocephalus*, *Ceriodaphnia*, and *Cypris*, the density of all species were not significantly different between the two studied sites. Turbidity and pH were significantly positively and negatively correlated with zooplankton abundance respectively.

### 6.2 Recommendations

There is a great need for promotion and capacity building among farmers and fishers on conservation and best farming practices such as agro-forestry in the lake's catchment area. Specific practices like contour farming on the catchment slopes will lead to reduction in runoffs in to the lake, reducing siltation in the lake. The introduction and integration of suitable tree species in crop production will also lead to reduced load of sediments in the lake. The present study lasted for three months; a follow up study covering a whole year is recommended.

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