

**THE ZOOPLANKTON AND MACROBENTHIC INVERTEBRATE FAUNA
OF SILUKO RIVER, EDO STATE, NIGERIA**

BY

Aishat Abisola YUSUFF

B.Sc. (Benin)

PG/LSC1513530

**UNIVERSITY OF BENIN
BENIN CITY**

APRIL, 2021

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**A THESIS WRITTEN IN THE DEPARTMENT OF ANIMAL AND ENVIRONMENTAL
BIOLOGY AND SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES IN
PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF MASTERS
OF SCIENCE (M.Sc.) DEGREE IN ENVIRONMENTAL QUALITY MANAGEMENT OF
THE UNIVERSITY OF BENIN, BENIN CITY.**

APRIL, 2021.

CERTIFICATION

This is to certify that this project work was successfully carried out by **Aishat Abisola YUSUFF (PG/LSC1513530)** in the Department of Animal and Environmental Biology, Faculty of Life Sciences, University of Benin.

Prof. M. O. Omoigberale
(Supervisor)

Date

Prof. A. A. Imasuen
(Head of Department)

Date

(External Examiner)

Date

DEDICATION

This work is dedicated to Almighty Allah.

ACKNOWLEDGEMENTS

First and foremost, my profound gratitude goes to Almighty Allah for his love and mercies upon me and for being my source of strength during the practical aspect and final compilation of this work. This project work wouldn't have been a success without the support and proper supervision of my amiable Supervisor, Professor M.O. Omoigberale whose constructive criticism, regular push, corrections and input in this work improved the standard of the work, despite his tight schedules, he created time out of no time for me. A big thank you goes to the Head of department Animal and Environmental biology Professor A.A. Imasuen and the staff of the department.

Immeasurable gratitude goes to my loving and caring parents late Mr R. O. Yusuff and Mrs O. I. Yusuff who through God's provision made this M.Sc. dream a reality even though daddy didn't wait to see the end of this work, May your gentle soul rest in perfect peace. And to my lovely sisters Gbemisola and Boluwatife Yusuff, you girls are the best. My profound gratitude goes to Mr. Suleiman Ikhuorah for his everyday support, encouragement and brotherly advice. A very big thank you to all the lecturers in Animal and Environmental Biology for the everyday knowledge you all impacted in us. May God bless you all abundantly.

Special thanks go to Mr Olowo Ukpamufo Cyril, Mr Cletus, George Urhoghide, Mr Festus Arijode and Mr Ifeanyi Ezenwa for their invaluable assistance during the field and laboratory works and compilation of this thesis. A big thank you goes to my project mates; Kema, Eronmosele and Emeka for their cooperation during the field work, laboratory work and compilation of this thesis. I sincerely appreciate you guys. My heartfelt gratitude goes to my friends, ken, Nonso, Tracy, Angela and Funke, your friendship and encouragement created a harmonious atmosphere during the compilation of this work. I love you all. My dearest Ololade Oduyoye, you already know how much I appreciate you. And to everyone who in one way or the other contributed to the success of this work, may Almighty God bless you all.

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ABSTRACT

Zooplankton and macrobenthic invertebrate fauna are good indicators of the overall water quality of rivers, as changes in water quality affect their general distribution and abundance. This study investigates the community structure of zooplankton and macrobenthic invertebrate fauna of Siluko River, Edo State, Nigeria.

Zooplankton and macrobenthic invertebrate samples were collected monthly from July 2016 to March 2017 at four designated stations between 09:00 hours and 12:00 hours using plankton net and filtering 100litres of water respectively and thereafter analyzed in the laboratory using standard methods.

A total of 20 zooplankton taxa comprising 386 individuals belonging to the group Cladocera, Cyclopoida, ploimida and flosculariaceae were encountered. *Tropocyclops prasinus* had the highest number of abundance. Cladocera accounted for 31.00% while Cyclopoida, Ploimida and flosculariaceae accounted for 62.00%, 6.00% and 1% respectively. Shannon-Weiner's diversity indices showed that highest value of 3.583 was obtained in station 4 and lowest value of 2.731 was obtained in station 2 for the zooplankton. There were no observed seasonal variation in Cladocera and Copepods composition and abundance except for Rotifers which were more abundant in dry season. A total of 52 macrobenthic invertebrates taxa comprising of 2163 individuals, three phyla; Annelida, Arthropoda and Mollusca were encountered in this study. *Centroptilum* sp. had the highest abundance. Diversity and evenness indices showed that there was no significant difference ($p>0.05$) in species composition across the study stations. Using the Shannon-Weiner's diversity index, highest value was obtained in station 1 and lowest was obtained in station 3. Ephemeroptera, Plecoptera, Trichoptera (EPT) index revealed that the water quality at stations 1, 3 and 4 were acceptable while that of station 2 was categorized as

good. The zooplankton and macrobenthic invertebrate communities in Siluko River were characterized by species which indicated good water quality. However further studies are recommended to monitor the changes to this water body and their probable health effects as anthropogenic activities such as farming and housing development are on the increase around this stretch of the River.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of Study

The aquatic environment is a major natural component of the earth which serves as habitat for a wide range of organisms from plankton to fish, other pelagic and benthic organisms. Plankton (singular plankter) is any drifting organism (animals, plants, archaea, or bacteria) that inhabit the pelagic zone of oceans, seas, or bodies of fresh water. While some forms are capable of independent movement and can swim hundreds of meters vertically in a single day; behaviour called diel vertical migration. Their horizontal position is primarily determined by the water currents. This contrasts with nektonic organisms such as squid, fish, and marine mammals that can swim against the ambient flow and maintain their position (Emiliani, 1991). Plankton covers a wide range of sizes, from the tiny phytoplankton to large organisms such as jellyfish. Plankton are defined by their ecological niche rather than phylogenetic or taxonomic classification. They provide a crucial source of food to larger, more familiar aquatic organisms such as crustacean and fish (Thurman, 1997).

Zooplankton species inhabit all freshwater habitats of the world, including industrial and wastewaters (Mukhopadhyay *et al.*, 2007), and they are also found in oceans and seas and play a very important role in the aquatic food chain and food web as energy flows from phytoplankton to herbivorous zooplankton which in turn provide energy for large epipelagic animals which cannot feed directly on the phytoplankton (Caber and Huber, 2001; Hickman *et al.*, 2001; Dejenet *et al.*, 2004). The population size or standing stock is therefore of great importance in any aquatic ecosystem since these organisms constitute an important food source for many nektonic species particularly the juvenile of fishes (Guy, 1992). The zooplankton species composition in a water body is the result of the interactions between the abiotic and biotic factors. Thus, it can be said that zooplanktonic composition responds to the

interannual variability in the aquatic ecosystem, thereby, affecting the production of the lower trophic level plankton (Iloba and Akawo 2013). Zooplanktons are globally recognized as indicators of pollution in any aquatic environment. Due to their sensitivity and fast response to wide range of environmental changes such as water temperature, pH, conductivity and nutrients (Yakubu *et al.*, 2000). They are not only useful as bio-indicators to help us detect pollution load but are helpful in ameliorating polluted waters (Mukhopadhyay *et al.*, 2007). Due to the various types of organic and industrial waste emptied into the stream biota, it is often subjected to environmental stresses which may alter the structure of natural ecosystem. The possible biological effect of these may be deleterious, beneficial or neutral to specific organisms in the aquatic community.

Changes in zooplankton abundance, species diversity and community composition can indicate the change or disturbance of the environment (Manickam *et al.*, 2018). The abundance and diversity of zooplankton vary according to limnological features and trophic state (Jeppesen *et al.*, 2002; Imoobe and Adeyinka, 2010). It is also influenced by climatic, physical and chemical parameters, bio-geographical factors, and biotic interactions, therefore some species could be found in a wide range of environmental conditions, while others are limited by many physical and chemical factors including pollution (Neves *et al.*, 2003). These factors have drawn the interest of several biologists focusing on zooplankton occurrence, composition, distribution and significant role in pollution studies (Ogbeibu and Obanor, 2002).

Most studies on the composition of zooplankton communities have focused on rotifers, cladocerans, and copepods (Kudariet *al.*, 2005; Kumari *et al.*, 2008; Imoobe and Adeyinka, 2010). Calanoid copepods are generally abundant in oligotrophic waters, while cyclopoids (copepods), rotifers and cladocerans dominate in eutrophic waters (Margalef, 1983; Wetzel, 2001).

The term “benthos” (ancient Greek βένθος meaning “depth, depth of the sea, bottom”) was introduced by the eminent German naturalist and artist Ernst Haeckel (1834–1919), who also introduced the term “ecology”. The benthic community is complex, and it includes a wide range of organisms from bacteria to plants (phytobenthos) and animals (zoobenthos), and from the different levels of the food web. Benthic animals are generally classified according to size: microbenthos < 0.063 mm, meiobenthos 0.063 to 1.0 mm (or 0.5mm), macrobenthos > 1.0 mm and, sometimes megabenthos > 10.0 mm. Benthic invertebrates can be differentiated by the position they occupy on or in bottom sediments, such as; Infauna are animals that live in sediments (almost all worms and bivalves belongs to this category), Epifauna are organisms that live on the surface of bottom sediments (many crabs and gastropods are considered epifauna and these animals can be found living attached to hard surfaces, such as the bricks and rocks of the banks or pilings). They also include epiphytic invertebrates, i.e. organisms that live on the surface of submerged vegetations, such as many amphipods.

Macrobenthic invertebrates are vital to the circulation and recirculation of nutrients in aquatic ecosystems and constitute the link between the unavailable nutrients in detritus and useful protein materials in fish and shellfish (Keke *et al.*, 2017). They also accelerate the breakdown of decaying organic matter into simpler inorganic forms such as phosphates and nitrates (Gallep *et al.*, 1978). They act as food source for larger organisms such as fish, thereby linking primary production with higher trophic levels and structure/oxygenate the bottom by reworking sediments. In addition, several benthic invertebrates, particularly clams, are consumed by humans and others, such as worms, are used for recreational purposes as fishing bait.

Macrobenthic invertebrates are an important component of the ecosystems, since they serve as a critical intermediate pathway for the transportation and utilisation of energy and matter. They are the most veritable tools in the area of biomonitoring (Nkwoji *et al.*, 2010)

and the relative stability of benthic communities and their sensitivity to changes in the aquatic environment have made them bioindicators for the studies of impact of environmental perturbation on aquatic environment (Edokpayi and Osimen, 2001; Adakole and Annune, 2003). Individual taxon has been known to respond differently to a variety of pollutants and provide an indication of water quality over varying periods of time (Bonada *et al.*, 2006; Odume and Muller 2011).

They provide information on these environmental conditions either due to the sensitivity of single species (indicator species) or because of some general feature that makes them integrate environmental signals over a long period of time. These features include: exposure to chemical contaminants often accumulated in the sediment; exposure to low dissolved oxygen levels (hypoxia/anoxia) that often occur near the bottom surface due to organic matter degradation; limited mobility that restricts their ability to avoid adverse conditions; taxonomic and functional diversity that make them suitable for the detection of different types and levels of stress and they provide more accurate changing condition than chemical and microbiological data, which gives short term fluctuation.

Marques *et al.* (2003) states that knowledge of the structure of macrobenthic invertebrate community provides precise and local information on recent events. Olomukoro and Dirisu (2013) reported that the use of macrobenthic invertebrates to ascertain the overall health status of aquatic environments remains the most suitable, reliable, and widely acclaimed method globally. The poor taxonomic knowledge of African freshwater faunas in general, allows few groups to be identified beyond the generic level, thus limiting detailed analysis of benthic communities (Avoaja *et al.*, 2007).

1.2 Justification of Study

River Siluko is in Ovia South West local Government Area Edo State, and it is a major source of water for the inhabitants of Siluko village and the communities in its catchments. River Siluko is mainly impacted by domestic, cultural and agricultural activities such as bathing, laundry, African traditional worship, fishing and runoff from farms. It also serves as a means of transportation. River Siluko is rich in fish fauna and reports on it include those of Ekhaton *et al.* (2011), Oboh and Agbala (2017) and Oboh and Olowo (2017), on its limnology, microbiology/water quality and biology of selected fish species respectively. While the zooplankton and benthic communities of other freshwater bodies in Southern Nigeria have been reported by various researchers, none exist for River Siluko to the best of my knowledge.

1.3 Aim and Objectives

The aim of this study was to determine the Community structure of zooplankton and macrobenthic invertebrate fauna of Siluko River, Benin City, Nigeria.

The specific objectives of the study were to:

1. Determine the species composition and diversity of the zooplankton and macrobenthic invertebrates in Siluko River.
2. evaluate the spatial and temporal variations in the abundance of zooplankton and macrobenthic invertebrates in Siluko River.
3. evaluate the water quality of Siluko River using Macro-benthic invertebrates as Biological indicators.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Zooplankton

In the last few decades, aquatic ecologists have focused more on water quality, resources management and sustainable utilization of aquatic resources. However, inundation, siltation, agriculture and deforestation outside industrialization and urbanization, also poses great challenges to aquatic regimes. Many studies on the relationship between zooplankton community structure and disturbance from natural, anthropogenic or pollution of the aquatic ecosystem have been reported (Green 1993; Arora 1996; Battish 2002; Kumari *et al.*, 2008; Jain *et al.*, 2010; Imoobe and Adeyinka 2010; Parmar *et al.*, 2016; Olga and Rezeda 2016). The use of zooplankton as bioindicator for monitoring water quality in the aquatic environment has gained global recognition and has been reported by various authors (Yakubu *et al.*, 2000; Ogbeibu and Edutie 2009; Ogbeibu and Omoigberale 2005; Okogwu and Ugwumba 2006; Zorka *et al.*, 2006; Omoigberale and Ogbeibu 2007; Mohammed *et al.*, 2016).

Akin-Oriola (2002) studied the zooplankton associations and environmental factors in Ogunpa and Ona Rivers, Nigeria and reported 49 species from both rivers comprising 32 species of rotifera, 6 species of protozoa, 6 species of cladocera and 4 species of copepoda. Brachionidae had the highest species richness among the rotifers, the cyclopoda were the most abundant group of copepods in the two rivers with three species: *Thermocyclops neglectus*, *Eucyclops serrulatus* and *Mesocyclops* sp., the cladoceran fauna included *Diaphanosoma excisum* and *Ceriodaphnia cornuta*. The hydrological investigation in Okhuo River by Edema *et al.* (2002) revealed that the water had low level of organic matter and that rotifers and insects dominated by Ephemeroptera were the dominant biota. Dejen *et al.* (2004) in their report on temporal and spatial distribution of microcrustacean zooplankton in relation

to turbidity and other environmental factors in lake Tana, Ethiopia reported that among the environmental factors, zooplankton abundance correlated with species abundance, especially for *Daphnia* sp. and to the least extent for *Diaphanosoma* sp.

Omoigberale and Ogbeibu (2007) studied the impact of crude oil exploration on the crustacean zooplankton of Osse River, Edo State and observed that cladocera accounted for 60.85% of the total number of organisms, while the copepoda contributed 39.15%. Chydoridae was the only cladoceran family recorded and represented by 11 taxa of two subfamilies, Aloninae (7) and Chydorinae (4). The temporal dynamics revealed higher faunal abundance during the dry season.

Imoobe and Adeyinka (2010) assessed the trophic status and investigated the zooplankton community structure of a Nigeria forest river. They observed that the zooplankton composition was typical of a tropical freshwater river, with a total of 40 species made up of 16 rotifers, 12 cladocerans and 12 copepods and their developing stages in the following order of dominance; Rotifera > Cladocera > Cyclopoids. They further reported that the zooplankton community was dominated by numerous species of rotifers and crustaceans, which are typical of Oligotrophic to mesotrophic systems, amongst these were *Conochiludos suaris* and *synchaeta longipes*. While the most dominant zooplankton species were *keratella tropica*, *keratella quadrata*, *Brachionus angularis*, *Trichocerca psusilla*, *Fillinia longiseta*, *pompholyx sulcata*, and *Proales* sp.

Imoobe (2011) investigated the diversity and seasonal variation of zooplankton in Okhuo River, Edo State and revealed that species richness, evenness and diversity of zooplankton were high and typical of a tropical freshwater river. A total of 51 species, made up of 24 rotifers, 15 cladocerans and 12 copepods were observed in the following order of dominance: Rotifera > Cladocera > Copepoda. Higher species number and density was found during the rainy season with a trend toward a declining proportion during the dry season. He

concluded that flooding during the rainy season may have contributed positively to increase in zooplankton population.

Ogbuagu and Ayoade (2012) in an investigation on the seasonal dynamics in plankton abundance and diversity of a freshwater body in Etche, Nigeria reported that the zooplankton consisted of 7 taxa and a mean density of 433 organisms/ml and dominance was Cladocera (25.87%), Copepoda (20.55%), Protozoans (19.17%), Rotifera (18.71%), fish eggs and larvae (9.24%), Crab larvae (4.62%), and Beetle larvae (0.69%). Higher Margalef's values were recorded in the dry season (3.655; 57% and 1.273; 61%) than the wet season (2.732; 43% and 0.810; 39%) for phytoplankton and zooplankton biotypes, respectively. They observed seasonal peaking in their abundance was attributed it to periods of high nutrients concentration and stability in growth factors of plankton biotypes.

Ekpo (2013) on the effect of physico-chemical parameters on zooplankton species and density of a tropical rainforest river in Niger Delta, using canonical cluster analysis observed that all the sampling stations were significantly different ($CV=17.72$; $F=46.09$; $p=<0.0001$) and that the total number of classes, genera and species of zooplankton sampled were 4, 41 and 53 respectively. Zooplankton was observed in the order rotifers 37.74%, protozoa 18.87% and copepods 16.98%. It was reported that clean water species clustered in upper course where the most important environmental factor was transparency while pollution-tolerant species clustered in the downstream station which had nutrients, water level, total dissolved solids and biochemical oxygen demand as determinant environmental vectors. The middle course had fewer species clustered with the vectors of dissolved oxygen and total hardness. In conclusion these trends were attributed to anthropogenic perturbations that altered the ecosystem stability and cause a shift in the longitudinal pattern downstream.

Iloba and Akawo (2013) in a study of the zooplankton diversity of river Adofi, Delta State alongside its physico-chemical parameters observed that the two taxonomic groups were identified were rotifera and Cladocera while nutrient levels were significantly very high.

Rotifers were the most occurring species (15) constituting 98.7% of the total zooplankton species while the Cladocera had two species with 1.3%. Of the phylum rotifera, the family Brachionidae (*Brachionus calyciflorus*, *Brachionus leydigi*, *Brachionus falcatus*, *Cohurella uninata*, *Lepadella ovalis*, *Notholca acuminata*) recorded six species constituting 40% of the total number of species, while the other three families Lecanidae (*Lecane papauna*, *Lecane curvicornis*, *Lecane luna*), Proalidae (*Proalessp 1*, *Proalessp 2*, *Proalessp 3*) and Trichocercidae (*Trichocerca cylindrica*, *Trichocerca obtusteins*, *Trichocerca iarnis*) each had three species (20%). The two species of Cladocera recorded were *Ceriodaphnia audragula* and *Diaphanosoma maleuchen*. They further reported that no significant difference was found between the physico-chemical parameters but zooplankton abundance ($P < 0.01$) differed significantly with physico-chemical parameters.

Onyema (2013) carried out a study on the composition and abundance of zooplankton in a polluted section of Eruvbi stream and reported the presence of forty (40) species made up of nine species of cladocerans, nine species of copepods and their developing stages and 22 species of rotifers with rotifers being the dominant taxa. The most frequent zooplankton species in the polluted part of the stream were the rotifers *Brachionus calyciflorus*, *Brachionus falcatus*, *Brachionus caudatus* and *Testudinella patina*. Relative abundance was in the order rotifers < copepods < cladocerans.

In an assessment of the physico-chemical water condition and zooplankton fauna of the two main inflows of Aiba Reservoir, Iwo, Osun State, Nigeria, Akindele and Olutona (2014) revealed that the concentrations of total solids (TS) and total suspended solids (TSS) in the two streams were unusually high in the dry season and showed a decrease from the upper reaches towards the lower reaches (reservoir's inlet). Dissolved oxygen, NO_3^- and PO_4^{3-} concentrations were highest at the reservoir's inlet while a total of 37 species of zooplankton comprising 5 species of Protozoa, 14 species of Rotifera, 10 species of Copepoda, 4 species of Ostracoda and 4 species of Insecta were recorded. The number of

zooplankton species and abundance showed an increase from the upper reaches to the lower reaches of both streams, species diversity and equitability generally showed a decrease. They further observed that correlation and regression analysis suggested that the concentration of TS and TSS played a major role in determining the zooplankton community structure of the streams and concluded that PO_4^{3-} concentrations as well as the community structures of zooplankton faunas in the two streams indicated a polluted freshwater system with unstable habitat structure.

Ikhuorih *et al.* (2015) in a study of the River Ossiomo, Ologbo identified a total of 42 taxa comprising 11 species of cladocerans, 6 species of copepods and 15 species of Rotifers in the following order of dominance: copepoda>cladocera>rotifera. The dominant copepod and cladocera species were *Thermocyclops neglectus* and *Alona eximia* representing 33.1% and 15.8% respectively of the total zooplankton population. They observed that higher species number and density were found during the wet season with a decreasing trend towards the dry months.

Arazu and Ogbeibu (2017) in a study of the composition, abundance and distribution of zooplankton along a stretch of the Niger River, Onitsha found out that a total of 26 species of, 8 species of copepoda and 23 species of rotifer were encountered. Diversity using Shannon Wiener and Margalef's indices showed higher diversity in decreasing order of stations $2 > 4 > 3 > 5 > 1$, while similarity indices using Jaccard's Bray Curtis and Euclidean distance indices showed that stations 1 and 5 and stations 2 and 4 respectively were more similar to each other, with station 3 being closer to 1 and 5 than to 2 and 4. They concluded that the adverse effect of human activities and perturbations affected the composition and distribution of zooplankton.

Kennie *et al.* (2017) on the zooplankton assemblage along Jebba Upper Basin, Nigeria reported that a total number of 658 individuals were enumerated and the most evenly distributed was cladocera (*Bosminopsis* sp, *Bosmina* sp, *Diaphanosoma excisum*,

Ceriodaphnia cornuta, *Moina micrura*, *Macrothrix* sp, *Nauplii* sp) which represented 40.58% of the total population, although copepoda with 41.19% (*Cyclopid copepods*, *Calanoid copepods*, *Copepodites*) was the most abundant, rotifers (*Lecane decipiens*, *Asplanchna* sp, *Brachionus calyciflorus*, *B. diversicornis*, *Polyarthra* sp, *Keratella tropica*, *Trichocerca cylindrica*, *B. angularis*, *B. falcatus*, *Filiniaopo liensis*, *L. papuana*) was the most diverse in terms of species representation. The zooplankton abundance followed the order copepoda>cladocera>rotifer. They concluded that zooplankton community of Jebba upper basin was dominated and characterized by species that indicated good ecological conditions.

Onyebuchi *et al.* (2019) in a preliminary investigation on the distribution and relative abundance of plankton and fish species in Ivo River Basin in Nigeria revealed that zooplankton was represented by cladocera 53.9% (*Plueroxusstriatus*) < protozoa 46.1% (*Arculla arenaria*, *Emiphrys pleurosigma*, *Dileptus binucleatatus*, *Chromogaster testudolauterborn*, *Arealla vulgaris*, *Hemiophrys pleurosigma*) and a total of 5 families in seven genera were recorded for fish with relative percentage abundance of 2.4%, 4.8%, 12.2%, 39% and 41.5% for claroteidae, schilbeidae, mormyridae, cichlidae and clariidae respectively. They observed that diversity was generally low for all biota, while the prevailing factors of wet season could be responsible for the low abundance and distribution recorded and that the relative high density of *Microcystis aeruginosa* cells in some sampling stations indicated that the stations were under pollution stress.

Mukhopadhyay *et al.* (2007) in a study of the spatial variation of zooplankton diversity in waters contaminated with composite effluents observed that site 1; a fish pond with stabilized composite waste water (a relatively less polluted site) to have the maximum species richness of 17 species, while site 2; waste water carrying canal (the waste water point source) had only 4 species. The result showed that *Shannon-Weiner* species diversity index (H^1) values were almost similar for the three relatively less polluted sites; site 1 (1.959), site 4 (2.010), site 5 (2.047). However, at the highly polluted sites viz, 2 and 3, H^1 value of 1.336

and 0.984 respectively were recorded. They also discussed the roles of zooplankton in the amelioration of wastewater. According to them, plankters played a major role in the amelioration process of the contaminated water through degradation of the suspended solids and progressive utilization and transformation of the nutrients.

The species composition, longitudinal distribution and seasonal dynamics of zooplankton were studied in the Zagyva River, Hungary by Meszaros *et al.* (2012). A total of 108 taxa were recorded from which 61 were new records for the river. Rotatoria was the most abundant group, microcrustaceans were less important, only nauplii and copepodites were represented in similar individual numbers. Frequent species included *Anuraeopsis fissa*, *Pompholyx* sp., *Keratella cochlearis*, *Brachionus angularis*, *Bdelloida* sp., *Bosmina longirostris*. Dominance of cosmopolitan species was observed both in the river and its reservoir, and species characteristic of eutrophic waters were of major importance in the latter. There was downstream decrease in zooplankton densities, which was explained by modified conditions. The relatively large number of individuals in autumn months, and the characteristic large number of individuals in the upper section contrasted with general findings of potamoplankton dynamics.

Watkari and Barbate (2013) studied the zooplankton diversity of Kolar River, Saoner Dist. Nagpur, India and reported the presence of 28 species of zooplankton belonging to five major groups. Five species of Protozoa, nine species of Rotifers, six species of Copepods, three species of Ostracods and five species of Cladocerans were recorded.

In a study carried out to show the abundance and diversity of zooplankton and macrobenthic invertebrates in relation to some environmental variables in El-Rayah El-Menoufy, Egypt, Khalifa and Bendary (2016) reported that rotifers formed the main component of zooplankton which indicated eutrophication. *Keratella cochlearis* was the main rotifer in spring and winter, *Brachionus calyciflorus* and *Epiphanes macrura* dominated in summer while *Collotheca pelagica* flourished in spring and autumn seasons. *Vorticella*

campanula was the most abundant protozoan and was observed in spring, summer and autumn with the highest population density of 149 ind.l⁻¹ in autumn. A sharp increase recorded in total zooplankton density for spring season (average, 1868 Ind.l⁻¹) and a marked decrease for summer and winter seasons with averages of 203 and 54 ind.l⁻¹ respectively which suggested seasonal changes in the trophic conditions .Principal Component Analysis (PCA) showed that the dominant zooplankton species could tolerate changes in physico-chemical variables and indicated that most of macrobenthos were positively influenced by temperature and pH and negatively with electrical conductivity (EC) and dissolved oxygen (DO).

Investigations by Manickam *et al.* (2018) on the impact of seasonal changes in zooplankton biodiversity in Ukkadam Lake, Coimbatore, Tamil Nadu, India revealed that the presence of 28 species of zooplankton, which includes 9 species of Rotifera and Cladocera and 5 species of Copepoda and Ostracoda. The total abundance of zooplanktons was Rotifera 35%, Cladocera 29%, Copepoda 29% and Ostracoda 7% while population density was observed in the following order Rotifera>Copepoda> Cladocera > Ostracoda. They further observed that zooplankton productivity was higher with increase in temperature and concluded that increased temperature due to global climate change might have influenced on the zooplankton production.

2.2 Macrobenthic Invertebrates

Indices based on macro-invertebrates assemblages have proven useful in measures of river health and are widely applied today (Omoigberale and Ogbeibu 2010). There are several advantages of using benthic macro-invertebrates in the assessment of water quality and according to Sengupta and Dalwani (2008) they are ubiquitous in rivers and can therefore be affected by environmental disturbances in many different types of aquatic systems and in most habitats/biotopes (Iyagbaye *et al.* 2017). Benthic macro-invertebrates are largely non-

mobile which makes them good representative of the location being sampled. With their lifespan being long enough to allow for the elucidation of temporal changes caused by disturbances and short enough to ensure observation of recolonisation patterns after these disturbances (Iyagbaye *et al.* 2017).

A study of the macrobenthic invertebrates of a fourth order stream in Southern Nigeria was carried out by Ogbeibu and Oribhabor (2002) to assess the ecological impact of impoundment. The density of the three dominant taxonomic groups; Diptera, Oligochaeta and Ephemeroptera differed significantly ($P < 0.05$) among the stations, while chironomid dipterans dominated the up and downstream stations and oligochaeta dominant in the reservoir. The density of Ephemeroptera was significantly reduced within the reservoir and the downstream station and they further reported that stream impoundment altered not only the river hydrology but also the faunal characteristics of downstream stations. In an assessment of the macrobenthic invertebrate fauna of rivers in southern Nigeria by Olomukoro and Ezemonye (2007) which comprised of water bodies in the rainforest and derived savannah ecozones. The macrobenthic invertebrate fauna of Edo Ecozone was found to comprise 55 taxa, belonging to 13 major groups. Taxonomic groups varied considerably among the surveyed aquatic ecosystems. Chironomidae (Diptera) were well represented and dominant in 11 of the 20 water bodies surveyed. The most rare and restricted species were gastropods (Mollusca), one such species, *Mutela cf. dibia*, being endemic to the catchment.

Avoaja *et al.* (2007) studied the macrobenthic fauna of a humid tropical water reservoir, Abia State and reported that three phyla of macrobenthos (Arthropoda, Mollusca and Annelida) prevailed with 644 (50.4 %), 165 (12.9 %), and 470 (36.7 %) respectively and a significant difference was observed ($P < 0.05$) among the phyla populations. Emere and Nasiru (2009) investigated the use of macroinvertebrates as indicators of the water quality in an urbanized stream in Kaduna and reported that a total of 1304 macroinvertebrates were recovered with twenty-seven taxa being recorded. The presence of low densities of pollution

tolerant macroinvertebrate groups, the deteriorating water quality and the physico-chemical conditions of the water during the dry season months reflected organic pollution. Physical and chemical parameters varied between the rainy and dry season months. Macroinvertebrate population were represented by Mollusca (*Bulinus* sp., *Physa* sp. and *Biomphalaria* sp.), Diptera (*Enstalis larvae*, *Simulium* sp., *Chironomus* sp., *Pentaneura* sp., *Coatate pupa*, *Chironomus pupa* and *Anopheles larva*), Coleoptera (*Sphaerodema* sp., *Hydrous* sp. and *Phthydrus* sp.), plecoptera (*Neoperla* sp. and *Brachythermis* sp. Odonata (*Coenagrion* sp., *Aeschna* sp., *Pseudagrion* sp. and *Enallagma* sp.), Annelida (*Tubifex*, *Nais*, *Stylaria* and *Glassiponia*), Crustacea (Astacidae), Ephemeroptera (*Pseudocleon* sp.), Hemiptera (*Notonecta* sp.) and Hirudinea (*Glossiphonia* sp.). The indices of general diversity (H), evenness (E) and dominance were high. Although diversity was higher at station 2 evenness and dominance were higher at station 1 and 3 respectively.

Studies by George *et al.* (2009) on the benthic macro invertebrate fauna and physico-chemical parameters in Okpoka creek sediments, Niger Delta, Nigeria revealed that a total of nineteen (19) of benthic invertebrates' fauna belonging to four (4) phyla (Annelida, Amphipoda, Arthropoda and Mollusca), six (6) classes (Oligochaeta Polychaeta Crustacea Insecta Bivalvia and Gastropoda) and twelve (12) families (Naididae, Arenicolidae, Eunicidae, Capitellidae, Glyceridae, Nereidae, Nephthyidae Gammaridae Callianassidae, Chironomidae, Tellidae) were observed. Polychaeta with six (6) families and twelve (12) species accounted for 63.2% followed by Crustacean with six (2) families and twelve (3) species and percentage of 15.8%. pH, temperature, salinity conductivity had a positive relationship with macrobenth invertebrate adundance.

Olomukoro and Azubuike (2009) in a study on the heavy metals and macroinvertebrate communities in bottom sediment of Ekpan Creek, Warri showed that nineteen macroinvertebrate taxa belonging to four major groups were identified. Mollusca (Gastropoda; Neritidae; *Neritina glabrata* and *Nerita senegalensis*, Hydrobiidae; *Hydrobia*

sp., *Potamopyrgus* sp. and *Argyronecta aquatica*, Potamididae; *Tympanotonus* sp., Pilidae, and Assimineidae) were the most dominant and constituted 92.51% density occurrence, while insect (Diptera; *Chironomus* sp. *Tanytarsus* sp. and *Tanytus* sp), crustacean (Apheidae; *Potamalpheops monodi*), and polychaeta (*Namanereis hawaiiensis*, *Lycastopsi* sp and *Nereis* sp constituted 1.94, 2.29, and 3.26% respectively. Diversity varied at the study stations, with the highest taxa richness recorded at station 1. A positively correlation was observed for mollusca with lead ($P < 0.05$, $r = 0.836$), and Zinc ($P < 0.05$, $r = 0.96$). Sorenson index indicated similarity in species composition between the stations.

The hydrochemistry and macrobenthic fauna characteristics of an urban draining creek by Edokpayi *et al.* (2010) revealed that a total of 246 organisms belonging to 16 benthic taxa, 13 genera, 12 families, 8 orders and 4 phyla were observed. Chironomid larvae and the Naidid worms were the most abundant groups and accounted for 25.61 and 22.76% of the total macrobenthic count. They further reported that high BOD₅, nitrates and phosphates values and the low number of taxa and numerical abundance of pollution indicator macrobenthos were indicative of a perturbed environment. Omoigberale and Ogedegbe (2011) investigated the spatial distribution and abundance of Diptera larvae at five different sites in a fourth order river in southern Nigeria, between thirteen taxa comprising three families were encountered from a total of 3,516 individuals recorded. The dominant species were *Chironomus transvaalensis* (19.65%), *C. fractilobus* (13.48%), *Pseudochironomus* sp (11.72%), *Pentaneura* sp (10.3%) and *Polypedium* sp (10.28%) with family Chironomidae dominating all stations. The overall fauna abundance varies significantly ($P < 0.05$) among the five study sites which received varying degrees of anthropogenic input from human activities along the stretch of the river. A *Posteriori* Duncan Multiple Range (DMR) test revealed that the mean abundance of stations 5 was significantly higher ($P < 0.05$) than that of other stations.

Andem *et al.* (2012) in a study on the composition, distribution and diversity of benthic macroinvertebrates in Ona River reported that three phyla of macrobenthic invertebrates were encountered which were Arthropoda (Diptera, Odonata and Plecoptera); Annelida (Oligochaeta) and Mollusca (*Indoplano bisexecutus*, *Melanoides tuberculata*, *Bulinus globosus*, *Biomphalaria pfferferi*, *Lymnaea* sp and *Physa* sp). Chironomus larvae dominated the macrobenthic invertebrates with a relative abundance of 59.1% while Isoperla larvae were the least abundant (0.19%). They further observed that the macrobenthic invertebrates recorded were pollution-tolerant/Clean water species.

Ogbeibu *et al.* (2013) carried out a research on the application of some biometric indices in the assessment of the water quality of the Benin River, Niger Delta, Nigeria. Rapid Bioassessment Protocols (RBP) using some biometric indices including taxa richness, Ephemeroptera, Plecoptera, and Tricoptera (EPT) taxa richness, EPT to total ratio, Hilsenhoff's Biotic Index (HBI) and Percent Model Affinity Score (PMAS) were employed in assessment of the water quality of the Benin River. The results showed that the water quality varied from non-impacted to severely impacted. HBI and PMAS showed similar results among the designated stations along the river. Shannon (H') and Margalef (d') diversity indices were highest at stations 4 and 3 respectively. Olomukoro *et al.* (2013) carried out an ecological study on three selected ponds of Agbede flood plain to assess and document the macrobenthicinvertebrates fauna composition, abundance and distribution. A total of ten (10) groups comprising macrobenthicinvertebrates taxa with one thousand and thirty-one (1,031) individuals were recorded in this study. Most dominant groups were represented by Coleopterans (374 individuals), Hemiptera (211 individuals) and Dipterans (193 individuals). Evenness was highest in pond 1 (0.4973). The highest number of macrobenthic invertebrates were collected from pond 2 (416) where no human activities occurred and however implied that human activities can rapidly alter any previously stable communities of aquatic environments.

Olomukoro and Dirisu (2013) carried out a study of the macrobenthic invertebrates community and pollution tolerance index (PTI) in Edion and Omodo Rivers in Agbede wetlands. Eight major taxonomic groups comprising 33 taxa were recorded. The dominant groups by percentage density occurrence were Ephemeroptera (45.4%) >Diptera (24.7%) >Decapoda (24.03%). The number of taxa was least for station 2 (14) and was highest (23) for station 4, with highest density recorded at station 1 (211 individuals). The heterogeneity indices revealed higher values for evenness across the stations except, for station 1 (0.3574), while pollution tolerance index (PTI) values showed moderate water quality with values that ranged from 7 to 16. Edegbene *et al.* (2014) in an investigation on the seasonal fluctuation and macrohabitat preference macrobenthic invertebrates in Atakpo River, Niger Delta, Nigeria observed a total of 3595 benthic invertebrates comprising of 23 taxa, 14 families and 9 orders. Decapoda was found to be restricted to the vegetative and rapid zone, while the Naucoridae was also restricted to the vegetative and rapid zones, but sparsely distributed among the three stations. The family Libellulidae was mainly found in the vegetative and rapid zone except *Bradinopgyna* sp. which was sparingly restricted to the rapid and pool zone while *Lestinogomphus* sp. and *Chironomus* sp. were widely distributed in all the microhabitats. They concluded that the vegetative zone harbours more macrobenthic than the other microhabitats.

Omoigberale *et al.* (2014) carried out a study on the composition, abundance and distribution of macrobenthic invertebrates associated with floating macrophytes along a stretch of the Okhuaihe River, in Edo State, Nigeria. A total of 20 taxa belonging to the Phylum Arthropoda were encountered while Diptera was well represented and dominant, with Plesiopora, Ephemeroptera and Decapoda constituting the subdominant groups. Odonata, Hemiptera, Coleopteran and Plecoptera made up the rare group. Spatial distribution showed variations while overall abundance was significantly different for the study stations ($P < 0.05$).

Olomukoro and Oviojie (2015) in a study to evaluate the benthic macroinvertebrate structure, abundance, distribution and diversity of Obazuwa Lake in Benin City reported a total of 748 benthic individuals composing of 46 taxa, 13 groups and 25 families. Dominant taxonomic taxa varied considerably; Diptera, Coleoptera, Mollusca, Oligocheata, Crustacea, Nematoda and Odonata. They observed that the variations in taxa and number of individuals for the stations were not significantly different ($P > 0.05$) while Sorenson's quotient (Q/S) indicated similarities in the species composition between the sites.

Adebayo *et al.* (2016) assessed the benthic macro-invertebrate fauna in middle course of Otamiri River, Imo State and reported that all physical parameters differed significantly ($p < 0.05$) with four macro-invertebrate benthic taxa in two phyla: Mollusca and Arthropoda identified. Gastropod (*Melanoides tuberculata*) an indicator of organically polluted water had highest percentage abundance of (53.4%) and highest diversity (Shanon-Wiener's index (H) = 2.4%) while *Gabiella africana* had lowest percentage abundance of (6.9%) with diversity (Shanon-Wiener's index (H) = 0.900). *Sybiocladis* sp was found to be most evenly distributed with equitability (J=0.979) while *Gabiella africana* constituted the least evenness (J=0.819). They further observed that *M. tuberculata* generally had the highest diversity index (H = 2.496) in the overall sampled while *Gabiella africana* was the least diverse at H = 0.900. Results obtained revealed that *Sybiocladis* sp (Chironomus larvae) accounted for the highest equitability (J = 0.979), followed by *M. tuberculata* (J = 0.946), *Tubifex* sp (J = 0.945), and *Gabiella africana* accounted for the least equitability of J = 0.819, while spatial variations showed that, the highest diversity index and evenness was constituted by *M. tuberculata*.

In an evaluation of some physicochemical parameters and benthic macroinvertebrates of Ikere Gorge Reservoir, Oyo State by Abed-Nego and Adedolapo (2016). It was observed that physicochemical parameters were within the allowable limits of USEPA for freshwater bodies except conductivity ($0.055 \pm 0.002 \mu\text{S}/\text{cm}$). Significant differences ($p < 0.05$) occurred

in meanvalues of DO, BOD, TDS, transparency, nitrate and sulphate across the sampled stations. A total of six genera (*Chironomus*, *Melanoides*, *Cloeon*, *Bulinus*, *Bellamyaa* and *Hirudo*) belonging to six orders (Diptera, Pelecypoda, Ephemeroptera, Heterobranchia, Caenogastropoda and Hirudinida) were recorded during the study. They further reported that pollution tolerant species were *Melanoides tuberculata* and *Chironomus* sp. with total number and percentage abundance of 674(56.88%) and 435 (36.71%) respectively and concluded that Ikere Gorge Reservoir was relatively under stress due to dominance of indicators of pollution.

In an ecological assessment of brewery effluent impact on the macrobenthic invertebrates of Ikpoba River, Edo State, Ibezute *et al.* (2016) reported that a total of seven macrobenthic invertebrate species comprised of 803 individuals were identified. These include four species of Diptera and one species each for Hemiptera, Lepidoptera, and Lumbriculida. Diptera dominated contributing 61.39% of the total density occurrence, while Lumbriculida, Lepidoptera and Hemiptera, made up of 33.25%, 3.23% and 0.13, respectively. They observed changes in some of the macrobenthic assemblages of Ikpoba River, which increased notably indicating inefficient effluent treatment in the breweries.

In an assessment of the density and diversity of Macroinvertebrates in River Illah, Delta State, Enwemiwe and Arimoro (2017) observed that Odonata and Crustacea were preponderant consisting (18.45%) of total abundance while its waters were well oxygenated (5.2 - 6.8 mg/l), contained low BOD5 (2.4 – 3.5 mg/l) and had a moderate flow rate (0.11 – 0.25 m/s). The various orders encountered were Odonata, Coleoptera, Tricoptera (, Hemiptera, Ephemeroptera, Decapoda, Mollusca and Diptera. A total of 26 taxa were encountered with only *Polymorphanisus bipunctatus* (Tricoptera species) occurring at all sampled stations with the presence of Ephemeroptera, Zygoptera and Tricoptera in abundance and low abundance of Diptera (8.74%) indicating that the quality of the water body was fairly good.

In an assessment of benthic macro-invertebrates of freshwater ecosystem at Iguoriakhi, Edo State, Iyagbaye *et al.* (2017) observed the species richness, evenness and diversity of the benthic macro-invertebrates in the study area were high and typical of a tropical fast-flowing freshwater river. A total of 45 taxa, made up of 1,135 individuals; 10 Ephemeroptera, 10 Diptera, 7 Coleoptera, 4 Hemiptera, Lepidoptera, Annelida (and Arthropoda were represented. The dominant taxa include ephemeroptera, while diptera was the only sub-dominant order identified. Analysis of Variance (ANOVA) revealed that the overall density was significantly different ($P < 0.05$) in the study stations, while EPT to total ratio indicated that the water quality of all the studied stations were non-impacted. They concluded that benthic macro-invertebrates were good candidate and less expensive indices for water quality monitoring.

Keke *et al.* (2017) on the temporal and spatial variability in macroinvertebrate community structure in relation to environmental variables in Gbako River, Niger State observed that there was an abundance of the pollution sensitive taxa such as Ephemeroptera (mayflies), Coleopteran (*Gyrinus* sp., *Dytiscus* sp.) and Anisoptera (*Gomphus* sp., *Lestino gomphus*, *Cordulex* sp.), especially for the upper and lower reaches, while pollution tolerant species like the Crustaceas, Dipterans, Mollusca (*Neritina rubricate*, *Potadoma* sp.) were merely restricted to the middle reaches. Of the total number of individual benthic invertebrates recorded during the entire study, 53% was recorded in the dry season while the remaining 47% was recorded in the wet season. Canonical Correspondence Analysis (CCA) separated the less impacted from the more impacted sites and also showed that the invertebrate fauna was significantly ($P < 0.05$) associated with environmental factors and identified conductivity, depth, flow velocity, dissolved oxygen, biological oxygen demand, and phosphates as important variables structuring the macroinvertebrate assemblages. They further attributed the higher number of benthic invertebrates recorded in the dry season to the unstable nature of the substrates through inputs and influx of storm water during the rainy season months.

Oyediran *et al.* (2017) on the abundance and distribution of macro-benthic invertebrates as bio-indicators of water quality in Ikwo River, Ishiagu observed a total of 1381 individuals from seventeen (17) taxa. These include: Mollusca; *Melanoide tuberculata*, *Magraritifera cardiida*, *Viviparus contectus* and *Sphaerium cardiidae*, Annelida; *Lumbricus rubellus*, *Nematomorpha*; *Paragodius tricuspidatus*, Odonata; *Sympetrum striolatum*, *Aphylla* sp and *Eristalis* sp (larva), Hemiptera; *Nepa apiculata* and *Baelostoma* sp, Ephemeroptera; *Ameletusino pinatus* and *Baetis fuscatus*, Trichoptera; *Phitopotamus lusificatus*, Coleoptera; *Hydrocanthus* sp (larva) and Diptera; *Chironomus* sp. The most abundant and dominant species encountered was *Melanoides tuberculata*, which was distributed in all the stations, accounting for 93.8%, followed by *Lumbricus rubellus* and *Chironomus* sp accounting for 1.1% each; while every other species collected were each less than 1% of the total individuals. The Shannon-Wiener's diversity index indicated a maximum of 2.47, 0.00 and 0.45 for stations 5, 3 and 2 respectively, with indicating less anthropogenic activities. The variations taxa and number of individuals reported for the stations were not significantly different ($P>0.05$), while correlation analysis showed that there was a significant difference in the species abundance between the dry season and wet season. They further revealed that the low diversity, abundance and distribution of the marco-benthic invertebrates was an indication of poor water quality and concluded that strict measures in regulating the discharges with particular emphasis on acid mine drainage (AMD) from the mining operations that constituted pollution in the water body be enforced.

Investigation by Shailendra *et al.* (2013) on the benthic macro invertebrate abundance and its correlations with Physico-chemical Parameters from Kunda river, Khargone, India revealed that a total of Forty-two (42) species of benthic macro-invertebrates belonging to three (3) phyla (Annelida, Arthropoda and Mollusca), five (5) classes (Oligochaeta, Hexapoda, Gastropoda, Pelecypoda and five (5) families (Baetidae, Caenoidae, Heptagenidae and Chironomidae) were present. Molluscs and Arthropods percentage composition were 47%

and 35.57% respectively and occurred most, while Annelids (17.35%) occurred least. Benthic macro-invertebrates correlated positively with transparency and nitrate, while temperature correlated with annelids, and total hardness with annelids and arthropods. A negative correlation was observed for pH, D.O., B.O.D., alkalinity, chloride and phosphate for benthic invertebrates, while temperature correlated with arthropods.

Sharma and Barkale (2016) on the species richness and abundance of macroinvertebrates in Bilawali Talab, Indore, India reported the presence of 38 species which includes; 12 species of Annelides, 13 species of Molluscans and 13 species of Arthropoda. They observed that the different phyla were made up of Annelida; Oligochaeta and Hirudinea, Mollusca; Gastropoda and Pelecypoda, Arthropoda; Insecta and Crustacea. . In a study carried out to show the abundance and diversity of zooplankton and macrobenthic invertebrates in relation to some environmental variables in El-Rayah El-Menoufy, Egypt, Khalifa and Bendary (2016) reported that Macrobenthic invertebrates was represented by three groups; Mollusca (9 species), Annelida (4 species) and Arthropoda (3 species) and their low diversity was attributed to pollution due to discharges from cities and cultivated lands. Among molluscs, *Cleopatra bulimoides* was the most dominant, *Melanooides tuberculata* flourished in summer and autumn while *Corbicula fluminalis* and *Theodoxus niloticus* were common. Oligochaetes abundance was dominated by *Limnodrilus udekedmianus* and it was the sole form of annelids in autumn season while *Chironomus* sp. was the most common arthropod and flourished highly in summer at sites with relatively low dissolved oxygen.

Brraich and Kaur (2017) in an assessment of the temporal composition and distribution of benthic macroinvertebrates in wetlands, Egypt indentified twenty-four genera of benthic macroinvertebrates, out of which five belonged to Ephemeroptera (*Cloen* sp, *Ephemerella* sp, *Heptagenia* sp, *Rithrogenia* sp and *Baetis* sp), two to Plecoptera (*Isoperia* sp and *Peria* sp), five to Hemiptera (*Gerris* sp, *Notonecta* sp, *Micronecta* sp, *Lethocerus* sp and *Ranatra* sp), three to Diptera (*Chrinomus* sp, *Antocha* sp and *Culex* sp), two to Tricoptera

(*Rhyacophila* sp and *Hydropsyche* sp), two to Coleoptera (*Gyrinus* sp and *Dytiscus* sp), one to Araneae (*Argyroneta* sp), one to Odonata (*Macromia* sp), two to Annelida (*Pheretima posthuma* and *Glossiphonia* sp) and one to Gastropoda (*Lymnaea* sp). The Simpson's index indicated that the wetland was moderately polluted which affects the occurrence of benthic macroinvertebrates.

2.3 Water Quality Assessments

USEPA (2016) defined water quality standards as provisions of the State, territorial authorities or Federal law approved by Environmental Protection Council/ Ministry of Environment that describe the desired condition of a water body and protect its designated users. Water quality of any specific area or specific source can be assessed using physical, chemical and biological parameters whose concentration values are found to be harmful to human health, when they exceed certain defined permissible limits (WHO, 2011).

The bio-survey of plankton as indicators of water quality for recreational activities in Calabar River, Nigeria by Uttah *et al.* (2008) revealed that Amongst the zooplankton, the Copepods were the most abundant (54.89%), others were Protozoa (14.13%), Polychaeta larvae (7.07%), Cyclopoida (5.43%), Cladocera (5.43%), Arthropoda (4.89%), Ostracoda (3.26%), Rotifera (2.72%), Malacostraca (1.09%), and Foraminiferida (1.09%). They however did not observe any preponderance of harmful plankton in the Calabar River and concluded that there was no evidence of stress beyond the rivers carrying capacity, with it being biologically suitable for contact recreational activities.

Li *et al.* (2007) evaluated the water quality and identification of pollution sources of plateau lakes in Yunnan, China in which multivariate statistical techniques, including cluster analysis (CA), factor analysis (FA) and principal component analysis (PCA), were employed to better interpret information about the water quality and its pollution sources, observed that no obvious data occurred for CA/FA because three principal components (PCs) needed 14

variables to explain 85.01% of the total variance. These latent factors accounted for pollution mainly from; agricultural activities, residential activities and anthropogenic-toxic pollution from industrial effluents, or other special activities. Box-whiskers plots for the interpretation of the spatio-temporal variations of water quality variables revealed that they were highly correlated with the three PCs. They concluded that their results may provide helpful information for the authorities to effectively manage the water quality and make sound policies.

Nyakeya *et al.* (2009) in an assessment of pollution impacts on the ecological integrity of the Kisian and Kisat rivers in Lake Victoria drainage basin, Kenya with the use of its macro-invertebrate assemblages observed that there were inconsistencies in the variation of physico-chemical parameters along the two rivers while macro invertebrate diversity, richness and evenness values failed to delineate stations according to the different levels of degradation they were experiencing. The index of biotic integrity showed that River Kisat stations scored lowest index values, less than 15 out of 25, while two river Kisian stations scored the highest value, more than 19. In conclusion they reported that the index provided evidence of response to changes in ecosystem integrity exhibited by resident macro invertebrate assemblages to pollution arising from both point and nonpoint sources.

Jaber *et al.* (2015) carried out an assessment on ecological quality of the Tajan River in Iran using a multimetric macroinvertebrate index and species traits-based method. Four components of ecosystem quality were assessed these included; tolerance (Hilsenhoff, SIGNAL), diversity (Margalef, Shannon–Wiener, Simpson, and Evenness), abundance (total number of taxa, individuals, Ephemeroptera, Plecoptera, Tricoptera, EPT, and Insects), and composition of assemblages (% Ephemeroptera, % Plecoptera, % Tricoptera, and % EPT Taxa). Information on the biological traits of macroinvertebrates was evaluated to determine whether these traits could be indicative for specific or general stress. They observed a decrease in MMI from upstream (very good water quality) to downstream (bad) due to human

activities while industrial activities like pulping and papermaking operations or sand mining in the downstream part had more effects than agriculture and fish ponds in the upstream part. They concluded that the traits showed could be indicative for different kind of stress but that more effort must be put into gathering data sets to disentangle the effect of habitat quality and pollution.

Khalifa *et al.* (2015) in an environmental biotic index to assess water quality of Lake Nasser, Egypt using zooplankton employed the Species richness index (d), Wetland Zooplankton Index (WZI) and Saprobity index (S). The richness index values indicated that, the water quality of Lake Nasser was lower and may be polluted at some sites and this did not reflect the actual ecological status of the lake. However, wetland zooplankton index scores revealed that water quality at the three localities increased in spring (good water) followed by winter, while it was moderate in summer and autumn when water level is high. Saprobiological analysis showed that, the main channel had the best water quality (good water) in spring, while Khor Wadi Abyad contained good water quality in summer, but Khor Tushka had moderate water quality during the study period. They concluded that wetland zooplankton index and saprobity index were good indication to assess water quality of Lake Nasser and that some developments were needed according to the nature of the lake and their dominant zooplankton indicator species.

Ojija and Laizer (2016) in a study carried out to assess the water quality of Nzovwe stream using macroinvertebrates. A total of 584 aquatic macroinvertebrates belonging to 22 families were identified. The biological monitoring working party (BMWP) scoring system was the index used to assess the ecosystem health. The most abundant taxa were Odonata (35.959%), Hemiptera (25.514%), Coleoptera (18.493%), and Diptera (12.842%). Whereas the least abundant taxa were Ephemeroptera and Gastropoda, each constituting 1.028% of all macroinvertebrates. They further reported that BMWP score of Nzovwe stream was 115 and based on this the water of Nzovwe stream was slightly altered. Agricultural activities such as

washing and bathing altered the physico-chemical parameters of the stream and hence changed the abundance of macroinvertebrates as well as the quality of water. They concluded that Nzovwe stream was moderately polluted due to non-point source pollution from several sources and recommended that the source of pollutants should be controlled, and the stream regularly monitored by the relevant authorities.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Description of the study area

3.1.1 Geographic Location

This study was carried out in River Siluko (lat. 6.2888⁰N and Long. 5.0071⁰E) which is about 68.5km from Benin City and situated in Ovia South West Local Government Area, Edo State, Nigeria (Fig 3.1). River Siluko rises from the hills of the North-East catchment area around Effon-Alaaye in Ekiti State, and flows southwards joining the Ofosu and Aden Rivers, north of Siluko village (Akinro and Olawale, 2007). It drains into the Atlantic via the Benin River, after being joined by the Okomu and Osse Rivers (Arimoro *et al.*, 2006). Along its course are the following neighbouring communities Saforogbo, Ubarogbo, Arogbo and Kekemeke-oke.

3.1.2 Climate

River Siluko falls within the rain-forest zone which is governed by two distinct climatic seasons; the rainy (wet) and dry seasons. The wet season which has a high amount of rainfall usually spans from April to October with high humidity, low atmospheric temperature and intermittent dry spells with discontinuity of rains in August, termed “August break”(Omoigberale and Ogbeibu, 2010). The dry season with low humidity and high atmospheric temperature occurs from November to March and dry harmattan breeze in December and January. Due to the current global change in climate, this may not always be the case as some degree of precipitation takes place in the dry season months.

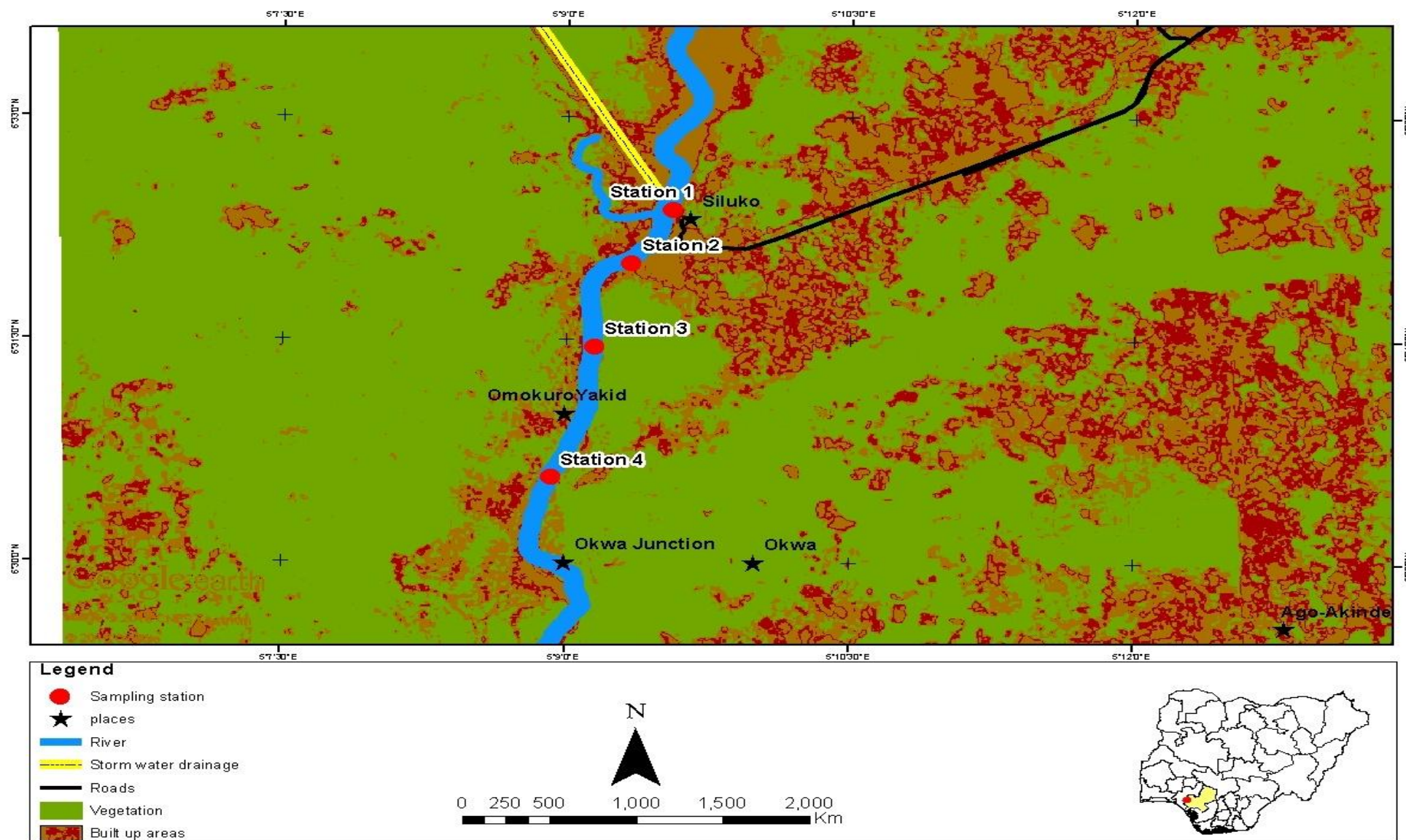


Fig 3.1: Map of Study Area showing sampling stations

3.1.3 Geology

The various formations in the geology of Edo State are the Benin, Bende-Ameki, Ogwashi-Asaba, Imo and Nsukka. The study area is characterized by coarse sand interspersed with lignite and patches of lateritic sand clay that form into beds having ground water retention capacity (Omoigberale and Ogbeibu, 2010).

3.1.4 Vegetation and Land Use

This region is primarily a tropical rainforest with residential houses located some distances away from the riverbanks. Along the banks are rubber trees (*Haveabra siliensis*), palm trees (*Elaeis guineensis*), bamboo trees (*Bambusa* sp.) and shrubs. On the river are floating vegetation such as water hyacinth (*Eichhornia crasipes*), *Salvinia* sp. and *Lemna* sp. The river serves as the major source of water for the surrounding communities. Occasional human activities in this river are domestic washing and bathing, while major activities include fishing, farming, trading which include locally distilled gin and basket weaving (Obasogie and Ogunjemite, 2014). There is a large market on the Riverbank, which serves as a landing area for other many commercial crops such as yam, pineapple, plantain from neighbouring communities like Arogbo, Ubarogbo and New-camp.

3.1.5 Environmental Condition of Siluko River

The summary of physicochemical parameters at the Siluko River is shown in Table 3.1 below. The pH of the river ranged between 4.83 – 6.82 indicating that the water body is slightly acidic. The salinity was that of a freshwater habitat. Turbidity ranged between 1.10 to 11.90 NTU across the stations, Total dissolved solids was highest at station 1 (17.71 mg/l) and lowest (57.22mg/l) at station 4. Dissolved oxygen in the water was high enabling it to support aquatic life with mean concentrations of 5.61 to 5.83 mg/l. BOD ranged between 1.50 to 4.70

mg/l while COD ranged between 5.30 to 3520 mg/l. The ionic balance of the water body was maintained by the anions and cations ensuring a dynamic balance in the physicochemical parameters. Heavy metals (Iron, manganese, zinc, copper, chromium, cadmium, nickel, lead and vanadium) were detected in the water body at varying concentrations. Total hydrocarbon content of the water ranged between 0.02 to 1.10 mg/l. No significant difference ($p < 0.05$) was observed between the stations throughout the duration of the study.

Table 3.1: Environmental Condition of Siluko River from July, 2016 to March, 2017.

Parameters	Station 1 Mean ± SD (Min – Max)	Station 2 Mean ± SD (Min – Max)	Station 3 Mean ± SD (Min – Max)	Station 4 Mean ± SD (Min – Max)	F value	P value
Ph	6.05±0.18 (5.10 – 6.82)	6.06±0.14 (5.11 – 6.61)	6.01±0.17 (4.83 – 6.48)	5.96±0.10 (5.52 – 6.39)	0.085	<i>p</i> > 0.05
EC (µS/cm)	191.74±38.18 (83.60 – 471.20)	158.58±21.42 (92.50 – 302.30)	136.98±11.17 (96.90 – 188.80)	123.76±13.23 (84.20 – 216.20)	1.591	<i>p</i> > 0.05
Sal (mg/l)	0.09±0.02 (0.04 – 0.21)	0.06±0.01 (0.04 – 0.10)	0.06±0.00 (0.04 – 0.09)	0.05±0.00 (0.04 – 0.08)	2.272	<i>p</i> > 0.05
Col. (Pt.co)	5.94±1.04 (2.50 – 12.20)	4.49±0.68 (1.80 – 7.30)	5.13±0.90 (1.70 – 10.01)	5.78±1.07 (1.40 – 12.40)	0.504	<i>p</i> > 0.05
Tur (NTU)	4.90±1.00 (1.90 – 10.80)	3.43±0.59 (1.20 – 6.40)	4.16±0.83 (1.30 – 8.90)	4.73±1.10 (1.10 – 11.90)	0.539	<i>p</i> > 0.05
TSS (mg/l)	7.63±0.92 (3.80 – 12.70)	5.11±0.86 (1.70 – 8.50)	6.41±0.91 (2.90 – 11.30)	7.06±1.19 (2.50 – 14.70)	1.227	<i>p</i> > 0.05
TDS (mg/l)	117.71±43.78 (42.10 – 464.50)	69.90±5.69 (46.20 – 104.90)	64.57±4.56 (48.30 – 93.90)	57.22±3.24 (43.60 – 68.70)	1.52	<i>p</i> > 0.05
DO (mg/l)	5.61±0.13 (5.10 – 6.20)	5.73±0.23 (4.70 – 6.60)	5.63±0.22 (0.22 – 4.20)	5.83±0.18 (4.90 – 6.50)	0.287	<i>p</i> > 0.05
BOD ₅ (mg/l)	3.53±0.27 (1.90 – 4.70)	2.92±0.25 (1.50 – 3.90)	2.86±0.30 (1.50 – 4.10)	2.86±0.28 (1.50 – 4.10)	1.404	<i>p</i> > 0.05
COD (mg/l)	15.81±1.21 (8.60 – 20.80)	15.44±2.23 (7.20 – 27.40)	16.38±3.13 (7.40 – 35.2)	17.62±3.17 (5.30 – 30.60)	0.138	<i>p</i> > 0.05
HCO ₃ (mg/l)	36.77±4.48 (18.80 – 61.10)	30.49±3.88 (12.20 – 48.80)	30.98±2.95 (16.20 – 43.60)	24.86±2.33 (14.90 – 31.20)	1.798	<i>p</i> > 0.05

Na (mg/l)	0.80±0.20 (0.00 – 1.91)	0.60±0.13 (0.00 – 1.17)	0.59±0.13 (0.00 – 1.15)	0.57±0.12 (0.00 – 0.96)	0.203	<i>p</i> > 0.05
K. (mg/l)	0.32±0.10 (0.06 – 0.91)	0.23±0.07 (0.07 – 0.68)	0.27±0.10 (0.10 – 1.01)	0.24±0.08 (0.08 – 0.85)	0.616	<i>p</i> > 0.05
Ca. (mg/l)	2.07±0.48 (0.12 – 4.53)	1.47±0.34 (0.08 – 3.42)	1.78±0.35 (0.12 – 3.06)	1.44±0.32 (0.09 – 2.76)	0.325	<i>p</i> > 0.05
Mg. (mg/l)	1.09±0.26 (0.40 – 2.83)	0.78±0.14 (0.32 – 1.45)	1.00±0.37 (0.34 – 3.87)	0.85±0.15 (0.44 – 1.65)	0.535	<i>p</i> > 0.05
Cl. (mg/l)	37.92±7.91 (0.68 – 72.80)	32.70±6.27 (0.59 – 58.40)	32.22±7.02 (0.84 – 74.50)	26.07±4.96 (0.53 – 52.50)	0.087	<i>p</i> > 0.05
P. (mg/l)	5.19±2.96 (0.95 – 28.80)	3.37±2.27 (0.37 – 21.50)	4.27±2.85 (0.52 – 26.90)	4.50±1.94 (1.37 – 19.70)	0.435	<i>p</i> > 0.05
NH ₄ N (Mg/Kg)	0.33±0.18 (0.03 – 1.75)	0.17±0.08 (0.04 – 0.83)	0.38±0.20 (0.03 – 1.65)	0.25±0.07 (0.07 – 0.74)	1.904	<i>p</i> > 0.05
NO ₂ (Mg/Kg)	0.07±0.01 (0.03 – 0.10)	0.04±0.01 (0.02 – 0.07)	0.09±0.03 (0.01 – 0.33)	0.07±0.01 (0.03 – 6.11)	2.794	<i>p</i> > 0.05
NO ₃ (Mg/Kg)	3.28±0.59 (0.09 – 5.37)	1.66±0.39 (0.02 – 3.86)	2.05±0.48 (0.06 – 4.67)	3.58±0.72 (0.03 – 6.11)	2.938	<i>p</i> > 0.05
SO ₄ (Mg/Kg)	1.47±0.40 (0.35 – 3.54)	0.83±0.15 (0.27 – 1.59)	0.75±0.09 (0.38 – 1.16)	0.61±0.08 (0.33 – 1.03)	1.311	<i>p</i> > 0.05
Fe (Mg/Kg)	1.48±0.17 (0.51 – 2.18)	1.09±0.17 (0.42 – 1.85)	1.08±0.13 (0.59 – 1.86)	1.18±0.17 (0.44 – 1.89)	1.876	<i>p</i> > 0.05
Mn. (Mg/Kg)	0.15±0.03 (0.04 – 0.28)	0.08±0.02 (0.03 – 0.16)	0.09±0.02 (0.02 – 0.34)	0.13±0.04 (0.02 – 0.34)	2.201	<i>p</i> > 0.05
Zn. (Mg/Kg)	0.50±0.08 (0.12 – 0.93)	0.25±0.06 (0.05 – 0.58)	0.26±0.03 (0.15 – 0.39)	0.37±0.12 (0.05 – 0.91)	1.493	<i>p</i> > 0.05

Cu. (Mg/Kg)	0.06±0.01 (0.02 – 0.09)	0.03±0.01 (0.01 – 0.07)	0.04±0.01 (0.01 – 0.07)	0.05±0.01 (0.01 – 0.12)	1.052	<i>p</i> > 0.05
Cr. (Mg/Kg)	0.05±0.01 (0.02 – 0.07)	0.03±0.01 (0.01 – 0.06)	0.04±0.01 (0.01 – 0.08)	0.04±0.01 (0.01 – 0.06)	1.438	<i>p</i> > 0.05
Cd (Mg/Kg)	0.05±0.01 (0.01 – 0.11)	0.03±0.01 (0.01 – 0.07)	0.04±0.01 (0.01 – 0.08)	0.03±0.01 (0.01 – 0.07)	2.104	<i>p</i> > 0.05
Ni. (Mg/Kg)	0.02±0.00 (0.01 – 0.04)	0.01±0.00 (0.00 – 0.03)	0.01±0.00 (0.00 – 0.03)	0.01±0.00 (0.01 – 0.02)	0.364	<i>p</i> > 0.05
Pb. (Mg/Kg)	0.05±0.01 (0.02 – 0.09)	0.03±0.01 (0.01 – 0.07)	0.04±0.01 (0.01 – 0.08)	0.03±0.01 (0.01 – 0.07)	0.085	<i>p</i> > 0.05
V. (Mg/Kg)	0.01±0.00 (0.01 – 0.03)	0.01±0.00 (0.00 – 0.02)	0.01±0.01 (0.00 – 0.02)	0.01±0.00 (0.01 – 0.02)	1.591	<i>p</i> > 0.05
THC. (Mg/Kg)	0.27±0.13 (0.02 – 1.25)	0.22±0.11 (0.04 – 1.10)	0.22±0.09 (0.05 – 0.94)	0.13±0.01 (0.06 – 0.20)	2.272	<i>p</i> > 0.05

* = Significant value at 0.05

3.2 Sampling Stations

Four sampling stations were selected along the study stretch of the river from station 1 (upstream) as control, to station 4 (downstream).

Station 1: This station on latitude 06°32'431"N and longitude 005°09'529"E was located upstream of the river and it served as the control point for the study (Plate 3.1). The average depth at this station was 1.25±0.21m and water current velocity of 0.51m/s. The station is a clear water zone and the riverbank is flanked with water hyacinth (*Eichhornia crasipes*) and other floating macrophytes (*Salvinia* sp and *Nymphaea lotus*). Apart from occasional fishing activities, human disturbance at this station is minimal. The substratum is a mixture of sand and decaying organic matter.

Station 2: This station is about 0.6km from the control station (station 1) and lies on latitude 06° 31'960'N and longitude E005° 09' 271'E and has an elevation of 4m (Plate 3.2). This station had an average depth of 1.19±0.34m and a mean flowing velocity of 0.71m/s. The vegetation here is sparse with no trees but some grasses and shrubs. Macrophytes such as *Eichhornia crasipes* and *Nymphaea lotus* were present. The substratum is composed of mud and decaying organic materials. The human activities include fishing and farming around the riverbank and the wastes generated are channeled directly to the river.

Station 3: Station 3 is about 0.5km downstream of station 2 located on latitude 06° 31'448'N and longitude 005° 09'135'E and an elevation of 5m above sea level (Plate 3.3). The flow rate is 1.10m/s and the density of *Eichhornia crasipes* (water hyacinth) high in this station and the human activities include fishing and farming. The substratum is composed of mud and decaying organic materials.

Station 4: This station is located about 3km downstream of station 3 (latitude 06° 31'627'N and longitude 005° 08'993'E) and has an elevation of 4m (Plate 3.4). The average depth at this station is about 1.46±0.48m and its bank are bounded by trees and aquatic macrophytes (*Eichhornia crasipes*, *Nymphaea lotus*, *Salvinia* sp. and *Lemna* sp) while the major human activity here is fishing. Also, some logging activities were observed around this station.



Plate 3.1: Station 1



Plate 3.2: Station 2



Plate 3.3: Station 3



Plate 3.4: Station 4

3.3 Sampling periodicity

Zooplankton and macrobenthic invertebrate samples were collected monthly from July 2016 to March 2017, between 09.00 hours and 12.00hours from the sampling stations.

3.3.1 Zooplankton

Collection

Qualitative plankton samples were collected by towing a 55µm mesh hydrobios plankton net behind an outboard powered boat just below the water surface for 5 min at each sampling station. Quantitative samples on the other hand were collected by filtering 100 litres of water fetched with a bucket through a 55 µm mesh hydrobios net. The resultant filtrates were upturned into a 250 ml plastic container and preserved in 4% buffered formalin solution (Imoobe, 2011; Arazu and Ogbeibu, 2017).

Sorting

In the laboratory, both the qualitative and quantitative sample specimens were sorted together under an optical microscope (model 570) at X10 magnification. Zooplankton were picked with the aid of micro pipette and carefully placed on a glass slide and covered with a cover slip prior to viewing under the microscope with eye and objective lens of X10 and the microphotographs of species observed were taken.

Identification and Counting

Identification and enumeration were carried out using x20 and x40 objectives of an Olympus binocular microscope according to the methods of Jeje and Fernando (1986). These organisms were mounted on a clean glass slide in 100 % glycerin (Arazu and Ogbeibu, 2017). The counting was done using a hydrobios counting chamber. Systematic identification was

done using standard identification guides (Jeje and Fernando, 1986; Koste, 1978; Braioni and Gelmini, 1983; Nogrady and Segers, 2002; Margaritora, 1983; Einsle, 1996; Fernando, 2002) at the University of Benin Animal And Environmental Biology laboratory. The abundance of zooplankton was determined according to Brakovska and Skute (2009) and Akindele (2013).

3.3.2 Macrobenthic Invertebrates

Collection

Macrobenthic fauna were collected from the river substratum using an Ekman grab (Hydrobios, West Germany) as recommended for sand and silt (Hynes, 1961). A hand net of 0.50 mm mesh size was used in sampling the Bank-roots for macrophytes (Olomukoro and Dirisu, 2012). Benthic samples were washed through a sieve of 1mm x 1mm mesh size to collect the benthos. The washed sediment with macro benthos were poured into a wide mouth labeled plastic container and preserved with 10% formalin solution (Zabbey, 2002; Idowu and Ugwumba, 2005).

Sorting

The organisms were sorted using the American Optical Dissecting Microscope (LB-570, w Bausch and Lomb Optical Co.). The sorting was made effective by adding moderate volume of water into the container to improve visibility. Large benthos were hand picked using forceps while the smaller ones were pipetted out. The organisms were sorted into their different groups and preserved in 4% formalin in labelled specimen bottles for identification and counting.

Identification and Counting

Identification of the organisms was done using the dissecting microscope described above and binocular Olympus (WF 10x, Olympus Global). The organisms were identified using identification keys of Olomukoro, (1983); Egborge (1995).

3.4 Data Analysis

3.4.1 Analysis of variance (ANOVA) and correlation

Inter station comparisons were carried out to test for significant differences in the faunal abundance using parametric analysis of variance (ANOVA). Where significant value ($p < 0.05$) was obtained in the ANOVA, Duncan multiple range (DMR) test was performed to determine the location of significant differences. Non-Parametric Spearman correlation was used to determine the relationship among the invertebrates. These analyses were done using the computer application SPSS 20.0 and Microsoft Excel for windows.

3.4.2 Diversity indices

Diversity indices combine the information on multiple species into a single number (Smith, 2002). Macro-benthic invertebrates collected at the sampled stations were subjected to diversity indices.

The following indices were evaluated:

a) Margalef's Index for species richness:

$$D = \frac{S - 1}{\ln N}$$

Where: S = number of taxa

N = total number of individuals in all taxa.

b) Shannon-Wiener Index (H') for general species diversity.

$$H' = \frac{N \log N - \sum p_i \ln p_i}{N} \text{ but}$$

$$H' = - \sum p_i \ln p_i$$

where $p_i = \frac{n_i}{N}$

N = total number of individuals in all taxa

n_i = the number of individuals in i th taxa

c) Evenness index (E)

$$E = \frac{H'}{H_{\max}}$$

Where:

H' = Shannon-Wiener diversity

H_{\max} = Maximum species diversity

$H_{\max} = \log_{10} S$. Where S = number of species present.

3.4.3 Taxonomic similarities

Taxonomic similarities between pairs of stations were tested for significance using Bray Curtis similarity index (Slack *et al.*, 1979, Ogbeibu and Victor, 1989).

3.4.4 Assessment of Water Quality Using Biotic Indices

One important way to determine the status of water's living systems is through biological assessment (bioassessment), with the use of biological surveys and other direct measurements of living systems within a watershed. The following biological metrics were adopted in the study stations: Pollution tolerance index (PTI), Ephemeroptera, Plecoptera, and Trichoptera index (EPT INDEX), EPT TO TOTAL RATIO and Predominant taxon ratio.

3.4.4.1 Pollution Tolerance Index (PTI)

Pollution tolerance Index (PTI) was determined using the procedure described by Bonada *et al.* (2006). Three groups of macroinvertebrates were chosen and assigned a multiplication factor of 3 for the pollution sensitive group (Ephemeroptera, Plecoptera and Trichoptera), 2 was assigned to the facultative or somewhat tolerant group (Anisoptera, Zygoptera and Decapoda) and 1 to the pollution tolerant group (Oligochaetes, Diptera and

Chironomidae) as utilized in this study after which they were sum to get the PTI values for the four stations and the same was done for the monthly, and spatial variations. Values obtained were thereafter compared with established standard values.

Table 3.2: Pollution tolerance Index ratings

POLLUTION TOLERANT INDEX			
Good	Acceptable	Marginal	Poor
>22	22 - 17	16 - 11	<11

3.4.4.2 EPT Index

The EPT Index is the total number of distinct *taxa* within the groups, Tricoptera, Ephemeroptera, and Plecoptera. The EPT Index summarizes the richness in groups that are generally considered pollution sensitive. The Index generally increases with increasing water quality. It is based on the premise that high-quality streams usually have the greatest species richness. Many aquatic insect species are intolerant of pollutants and will not be found in polluted waters. The greater the pollution, the lower the species richness expected, as only a few species are pollutant tolerant.

Table 3.3: EPT index ranges and their corresponding water quality ratings

EPT Index			
Good	Acceptable	Marginal	Poor
>8	5 - 8	2 - 5	0 - 1

3.4.4.3 EPT to Total Ratio

Total number of individuals in Orders Ephemeroptera, Plecoptera, and Tricoptera divided by the total number of individuals. The Ratio of EPT to total ratio abundance shows the number of individuals from sensitive orders (Ephemeroptera / mayflies; Plecoptera / stoneflies; Tricoptera / caddisflies) compared to pollution tolerant groups.

Table 3.4: EPT to Total Ratio ratings

EPT To Total Ratio			
Good	Acceptable	Marginal	Poor
0.76 -1.00	0.51 - 0.75	0.25 - 0.50	0 - 0.26

3.4.4.4 Predominant Taxon Ratio

This is highest number of individuals in a given taxa divided by the total number of individuals in the subsample. It can reveal an overabundance of one group and little diversity, while the characteristics of the dominant group may indicate the problem such as habitat type present and little dissolved oxygen. A high number indicates environmental stress.

Table 3.5: Predominant Taxon Ratio ratings

PREDOMINANT TAXON RATIO			
Good	Acceptable	Marginal	Poor
0 - 0.40	0.41 - 0.60	0.61 - 0.80	0.81 - 1.0

CHAPTER FOUR

RESULTS

4.1 Species Composition for Zooplankton

Table 4.1 shows the taxonomic checklist of zooplankton recorded in this study. This is comprised of Twenty (20) species distributed in Seven (7) families, Four (4) orders and Two (2) phyla.

A total of 20 taxa comprising the Cladocera, Cyclopoida, Ploimida and flosculariaceae were encountered in this study (Table 4.1). Cladocera accounted for 31.0% while Cyclopoida, Ploimida and flosculariaceae accounted for 62.0%, 6.0% and 1% respectively of the zooplankton population (Figure 4.1). Stations 1, 2, 3 and 4 had a total of 70, 81, 115 and 120 individuals respectively, with station 4 having the highest number of individuals and station 1 with the lowest number of individuals (Figure 4.2). The abundance of zooplankton species showed no significant difference ($P>0.05$) across the sampled stations. Further test showed that stations 1, 2, 3 and 4 were not significantly different from one another, even with the higher values recorded in 3 and 4 (Figure 4.3). Photographs of the identified species of zooplankton are shown in Plates 4.1 to 4.20.

Table: 4.1 Checklist of Zooplankton

PHYLUM:	Arthropoda
SUBPHYLUM:	Crustacea
CLASS:	Branchiopoda
ORDER:	Cladocera
FAMILY:	Moinidae
<i>Moina reticulata</i>	Daday, 1905 (Plate 4.1)
FAMILY:	Sididae
<i>Diaphanosoma</i> sp.	Fischer, 1850 (Plate 4.2)
FAMILY:	Macrothricidae
<i>Macrothrix</i> sp.	Baird, 1843 (Plate 4.3)
<i>Ilyocryptus spinifer</i>	(Plate 4.4)
<i>Echnisca</i> sp.	(Plate 4.5)
FAMILY:	Chydoridae
<i>Kurzia longirostris</i>	Daday, 1898 (Plate 4.6)
SUBPHYLUM:	Crustacea
CLASS:	Copepoda
ORDER:	Cyclopoida
FAMILY:	Cyclopidae
<i>Microcyclops varicans</i>	Sars, 1863 (Plate 4.7)
<i>Mesocyclops bodanicola</i>	Keifer, 1955 (Plate 4.8)
<i>Metacyclops minutus</i>	Claus, 1863 (Plate 4.9)
<i>Eucyclops serrulatus</i>	Fischer, 1851 (Plate 4.10)
<i>Tropocyclops prasinus</i>	Fischer, 1860 (Plate 4.11)
<i>Thermocyclops neglectus</i> Sars,	1901 (Plate 4.12)
<i>Cryptocyclops bicolor</i>	Sars, 1863 (Plate 4.13)
PHYLUM:	Rotifera
CLASS:	Monogononta
ORDER:	Ploimida
FAMILY:	Brachionidae
<i>Platyias lelupui</i>	(Plate 4.14)
<i>Platyias quadricornis</i>	Ehrenberg, 1832 (Plate 4.15)
FAMILY:	Lecanidae
<i>Lecane papuana</i>	Murray, 1913 (Plate 4.16)
<i>Lecane acronychal</i>	Hauer and Murray, 1913 (Plate 4.17)
<i>Lecane curvicornis</i>	(Plate 4.18)
ORDER:	Flosculariaceae
FAMILY:	Testudunellidae
<i>Filinia terminalis</i>	Plate, 1886 (Plate 4.19)
<i>Filinia</i> sp.	(Plate 4.20)



Plate 4.1: *Moina reticulata*



Plate 4.2: *Diaphanosoma* sp.



Plate 4.3: *Macrothrix* sp.



Plate 4.4: *Ilyocryptus spinifer*



Plate 4.5: *Kurzia longirostris*



Plate 4.6: *Echnisca* sp.



Plate 4.7: *Microcyclops varicans*



Plate 4.8: *Mesocyclops bodanicola*



Plate 4.9: *Metacyclops minutus*



Plate 4.10: *Eucyclops serrulatus*



Plate 4.11: *Tropocyclops prasinus*



Plate 4.12: *Thermocyclops neglectus*



Plate 4.13: *Cryptocyclops bicolor*



Plate 4.14: *Platyias lelupui*



Plate 4.15: *Platyias quadricornis*

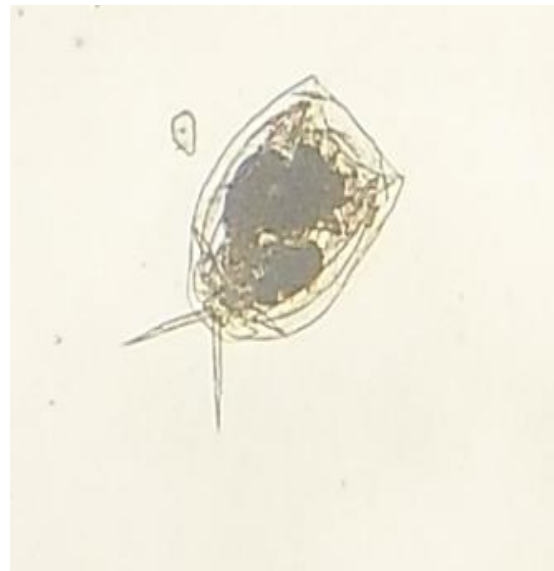


Plate 4.16: *Lecane papuana*

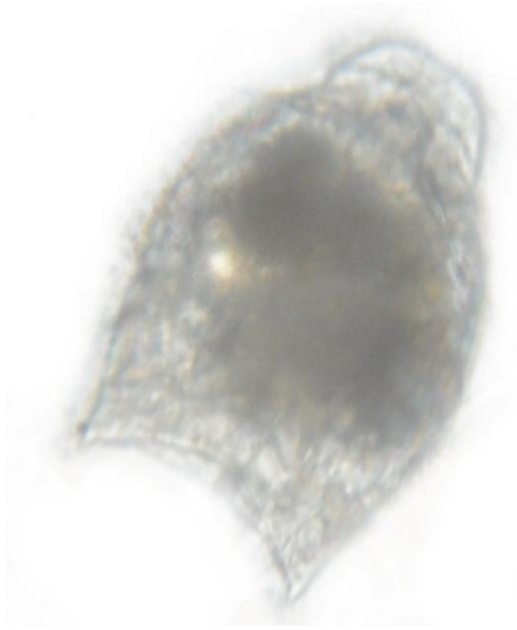


Plate 4.17: *Lecane acronychal*



Plate 4.18: *Lecane curvicornis*



Plate 4.19: *Filinia terminalis*



Plate 4.20: *Filinia terminalis*

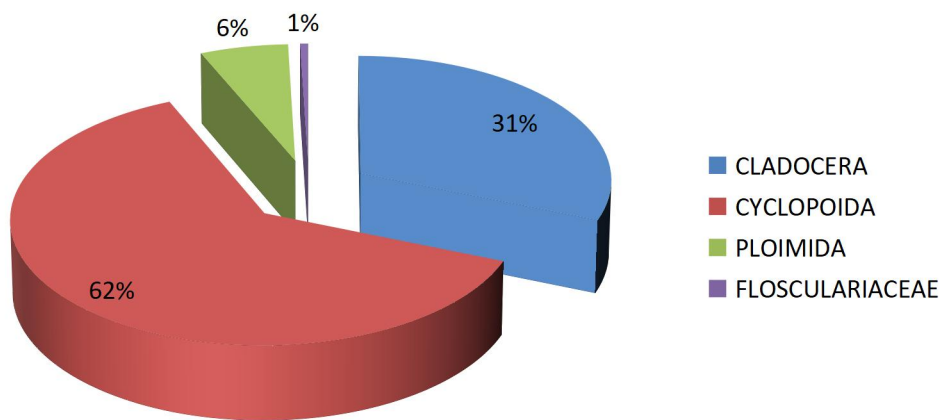


Figure 4.1: Relative Abundance of Zooplankton taxa

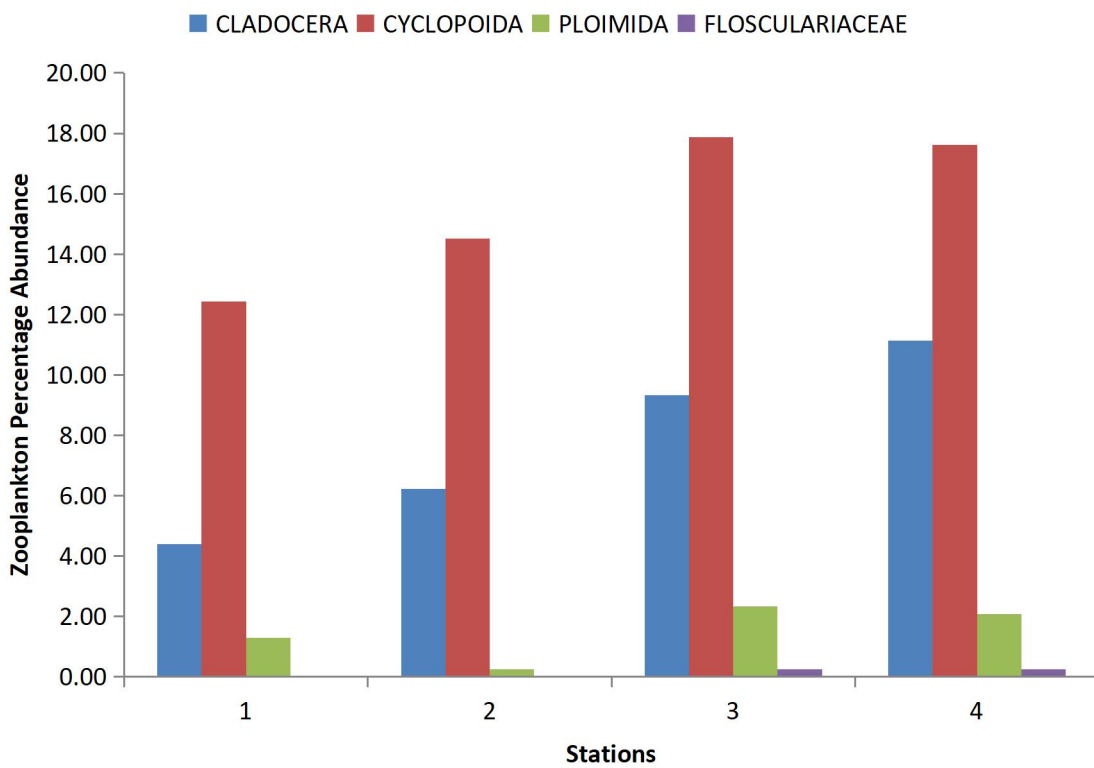


Figure 4.2: Relative Abundance of Zooplankton taxa across the stations

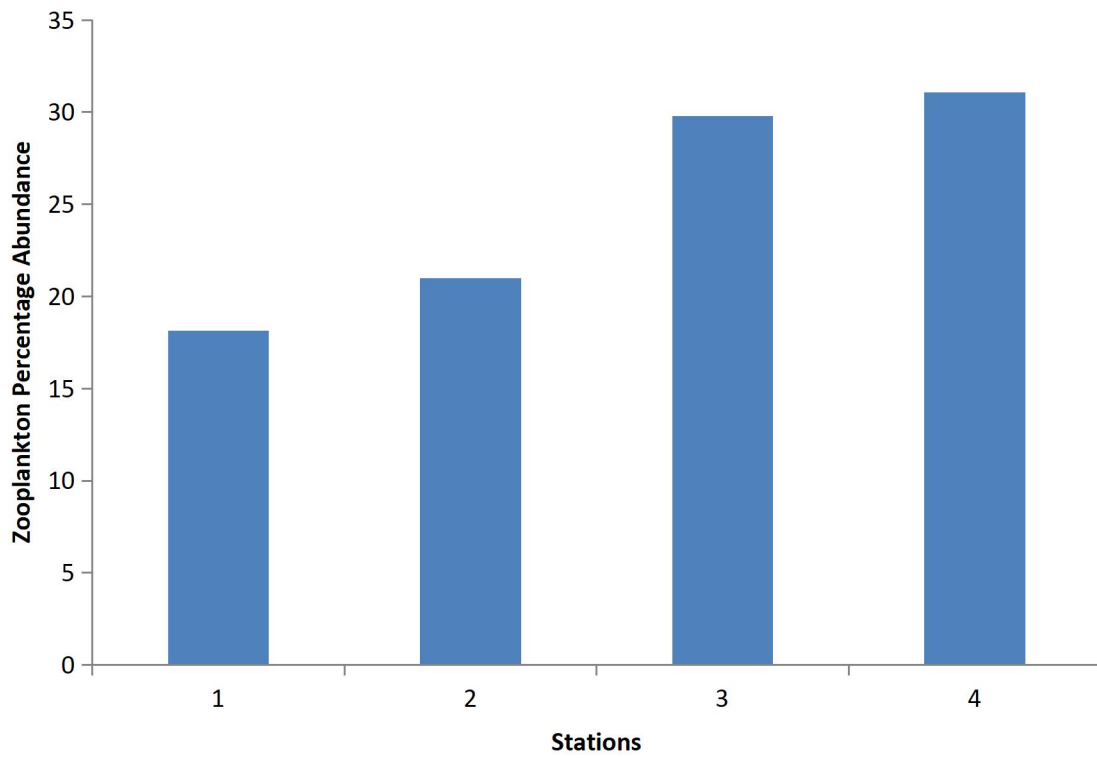


Figure 4.3: Spatial Variations in Zooplankton abundance across the stations

Table 4.2: Composition, distribution and abundance of the Zooplankton fauna in the study stations from siluko River from July 2016 to March 2017

Taxonomic groups	Station 1	Station 2	Station 3	Station 4	Total
SUBPHYLUM CRUSTACEA	-	-	-	-	-
CLASS BRANCHIOPODA	-	-	-	-	-
ORDER CLADOCERA	-	-	-	-	-
FAMILY MOINIDAE	-	-	-	-	-
<i>Moina reticulata</i>	5	6	7	6	24
FAMILY SIDIDAE	-	-	-	-	-
<i>Diaphanosoma</i> sp.	4	4	7	9	24
FAMILY					
MACROTHRICIDAE	-	-	-	-	0
<i>Macrothrix</i> sp.	1	4	11	15	31
<i>Ilyocrytus spinifer</i>	1	-	1	3	5
<i>Echnisca</i> sp.	3	5	6	3	17
FAMILY CHYDORIDAE	-	-	-	-	-
<i>Kurzia longirostris</i>	3	5	4	7	19
SUBPHYLUM CRUSTACEA	-	-	-	-	-
CLASS COPEPODA	-	-	-	-	-
ORDER CYCLOPOIDA	-	-	-	-	-
FAMILY CYCLOPIDAE	-	-	-	-	-
<i>Microcyclops varicans</i>	5	5	3	6	19
<i>Mesocyclops bodanicola</i>	17	20	13	15	65
<i>Metacyclops minutus</i>	6	1	4	4	15
<i>Eucyclops serrulatus</i>	9	4	1	8	22
<i>Tropocyclops prasinus</i>	6	20	22	21	69
<i>Thermocyclops neglectus</i>	4	5	22	11	42
<i>Cryptocyclops bicolo</i>	1	1	4	3	9
PHYLUM ROTIFERA	-	-	-	-	-
CLASS MONOGONONTA	-	-	-	-	-
ORDER PLOIMIDA	-	-	-	-	-
<i>Platyias lelupui</i>	2	-	5	3	10
<i>Platyias quadricornis</i>	3	1	-	4	8
<i>Lecane papuana</i>	-	-	1	1	2
<i>Lecane acronychal</i>	-	-	2	-	2
<i>Lecane curvicornis</i>	-	-	1	-	1
ORDER					
FLOSCULARIACEAE	-	-	-	-	-
FAMILY					
TESTUDUNELLIDAE	-	-	-	-	-
<i>Filinia terminalis</i>	-	-	-	1	1
<i>Filinia</i> sp.	-	-	1	-	1
Total	70	81	115	120	386

4.1.1 Dominant orders of zooplankton

Zooplankton assemblages at various stations showed that Cladocera and Cyclopoida were dominant with relative abundance of 32.82% and 60.85% respectively (Table 4.3). Cladocera abundance was highest in stations 3 and 4 in January and March 2017 while stations 2 and 1 recorded the least values in the months of September 2016 to January 2017 (Figure 4.4). The order Cladocera was represented by four families; Moinidae, Sididae, Macrothricidae and Chydoridae. Moinidae and Sididae were represented by *Moina reticulata* and *Diaphanosoma* sp. respectively while Chydoridae was represented by *Kurzia longirostris*. *Moina reticulata*, *Diaphanosoma* sp and *Kurzia longirostris* were present in all the stations. Macrothricidae was represented by 3 taxa; *Macrothrix*, *Ilyocrytus spinifer* and *Echnisca* sp. *Macrothrix* sp. was the dominant species in this family recording a total number of 31 individuals followed by *Echnisca* sp. with a total number of 17 individuals and *Ilyocrytus spinifer* had the lowest number of individuals recorded amongst the 3 species present in Family Macrothricidae. *Ilyocrytus spinifer* was recorded in stations 1, 3 and 4, but absent in stations 2. Cladocerans were found almost in equal proportions in the wet and dry seasons (Figure 4.4). Station 4 contributed 11.13%, followed closely by station 3 (9.32%) before stations 2 and 1 which contributed 6.21% and 4.40% respectively. There was no significant difference ($P>0.05$) in the abundance of cladocerans across the study stations. Stations 1, 2, 3 and 4, were not significantly different from one another ($P>0.05$). Even with the higher values recorded in 3 and 4.

The order cyclopoida (60.85%) was the most abundant of all the zooplankton encountered. Cyclopoida abundance was least in station 3 in August 2016 and highest in station 4 in July 2016 (Figure 4.5). Station 3 contributed 17.87%, followed closely by station 4 (17.61%) before stations 2 and 1 which contributed 14.50% and 12.43% respectively. There was no significant difference ($P>0.05$) in Cyclopoida abundance across the stations with the

Stations (1, 2, 3 and 4) not being significantly different from one another ($P>0.05$) even with the higher values recorded in 3 and 4. Seven (7) taxa were recorded from Cyclopida namely; *Microcyclops varicans*, *Mesocyclops bodanicola*, *Metacyclops minutus*, *Eucyclops serrulatus*, *Tropocyclops prasinus*, *Thermocyclops neglectus* and *Cryptocyclops bicolor* with relative abundance of 0.07%, 26.97%, 6.22%, 9.12%, 28.63%, 17.42% and 3.73% respectively. All the 7 taxa were present in the four stations with *Tropocyclops prasinus* having the highest number of individuals (69) while *Cryptocyclops bicolor* had the lowest number of individuals recorded in the family (9). There was little or no seasonal difference in their abundance across the sampled stations (Figure 4.5).

4.1.2 Subdominant Order of Zooplankton

The sub-dominant order was Ploimida with a relative abundance of 5.96% (Table 4.3). This was represented by 5 taxa namely; *Platytias lehupi*, *Platytias quadricornis*, *Lecane papuana*, *Lecane acronychal* and *Lecane curvicornis* with total number of 43.47%, 34.78%, 8.69%, 8.69% and 4.34% respectively. *Platytias lehupi* and *Lecane curvicornis* having the highest (10) and lowest (1) numbers of individuals respectively. *Platytias lehupi* was present in station 1, 3, and 4 and while absent in station 2. *Lecane acronychal* and *Lecane curvicornis* were present only station 2. *Platytias quadricornis* was present in stations 1, 2, 4 and absent in station 3. *Lecane papuana* was present in stations 3, 4 and in stations 1 and 2. Ploimida was absent in July and September 2016 while abundance was highest in January 2017 in station 3 and lowest in stations 1, 2, 3 and 4 in October, 2016 to January and March 2017 (Figure 4.6). There was no significant difference ($P>0.05$) in Ploimida abundance across the stations, even with the higher values recorded in 3 and 4.

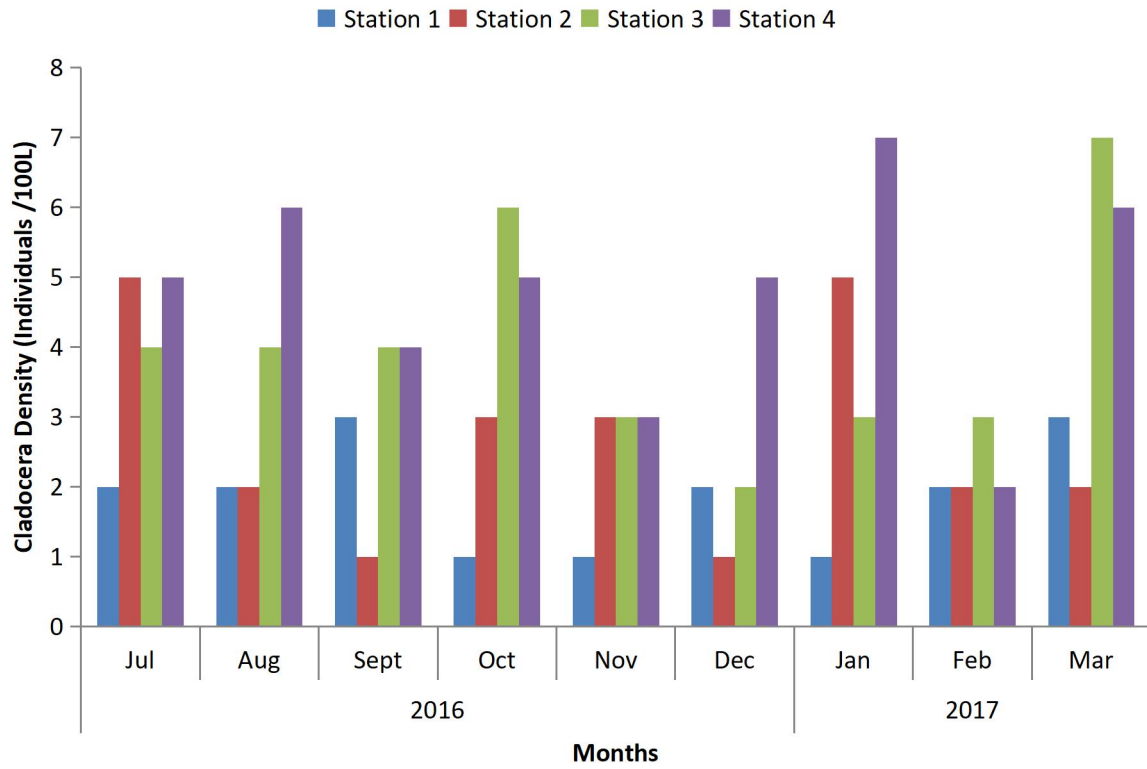


Figure 4.4: Spatial and temporal variations in the Cladocera Abundance

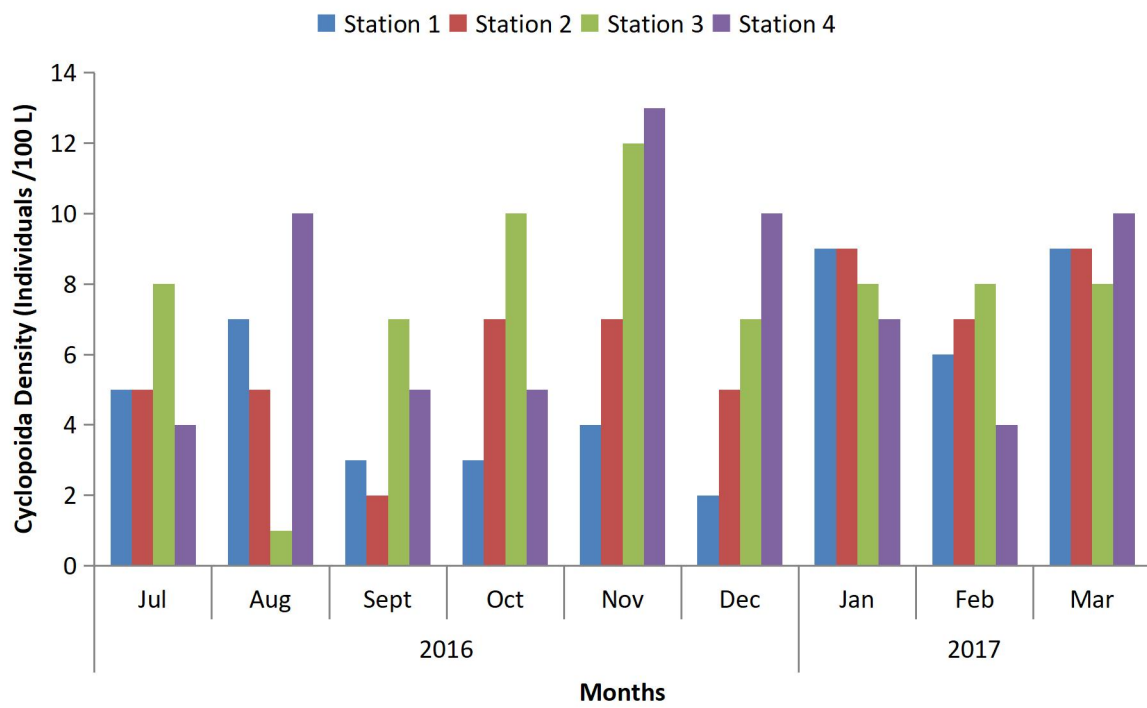


Figure 4.5: Spatial and Temporal variations in Cyclopoida Abundance

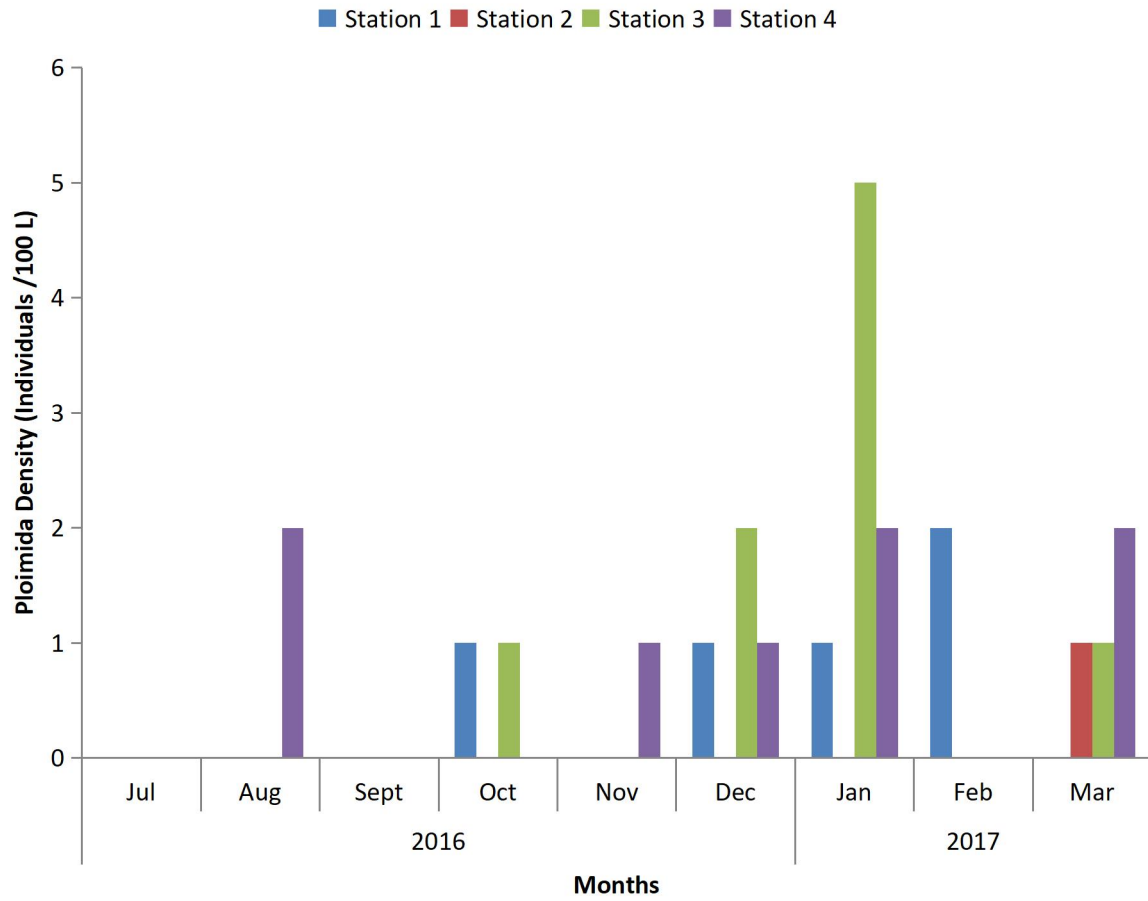


Figure 4.6: Spatial and Temporal variations in Ploimida Abundance

Table 4.3: Summary of the Abundance of Dominant and Subdominant orders of Zooplankton across the study stations

Status	Taxa	Station	Station	Station	F	p-Values	
		Station 1	2	3			4
Dominant	Cladocera	17	24	36	43	1.83	0.18
	Cyclopoida	48	56	69	68	0.33	0.80
Subdominant	Ploimida	5	1	9	8	1.28	0.32
Overall Abundance		70	81	115	120	1.32	0.28

P>0.05 – No Significant Difference

4.1.3 Diversity Indices

Table 4.5 presents the indices calculated for taxa richness (d), Dominance (D), Shannon (H), Simpson, Margalef's, Evenness and Equitability. Station 4 was the highest in taxa richness, followed by stations 3 and 1. The lowest in taxa richness was station 2. Margalef's Index, Shannon –Weiner Index, Evenness index and Equitability index exhibited similar trend in diversity with stations 4 and 2 showing the highest and lowest values respectively. Simpson index sequence of values was in the decreasing order station 4 > station 3 > station 1 > station 2.

4.1.4 Similarity Indices

The coefficients of Bray Curtis similarity indices in the paired stations comparison were greater than 0.5, thus significant similarities were recorded among them. Adopting Bray Curtis similarity index, the highest and lowest levels of similarity was obtained between stations 3/4 and stations 1/3 respectively (Table 4.5).

Table 4.4: Summary of the Zooplankton Diversity Indices across the sampling stations of River Siluko

	Station 1	Station 2	Station 3	Station 4
Taxa_S	15	13	18	17
Individuals	70	81	115	120
Dominance_D	0.114	0.150	0.112	0.094
Simpson_1-D	0.886	0.850	0.888	0.906
Shannon_H	2.421	2.180	2.457	2.559
Evenness_e^H/S	0.751	0.680	0.649	0.761
Margalef	3.295	2.731	3.583	3.342
Equitability_J	0.894	0.850	0.850	0.903

Table 4.5: Summary of the Similarity Indices (Bray Curtis Indices) across the Stations.

Bray Curtis				
	Station 1	Station 2	Station 3	Station 4
Station 1	1.00			
Station 2	0.73	1.00		
Station 3	0.55	0.68	1.00	
Station 4	0.68	0.74	0.78	1.00

Degree of relative similarity evaluated from 0=complete dissimilarity to 1=complete similarity; critical level of significance= 0.50; Asterisk (*) - indicates significant dissimilarity.

4.2 Taxonomic list Macrobenthic invertebrate species

Table 4.7 shows the taxonomic checklist of macrobenthic invertebrates observed for this study, it consists of Fifty-two (52) species distributed in Twenty-two (22) families , Twelve (12) orders and Four (3) phyla.

4.3 Photographs of the identified Macrobenthic invertebrates

Photographs of the identified species macrobenthic invertebrates are shown in Plates 4.21 to 4.72.

4.4 Composition of Macrobenthic invertebrates

The macrobenthic invertebrates were found to exist in both bankroot and erosional biotopes and belonged to the Phyla Annelida (4.81%), Arthropoda (94.08%) and Mollusca (1.11%). A total number of 52 taxa comprising of 2163 individuals were obtained in this study. The total number of taxa present in the bankroot biotope of stations 1, 2, 3 and 4 were 35, 38, 27 and 35 respectively, giving a total number of 322, 413, 658 and 602 individuals. While the total number of taxa present in the Erosional biotope of stations 1, 2, 3 and 4 were 12, 8, 14, 11 giving a total number of 48, 24, 45, and 51 individuals respectively (Figure 4.7, Table 4.7). Macrobenthic invertebrate abundance showed no significant difference ($P > 0.05$) across the sampled stations, even with the higher values recorded in 3 and 4. The total taxa composition, distribution and abundance of macrobenthic invertebrates are presented in Table 4.7.

4.4.1 Dominant orders of Macrobenthic invertebrates

The distribution of macrobenthic invertebrate assemblages at various stations showed that Ephemeroptera and Diptera were the dominant taxon with relative abundance of 64.00% and 10.00% respectively. The sub-dominant taxa were Coleoptera, Odonata and Prosopora with relative abundance of 9.00%, 8.00% and 5.00% (Figure 4.8, Table 4.8).

Table 4.6: Checklist of Macrobenthic Invertebrates

PHYLUM:	ANNELIDA
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Class:	Oligochaeta
Order:	Prosopora
Family:	Naididae
	<i>Branchiodrilus</i> sp. Michaelson, 1900 (Plate 4.21)
	<i>Nais</i> sp. Muller, 1773 (Plate 4.22)
	<i>Nais communis</i> Piguet, 1906 (Plate 4.23)
	<i>Nais simplex</i> Piguet, 1906 (Plate 4.24)
	<i>Nais obtusa</i> Piguet, 1906 (Plate 4.25)
Family:	Nadidae
	<i>Nadiumos osborni</i> Ehrenberg, 1823 (Plate 4.26)

PHYLUM: MOLLUSCA

Order:	Basommatophora
	<i>Lymnea natalensis</i> Krauss, 1848 (Plate 4.27)
	<i>Biomphalaria</i> sp. Preston, 1910 (Plate 4.28)

PHYLUM: ARTHROPODA

Class:	Arachnida
Order:	Hydrachnellae
Family:	Arrenuridae
	<i>Argyroneta</i> sp. Latreille, 1804 (Plate 4.29)
	<i>Argyroneta aquatica</i> Clerck, 1757 (Plate 4.30)
Class:	Insecta
Order:	Tricoptera
Family:	Hydrosychidae
	<i>Agraylea</i> sp. Curtis, 1834 (Plate 4.31)
Order:	Tricoptera
	<i>Tricoptera larva</i> (Plate 4.32)
Family:	Glossosomatidae
	<i>Glossosoma</i> sp. Curtis, 1834 (Plate 4.33)
	<i>Limnophilus</i> sp. Brewster, 1815 (Plate 4.34)

Order:	Ephemeroptera
Family:	Adenophlebiidae <i>Adenophlebiodes</i> sp. Edmunds, 1953 (Plate 4.35)
Family:	Baetidae <i>Baetis</i> sp. Dodds, 1923 (Plate 4.36) <i>Centroptilum</i> sp. Wuillot and Gillies, 1993(Plate 4.37) <i>Cloeon bellum</i> Leach, 1815 (Plate 4.38) <i>Cloeon simplex</i> McDunnough, 1925 (Plate 4.39)
Family:	Caenidae <i>Caenis</i> sp. Stephens, 1835 (Plate 4.40)
Order:	Hemiptera
Family:	Pleidae <i>Plea stiola</i> Leachi, 1817 (Plate 4.41)
Family:	Veliidae <i>Velia</i> sp. Latreille, 1804 (Plate 4.42)
Family:	Naucoridae <i>Naucoris</i> sp. Palisot de Beauvois, 1820 (Plate 4.43)
Family:	Belostomatidae <i>Lethocerus</i> sp. Mayr, 1853 (Plate 4.44)
Order:	Coleoptera
Family:	Hyrophilidae <i>Philhydrus</i> sp. LeConte, 1855 (Plate 4.45)
Family:	Hydrophilinae <i>Hydroporus</i> sp. Clairville, 1806 (Plate 4.46)
Family:	Dytiscidae <i>Amphiops gibbos</i> Latreille, 1816 (Plate 4.47) <i>Dystiscus</i> sp. Linnaeus, 1758 (Plate 4.48) <i>Dystiscus marginalis</i> Linnaeus, 1758 (Plate 4.49) <i>Dystiscus marginalis larva</i> Linnaeus, 1758 (Plate 4.50) <i>Nymphula</i> sp. Schrank, 1802 (Plate 4.51)

Family: Curculionidae
Endulus sp. (Plate 4.52)

Order: Lepidoptera

Family: Noctuidae
Noctuidae larva Latreille, 1809 (Plate 4.53)

Order: Diptera

Family: Ceratopogonidae
Ablabesmyia sp. Johannsen, 1905 (Plate 4.54)

Family: Chironomidae
Chironomid pupa (Plate 4.55)
Polypedilum sp. Kieffer, 1912 (Plate 4.56)

Subfamily: Orthocladinae
Cricotopus sp. Van der Wulp, 1874 (Plate 4.57)

Subfamily: Tanypodinae
Pentaneura sp. Philippi, 1865 (Plate 4.58)

Family: Culicidae
Culex sp. Linnaeus, 1758 (Plate 4.59)

Order: Odonata

Suborder: Anisoptera

Family: *Lestinogomphusae*
Aphylla sp. Selys, 1854 (Plate 4.60)
Lestinogomphus sp. Rambur, 1842 (Plate 4.61)

Family: Libellulidae
Libellula sp. Linnaeus, 1758 (Plate 4.62)
Orthemus sp. Hagen, 1861 (Plate 4.63)
Orthetrum cancellatum Linnaeus, 1758 (Plate 4.64)
Sympetrum sp. Newman, 1833 (Plate 4.65)

Suborder: Zygoptera

Family: Coenagrionidae
Coenagrion sp. Kirby, 1890 (Plate 4.66)
Coenagrion scitulum Rambur, 1842 (Plate 4.67)

Enallagma sp. Charpentier, 1840 (Plate 4.68)

Lestes sp. Leach, 1815 (Plate 4.69)

Class: Crustacea

Order: Decapoda

Family: Atyidae

Caridina africana Kingsley, 1883 (Plate 4.70)

Family: Desmocaridae

Desmocaridius bislineatus (Plate 4.71)



Plate 4.21: *Branchiodrilus* sp.



Plate 4.22: *Nais* sp.



Plate 4.23: *Nais communis*



Plate 4.24: *Nais simplex*



Plate 4.25: *Nais obtuse*



Plate 4.26: *Naidium osborni*

PHYLUM MOLLUSCA



Plate 4.27: *Lymnea natalensis*



Plate 4.28: *Biomphalaria* sp.

PHYLUM ARTHROPODA



Plate 4.29: *Argyroneta* sp.



Plate 4.30: *Argyroneta aquatica*



Plate 4.31: *Agraylea* sp.



Plate 4.32: Tricoptera larva

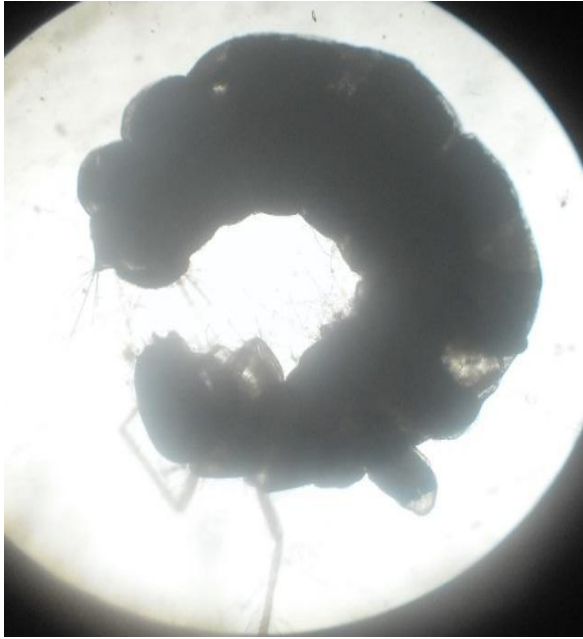


Plate 4.33: *Glossosoma* sp.



Plate 4.34: *Limnophilus* sp.



Plate 4.35: *Adenophlebiodes* sp. (anterior)



Adenophlebiodes sp. (posterior)



Plate 4.36: *Baetis* sp.



Plate 4.37: *Centropilum* sp.



Plate 4.38: *Cloeon bellum* (anterior)



Cloeon bellum (posterior)



Plate 4.39: *Cloeon simplex*



Plate 4.40: *Caenis* sp.



Plate 4.41: *Plea stiola*



Plate 4.42: *Velia* sp.



Plate 4.43: *Naucoris* sp.



Plate 4.44: *Lethocerus* sp



Plate 4.45: *Philohydus* sp.



Plate 4.46: *Hydroporus* sp. (anterior)



***Hydroporus* sp. (posterior)**



Plate 4.47: *Amphiops gibbos*



Plate 4.48: *Dystiscus* sp.



Plate 4.49: *Dystiscus marginalis*



Plate 4.50: *Dystiscus marginalis* larva



Plate 4.51: *Nymphula* sp



Plate 4.52: *Endulus* sp.



Plate 4.53: *Noctuidae* larva

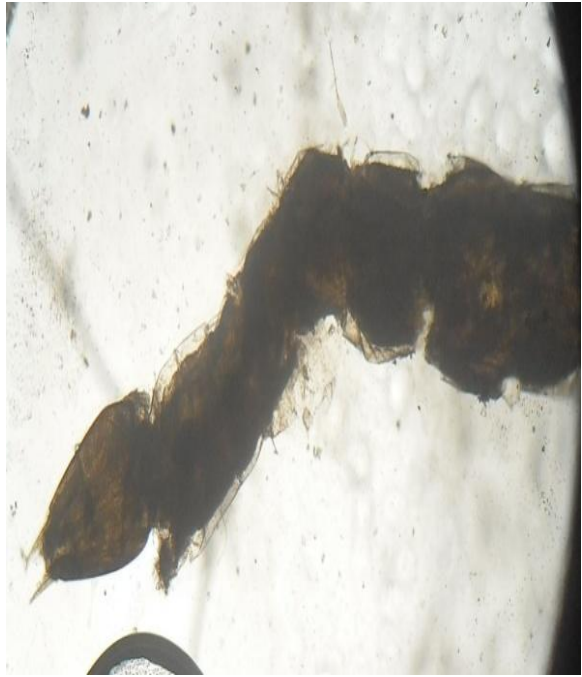
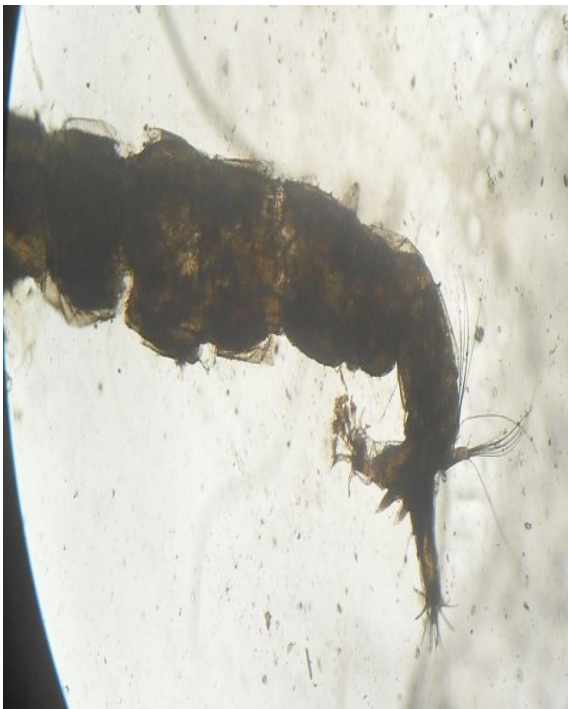


Plate 4.54: *Ablabesmyia* sp. (anterior)



***Ablabesmyia* sp. (posterior)**



Plate 4.55: *Chironomid* pupa



Plate 4.56: *Polypedilum* sp.



Plate 4.57: *Cricotopus* sp.



Plate 4.58: *Pentaneura* sp.



Plate 4.59: *Culex* sp. (anterior)



***Culex* sp. (posterior)**



Plate 4.60: *Aphylla* sp.



Plate 4.61: *Lestrogomphus* sp.



Plate 4.62: *Libellula* sp.



Plate 4.63: *Orthemus* sp.



Plate 4.64: *Orthetrum cancellatum*



Plate 4.65: *Sympetrum* sp.



Plate 4.66: *Coenagrion* sp. (anterior)



Coenagrion sp. (caudal gill)



Plate 4.67: *Coenagrion scitulum*



Plate 4.68: *Enallagma* sp.



Plate 4.69: *Lestes* sp.



Plate 4.70: *Caridina africana*



Plate 4.71: *Desmocarid bislineata*

Table 4.7: Composition, Distribution and Abundance of Macrobenthic Invertebrates fauna in Siluko River

	Station 1		Station 2		Station 3		Station 4		Total
	Erosional Biotopes	Bankroot Biotopes	Erosional Biotopes	Bankroot Biotopes	Erosional Biotopes	Bankroot Biotopes	Erosional Biotopes	Bankroot Biotopes	
PHYLUM ANNELIDA	-	-	-	-	-	-	-	-	-
Class Oligochaeta	-	-	-	-	-	-	-	-	-
Order Prosopora	-	-	-	-	-	-	-	-	-
Family Naididae	-	-	-	-	-	-	-	-	-
<i>Branchiodrilus</i> sp.	-	-	-	1	-	-	-	4	5
<i>Nais</i> sp.	5	3	-	2	11	5	4	12	42
<i>Nais communis</i>	-	3	11	8	4	3	6	2	37
<i>Nais simplex</i>	-	3	1	-	-	5	-	3	12
<i>Nais obtuse</i>	1	1	-	-	3	1	1	-	7
Family Nadidae	-	-	-	-	-	-	-	-	-
<i>Nadium osborni</i>	-	-	1	-	-	-	-	-	1
PHYLUM ARTHROPODA	-	-	-	-	-	-	-	-	-
Class Arachnida	-	-	-	-	-	-	-	-	-
Order Hydrachnellae	-	-	-	-	-	-	-	-	-
Family Arrenuridae	-	-	-	-	-	-	-	-	-
<i>Argyroneta</i> sp.	-	-	-	-	1	-	-	-	1
<i>Argyroneta aquatic</i>	-	2	-	1	-	1	-	2	6
Class Insecta	-	-	-	-	-	-	-	-	-
Order Plecoptera	-	-	-	-	-	-	-	-	-
Family Hydropsychidae	-	-	-	-	-	-	-	-	-
<i>Agraylea</i> sp.	-	-	-	2	-	-	-	-	2
Order Tricoptera	-	-	-	-	-	-	-	-	-
Tricoptera larva	-	-	1	-	-	-	-	-	1

	Station 1		Station 2		Station 3		Station 4		Total
	Erosional Biotopes	Bankroot Biotopes	Erosional Biotopes	Bankroot Biotopes	Erosional Biotopes	Bankroot Biotopes	Erosional Biotopes	Bankroot Biotopes	
Family Glossosomatidae	-	-	-	-	-	-	-	-	-
<i>Glossosoma</i> sp.	2	2	-	2	-	2	-	-	8
Family	-	-	-	-	-	-	-	-	-
<i>Limnophilus</i> sp.	1	1	-	-	-	-	-	-	2
Order Ephemeroptera	-	-	-	-	-	-	-	-	-
Family Adenophlebiidae	-	-	-	-	-	-	-	-	-
<i>Adenophlebiodes</i> sp.	-	31	-	38	-	72	-	92	233
Family Baetidae	-	-	-	-	-	-	-	-	-
<i>Baetis</i> sp.	6	40	-	43	6	84	9	111	299
<i>Centroptilum</i> sp.	2	53	2	41	2	225	3	176	504
<i>Cloeon bellum</i>	-	2	-	4	-	37	-	6	49
<i>Cloeon simplex</i>	2	7	2	21	2	89	3	36	162
Family Caenidae	-	-	-	-	-	-	-	-	-
<i>Caenis</i> sp.	-	27	-	36	2	45	7	25	142
Order Hemiptera	-	-	-	-	-	-	-	-	-
Family Pleidae	-	-	-	-	-	-	-	-	-
<i>Plea stiola</i>	-	-	-	4	-	1	-	1	6
Family veliidae	-	-	-	-	-	-	-	-	-
<i>Velia</i> sp.	-	-	-	1	-	-	-	-	1
Family Naucoridae	-	-	-	-	-	-	-	-	-
<i>Naucoris</i> sp.	2	3	-	6	-	-	-	1	12
Family Belostomatidae	-	-	-	-	-	-	-	-	-
<i>Lethocerus</i> sp.	-	-	-	2	-	-	-	1	3
Family Gerridae	-	-	-	-	-	-	-	-	-
<i>Gerris lacustris</i>	-	1	-	-	-	-	-	-	1
Order Coleoptera	-	-	-	-	-	-	-	-	-

Family Hyrophilidae	-	-	-	-	-	-	-	-	-
<i>Philhydrussp</i>	-	6	-	3	1	3	-	-	13
Family Hydrophilinae	-	-	-	-	-	-	-	-	-
<i>Hydroporus</i> sp.	-	1	-	2	-	-	-	-	3
Family Dytiscidae	-	-	-	-	-	-	-	-	-
<i>Amphiops gibbos</i>	-	17	-	89	-	2	-	1	109
<i>Dystiscus</i> sp.	-	-	-	10	-	1	1	2	14
<i>Dystiscus marginalis</i>	-	11	-	11	1	-	3	-	26
<i>Dystiscus marginalis</i> larva	-	4	-	3	-	3	-	2	12
<i>Nymphula</i> sp.	-	-	-	1	-	1	-	-	2
Family Curculionidae	-	-	-	-	-	-	-	-	-
<i>Endulus</i> sp.	-	6	-	2	-	-	-	5	13
Order Lepidoptera	-	-	-	-	-	-	-	-	-
Family Noctuidae	-	-	-	-	-	-	-	-	-
Noctuidae larva	-	2	-	3	-	-	-	1	6
Order Diptera	-	-	-	-	-	-	-	-	-
Family Ceratopogonidae	-	-	-	-	-	-	-	-	-
<i>Ablabesmyia</i> sp.	1	-	-	-	-	-	-	-	1
Family Chironomidae	-	-	-	-	-	-	-	-	-
Chironomid pupa	-	-	-	1	-	-	-	4	5
<i>Polypedilum</i> sp.	-	1	-	-	-	-	-	4	5
Subfamily Orthocladinae	-	-	-	-	-	-	-	-	-
<i>Cricotopus</i> sp.	5	15	2	12	5	4	-	5	48
Subfamily Tanypodinae	-	-	-	-	-	-	-	-	-
<i>Pentaneurasp</i>	19	37	4	28	4	25	13	31	161
Family Culicidae	-	-	-	-	-	-	-	-	-
<i>Culex</i> sp.	-	2	-	1	-	-	-	-	3
Order Odonata	-	-	-	-	-	-	-	-	-
Suborder Anisoptera	-	-	-	-	-	-	-	-	-
Family Lestiniogomphusae	-	-	-	-	-	-	-	-	-
<i>Aphylla</i> sp.	2	4	-	6	-	-	1	11	24

<i>Lestinogomphus</i> sp.	-	1	-	3	-	-	-	7	11
Family Libellulidae	-	-	-	-	-	-	-	-	-
<i>Libellula</i> sp.	-	15	-	3	1	13	-	9	41
<i>Orthemus</i> sp.	-	-	-	-	-	3	-	-	3
<i>Orthetrum cancellatum</i>	-	-	-	-	-	1	-	-	1
<i>Sympetrum</i> sp.	-	1	-	4	-	6	-	7	18
Suborder Zygoptera	-	-	-	-	-	-	-	-	-
Family Coenagrionidae	-	-	-	-	-	-	-	-	-
<i>Coenagrion</i> sp.	-	3	-	-	-	18	-	4	25
<i>Coenagrion scitulum</i>	-	10	-	2	2	-	-	6	20
<i>Enallagma</i> sp.	-	2	-	4	-	3	-	5	14
<i>Lestes</i> sp.	-	3	-	8	-	5	-	6	22
Class Crustacea	-	-	-	-	-	-	-	-	-
Order Decapoda	-	-	-	-	-	-	-	-	-
Family Atyidae	-	-	-	-	-	-	-	-	-
<i>Caridina africana</i>	-	-	-	-	-	-	-	2	2
Family Desmocaridae	-	-	-	-	-	-	-	-	-
<i>Desmocaridius bislineata</i>	-	-	-	-	-	-	-	1	1
PHYLUM MOLLUSCA	-	-	-	-	-	-	-	-	-
Order Basommatophora	-	-	-	-	-	-	-	-	-
<i>Lymnea natalensis</i>	-	2	-	1	-	-	-	7	10
<i>Biomphalaria</i> sp.	-	-	-	4	-	-	-	10	14
Total	48	322	24	413	45	658	51	602	2163

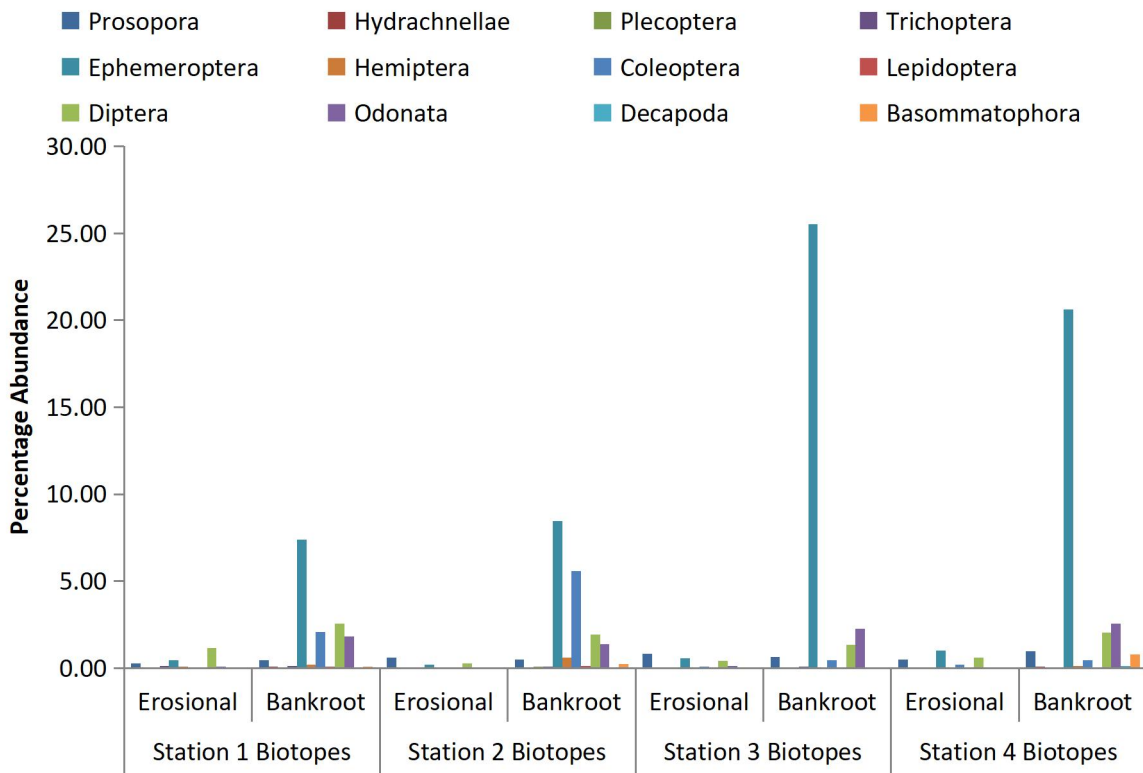


Figure 4.7: Spatial Variations in the Percentage Abundance of various Macroinvertebrate Orders

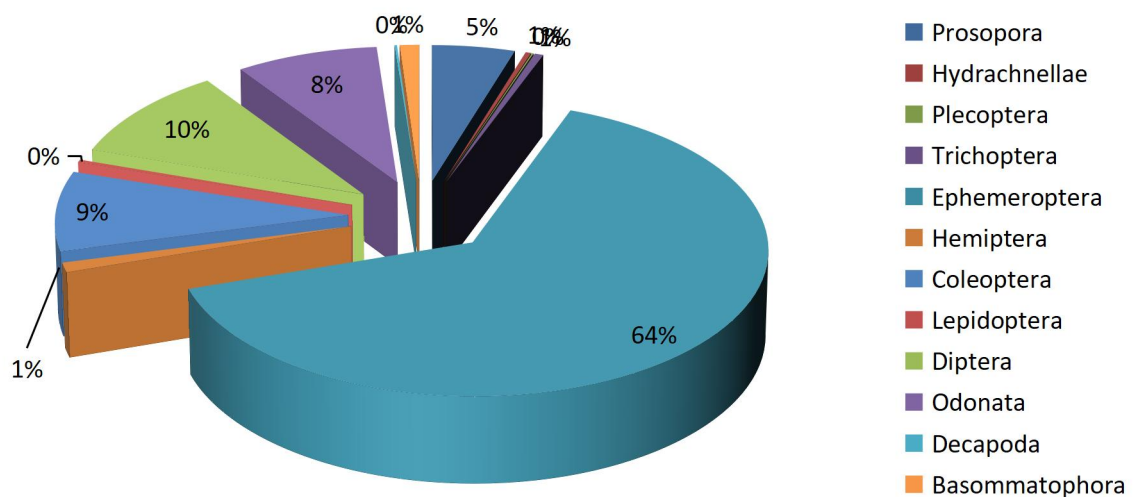


Figure 4.8: Relative Abundance of Macrobenthic invertebrates

Ephemeroptera accounted for approximately 64.0% of the overall percentage abundance of macrobenthic invertebrates. Their abundance was highest in August 2016 in station 3 and lowest in December 2016 and March 2017 in stations 1 and 2 (Figure 4.9). The Ephemeroptera families encountered in these study includes; Adenophlebiidae, Baetidae and Caenidae. Adenophlebiidae was represented by *Adenophlebiodes* sp., Baetidae was represented by *Baetis* sp., *Centroptilium* sp., *Cloeon bellum* and *Cloeon simplex*. while the Caenidae was represented by *Caenis* sp. *Baetis* sp. was present in all the sampling stations except the erosional biotope for station 2. *Centroptilium* sp and *Cloen simplex* were found in all the stations in both bankroot and erosional biotopes all through the sampling period and peaked in the bankroot biotopes of station 3 and the erosional biotope of station 4. *Cloen bellum* was found in only the bankroot and absent in the erosional biotope. *Caenis* sp was found more in the bankroot and absent in the erosional biotope for station 3 and 4. Station 3 contributed 27.02%, followed closely by station 4 (22.225) before stations 2 and 1 which contributed 7.266% and 7.10% respectively. There was no significant difference ($P > 0.05$) in the abundance of Ephemeropterans across the study stations, although higher values were recorded in stations 3 and 4.

The order Diptera constituted 10.0% of the overall abundance of the dominant taxa of macrobenthic invertebrates. Diptera abundance was least and highest in station 1 in August and October 2016 respectively (Figure 4.10). This was represented by Family Ceratopogonidae (*Ablabesmyia* sp.), Culicidae (*Culex* sp.), Chironomidae (Chironomid pupa and *Polypedilum* sp.), Orthocladinae (*Cricotopus* sp.), Tanypodinae (*Pentaneura* sp.) *Ablabesmyia* was found once all through the sampling period and it was found in the erosional biotope of station 1, *Pentaneura* sp. was found in all the stations, both in erosional and bankroot biotope, *Cricotopus* sp was found in all the stations except the bankroot of station 4. *Polypedilum* sp was found in bankroot of station 1 and 4. Chironomid pupa was

found in bankroot of station 2 and 4. Station 1 contributed 3.83%, followed closely by station 4 (2.73%) before stations 2 and 3 which contributed 2.30% and 1.82% respectively. There was no significant difference ($P>0.05$) in dipteran abundance across the stations with the Stations (1, 2, 3 and 4) not being significantly different from one another ($P>0.05$) even with the higher values recorded in 1 and 4.

4.4.2 Subdominant Orders of Macroinvertebrates

The Odonata constituted 8.00% of the overall percentage composition of the macroinvertebrates obtained in this study. Odonata abundance was highest in November in station 1 and lowest in July, August 2016 and March 2017 in stations 2, 3, 1 and 4 (Figure 4.11). The order Odonata was represented by 10 taxa within 3 families which includes Family *Lestiniogomphusae* (*Aphylla* sp. and *Lestiniogomphus* sp.), Libellulidae (*Libellula* sp., *Orthetrum* sp., *Orthetrum cancellatum* and *Sympetrum* sp.) and Coenagrionidae (*Coenagrion* sp., *Coenagrion scitulum*, *Enallagma* sp. and *Lestes* sp.). *Libellula* sp. were the most abundant of the order Odonata while the least abundant was *Orthetrum cancellatum* with just an individual found in station 3. Temporal variations across the stations were high in abundance during the dry seasons months. Station 4 contributed 2.68%, followed closely by station 3 (2.49%) before stations 1 and 2 which contributed 1.96% and 1.44% respectively. There was no significant difference ($P>0.05$) in odonata abundance across the stations.

Figure 4.12 shows the spatial and temporal distribution of coleoptera, with the highest abundance observed in station 1 in September 2016 and the least in stations 3, 1 and 2 in August, November, December 2016 and February 2017. The Coleopterans had a relative abundance of 9.00%. Three families which include; Hydrophilidae, Dytiscidae and Curculionidae were encountered during this study with *Philhydrus* sp. and *Hydroporus* sp. representing Hydrophilidae while Dytiscidae was represented by 5 taxa namely; *Amphiops*

gibbos, *Dystiscus* sp., *Dystiscus marginalis*, *Dystiscus marginalis larva* and *Nymphula* sp. Family curculionidae was represented by *Endulus* sp. *Endulus* sp. was present in the bankroot of station 1, 2 and 4 and absent in both bankroot and erosional biotope of station 3. *Nymphula* sp was found in station 2 and 3 and absent in station 1 and 4. *Dystiscus marginalis* larva were present in all the bankroot biotope and absent in the erosional biotope of the four stations. *Amphiops gibbos* was the most abundant Coleoptera with a relative abundance of 46.35% and it peaked at station 2 in september. Station 2 contributed 5.80%, followed closely by station 1 (2.16%), while stations 4 and 3 contributed 0.67% and 0.57% respectively. There was no significant difference ($P>0.05$) in Coleopteran abundance across the stations.

The order Prosopora constituted 5.00% of the overall abundance of the macrobenthic invertebrates. Prosopora abundance was highest in December 2016 in station 3 and lowest in stations 1 and 4 in August 2016 and February, March 2017 (Figure 4.13). It was represented by two families; Naididae (*Branchiodrilus* sp., *Nais* sp., *Nais communis*, *Nais simplex* and *Nais obtuse*) and Nadidae (*Nadium osborni*). *Branchiodrilus* sp. occurred in the bankroot biotopes of station 2 and 4. *Nais* sp. was distributed across all the stations except the erosional biotope of station 2. *Nais obtuse* was present in station 1, 3 and the erosional biotope of station 4 but was completely absent from station 2. *Nais obtuse* was present in all the stations except the erosional biotope of station 1. The most abundant taxa of this order was *Nais* sp. while *Nais osborni* was the least abundant (0.96%) with just a single individual. Prosoporans were found more in the dry season than the wet season. Stations 4 and 3 contributed 1.53% respectively, followed by station 2 (0.77%) and before stations 1 (0.67%). There was no significant difference ($P>0.05$) in their abundance across the stations.

Table 4.8: Summary of the Abundance of Dominant and Subdominant Orders of Macroinvertebrates across the Stations

		Station	Station	Station		p-	
	Taxa	Station 1	2	3	4	F	Value
Dominant	Order						
	Ephemeroptera	170	187	564	468	2.50	0.09
Subdominant	Order Prosopora	16	24	32	32	0.31	0.82
	Order Coleoptera	45	121	12	14	2.58	0.07
	Order Diptera	80	48	38	57	0.21	0.89
	Order Odonata	41	30	52	56	0.57	0.64
	Overall Abundance	370	437	703	653	0.27	0.85

P-Value >0.05 = No Significant Difference

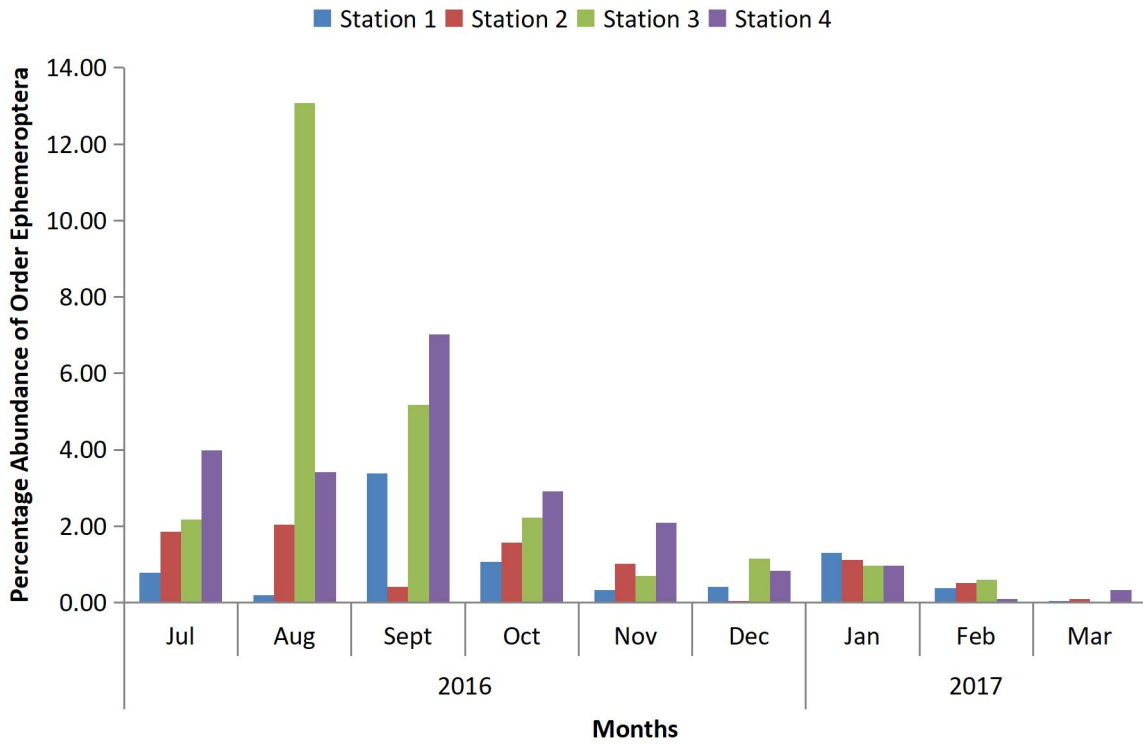


Figure 4.9: Spatial and Temporal variations in Ephemeroptera Abundance

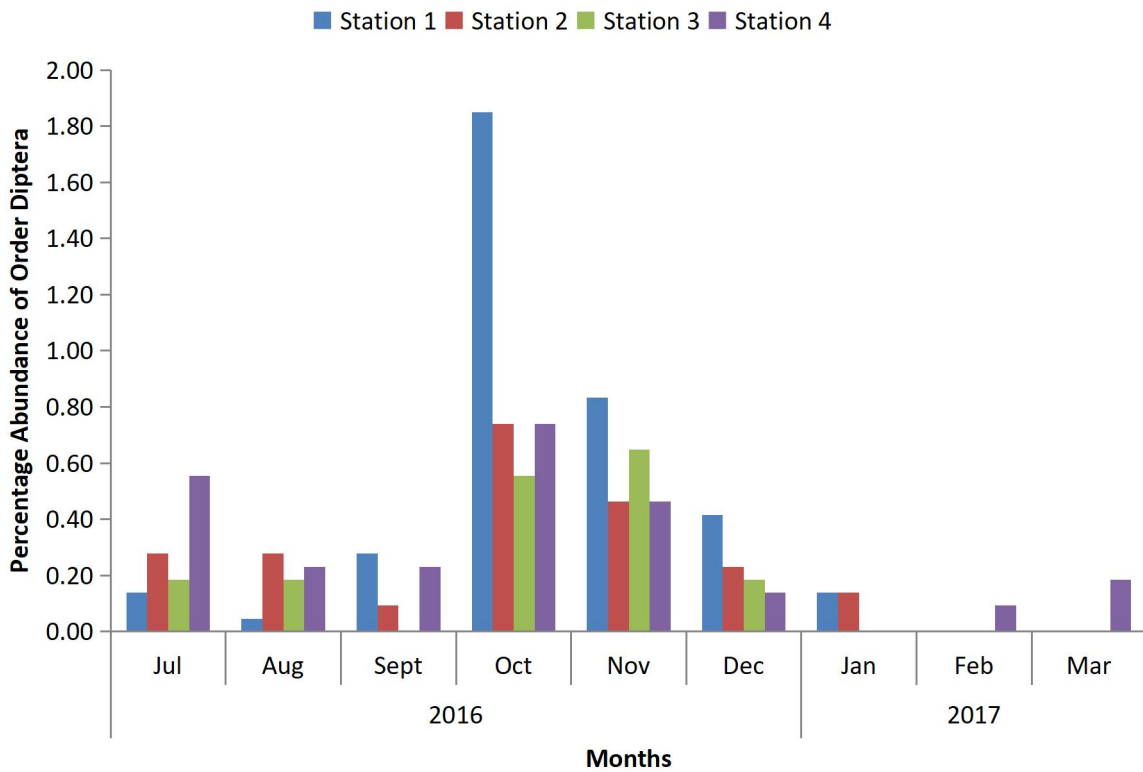


Figure 4.10: Spatial and Temporal variations in Diptera Abundance

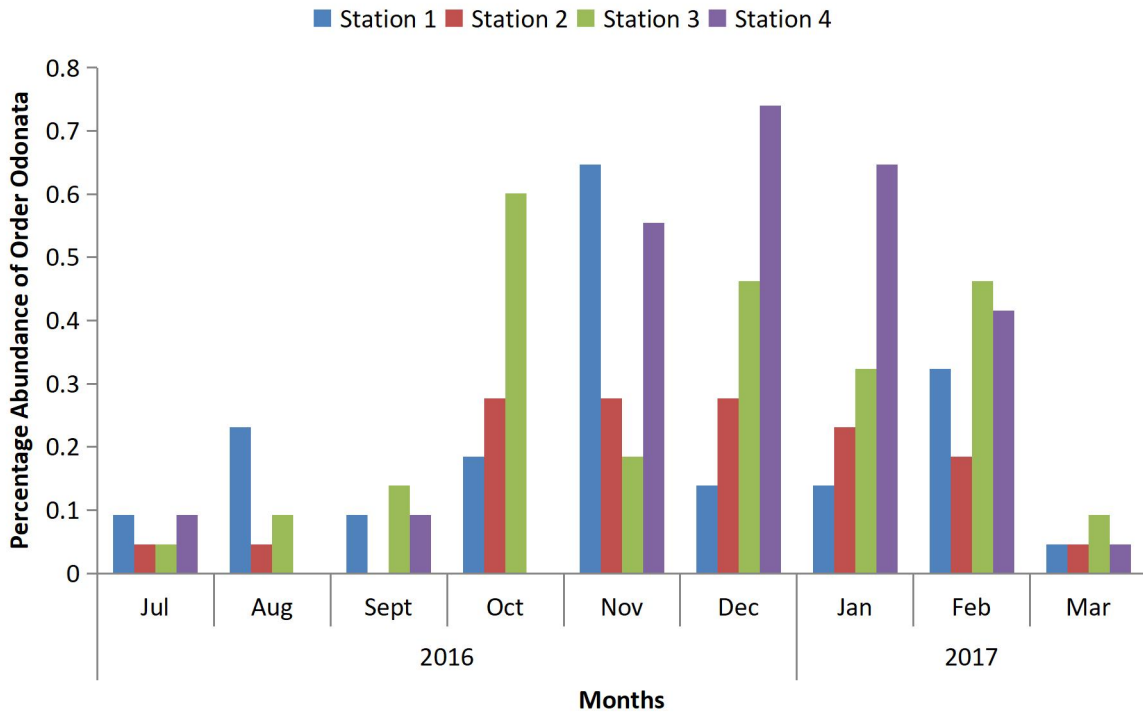


Figure 4.11: Spatial and Temporal variations Odonata Abundance

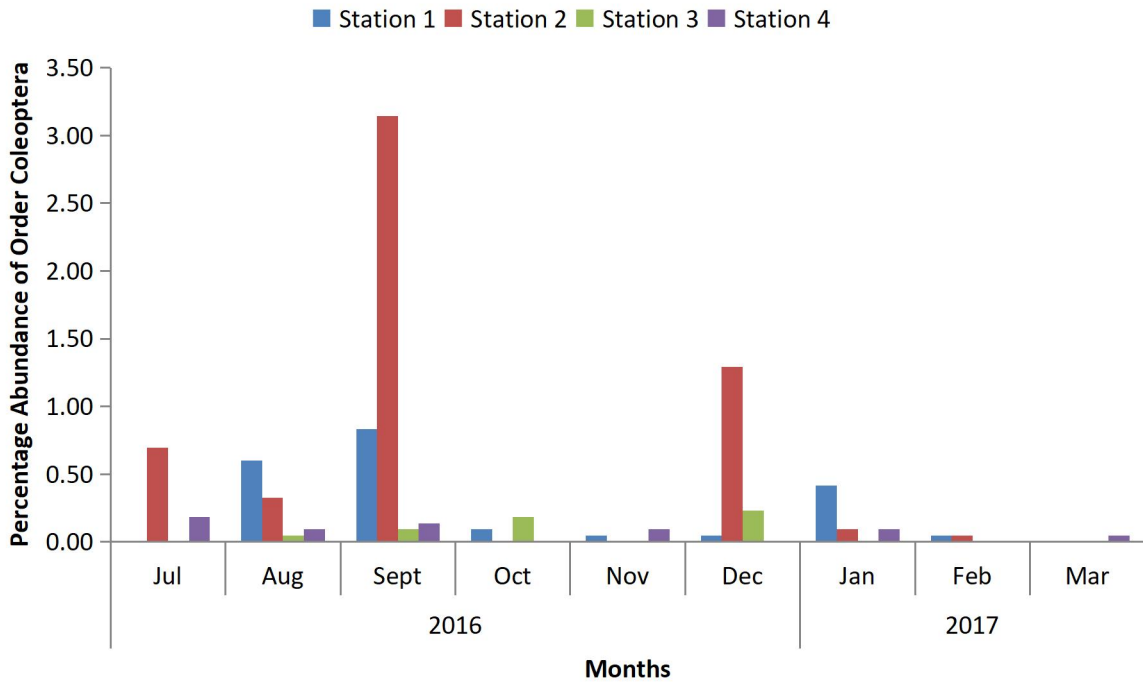


Figure 4.12: Spatial and Temporal variations in Coleoptera Abundance

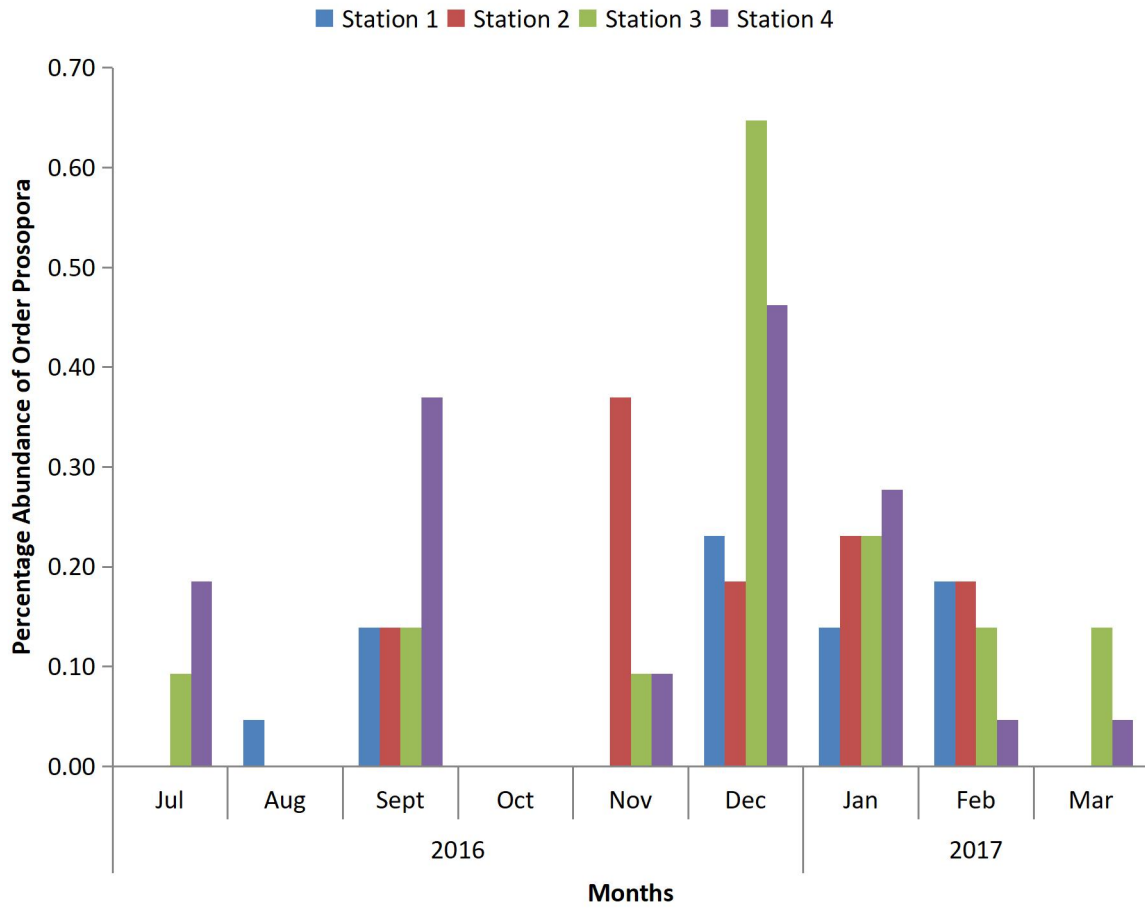


Figure 4.13: Spatial and Temporal variations in Prosopora Abundance

4.4.3 Diversity Indices

Table 4.9 presents the indices calculated for taxa richness (d), Dominance (D), Shannon (H), Simpson, Margalef's, Evenness and Equitability. Station 2 was the highest in taxa richness, followed by stations 4 and 1. The lowest in taxa richness was station 3. Margalef's Index was highest in Station 2 (6.579) and lowest in Station 3 (4.424). Shannon – Weiner Index was highest in Station 1 (2.866) and lowest in Station 3 (2.308). Simpson index and Equitability index exhibited similar trend in diversity with stations 1 and 3 recording the highest and lowest values respectively. Evenness index sequence of values was in the decreasing order station 1 > station 2 > station 3 > station 4.

4.4.4 Similarity Indices

The various clusters observed for macrobenthic invertebrates are shown in Figure 4.15. The coefficients of Bray Curtis similarity indices in the paired stations comparison were greater than 0.5, thus significant similarities were recorded among them. Adopting Bray Curtis similarity index, the highest and lowest levels of similarity were obtained between stations 1/2 and 2/3 respectively (Table 4.10).

Table 4.9: Summary of the Diversity Indices across the Stations

	Station 1	Station 2	Station 3	Station 4
Taxa_S	36	41	30	37
Individuals	370	437	703	653
Dominance_D	0.084	0.089	0.159	0.142
Simpson_1-D	0.916	0.911	0.841	0.858
Shannon_H	2.866	2.859	2.308	2.490
Evenness_e^H/S	0.488	0.426	0.335	0.326
Margalef	5.919	6.579	4.424	5.554
Equitability_J	0.800	0.770	0.679	0.690

Table 4.10: Summary of the Similarity Indices (Jaccard and Bray Curtis Indices) across the Stations

	Jaccard				Bray Curtis			
	Station 1	Station 2	Station 3	Station 4	Station 1	Station 2	Station 3	Station 4
Station 1	1.000				1.000			
Station 2	0.638	1.000			0.743	1.000		
Station 3	0.571	0.543	1.000		0.691	0.661	1.000	
Station 4	0.659	0.696	0.558	1.000	0.714	0.719	0.727	1.000

Degree of relative similarity evaluated from 0=complete dissimilarity to 1=complete similarity; critical level of significance=0.50; Asterisk (*) - indicates significant dissimilarity.

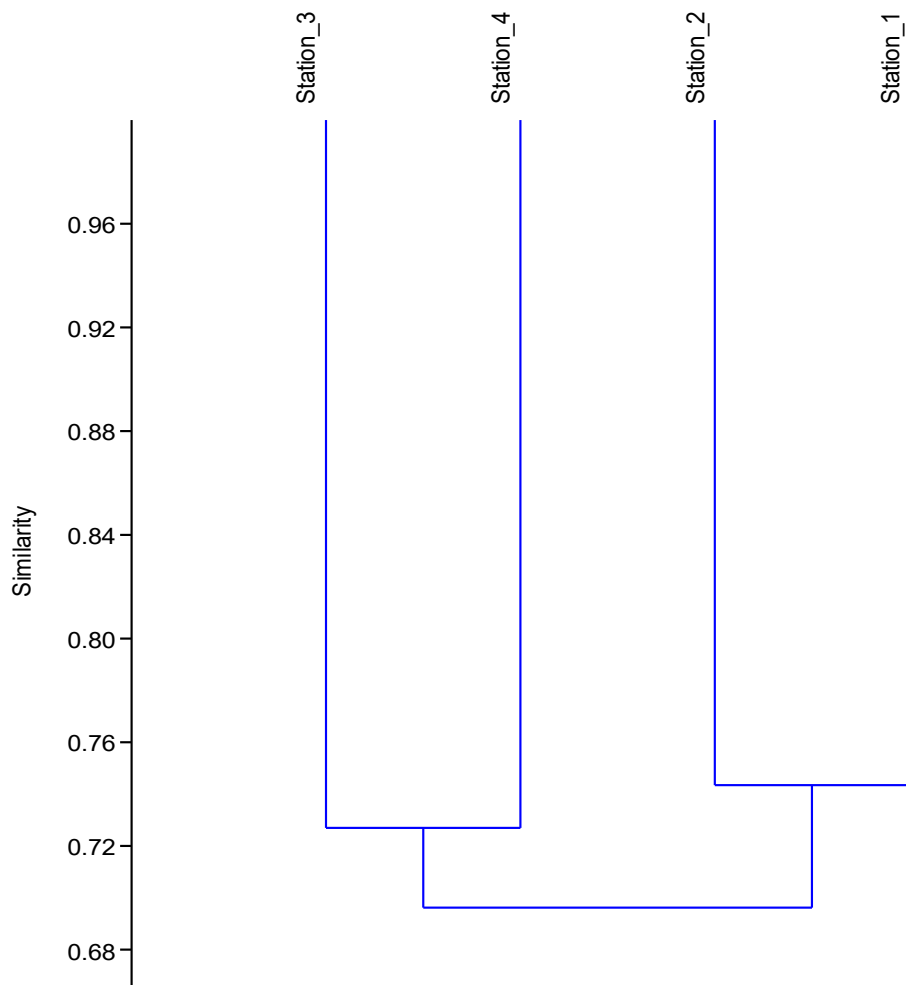


Figure 4.14: Dendrogram for cluster analysis based on Bray Curtis similarity index for Macrobenthic invertebrates fauna of Siluko River

4.5 Water quality assessments

Taxa richness, Pollution tolerance index, EPT index, EPT to Total ratio and Predominant taxon ratio were used to assess the quality of the water (Table 4.11). At station 1, the water quality was certified good, good, acceptable, marginal and acceptable by Taxa richness, Pollution tolerance index, EPT index, EPT to Total ratio and Predominant taxon ratio respectively. The station 2 assessment for Taxa richness and pollution tolerance index was the same as that in station 1, while EPT index, EPT to Total ratio and Predominant taxon ratio were recorded as good, marginal and good respectively. In terms of water quality, Taxa richness, Pollution tolerance index and EPT were same as reported for station 1 in station 3, except for EPT to Total ratio and Predominant taxon ratio which were good and marginal. The assessment sequence observed in station 1 for the biotic indices was replicated in station 4 except for EPT to Total ratio and Predominant taxon ratio which were acceptable and marginal respectively.

Table 4.11: Biotic index assessments of the four study stations

Assessment Indices	Station 1	Station 2	Station 3	Station 4
TAXA RICHNESS	36 (Good)	41 (Good)	30 (Good)	37 (Good)
POLLUTION TOLERANCE INDEX	64 (Good)	70 (Good)	58 (Good)	62 (Good)
EPT INDEX	8 (Acceptable)	9 (Good)	7 (Acceptable)	6 (Acceptable)
EPT TO TOTAL RATIO	0.5 (Marginal)	0.4 (Marginal)	0.8 (Good)	0.7 (Acceptable)
PREDOMINANT TAXON RATIO	0.5 (Acceptable)	0.4 (Good)	0.8 (Marginal)	0.7 (Marginal)

CHAPTER FIVE

5.0 DISCUSSION

5.1 Discussion

Zooplankton often exhibit dramatic changes in response to the changes in the physico-chemical and biotic properties of the aquatic environment hence are good bioindicators for the assessment of trophic state of water (Paturej and Goździejewska, 2005; Imoobe and Adeyinka, 2010). The use of macrobenthic invertebrates to ascertain the overall health status of aquatic environments remains the most suitable, reliable and the most widely acclaimed method globally. Their community structure plays significant role in determining the nutrient and pollution status of aquatic ecosystem (Ogbeibu *et al.*, 2013).

5.1.1 Zooplankton

The 20 zooplankton fauna encountered in this study includes Cladocerans, Copepods and Rotifers which have been commonly reported in Nigerian freshwater bodies (Akin-Oriola, 2003; Ayodele and Adeniyi, 2005; Omoigberale and Ogbeibu 2007; Imoobe 2011). All the twenty species of zooplankton fauna reported in this study (rotifers, cladocera and copepods) are common occurrence in several other rivers (Omoigberale and Ogbeibu 2007; Imoobe *et al.*, 2008; Imoobe and Akoma, 2009; Imoobe and Adeyinka, 2010). The zooplankton species recorded in this study were comparable to that of Watkar and Barbate (2013) 28 species from Kolar River in Maharashtra, Arazu and Ogbeibu (2017) (26 species) in Niger River, but were lesser than those reported by Akin-Oriola (2002) (49 species) in Ogunpa and Ona Rivers, Imoobe and Adeyinka (2010) (40 species) in Ovia River, Imoobe 2011 (51 species) in Okhuo River, Meszaros *et al.* (2012) (108 species) in Zagyva River, Onyema (2013) (40 species) in Eruvbi stream, Akindele and Olutona (2014) (37 species) for Aiba Reservoir and Ikhuorih *et al.* (2015) (42 species) in Ossiomo River. In this study zooplankton abundance was observed

to increase from the upper reaches to the lower reaches and species diversity and equitability generally followed the same trend and has similarly been reported by Akindele and Olutona (2014) for Aiba Reservoir.

FAO (2006) had earlier reported that distributions of zooplankton vary from place to place and year to year due to the dynamic nature of aquatic systems. Zooplanktons are known to respond to disturbances in the aquatic environment as well as phytoplankton abundance, which is their food source. Temperature and the availability of food are about the most important factors controlling the abundance of zooplankton in water (Imoobe and Adeyinka, 2010). The discharge rate of water from rivers is also an important factor, as it influences the environment by creating turbulence and high turbidity (Nelson and Lieberman, 2002), which increase the amount of dissolved particles and suspended matter in the water body. Suspended particles have been proven to hinder metabolism in copepods (Sharp *et al.*, 1979), while turbulence prevented larval forms of copepods from settling and developing into adult, hence die shortly before metamorphosis (Edung, 2001). (Akin-Oriola, 2003) reported that variations in zooplankton abundance can be attributed to differences in flow, turbidity, DO concentration, temperature and conductivity as well as the density of fish population.

The zooplankton composition was dominated by Cladocera and Copepoda in this study and has similarly been reported by Omoigberale and Ogbeibu (2007), Imoobe and Adeyinka (2010), Ogbuagu and Ayoade (2012), Ekpo (2013), Ikhuorlah *et al.* (2015), Kennie *et al.* (2017) and Manickam *et al.* (2018). This was in contrast to the observations of Iloba and Akawo (2013), Onyema (2013) and Khalifa and Bendary (2016) who reported the dominance of rotifers only. Rotifers and crustaceans zooplankton are often considered as good indicators of the trophic state of water bodies with communities populated mainly by copepods and cladocerans indicative of good water quality (Sendacz *et al.*, 1985). This

showed that the water in Siluko River was of good quality and with reduced impact of organic pollution.

The cladocera community recorded in this study comprises of 6 species, and 4 families namely Moinidae, sididae, Macrothricidae and Chydoridae. The Cladocerans *Diaphanosome* sp., *Macrothrix* sp., *Ilyocryptus spinifera* and *Kurzia longirostris* recorded in this study have been similarly reported by Akin-Oriola (2002) in Ogunpa and Ona Rivers, Dejen *et al.* (2004), Imoobe (2011) in khuo River, Arazu and Ogbeibu (2017) in Niger River and Kennie *et al.* (2017) from Jebba Upper Basin.

Copepods are abundant in most water bodies and are more abundant in marine environment than in fresh water (Raymond, 1983). The Order Cyclopoida was the only copepod encountered in this study. This is common to most tropical fresh waters as harpacticoids are not common and are almost restricted to the littoral zone, while calanoids are more abundant in the marine environment. Copepod species such as *Microcyclops varicans*, *Metacyclops minute*, *Eucyclops serrulatus*, *Tropocyclops prasinus* and *Thermocyclops neglectus* observed in this study have similarly been reported by Akin-Oriola (2002) Ogunpa and Ona Rivers, Imoobe (2011) in khuo River, Ekpo (2013) in Niger Delta, Akindele and Olutona (2014) in Aiba Reservoir, Ikhuorihah *et al.* (2015) in Ossiomo River and Arazu and Ogbeibu (2017) in Niger River.

Rotifers (8.66%) were the least abundant of the zooplankton encountered in this study. This is similar to reports by Ikhuorihah *et al.*, (2015). Rotifers such as *Filinia* sp and *Lecane papuana*, *Lecane curvicornis* reported in this study have been similarly observed by Imoobe (2011) in Okhuo River, Iloba and Akawo (2013) in River Adofi and Kennie *et al.* (2017) from Jebba Upper Basin.

Comparatively, zooplankton abundance was higher in station 4 than the other stations. There were no observed seasonal variations in Cladocera and Copepods composition

and abundance except for Rotifers. High Rotifer abundance was recorded in the dry season and this has similarily been reported by Egborge (1979). This however did not agree with the observations of Imoobe (2011) who reported higher species number and density during the rainy season.

5.1.2 Macrobenthic Invertebrate

A total of 52 macrobenthic invertebrate taxa comprising 2163 individuals shared within 3 phyla were observed. The macrobenthic invertebrate phyla recorded were Annelids, Arthropods, and Molluscs which has also been reported by Avoaja *et al.* (2007), Emere and Nasiru (2008), George *et al.* (2009), Andem *et al.* (2012), Shailendra *et al.* (2013), Sharma and Barkale (2016), Brraich and Kaur (2017), Iyagbaye *et al* (2017), Oyediran *et al.* (2017).

Macrobenthic abundance and composition in this study was quite high. High diversity of benthic fauna has been reported by Victor and Ogbeibu (1985); Olomukoro and Ezemonye (2007); Omoigberale and Ogbeibu (2010); Olomukoro and Dirisu (2013); Shailendra *et al* (2013); Olomukoro and Oviojie (2015); Iyagbaye *et al* 2017). The total number of taxa from this survey was higher when compared to records of Emere and Nasiru (2008) (twenty-seven taxa) from an urbanized stream in Kaduna, Edokpayi *et al.* (2010) (sixteen taxa) in an urban draining creek in southern Nigeria, Olomukoro *et al.*, (2013) (ten taxa) from the Agbede flood plain, Olomukoro and Dirisu (2013) (eight taxa) in Edion and Omodo Rivers in Agbede wetlands, Edegbene *et al.* (2014) (twenty-three taxa) in Atakpo River, Omoigberale *et al.* (2014) (twenty taxa) in Okhuaihe River, Olomukoro and Oviojie (2015) (forty-six taxa) in Obazuwa Lake, Adebayo *et al.* (2016) (two taxa) in Otamiri River, Abed-Nego and Adedolapo (2016) (six taxa) from Ikere Gorge Reservoir, Enwemiwe and Arimoro (2017) (twenty-six taxa) in River Illah, Brraich and Kaur (2017) (twenty-four taxa) from wetlands in

Egypt, Iyagbaye *et al.* (2017) (forty-five taxa) in Ovia River and Oyediran *et al.* (2017) (seventeen taxa) in Ikwo River.

Higher diversity also results when many species have equal or near-equal opportunity of co-existence (Jeppesen *et al.* 2002). Mckintosh (2000) observed that in the absence of disturbance, community composition may be strongly influenced by biotic interactions such as competition and predation. A decrease in diversity and corresponding increase in abundance of a limited number of species is a common community response to environmental disturbance. In other words, low diversity is an indication of environmental stress while high diversity is a reflection of stress-free environment.

The dominant groups from this study were Ephemeroptera and Diptera, while Coleoptera, Odonata and Prosopora were sub-dominant. Ephemeroptera and Diptera dominance has been reported by Ogbeibu and Oribhabor (2002) in a fourth order stream in Southern Nigeria, Olomukoro and Dirisu (2013) in Edion and Omodo Rivers in Agbede wetlands, while Dipteran dominance was observed by Olomukoro and Ezemonye (2007) from rivers in southern Nigeria, Olomukoro *et al.* (2013) in Agbede flood plain, Omoigberale *et al.* (2014) in Okhuaihe River, Olomukoro and Oviojie (2015) in Obazuwa Lake, Ibezute *et al.* (2016) in Ikpoba River. However, this was in contrast to that of Olomukoro and Azubuike (2009) in Ekpan Creekin Warri and Enwemiwe and Arimoro (2017) in River Illah, where Molluscan and Odonata/Crustacea dominance respectively was reported for macrobenthic invertebrates. The distribution of macrobenthic invertebrates in the bankroots among the various stations increased in the order Station 3>station 4> Station 2> Station 1. This could be due to ecological imbalance governing their abundance and distribution such as water quality, immediate substrates of occupation and food availability (Dance and Hynes, 1990). The bottom substrate of Siluko River varied predominantly from sand to sandy-silt. The spatial changes in abundance of macrobenthic invertebrate species may be due to differences

in composition of the substratum. According to Nelson and Lieberman (2002), flow velocity influences the type of river bed, amount of silt deposition, which in turn affects macro-invertebrate abundance. The nature of bottom sediments is often associated with the evolutionary and ecological history of the river with ecosystem diversity increasing as it grows older in evolutionary time. The root of aquatic macrophytes is known to serve as shelter or direct and indirect food source for macrobenthic invertebrates (Lodge, 1991; Newman, 1991). The high taxa recorded in this study are supported by the fact that tropical streams generally harbor a large number of taxa compared to temperate streams (Hynes, 1970; Bishop, 1973). Furthermore, tropical rivers tend to recover rapidly; the rate of reproduction and relatively high primary production has been suggested as factors that are responsible (Udebuana *et al.*, 2015).

Oligochaetes such as *Branchiodrillus* sp., *Nais simplex* and *Naisa* sp. have been similarly observed by Avoaja *et al.* (2007), Emere and Nasiru (2009), Shailendra *et al.* (2013), Olomukoro and Oviojie (2015), Sharma and Barkale (2016) and Iyagbaye *et al.* (2017). Mollusc observed in this study were *Lymnaea natalensis* and *Biomphalaria* sp. and have similarly been recorded by Avoaja *et al.* (2007) and Emere and Nasiru (2009) respectively.

Arthropods such as *Argyroneta aquatic* recorded in this study have been reported by Olomukoro and Azubuike (2009) and Iyagbaye *et al.* (2017). *Adenophlebiodes* sp., *Centroptilum* sp., *Cloeon* sp. and *Caenis* sp. observed in this study have been reported by Abed-Nego and Adedolapo (2016), Enwemiwe and Arimoro (2017), Brraich and Kaur (2017) and Iyagbaye *et al.* (2017). Olomukoro and Oviojie (2015) and Iyagbaye *et al.* (2017) have similarly reported arthropods such as; *Plea stiola*, *Naucoris* sp., *Lethocerus* sp. and *Gerris lacustris* recorded in this study. Species such as *Philhydrus* sp., *Amphiops gibbnos*, *Dystiscus* sp. and *Nymphula* sp. recorded in this study have been reported by Avoaja *et al.* (2007),

Olomukoro and Oviojie (2015), Brraich and Kaur (2017), Iyagbaye *et al* (2017) and Keke *et al.* (2017).

Ablabesmyia sp., *Chironomid pupa*, *Polypedilum* sp., *Pentaneura* sp. and *Culex* sp. recorded for this study have been reported by Avoaja *et al.* (2007), Emere and Nasiru (2008), Olomukoro and Oviojie (2015), Enwemiwe and Arimoro (2017), Brraich and Kaur (2017) and Iyagbaye *et al* (2017). Avoaja *et al.* (2007), Emere and Nasiru (2008), Olomukoro and Oviojie (2015), Enwemiwe and Arimoro (2017), Iyagbaye *et al* (2017) and Oyediran *et al.* (2017) has similarly recorded species *Aphylla* sp., *Lestinogomphus* sp., *Libellula* sp., *Coenagrion* sp., *Coenagrion scitulum*, *Enallagma* sp. and *Lestes* sp. observed in this study, while *Caridina africana* has also been reported by Olomukoro and Oviojie (2015) and Enwemiwe and Arimoro (2017).

Sensitive species of the orders Ephemeroptera, Tricoptera and Coleoptera which indicate unpolluted water with low organic waste were present in this study. The occurrence of insects throughout the sampling stations confirms their ubiquitous nature and the knowledge that they do not show habitat restriction. The significance of ephemeroptera species as indicators of trophic status of freshwater ecosystem has been stressed by Olomukoro (1996) and Ogbeibu (2001). They tend to live mostly in unpolluted lakes, ponds, streams and rivers, where they contribute substantially to secondary production. The occurrence of *Chironomus* species is perceived to be normal as they are usually present in water bodies (Emere and Narisu, 2007).

Diversity and Evenness indices show that there are no significant differences in species composition between the stations. The organisms are similar to a great extent in all stations. Diversity is often considered as a measure of community stability with diversity index indicating that the stations are relatively stable and free of stress. The high Shannon-Weiner and Margalef diversity values recorded for zooplankton and macrobenthic were due

to the fact that the former incorporates evenness of distribution while the later only measures species richness. Thus, Shannon-Weiner diversity values were as a result of the much higher relative abundance of the dominant taxa for zooplankton and macrobenthic invertebrates.

The comparable number of zooplankton and macrobenthic invertebrate taxa as well as their abundance and diversity levels in the different stations indicates uniform distribution of zooplankton and macrobenthic invertebrate fauna in the study area, which has similarly been reported by Olomukoro and Oviojie (2015). Generally, high biodiversity is expected in ecosystems devoid of significant anthropogenic impact (Ogbeibu *et al.* 2013). Species richness and abundance of macrobenthic invertebrates were higher than that of the zooplankton. Using the correlation matrix, correlation yielded a negative correlation which implies that zooplankton is being fed on by other organisms in the open water column.

5.1.3 Water Quality Assessment

The occurrence of relatively higher taxa and individuals' in the bankroot of station 3 may be an indication of lower degree of anthropogenic activities at this station compared to other stations. Species abundance of the erosional macrobenthic invertebrates increased in the order 4> Station 1> Station 3> Station 2. Ephemeroptera, Plecoptera and Tricoptera richness can serve as a good tool for water quality assessment and is a better tool than taxa richness in assessment of water quality; however, these indices consider the quantitative characteristic of macroinvertebrates taxa encountered in a study. Ephemeroptera, Plecoptera and Tricoptera index was acceptable in all stations except in station 2 where it was good, this was indicative of good water quality in this study. Observations of this study were similar to those of Enwemiwe and Arimoro (2017) in River Illah, Iyagbaye *et al* (2017) in Ovia River, but were in contrast to that for Nyakeya *et al.* (2009) in Kisian and Kisat Rivers in Lake Victoria, Ogbeibu *et al.* (2013), Abed-Nego and Adedolapo (2016) in Ikere Gorge Reservoir, Ibezute

et al. (2016) in Ikpoba River, Ojija and Laizer (2016) from Nzovwe stream in Kenya and Oyediran *et al.* (2017) in Ikwo River. Ephemeroptera, Plecoptera and Tricoptera are restricted to cool, clean streams and rivers, these groups of macroinvertebrates serve as bio-indicators of pollution in the aquatic ecosystem (Olomukoro and Ezemonye, 2007).

According to Stewart and Stark (1993), plecopterans are the most sensitive order of aquatic insects. The abundance of these species is an indication of good water quality and may be due to habitat preference and availability of food. The relatively high diversities of Ephemeroptera, Diptera and Coleoptera in this study may be due to habitat preference and could be due to low level of pollution in this water body.

Assessment of water quality based on different biotic indices showed that all stations were not impacted, with results varying from acceptable to good and marginal. Ephemeroptera, Plecoptera and Tricoptera were present in stations 1, 2, 3 and 4 while Tricoptera was absent in station 4. This gave an indication of good water quality in all stations and this observation has similarly been reported by Olomukoro and Dirisu (2013). The good water quality observed for the stations could be due reduced or controlled human activities or the fast flowing nature of the river, which encourages aeration, thereby, increasing microbial breakdown of pollutants. The Taxa richness assessment of station 3 and 4 may also be attributable to the high flow rate of this river.

5.2 Conclusion

The zooplankton and macrobenthic invertebrate communities were characterized by species which indicated good water quality. Macrobenthic invertebrate fauna was generally higher than the zooplankton fauna in both species diversity and abundance. The highest number of macrobenthic invertebrate was recorded from station 3 while that of Zooplankton was collected from station 4 with just a little difference from the values obtained from station

3. Stations 3 and 4 had little or no human activities observed when compared with stations 1 and 2. The common practice of using natural water bodies as disposal media for wastes/effluents in Nigeria poses a serious threat to the aquatic ecosystems. Thus, human activities can rapidly alter the ecosystem balance of any previously stable aquatic community. The overall site assessment using the macrobenthic invertebrate fauna rated River Siluko as 'acceptable' in terms of its water quality, but further studies are advised to properly enumerate the extent of anthropogenic activities on this water body as human activities such as farming and housing development are on a continuous increase around this stretch of the River.

5.3 Contribution to Knowledge

The study has contributed to knowledge in the following ways:

1. Provided information on the zooplankton and macrobenthic invertebrate fauna community structure in Siluko River.
2. Provided information on the dominant species of zooplankton and macrobenthic invertebrate fauna in Siluko River.
3. Provided information on the water quality of Siluko River based on biological indices.

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