PHYSICO-CHEMICAL PARAMETERS, OCCURRENCE AND ABUNDANCE OF MACRO-INVERTEBRATES OF ERELU RESERVOIR IN OYO TOWN, NIGERIA

BY

Afusat Ibiwumi AMUSAT
B.Sc. (Ed) Biology (UNAAD), M.Sc. Zoology (Ibadan)
Matric No.: 146552

A Thesis in the Department of Zoology
Submitted to the Faculty of Science
in partial fulfillment of the requirements for the Degree of

DOCTOR OF PHILOSOPHY

Of the

UNIVERSITY OF IBADAN

JANUARY 2020

ABSTRACT

Erelu reservoir is the main source of water supply for domestic, agriculture and fishing activities in Oyo town. The reservoir receives inflow of materials from the catchment where various anthropogenic activities occur which could impact its ecosystem. Despite the socio-economic importance of Erelu reservoir, there is paucity of information on the reservoir limnology, which is important for its management. This study was conducted to determine the physico-chemical parameters, occurrence and abundance of macro-invertebrate fauna in Erelu reservoir.

Surface water, macro-invertebrates and sediment samples were collected monthly from June, 2013 to May, 2015 at seven selected stations on the reservoir. Water temperature and transparency were measured *in-situ* using standard methods. Dissolved Oxygen (DO) and Biological Oxygen Demand (BOD) were measured with standard kits. Total Alkalinity (TA), Primary nutrients (phosphate and nitrate) and turbidity were determined using APHA methods. Lead, iron, chromium, zinc and calcium were determined using Atomic Absorption Spectrophotometry. Aquatic insects were collected using sweep nets (250 and 500 µm mesh sizes). Benthos and sediment samples were collected with van-Veen grab (surface area $0.6m^2$), benthic samples were sieved with 0.5mm sieve, sorted, identified with standard identification guides and counted. Species diversity was determined using Margalef (d) and Shannon Wiener Index (H'). Data were analysed with descriptive statistics, ANOVA, Pearson's correlation coefficient and paired t-test at $\alpha_{0.05}$.

The physicochemical parameters of the reservoir water were temperature 28.50±0.12°C; transparency 64.82±1.80 cm; turbidity 10.79±1.28 NTU; DO 8.36±0.11mg/L; BOD 1.18±0.11 mg/L; TA 98.23±2.70 mg/L and Calcium ion 17.11±0.54 mg/L. Phosphate (0.14±0.03 mg/L) and nitrate (0.84±0.08 mg/L) values were within NESREA (3.5mg/L and 10mg/L, respectively) guideline limit for drinking water while turbidity (5mg/L) was not. Temperature (27.52±0.32°C), TA (104.71±11.34 mg/L), Fe (0.62±0.16 mg/L), Zn (1.43±0.71 mg/L) and Cr (0.54±0.30 mg/L) in wet season were significantly different from dry season, (30.04±0.14°C; 96.20±7.50; 0.77±0.22; 0.62±0.14; 0.19±0.07 mg/L, respectively). The transparency, BOD and lead significantly varied across sampling stations. Lead, iron and chromium were lower in water (1.01±0.06; 0.59±0.04; 0.26±0.03 mg/L, respectively) than sediment (23.79±1.72; 20.63±2.25; 11.51±1.54 mg/kg, respectively, an indication of the sediment acting as the favourable sink for the metals. Fifty six species (Aquatic insects=38, Benthos=18) of macro-invertebrates were identified. Four orders of aquatic insects encountered were Hemiptera (92.06%) > Coleoptera (7.61%) > Odonata (0.33%), while the least was Diptera (0.01%) across all stations. Among the eighteen species of benthic macro-invertebrates encountered, the pollution tolerant species: *Melanoides tuberculata* (61.61%) and *Potadoma moerchii* (14.51%) had the highest percentage occurrence, an indication of the pollution status. Transparency showed significant positive correlation with Hemiptera (r=0.88), while phosphate had positive relationship with Capitellida (r=0.94), which indicated that the parameters had positive effect on the abundance of the organisms. Diversity values recorded for aquatic insects and benthic macro-invertebrates were (H'=0.64; d=0.54) and (H'=1.06; d=0.50), respectively.

Turbidity and heavy metal concentrations exceeded the recommended limits in Erelu reservoir. A high percentage of pollution tolerant species suggest poor water quality, hence, the need for the introduction of appropriate management methods.

Keywords: Reservoir turbidity, Macro-invertebrates, Fauna diversity, Heavy metal pollution
Word count: 487

DEDICATION

This project is dedicated to Almighty Allah who has been protecting my life and to the memory of my late parent: Alhaji Shittu Mustapha Alalikimba and Mrs Fadhilat Abake (Nee Alawiye).

ACKNOWLEDGEMENTS

All glory and adoration are due to Almighty Allah, the immaculate lord for the opportunity given to me and for preserving my soul in the course of this programme.

My profound gratitude to my able supervisors and mentor, Dr. K.O.K. Popoola and Dr. A.A. Sowunmi, for their understanding, hospitality, words of encouragement and their immeasurable contributions towards the successful completion of this work. May the mercy of Almighty God search for your wards wherever they may be and God bless.

My gratitudes to the former Head of Department of Zoology, University of Ibadan, Professor A. A. A. Ugwumba and the present Head of Department, Professor A. A. Bakare, all other academic staff such as Professor O. A. Ugwumba, Professor A. B. Odaibo, Professor A. O. Adeogun, Dr. H. Awobode, Dr. A. Ayoade, Dr. Olajumoke Morenikeji, Mr. Ibrahim Kolade and host of others for their constructive criticism, words of encouragement and immense contribution towards the success of this programme. May Almighty Allah continue to be with you all.

My fervent thank also to Mr. M. A. Tijani (Fisherman), Mr. O. Akinwale (Laboratory Scientist), Erelu reservoir, Mr. B. Shittu, Mr. Lamidi Abdullahi, all workers of Erelu reservoir for their words of encouragement. May Almighty Allah shower His blessings upon you all.

I am also grateful to Professor A. E. Ayodele of Botany Department, University of Ibadan for his immeasurable contribution in identification of higher plants collected from Erelu reservoir may you live to reap the fruit of your labour sir (Amen). My gratitude will not be complete without mentioning. Dr. T. O. Salawu, Mr. Ope, Mr. Adejumo, Aunt Biodun of Zoology Department for their contribution to the success of this programme.

The contribution of Mr. Alatise Akeem, Mr. A. Adetimirin of Survey school, Oyo will always be appreciated. Also to Abanik Computer who was always ready to welcome any complain in the course of typing this work, may Almighty Allah continue to be your guard and guide.

My sincere gratitudes to my uncles, sisters and brothers: Alhaji Moruf (Daddy Tunde), Alhaji Shittu Rafiu (Daddy Abu), Idris Ayinde, Rafiat Abolore, Mr. Omobonike Tajudeen, Sister Risikat Moromoke, Mr. Ayuba Wasiu, Mr. Rauf Alawiye (Alfa), Mr. Omolewu Alawiye (Baba Idiose) for their moral and spiritual support during the period of this programme.

My appreciation also to the Provost in person of Professor J. G. Adewale and all staff of Department of Science Laboratory Technology, Oyo State College of Agriculture and Technology, Igboora for their quantifiable contribution to the successful completion of this programme, may you live from glory to glory.

To all my friends and post graduate colleagues, Mrs. Oyebamiji Khadijat, Mrs. Abdul Rahmon (Goodall), Mrs. Akinwande Mariam, Mrs. Jim-Salam Suliah, Mrs Araromi Hadirat, Mrs. Uthman Fasilat, Mrs. Zakariyyau Misrafat, Mummy Roqeebat, Mrs Abdul-Azeez Kudirat, Mrs. Abdul-Azeez Monsurat, Mrs. Abdul-Azeez Khadijat, Mrs. Latifat Abdul-Azeez, Mrs Abdul Yekeen Latifat, Mrs. Busari, Sister Mutiyat Ajelabani, Mr Braimah Jafar, Mrs. Hassan, Sister Kehinde Sekinat (Kenny), for their spiritual and financial support. May God reward you abundantly.

To my fathers and brothers in the Lord, Alhaji Moruf Abdul-Azeez (Amir), Dr. (Engr.) D. O Araromi, Alhaji Uthman Taofeek, Dr. Mosobalaje Mutiu, Mr Amuzat Adekunle Isiak, Mrs Olawale Rofiat, Miss Suliyat Alaro, Mrs Daud Saidat, Mrs. And Dr. Rafiu, Mrs. Alli Aolat, Mrs. Alawode, Mrs Olore, Mrs Adepoju, Mrs Oyeleke, for their moral support and words of encouragement. May God Almighty grant all your requests.

Finally, my immeasurable thanks to my enduring and everloving husband, Alhaji. Dr. Amusat Mumini Adekunle and my children Ridwanullahi, Abdul-Awwal, Zeenat, and Aishat for their understanding, words of encouragement, painstaking, their spiritual and moral support throughout the streneous period. May Almighty Allah shower His blessing on you all.

CERTIFICATION

I certify that this work was carried out by Mrs. A. I. Amusat in the Department of Zoology, University of Ibadan

----

Supervisor
K.O.K. Popoola,
B.Sc., Ph.D (Ibadan)
Reader, Department of Zoology.
University of Ibadan, Nigeria

Co-Supervisor
Dr. A. A. Sowunmi
B.Sc., Ph.D (Ibadan)
Reader, Department of Zoology.
University of Ibadan, Nigeria

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

CHAPTER ONE

1.0 INTRODUCTION

1.1 Natural Aquatic System Status

Surveillance assessment of environmental quality parameters is a key activity in managing the environment, reestablishing contaminated ecosystem, and predicting the impacts of counterfeit changes on the environment. Fresh water is of crucial concern to human being, because it is connected to human health. Freshwater is generally described to have low concentration of dissolved salts and other aggregate solids. It is classified into lentic systems which are non-running waters (ponds, lakes, swamps & mires) and lotic systems or running waters which flow in rocks and acquifers (Jackson *et al*., 2001). These surface water bodies, that serve as the most crucial sources of water supply for human use are lamentably under serious ecological pressure today and are being threatened due to the outcome of developmental activities. These ecological pressures could be natural, artificial or chemical qualities. Their alterations and measurement in terms of values and concentration attributed to such parameters can be utilised to depict the prevailing condition of an environment and how it influences its biotic assemblage.

Freshwater systems are important components of landscapes, the organisms that make up foodwebs in freshwaters are diverse and important both ecologically and economically. Many aquatic species are well known, including a variety of important fish species, insects, but at the bottom of a water body are organisms that are members of benthic communities (Nedeau, 2006). Anthropogenic impact on the water environment is a cumulative manifestation of all kinds of human activity which causes obvious or hidden disturbances in the natural structure and function of water, biotic communities anomalies in their habitats, changes in the hydrology and geomorphology of water bodies leading to deterioration in their fisheries and recreational value and other negative impacts on ecology, economic or socio economic nature. The impact cummulatively accrues to structural and functional responses of the water ecosystems and biota (Debbie and Stanislav, 2012).

1.2 Aquatic Organisms of Benthic Region

Benthic organisms are animals or plant that lives at /on/in the substrates of a water body. They creep over, burrow into, or are connected to the sediments or other things at the base of water body. Benthos assumes vital roles in the estuarine food chains, giving a source of nourishment to fishes, feathered creatures and mammals. Without benthic living beings, these bigger creatures may be unable to survive (Davide and Margo Sigovini, 2010). Benthic fauna are generally grouped based on their sizes: Microbenthos under (0.063mm), Meiobenthos extends between (0.063-1.0 or 0.5) mm, Macrobenthos more than (1.0 or 0.5) mm and once in a while Megabenthos are larger than 10.0mm (Castelli *et al*., 2004). Popular groups of benthic creatures are helminthes like Polychaetes and Oligochaetes, Molluscs like mussels and univalves, Crustaceans, for instance, amphipods and decapods. Benthos may be distinguished in term of location they fill above or within the sediment.

In-fauna animals are those that live inside the sediments, majority of worms and mussels are found in this group, and epi-fauna organisms are those that are found above the sediment, larger parts of crabs and gastropods are regarded as epi-fauna (Davide and Margo Sigovini, 2010). Among epi-fauna creatures are those that attached themselves to hard surfaces, for example, blocks and rocks of banks of the water body, additionally included are epiphytic invertebrates, i.e. living beings that are found attached to the surface of submerged hydrophytes, such as numerous amphipods.

1.2.1 Role of Benthic Organisms

Benthos assumes a critical part in transitional ecosystem by filtering phytoplanktons and then serves as a source of food for bigger organisms like fish, thereby connecting food cycle with higher tropic level (Fagade, 1970; Davide and Margo Sigovini, 2010). In addition, they structure and aerate the bottom by rebuilding sediment and assume a major part in disintegrating organic material into simpler inorganic forms like phosphate and nitrate before remineralization. The supplement can be utilized by wide range of plants in aquatic medium which are the main connection of numerous channel of food occuring in aquatic ecosystem. Benthos play imperative roles in the ecology of aquatic ecosystem, their abundance and distribution can be affected by water quality (Idowu and Ugwumba, 2005). Moreover, various benthic invertebrates especially molluscs, are consumed by human and others, for example, worms are utilized for recreational purposes and as fishing trap (Ajao and Fagade, 2002; Davide and Margo Sigovini, 2010).

1.2.2. Benthic organisms as index of pollution

Benthos communities are frequently utilized as biological indicators since they can give data on ecological situation , either because of the responsiveness of just one species (indicator species) or due to some broad qualities that influence them to incorporate ecological signals over an extensive period of time (Juarez *et al*., 2003). These highlights include: contact with chemical pollutants often accumulated within the sediment, exposure to reduced DO concentrations (Hypoxia/Anoxia) which frequently takes place very close to the base surface because of decomposition of organic matter, restricted movement that limits their capability to shun unfavourable circumstances, taxonomic and functional variability which enable them to be appropriate or fit for identification of various kinds and stages of pressure (Juarez *et al*., 2003).

1.2.3 Aquatic insects as index of Pollution

Biologically, insects in no uncertainty form the most successful group in the animal kingdom. They belong to the class insecta under the phylum Arthropoda. Insects are extremely different in the various territories; terrestrial and aquatic. Over years, it is evaluated that excess of one million species have been described both on land and in water (Pennak, 1978). In terrestrial habitats (land), insects are highly specialized and well adapted. Consequently, they have possessed the capacity to effectively colonize every habitable region. Nevertheless, as a group, they have not been able to successfully colonize the aquatic environments (water bodies) but majority of them have aquatic stages (Merritt and Cummins, 1996). The Hemiptera (bugs) for instance is the only order of insect containing total aquatic forms, many species of this group occur beneath water surfaces both in their nymphal and adult stage, others move about on the surface of water film (Rosenberg and Resh, 1993). The adult stage of the Mayfly (Ephemeroptera), Odonata (Dragonflies and Damselflies) and Plecopterans (Stoneflies) are terrestrial, but their nymphs (naiads) are aquatic, possessing accessory gills for respiration in water. Mandeville (2002) characterizes aquatic insects as small-stream inhabiting living beings which are adequately big to be seen without aided eye and spend complete or portion of their life stage within or beneath aquatic ecosystem. A few of them live close to water and are called semi-aquatic insects.

Moreover, the vast majority of aquatic insects occur in freshwaters, only a few species have invaded the marine and brackish environment. They have become adapted to all types of freshwater habitats from the smallest brooks to sluggish rivers; from puddles to the biggest lakes and reservoirs. With few exceptions, aquatic insects are found near shores attached to hydrophytes (aquatic plants), in the shallows, and where there is adequate supply of oxygen. Some have become adapted to live in oxygen depleted areas, for example, Dipteran family; *Chironomus* larvae, *Chaoborus* larvae e.t.c. because they possess haemoglobin which transport dissolved oxygen within their systems. Aquatic insects are of greater significance in the aquatic environment where they are available, huge numbers of them serves as means of sustenance to fishes and other invertebrates. A few serves as vectors that transmits different pathogens to both humans and other creatures e.g. the blackflies (*Simulium larvae*) that transmit the parasites which cause river blindness, mosquito larvae which transmit the parasite that causes malaria (Foil, 1998; Chae *et al*., 2000).

In particular, insects of aquatic environment are identified to be great indicators of water quality, because they possess varied levels of enduring contamination. A couple of them are exceptionally unguarded and easily aware of contamination, while others can flourish well and reproduce in contaminated and unhealthy waters (Merritt and Cummins, 1996). As a consequence of human (anthropogenic) activities like discharge of untreated animal wastes, domestic wastes, sewage discharge, run-off from agricultural lands, laundering, wastes from livestock and fish farms, effluent discharge from industries, e.t.c. The health status of most rivers in less developed nations like Nigeria keep expanding contamination load, subsequently deteriorating the quality of such rivers (Merritt and Cummins, 1996).

1.3. Statement of the Problem

Erelu reservoir is one of the South-western water bodies that supplies drinkable water for domestic purposes, agriculture and fishing activities in Oyo and its environs. However, the reservoir receives run-off from nearby agricultural fields, effluents from cassava processing industries, automobile workshops, discharged spent oil in the cause of washing motor cars and bicycles and lot of others. Meanwhile, the water body needs attention so as to determine its status in term of pollution load, physical and chemical parameters and macro-invertebrates assemblage. To give a complete assessment of water health status, most ecologist have used biological indicators in relation with the chemical and physical parameters of water, so as to give both the present and past conditions in response to changes that have or may have occurred as a result of introduction of effluents or organic pollutants into the water body.

The composition of insects from any given point in a river reflects the average water quality at that particular point. It is this fact that makes the insect assessment procedure a valuable tool in water quality assessment. Benthic macro-invertebrates also play an imperative part as biological indicators of water quality deterioration that tells the actual condition of the the water body at a particular point in time. However, there was no information on the use of indicator species in relation to physical and chemical parameters of Erelu reservoir from the past researchers on the water body.

1.4. Justification for the Study

Several studies have implicated the occurrence of some benthic organisms and aquatic insects as indicators of water pollution. Changes in level of physical and chemical properties that deviated from critical values which indicated the level of perturbation to the water bodies have also been documented by different researchers. Most of these studies from literature search were carried out both within and outside Nigeria. However, some of the studies done in Nigeria are limited and have not covered certain areas such as Erelu reservoir in Oyo. Nevertheless, studies done on Erelu reservoir in Oyo are limited. Some of the few works done on Erelu includes: Akintola and Adeniyi (1997) who investigated land use changes and water quality in impounded water supply dams in Southwest, Nigeria, Iroko (2003) worked on the effects of Erelu water dam on livelihood activities of settlers in Atiba local Government Area of Oyo State. Ayoola and Ajani (2009) investigated seasonal variations in the distribution of fish and physico-chemical parameters of selected reservoirs in Oyo State and Kaeem *et al.,* 2018 on spatial and temporal limnological status of Erelu reservoir.

Consequently, there is dearth of information on the ecological characteristics of Erelu reservoir especially with respect to the assemblage and dynamics of macro-invertebrate communities of the reservoir. In other to fill this gap, this research work was designed to find out current informations on the population and distribution of macro-invertebrate fauna and physico-chemical parameters of Erelu reservoir in Oyo for efficient and sustainable management of the water bodies.

1.5 Aim of the Study

The goal of this research is to determine the status of various macro-invertebrates, their assemblage and physico-chemical properties of the reservoir for the assessment of the water body qualities.

1.6 Objectives of the Study

The objectives of this research are to determine the:

- Physical and chemical properties of water in the reservoir.
- Composition, abundance and variation of macro-invertebrates of the reservoir.
- Bio-indicator species among the benthic and aquatic insects of the reservoir.
- Relationship between physico-chemical parameters and distribution of macro-invertebrates collected from the reservoir.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Benthic Macro-invertebrates Surveillance

Biological surveillance is an exploitation of biological responses to evaluate changes in the ecosystem, usually, changes that originated from human activities. Surveillance assessment of water bodies is a profitable appraisal instrument that receives expanded used in stream quality assessment programme of all kinds. There are two kinds of surveillance. First one is; surveillance before and after a project is completed while another one is; surveillance before and after a harmful substance is released into the water bodies. Biosurveillance additionally includes the utilization of indicator species or indicator communities to determine aquatic condition at a specific period of time (Batiuk *et al*., 1992). Usually, macro-benthic invertebrates, fish and algae are used as indicators, a few reliable hydrophytes had been employed as index of pollution for contaminants containing nutrient enhancement (Phllips and Rainbow, 1993). Macro-invertebrates are regularly utilized for monitoring stress in aquatic environment (Rosenberg and Resh, 1993). Biochemical, hereditary materials, structural, functional and physical changes in specific life forms have been inspected as being identified with specific ecological contaminants and can be used as indicators.

The existence and non-existence of the index or biomarker species or indicator community reflects environmental conditions. Non occurence of an organism is as noteworthy as it may not be appeared, there might be causes other than contamination, that subsequently prompts its non-appearance (e.g. predation, rivalry or geographic boundaries that kept it from not being present at the location) (Johnson *et al*., 1993). Absence of multiple species of different orders with similar tolerance levels that were present previously at the same site is more indicative of pollution than absence of a single species. It is clearly necessary to know which species should be found at the site or in the system (Phillips and Rainbow, 1993).

2.2. Sentinel Organisms

Sentinel organisms, or pollution index species that accumulate pollutants in their bodies from their closest environment or from nourishment, are vital bioassessment tools. The mussel, gastropods are creatures that are used for such sentinel species (Phillips and Rainbow, 1993; Kennish, 1992). Filter feeders, for example, bivalves (Clams and Mussels), tend to bioaccumulate metals in their body or other tissues. The far reaching blue mussel (*Mytilus edulis)* aggregates metals in specific tissues after some time. Consequently, *M. edulis* became an animal variety observed in U.S. waters and in addition universally for changes in levels of contamination. Seaweeds, (e.g. *Fuccus spp.*) aggregate metals. Grown-up algal tissue can be contrasted to fresh tissue in the similar creature to ascertain the record of pollutants in the region (Phillips and Rainbow, 1993). Metals and organochlorines build up in finfish and territorial species or non-mobile species for example, pike, largemouth bass, may possibly be utilized for perfect implication of mercury and organochlorines contamination in the aquatic ecosystem (Kennish, 1992).

Tables 1&2 shows the different organisms and metals absorbed

Table 2.1: **Extreme Uptake of Metals by Benthic Organism**

Organisms	**Heavy metals absorbed**
Barnacles	Zinc (Zn)
Bivalves	Copper, Iron, Manganese
Gastropods mollusks	Copper, Zinc
Isopods, Amphipods	Copper, Iron, Lead
Polychaetes	Copper

Table 2.2: **Moderate Uptake of Heavy metals by Benthic Organisms**

Organisms	**Heavy metals absorbed**
Macro algae (sea weeds)	Many metals
Mussels/other bivalves	Metalothioneins
Polychaetes	Cadmium, lead
Decapods (Crayfish)	Cadmium, lead
Finfish	Cadmium, lead

(Adapted from Philips and Rainbow, 1992)

2.3 Advantages of Benthic Macro-invertebrates commonly used for Biomonitoring

Benthic macro-invertebrates are found in most aquatic habitat. There are a large number of species and different stresses produce different macro-invertebrate communities, along these lines they are Macro-invertebrates generally have limited mobility, thus they are indicators of localized environmental conditions. They have long life cycle. Since benthic macro-invertebrates hold (bioaccumulate) harmful substances, compound investigation can reveal the poison in the benthos, wherever concentrations are undiscovered in the water source. Benthic macro-invertebrates are sufficiently small enough to be eily easily collectible and identified. They are primary food source for recreationally and economically important fishes. Any impact on macro-invertebrates influence the nourishment and assigned purpose of water supply (Reese*, et al*., 1991; Gamier and Billen, 1994).

Numerous benthic organisms are predators that manipulate the numerical abundance, regions and sizes of organisms they feed on. A number of benthic invertebrates species (e.g. *Tubifex tubifex*) acts as parasite conveying vectors, if these invertebrates multiply in large quantity in the river sediment, they can increase a deadly illness to trout, causing trout population to diminish (Brinkhurst, 1997). Fish kill could as well happen due to nutrients increment, that cause growth of poisonous algal blooms, hypoxia condition of deeper density-stratified waters and high concentration of ammonia or hydrogen sulphide (Covich, 1993).

2.3.1 Disadvantages of Benthic organisms commonly used for Biomonitoring

Benthic macro-invertebrates do not react to every influence. Seasonal variation may prevent comparisons of sample taken in different seasons. Water movement could transport benthic macro-invertebrate into aquatic environment where they might not naturally exist. A few species are very hard to identify to the species level. The occurrence or non occurrence of any organism might be caused by other determinants such as substrates type, drought, unsuitable water movement asides from contamination. Their wide spread and abundance may differ seasonally due to water characteristics. Inspite of all the limitations, the merit of employing benthic macro-invertebrates for evaluating water property exceeded its weakness. Nevertheless, an accurately planned bioassessment investigation can bring out good image of water quality of any stream (Reese *et al*., 1991).

2.4 Benthic Fauna as Water Quality Indicator

Benthic fauna are viewed as imperative marker of water quality and are utilized as a part in varieties of ways to survey and screen general soundness of aquatic environment. They are utilized to follow a long term monitoring program relating to effects of human activities (Boesch *et al*., 1997). Long term series are appropriate so as to discover changes identified with climatic disparity (Cabioch, 1991). Among the principle determinants accountable for number and compositional alternation of benthos are warmth (Beukemia, 1984), hydrodynamic and supplement imputs (Beukemia, 1991). The combined chemical and biological methods constitute the most astounding biochemical surveillance investigations for demonstrating water quality. Their reactions to organic or inorganic contaminants have been utilized to create biotic indices. For appropriate utilization of ecological parameters, the community make-up of the local faunal in an area should be properly known. After this, the biotic indices might be changed and then employ individuals of local fauna and afterward the suitability of regional index could be sustained (Halse *et al*., 2002).

Variation in species composition is the most frequently used parameters in biology to evaluate how fit an ecosystem is (Mason, 1992; Horsfall and Spiff, 2001; Ogbeibu, 2005). This is because of its capability to quantify fluctuation among the species of a community and in addition accesibility of various ecological habitats for different individuals or species to occupy within an ecosystem. An extensive number of studies have been done on macro-invertebrate fauna of fresh water ecosystem in Tropical Africa. Gallep *et al*. (1978), Idowu and Ugwumba (2005) were of the opinion that benthic macro-invertebrates stimulate the degradation of decomposing organic matter into less complex inorganic forms, for example, Nitrates and Phosphates which can be used by all types of aquatic plants forming the main connection in the food chain. Benthic organisms commonly found in streams include *Pachymelania aurita*, *Neritina glabrata, Helisoma trivolvis, Melanoides tuberculata, Bulinus globosus, Physa waterlotii, Americana cariana and Indoplanorbis exustus*, Bivalvia, Polychaetes, Oligochaetes (Chukwu and Nwankwo, 2003; Atobatele *et al.,* 2005).

Tolerant benthic macro-invertebrates include: *Chironomids, Tubifex, Physa sp. Bulinus sp*. *Indoplanorbis* sp. among others. Chindah *et al*. (1999) reported five taxonomic group in Port-Harcourt, where their distribution and abundance were been greatly affected by municipal waste. In Awba stream and reservoir, few hardy and tolerant macro-invertebrate such as *Tubifex* and *Chironomus* species were found at the site of sewage effluent discharged into the stream, with an overall low density index (Tyokumbur *et al*., 2002). The impact of land-based pollution on the macrobenthic community of Porto Norvo creek, Lagos was investigated by Chukwu and Nwankwo (2003) and it was observed that low quantity and composition of macro benthic fauna were recorded and the prevalent classified orders were annelids. This was ascribed to the pressure inflicted by liquid wastes leakage from land based source and also substrate unsteadiness.

Frances and Emeka (2006) observed that the effect of mill wood waste on the distribution of benthic macro-invertebrates at Sapele section of Benin River and reported the complete absence of sensitive/non-tolerant species like Ephemeroptera and Plecoptera at the impacted site. Similar results were reported in Barnawa stream in Kaduna where Emere and Nasiru (2007) recorded a total number of 1,304 macro-invertebrates belonging to twenty seven taxa. The low density of pollutants intolerant macro-invertebrates group, degenerating water health status and the physical and chemical condition of the water was an indication of organic contamination that was caused by decomposition of household waste and inorganic fertilizers flushed down the water environment.

Similar result was observed by Ogbeibu and Oribhabor (2002) in Ikpoba River, Benin city where the tolerant species (Chironomids, Dipteran and Oligochaeta) dominate the reservoir and the downstream. Correlated reports were observed by Ndaruga *et al*. (2004), Ikomi *et al*. (2005), Doisy and Rabeni (2001). Emere and Nasiru (2007) reported existence of diverse unpolluted water indicators of insect orders which includes; Odonata, Plecoptera, Trichoptera and Ephemeroptera as well as Gastropoda and that each are represented by several species and demonstrated a generally peaceful environmental condition in the study area. Highest number of macro- invertebrates abundance were recorded in the dry season compared to rainy season in new Calabar and the middle reaches of Imo-Rivers respectively (Zabbey, 2006).

Odiete (1999) opined that a good number of commonly known ecological procedures in the evaluation of freshwater bodies receiving residential and industrial waste waters is the utilization of macro-benthic invertebrates. *Tubifex species, Chironomus species, Brachydeutera species, Melanoides tuberculata, Physa waterlotii* and *Bulinus globosus* were the only macro-invertebrate found in all the stations of Ogunpa River in Ibadan (Atobatele *et al*., 2005). Similar results were recorded in one of the Southern Nigeria Reservoirs in Ibadan by Idowu and Ugwumba (2005). Adebayo (2009) recorded two categories of macro-invertebrates, the fairly tolerant group (*M. tuberculata*, *Lanistes sp*., *B.pfeifferi* and Dragonfly nymph) and the tolerant group (*Chironomus larvae, Physa sp., I. exustus* and *Tubifex sp*.) He also reported highest abundance of *Chironomids* in Awba dam while highest *M. tuberculata* was reported for Eleyele reservoir. Tyokumbur *et al*. (2002) observed the same result along Awba stream where he reported *Tubifex* and *Chironomus sp*ecies to be the only tolerant species. Perfect *et al*. (1999) reported that worms were the frequently very abundant organisms in heavily polluted waters as a result of the tubifex ability to respire under a very low oxygen tensions.

2.5 Aquatic Insects Biomonitoring

Biomonitoring studies using aquatic insects can help identify trends in water quality by indicating changes within the structure of the aquatic community. Aquatic insects are found inhabiting almost all water bodies; hence, they are diverse and well represented in most healthy water bodies. They are non-resistant and react to the two effects, such as normal and human- initiated impacts in the ecosysem (Ndaruga *et al*., 2004).

Insects of water environment are in the midst of the most directly influenced and defenceless life forms concerning surface water contamination, their immature stages have short life cycles, often with several generations in a year and they are less mobile (Verneaux *et al*., 2003). Thus when environmental changes occur, they endure the disturbance, adapt, or die and are replaced by species that are well modified to the new natural conditions. Hence, they constitute an important component for assessing water quality.

Aquatic insects have been reported to be able to give early warning of possible harm to water bodies as they spend their lives or part of their life span within the water system (Ogbogu and Akinya, 2001, Arimoro *et al*., 2007a). Important features of aquatic insects that make them suitable for assessing water conditions are as follows:

- Existing in all aquatic environments.
- Demonstrate diversity and are non-resistant to contamination, showing different pressure levels to different toxins.
- Display a broad scope of reactions to contamination.
- The developing stage (larvae and nymphs) are less mobile than numerous other groups of living beings (i.e fish).
- Are often of easily collectible size.
- They are very modest to investigate and obtained.
- Many live in water for a brief period while others live in water for nearly their entire life.
- Few are sensitive (intolerant) to contamination, habitat alterations, and extreme natural events, while others are more resistant (Rosenberg and Resh, 1993; Mitchell and William, 1996).

Despite the fact that, the importance of aquatic insects in demonstrating the quality, wellbeing status and ecological integrity of water-bodies have been disregarded before (Karr, 1991), particularly when contrasted with customarily well-known ecological indicators, for example, Mollusk, Fish and birds (Baunernfeind and Moog, 2000). Recent studies are tending towards their utilization in ecological integrity and water quality evaluation as reported by Merritt and Cummins (1996), Arimoro *et al*. (2007) and Arimoro and Ikomi (2008).

Most notable among the use of insect species as a pollution index of water quality is the EPT Index (The order Ephemeroptera, Plecoptera, and Tricoptera collectively form the (EPT) index). This index focused on the assumed high quality streams usually have a very good species abundance and the species composition is mostly dominated by intolerant species (organisms that cannot thrive in polluted waters) (Lenat *et al*., 1988; Karr (1996). The abundance of Chironomid larva is also used in assessing the quality of water (Rosenberg and Resh, 1993). From various studies carried out in Nigeria, (Obgeibu, 2001). It was observed that EPT index, increases with improving water quality. When evaluating quality of water of a stream (water body), the species of insects, encountered during sampling, are evaluated in terms of responsiveness to different types of stress. Insects that can tolerate and adapt with changes in water conditions are called 'Tolerant species' and they include bugs, Midges or flies which belong to the class Diptera. These groups of insects exhibit a range of responses to virtually any type of pollution. On the other hand, 'sensitive species' like the caddis fly larvae, stonefly larvae, and may fly larvae cannot withstand polluted waters.

Generally, aquatic insects are known to be good ''indicator species'' for evaluating water health status and ecological integrity of streams. Indicator species in this context refers to species (or species assemblage) that have specific prerequisites regarding to a familiar set of physical or chemical variable, such that alterations in existence, absence, numbers, organisms make-up, life functioning, or behaviour of that species show that the current physical or chemical parameters are not favourable (Rosenberg and Resh, 1993). Aquatic insects have proven to be quite valuable, particularly in the area of building past temperature in water bodies (Barttabee, 2000), identifying stressors like heavy metal pollution, organic contamination from sewage outflow, estimating concentrations of trace metals present in water that are in low amounts which may not be detected in water sample analysis. Barr (1996) for instance, used aquatic insect as biomonitors of heavy metal pollution. In his investigations, Mayflies and stoneflies were used to test the concentration of copper, lead, mercury and zinc in water and the outcome indicated that insects do accumulate metals in their tissues from water where they inhabit. Timothy *et al*. (2004) also used insects (*Gerris sp*) as indicator of mercury pollution in water bodies. In this study, they reported that *Gerris sp.* (water striders) had an abnormal level of mercury accumulation.

Not only aquatic insects have been used for pollution analysis based upon their abilities to accumulate metals, but the presence and absence of different genera have also been used to indicate water quality. Studies like that of, Epler (2001), identified chironomidae (Diptera) as the most abundant aquatic insect group, both regarding number of species and number of individual dipteran in freshwater habitats indicating high levels of organic pertubation. Members of the genera *Chironomus* were well represented along the stations that were organically enriched. He also noted changes in the species composition along the newly impounded stream areas, as sensitive species like Ephemeropterans dominates the areas with high velocity, dissolved oxygen and transparency.

Resh and Kobzina also made a database search from 1993 to 1998 at a streamin Berkeley, Califonia; where the result showed high abundance of pollution tolerant organisms like Chironomidae, Culicidae indicating organic perturbation in the stream. Therefore, they inferred that insect studies were most valuable in water quality evaluation practices (cited in Mandeville, 2002). Merritt and Cummins (1996), among others have described the advantages and disadvantages of using insects as bioindicators of environmental stressors and they concluded that undisturbed aquatic systems generally have a high diversity of species, dominated by the most sensitive organisms. Meanwhile, existence of numerous families of exceptionally tolerant life forms more often than not shows poor water quality.Also, a recent study carried out by Arimoro and Osakwe (2006), in Orogodo stream, Delta State on an impacted abattoir effluent on water quality, showed how organic effluent from cassava influenced the distribution and abundance of Diptera. They also noted that richness and community composition of dipteran patterns, particularly Chironomidae, Culicidae and syrphidae families are (all indicators of bad water quality) which indicated solid confirmation of natural contamination.

Ogbeibu *et al*. (2002) also recorded high diversity and abundance of diptera (*Chironomus larvae)*, Odonata nymphs in Ikpoba River in Benin, indicating some level of organic pollution. Emere and Nasiru (2007) also recorded high diversity on the invertebrate fauna in Barnawa stream in Kaduna, totality of 1,304 macro-invertebrates belonging to twenty seven general was reported, with high abundance in the family Chironomidae and Chaoboridae, demonstrated the worsening condition of the quality of water. Furthermore, the physical and chemical state of the water was an indication of organic pollution pressure caused by decaying of residential waste, garbage and inorganic compost flushed into the Barnawa stream. Tyokumbur *et al*. (2002) investigated the water quality of Awba reservoir, in their findings, abundance of Chironomids larvae, Baetid nymphs and naiads, Oligochaetes were indicative of organic perturbation.

Moreover, Ndaruga *et al*. (2004) in their studies, recorded high abundance of chironomid or midge larvae and tubificid worms. They attributed the abundance of *Chironomus larvae* to their ability to respire at very low oxygen tensions. Ogbogu and Akinya (2001) also observed the distribution pattern of aquatic insects in connection to the water quality status of the Opa stream and reservoir systems in Ile-Ife and came across high species richness of the pollution tolerant organisms which reflected a high level of organic perturbation.

Ogbogu and Olajide (2002) observed similar result in their study in Opa stream and reservoir. The total number of taxa recorded was low with pollution tolerant species dominating, therefore indicating stressed ecosystem. High abundance *Chironomus* species and Odonate nymph was attributed to environmental stress. In an investigation carried out by Victor and Onomivbori (1996), Collembolla, Ephemeroptera, Hemiptera, Coleopteran, Hydrachnellae and Hirudina were recorded just in one station. Their abundance in the other stations reflect their non-tolerant abilities to organic and inert pollution. Ogbeibu (2001) also posits that the biological prerequisite of individual taxa of aquatic insects seems to control their spatial distribution and abundance. Chironomidae more often than not demonstrate no environmental limitations (Ogbeibu and Victor, 1989) and are identified to substitute other invertebrate orders in water bodies disturbed by agrarian and residential wastes (Ogbeibu and Victor, 1985). The frequency of the two chironomid taxa, chironomus and polypedilum, are managed by their ecological prequisites for example, great organic matter, sufficient organic debris, wide oxygen resilience and sloppy substratum (Ogbeibu, 2001).

2.6 Adaptation for Aquatic Habitats

Majority of the insects that land on water are trapped by the water surface pressure, and smaller ones can even perish in a smalldrop of water with inability to break out of the air pocket surface. Aquatic insects adjust by having water sealed skin and so a considerable amount of fresh water do not spread over in their bodies. Majority of them are secured with a water repellent waxy layer. Likewise, they have furry or waxy leg, which repulses water so they do not get caught by the water surface pressure. Many of these insects are strong swimmers or crawlers as nymphs or larvae and as adults can also fly, although the degree to which they use their ability to fly quite a bit. Water boatmen are the only aquatic beetles than can take off from the water without having to crawl out of the water (Mitchell and William, 1996).

2.7 Macro-invertebrates Characteristics

The different classes of macro-invertebrates and their diverse features are:

2.7.1 Aquatic Earthworms

Aquatic earthworms are nearly alike with terrestrial earthworms. They possess lung, mild muscular, cylindrical body composed of circle-like segments. Many aquatic earthworms have length ranges from 1-30 mm long, not withstanding a few may be as long as 150 mm. The anterior end of the worm has no sucker or eyespot. Aquatic worms are hermaphroditic or can recreate sexually or asexually. Since these worms undergo no metamorphosis as they are maturing, juveniles can only be differentiated from adult by their smaller relative size (Brusca and Brusca, 2003). They are generally collector or gatherers that burrow through the upper layer of soft, fine sediments feeding on bacteria, protozoa, algae and dead organic matters. Other live in vertical mud tubes in the sediments with their hind end protruding to absorb oxygen. They can retain oxygen over their entire surface area. Numerous can upgrade their oxygen utilization by engrossing oxygen via the digestive tract. Some worms have even more specialized adaptation to cope with low oxygen, such as gills or haemoglobin in their blood that helps transport oxygen and turns them bright red. This is because aquatic earthworms can in low oxygen condition and eat detritus, they can be found in virtually all aquatic habitat (Voshell *et al*., 2002; Brusca and Brusca, 2003).

Aquatic worms have crucial impacts on the bottom sediment where they live. Their feeding behaviour mixes the sediment, keeping it aerated and providing oxygen for other organisms. They are naturally part of many healthy ecosystems and tend to control habitat such as deep or lentic waters that are naturally low in oxygen. Their high resilience for low oxygen implies that they have ability to survive in the anoxic situations cause by an extreme nutrient contamination, such as a sewage discharge that eradicated other invertebrates. An aquatic invertebrate community dominated by large red worms in an area that is not naturally oxygen-deprived is often an indication of organic pollution (Voshell *et al*., 2002).

2.7.2 Gastropods

The gastropods are an extensive group of molluscs which are frequently identified as snails and slugs. The reminant body history of this group could be traced back to the late Cambrian. In attendance are 622 groups of univalves, of which 202 ancestors are dead and are discovered just in the relic records (Bouchet *et al*., 2005). Gastropoda (formerly called Univalves and residue degraded creatures) are a noteworthy piece of the phylum comprising living snail and slug species. Anatomical structure, behaviour, mourishy and regenerative adjustments of gastropods change noteceably from one clade or group to another. Nevertheless, it is cumbersome to highlight considerable number of generic names for all gastropods (Robin, 2008). They have varying habitats. Members are found in yards or farms, woodlands, arids, and on hills; in abandoned places,big creeks and streams, in brackish, sub-tidal, and many other biological habitats, including non free-living (Chapman, 2009).

Gastropods belong to the class molluscs with the greatest numbers. Meanwhile, gastropod species in collection fluctuates generally, based on their location. The numerical abundance of species of gastropod could be infered from total number of the portrayed species of Mollusca with accepted names which is around 85,000. Minimum could be 50,000, while most extreme can be 120,000). In any case, the aggregate quantity of Mollusca, comprising unreported individuals is around 200,000 species. However, the aggregate number of molluscs included 24,000 depicted types of land gastropods (Poppe and Tagaro, 2006; Chapman, 2009). In every cases of classification, univalves are immediately next to the insects as far as their variety is concerned. Numerical aggregate of new species of freshwater molluscs is about 4,000 (McArthur and Harasewych, 2003; Strong *et al*., 2008). Diverse estimation (from variety of basis) for gastropods of water body, present around 30,000 species of salt water univalves and around 5,000 of freshwater species and estuarine molluscs (Geyer, 2010).

Gastropods have both sexes in the same body (hermaphroditic) in nature. The main organ of discharge in univalves is nephridia which releases either ammonia or uric acid as an excretory product. Nephridium as well assumes an imperative part in keeping up osmoregulation in freshwaters and land dwelling gastropods. Extra organs of discharge in a few species incorporate pericardial organs opening into the stomach. Univalves possess open circulatory systems and their conveying fluid is hemolymph. Hemocyanin is available in the hemolymph as the respiratory pigment (Poppe and Tagaro, 2006; Robin, 2008). Gastropods, particularly freshwater species and more than half of land dwelling species have a pallial lung for breathing. They process their food with the guide of radula which is modified based on the nourishment which a species consumes. The least univalves are the Limpets and abalones, herbivores that use their hand or radula to rasp at seaweeds on rocks (Ponder and Linberg, 1997; Brusca and Brusca, 2003).

2.7.3 Platyhelminthes

Platyhelminthes are delicate worm-like creatures with gentle and non segmental bodies. They are known to possess two-sided symmetry, absence of body cavity, respiratory and circulatory organs. Present of well developed flame cells to exhibit the excretory function. Platyhelminthes are known as ‘flat-worms’, belong to a phylum of three germ layers and invertebrate creatures without coelom. They are very soft without body division, flattened towards back or side and resemble ribbons. Their flattened shape enables them to absorb oxygen and nutrients by diffusion through their body flexible coverings. Some of their species feed on flesh, while the rest are not free-living. Almost, all of them are aquatic, mostly found in salty environment and few are freshwaters while some are land dwellers.

They consist of 34,000 known species which are classified under three main classes. Turbellaria, Trematoda and Cestoda with sub-classes. Class Turbellaria; which comprises flatworms that have organs of locomotion (Cilia) and non-parasitic while individuals of sub-class Monognea are ecto-parasites (live outside the host body) and comprises of monogenetic flukes. Class Trematoda are outstanding flukes and the third class Cestoda contains endo-parasites (live inside the body of the host), which is known as tapeworm (Priya, 2011).

They do not possess organs of circulation and respiration, that is the reason for their even or smooth bodies. The smooth body form enables the movement of air and nourishments to circulate throughout the body by simple diffusion process. CO_2 moves out of the body by the similar diffusion process. The alimentary canal of these animals is divided continously in order to ease adequate diffusion of nutrient to all parts of the body. Digestive system is not complete, containing only one opening serving two purposes as the (buccal cavity and anus). Possesion of a solitary layer of endodermal cells line the alimentary canal or intestine whose function is to engulf and digest the food materials. A few species also secretes the catalysts in the alimentary canal or pharynx to mollify and disintegrate the food into pieces. Non-digested food material is vomitted via the mouth as anus is not presentexcepts in the large species that have an anal opening and few with exceptionally continuosly divided alimentary canal having more than one anus. This is because, removing waste product from the mouth alone would prove uneasy for them (Brusca and Brusca, 2003; Priya, 2011).

Waste removing organ of these animals is well developed and is called protonephridia. They osmoregulate the water and ion levels in the body by enabling their body tissues to have similar concentration level as that of the environment with the help of protonephridia network. They reproduce sexually and asexually and their nervous system comprises of pair of anterior ganglia called brain (Priya, 2011).

2.7.4. Arthropods

Arthropods are everywhere present organisms of freshwater streams. They have paired and jointed outgrowth, chitinous exoskeleton, pair of antennae and mouth externally located. This includes the Crustaceans and insects of aquatic environment as sub-group within the phylum. The class insecta incorporates aquatic insects that can metamorphosise into three or four phases in an aquatic environment. The intermediate stages in many cases in insects bear no similarity with their adult (Pennak, 1989). Many of the benthic macro-invertebrates have many stage life cycles which take place within a year in some species, whereas it take several years to complete the life cycles in others. In some aquatic insects of incomplete metamorphosis, the three common stages of their life-cycle include the egg, nymph and adult (e.g. Mayflies, stoneflies). However, nymph is replaced with larva and pupa in those insects exhibiting four stages of life-cycle (e.g. Caddisflies, Beetles, Chironomids).

2.7.5. Why are Insects so Successful both on Lands and in Aquatic Environment?

The many features contributing to their widespread are:

- They have smaller sizes that make them occupy larger spaces on earth. e.g. insects can leave solely in a specific plant.
- Short life cycle.
- Wide reproduction ability that gives them substantial quantities of offsprings which support a large difference in their life cycle of various stages in an insect (e.g. caterpillar against butterfly) lowers competition for limited resources among the species.
- Possession of appendages for flying is somewhat uncommon in other organisms and has allowed them to colonize freely.
- Highly developed sensory organs of insects have made them to overstep most other organisms.
- Their evolutionary relationship with other organisms brings about variability in species and leads to specialization.

- Highly adapted appendages like mouthparts, wings and legs,mostly become highly specialized (Adapted from Joydeb *et al*., 2013).

2.7.6 Economic Importances of Aquatic Macro-invertebrates

Aquatic macro-invertebrates may be of merit or regarded as harmful. Mostly, many of them are helpful or have an indirect impact. Less than 0.1% of aquatic insects are called vermin.

2.7.6.1 Beneficial Roles

They decompose large pieces of detritus from terrestrial vegetations near them (shredders), Scraping excess algae from the rocks and other solid substrates (scrapers), sifting particles from suspension in the water (collector-filter), blending the bottom sediments (burrowers). They as well purify water body e.g. Mussel and Clams. They are source of nourishment to aquatic birds, fish and other animals that are of immense relevant to man. Some macro-invertebrates are plant pollinators e.g. bees, beetles e.t.c (Reese and Voshell, 2009; Abowei and Ukoroje, 2012).

2.7.6.2 Detrimental Effects

Some are diseases vectors, some keep the population numbers of other invertebrates under control (predators). They are as well as parasites, and recycler of dead matter. Some benthic serves as intermediate host for some disease like *Fasciola hepatica*, Schistosomiasis e.t.c. e.g. *Lymnae natalensis*, *Melanoides tuberculata* e.t.c (Abowei and Ukoroje 2012; Joydeb *et al*., 2013).

2.8 Physical and Chemical Parameters of Water in relation to Species Distribution and Abundance

Physico-chemical parameters of water like Hydrogen ion Concentration (pH), Temperature, Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), Total Alkalinity (TA), water depth, Current velocity, Transparency, Total Dissolved Solid (TDS), Turbidity, Total hardness, Nitrates, Phosphates, e.t.c. assume imperative parts in the wide spread and community composition of aquatic life forms. These parameter measures the present status of the water body and also help determine what type of life forms the water body will supports. The utilization of water by man for daily activities is as pertinent as related to the organisms inhabiting the water body. It has been observed that water quality parameters have immense impact on the biotic community of aquatic ecosystem (Okogwu and Ugwumba, 2006).

2.8.1 Temperature

Temperature determines how hot or cold an object is (Adeniyi, 1978). Water temperature performs a critical function in the widespread of aquatic life forms in water bodies; the reason is not far reached since most organisms depend on water temperature for their metabolic activities. In temperate waters, breathing rates rises, resulting to rise in oxygen utilization and elevated the decaying of organic matter. However, high water temperature above $40^{o}C$ cause decrease in density and subsequently decrease in its viscosity which will eventually reduce the buoyance of organisms in it which consequently increase the amount of energy that an organism must exert in order to support its position in water. Also, most aquatic organisms are stenothermal, so when extreme temperature sets in, these organisms respond by migrating into suitable areas. High temperature results in mortality among warm water organisms or in the alternative it can result to their mass movement to cooler regions. In the tropics, temperature generally has high concentrations in the dry season than in the wet season as observed by many authors (Moody, 1991; Egborge, 1994). According to Cummins (1973) feeding rate of aquatic insects is also temperature dependent. Ayodele and Ajani (1999) posit that the optimal temperature range of tropical freshwater bodies is between 21°C - 32°C, hence within this range, insects thrive better.

Ikomi *et al*. (2005) also noted that most species of aquatic insects; Ephemeroptera, Tricoptera, Plecoptera thrive better in cooler waters (water within the optimal range) whereas the larva stage of some Dipterans, Chironomus, Chaoborus prefers warmer water. High value of water temperature was recorded in Awba reservoir and might be ascribed to breakdown of the organic effluents discharged into the water body (Tyokumbur *et al*., 2002). Highest numbers of aquatic insects were collected when temperature was relatively higher, than when there was a drop in temperature (Otalekor, 2009). She also reported that some insect species depends on temperature, possibly because temperature helps in their feeding rate and metabolism, while a few species such as *Tabanus sp.*, *Gyrinus sp.,Culex sp.*, *Chaoborus sp.,Gerris sp*., *Lubellulla sp.* And *Neopla species* correlated negatively with temperature and further reported that these categories of insects recorded highest number with reducing temperature, the reason being that they might prefer cold aquatic environment for their feeding and metabolism rates and proliferation. Lower temperature values were recorded during the period of heavy rainfall in Ado-Ekiti reservoir and were attributed to the cool atmosphere because of impacts of rain and increased amount of water vapour which might decrease the evaporation of water (Idowu *et al*., 2013). Adebayo (1993) reported lower values of temperature during the intense period of harmattan in Ado-Ekiti reservoir and attributed it to extreme values of water temperature recorded during the dry season to rise in atmospheric temperature, diminished relative humidity and high level of transparency.

2.8.2 Biological Oxygen Demand (BOD)

This is an estimation of the quantity of oxygen required by microbes to breakdown the organic matter in an aquatic environment at a certain temperature for a specific period of time (Boyd, 1979). It is also the amount of oxygen consumed for biological activities by all organisms in the water body. Non contaminated surface waters do contain BOD concentrations of 2 mg/L or less. Wastes from industries couldalso hold BOD concentrations of 25,000 mg/L or above. BOD values more than required limits may reflect contamination from industry, domestic or agricultural sources and might be the reason behind reduction in dissolved oxygen condition within the water body (Diaz, 1995). Highest BOD value is an index of organic pollution as identified by Egborge (1979). In Eleyele reservoir, Idowu and Ugwumba (2005) observed BOD range between 3.1–4.3 mg/L which was observed to support the organic nutrient of the reservoir. High BOD ranges between 15.48–26.78 mg/L was obtained in river Ogunpa in Ibadan which suggested high organic enrichment of the river and an index of pollution (Atobatele and Ugwumba, 2005).

2.8.3 Dissolve Oxygen (DO)

Dissolved Oxygen concentration is the quantity of oxygen available in the water. It is an important parameter because it is essential for most forms of biological life and determines population size and community composition. DO concentration is not influenced by natural factors like temperature, salinity, plant respiration and amount of organic material present alone but also by organic contamination and eutrophication. Reduced concentrations of dissolved oxygen can raise up death rate, decrease developmental rate and change the distribution and behaviour of aquatic life forms, in totality can provide major changes in the general brackish complex channel of food (Breitbug, 2002). Dissolved Oxygen in normal body of water is naturally sourced from two entity: DO as by-product of photosynthesis activities and DO resulting from atmospheric reactions by wind or waves which spread over into the water at the surface. The estimation of dissolved oxygen in water is important because it is one of the practical indicators of purity (Egborge, 1994). However, DO alone is not enough to establish water quality standard because the required concentration varies among species and in different life stages (Kalff, 2002). Ward (1992) pointed out that changes in dissolved oxygen concentration can cause reduction in the diversity and great quantity of insect communities. The introduction of pollutant into river system causes abrupt reduction in the dissolved oxygen levels at the point of release and massive increase in the biochemical oxygen demand because microorganism in the effluent and those availablein the aquatic medium utilize the available oxygen to break down the organic matter present (Holdgate, 1979).

Tyokumbur *et al*. (2002) recorded extremely reduced concentrations for dissolved oxygen in an effluent discharge station sampled. This reduction in the oxygen concentration stresses the aquatic organisms and the benthic macro-invertebrates nonetheless. Mobile fauna like Finfish, and the adult stage of most insects are pre adapted to avoid these stress conditions to an extent by moving away, but the benthic organism, being relatively immobile and rather sedentary, are fully impacted by the effects of the pollutants (Rosenberg and Resh, 1993). The reduced concentrations of dissolved oxygen cause extinction of sensitive taxa like Ephemeroptera, Plecoptera and Tricoptera and the proliferation of very tolerant species such as *Culex sp*., *Chaoborus sp*., *Chironomus sp*., e.t.c (Tyokumbur *et al*., 2002). One of the most useful indicators of the ability of a body of surface water to support fish and most other forms of aquatic life is its dissolved oxygen content.

When surface waters are heavily loaded with biodegradable wastes, the subsequent populace of oxygen dependent decomposers can decrease the availability of dissolved oxygen so that aquatic organisms especially fish die from suffocation, total elimination of intolerant species (Ephemeroptera, Plecoptera and Tricoptera) and proliferation of very tolerant species (Holdgate, 1979; Mason, 1992; Ahmed, 1997). Therefore, the more the degree of contamination, the greater the biochemical oxygen demands (BOD). Ndaruga *et al.* (2004) pointed out that alterations in water health conditions such as temperature characteristics and DO concentrations can brings about decrease in the variety and abundance of Zoo-benthic community. Thus, Schindler (1990), Yakub (2004) and Otalekor (2009) concluded that pollution is induced by anthropogenic activities. Otalekor (2009) reported negative correlation between DO and water temperature. Arimoro and Ikomi (2008) also recorded that elevation in the concentration of water temperature leads to decline in Dissolved Oxygen and the reason was ascribed to the fact that when temperature rises, DO decreases due to respiration and other processes such as decomposition of organic matter. Yakub (2004) and Otalekor (2009) also reported highest species diversity in point where the dissolved oxygen was highest and that the low DO concentration values in other points is an indication of deterioration of water quality as a consequence of human activities in those points.

2.8.4 Hydrogen ion Concentration (pH)

Hydrogen ion concentration (pH) denotes the intensity of the acidic or basic character of a solution. There is variation in pH fluctuation in aquatic environment, removal of CO_2 from water during day light by aquatic plants due to photosynthetic activities and causes elevation in pH value while during the night when photosynthesis ceased, respiratory procedures release CO_2 to the water and pH declines. Hydrogen ion concentration is very essential in the aquatic medium due to many biological activities that takes place within a smaller range, so, any difference from the limits may be deadly to a specific organism. The pH range of most normal waters ranges between 6.0-8.5 mg/L, Despites the fact that, lower values can be recorded in diluted water that contains high organic content, and higher values could be experienced in water that is rich in nutrients (eutrophic) water, ground water brines and salt lakes. According to Kalff (2002), there are insects for example, water boatmen, *Chironomus sp*. and damselflies that are only negligibly influenced by acidity in water bodies, perhaps because of reduced predation from fish; whereas others like mayflies are acid-sensitive. Ogbeibu (2001) worked on density, diversity and distribution of dipterans in a temporary pond in Okomu forest reserve and observed that hydrogen ion concentration influenced temporal variation in diversity of dipterans. Fakayode (2005) also reported that pH has adverse effects on water quality. It affects the metals solubility, hardness and alkalinity of the water.

Organisms of aquatic ecosystem are also impacted by Hydrogen ion concentration since majority of their metabolic activities relies upon pH. The larva phases of aquatic creatures are mostly non tolerant to reduction in pH levels anda few sensitive species will be absent completely in water with pH value less than six (6). Otalekor (2009) also reported pH between 6.0-7.0 mg/L in Awba reservoir during her study period. Amusat *et al*. (2015) reported pH of Erelu reservoir to be between 6.4-7.8 mg/L which were within the standard limits. The pH values ranged between (6-9) mg/L were reported for one of the southern Nigeria reservoir in Ibadan and that it was said to be suitable for most animals (Abohweyere, 1990; Idowu and Ugwumba, 2005). Studies however abound to show that this balance might shift either to the right causing increased pH or to the left causing reduced pH (an acidification) due to the inclusion of pollutants.

Mason (1992) also posits that acidification also leads to the disappearance of shrimps and the loss of calcium in the exoskeleton of Crayfish. Several authors had reported alkaline pH concentrations in the dry season and slightly acidic in the period of wet season (Tyokumbur, *et al*., 2002; Ikomi, *et al*., 2003; Okogwu and Ugwumba, 2006). They also attributed elevated concentration of pH during the period of dry season to the rise in photosynthetic activity during this period therefore boosting primary productivity.

2.8.5 Nutrients

Nitrogen and phosphorus are two forms of nutrient in water bodies; all organisms require nutrients for growth and development. They also influence the distribution of aquatic organisms within the water body. Nitrogen is present in aquatic environments in several forms, including Ammonia, Nitrates and Nitrites. Nitrate ion (NO_3^-) is the common form of Nitrogen in the aquatic environment (Horne and Goldman, 1994; Kalff, 2002). It is important in determining the productivity of any given community (Olaniyan, 1969). Excess nitrate as a result of run-off from fertilizers, from nearby farmlands, farm animals and other animal wastes, escaping septic tanks, sewer overflows can lead to eutrophication in water bodies and this may result to hypoxia (reduced concentration of DO) which in turn will affect the organisms present at those areas and organisms that cannot tolerate low level oxygen will be redistributed. Freshwater usually contain 0.00 mg/L nitrate, and rarely higher than 1mg/L (USEPA, 2004). Nitrate concentration in seawater is normally less than 0.5 mg/L, though, can rise with contaminants such as sewage effluents and also influenced by time of the year. High amount of nitrate are general indicative of pollution.

Phosphorus (P) occur mostly as dissolved orthophosphates in water bodies such as $H_2P0_4^-$, HPO_4^{2-} and PO_4^{3-} and it is another such of nutrients enrichment to water bodies. Olaniyan (1969) described that the concentration of total phosphate in the water depends on a number of factors; chief amongst them being the rate at which organic phosphate are lost to the mud and bottom deposits and to the organisms. The major sources of phosphate are sewage from homes, detergents, run-off from agricultural field associated with fertilizers and industrial waste waters. It is considered a limiting nutrient for algae and macrophytes and since it is actively absorbed by plants, is usually found at low concentrations (Horn and Goldman, 1994). Undisturbed waters usually have 0.005 to 0.020mg/L, or as low as 0.001mg/L in freshwaters and as high as 200 mg/L in some saline waters.

High concentration of phosphorus could also affect diversity and abundance of invertebrates. This could happen in three ways: reduction of food availability, alteration of the macrophyte community, resulting in a diminution or elimination of the open waters, and / or reduction of oxygen content due to shading from plants (Radder, 1999). Generally, high concentration of phosphate is an indication of pollution. According to U.S.EPA (2004), the concentration of PO_4^- should not go beyond 50 mg/L in any tributary to river or a lake and 25 mg/L within these main resources. Otalekor (2009) recorded nutrients input as being correlated positively with insect species and most likely, the imput enhanced secondary production in the reservoir. Zabbey and Hart (2006) reported similar results in Woji Creek, Niger Delta, where biological wastes are released repeatedly into the stream which influenced the composition of benthic macro-invertebrates. Arimoro *et al*. (2007a) also recorded same result in Ethiope River in Niger Delta, where nutrient was emphasized as a pertinent agent in the dissemination and greater quantity of *Chironomus sp*. Positive relationship of nutrient with benthic macro-invertebrates collected in Central Florida was reported by Ali *et al*. (2003). Ndaruga *et al*. (2004) observed that highly organic impacted areas, have low species diversity of organisms and many of the species governing such regions are resistant to contamination.

2.8.6 Total Dissolved Solids (TDS)

Total Dissolved Solids (TDS) refers to the aggregate of the dissolved chemicals or salts in a sample of water. Clean water bodies did not have anything dissolved in it. Hence, perfect water has below detectable limits of TDS. Nevertheless, when minerals salts and contaminants dissolved in water, the aggregate sum of these dissolved solids call attention to the quality of the water. A high TDS level shows that sufficient amount of nutrients are present such as chloride, magnesium, sodium, calcium potassium, bicarbonate and bromine salts. Sources include hard water ions, fertilizers in agricultural runoff and urban runoff. Waters with high TDS values will taste salty or even have metallic or bitter taste. The required limits of total dissolved solids for drinking waters according to EPA (2003) was 500 mg/L of water and at most freshwater can have 200 mg/L of total dissolved solids. Rain water has zero dissolved solids in it. Nevertheless, when rain contacts the ground, it dissolves fertilizers, salts and minerals, animal wastes, pesticides and other chemicals that may be sourced from cars and industrial contamination. Exceeded levels of TDS can create harmful impacts on fish and fish eggs. TDS can as well impact water taste and often signifies a high alkalinity or hardness (Chapman, 1992).

2.8.7 Electrical Conductivity (EC)

This is the ability of a substance/material or solution to conduct electricity. EC is measure of the current carried by electrolyte in a solution. Electrical conductivity is a reciprocal of the resistance. It depends on the ionic strength of water, type of different soluble substances and the temperature at which the water is measured. As much salts is present in water, so also are the ionic contents which are able to conduct current, therefore, conductivity is a good and rapid measure of total dissolved solid. In general, seawater has a higher conductivity than freshwater owing to its ionic concentration. The sodium chloride and other salts in marine environment offer it a higher conductivity values more than freshwater. The normal water usually has conductivities ranging from 20-1500µs/cm (Boyd, 1979). Adebisi (1982) stated that increase in temperature has a consequent increase in conductivity and it varies by 20^{o}C as observed in upper Ogun River. Atobatele *et al*. (2005) reported highest TDS, COD and pH in station 2 which correspond to the high residential area and commercial centres (core) of Ibadan city and was categorized to be the worst polluted areas in their study of spatial disparity in physical and chemical parameters and macro-benthic invertebrate fauna of River Ogunpa. Conductivity relies upon locations, geological history of the water basin, drainage, rainfall, base deposits, appearance or non-appearance of inflowing water and characters of the living organisms (Stirling, 1985). Generally, water with conductivity less than 1000 µs/cm is fresh water while values above 40,000 µs/cm indicated marine water and those values between 1000-40,000 µs/cm are brackish water (Egborge, 1994).

2.8.8 Total Alkalinity (TA)

This is the evaluation of the buffering ability of water or the capability of bases to neutralize acids. Alkalinity is expressed as equivalent of $Caco_3$. Carbonate and bicarbonates are the predominant bases in various waters. TA for natural water ranges from 5mg/L to several 100mg/L. It also depends on the carbonate content of water rocks/soils or bottom muds. Normal water has TA of 40 mg/L or more, any water with high TA are considered hard waters while those with waters with lower alkalinity are regarded as soft water. Hard waters are generally more productive due to higher phosphorus level and other essential elements which increase along with alkalinity than soft waters. It is an essential water quality parameter because it helps in establishing stream's ability to neutralize acidic contamination. Alkalinity has been reported to protect aquatic life forms from acid wastes and poisonous metals such as Arsenic, Lead and Cadmium by precipitating the metals out of the solution (Deliz Quinone, 2005). The increase in mean alkalinity in one of the station in River Ogunpa was reported to occur due to a diminishing pH value at such station (Atobatele *et al*., 2005). This implies a rise in the buffering capacity of the River with corresponding decrease in pH since alkalinity of an aquatic environment is its acid neutralizing power (John Dezuane, 1990; APHA, AWWA, WEF, 1992). However, Adebisi (1981) reported increase in alkalinity of water with decreasing water level.

2.8.9 Transparency/Turbidity

Transparency denotes the amount of light entering the water body and it is measured using seechi disc, the best time to measure accurate transparency is between 9am-3pm and period for best result is between 10 am to 2 pm (Egborge, 1994), while the amount of suspended particles is known as turbidity. It also implies clarity of water, which is influenced by the amount of suspended solids present in it. Provided there are large amount of floated particles in water, it is injurious to the gill-possessing creatures, as the particles assembled on the gill filaments, obstruct the gill and decrease the surface area for gaseous exchange. As this progress, the animals will die as they are unable to obtain sufficient oxygen to supply their metabolism. High turbidity often accompanies organic pollution. The more the free drifting solids the greater the cloudiness, consequently leads to less light penetration through water, therefore, impedes photosynthesis required for healthy aquatic plant growth and provision of DO. The water turns out to be hot since suspended particles absorb heat directly from sun.

Reason for studying the transparency/turbidity is because, water that remains very turbid for a long time poses stress to aquatic life and the following signs are noted, such as: increase breathing rate, diminished growth and feeding rate, delayed hatching and in extreme situations it leads to mortality. High turbidity also affects human and the acceptable values ranges between 1-5 NTU (Roland, 2013).

The lower transparency of water bodies during the period of heavy rainfall had been reported by (Anethekhai, 1986; Oso and Fagbuaro, 2008) and adduced the reasons to run-off into the reservoir, which might be related to heavy rainfall during this period or because of much floating particles on the water surface. It was additionally identified with reduction in the intensity of sunlight due to the availabilityof heavy cloud in the atmosphere, which in turn lessened the amount of light penetrating into the water body. Additionally, higher values of transparency in water bodies in the dry seasons have been also reported by many authors such as Ikomi *et al*. (2003) in River Adofi, Adebisi (1981) in Upper Ogun River, Egborge (1981) in Asejire Reservoir, Idowu and Ugwumba (2005) in Eleyele Reservoir, Ayoade *et al*. (2006) in Asejire and Oyan lakes, Oso and Fagbuaro (2008) in Ero Reservoirs. They all attributed it to decrease in allochtonous materials that get themselves into the reservoir with flood.

2.8.10 Calcium ion

Calcium (Ca^{2+}) ion, is one of the major inorganic cations, or positively charged ions in marine and freshwater. It can be gotten due to break-up of salts like Calcium chloride or Calcium sulphate in water. Majority of Calcium in surface water originates from stream moving above marble ($CaCO_3$), gypsum ($CaSO_4.2H_2O$), dolomite ($CaCO_3$-$MgCO_3$) and other rocks and minerals that contains calcium. Ground water and underground aquifers easily get higher concentration of calcium ions from rocks and soil. Calcium carbonate is moderately undissolved in water, however, disintegrates more easily in water comprising noticeable level of dissolved CO_2 (Chapman, 1992). The values of calcium ions (Ca^{2+}) in freshwater ranges between 0-100 mg/L, and more often than not has the most elevated concentration of any freshwater cations. A required limit of 50 mg/L is suggested as far as possible for drinking water. Abnormal values are not regarded as a health concern. However, levels more than 50 mg/L can be detrimental because of the creation of excess calcium carbonate that stores in water pipe or in lowered cleaning activity of soaps. Perhaps, if the amount of calcium ion in freshwater falls below 5mg/L, it may only favour few flora and fauna life, which is referred to as oligotrophic condition. Normal sea water has Ca^{2+} levels of about 400 mg/L (Chapman and Hall, 1992).

2.8.11 Magnesium ion

Magnesium ($Mg^{2+)}$ ion is the most abundant cation next to sodium in seawater, because it is about 12% lesser in amount compared to the mass of sodium in the marine environment, perhaps the reason that makes marine water and sea-salt an attractive resource of Mg. Magnesium ion in great quantity is an ionic laxative and MgSO4 (Epsom salt) is sometimes utilized for the aforementioned purpose and is reffered to as 'Milk of Magnesia' which is a water suspension of one of the few undissolved magnesium composites, i.e. Magnesium hydroxide. The insoluble particles bring about its figure and reputation. Mg ions are important to majority of living cells, where they assume a noticeable parts in controlling significant metabolical polyphosphate complexes for example, ATP, DNA and RNA. Larger parts of enzymes require Mg ions to perform their roles (Lentech, 2012). Magnessium compounds are utilized medicinally as laxatives, antacid (e.g. milk of magnesia), and in various circumstances where steadiness of irregular nerve stimulation and blood vessel contraction is needed (e.g. to treat eclampsia). Mg ions are acidic to the taste and in small amounts they assist to give a normal bitterness to fresh mineral water. Mg is a common additive to fertilizers and in freshwater is normally present at concentration range below 10 mg/L to 50 mg/L (Hem, 1992). Seawaters contain approximately 1350 mg/L.

2.8.12 Metals and Heavy Metals

Metals get into the freshwater due to breaking down of soils and rocks. Rocks are originated out of volcanic outbreaks and different kinds of human activities for example, mining, metal processing or utilization or substances that consist of metal contaminants. Generally, familiar heavy metal contaminants include Arsenic, Cadmium, Chromium, Copper, Nickel, Lead and Mercury (Chapman, 1992). Heavy metals are described as metals with atomic numbers above 20, but alkali metals, alkaline earth metals, Lanthanides and Actinides are excluded from the group. Presence of too much heavy metals in freshwaters causes fall in pH of water, metal solubility rises and metal particles are easily mobile which is the reason why metal toxicity occurs in most soft waters and locking up of metal in the bottom sediment of water bodies for a considerable period of time, since they are non-biodegradable (i.e. cannot be splitted into less injurious constituents in the ecosystem). Harmful chemicals can be accumulated in the body tissue of organisms, particularly fat tissues, depending on the sensitivity of individual species to the contaminants which can also be influenced by factors like the duration of exposure, sex, age e.t.c. Generally, the metal concentrations in invertebrates are varied according to their body weight. In fish, the embryonic and larval phases are normally the most intolerant to the contaminants. Perhaps, benthic organisms are the most throughly influenced by metal strength in the sediment since the benthos serves as the essential store house for the particulate matters that are wiped down into the water ecosystems (Valavanidis and Thomie, 2010).

The concentration of heavy metals is commonly studied to determine water quality in accordance with the organisms present. Living organisms needed small amount of a few heavy metals like Cobalt, Manganese, Iron, Copper, Molybdenum, Strontium, Vanadium or Zinc to control numerous biochemical procedures, inspite of this fact, extreme concentrations of important metals may be harmful to life forms (Kennish, 1992). It is noticeable that little amount of some metals can retain equally suitable and injurious impacts on the biota. These trace metals consist of Sodium, Potassium, Magnesium, Calcium, Manganese, Iron, Cobalt, Copper, Zinc, and Molybdenum and are available in different amounts in all living tissues and they are important for organisms successful development and metabolic activities. However, absence of these trace metals in an organism impedes biochemical functioning, although over abundant will often results to harmful impacts. Metal ions to be utilized by biota must be normally accessible and abundant in solution (Kelly, 1988).

There are many authors that have investigated on the sources of heavy metals into different water bodies, and have been reported as follows:

Tyokumbur *et al*., 2002 reported the source to be deposition of abattoir wastes. The deposition was also from influx of laboratory waste, automobile exhaust fumes washed into Rivers and streams by surface run-offs (Ezenroye and Ubalua, 2005). Other sources include the processed water from cosmetics, detergents, and textiles. These heavy metals include Pb, Fe, Zn Cu, Hg, Co, Cd, Mn, Ni, Ag (EPA, 1987). Oben (2003) reported the impact of heavy metals on the benthic community of Awba reservoir. Otalekor (2009) also reported high mean values of Pb, Zn, Cu and Cd concentrations in point 2, which was ascribed to the discharge of wastes coming from Chemistry and Physics laboratories of the University of Ibadan that enters the reservoir. Related observation was reported in Ogunpa River by Atobatele *et al*. (2005).

Onwumere and Oladimeji (1990) reported that *Oreochromis niloticus* exposed to treated NNPC Kaduna petroleum refinery effluents accumulated trace metals in this order: Pb> Cu> Mn> Cr> Ni> Cd. Past research had observed that aquatic plants, insects, and bivalves are not capable to successfully control metal uptake (Connell and Miller, 1984). For this reason, bivalves and insects are often used as biomonitoring organisms in area of suspected metal pollution (Kennish, 1992). On the contrary, Chironomids of the sub-family Chironomidae can tolerate contamination by heavy metals, although there are some exceptions (Deliz Quinones, 2005). Water striders (*Gerris sp.)* have also been reported as indicators of mercury in small water ecosystems since they are tolerant of high mercury concentrations (Timothy *et al*., 2004). Campbell and Tessier (1991) reported that sediments are both potential source and carriers of pollutants especially when metals dislodged, as a result, there will be movement of metal from the bottom silts to the inhabitant and benthos are affected specifically by the amount of metal contained in water settling due to the fact that the organisms found in the water basement are the main recipient of the organic matters that flushed down into the water system.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1.0 Description of the Study Area

The study site for this research work is Erelu reservoir. Erelu reservoir is located in Oyo town, while Oyo town is situated in the North of Ibadan, the capital of Oyo State. The reservoir was built on Aawon River along Oyo /Iseyin road in 1959 and was commissioned in 1961 to provide water for drinking, agricultural, irrigational purposes and fishing activities. Currently, it lso provides water for International Institute of Tropical Agriculture (IITA) for their nursery unit in Oyo Town. This study site lies between latitude 7^{o} $8^{'}$ $33^{''}$ and 7^{o} $9^{'}$33"N and longitude 3^{o} $8^{'}$ 67"E and 4^{o} $0^{'}$ 00" E (Ufoegbune, 2011). The impoundment of the dam is 161.07ha, and the catchments area is 243.36km. Erelu reservoir is approximately 6.4km from the core of Oyo town and it supplies potable water to the town. An output of 7.5million litres is released per day, from a reservoir capacity of $10cm^3$ (Akintola and Adeniyi, 1997).

Vegetation around the reservoir is evergreen, interspersed with grasses and trees. Some of the predominant trees species around the reservoir are, *Anacardium occidentale*, *Cocos nucifera*, *Parkia biglobosa*, *Psidium guajava, Mangifera indica, Antiaris africana, Azadirachta indica, Carica papaya, Saccharium officinarum etc.* Reservoir banks are covered with *Pistia stratiotes, Eichnorrnia crassipes, Persicaria senegalensis, Commelina benghalensis, Ceratophylum demersum, Ipomoea aquatica, Typha domigoensis, Sacciolepis africana, Cyperus esculentus, Alchornea cordifolia and Ludwigia abyssinica* and the floating plant varieties around the reservoir are *Lemna minor, Nymphaea sp.* etc. The notable herbs along the banks are *Talinum triangulare, Jatropha gossipiifolia, Ocimum bacilicum, Amaranthus spinosus, Vernonia amydgalina.* Aquatic birds like Eagle, Egrets, Heron, Ducks do visit the reservoir on daily basis. Fish fauna found in the reservoir includes *Coptodon zilli, Chrysichthys nigrodigitatus, Hepsetus odoe, Oreochromis niloticus, Momyrus rume e.t.c.* (Amusat *et al.,* 2015).

Table 3.0: Description of sampling sites

Stations	Description
Inlet (Stations 1 and 2)	This is a site from Oya Tutu, is 5 km to the main reservoir, it is partially shaded by trees that form canopy over it. The substratum is sandy with decaying plant matters. Human activities is restricted to bathing, especially people from nearby villages and washing down of nutrients from N.P.K. fertilizer as a result of farming activities in the points. There is overhead bridge which is motorable (Plate: 1&2).
Main reservoir (Stations 3, 4 and 5)	It is about 200m apart. Its substrate is mud, surrounded with many shrubs and trees like palm, Guava, lemon, orange,, mango, e.t.c**.** Landing station for the fishermen, many shrubs and water plants surrounded its bank. The plants here are always evergreen and produce shade over the water in the reservoir (Plate: 3, 4 & 5).
Outlet (Stations 6&7)	This is located at Oke Odo Olooro, the bridge side of Aawon river where the reservoir exits into the river. The substratum is sandy and shaded by trees, contain decay plant matters and human activity like ritual bath, Cattle grazing and their faecal content, motor and bicycle wash, catching of fish with lindane (Garmalin 20) occasionally occurs here**.** There is also overhead bridge which is motorable to link the villages (Plate: 6 &7).

Above are the seven sample locations that were selected for the study in Erelu reservoir. These locations were chosen based on the hydrological properties of the water body and likely variations, also based on the abundance and occurrence of macro-invertebrates within the reservoir, at the inlet and outlet stations of Erelu reservoir.

3.1.1 Co-ordinates of the Sampling Stations in the Erelu Reservoir.

Stations	Eastings	Northings	Longitude	Latitude
1	599225.1671	871975.6558	3^{o}54ˈ0.5”E	7^{0}53ˈ15.3”N
2	599425.1671	872175.6558	3^{o}54ˈ7.0”E	7^{0}53ˈ21.8”N
3	599625.1671	872375.6558	3^{o}54ˈ13.6”E	7^{0}53ˈ28.3”N
4	598025.1671	870975.6558	3^{o}53ˈ21.2”E	7^{0}52ˈ42.8”N
5	598225.1671	871175.6558	3^{o}53ˈ27.8”E	7^{0}52ˈ49.3”N
6	601225.1671	874775.6558	3^{o}55ˈ6.0”E	7^{0}54ˈ46.3”N
7	601425.1671	875375.6558	3^{o}55ˈ12.6”E	7^{0}55ˈ5.8”N

3.1.2 Climatic Data Collection

Data on monthly bases for rainfall, minimum and maximum temperature and relative humidity for 2013-2015 were collected from Nigerian meteorological agency, Ibadan synoptic station Oyo State, Nigeria.

3.2.0 Sampling Techniques

3.2.1 Sample Collection

3.2.2 Collection of Water Sample for Physical and Chemical Parameter

Water samples were collected from each station very early in the morning (8am-10am) once in a month for the period of two years (June 2013-May 2015). Water samples for physical and chemical analysis were collected in plastic container (4-litres) from selected stations. Surface water collections were made with 300ml BOD bottles. The bottles were lowered into the reservoir at 1m depth. Water sample at that depth was transfered into sample container. Water samples were preserved by 1ml of trioxonitrate (v) acid (HNO_3) (Boyd, 1979). The sample water taken were transported to the research laboratory and analysed instantly to guarantee that the physical and chemical parameters of the water were sustained.

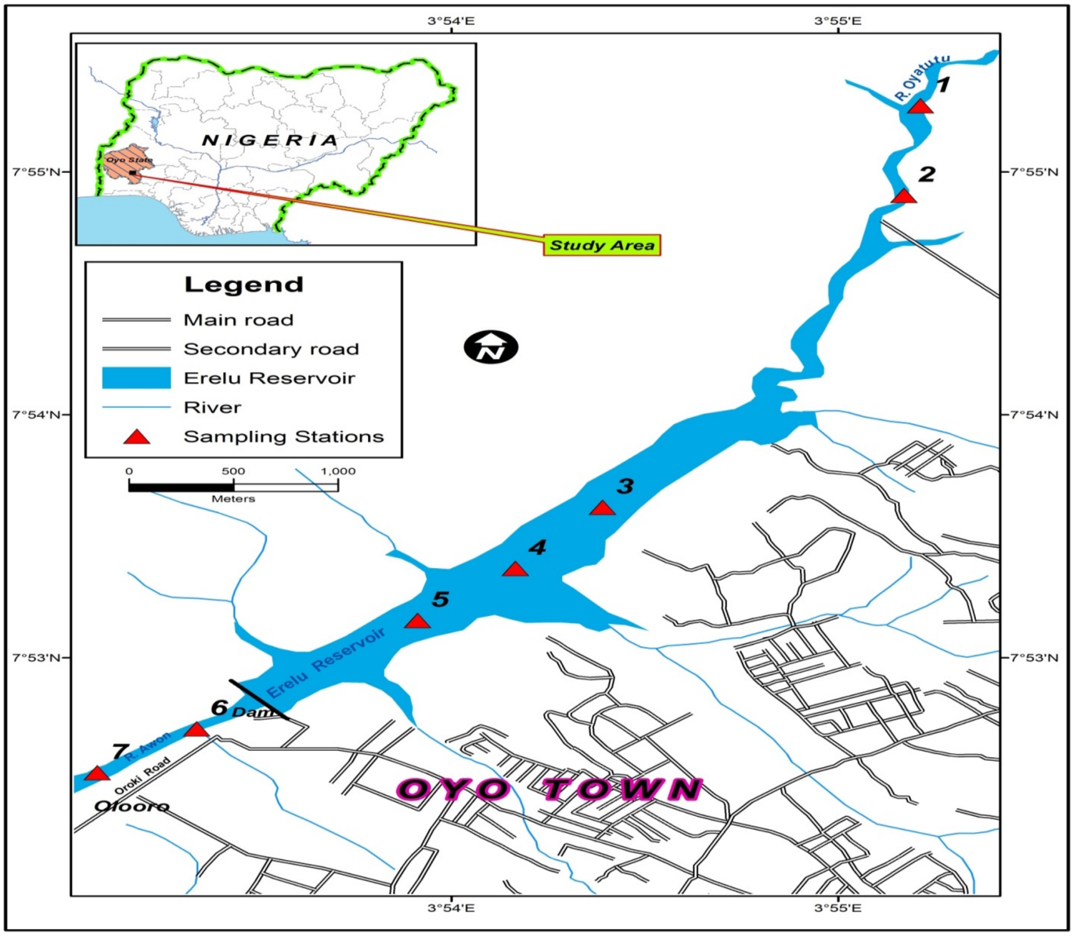

Fig 1: Erelu reservoir map of study area showing the sampling locations

Plate 1: Sampling station **1** is located at Oya tutu, the inlet of the reservoir, which is about 5 km away from the reservoir, agricultural activities are taken place here, fertilizer and other villagers activities could impact this stations.

Plate 2: Sampling station **2,** this is second station located at Oya tutu, which is the inlet of the reservoir. This area is affected by run-off, fertilizer effluents and bathing.

Plate 3: Sampling station **3 is** third station located within the reservoir. Its substrate is mud, its bank is shaded and surrounded with many shrubs and trees. There is restriction of human activities here.

Plate 4: Sampling Station **4** is fourth station within the reservoir**,** is muddy with smaller pebbles and clear water. Landing station for the fishermen and surrounded with many shrubs and hydrophytes alongs its bank

Plate 5: Sampling Station **5 is** fifth sampling station which is located within the reservoir. The station is sandy and stony substratum with clear water with less human activity. Surrounded with shrubs and hydrophytes.

Plate 6: Sampling station **6** (Oke Odo Olooro) is the sixth station situated at the point of reservoir exits into the river, impacted with human activities such as used motor oil, detergent and ritual bath and faecal content of grazing animals.

Plate 7: Sampling Station **7**(Oke Odo Ooloro) is the second station in the downstream, at the point of reservoir exits into the river. Receives dust particles due to motor passage, ritual bath, effluent and run-off.

3.3.0 Sampling Procedures

3.3.1 Determination of Physical and Chemical Parameters

The different physico-chemical parameters that were examined includes: Temperature, Hydrogen ion concentration (pH), Total Alkalinity (TA), Total Dissolved Solids (TDS), Conductivity (EC), Dissolved Oxygen (DO), Nitrate (NO_3^-), Phosphate (PO_4^-), Calcium ion (Ca^{2+}), Magnesium ion (Mg^{2+}), Biological Oxygen Demand (BOD), Transparency and Turbidity.

3.3.2 Transparency

Transparency of each station was measured *in-situ* using a seechi disc with a diameter of 20-25cm. The seechi disc was allowed to sink down slowly in the water on a marked line until it disappears, the rope was measured and recorded in cm and was raised up again until it re-appears, the average of the two depths were calculated as the seechi disc depth and expressed in cm as recommended by Egborge (1994).

3.3.3 Temperature

Temperatures at different stations were measured *in-situ* using mercury in glass thermometer. The thermometer was lowered into the water body for 2-3 minutes and the readings were recorded as recommended by Williams (1996).

3.3.4 Measurement of Hydrogen ion Concentration (pH)

The pH was measured also using EC500 ExStik multimeter kit. The meter was calibrated using pH of 7.00 buffer solution. The surface probe of the metre was then dipped in 300ml volume of the water sample in the beaker, and swirled for 2-3 minutes and the pH were recorded as recommended by (A.O.A.C., 1996).

3.3.5 Electrical Conductivity and Total Dissolved Solids (TDS)

Conductivity and TDS were determined in the laboratory using Conductivity, TDS, and pH combined meter ExStik EC500 model. Some quantity of water was poured into a small beaker and the probe was dipped into the beaker for 2-3 minutes and the conductivity and TDS were measured as recommended by (William, 1997 and A.O.A.C., 1996) and expressed in µs/cm and mg/L respectively.

3.3.6 Determination of Nitrate Using Hannah Instrument (H183200 Bench Photometer)

The Hannah instrument (model: H183200) was utilized to examine nitrate of sampled water, meter was turn on and allowed to heat up a little for half an hour. 6ml of water sample was pour into the cuvette using pipette. The cuvette was covered and placed inside its holder. The zero key was pressed to zero the machine in preparation for measurement. The cuvette was removed and the Nitrate (pillow) reagent (H193728.0) was added to the sample water in the cuvette and mixed thoroughly for ten seconds and replace into cuvette holder, it was allowed to read for 4 minutes 30 seconds by pressing the timer, then nitrate value was read and recorded in mg/L (A.O.A.C., 2000).

3.3.7 Phosphate Determination Using (Vanado-Molybdo Phosphoric Acid)

This was determined using calorimetric method (Ademoroti, 1996). 0.2g of activated carbon was added to 50ml of water sample and in an Erlenmeyer flask for about 5 minutes and was filtered through Whatman filter paper No.42 or equivalents. After mixing thoroughly, 10ml of vanadate-molybdate reagent was added to 25ml (dilution factor) of water sample in 50ml volumetric flask and added up to the marked line with distilled water in order to induce colour development. After 10 minutes of vanadate – molybdate reagent, each sample absorbance was calculated at 470nm in the spectrophotometer, using the reagent blank as the reference solution. The phosphate was read from the standard curve prepared using standard phosphate. To prevent interference, 1-2 drops of concentrated Tetraoxosulphate (vi) acid was added to the sample. The colour is stable for few days and its strength is not influenced by variations in room temperature which is an advantage of this method over others.

$$\text{Mg/L } PO_4^{3-} = (P) = \frac{\text{Reading from curve X 1,000 X D}}{\text{Sample water used (ml)}}$$

Where D = Dilution factor

3.3.8 Determination of Total Alkalinity.

According to (Ademoroti, 1996; A.O.A.C., 1996), 50ml of sample of water collected was added into the conical flask. 2 drops of methyl orange was added and mixed thoroughly. This was titrated against 0.02N H_2SO_4;

$$\text{Alkalinity} = \frac{\text{Volume (ml) X molarity of titrant X 100,000}}{\text{Volume (ml) Sample}}$$

3.3.9 Determination of Biological Oxygen Demand and Dissolved Oxygen

Sampled water was used to determine dissolved Oxygen on the first day. The sampled water was then incubated for 5 days in the dark at 20^{o}C in cooled incubator and determined the BOD and DO after 5 days.

$$\text{BOD (mg/L)} = \frac{(DO_o - DO_d) \text{ x Volume of BOD Bottle}}{\text{Ml sample used}}$$

Where, DO_o = Dissolved Oxygen values found in the sample on the first day.

DO_d = Dissolved Oxygen values found after five days.

The DO was determined by putting the water samples in a 300ml bottle and added 2ml of manganese sulphate ($MnSO_4$) solution and 2ml alkali-iodide-azide reagent was added to the liquid, stopper with care to release air bubbles and mixed by inverting the bottle a number of times until a clear super natant water is obtained. 2ml of concentrated H_2SO_4 is added and allow the acid to move to the bottom of the bottle and mixed gently upside down until there is complete homogenization of the compound, a brown colour was obtained. The 0.025N sodium thiosulphate solution was used to titrate the solution obtained to give a pale straw colour and added 2ml starch solution, the colour becomes blue, the titration is continue until the blue colours disappeared and DO value was determined (Ademoroti, 1996).

3.3.10 Turbidity Determination Using Turbidometer

The SX-B26 model turbidometer was used and allowed to worm up for at least 30 minutes. The instrument was calibrated using standardized solution by pouring distilled water into the sample slot and placed into the slot base, also covered the slot cap, then the reset key was pressed, the screen showed flashing 00000, and stopped flashing when the reset ends. The machine was shut down and restarted. The water sampled was poured into the sample slot, covered and replaced into its base, numerical reading was pressed and weighed for few minutes, then, turbidity value was recorded in Ntu (A.O.A.C., 2000).

3.3.11 Heavy Metals Determination in water and sediment samples

Lead (Pb), Iron (Fe), Zinc (Zn), Cadmium (Cd), Chromium (Cr), Calcium ion (Ca^{2+}) and Magnesium ion (Mg^{2+}) in water samples were determined using an Atomic Absorption Spectrophotometer, Model Analyst A10 PGP.About 2g of water soil sediment was air-dried, grinded and sieved using 2mm diameter sieve while the digestion was determined by heating 1gram of grinded soil sediment with 20ml of mixture of 70% $HCLO_4$ and concentrated HNO_3 (2:1) to near dryness and 20ml of 0.5M HNO_3 were added after cooling, sieved and add up to 50ml with distilled water. The amount of Pb, Cr, Cd, Zn, and Fe were determined using the above model AAS (A.O.A.C., 2000).

3.3.12 Benthic and Aquatic Insect Collections

The benthic organisms were collected from the sampling stations using a Van-veen grab with a surface area of 66.6cm^2. Sediments collected from each station were emptied into a pre labeled polythene bags. The sample collected from each station was sieved with a net of mesh size of 0.5mm to remove the excess sediments. Macro-invertebrates collected from the residue were stored in 70% alcohol (Fred, 2004), as preservative for onward transfer to the laboratory for identification. The benthic fauna was identified in the laboratory using aquatic benthic taxonomic keys, (Pennak, 1978; Fred, 2004; WHO, 1978). Extramadura keys for identification of Damsel flies and Dragon flies (John, 2012).

Aquatic insect collections were done using a dip-net of 500 µm mesh size. The net was dipped in water at different stations and swirled for about 2-3 minutes at the surface of water to allowed for the entrance of the aquatic insects and their nymphs and were emptied into pre-labelled plastic bottles according to stations. Adult insects like dragonflies, Damselflies were also gathered from the vegetation around the reservoir using a sweep net of mesh size of 250µm. The net was swept over vegetation for 2-3 minutes and were emptied into pre-labelled plastic bottles. Aquatic insects were identified using aquatic taxonomic keys, (Phyllis *et al.,* 1970; Pennak, 1978; Merritt and Cummins, 1996; Needham *et al.,* 2000; John, 2012).

The acronym used for the sampling stations were as follows:

SW-AR1=Station1 (surface water Aawon river 1)

SW-AR2=Station2 (surface water Aawon river 2)

SW-ER1=Station3 (surface water Erelu Reservoir 1)

SW-ER2=Station4 (surface water Erelu Reservoir 2)

SW-ER3=Station5 (surface water Erelu Reservoir 3)

SW-AR3=Station6 (surface water Aawon river 3)

SW-AR4=Station7 (surface water Aawon river 4)

SON= Standard Organization of Nigeria

WHO= World Health Organization

NESREA= National Environmental Standard and Regulation Enforcement Agency

3.4.0 Ecological Index Analysis

3.4.1 The total number of species was determined in each sampled stations using Margalef's species richness. Margalef Diversity Index **(d)** measures species richness and was expressed as:

Margalef Index (d) = $\frac{S-1}{LnN}$

S= no of species, Ln= The natural or Naperian logarithm, N= Total no of organisms,

3.4.2 Menhinick Index (D) is a diversity index initially proposed as a replacement for Margalef's and Gleason's index because it allowed wider comparison of different sample size. Its use is very limited in aquatic system. It is expressed as:

Menhinick (D) = $S/\sqrt{N}$

Where S=richness and N=number of individuals.

3.4.3 Shannon Weiner's diversity index (H) was used to examine family and species abundance of data collected from each sample station. Shannon-weiner's index **(H)** was expressed as:

Shannon's Index (H') $= \dfrac{N\log N - \sum f1\log f1}{N}$

3.4.4 Equitability **(J)** estimates even distribution of the species in a sampled community, i.e. Evenness is being used to examine equal distribution of the species to the maximum and was expressed as:

Equitability Index (J) $= \dfrac{H'}{H'\max} = \dfrac{H'}{\log S}$

Where,

H= Shannon Weiner's index

H_{max} = maximum possible diversity value given as logS

S= Numbers of genera

3.4.5 Jaccard's similarity Index (Ravera, 2001) was used to determine the similarities within the seven sampling stations which only take into consideration species number and not abundance and as a measure of community structure which was expressed as:

Jaccard Index (D) $= \dfrac{c}{a+b-c}$

Where a= number of species in sample A, b= number of species in sample B and c = number of species common to both samples.

3.4.6 Redundancy **(R)** is a measure of the extent that the dominance (abundance) is expressed by one or more species. It depends on the strength of internal association in the system and how individual are dispersed into species, having maximum value of one. It is at minimum when the species are equally frequent and a maximum when one species is represented by N-(S+1) individuals. Hence, as a measure of degree of organization in a system decreases, redundancy increases.

Redundancy (R) $= \dfrac{H'\max - H'}{H'\max - H'\min}$

H_{max} =maximum possible diversity value given as logs

H_{min} = minimum possible diversity = $\frac{1}{N} \ln \frac{N!}{(N-S+1)!}$ (Pielou, 1975)

3.4.7 Berger-Parker Dominance **(d)** estimates the abundance of the major numerically important species. The inverse of index d, which is 1/d is mostly used, so that an improvement in the value of index comes with a rise in diversity and a fall in dominance.

Dominance d = $\frac{N \max}{N}$

Where **Nmax** is the number of individuals in the most abundant species

N is the total number of individual in the sample (Berger and Parker, 1970)

3.5.0 Statistical Analysis

The results of laboratory analysis of physical and chemical parameters and data collected for benthic and aquatic insect macro-invertebrates were subjected to data analysis using SPSS, Version 20 to determine analysis of variance (ANOVA), while Duncan's Multiple Range Test (DMRT) was used to separate the means.

3.5.1 Descriptive Statistics

Mean, Standard error of means were also used and Pearson's Correlation Coefficient (r) was used to determine the relationship between physico-chemical parameters in relation to benthic and aquatic insect macro-invertebrates abundance. Test of significance (t-test) was used to determine seasonal variations of physico-chemical parameters.

CHAPTER FOUR

4.0 RESULTS

4.1 Climate

The summary of relative humidity, daily rainfall, minimum and maximum atmospheric temperature is presented in Table 4.1. The highest value of relative humidity recorded was 88% in August, 2014 and September, 2015, although the least value of 51% was recorded in January, 2015 and 61% in January, 2013 respectively. Highest daily rainfall of 231.10mm in September, 2013,184.00mm in April, 2013, 173.10mm in July 2013, 139.00mm in March, 2013 and 115.30mm in May, 2013 respectively. The highest value of daily rainfall of 221.40mm was recorded in October, 2014, 174.4mm in August, 2014, 170.10mm in May, 2014 and 143.10mm in April, 2014. Highest values of 184.30mm, 183.60mm, 180.90mm, 159.90mm and 132.20mm were recorded for rainfall in October, June, September, May and April, 2015 consecutively. The minimal values of 0.00mm were recorded in December, 2014 and January, 2015 and 0.20mm in December, 2015. The maximum temperature values of 35.10^{o}C was recorded in February, 2013, 2014 and 35.40^{o}C in February and March, 2015, while the least values of 21.10^{o}C were recorded in October, 2014, 21.30^{o}C in August, 2013, 21.80^{o}C in January, 2015, July, 2013 and August, 2014 respectively.

Generally, temperature had a mean values of 27.44$\pm$0.45 with a range of (24.75^{o}C-29.50^{o}C) in 2013, 27.50$\pm$0.43 with the range of (25.20-29.60^{o}C) in 2014, but mean values of 27.67$\pm$0.50 with a range of (25.75-30.25^{o}C) in 2015. Rainfall had a mean value of 97.52$\pm$20.56 with range values of (3.30-213.10mm) in 2013, 90.98$\pm$20.35 mean value with range of (0.00-221.40mm) in 2014 and 92.98$\pm$21.03mm with range of (0.00-184.30mm) in 2015. Relative humidity mean value was 78.75$\pm$2.14 and range of 61-87% in 2013, mean value of 80.58$\pm$1.69 with range of 67-88% in 2014 and mean value of 78.42$\pm$2.80 and range of 51-88% was recorded in 2015 respectively.

Table 4.1a: Monthly Climatological Data of Oyo State from 2013-2015

	RELATIVE HUMIDITY			RAINFALL			TEMPERATURE					
	2013	2014	2015	2013	2014	2015	2013		2014		2015	
MONTHS/YEARS							MAX.	MIN.	MAX.	MIN	MAX.	MIN.
JANUARY	61%	81%	51%	3.3	17.5	0.0	34.8	23.0	33.9	23.9	34.2	21.8
FEBRUARY	73%	73%	77%	64.4	37.2	17.7	35.1	23.8	35.1	24.1	35.4	24.9
MARCH	80%	79%	78%	139.0	68.2	54.4	34.1	23.7	34.0	23.9	35.4	25.1
APRIL	81%	80%	79%	184.0	143.1	132.2	33.2	23.6	32.9	23.6	34.2	24.4
MAY	79%	79%	80%	115.3	170.1	159.9	31.8	23.0	32.2	23.5	32.8	24.0
JUNE	82%	83%	84%	54.7	85.1	183.6	30.5	23.0	30.9	23.3	30.2	22.0
JULY	86%	85%	85%	173.1	77.5	36.7	28.5	21.8	29.3	22.7	29.0	22.6
AUGUST	84%	88%	86%	52.4	174.4	95.4	28.2	21.3	29.6	21.8	29.4	22.4
SEPTEMBER	87%	87%	88%	213.1	28.2	180.9	29.7	22.2	29.2	22.2	29.3	22.2
OCTOBER	82%	83%	82%	131.2	221.4	184.3	31.0	22.4	30.6	21.1	31.4	22.6
NOVEMBER	80%	82%	79%	11.0	69.1	70.5	33.1	23.6	32.2	23.5	30.2	22.5
DECEMBER	70%	67%	72%	28.7	0.0	0.2	33.4	23.6	33.5	23.9	33.4	23.0

Source: NIMET. Ibadan, Oyo State

Table 4.1b: Seasonal Climatological Data of Oyo State from 2013-2015

Parameters	Seasons	2013	2014	2015
Relative Humidity (%)	**Rainy**	**83.00±1.07** 79.00-87.00	**83.57±1.27** 79.00-88.00	**83.43±1.23** 79.00-88.00
	Dry	**72.80±3.54** 61.00-80.00	**76.40±2.82** 67.00-82.00	**71.40±5.24** 51.00-79.00
Rainfall (mm)	**Rainy**	**131.97±23.68** 52.00-213.00	**128.54±25.46** 28.00-221.00	**139.00±21.07** 37.00-184.00
	Dry	**49.28±24.78** 3.30-139.00	**38.40±13.68** 0.00-69.10	**28.56±14.43** 0.00-70.50
Temperature (oC)	**Rainy**	**26.44±0.48** 24.75-28.40	**26.64±0.41** 25.70-28.25	**26.89±0.54** 25.75-29.30
	Dry	**28.82±0.19** 28.35-29.45	**28.80±0.28** 27.85-29.60	**28.59±0.73** 26.35-30.25

Source: NIMET. Ibadan, Oyo State

4.2. Physical and Chemical Parameters

Summary of seasonal variations in physical and chemical parameters for Erelu Reservoir and each of its sampled locations are presented in table 4.2. and monthly variation for each parameter are presented as Figs. 2-14.

4.2.1 Transparency

Transparency values in the dry season were higher generally than the wet season values. Higher transparency value of 96.30 ± 5.19cm was recorded in the dry season in station 5, while the least mean value of 40.46 $\pm$ 3.77cm was recorded in the wet seasons in station 7. Monthly variation of transparency presented in figures. 2, 3 and 4 showed that stations 3, 4, 5 (reservoir) were higher across months and highest values were recorded in November, 2013, December, 2013 and 2014 and January, 2015. Summarily, it was also shown that across the year, highest values were recorded during dry season and lowest values during rainy seasons.

4.2.2 Turbidity

Rainy season turbidity ranged between 0.00-66.80 NTU with least mean values 11.87 ± 4.74 NTU recorded in station 4 and maximum mean value 18.48 ± 6.94 NTU was recorded in station 7. Values of 0.00-64.70 NTU were recorded during the dry season and mean concentration of 2.68 ± 0.89 was the least in station 5 while peak mean concentration of 10.58 ±6.30 was recorded in station 2. The highest concentration of turbidity was recorded for all stations in September 2014 and lowest values were recorded in April and March, 2015. Turbidity concentration values were higher during rainy season in 2013, 2014 but lower in 2015 (Figs.5 and 6).Inlet and outlet points recorded highest values in the reservoir in 2013 and 2014 (Fig. 7).

4.2.3 Temperature

Temperature mean value of 28.10±0.34^{o}C being the maximum value in station 4 and the least mean value of 27.52± 0.32^{o}C was recorded during rainy season at station 6, while range of 28.00- 32.60^{o}C was the highest value across stations during dry season. The highest average value of 30.08±0.29^{o}C was recorded in station 6, while the least value of

29.39±0.28°C was recorded in station 1 during dry season. Seasonal variation showed that in 2015, highest temperature values were recorded during rainy season while lowest values were recorded in 2013 and 2014 (Fig.9).

4.2.4 Calcium ion

Calcium ion ranged from 2.44-35.20 mg/L during the wet season with the elevated mean concentration of 17.32 ± 2.44 mg/Lwas recorded in stations 1 and least mean concentration of 14.74 ± 1.93 in station 5. During dry season, it ranged from 7.20-35.00 mg/L and maximum mean value of 20.16 ± 1.63 and 20.00 ± 1.43 mg/L were recorded repectively in 6th and 7th stations and least mean value of 17.20±1.11 mg/L was recorded in station 5.Monthly variation in calcium ion showed high concentration in June, 2013 and low concentration in July, 2014, April, 2014 and 2015, February, 2015. Highest concentrations were recorded during dry season in 2014 and 2015 but lower concentration in 2013 (Figs. 11, 12 and 13).

4.2.5 Magnesium ion

Magnesium ion range of 0.49-34.00 mg/L in the rainy season with a peak average concentration of 10.88 ± 1.93 mg/L in station 5and least average value 8.37 ± 1.78 mg/L was recorded in station 1, while during dry season, it ranged from 0.34 - 26.00 mg/L with elevated mean of 6.68 ± 2.43 mg/L recorded for station 3 and least mean concentration of 4.54 ± 0.78 mg/L was recorded for station 5. Monthly variation showed that highest Mg ion concentrations were observed in station 2 and 3 in September, 2014, station 3 and 6 in February, 2014 and that during rainy season highest values were recorded in 2013, 2014 and 2015 with the exception of the reservoir that recorded lower concentration in 2013 (figs. 14, 15 and 16).

Table 4.2: Seasonal variation of physical and chemical parameters of Erelu Reservoir in Oyo Town between June 2013 to May 2015

Parameters	Seasons	SW-AR1	SW-AR2	SW-ER1	SW-ER2	SW-ER3	SW-AR3	SW-AR4
Transparency (cm)	**Rainy**	**44.07±3.88**	**41.86±3.32**	**76.07±1.40**	**78.40±1.65**	**79.36±1.90**	**41.61±3.69**	**40.46±3.77**
		22.50-75.00	23.00-75.00	70.00-85.00	70.00-90.00	70.00-95.00	23.00-70.00	22.00-75.00
	Dry	**61.00±4.82**	**58.50±5.43**	**92.25±3.51**	**94.75±3.62**	**96.30±5.19**	**61.50±5.82**	**60.20±5.49**
		40.00-80.00	25.00-85.00	72.50-110.00	77.50-115.00	75.00-120.00	35.00-90.00	35.00-85.00
Turbidity (NTU)	**Rainy**	**13.92±3.59**	**13.50±3.89**	**15.38±5.25**	**11.87±4.74**	**12.78±4.18**	**17.86±7.02**	**18.48±6.94**
		0.00-50.72	0.00-57.90	0.00-64.60	0.54-66.80	0.96-63.50	0.13-101.5	ND-19.13
	Dry	**6.68±3.33**	**10.58±6.30**	**4.20±0.98**	**2.90±0.76**	**2.68±0.89**	**3.94±0.97**	**5.07±1.91**
		0.40-36.00	0.23-64.70	1.42-11.21	0.72-8.50	0.00-7.82	0.00-8.40	0.00-19.13
Temperature (^{o}C)	**Rainy**	**27.54±0.39**	**27.69±0.39**	**28.00±0.29**	**28.10±0.34**	**27.70±0.41**	**27.52±0.32**	**27.60±0.39**
		25.50-29.20	25.50-29.50	25.70-29.00	25.80-29.20	25.50-29.20	25.60-29.00	25.40-29.80
	Dry	**29.39±0.28**	**29.82±0.39**	**29.40±0.30**	**29.67±0.29**	**29.72±0.32**	**30.08±0.29**	**29.93±0.25**
		28.00-30.60	28.30-32.60	28.00-30.90	28.20-31.10	28.50-31.60	28.40-31.80	29.10-31.70
Calcium ion (mg/L)	**Rainy**	**17.32±2.44**	**16.72±2.11**	**16.02±2.23**	**14.78±2.00**	**14.74±1.93**	**15.90±1.97**	**15.75±2.11**
		2.44±35.20	2.93-30.40	3.42-32.00	2.93-28.80	3.90-28.00	3.42-28.00	2.93-29.60
	Dry	**18.00±2.46**	**19.44±2.31**	**18.40±1.38**	**19.68±1.94**	**17.20±1.11**	**20.16±1.63**	**20.00±1.43**
		720-35.00	8.00±31.20	11.20-24.80	11.20-32.00	12.00-24.00	10.40-28.00	11.20-27.20
Magnesium ion (mg/L)	**Rainy**	**8.37±1.78**	**9.15±2.20**	**9.81±2.21**	**9.04±2.02**	**10.88±1.93**	**8.38±1.42**	**8.64±2.00**
		1.46-26.00	0.98-34.00	0.97-30.00	0.98-30.00	1.46-29.00	0.49-20.00	0.49-26.00
	Dry	**6.06±1.09**	**5.45±1.24**	**6.68±2.43**	**4.70±0.87**	**4.54±0.78**	**5.85±2.14**	**6.64±2.29**
		0.82-12.00	0.62-11.71	0.34-28.00	0.43-10.00	0.43-8.30	0.48-24.00	0.62-26.00

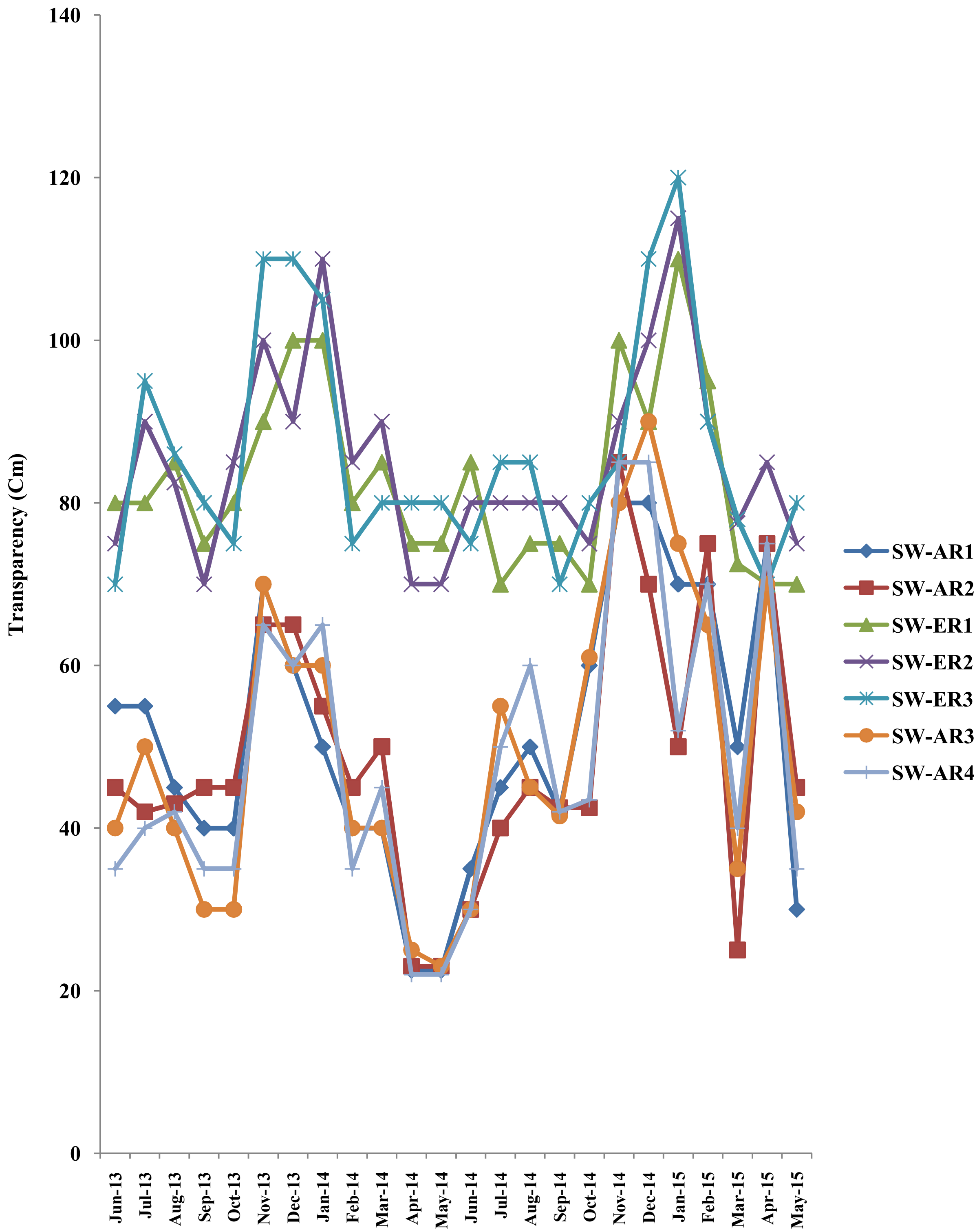

Fig. 2: Monthly Transparency of Erelu reservoir across sampling stations from June 2013 to May 2015

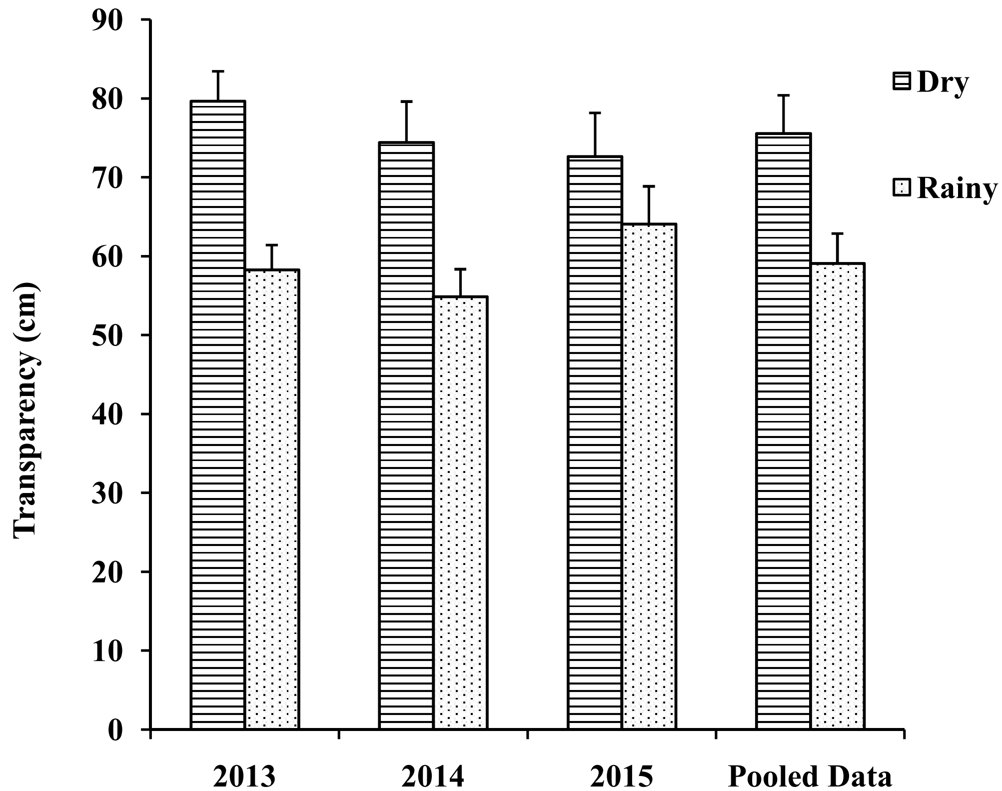

Fig. 3: Annual and pooled seasonal variation in transparency of Erelu Reservoir in oyo town, Nigeria

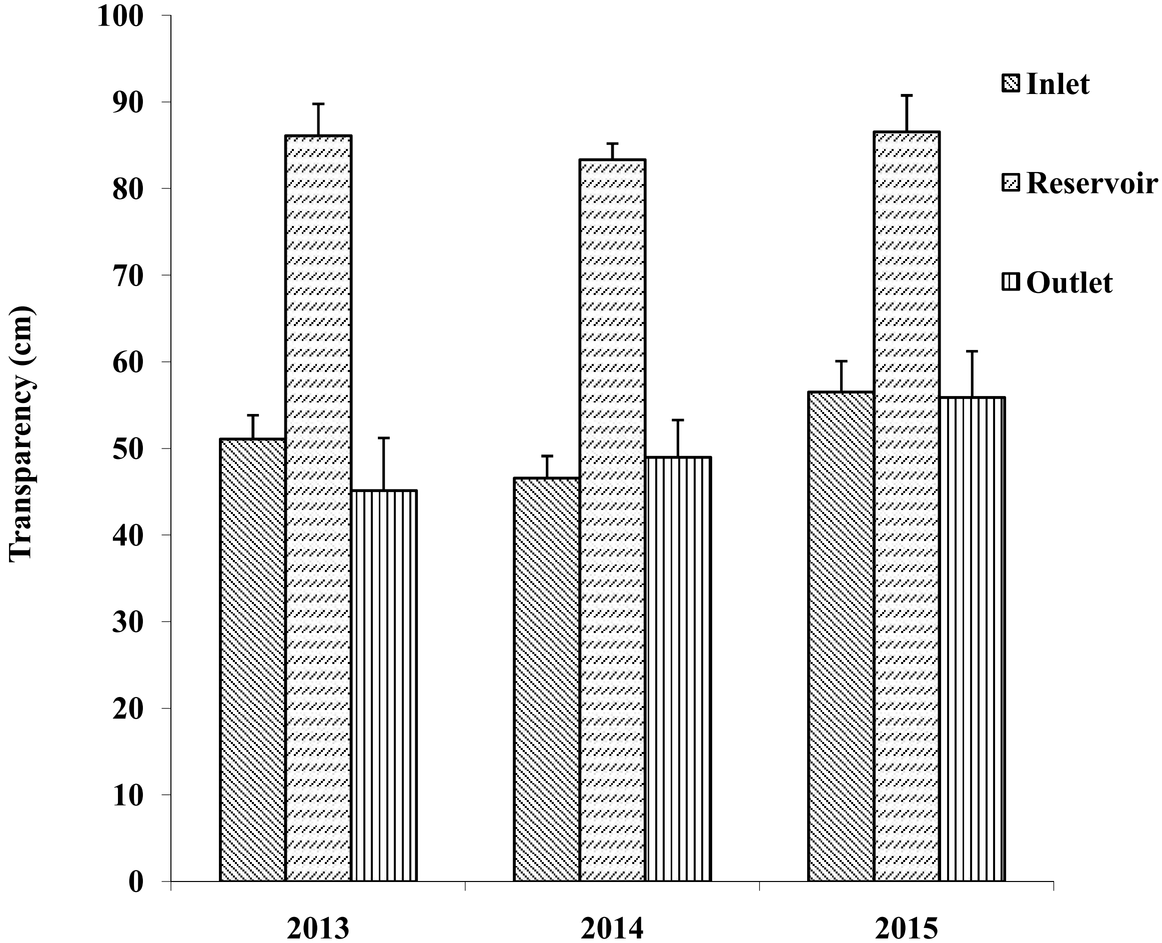

Fig. 4: Annual spatial variation in transparency of Erelu Reservoir in Oyo Town, Nigeria

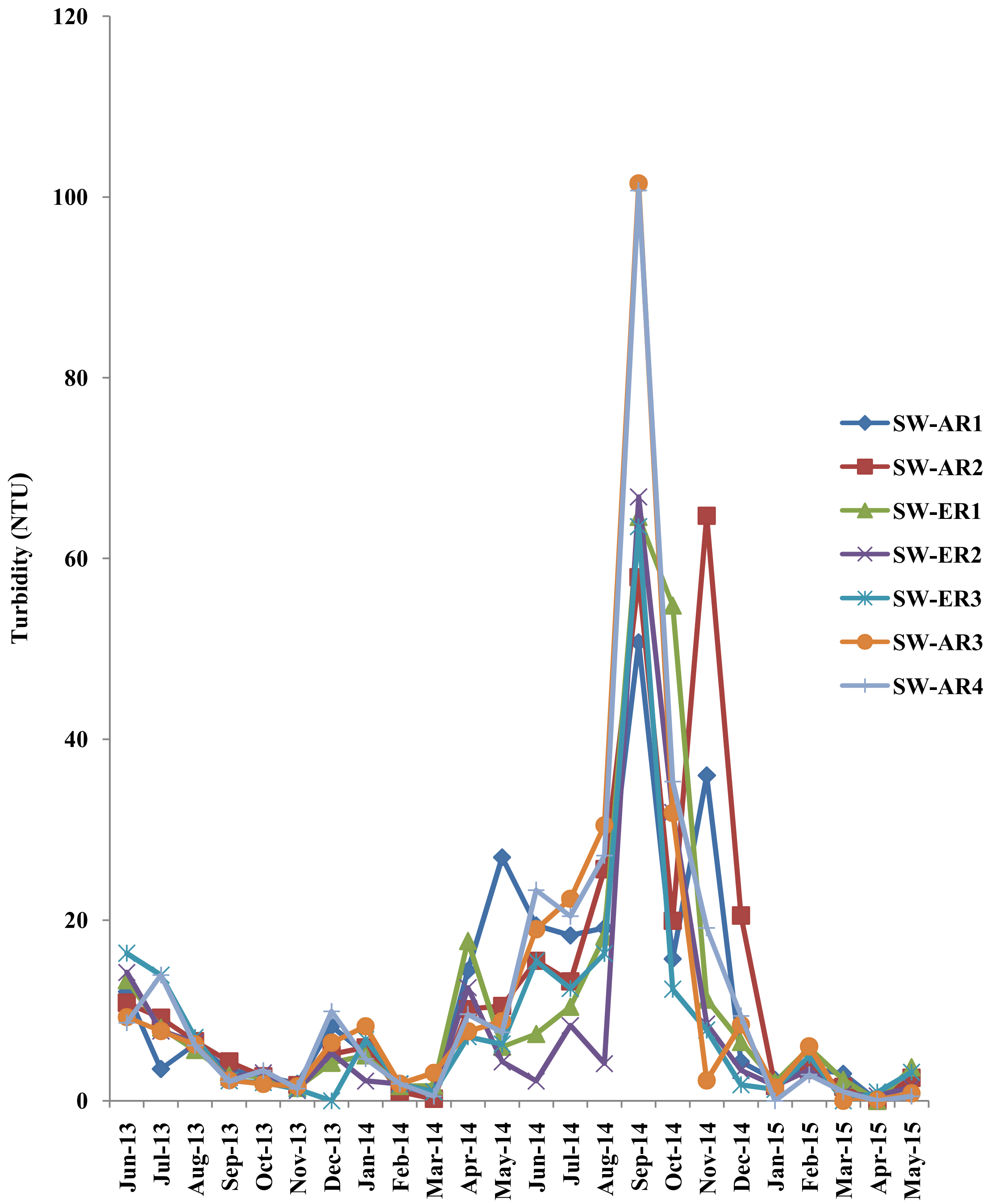

Fig.5: Monthly Turbidity of Erelu Reservoir across sampling stations from June 2013 to May 2015

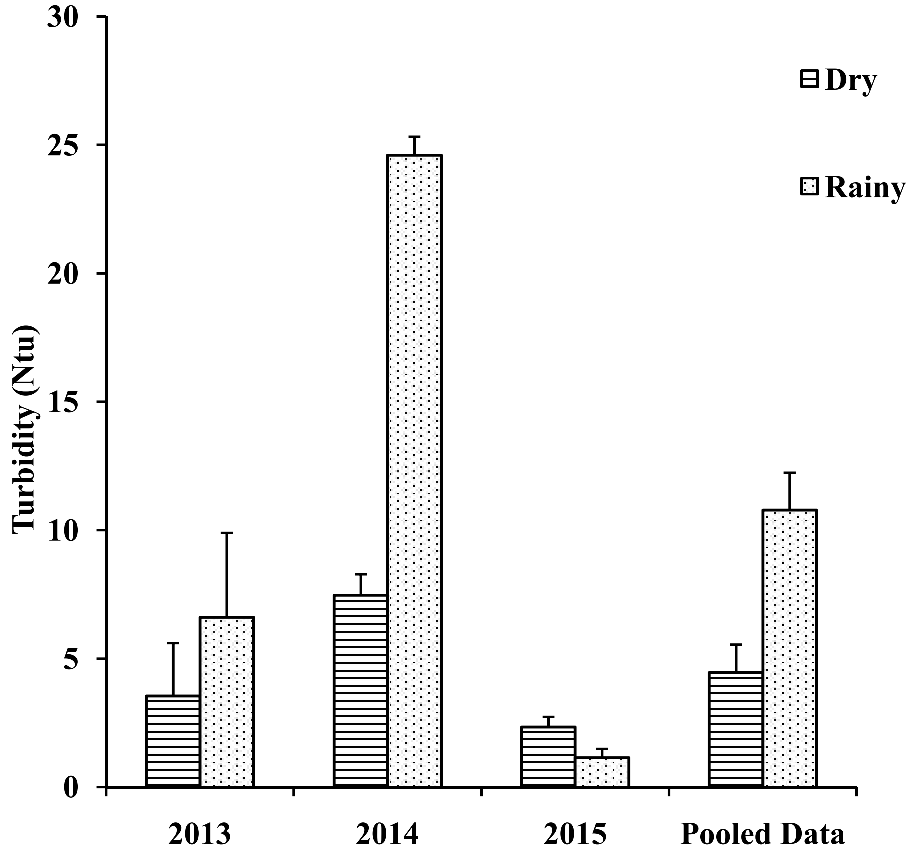

Fig. 6: Annual and pooled seasonal variations in turbidity of Erelu Reservoir in Oyo Town, Nigeria

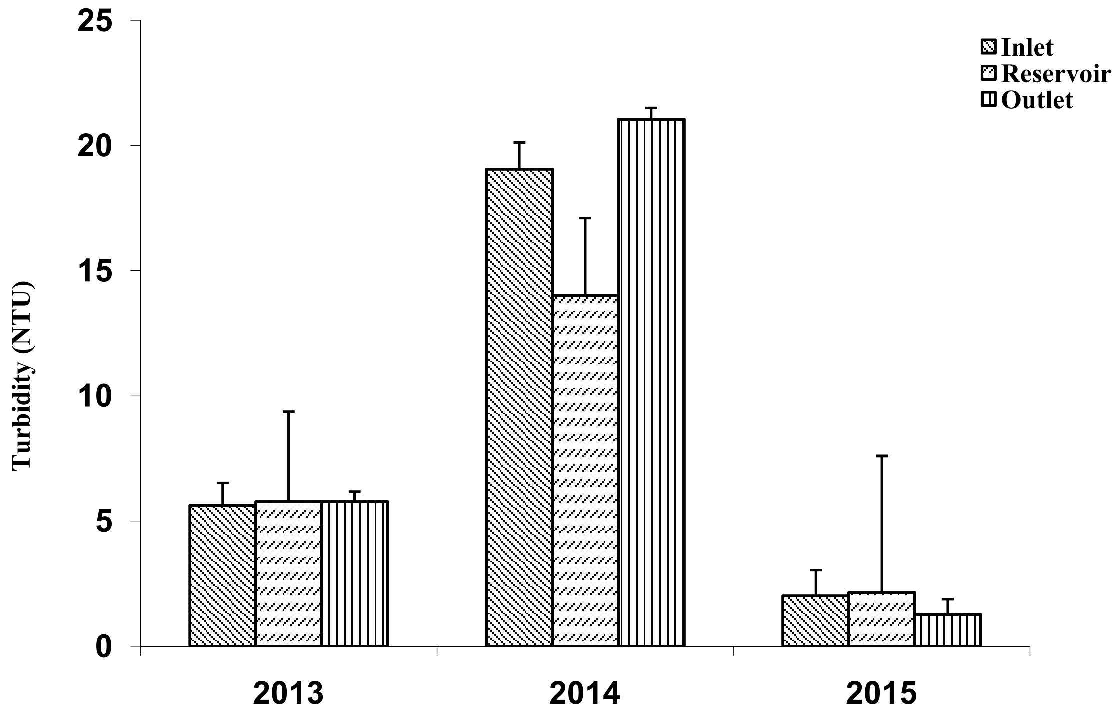

Fig. 7: Annual spatial variations in turbidity of Erelu Reservoir in Oyo Town, Nigeria

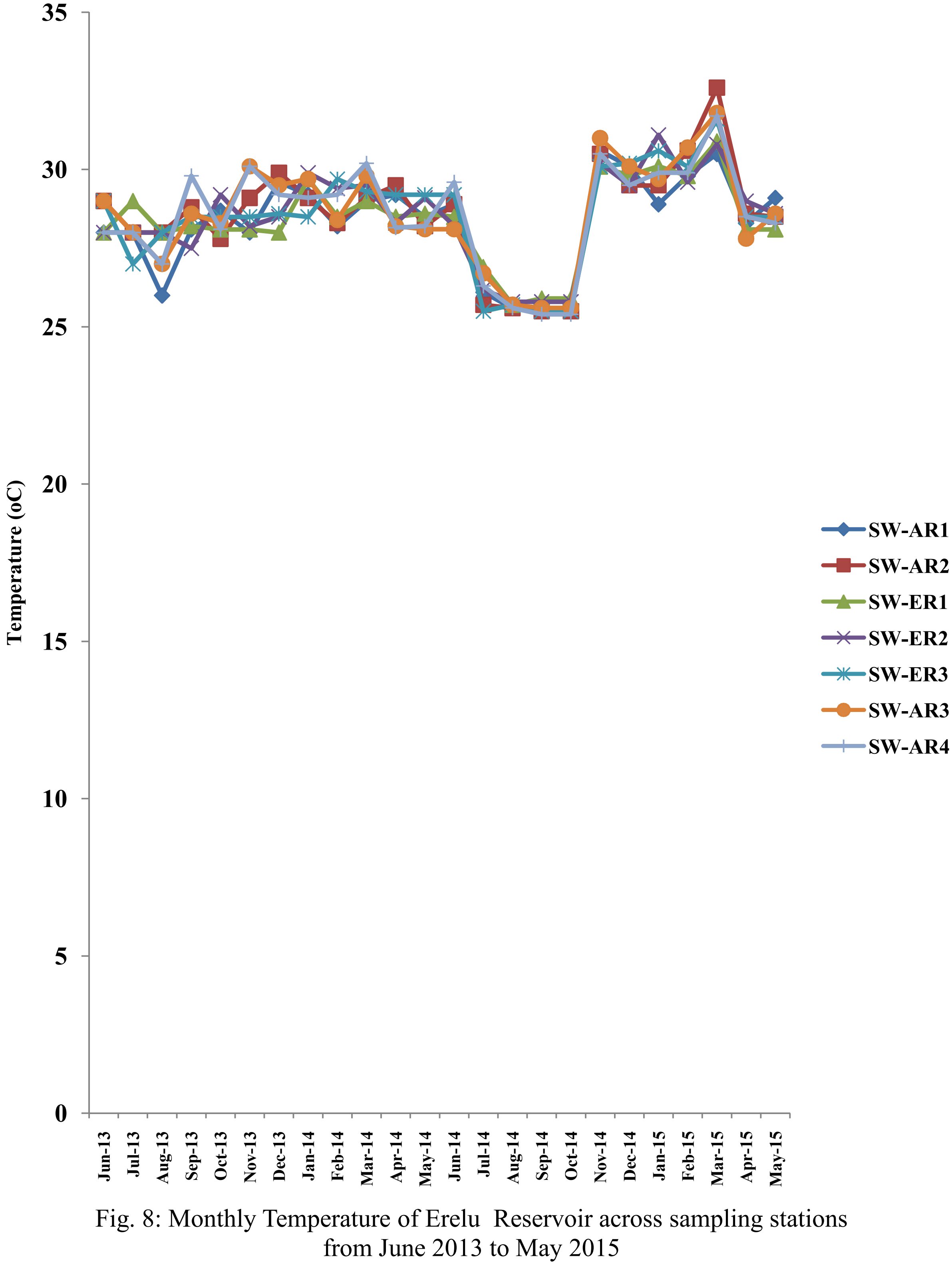

Fig. 8: Monthly Temperature of Erelu Reservoir across sampling stations from June 2013 to May 2015

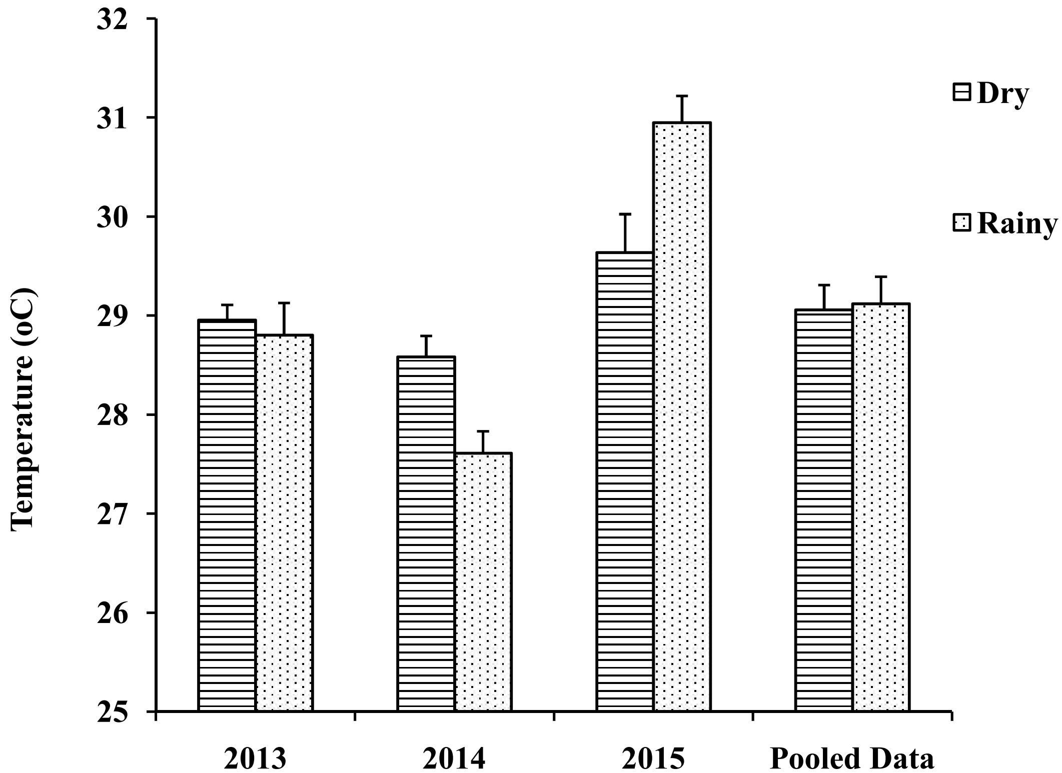

Fig. 9:Annual and pooled seasonal variation in temperature of Erelu Reservoir in Oyo Town, Nigeria

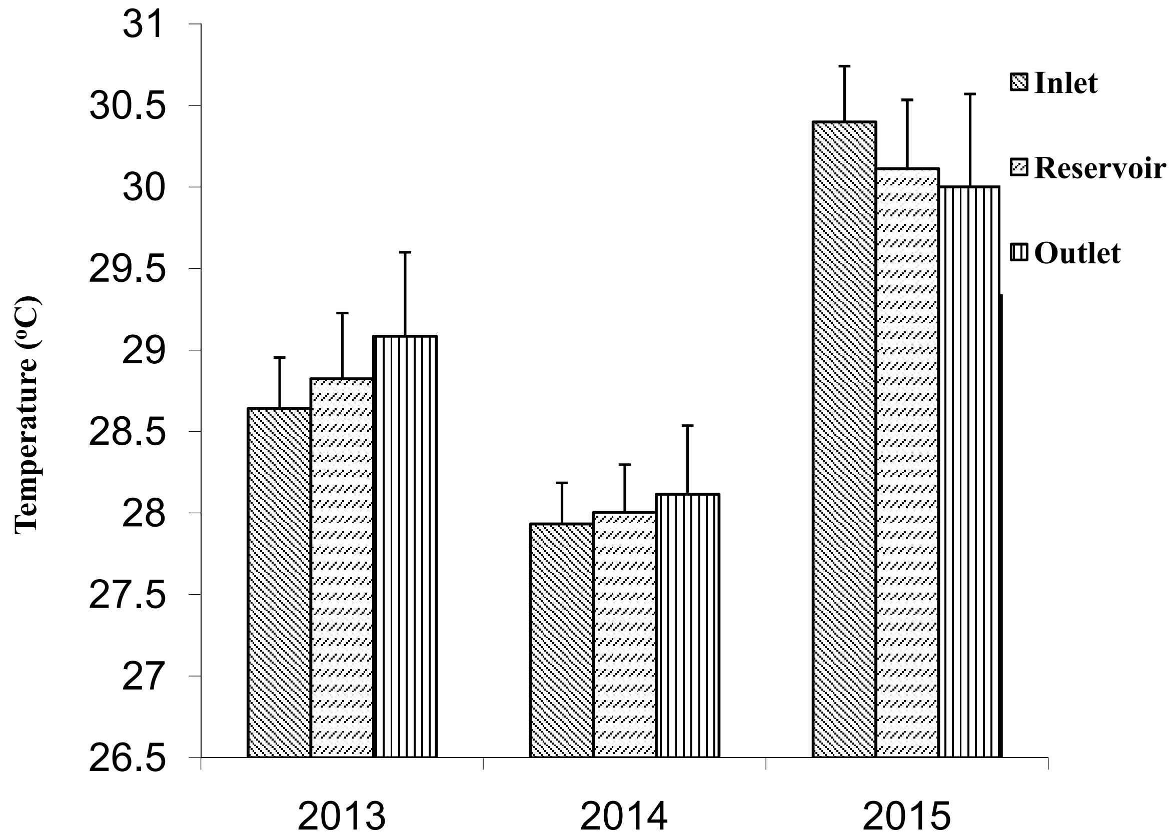

Fig.10: Annual spatial variation in temperature of Erelu Reservoir in Oyo Town, Nigeria

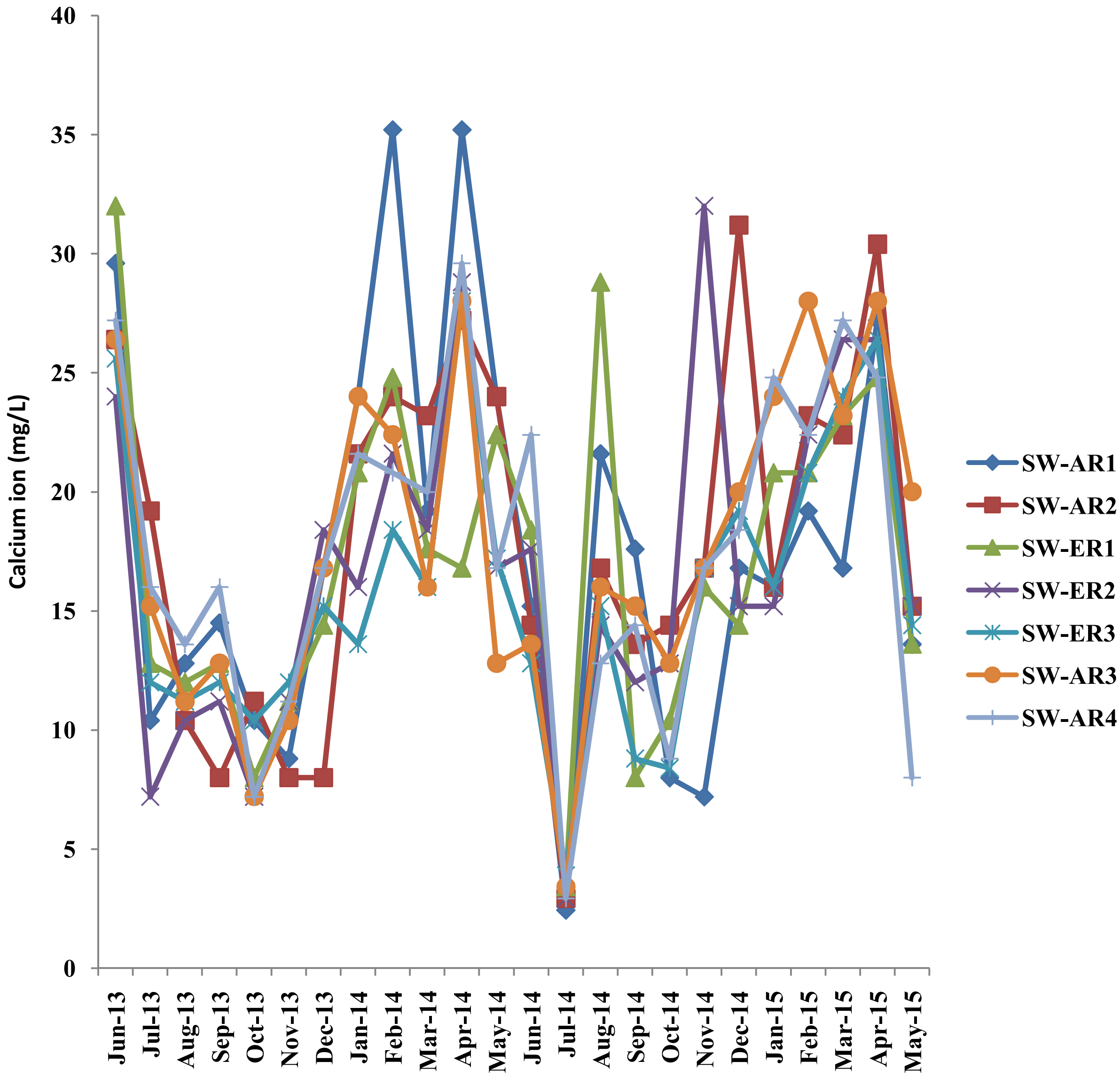

Fig.11: Monthly Calcium ion concentration of Erelu reservoir across sampling stations from June 2013- May 2018

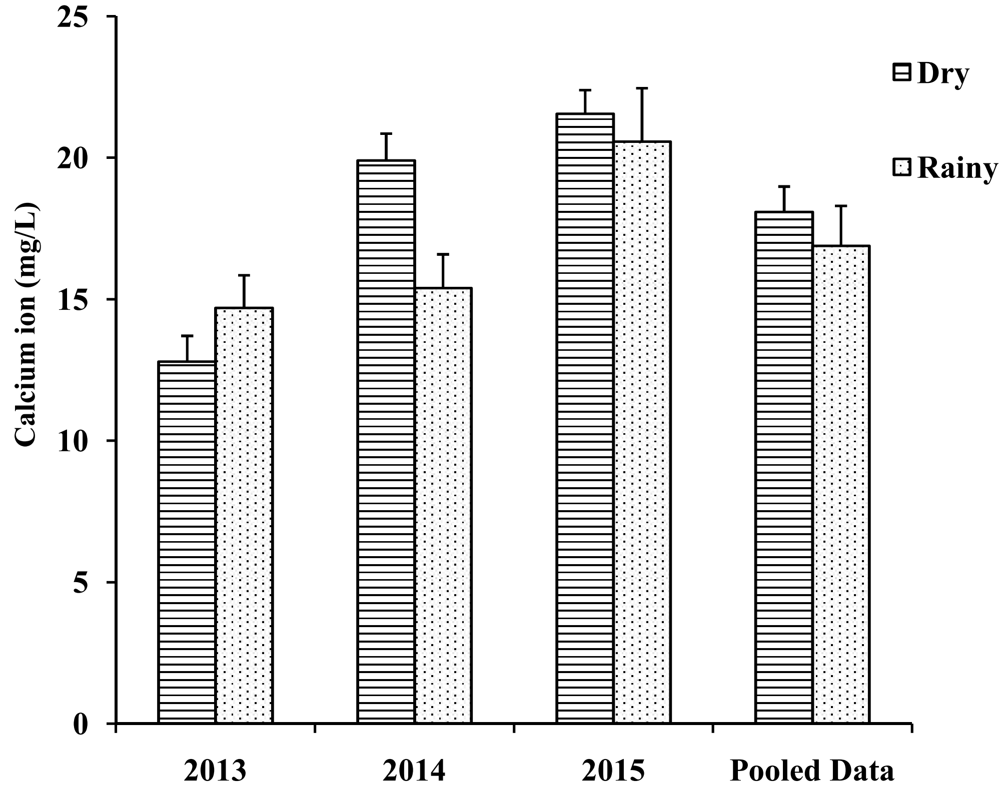

Fig.12: Annual and pooled seasonal variations in Calcium ion concentration of Erelu Reservoir in Oyo Town, Nigeria

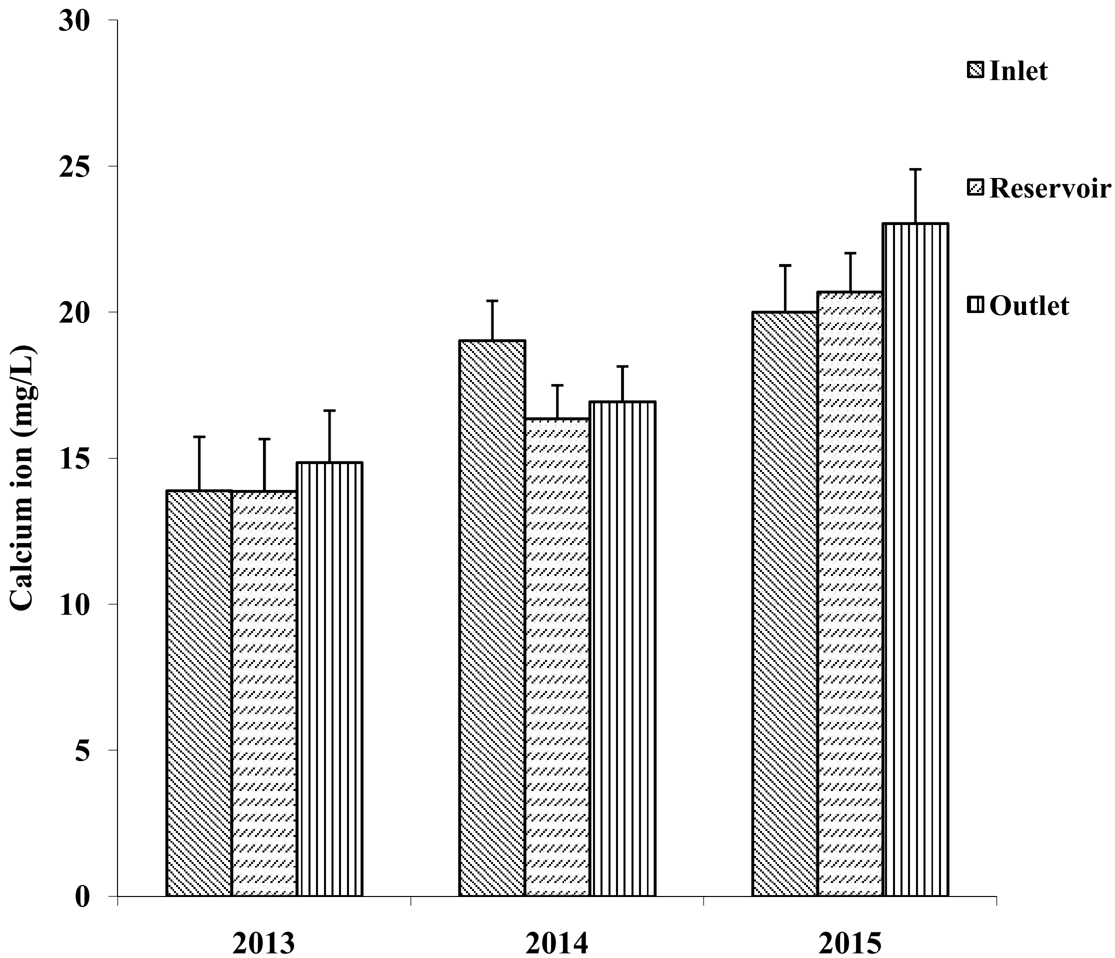

Fig.13: Annual spatial variations in Calcium ion concentration of Erelu Reservoir in Oyo Town, Nigeria

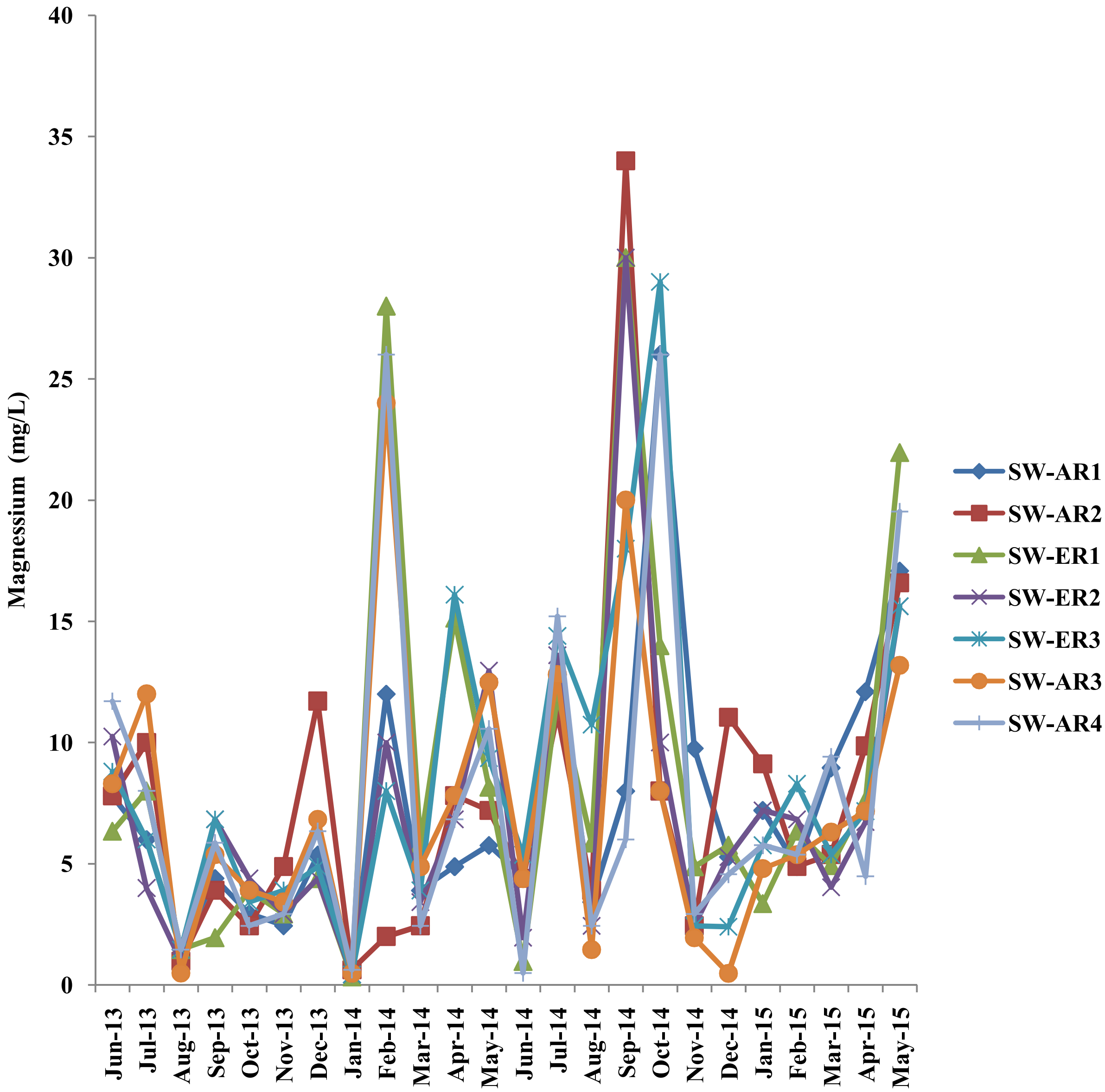

Fig. 14: Monthly Magnessium ion concentration of Erelu Reservoir across sampling stations during study from June 2013 to May 2015

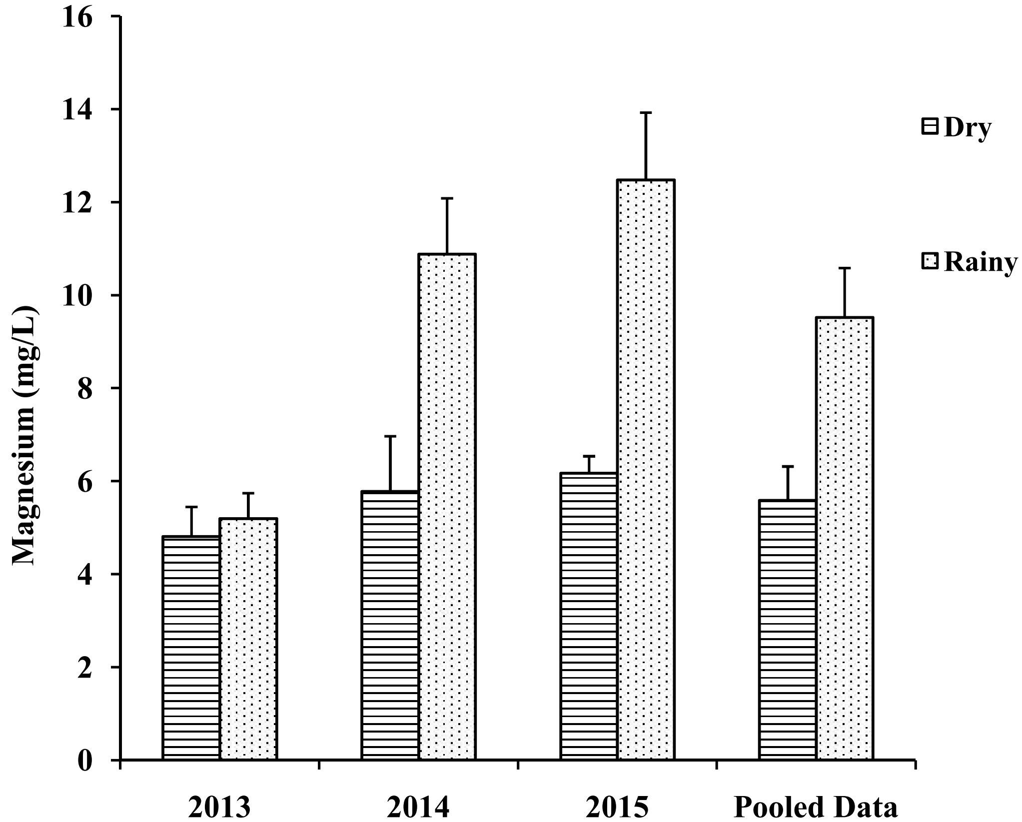

Fig.15: Annual and pooled seasonal variations in magnessium ion concentration of Erelu Reservoir in Oyo Town, Nigeria

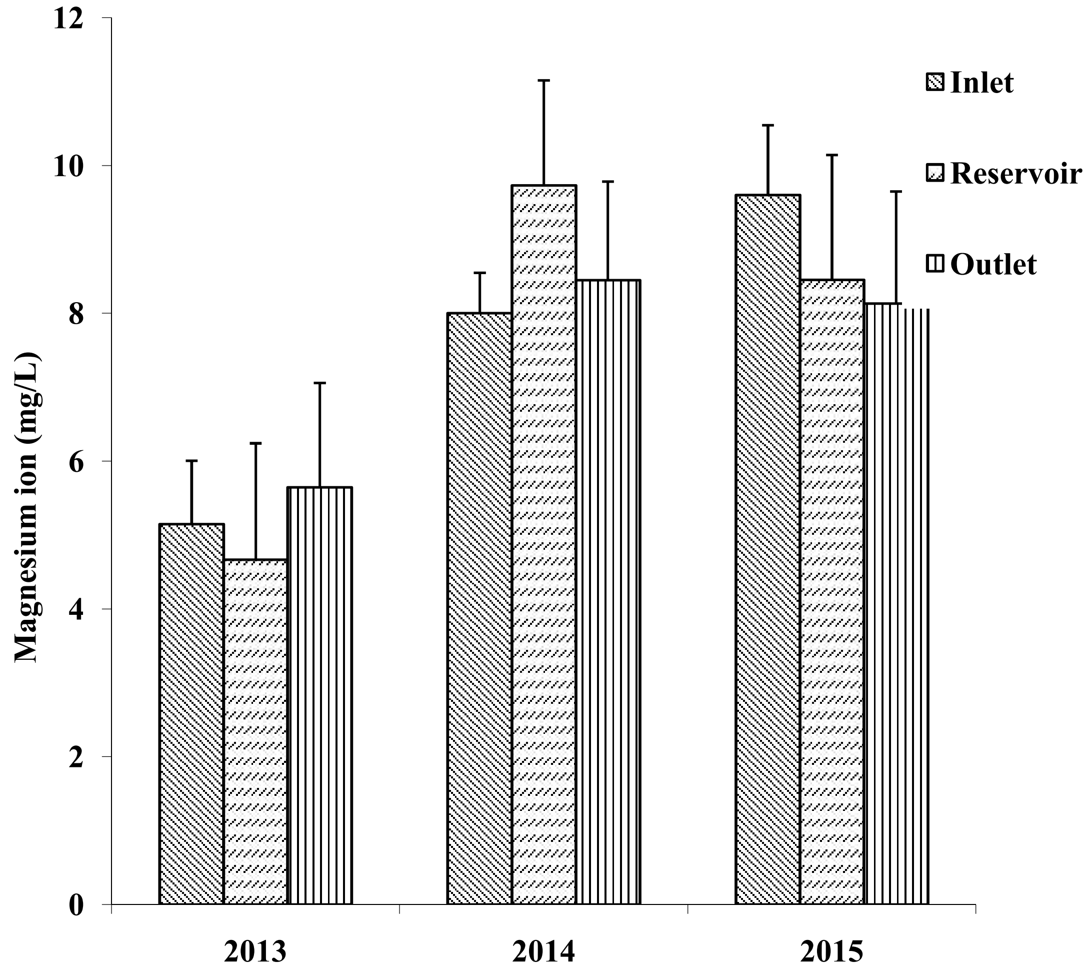

Fig.16: Annual spatial variations in magnessium ion concentration of Erelu Reservoir in Oyo Town, Nigeria

4.2.6 Phosphate

Phosphate ranged from 0.01- 0.77 mg/L with highest mean value of 0.30 ± 0.18 mg/L in station 6 and least mean value of 0.10 ± 0.03 and 0.10 ± 0.04 mg/L were recorded for station 1 and 2 during wet season respectively. It ranged from 0.01-0.46 mg/L with highest mean value of 0.10 ± 0.04 mg/L observed in station 3 and 6 and minimum mean concentration of 0.08 ± 0.03 mg/L was recorded in station1 during dry season. Monthly variation showed higher concentration of Phosphate in station 4 and 7 in July, 2013 and highest value was recorded in station 6 in October, 2014, high concentration values in wet seasons were recorded in 2013 and 2014 but least mean values were observed in 2015. Highest values across stations were recorded in 2013 compared to 2014 and 2015 (Figs.17, 18 and 19).

4.2.7 Nitrate

Nitrate range of 0.00-3.89 mg/L with mean value ranging from 0.75 ± 0.20 and 1.60 ± 0.37 recorded across all sampled points in the wet season while a range of 0.00-3.12 mg/L with highest mean value of 0.65 ± 0.33 was recorded in station 3 and least mean concentration of 0.26 ± 0.15 was recorded for station 6 in the dry season. Seasonal variation showed that nitrate values were higher during rainy season in 2013, 2014 but low concentrations were observed during wet season in 2015. Maximum concentration values were recorded across stations in October, 2013. Nitrate in some stations were not detected in January, February, September and December 2014 respectively. (Figs. 20 and 21).

4.2.8 Dissolved Oxygen (DO)

DO range of 5.68-14.60 mg/L with the maximum mean value of 8.85 ± 0.50 mg/L recorded in station 1, the least mean concentration 8.48 ± 0.40 also recorded in station 4 in the wet season while during dry season, it ranged from 3.96-12.20mg/L with highest mean concentration of 8.44 ± 0.54 mg/L was recorded in 6th station and least concentration of 7.54 ± 0.51 mg/L was recorded in station 3. Monthly profile revealed that highest concentrations of DO were recorded in June 2013, and least value in April 2014 across stations. DO concentration recorded most elevated values during rainy season in 2013.

Values of inlet and outlet points were higher, when compared with the reservoir stations across season periods (Figs. 22, 23 and 24).

4.2.9 Biological Oxygen Demand (BOD)

BOD range of 0.03-4.39 mg/L with the least mean concentration of 0.93 ± 0.23 mg/L recorded in station 5 and maximum mean value of 1.13 ± 0.28 was recorded in station 2 in rainy season while it ranged between 0.00-7.38 mg/L with the peak mean value of 1.73±0.72 mg/L recorded in station 1 and the least value of 0.75 ± 0.36 mg/L was recorded for station 5 during the dry months. The BOD profile showed highest concentration values in January, 2014 and lowest values in August, 2013 across stations. Highest concentrations were recorded during dry season in 2014 while maximum values were also recorded during wet season in 2013 and 2015. There were low values across the reservoir stations and increased values in the inlet and outlet stations from 2013-2015 (Figs. 25, 26 and 27).

Table 4.2: Summary of seasonal variation of physical and chemical parameters of Erelu Reservoir in Oyo Town contd.

Parameters	Seasons	SW-AR1	SW-AR2	SW-ER1	SW-ER2	SW-ER3	SW-AR3	SW-AR4
Phosphate (mg/L)	**Rainy**	**0.10±0.04**	**0.10±0.03**	**0.11±0.04**	**0.11±0.06**	**0.26±0.19**	**0.30±0.18**	**0.28±0.19**
		0.01-0.48	0.01-0.43	0.01-0.59	0.01-0.77	0.02-2.73	0.01-2.50	0.01-2.73
	Dry	**0.08±0.03**	**0.09±0.04**	**0.10±0.04**	**0.09±0.03**	**0.09±0.04**	**0.10±0.04**	**0.09±0.04**
		0.01-0.37	0.01-0.44	0.02-0.46	0.01-0.37	0.01-0.41	0.04-0.45	0.20-0.44
Nitrate (mg/L)	**Rainy**	**0.82±0.20**	**0.86±0.20**	**1.47±0.33**	**1.43±0.36**	**1.60±0.37**	**0.88±0.18**	**0.75±0.20**
		0.05-2.66	ND-2.69	0.005-3.89	ND-2.79	0.03-3.89	0.02-2.45	0.04-2.88
	Dry	**0.30±0.020**	**0.36±0.25**	**0.65±0.33**	**0.64±0.33**	**0.62±0.36**	**0.26±0.15**	**0.31±0.18**
		ND-2.09	0.003-2.54	ND-3.12	ND-2.92	ND-2.79	ND-1.56	0.002-1.89
Dissolved Oxygen (mg/L)	**Rainy**	**8.85±0.50**	**8.75±0.42**	**8.76±0.48**	**8.48±0.40**	**8.58±0.26**	**8.55±0.35**	**8.55±0.40**
		6.10-14.60	6.22-13.20	6.44-14.00	5.68-12.00	6.76-10.80	6.42-12.00	6.18-12.20
	Dry	**8.00±0.62**	**8.00±0.42**	**7.54±0.51**	**8.33±0.36**	**8.00±0.26**	**8.44±0.54**	**8.08±0.15**
		3.96-11.00	5.47-10.70	3.36-9.20	6.96-11.30	6.30-9.38	6.02-12.20	6.95-8.62
Biological Oxygen Demand (mg/L)	**Rainy**	**1.00±0.29**	**1.13±0.28**	**1.08±0.29**	**1.00±0.28**	**0.93±0.23**	**1.03±0.26**	**0.99±0.24**
		0.03-4.23	0.06-4.39	0.04-4.38	0.04-4.01	0.15-3.39	0.14-3.95	0.05-3.72
	Dry	**1.73±0.72**	**1.29±0.58**	**1.41±0.59**	**1.46±0.65**	**0.75±0.36**	**1.65±0.70**	**1.40±0.61**
		ND-7.03	0.14-6.19	0.09-4.90	0.19-6.77	0.01-3.84	0.23-7.38	0.01-5.20

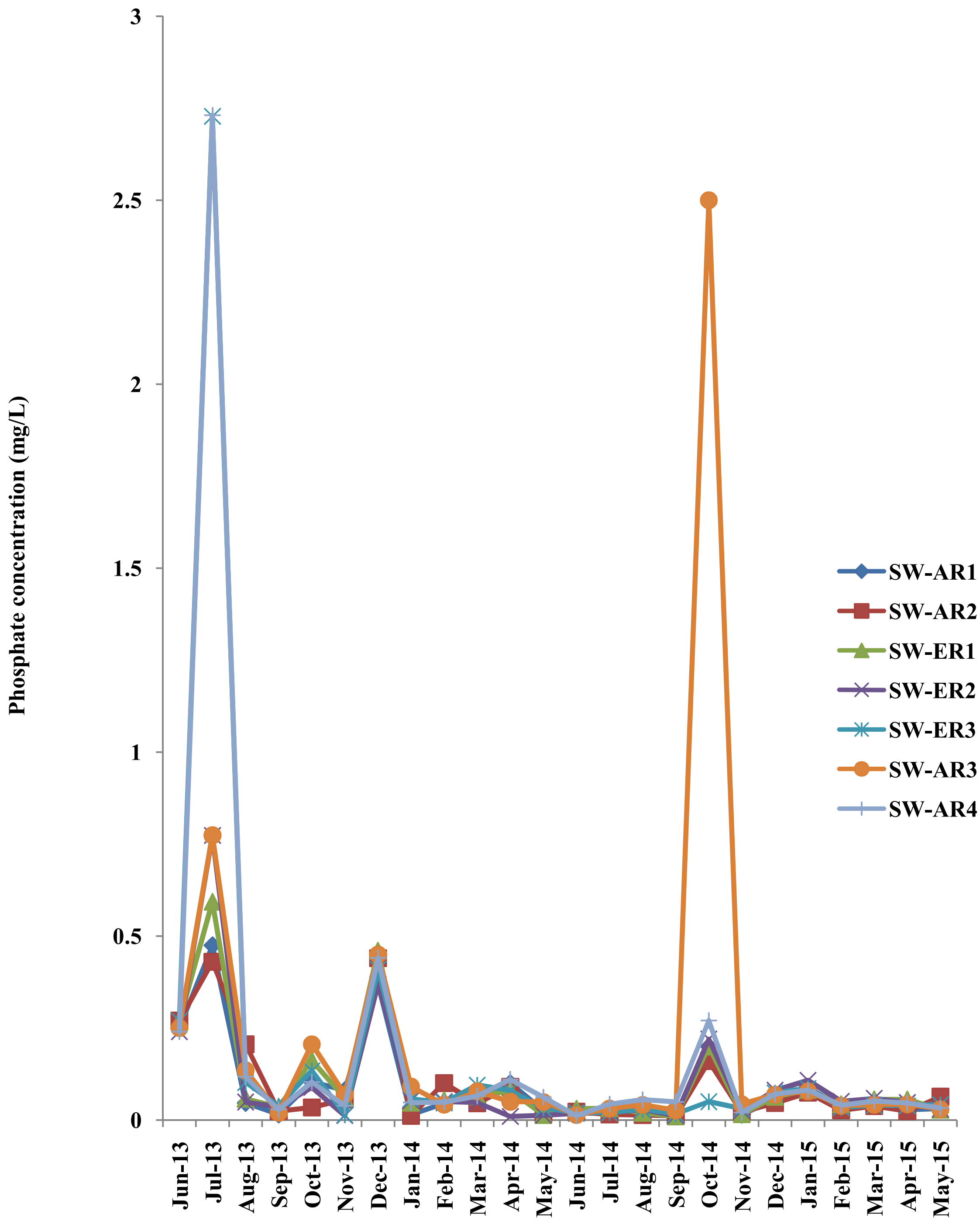

Fig. 17: Monthly Phosphate concentration of Erelu Reservoir across sampling stations from June 2013 to May 2015

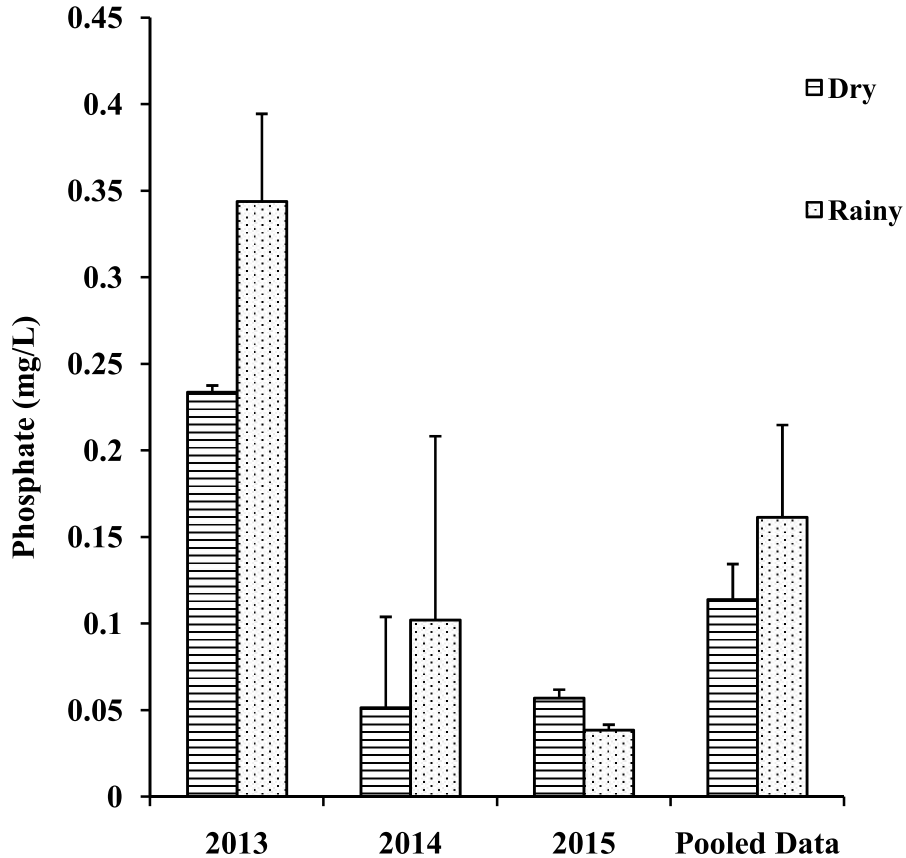

Fig.18: Annual and pooled seasonal variations in Phosphate concentration of Erelu Reservoir in Oyo Town, Nigeria

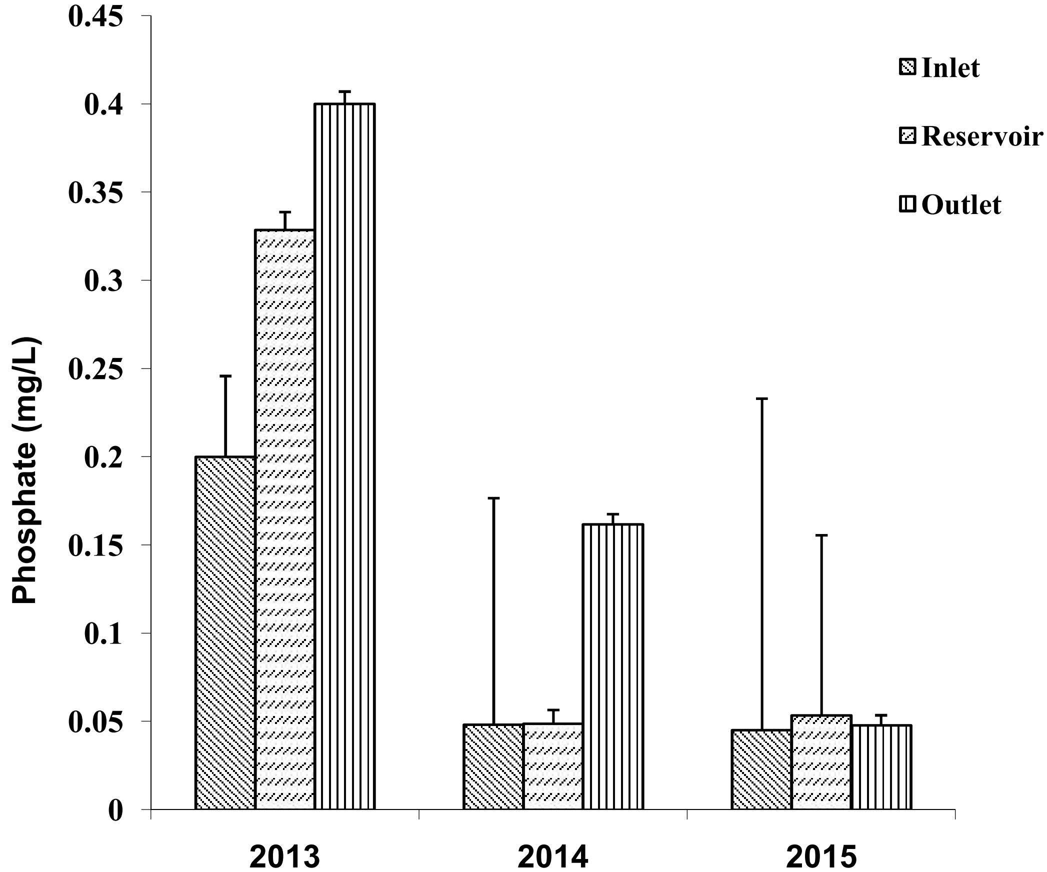

Fig. 19: Annual spatial variation in Phophate concentration of Erelu Reservoir in Oyo Town, Nigeria

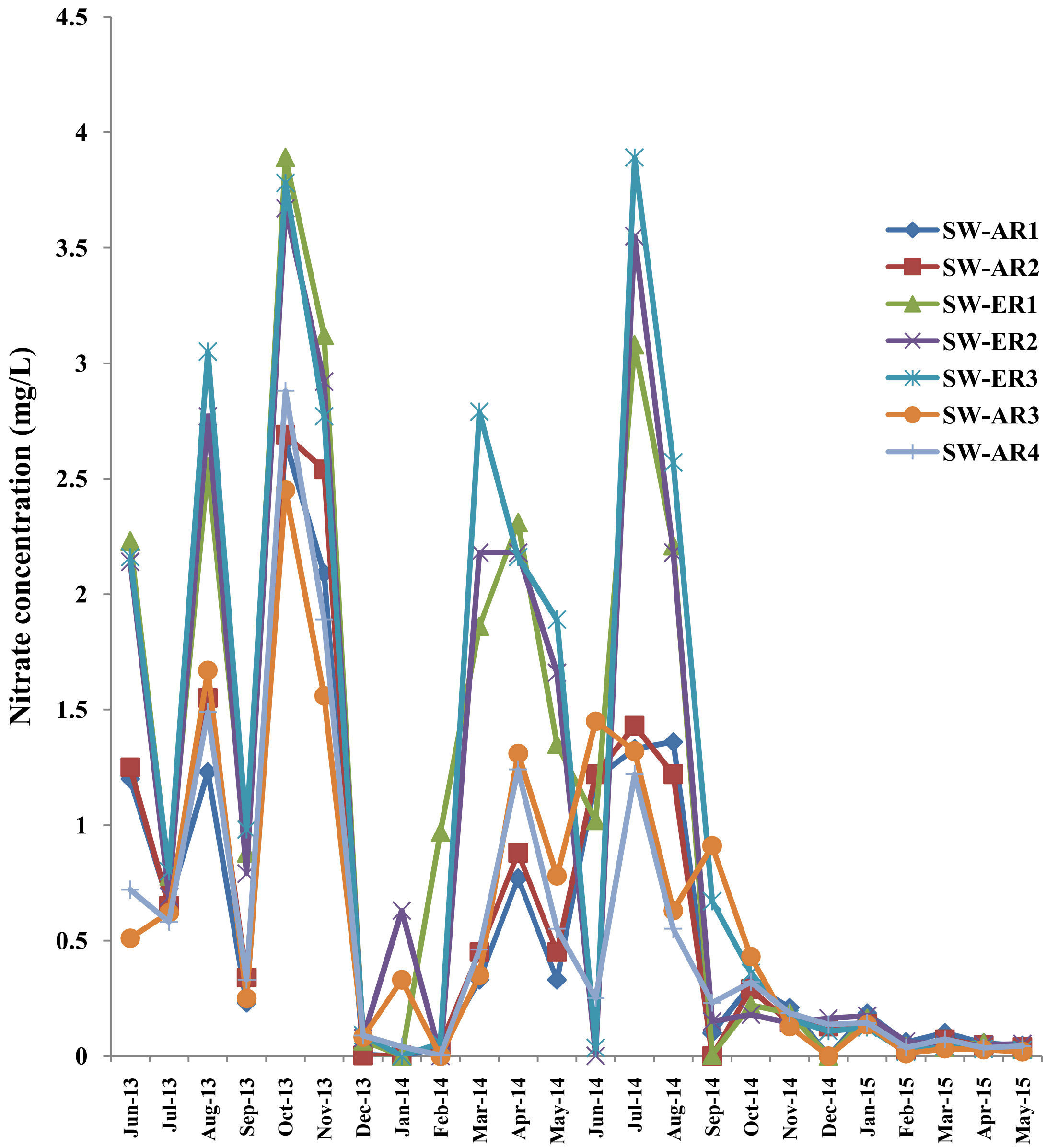

Fig.20: Monthly Nitrate concentration of Erelu Reservoir across sampling stations from June 2013 to May 2015

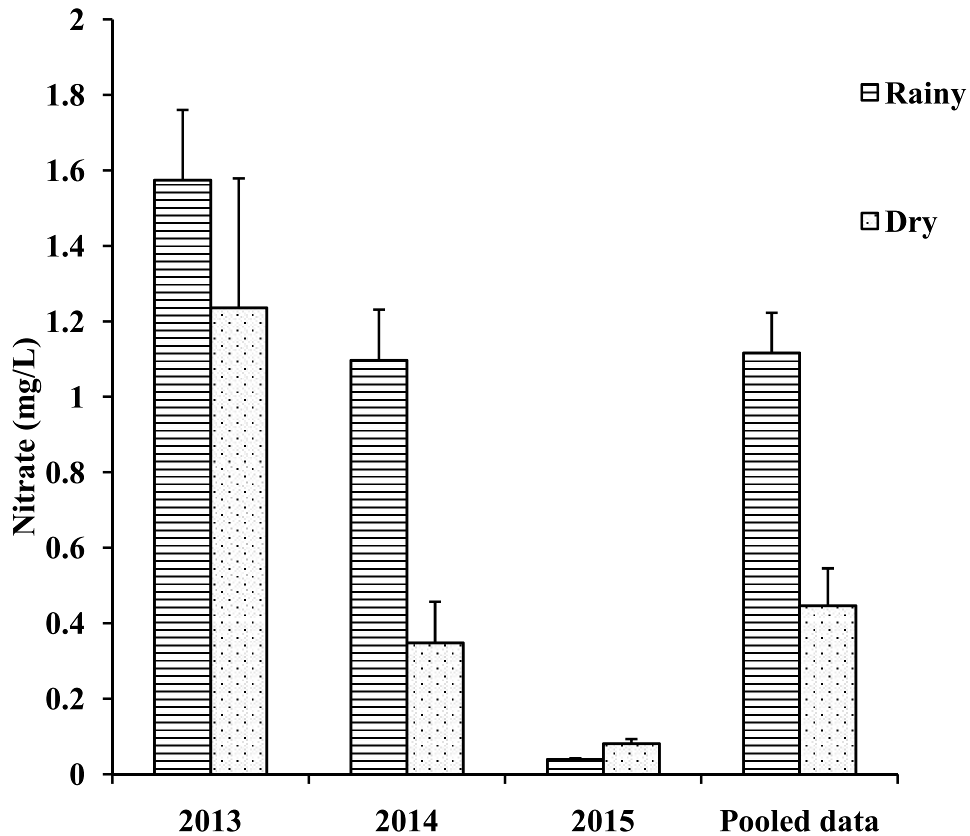

Fig.21: Annual and pooled seasonal variation of nitrate concentration in Erelu Reservoir in Oyo Town, Nigeria

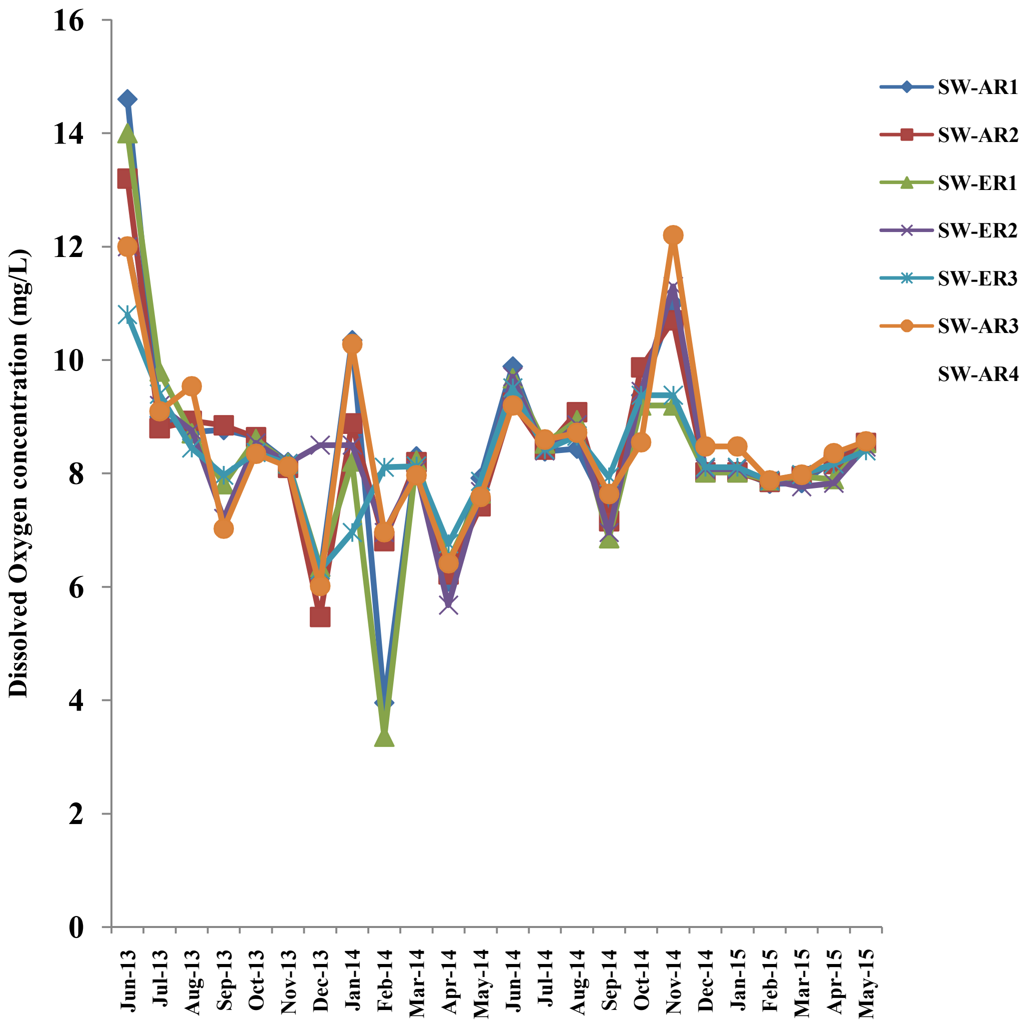

Fig. 22: Monthly Dissolved Oxygen concentration of Erelu Reservoir across sampling stations from June 2013 to May 2015

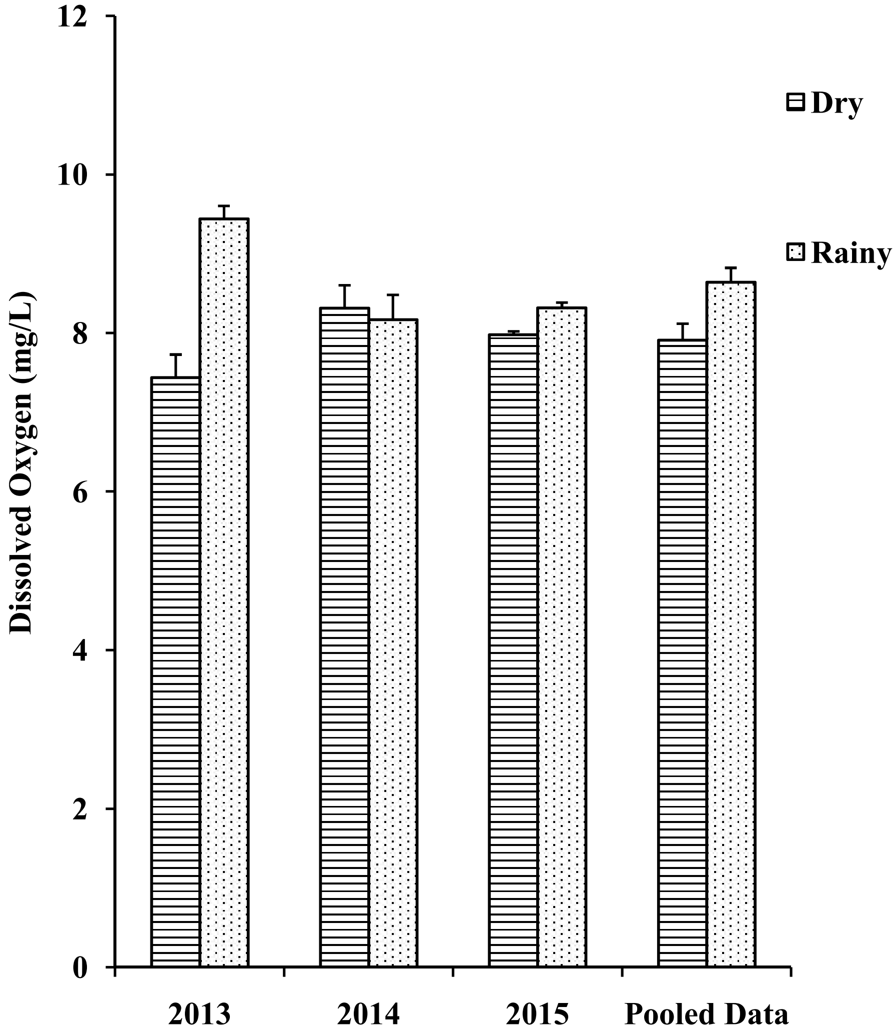

Fig.23: Annual and pooled seasonal variation in Dissolved Oxygen of Erelu Reservoir in Oyo Town, Nigeria

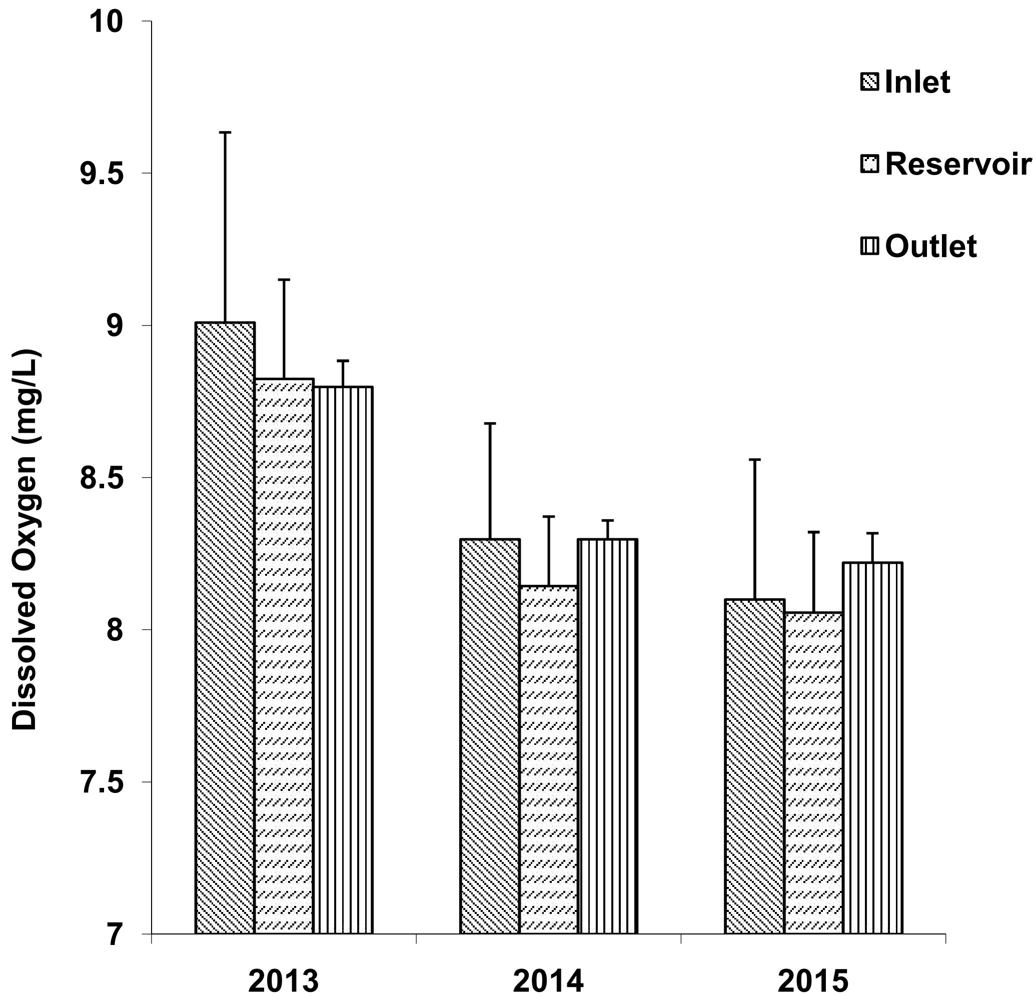

Fig. 24: Annual spatial variation in Dissolved oxygen concentration of Erelu Reservoir in Oyo Town, Nigeria

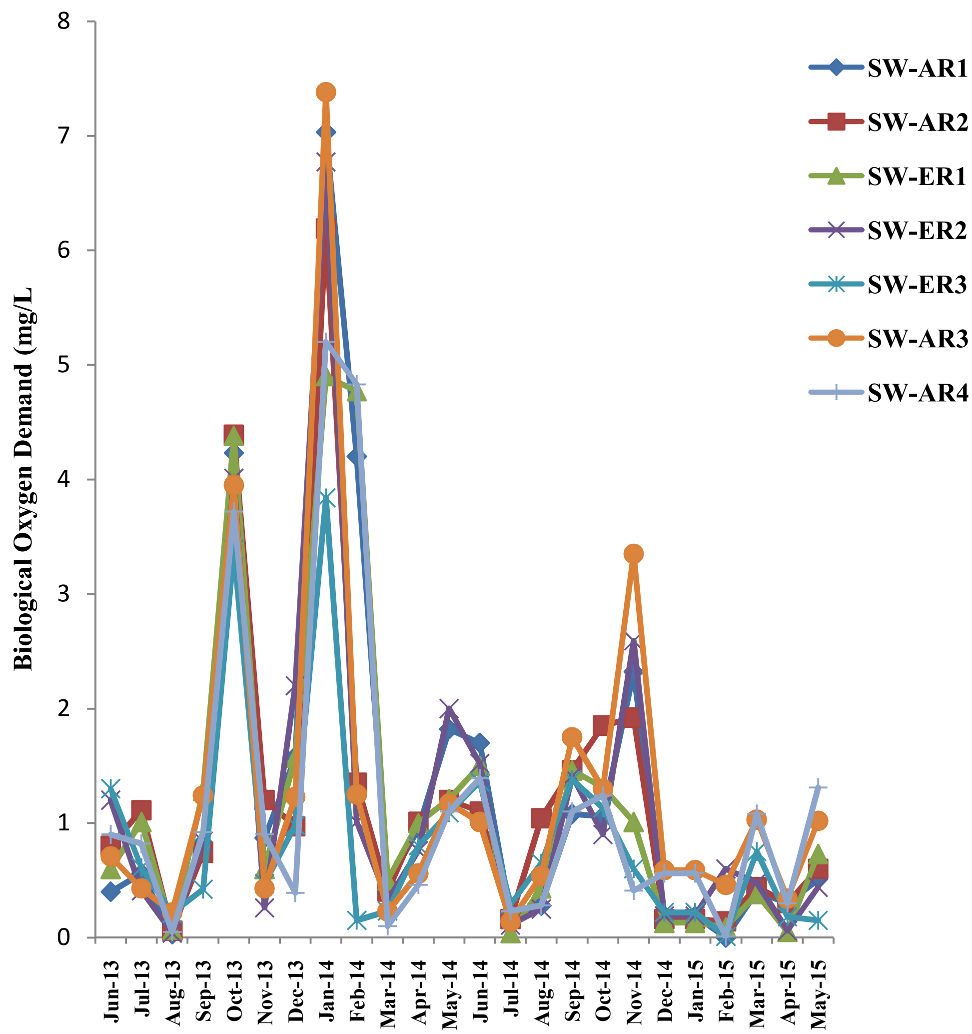

Fig.25: Monthly Biological Oxygen Demand of Erelu Reservoir across sampling stations from June 2013 to May 2015

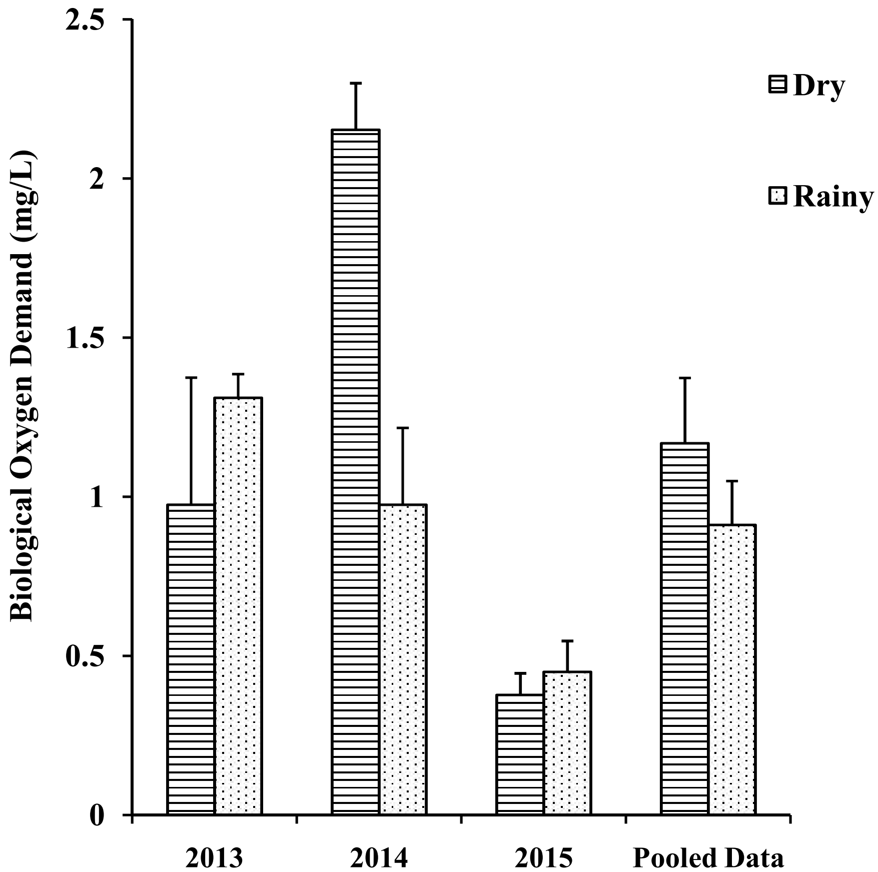

Fig. 26: Annual and pooled seasonal variation in BOD concentration of Erelu Reservoir in Oyo Town, Nigeria

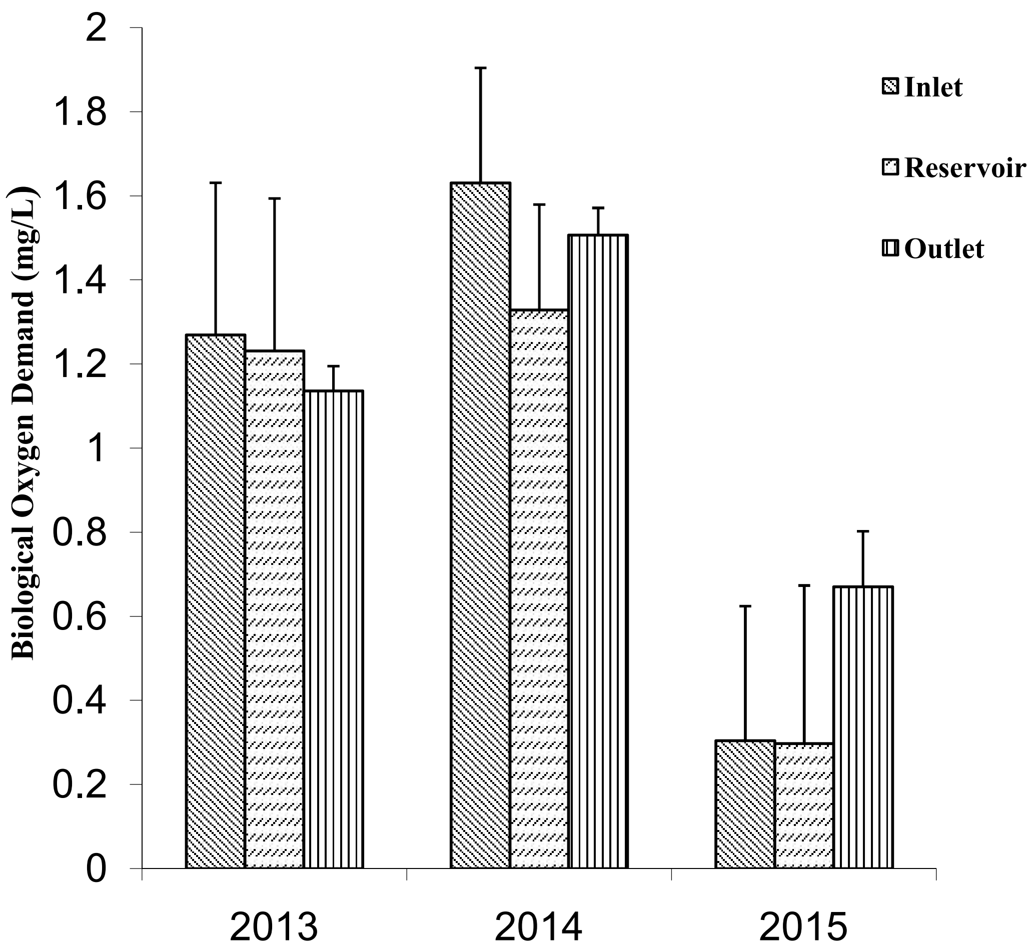

Fig. 27: Annual spatial variation in BOD concentration of Erelu Reservoir in Oyo Town, Nigeria

4.2.10 Hydrogen ion Concentration (pH)

pH concentration ranging from 6.60-8.80 mg/L with the highest mean value of 7.54±0.10 mg/L recorded in station 7 and least mean value of 7.18± 0.13 mg/L was recorded in station 5 during rainy season and a range of 6.80- 8.40 mg/L with the peak value of mean of 7.66±0.17 mg/L recorded in station 2 and the least mean value of 7.48 ± 13 mg/L was recorded in station 4 during dry season. Monthly variation as presented in (Figs. 28, 29 and 30) showed that pH was at a peak in March 2014 and that values are almost the same across stations. There were highest values during dry season compared to the wet season. The pH concentrations in the reservoir stations were lower compared to inlet and outlet stations of the reservoir across seasons.

4.2.11 Total Alkalinity

TA values ranged between 30.00-176.00mg/L with highest mean value of 104.71 ± 11.34 mg/L recorded for station 3 and the lowest mean value of 94.00 ± 9.87 mg/L was recorded in station 7 in the period of wet season, the range during dry season were between 50.00-174.00 mg/L with highest mean value of 102.40 ± 8.38 mg/L recorded in station 5 and the least mean value of 92.60 ± 7.32 was recorded in station 7. The TA mean values shown in the profile were highest in the rainy months across seasons but lowest values in October, 2013 (Figs. 31 and 32).

4.2.12 Total Dissolved Solid

TDS ranged from 14.00-260.00 mg/L with the most highest mean value of 130.97 ±19.46 mg/L being recorded in station 5 and least mean value of 118.95 ± 20.99 milligram per litre was also observed in station 1 in the wet season while the highest mean value of 174.48 ± 36.98 mg/L was recorded in station 7 but least mean value of 156.08± 36.46 mg/L was recorded in station 3 during dry season. TDS monthly variation showed a peak concentration of pH in December, 2013 while lower value was recorded for June, 2013. Values were at peak during dry season in 2013 and also during rainy season in 2014 and 2015. There were least values in the main reservoir stations across seasons compared to the inlet and outlet stations (Figs.34, 35 and 36).

4.2.13 Conductivity

Conductivity ranged between 11.43-453.00 $\mu scm^{-1}$with the highest mean value of 190.92±32.98 μscm^{-1} recorded in station 6, least mean value of 170.07±30.58 μscm^{-1} was observed in station 1 during wet period and ranged from 87.90–689μscm^{-1} with the most elevated mean value of 255.61±51.09 μscm^{-1} recorded in station 7 and the least mean value of 229.89±50.99 μscm^{-1} was recorded in station 3 during the dry season. Monthly variation showed peak values in December, 2013 and lowest in June, 2013. There were high values of conductivity during dry season in 2013, but maximum concentrations were observed during wet season in 2014 and 2015 (figs. 37 and 38). The concentration of conductivity were higher in the outlet stations across seasons compared to the inlet and reservoir stations in Erelu reservoir (Fig. 39).

Table 4.2: Seasonal variations of physical and chemical parameters of Erelu Reservoirin Oyo Town contnd.

Parameters	Seasons	SW-AR1	SW-AR2	SW-ER1	SW-ER2	SW-ER3	SW-AR3	SW-AR4
Hydrogen ion concentration(mg/L)	Rainy	**7.22±0.09**	**7.22±0.08**	**7.31±0.10**	**7.19±0.12**	**7.38±0.13**	**7.39±0.13**	**7.54±0.10**
		6.64-7.71	6.80-7.80	6.80±8.11	6.80-8.60	6.60-8.80	6.80-8.15	7.00-8.20
	Dry	**7.49±0.16**	**7.66±0.17**	**7.50±0.12**	**7.48±0.13**	**7.52±0.14**	**7.62±0.15**	**7.60±0.16**
		6.97-8.29	7.0-8.43	7.14-8.37	6.80-7.21	6.96-7.30	7.00-8.22	7.20-8.13
Total Alkalinity (mg/L)	Rainy	**98.21±11.07**	**101.29±11.33**	**104.71±11.34**	**101.29±11.11**	**102.86±11.47**	**94.43±11.10**	**94.00±9.87**
		48.00-166.00	50.00-176.00	50.00-168.00	50.00-170.00	30.00-172.00	30.00-160.00	46.00-146.00
	Dry	**101.20±9.01**	**93.80±9.28**	**96.20±7.50**	**99.80±9.38**	**102.40±8.38**	**93.40±8.82**	**92.60±7.32**
		58.00-148.00	50.00-140.00	64.00-156.00	74.00-174.00	64.00-154.00	60.00-160.00	64.00-150.00
Total Dissolved Solid (mg/L)	Rainy	**118.95±20.99**	**119.80±20.54**	**125.94±21.18**	**126.36±20.60**	**130.97±19.46**	**125.96±20.27**	**126.91±20.22**
		14-256.00	22.0-254.00	22.00-256.00	28.00-256.00	52.00-256.00	30.00-260.00	26.00-258.00
	Dry	**159.12±36.68**	**159.52±38.61**	**156.18±36.46**	**157.62±35.76**	**156.85±35.47**	**173.06±37.43**	**174.48±36.98**
		63.40-468.00	63.30-486.00	66.74-465.00	68.50-459.00	75.50-457.00	56.10-476.00	57.00-474.00
Conductivity(µs/cm)	Rainy	**170.07±30.58**	**173.19±30.38**	**183.29±31.72**	**183.87±31.00**	**189.99±29.27**	**190.92±32.98**	**186.60±30.84**
		11.43-372.00	31.43-377.00	31.43-382.00	40.00-387.00	74.29-390.00	42.86-453.00	37.14-392.00
	Dry	**238.66±51.82**	**234.62±53.64**	**229.89±50.99**	**234.16±50.58**	**230.54±50.03**	**253.93±51.72**	**255.61±51.09**
		87.90 -678.00	88.40-689.00	102.50-604.00	109.10-662.00	103.10-654.00	101.20-676.00	103.00-694.00

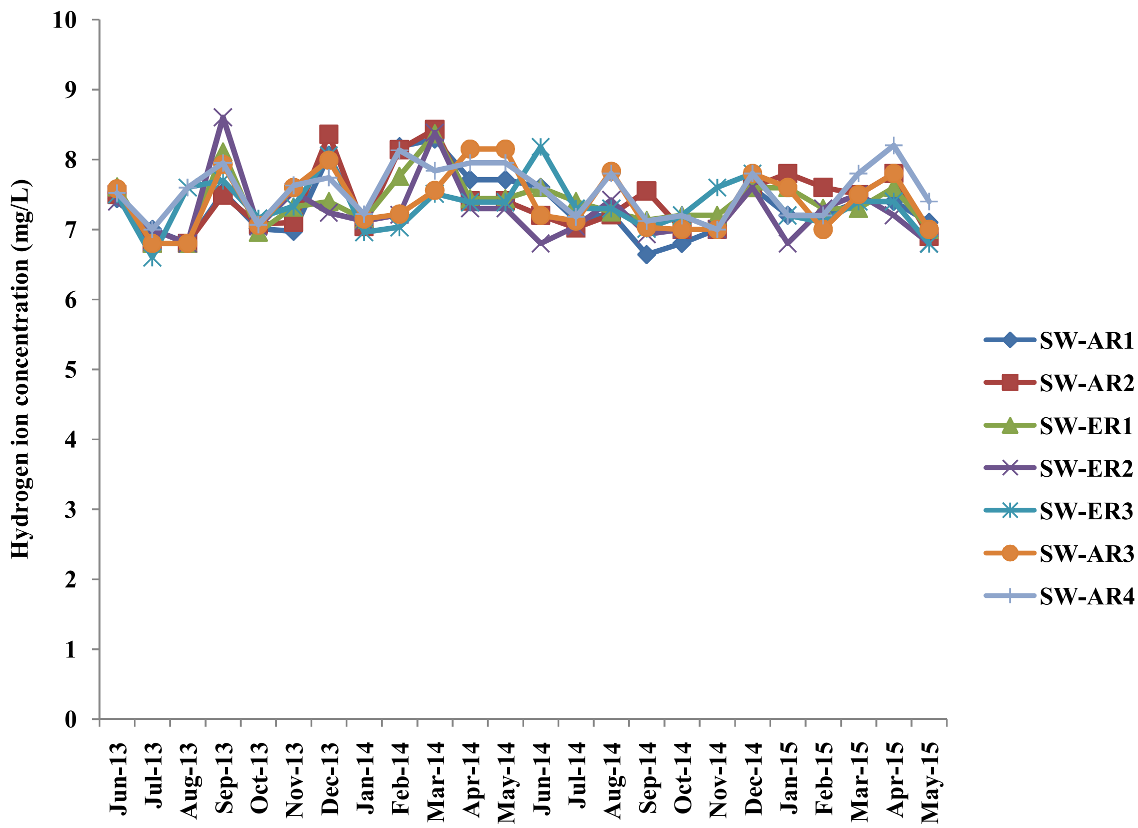

Fig. 28: Monthly concentration of Hydrogen ion of Erelu Reservoir across sampling stations from June 2013 to May 2015

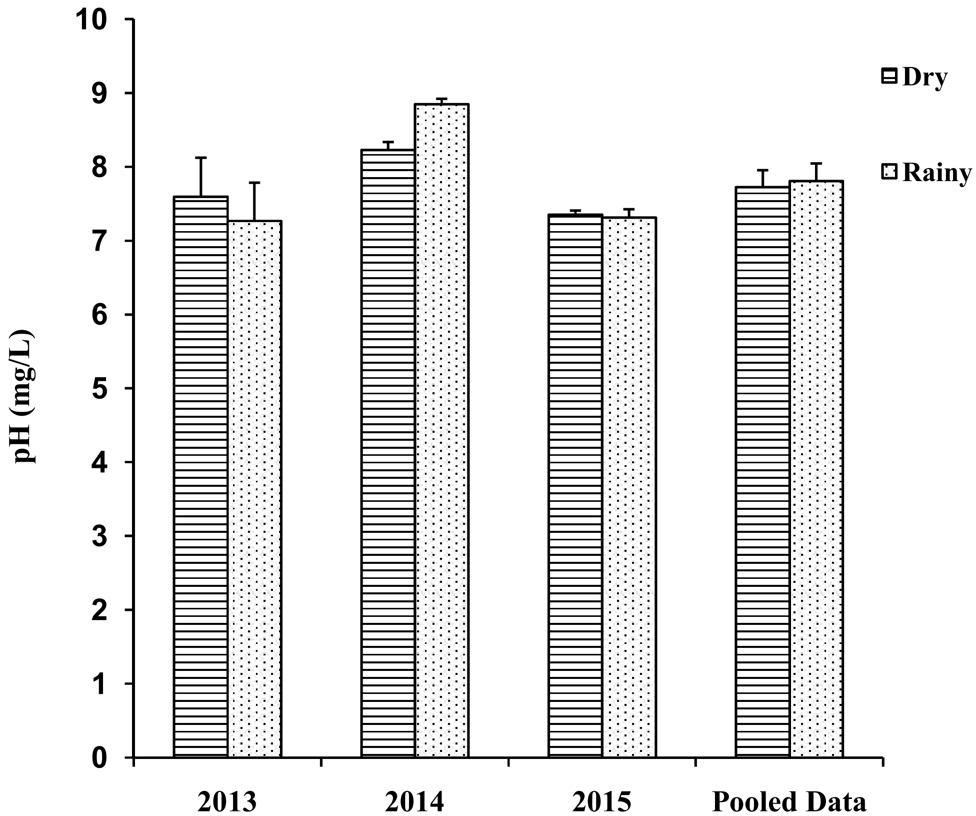

Fig. 29: Annual and pooled seasonal variation in pH concentration of Erelu Reservoir in Oyo Town, Nigeria

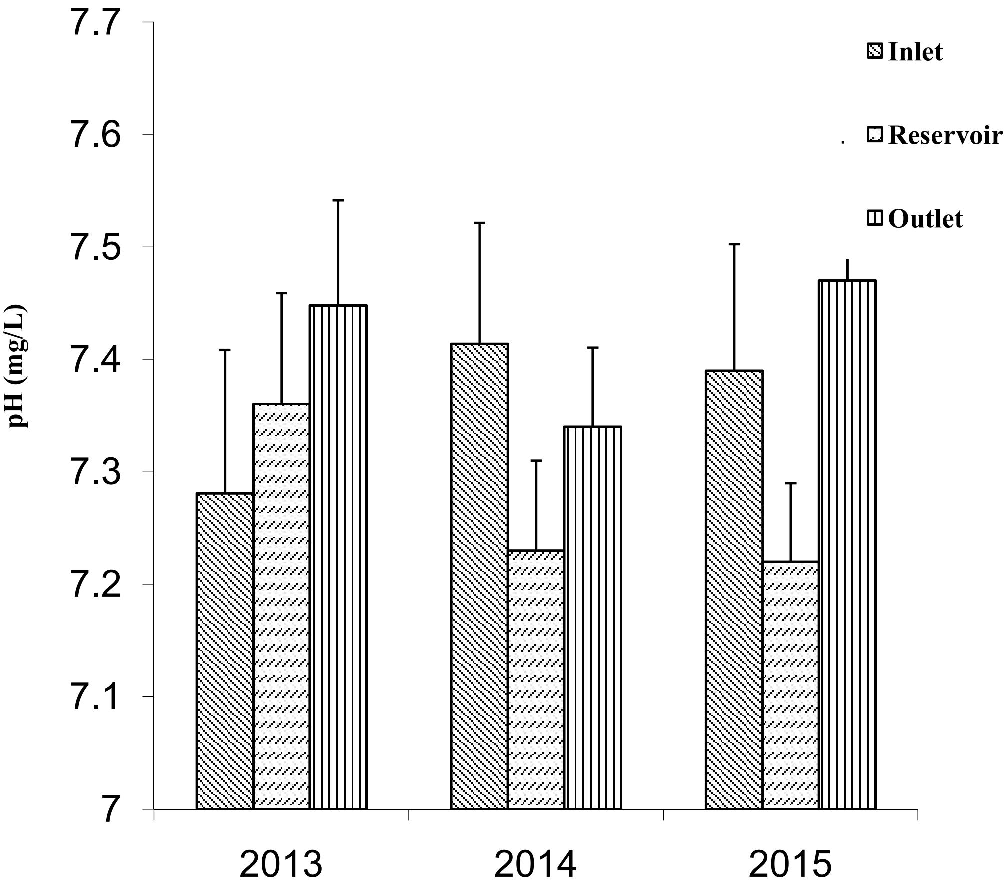

Fig.30: Annual spatial variation in pH concentration of Erelu Reservoir in Oyo Town, Nigeria

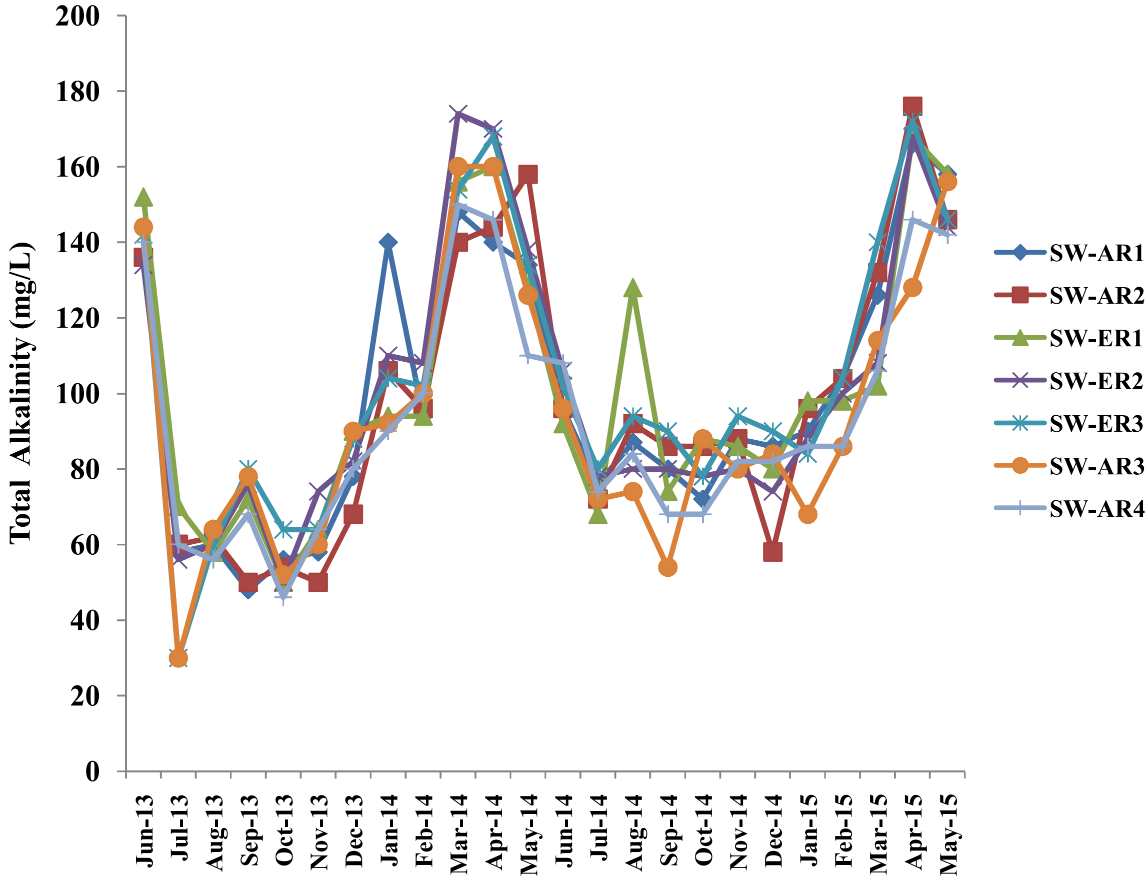

Fig.31: Monthly concentration of Total Alkalinity of Erelu Reservoir across sampling stations from June 2013 to May 2015

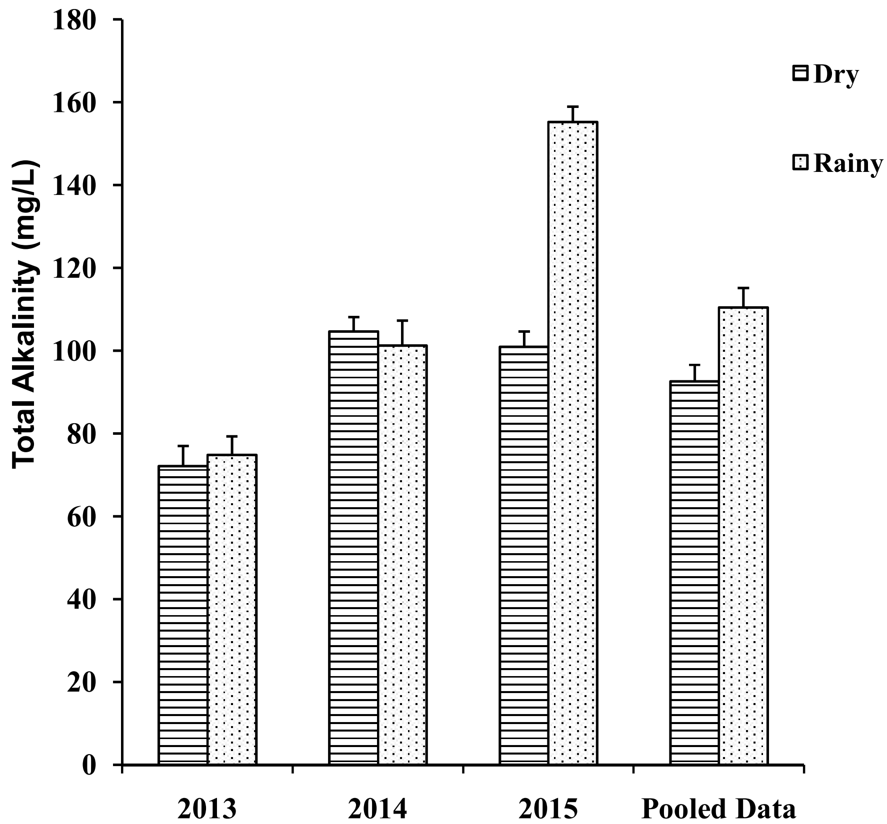

Fig.32: Annual and pooled seasonal variation in Total Alkalinity concentration of Erelu Reservoir in Oyo Town, Nigeria

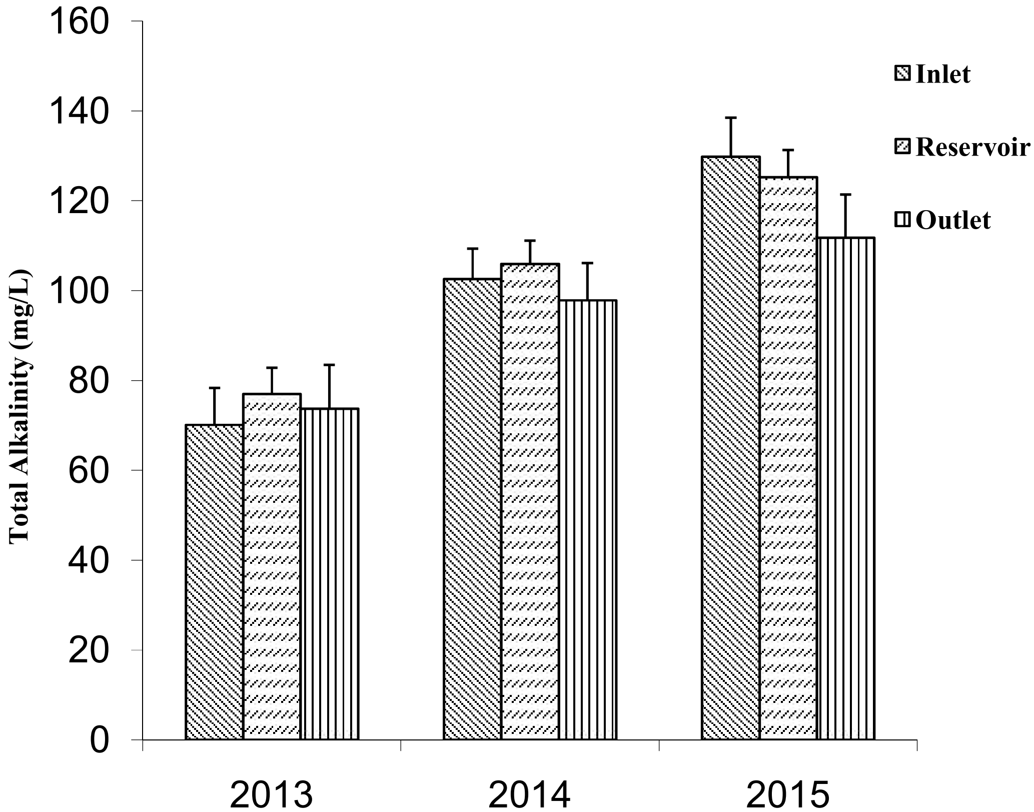

Fig.33: Annual spatial variation in Total Alkalinity concentration of Erelu reservoir in Oyo Town, Nigeria

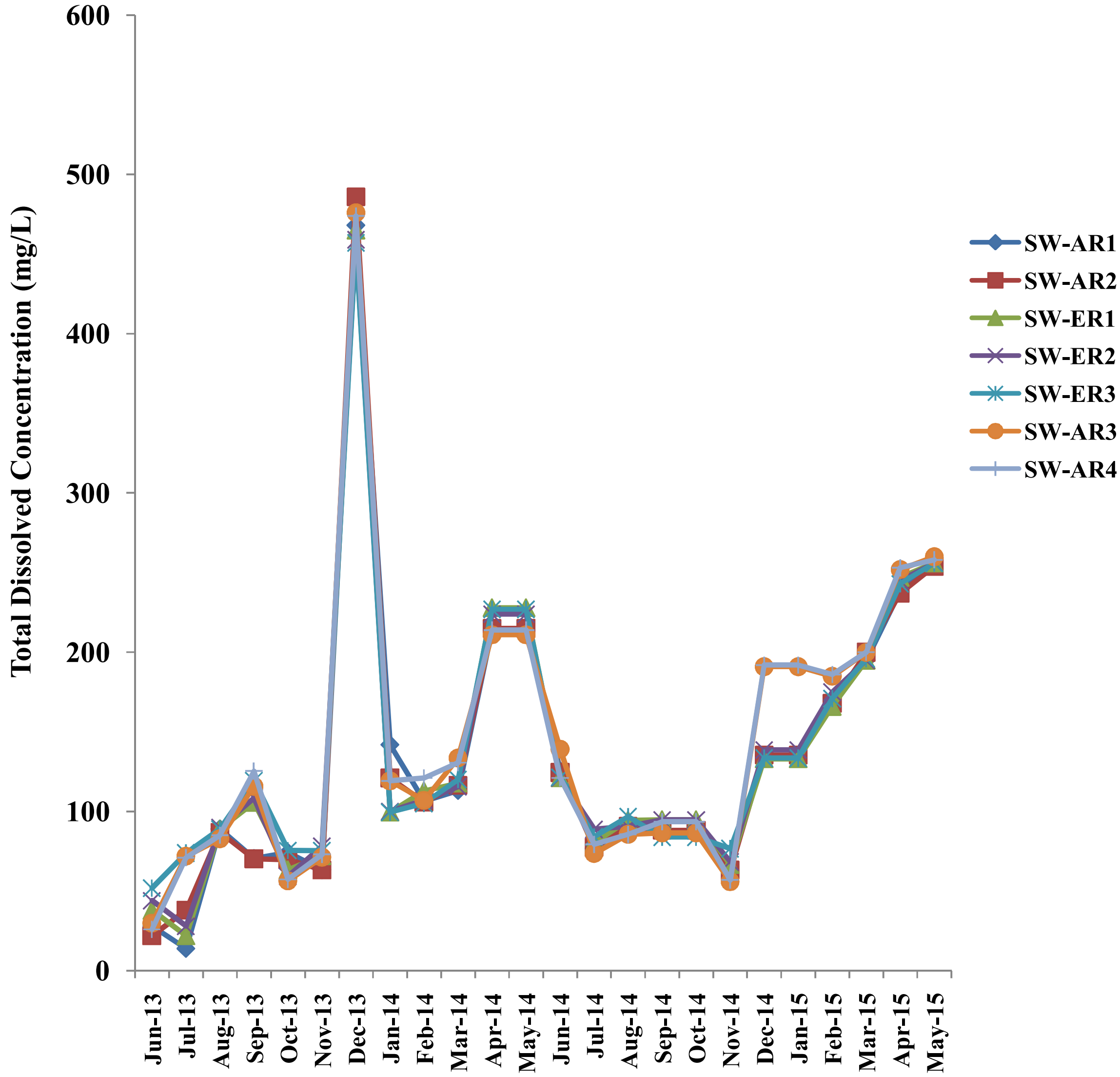

Fig.34: Monthly concentration of Total Dissolved solid of Erelu Reservoir across sampling stations from June 2013 to May 2015

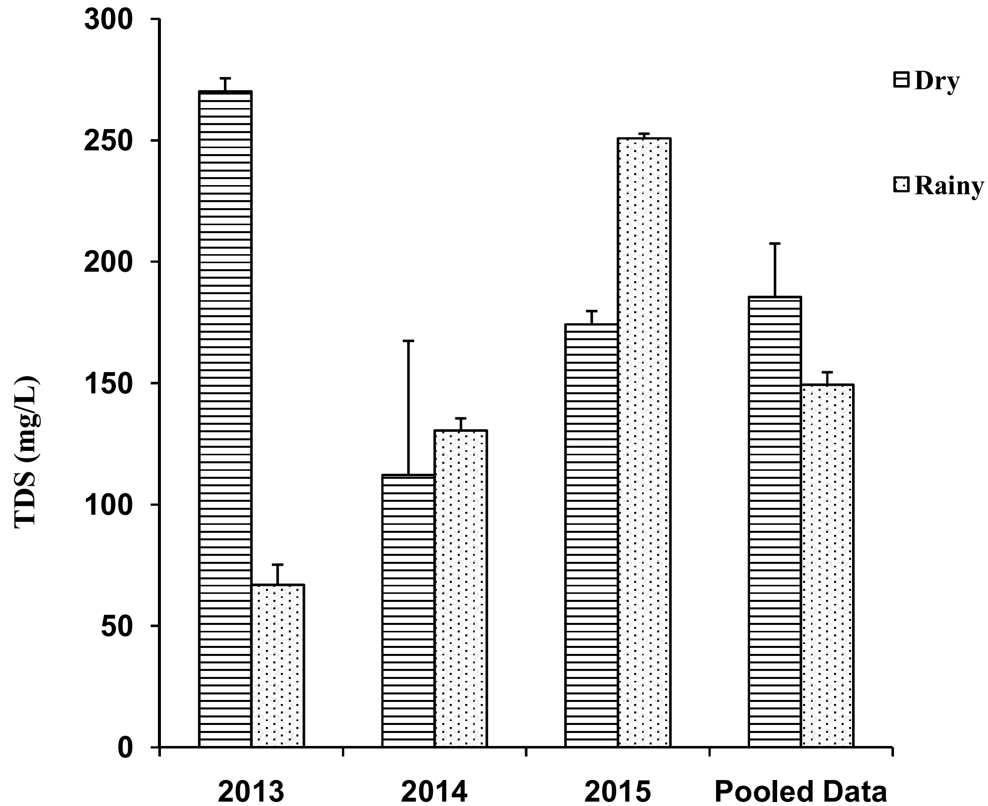

Fig.35: Annual and pooled seasonal variations in TDS concentration of Erelu Reservoir in Oyo Town, Nigeria

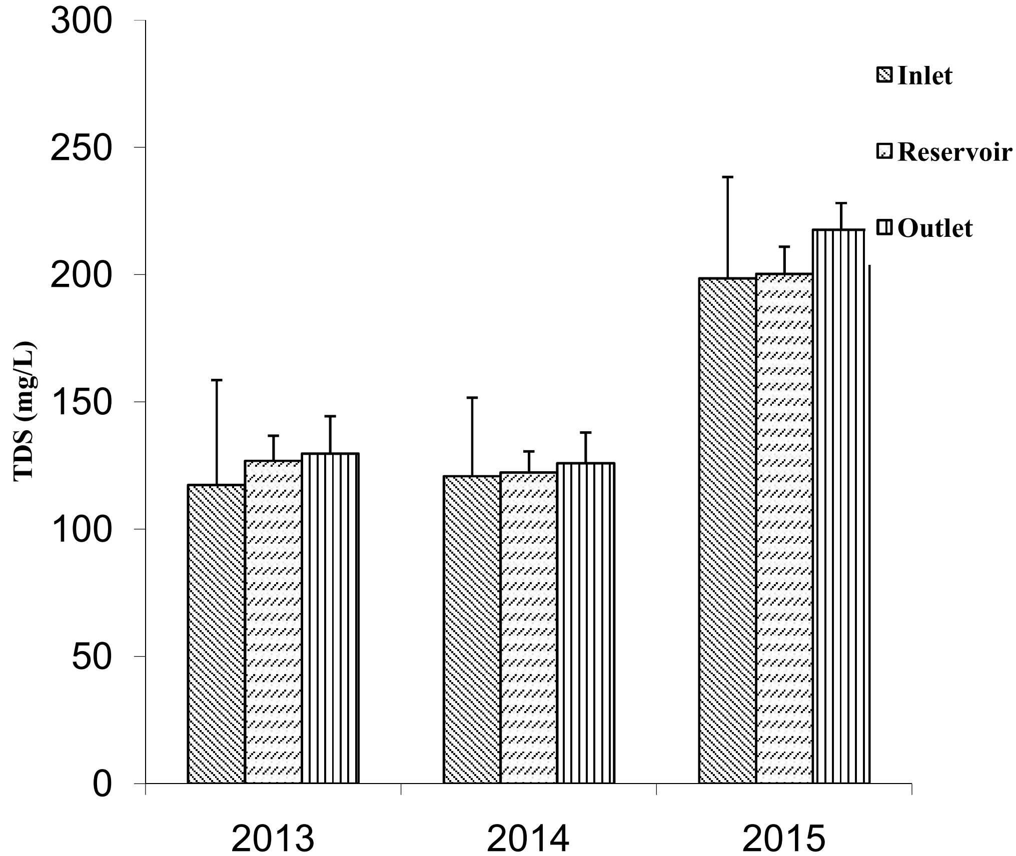

Fig.36: Annual spatial variation in TDS concentration of Erelu Reservoir in Oyo Town, Nigeria

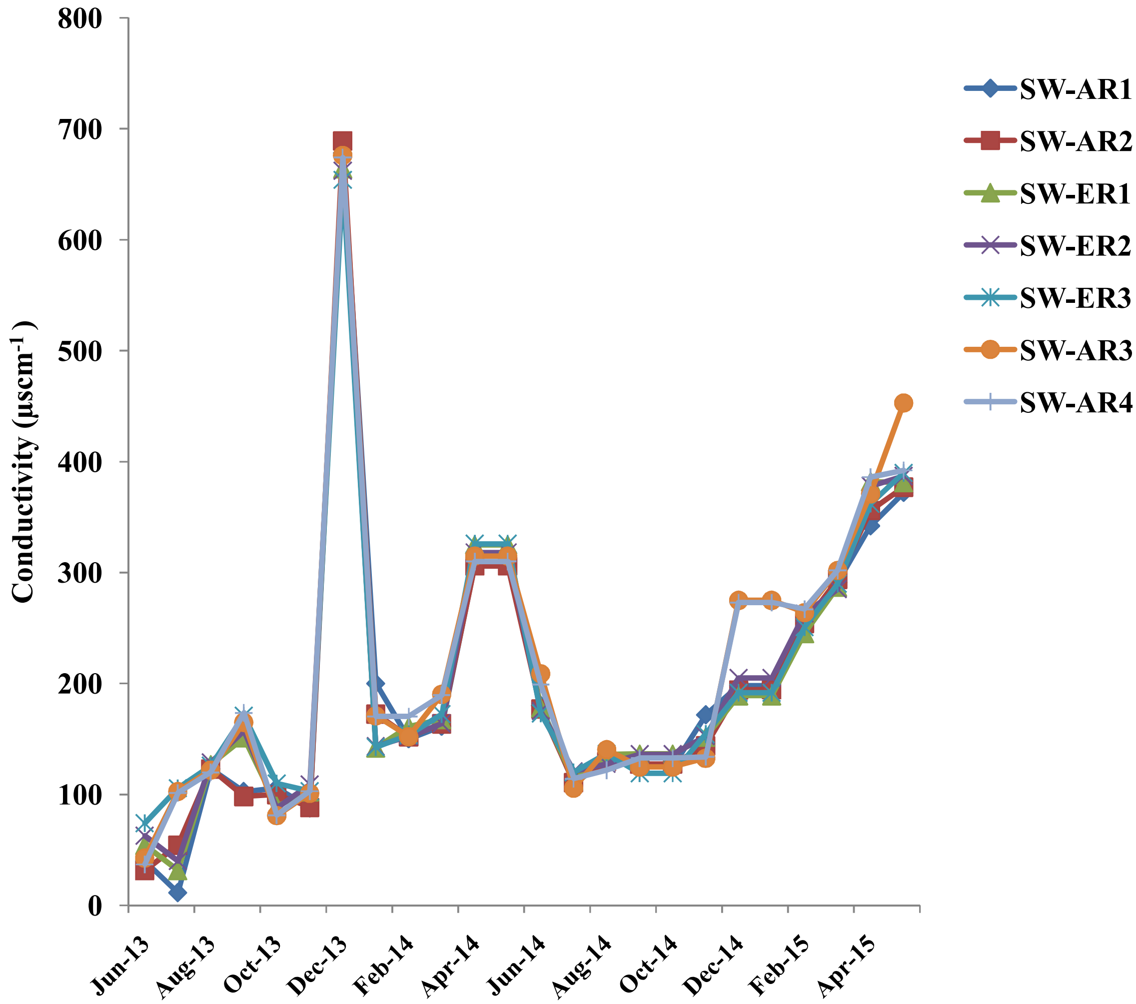

Fig. 37: Monthly concentration of Conductivity of Erelu Reservoir across sampling stations from June 2013 to May 2015

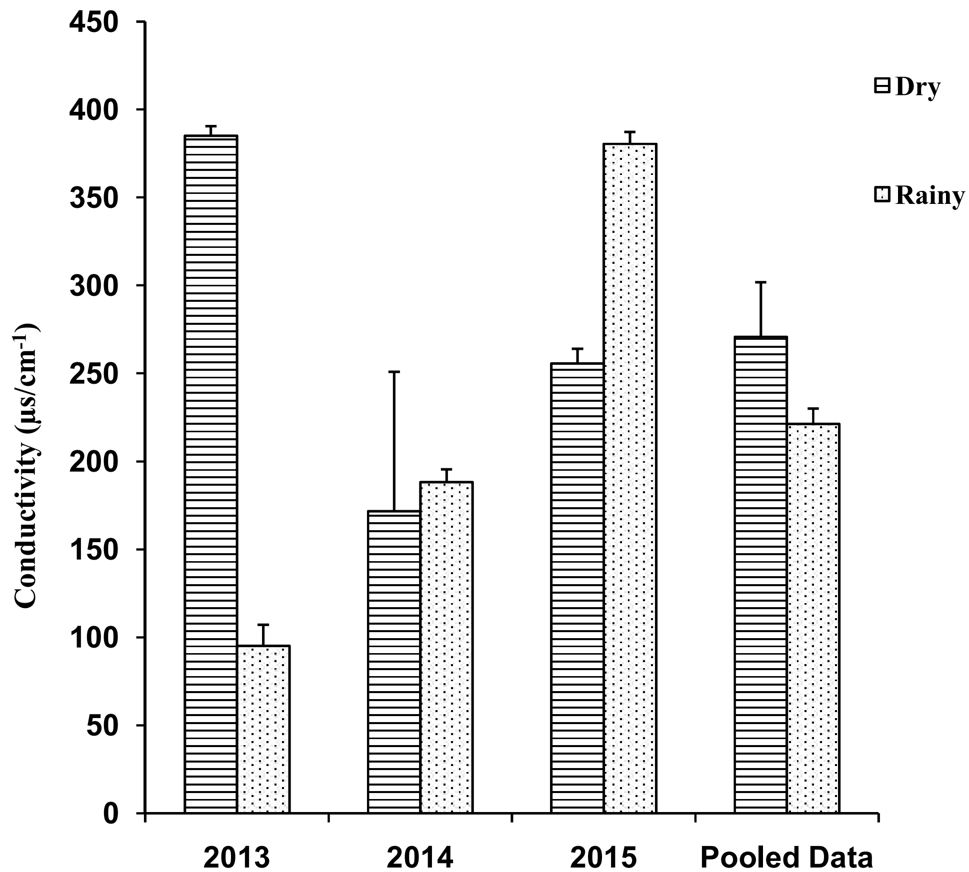

Fig. 38: Annual and pooled seasonal variation in Conductivity of Erelu Reservoir in Oyo Town, Nigeria

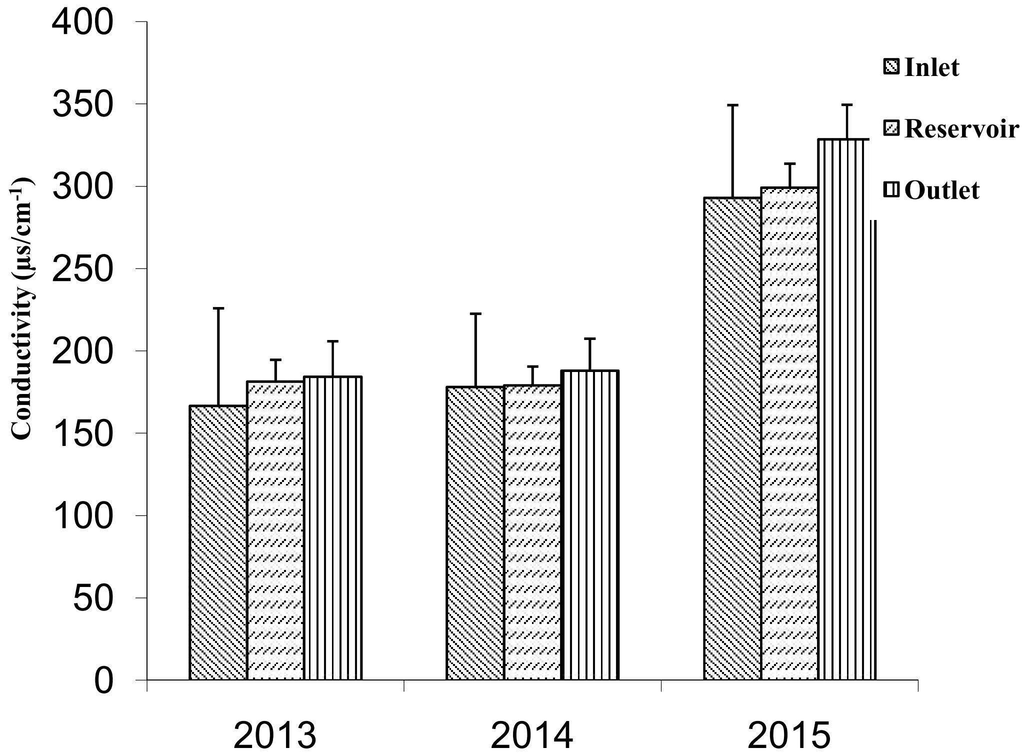

Fig.39: Annual spatial variation in Conductivity of Erelu Reservoir in Oyo Town, Nigeria

4.3. Heavy Metals

4.3.1 Summary of seasonal variations of heavy metals in water samples of Erelu Reservoir

4.3.1.1 Lead (mg/L) Pb

Lead concentration range of 0.00-3.22 mg/L with the highest mean value of 1.01±0.25 mg/Lwas recorded in station 5 least mean value of 0.80± 0.16 mg/L was recorded in station 3 during rainy season. Dry season lead ranged from 0.03-3.00mg/L across stations and highest mean value 1.35±0.27 mg/Lwas recorded in station 5 and least mean value 0.98±0.18 mg/L was recorded in station 2 during study. Monthly variation in lead concentration showed that highest concentration of lead in water samples were recorded in August, 2013 and November, 2014 in all stations (Fig. 40). Seasonal variations showed that lead concentration values were at peak during dry season in 2014 and 2015 (Fig. 41).

4.3.1.2 Zinc (mg/L) Zn

Zn ranged between 0.02- 8.55 mg/L with the mean value 1.43±0.71 mg/L recorded in station 2 and least mean value of 0.83±0.58 mg/L was recorded in station 4 in the rainy months and ranges from 0.06 - 1.64 mg/L recorded with the mean values of 0.62±0.14 mg/L and 0.41±0.09 mg/L in station 2 and1 being the highest and lowest values during dry season. Monthly variation indicated that the maximum concentration of zinc in water samples was recorded in July, and August, 2013, February, 2014 across stations and there was no detection of zinc in some stations. Seasonal variation showed high concentration of zinc in 2013 and 2015 during rainy season but high dry season values were recorded in 2014 (Figs.42 and 43).

4.3.1.3 Iron (mg/L) Fe

Iron ranges from 0.00-2.50 mg/L with highest mean values of 0.62 ± 0.16 mg/L recorded in station 4. Station 7 recorded least mean values of 0.43 ± 0.14 during rainy season while it ranged from 0.01-1.83 mg/L with the highest mean value of 0.77± 0.22 mg/L recorded in station 4. Stations 1, 3 and 5 recorded minimum concentration of 0.65±0.17 mg/L, and 0.65±0.18 mg/L during dry season respectively. Monthly variation in iron concentration showed that elevated concentration of zinc in water samples was recorded in August, 2013 at station 4 and that iron concentration were not detected in station 1, 3 and 5 in June, 2013. Seasonal variation showed high concentration of iron during dry season across year (Figs.44 and 45).

4.3.1.4 Chromium (mg/L) Cr

Average values of chromium (Cr) were between 0.00-3.63 mg/L and the peak mean value of 0.54± 0.30 was recorded in station 4, the least mean value of 0.17 ±0.05 was also recorded in station 3 during rainy season with a range of 0.01 – 0.93 mg/L and highest mean value of 0.28± 0.10 mg/L was recorded in station 3, lower mean value of 0.14± 0.04 mg/L was recorded in station 1 during the dry season. Monthly variation of Cr in water samples showed highest concentration in September, 2013 in station 2, while Cr concentration was not detected in May, July, August, September and October, 2014 across stations. Seasonal variation showed that Cr had high concentration during rainy seasons across the year of study (Figs.46 and 47).

4.3.1.5 Cadmium (mg/L) Cd

Cadmium ranges from 0.00-1.79 mg/L with most elevated mean value of 0.34±0.12 mg/L recorded in station 3 and least mean of 0.17±0.03 mg/L was recorded in station 7 during rainy period, while a range of 0.00-0.88 mg/L with highest mean value of 0.31±0.10 mg/L recorded in station 6 and the least mean values of 0.21±0.06 and 0.21±0.08 mg/L in stations 1 and 3 were recorded during dry season respectively. Monthly Cd concentration was highest in June 2013 in station 3, while it was not detected in stations 4 and 5 in November, 2013 and also not detected across stations in October, 2014 respectively. Elevated concentrations were recorded in the dry season in 2014 and 2015, while high rainy season values were reported in 2013 (Figs.48 and 49). Generally, variability of heavy metal concentrations in water samples during wet season in Erelu reservoir are as follow Zn> Pb> Fe> Cr> Cd and dry season heavy metals variation are as follow Pb> Fe> Zn> Cd>Cr.

Table 4.3a: Seasonal variations of heavy metals in water samples from Erelu Reservoir in Oyo Town between June 2013 to May 2015

Metals	Seasons	SW-AR1	SW-AR2	SW-ER1	SW-ER2	SW-ER3	SW-AR3	SW-AR4
Lead (mg/L)	Rainy	**0.88±0.20**	**0.84-0.17**	**0.80±0.16**	**0.93±0.20**	**1.01±0.25**	**0.94±0.22**	**0.99±0.23**
		0.05-2.94	0.14-2.25	0.00-2.10	0.03-2.50	0.04-2.95	0.02-2.58	0.07-3.22
	Dry	**1.07±0.24**	**0.98±0.18**	**1.07±0.22**	**1.08±021**	**1.35±0.27**	**1.08±0.19**	**1.29±0.26**
		0.13-2.25	0.30-1.87	0.08-2.18	0.18-2.33	0.14-3.00	0.13-2.17	0.03-2.64
Zinc (mg/L)	Rainy	**1.42± 0.76**	**1.43±0.71**	**1.40±0.75**	**0.83±0.58**	**1.34±0.73**	**1.16±0.63**	**1.25±0.66**
		0.06-8.15	0.06-7.89	0.06-8.55	0.04-8.33	0.03-7.81	0.06-7.69	0.02-7.42
	Dry	**0.41±0.09**	**0.62±0.14**	**0.48±0.12**	**0.50±0.15**	**0.47±0.13**	**0.46±0.12**	**0.48±0.13**
		0.06-0.96	0.09-1.63	0.07-1.37	0.08-1.64	0.09-1.42	0.09-1.34	0.12-1.45
Iron (mg/L)	Rainy	**0.52±0.10**	**0.52±0.11**	**0.44±0.10**	**0.62±0.16**	**0.46±0.10**	**0.52±0.15**	**0.43±0.14**
		0.00-1.21	0.01-1.46	0.00-1.29	0.02-2.50	0.00-1.45	0.01-1.52	0.03-1.71
	Dry	**0.65±0.17**	**0.71±0.18**	**0.65±0.18**	**0.77±0.22**	**0.65±0.17**	**0.76±0.21**	**0.70±0.19**
		0.03-1.44	0.07-1.56	0.04-1.53	0.09-1.83	0.06-1.51	0.04-1.71	0.08-1.60
Chromium (mg/L)	Rainy	**0.26±0.08**	**0.31±0.10**	**0.17±0.05**	**0.54±0.30**	**0.35±0.14**	**0.22±0.07**	**0.21±0.08**
		0.00-0.76	0.00-1.17	0.00-0.61	0.00-3.63	0.00-1.60	0.00-0.66	0.00-1.08
	Dry	**0.14±0.04**	**0.18±0.05**	**0.28±0.10**	**0.19±0.07**	**0.24±0.09**	**0.19±0.05**	**0.91±0.05**
		0.10-0.36	0.01-0.43	0.01-0.93	0.02-0.62	0.01-0.91	0.03-0.51	0.01-0.47
Cadmium (mg/L)	Rainy	**0.18±0.03**	**0.22±0.05**	**0.34±0.12**	**0.23±0.05**	**0.19±0.04**	**0.20±0.04**	**0.17±0.03**
		0.00-0.39	0.00-0.53	0.00-1.79	0.00-0.61	0.00-0.42	0.00-0.46	0.00-0.37
	Dry	**0.21±0.08**	**0.28±0.07**	**0.21±0.06**	**0.25±0.08**	**0.28±0.09**	**0.31±0.10**	**0.28±0.09**
		0.03-0.78	0.02-0.63	0.03-0.49	0.00-0.63	0.00-0.86	0.03-0.88	0.03-0.74

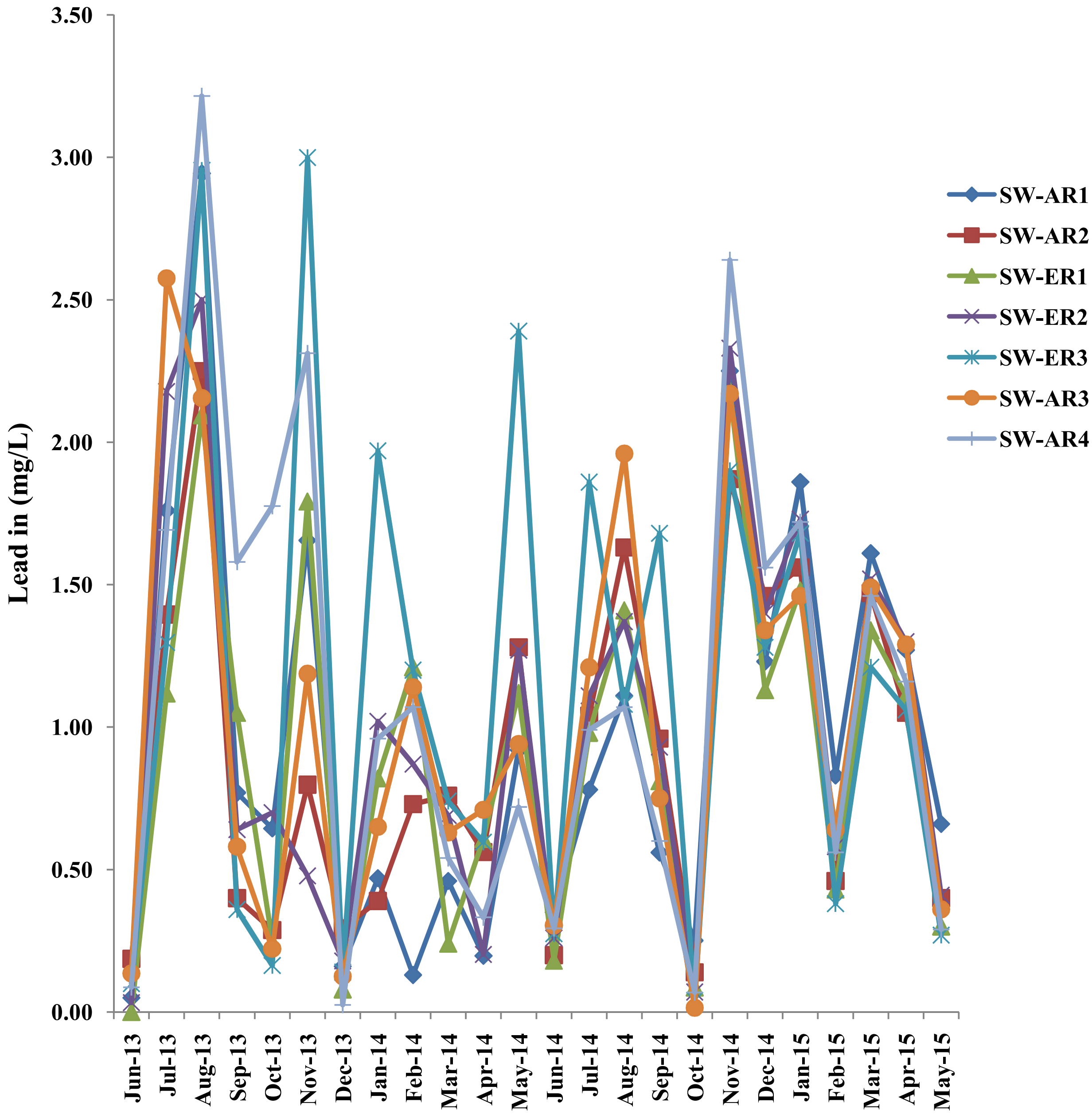

Fig. 40: Monthly variation in lead concentration of water samples of Erelu Reservoir from June 2013 to May 2015

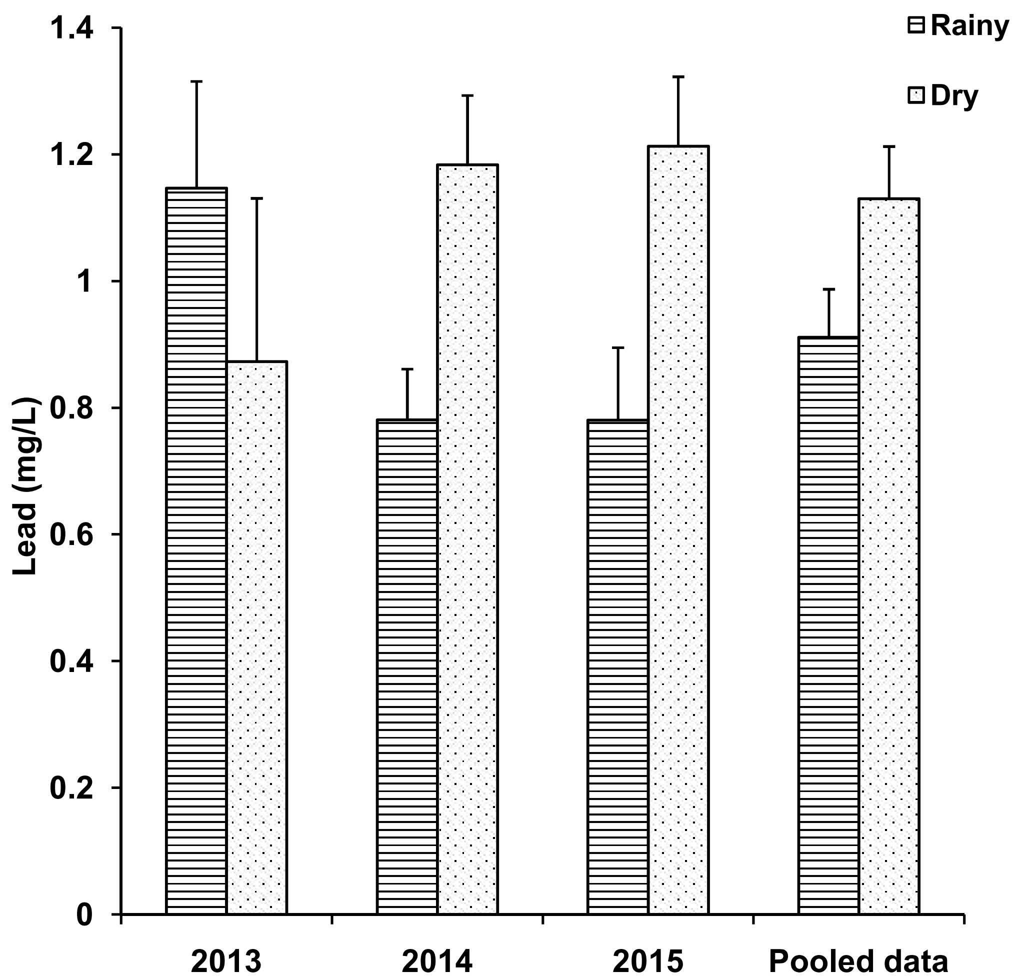

Fig.41: Annual and pooled seasonal variation of lead concentration in water samples of Erelu Reservoir in Oyo Town, Nigeria

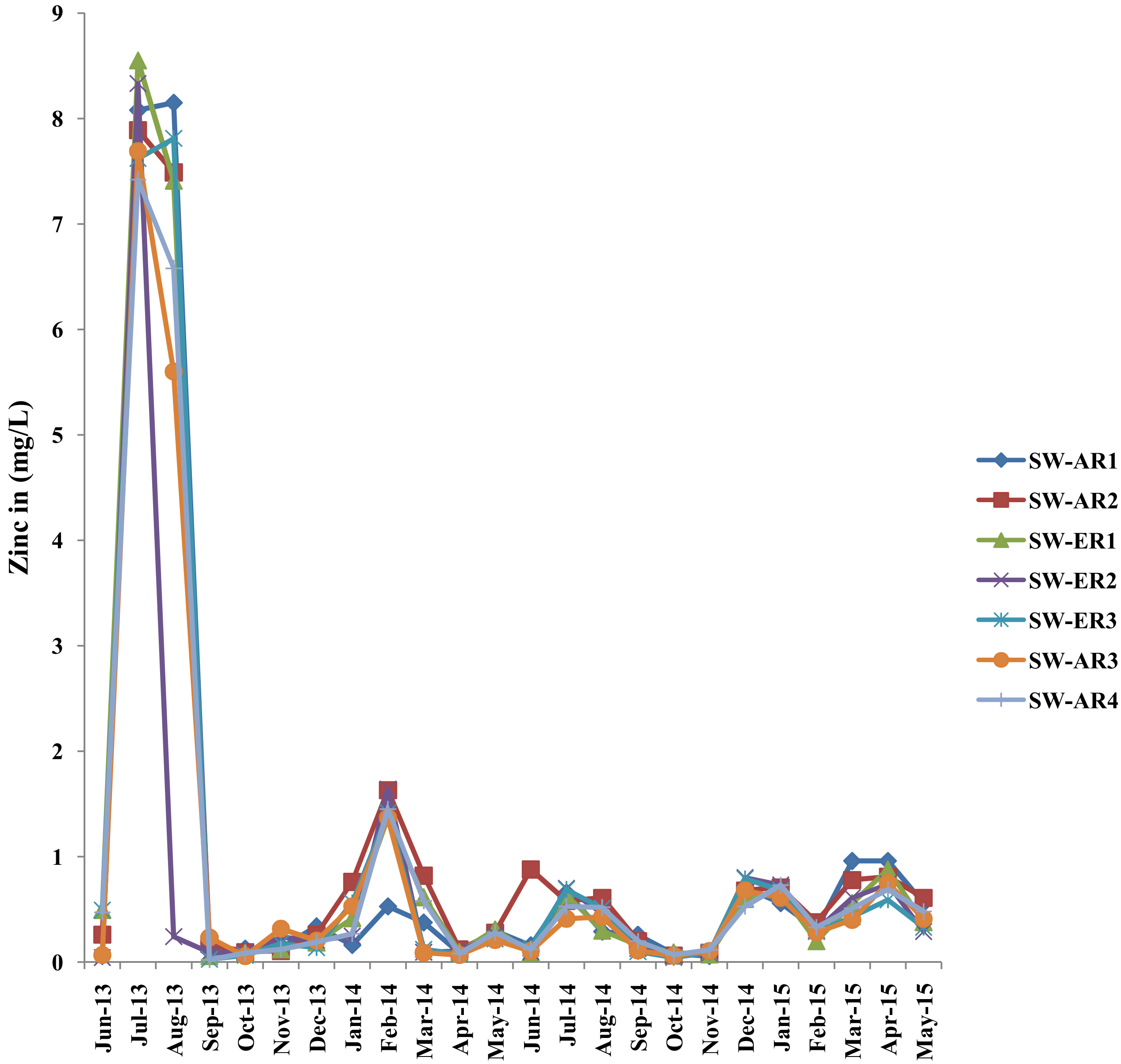

Fig. 42: Monthly variation in Zinc concentration of water samples of Erelu Reservoir from June 2013 to May 2015

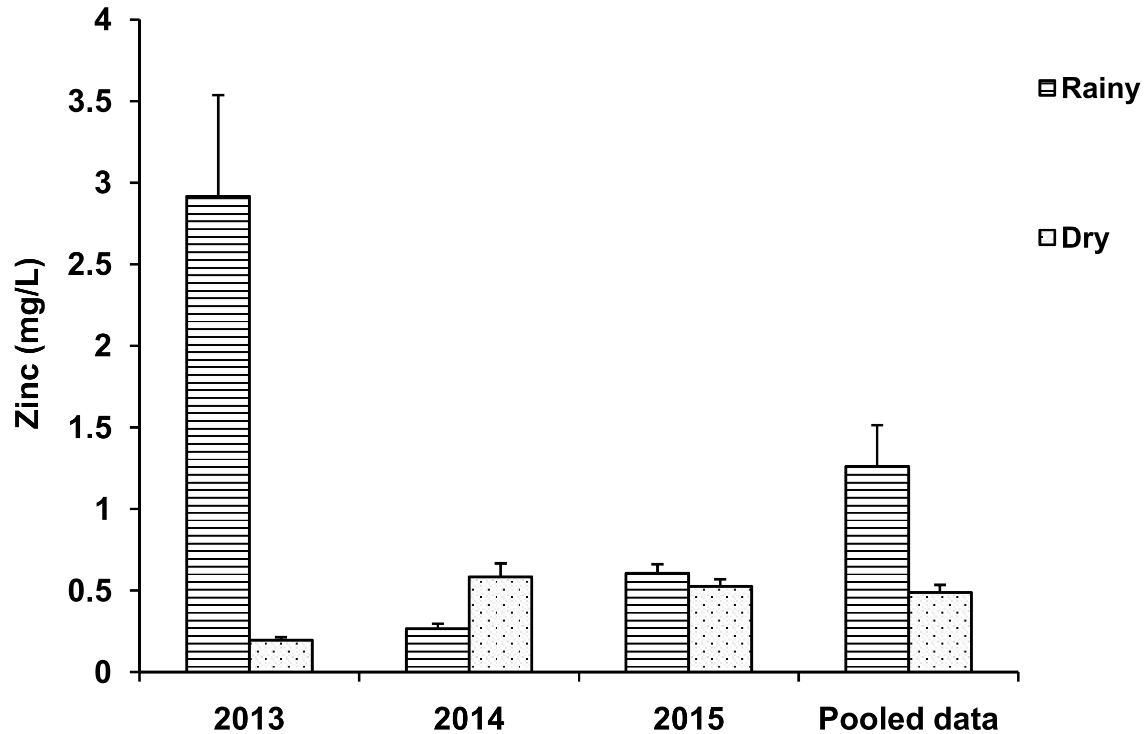

Fig. 43: Annual and pooled seasonal variations in concentration of zinc in sampled water of Erelu Reservoir in Oyo Town, Nigeria

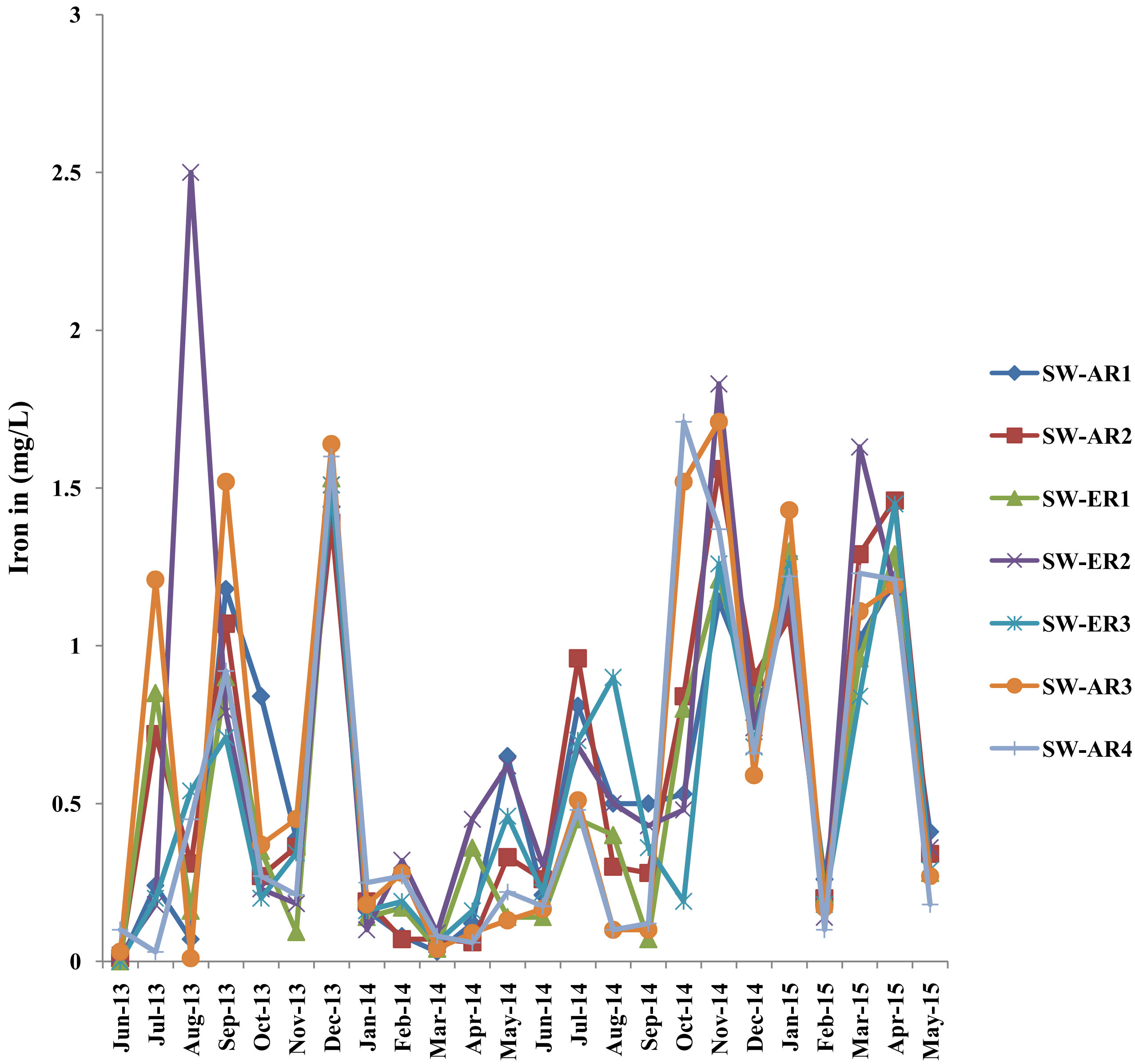

Fig. 44: Monthly variation in Iron concentration of water samples of Erelu Reservoir from June 2013 to May 2015

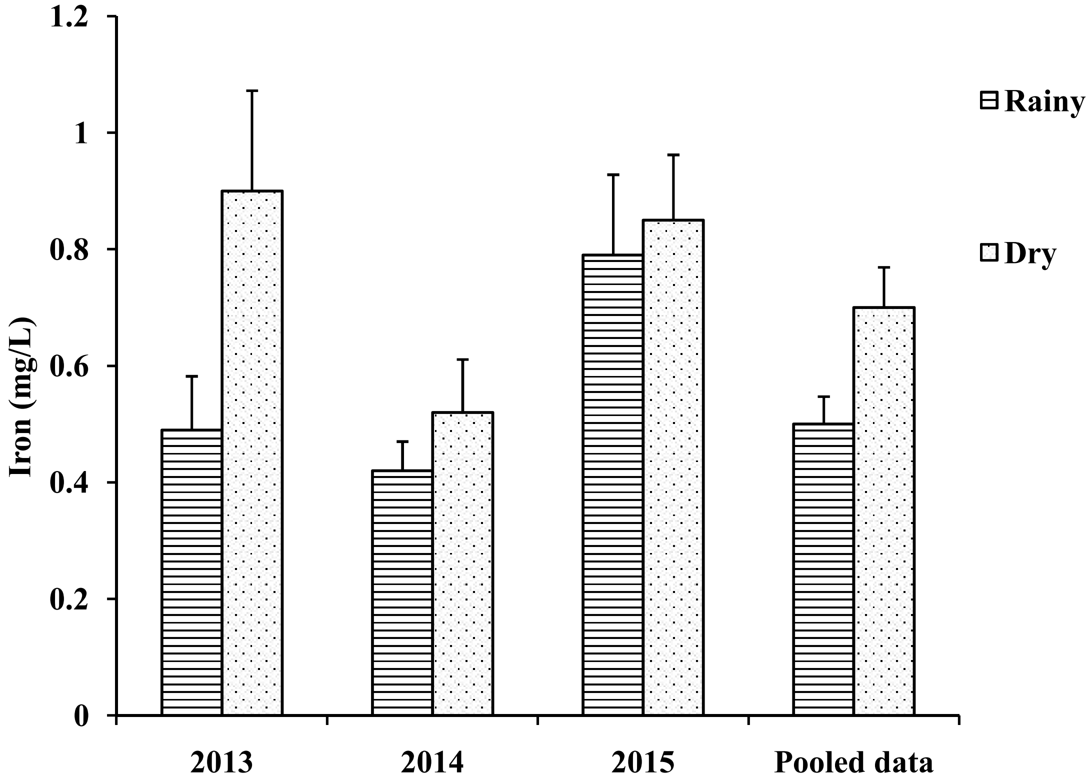

Fig.45: Annual and pooled seasonal variation of iron concentration in water samples of Erelu Reservoir in Oyo Town, Nigeria

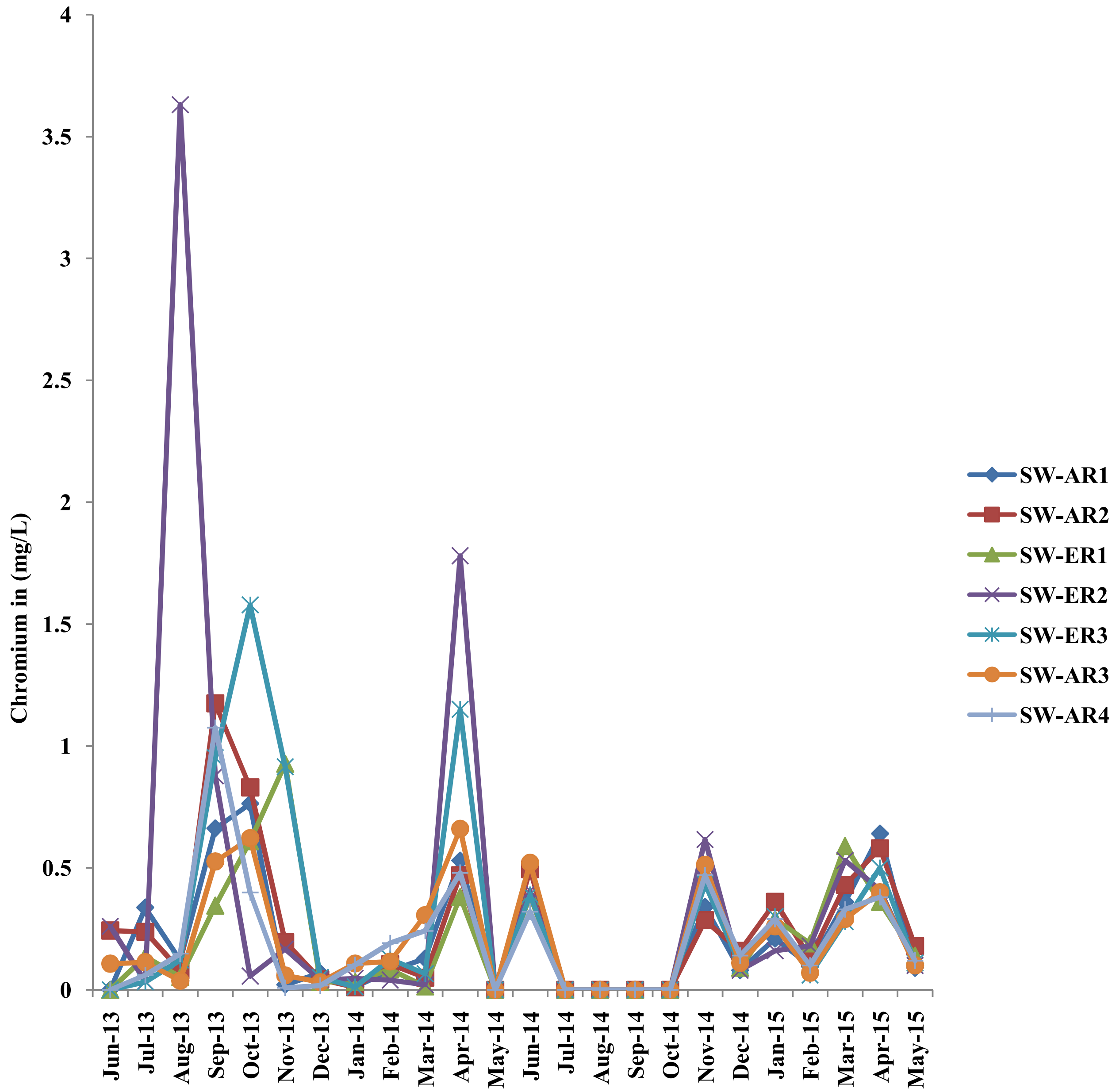

Fig. 46: Monthly variation in Chromium concentration of water samples of Erelu Reservoir from June 2013 to May 2015.

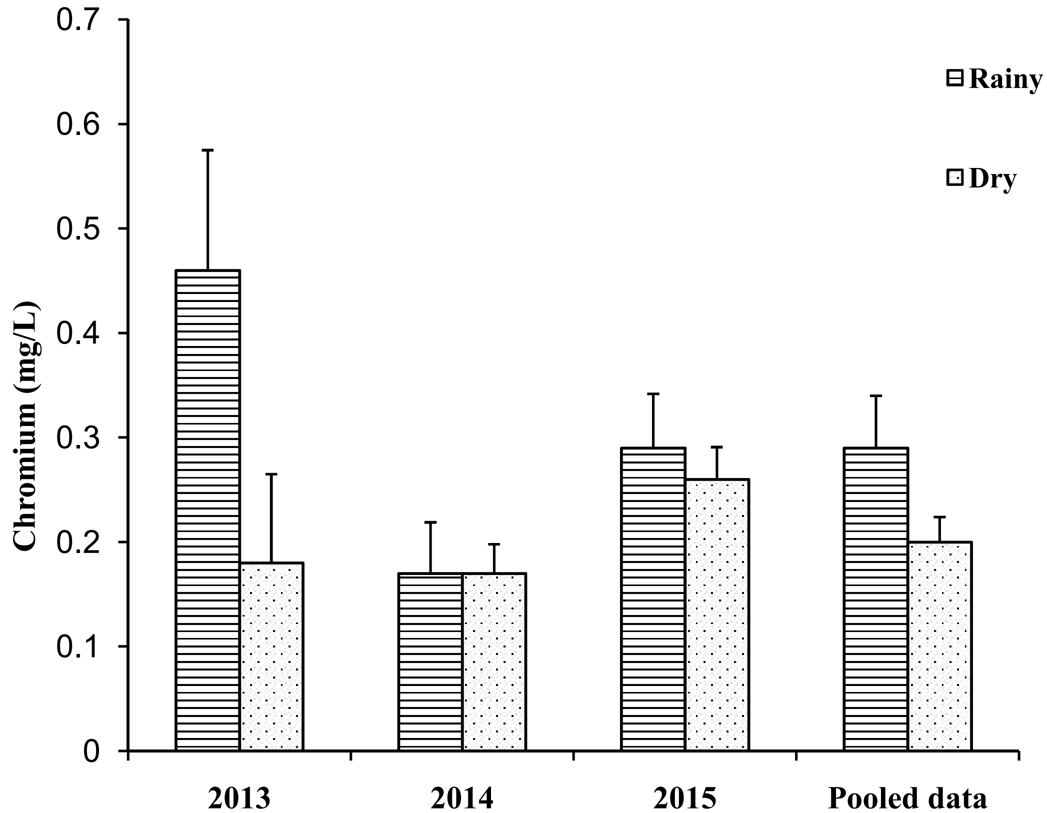

Fig. 47: Annual and pooled seasonal variation in concentration of chromium in water sample of Erelu Reservoir in Oyo Town, Nigeria

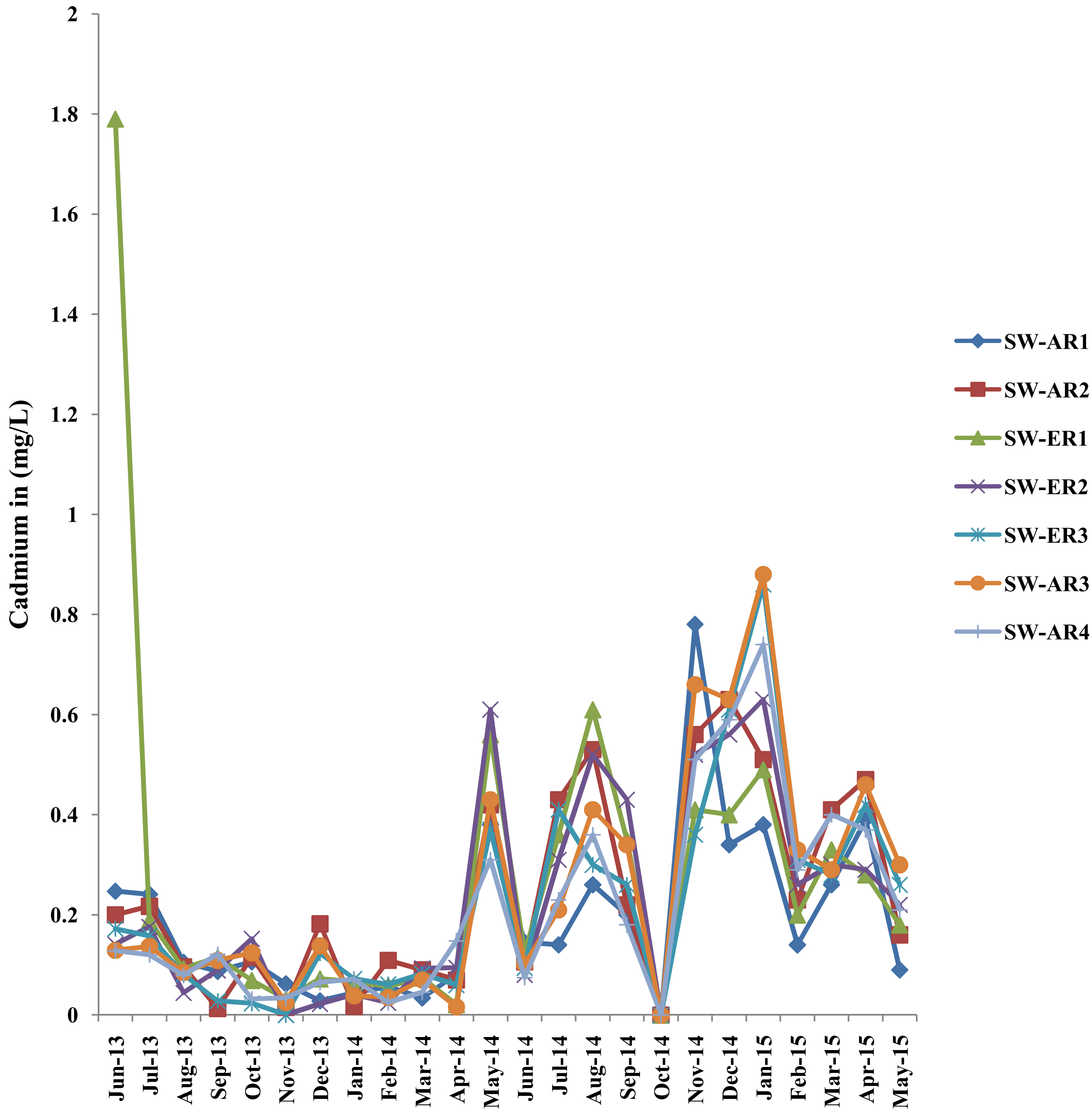

Fig.48: Monthly variation in Cadmium concentration of water samples of Erelu Reservoir from June 2013 to May 2015

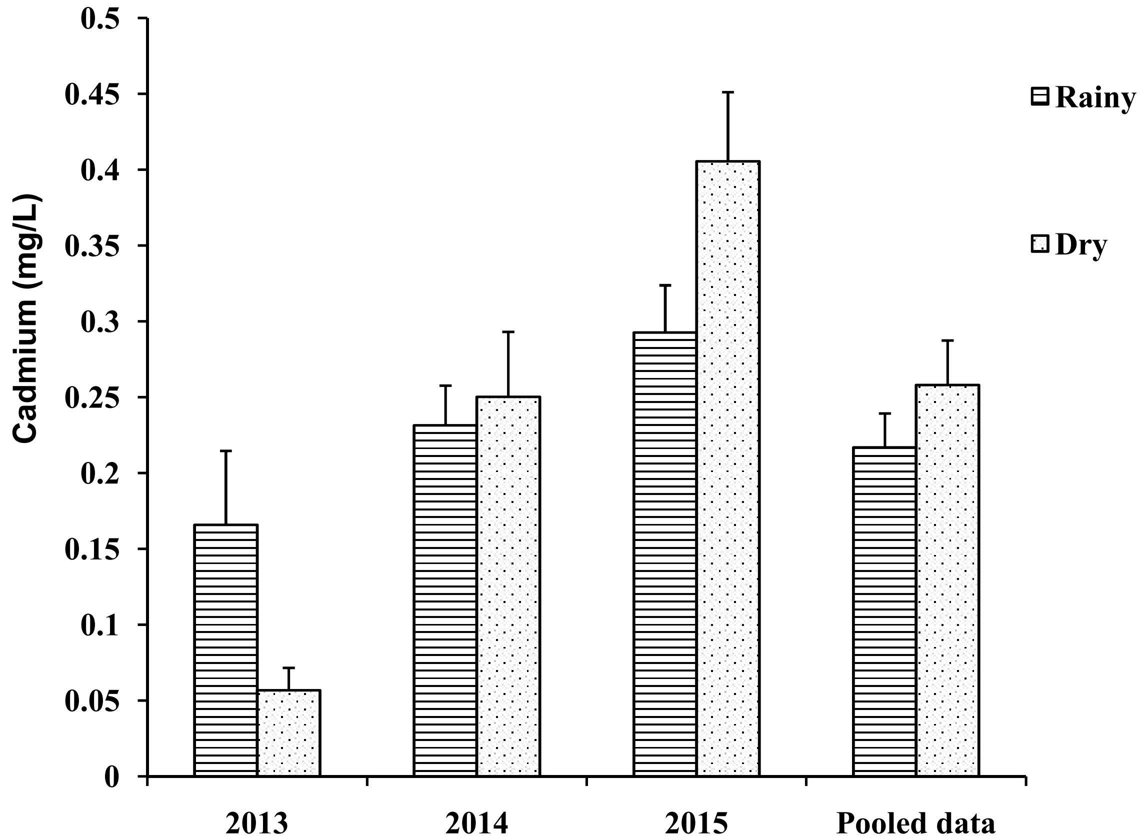

Fig. 49: Annual and pooled seasonal variation in cadmium concentration of water samples from Erelu Reservoir in Oyo Town, Nigeria

4.3.2. Summary of seasonal variations of heavy metals in sediment samples of Erelu Reservoir

4.3.2.1. Lead (mg/kg) Pb

Lead concentration from sediment ranged from 1.06-37.50 mg/kg with highest mean of 17.63±3.15 mg/kg observed in station 1. Lowest mean value of 13.19±2.74 mg/kg and 13.30±2.80 milligram per kilogram were recorded in point 5 and 6 during wet season, respectively. Lead concentration ranges from 1.86-96.03 mg/kg in the dry season with high mean value of 39.73±8.57 mg/kg recorded in station 6 and the least mean value of 32.39±10.26 mg/kg was recorded in station 1 in the dry season. Monthly variation of lead concentration in sediment samples showed a peak concentration across the stations in January and February, 2014 and lower concentration was recorded in October, 2014 in station 6. Seasonal variation showed that Pb concentrations in sediment had elevated values across the year during dry season (Figs. 50 and 51).

4.3.2.2. Zinc (mg/kg) Zn

Zinc recorded a range of 0.10-8.15 $mgkg^{-1}$ with mean concentration of 2.56±0.95 mg/kg as the highest value in station 7 and the least concentration of 1.74±0.36 mg/kg in station 5 in the rainy season, while a range of 0.39-38.50 $mgkg^{-1}$ with the highest mean value of 8.67±4.04 mg/kg was recorded in station1 and the least value of 6.27±2.66 mg/kg was recorded in station 4 during dry months. Monthly Zn concentration showed elevated values in January, February and March, 2014 across the stations and lower values that exceeded standard limits were recorded in other stations. Seasonal variation of Zn concentration in sediment revealed more elevated values during the dry season in 2014, while high mean concentrations were recorded during the rainy season in 2013 and 2015 (Figs. 52 and 53).

4.3.2.3. Iron (mg/kg) Fe

Lead concentration ranges from 0.00-98.30 mg/kg with highest mean of 23.34±9.16 mg/kg recorded in station 3 and the least mean value of 14.63±6.55 $mgkg^{-1}$ and 14.10± 6.37 mg/kg were recorded in stations 2 and 7 in the rainy season. The highest mean value of 28.75± 11.30 mg/kg was recorded in station 3 and the lowest mean value of 21.62±9.38 mg/kg was observed in station 7 during the dry season. Monthly variation showed that concentration of iron were higher in July, September, November, 2013 and in January, March and April 2014 in all stations while lower values were recorded for the remaining months. Seasonal variations showed highest values during dry seasons across the sampling year (Figs.54 and 55).

4.3.2.4. Chromium (mg/kg) Cr

Cr had a range of 0.00-78.95 mg/kg while station 5 had highest mean value of 13.15±6.94 mg/kg recorded and the least mean value of 4.22±1.76 mg/kg was recorded in station 2 during the rainy season. Cr ranges from 0.00-88.14 mg/kg across stations in the dry season periods, but highest mean value of 18.06± 8.32 mg/kg was recorded in station1, while the least mean value of 13.33± 5.60 mg/kg was also recorded in station 5 in the dry season. Monthly variation of Cr showed highest concentration in September and October, 2013, then January, February and March, 2014 across sampling stations. Seasonal variation was observed to have high values during the dry seasons in 2014 and 2015 but high wet season values were observed in 2013 (Figs.56 and 57).

4.3.2.5. Cadmium (mg/kg) Cd

Cd recorded a range of 0.00-17.50 $mgkg^{-1}$ with highest mean value of 4.06±1.01 mg/kg in the station 6 and the lowest mean value of 3.30±0.59 $mgkg^{-1}$ was recorded in station 1 during the rainy season. A range of 0.36-16.25 $mgkg^{-1}$ with the highest mean value of 3.40±1.47 mg/kg was recorded in station 5 and the least mean value of 1.91±0.25 mg/kg was recorded in station 4 during the dry months. Monthly variation showed highest Cd concentration in October, 2013, but high value was observed in station 5 in December, 2013. Seasonal variation was observed to have high rainy season values in 2013 and 2014, but high dry season value was observed in 2015, respectively (Figs.58 and 59). Generally, heavy metals in sediment samples varied as Fe> Pb> Cr> Cd> Zn> in the rainy months and Pb>Fe > Cr>Zn >Cd in the dry months.

Table 4.3b: Seasonal variation of heavy metals in sediment samples from Erelu Reservoirin Oyo Town between June 2013 to May 2015

Metals	Seasons	SW-AR1	SW-AR2	SW-ER1	SW-ER2	SW-ER3	SW-AR3	SW-AR4
Lead (mg/kg)	**Rainy**	**17.63±3.15** 1.65-37.5	**17.32±3.03** 1.24-32.00	**14.66±3.03** 1.50-33.50	**14.70±3.00** 1.55-31.50	**13.19±2.74** 1.23-31.30	**13.30±2.80** 1.06-26.50	**14.29±2.72** 1.60-28.50
	Dry	**32.39±10.26** 1.96-87.51	**37.26±9.03** 2.08-82.14	**34.86±8.36** 2.03-81.26	**35.01±8.33** 2.14-83.28	**35.20±10.18** 1.93-96.03	**39.73±8.57** 1.86-88.56	**38.09±8.72** 2.02-79.35
Zinc (mg/kg)	**Rainy**	**2.39±0.58** 0.10-7.60	**1.97±0.34** 0.68-5.43	**1.95±0.56** 0.10-8.15	**2.34±0.47** 0.90-7.25	**1.74±0.36** 0.10-5.70	**2.01±0.35** 0.10-4.23	**2.56±0.95** 0.71-14.40
	Dry	**8.67±4.04** 0.60-36.55	**7.88±3.96** 0.52-38.50	**7.20±3.16** 0.63-28.10	**6.27±2.66** 0.48-23.50	**7.53±3.21** 0.39-25.30	**8.17±3.87** 0.52-37.50	**7.96±3.38** 0.50-28.28
Iron (mg/kg)	**Rainy**	**15.21±5.68** 1.86-73.40	**14.63±6.55** 0.41-79.70	**23.34±9.16** 1.68-95.20	**17.09±8.06** 0.00-98.30	**20.75±7.86** 1.41-75.10	**19.03±8.56** 0.00-86.50	**14.10±6.37** 1.22-85.10
	Dry	**22.71±8.06** 1.28-58-00	**27.98±11.34** 1.11-90.00	**28.75±11.30** 1.04-94.40	**26.26±10.71** 1.37-84.80	**25.16±10.12** 1.23-86.00	**22.46±9.10** 1.16-75.20	**21.62±9.38** 1.03-91.30
Chromium (mg/kg)	**Rainy**	**7.16±3.52** 0.40-40.05	**4.22±1.76** 0.00-24.90	**12.05±6.41** 0.68-75.50	**7.47±3.83** 0.00-43.30	**13.15±6.94** 0.49-78.95	**10.67±5.17** 0.00-58.35	**8.47±4.94** 0.60-69.00
	Dry	**18.06±8.32** 0.48-73.12	**15.75±7.26** 0.31-62.56	**16.52±6.98** 0.29-88.14	**13.69±6.60** 0.00-51.07	**13.33±-5.60** 0.43-46.33	**13.58±6.67** 0.38-61.04	**13.38±5.83** 0.31-53.27
Cadmium (mg/kg)	**Rainy**	**3.30±0.59** 1.06-9.10	**3.56±0.87** 0.55-13.65	**3.77±0.83** 0.25-12.95	**3.34±1.08** 0.00-16.65	**4.03±1.04** 1.08-16.15	**4.06±1.01** 1.08-16.00	**3.99±1.13** 0.55-17.50
	Dry	**2.45±0.50** 0.78-5.95	**2.81±0.69** 0.56-8.35	**2.01±0.34** 0.41-4.40	**1.91±0.25** 0.52-3.10	**3.40±1.47** 0.36-16.25	**2.45±0.53** 0.66-6.15	**2.58±0.43** 0.51-5.25

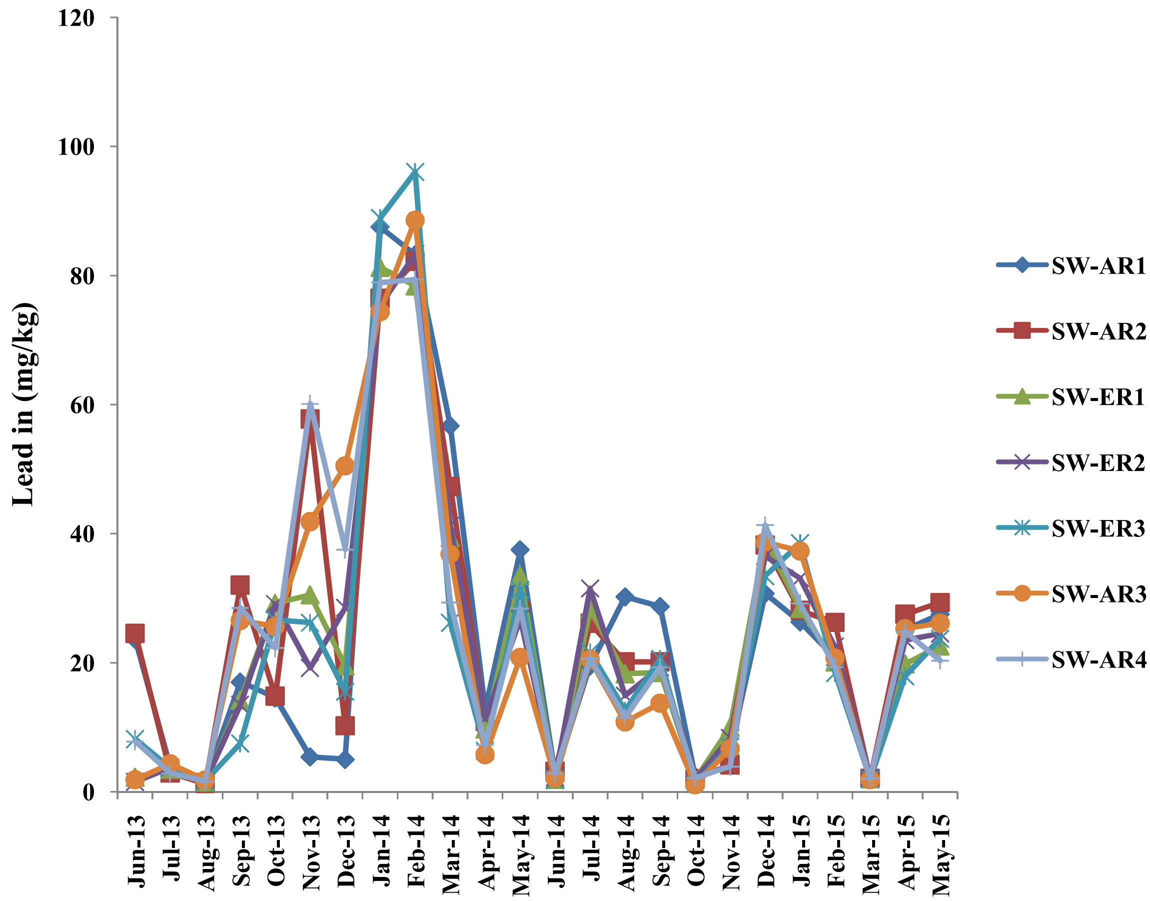

Fig. 50: Monthly variation in Lead concentration of sediment samples of Erelu Reservoir from June 2013 to May 2015

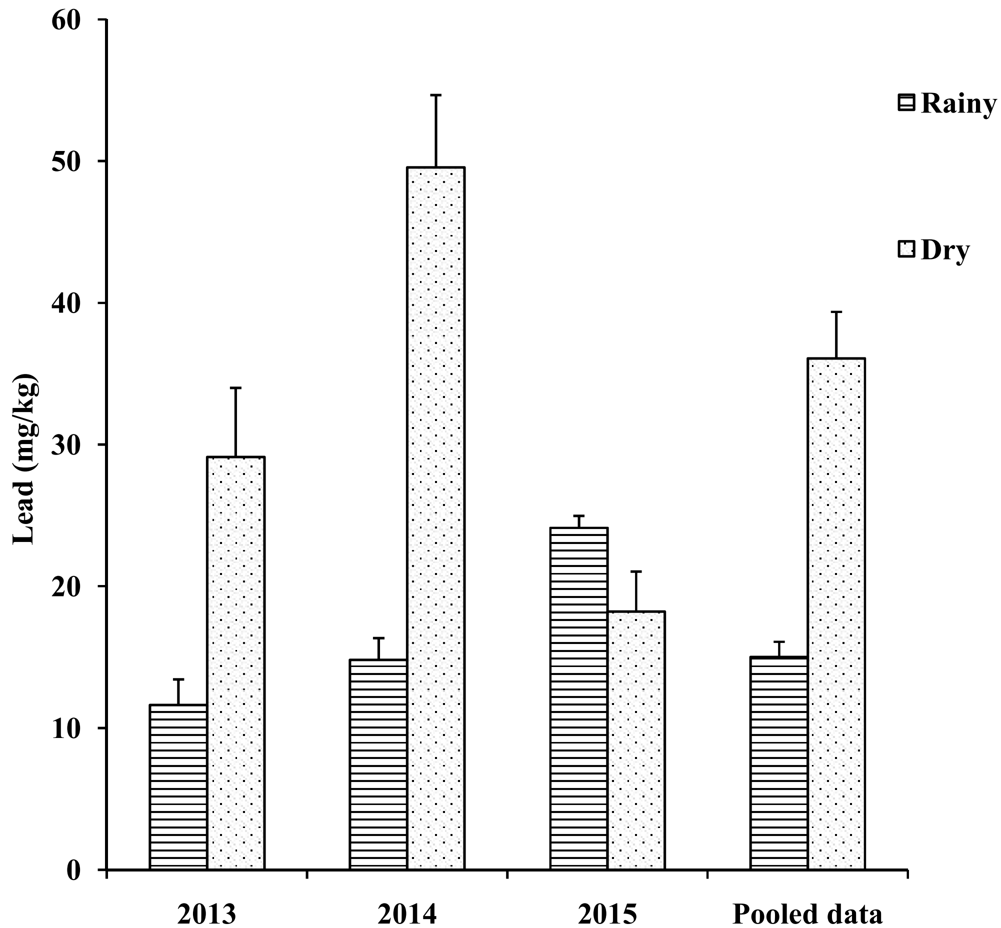

Fig. 51: Annual and pooled seasonal variation of lead concentration in sediment samples of Erelu Reservoir in Oyo Town, Nigeria

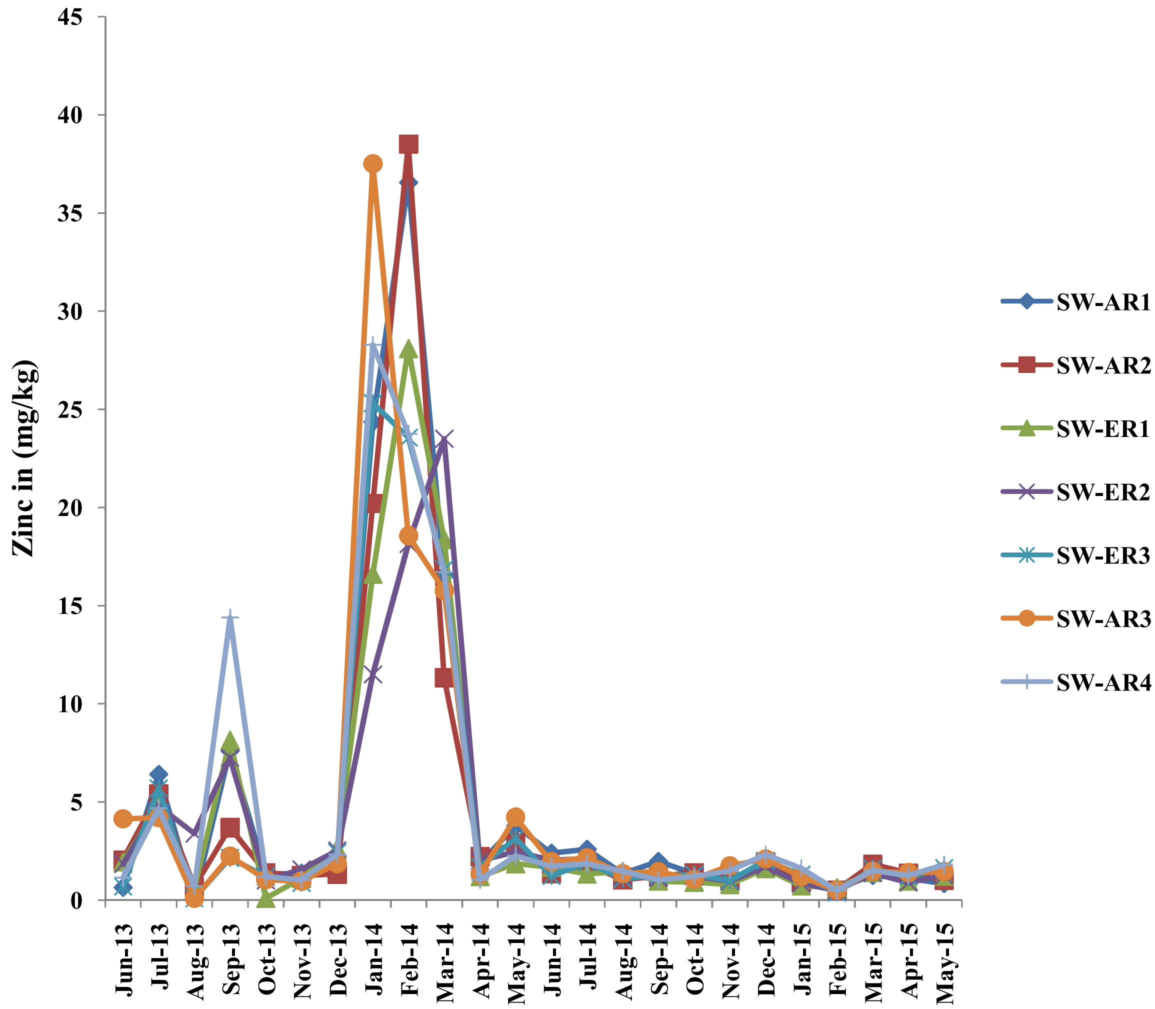

Fig. 52: Monthly variation in Zinc concentration of sediment samples of Erelu Reservoir from June 2013 to May 2015

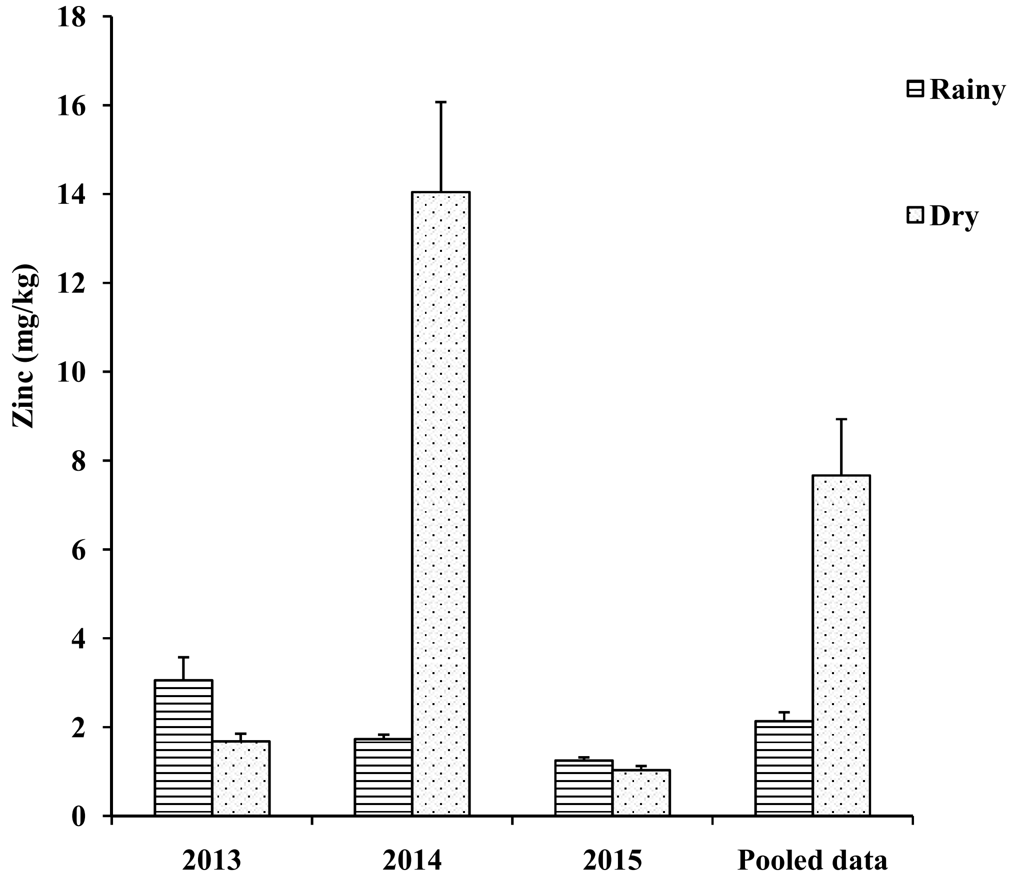

Fig. 53: Annual and pooled seasonal variation of zinc concentration in sediment of Erelu Reservoir in Oyo Town, Nigeria

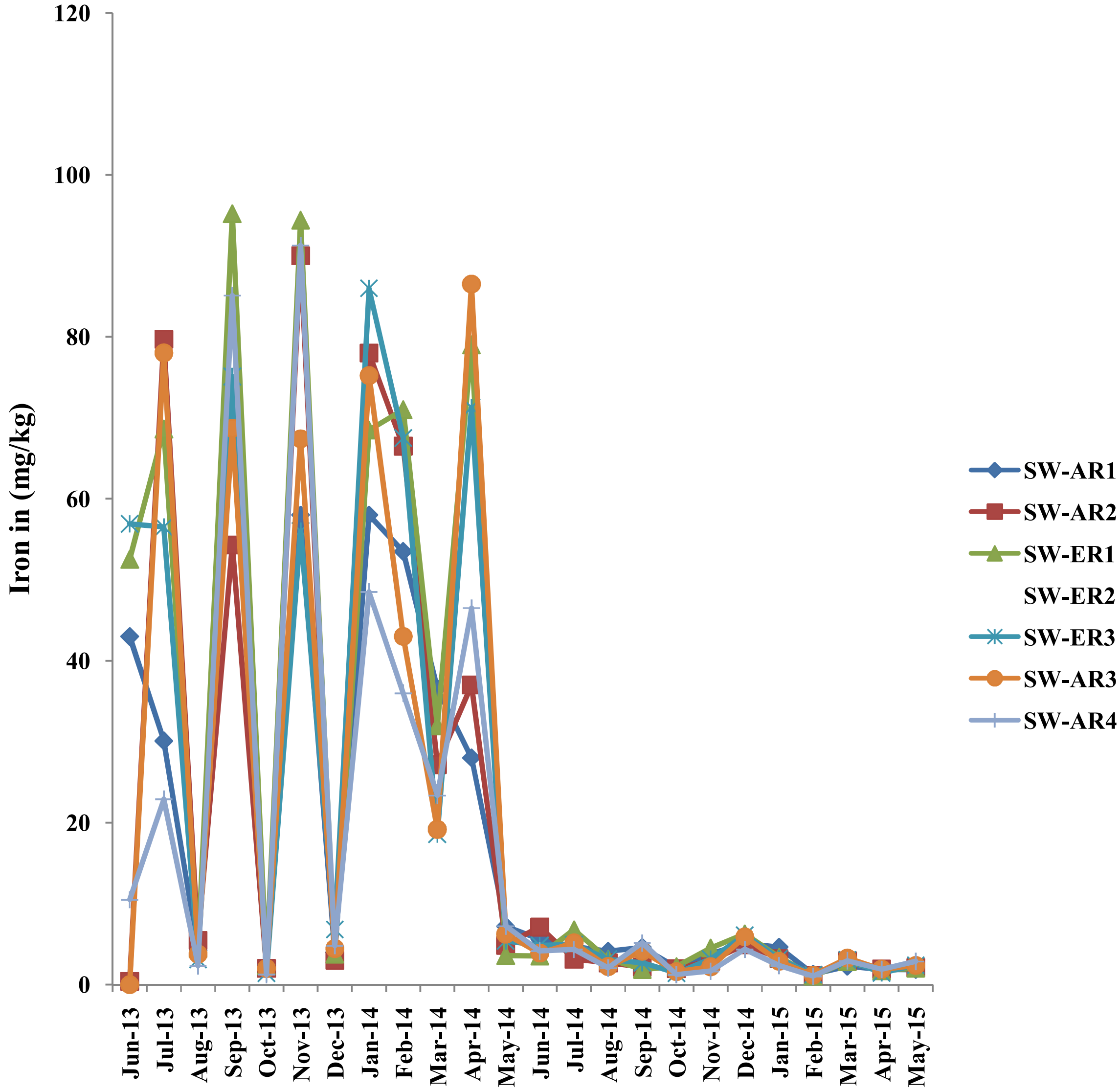

Fig. 54: Monthly variation in Iron concentration of sediment samples of Erelu Reservoir from June 2013 to May 2015

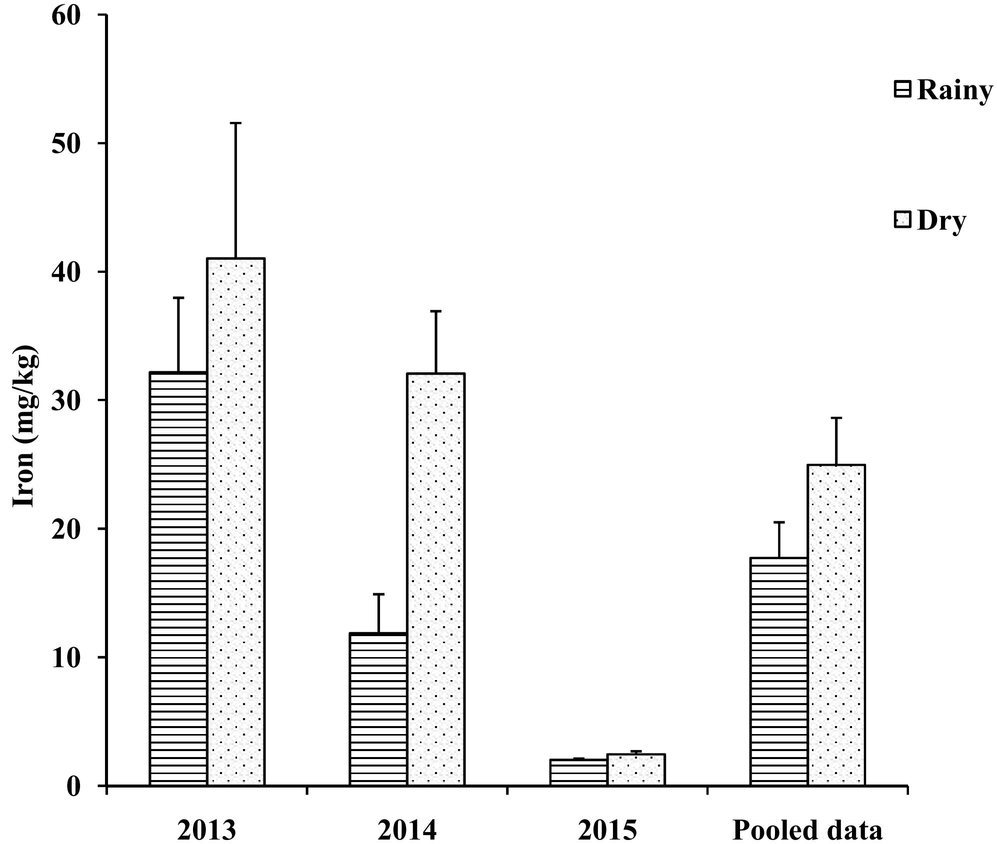

Fig. 55: Annual and pooled seasonal variation of iron concentration in sediment of Erelu Reservoir in Oyo Town, Nigeria

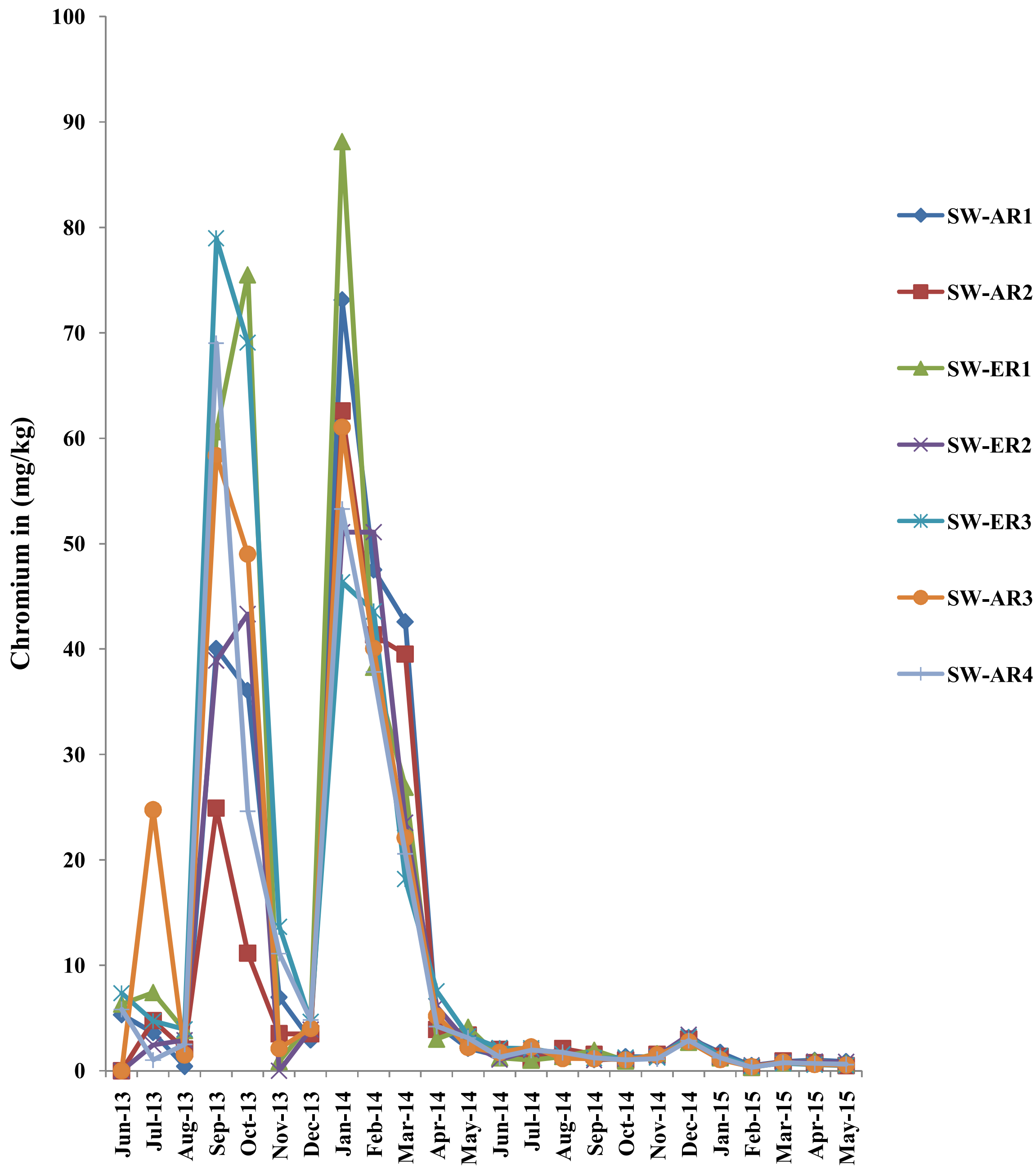

Fig. 56: Monthly variation in Chromium concentration of sediment samples of Erelu Reservoir from June 2013 to May 2015

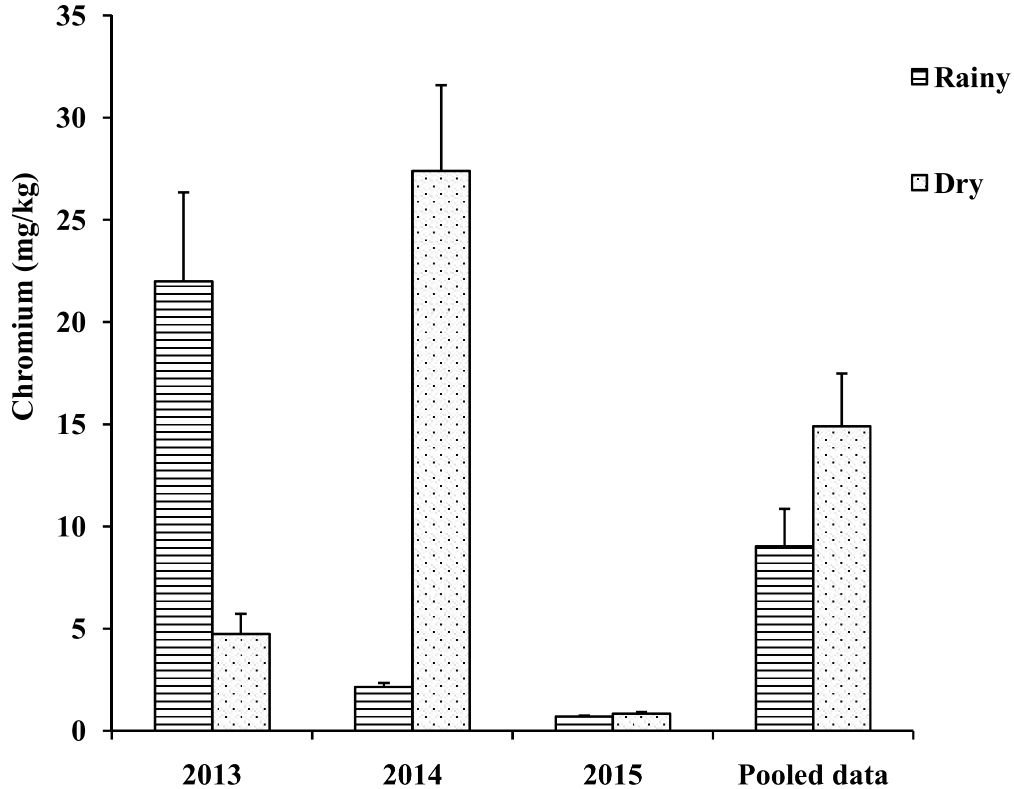

Fig. 57: Annual and pooled seasonal variation in chromium concentration in sediment samples of Erelu Reservoir in Oyo town, Nigeria

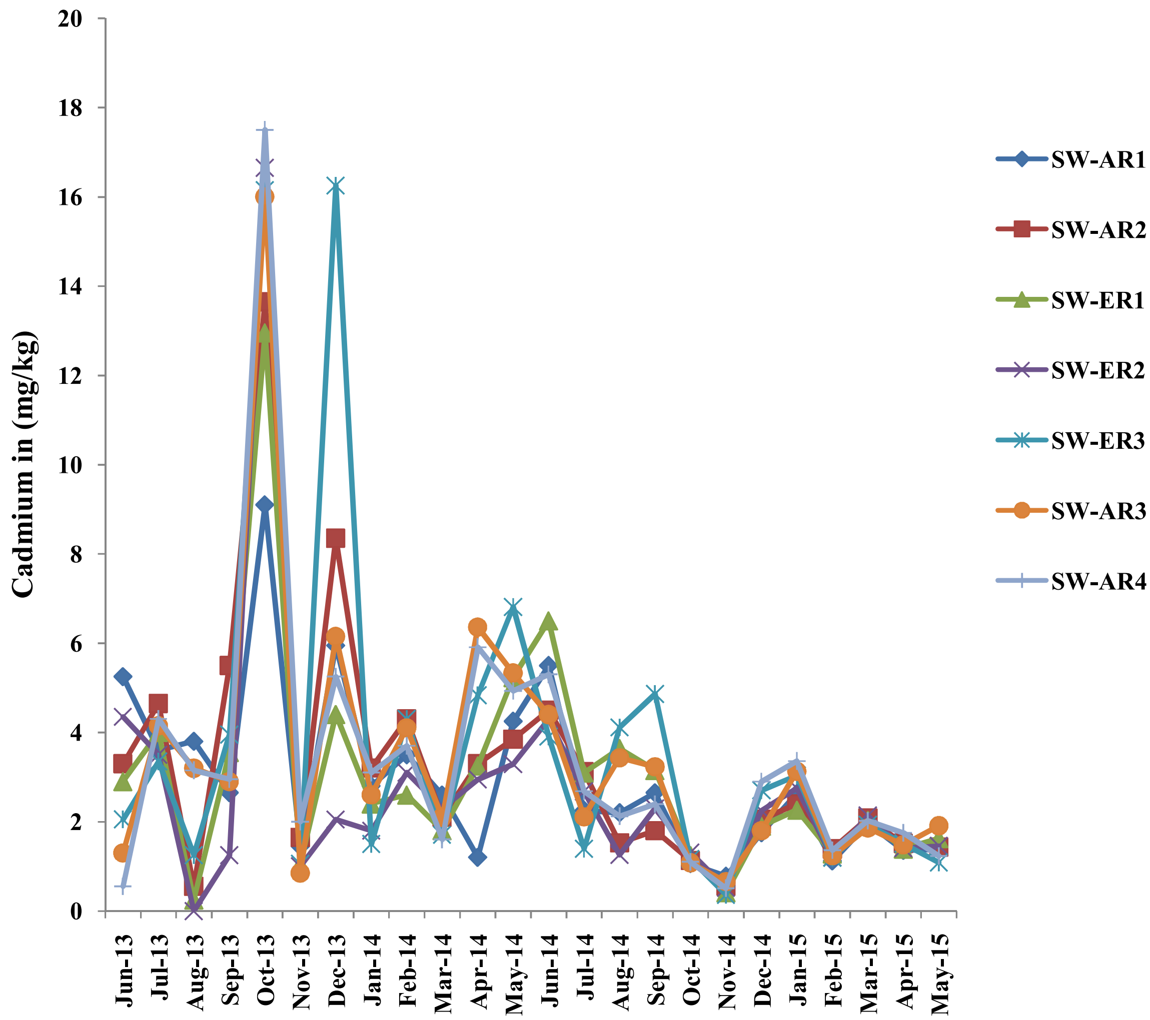

Fig. 58: Monthly variation in Cadmium concentration of sediment samples of Erelu Reservoir from June 2013 to May 2015

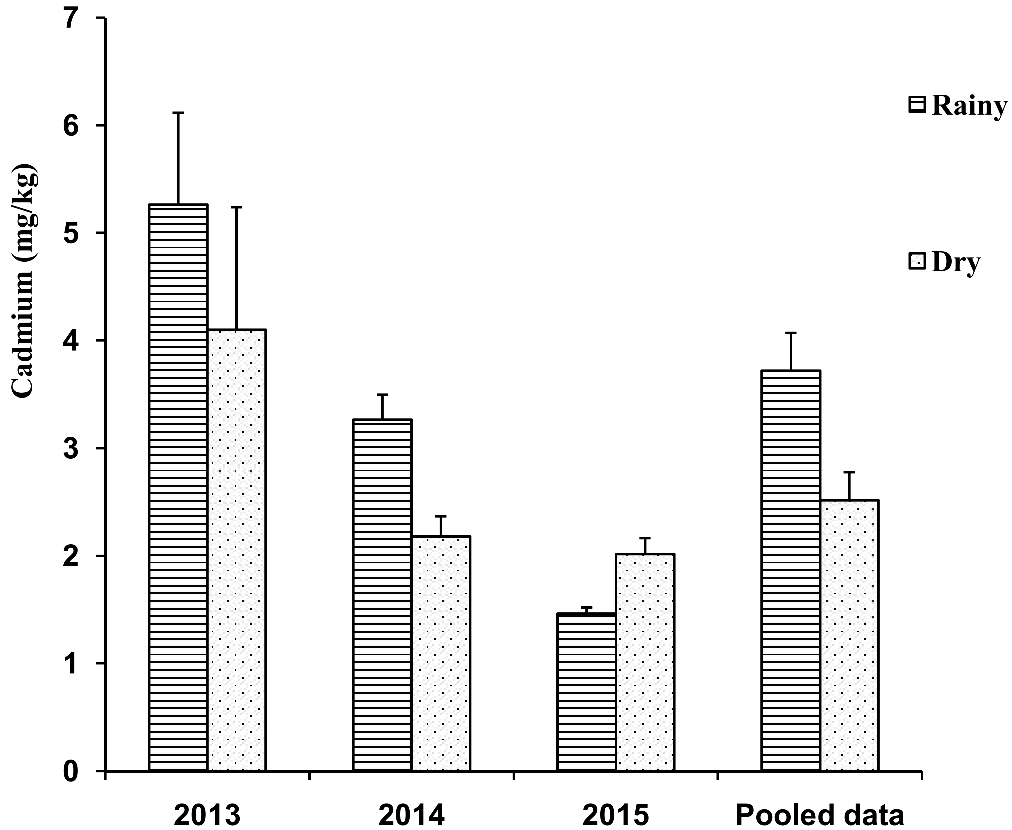

Fig. 59: Annual and pooled seasonal variation in cadmium concentration in sediment samples from Erelu Reservoir in Oyo Town, Nigeria

4.4: Mean comparison of physicochemical parameters from Erelu Reservoir (ANOVA)

4.4.1 Spatial comparison of physicochemical parameters within season

Transparency of the reservoir did not significant deviation ($p=0.05$) in the mean concentrations at the inlet and reservoir stations, however significant deviation ($p<0.05$) were recorded in the outlet station of the reservoir during rainy and dry seasons. Turbidity, Calcium ion, Magnesium ion, Phosphate, Nitrate, Dissolved Oxygen, Biological Oxygen Demand, Total Dissolved Solid, Total Alkalinity, pH, Temperature and Conductivity mean concentrations were not significant ($p=0.05$) at inlet, reservoir and outlet stations of Erelu reservoir during rainy and dry seasons except BOD that was significant ($p<0.05$) at the inlet and the reservoir stations during rainy and dry seasons (Appendix 1). Mean concentration of Iron, Zinc, Chromium and Cadmium from the water samples were not significantly ($p=0.05$) different across the reservoir inlet, main reservoir and the outlet during dry and rainy seasons. Lead (mg/L) mean values was not significantly ($p=0.05$) varied in the reservoir station compared to inlet and outlet stations that deviated significantly ($p<0.05$) in the rainy and dry seasons. The mean concentration of Lead, Zinc, Iron, Chromium and Cadmium from the sediment samples were not significantly different ($p=0.05$) across the stations of Erelu reservoir during wet and dry seasons (Appendix 2 and 3).

4.5. T-test of significance showing seasonal variation of physicochemical parameters

Transparency, temperature, BOD and TA were all significantly different ($p<0.05$) between seasons across stations while TDS, Conductivity and DO were not significantly different between seasons across the inlet, reservoir and outlet stations. Turbidity, calcium ion, nitrate, and phosphate revealed significant variations ($p<0.05$) in the reservoir and outlet stations, however, magnesium ion varied significantly ($p<0.05$) between seasons in the inlet and reservoir stations. Hydrogen ion concentration also revealed a significant deviation ($p<0.05$) between seasons in inlet and outlet stations of Erelu reservoir (Appendix 4). Iron, Zn and Cr in water samples were significantly different ($p<0.05$) between seasons across the inlet, reservoir and outlet stations. Lead values were not significantly different ($p>0.05$) across all stations.

Likewise Cadmium varied significantly in the reservoir inlet and outlet stations. Lead and Zinc in the sediment samples were significant between seasons in all stations, however, Cr was significantly deviated (p<0.05) at inlet station alone and Cd was significantly different between seasons in the reservoir station only (Appendix 5 and 6).

4.6. Comparison of Physico-chemical Parameters with National and International Criteria

Physico-chemical parameters from sampled stations compared with national and international standards were presented in table 4.6. All physico-chemical parameters examined during this study were within or below the limits recommended by national and international limits. Temperature, Dissolved Oxygen (DO), Hydrogen ion concentration (pH), Total Alkalinity (TA), Total Dissolved Solid (TDS) and Conductivity values were within the recommended limits of WHO, NESREA and SON respectively. Magnesium ion (Mg^{2+}), Calcium ion (Ca^{2+}), Phosphate (PO_4^{3-}), Nitrate (NO_3^-) and Biological Oxygen Demand (BOD) were below the recommended standard values of national and international criteria. However, turbidity values were higher than limits recommended (5.00 Ntu) in all cases for drinkable water and aquatic organism survival. Lead, Iron, Chromium Cadmium in the water samples exceeded the required limits in all cases and across the study stations except Zinc (Table 4.6b). Values of heavy metals in the sediment samples such as, Pb, Cr, Fe, Zn and Cd concentrations exceeded the limits for drinking water and aquatic life survival across the sampling stations (Table 4.6c).

Table 4.6a: Comparison of physico-chemical mean values of Erelu Reservoir with National and International Agencies Approved values

Parameters	Statistical Tool	Reservoir Inlet	Main Reservoir	Reservoir Outlet	Drinking water Limits By Agencies	NESREA Limits (Aquatic Environment)
Transparency (cm)	Mean Range	49.96±2.39 22.56-85.00	84.81±1.48 70.00-120.00	49.29±2.62 22.00-90.00	NS	NS
Turbidity (NTU)	Mean Range	11.59±2.11 ND-64.70	10.18±1.91 ND-66.80	12.48±3.00 ND-101.50	5.00[a] 5.00[b] 5.00[c]	10.00
Temperature (oC)	Mean Range	28.44±0.23 25.50-32.60	28.48±0.18 25.50-31.60	28.58±0.24 25.40-31.80	24-28°C[a] 32.00°C[b] NS[c]	25-30°C
Calcium ion (mg/L)	Mean Range	17.73±1.15 2.44-35.20	16.39±0.79 2.93-32.00	17.60±0.98 2.93-29.60	<15.00[a] 180.00[b] NS[c]	200
Magnesium ion (mg/L)	Mean Range	7.51±0.90 0.62-34.00	7.99±0.81 0.34-30.00	7.57±0.95 0.48-26.00	30-150[a] 40.00[b] 0.20[c]	200
Phosphate (mg/L)	Mean Range	0.09±0.02 0.01-0.48	0.13±0.04 0.01-2.73	0.21±0.08 0.01-2.73	0.10[a] 3.50[b] 100[c]	5.00
Nitrate (mg/L)	Mean Range	0.63±0.11 ND-2.69	1.14±0.15 ND-3.89	0.59±0.10 ND-2.88	50.00[a] 9-10[b] 50.00[c]	10.00

Keys to Abbreviations and Agencies

ND=Not detected

NS=Not specified

a=WHO

b=NESREA

c=SON

Table 4.6a: Comparison of physico-chemical mean values of Erelu Reservoir with National and International Agencies Approved values Contd.

Parameters	Statistical Tool	Reservoir Inlet	Main Reservoir	Reservoir Outlet	Drinking water Limit	NESREA Limits (Aquatic Environment)
Dissolved Oxygen (mg/L)	**Mean** **Range**	8.46±0.25 3.96-14.6	8.32±0.16 3.36-14.00	8.43±0.19 6.02-12.20	4-10[a] 6.00[b] NS[c]	NS
Biological oxygen Demand (mg/L)	**Mean** **Range**	1.25±0.22 ND-7.03	1.09±0.16 0.10-6.77	1.23±0.21 0.01-7.38	4.00[a] 3.00[b] NS[c]	30
Hydrogen ion concentration pH (Mg/L)	**Mean** **Range**	7.37±0.06 6.64-8.43	7.34±0.05 6.60-8.60	7.48±0.06 6.80-8.20	6.5-8.5[a] 6.5-8.5[b] 6.5-8.5[c]	6.5-8.5
Total Alkalinity (Mg/l)	**Mean** **Range**	98.81±5.21 48.00-176.00	101.50±4.19 30.00-174.00	93.71±4.80 30.00-160.00	100[a] 500[b] 100[c]	NS
Total Dissolved Solid (mg/l)	**Mean** **Range**	136.01±13.82 14.00-486.00	139.89±10.75 22.00-465.00	146.16±13.72 26.00-476.00	1000[a] 1200[b] 500[c]	2000
Conductivity (µscm-1)	**Mean** **Range**	198.01±19.84 11.43-689.00	204.81±15.58 31.43-664.00	216.26±19.95 37.14-676.00	1000[a] NS[b] 500[c]	NS

Keys to Abbreviations and Agencies

ND=Not detected

NS=Not specified

a=WHO

b=NESREA

c=SON

Table 4.6b: Comparison of heavy metal values in water sample from Erelu Reservoir with National and International Agencies Approved values

Parameters (mg/L)	Statistcal Tool	Reservoir Inlet	Main Reservoir	Reservoir Outlet	Drinking water Limits	NESREA Limits (Aquatic Environment)
Lead (Pb)	**Mean** **Range**	0.93±0.10 0.05-2.94	1.85±0.86 ND-3.00	1.06±0.11 0.02-3.22	0.05[a] 0.05[b] 0.01c	0.05
Iron (Fe)	**Mean** **Range**	0.59±0.07 ND-1.56	0.58±0.06 ND-2.50	0.58±0.08 0.01-1.71	0.30[a] 0.03[b] 0.30[c]	1.0
Zinc (Zn)	**Mean** **Range**	1.03±0.31 0.06-8.15	0.89±023 0.03-8.55	0.90±0.27 0.02-7.69	5.00[a] 1.5[b] 3.00[c]	1.0
Chromium (Cr)	**Mean** **Range**	0.23±0.04 ND-1.17	0.30±0.06 ND-3.63	0.21±0.03 ND-1.08	0.05[a] 0.10[b] 0.05[c]	0.03
Cadmium (Cd)	**Mean** **Range**	0.22±0.03 ND-0.78	0.25±0.03 ND-1.79	0.23±0.03 ND-0.88	0.005[a] 0.01[b] 0.003[c]	0.02

Keys to Abbreviations and Agencies

ND=Not detected

NS=Not Specified

a=WHO

b=NESREA

c=SON

Table 4.6c: Comparison of heavy metal values in sediment samples from Erelu Reservoir with National and International Agencies Approved values

Parameters (Mg/kg)	Statistical Tool	Reservoir Inlet	Main Reservoir	Reservoir Outlet	Drinking water Limits	NESREA Limits (Aquatic and Environment)
Lead (Pb)	**Mean** **Range**	24.70±3.26 1.24-87.51	22.86±2.59 1.23-96.03	24.26±3.23 1.06-88.56	0.05[a] 0.05[b] NS[c]	0.05
Iron (Fe)	**Mean** **Range**	19.26±3.80 0.41-90.00	23.03±3.71 ND-98.30	18.85±4.03 ND-91.30	NS[a] 5.00[b] NS[c]	1.0
Zinc (Zn)	**Mean** **Range**	4.72±1.23 0.10-38.5	4.09±0.77 0.10-28.1	4.70±1.14 0.10-37.5	NS[a] 1.00[b] NS[c]	1.0
Chromium (Cr)	**Mean** **Range**	10.36±2.61 ND-73.12	12.40±2.56 ND-88.14	11.20±2.71 ND-69.00	0.05[a] 0.05[b] 0.05[c]	0.03
Cadmium (Cd)	**Mean** **Range**	3.10±0.35 0.55-13.65	3.18±0.39 ND-16.65	3.40±0.46 0.51-17.50	0.005[a] 0.01[b] NS[c]	0.02

Keys to Abbreviations andAgencies

ND=Not detected

NS=Not specified

c=SON

a=WHO

b=NESREA.

4.7. Biological Assemblage of Erelu Reservoir

The Checklist and diversity of macro-invertebrates of Erelu reservoir are presented in Table 4.7

Seventy two thousand, one hundred and sixty five (72,165) individuals of insects macro-invertebrates comprising of four (4) orders, nineteen (19) families and thirty eight (38) species were collected. Eighteen (18) species, nine (9) orders, and eleven (11) families with seven thousand, one hundred and thirty (7,130) benthic macro-invertebrate individuals were encountered. Total of 56 species, 13 orders, 30 families and 79,295 individual macro-invertebrates were encountered in Erelu reservoir. *Gyrinus sp., Appasus sp., Notonecta sp., Velia caprai, Ptilomera sp. Cylindrothetus sp., Hydrometra sp., Corixa sp., Ischnura sp., Trithemis* species and *Aeshna sp* were recorded during the wet and dry seasons across stations. *Hydaticus sp., Dineutus sp., Syrphid species* and Tabanid larva were scantly found across stations in the reservoir. *Lethocerus species* and *Lacotrephes sp* were found just once in the reservoir during sampling.

Chironomus sp., Lymnae natalensis, Melanoides tuberculata, Indoplarnobis exustus, Bulinus senegalensis, Anodonta cygnea, Margaritifera margaritifera were commonly found across stations throughout sampling in Erelu reservoir, while *Lanistes lybicus, Potadoma libriensis, Bulinus globosus, Tarebia granifera and Amarinus sp* were found once throughout sampling in Erelu reservoir.

4.7. Biological Assemblage of Erelu Reservoir

Order/Species	Rainy seasons Inlet	Rainy seasons Reservoir	Rainy seasons Outlet	Dry seasons Inlet	Dry seasons Reservoir	Dry seasons Outlet
COLEOPTERA						
Gyrinus substriatus	+	+	+	+	+	+
Sphaeridium scarabeoides	+	+	--	+	--	+
Cyphonocerus ruficollis	+	+	+	+	+	--
Hydaticus sp.	--	+	--	--	--	--
Dineutus sp.	--	+	--	--	+	+
Dytiscus sp.	+	--	+	--	--	--
DIPTERA						
Syrphid sp.	+	--	--	--	--	--
Tabanid larva	+	--	--	--	+	--
HEMIPTERA						
Appasus sp.	+	+	+	+	+	+
Gerris sp.	+	+	+	+	+	+
Notonecta sp.	+	+	+	+	+	+
Velia caprai	+	+	+	+	+	+
Ptilomera sp.	+	+	+	+	+	+
Hydrometra sp.	+	+	+	+	+	+
Corixa Sp.	+	+	+	+	+	+
Cylindrothetus sp.	+	+	+	+	+	+
Ranatra sp.	+	+	+	--	+	+
Dytiscid larva	+	+	--	--	--	--
Lethocerus sp.	--	--	+	--	--	--
Lacotrephes sp.	--	--	--	--	+	--

Species status in sample stations

+ Present

_ Absent

4.7. Biological Assemblage of Erelu Reservoir contd.

Order/Species	Rainy seasons Inlet	Reservoir	Outlet	Dry seasons Inlet	Reservoir	Outlet
ODONATA						
Aeshna sp.	+	+	+	--	+	--
Libellula sp.	--	+	--	--	+	+
Miathyria sp.	+	+	+	--	+	--
Ischnura sp. (larva)	+	+	+	+	+	+
Ischnura pumilio	+	+	+	+	+	+
Sympetrum fonscolombii	+	+	--	+	+	+
Ceriagrion glabrum	+	+	+	--	+	--
Ceriagrion tenellum	--	+	--	+	+	--
Orthetrum Sp.	--	+	--	--	--	--
Ischnura elegan	--	--	+	+	+	+
Selysiothermis nigra	+	+	--	+	+	--
Trithemis Kirbyi	+	+	+	+	+	+
Trithemis annulata	+	+	+	+	+	+
Aeshna mixta	+	+	+	+	+	+
Cordulegaster sp.	_	+	_	_	_	_
Ischnura verticalis	--	+	--	--	--	+
Displacodes sp.	+	+	--	--	+	+
Lestes sp.	--	+	+	--	--	--
Libellula quadrimaculatus	--	--	--	+	+	--

Species status

+ Present

_ Absent

4.7. Biological Assemblage of Erelu Reservoir contd.

Order/Species	Rainy seasons Inlet	Reservoir	Outlet	Dry seasons Inlet	Reservoir	Outlet
ARCHITAENIOGLOSSA						
Lanistes lybiscus	--	+	--	+	--	--
Pomacea bridgesii	+	+	+	+	+	+
Viviparus contectus	+	+	+	+	+	+
CAPITELLIDA						
Arenicola sp.	+	+	+	--	+	--
DIPTERA						
Chironomus sp.	+	+	+	+	+	+
HYGROPHILA						
Lymnae natalensis	+	+	+	+	+	+
PHYLODOCIDA						
Nereis sp.	--	+	+	--	--	+
PULMONATA						
Indoplarnobis exustus	+	+	+	+	+	+
Bulinus truncatus	+	--	--	--	--	--
Bulinus senegalensis	+	+	+	+	+	+
Bulinus globosus	--	--	--	+	--	+
SORBEOCONCHA						
Melanoides tuberculata	+	+	+	+	+	+
Tarabia granifera	+	--	--	--	--	--
Potadoma moerchii	+	+	+	+	+	+
Potadoma libriensis	–	–	–	–	+	–
UNIONIDEA						
Anodonta cygnea	+	+	+	+	+	+
Margaritifera margaritifera	+	+	+	+	+	+
DECAPODA						
Amarinus sp.	--	--	--	+	--	+

Species status

+ Present

_ Absent

4.8. Percentage composition of macro-invertebrates in Erelu Reservoir

4.8.1 Seasonal variations in abundance of insect macro-invertebrates Encountered during sampling

The aquatic insect macro-invertebrates encountered in Erelu reservoir during the period of this study were the Coleoptera that was represented by six species, *Cyphonocerus ruficollis* made up the highest percentage composition of 2,732 (6.76%) and they were recorded in early April. This is followed by *Gyrinus substriatus* with 1,112 (2.75%) and they have the highest number of individuals at outlet station (581), inlet (286) and reservoir (245). *Hydaticus sp*. and *Dytiscus sp*. were encountered once during sampling.

The order Diptera was represented by two species, this gave the lowest percentage composition in both seasons. Hemiptera was represented by twelve species, *Notonecta sp*. made up the highest percentage composition (66.19%) and (31.91%) for rainy and dry seasons respectively. *Corixa sp*. had (19.36%) in rainy and (54.30%) in the dry season, while *Lethocerus sp., Lacotrephes sp., Ranatra sp.* had the least occurrence for the two seasons.

Furthermore, order Odonata was represented by nineteen species, *Trithemis annulata* had highest percentage composition (0.16%) and (0.06%) for rainy and dry seasons, while the least abundant were *Ischnura elegan Ceriagrion glabrum, Cordulegaster sp*., with percentage abundance of (0.01%) and (0.04%) for rainy and dry seasons. Generally, the order of insect macro-invertebrates had highest abundance at the reservoir inlets and outlets in the wet and dry seasons, but the abundance during dry season were at maximum compared to the one encountered during wet season (Figs. 62 and 63).

4.8.2 Seasonal variations in abundance of benthic macro-invertebrates Encountered during sampling

Macro-benthic invertebrates encountered in Erelu reservoir are made up of order Architaenioglossa which was represented by three species namely; *Viviparus contectus* with highest percentage composition of 12.89%, followed by *Pomacea bridgesii* (6.76%), *Lanistes lybicus* had the least abundance in both seasons. Highest percentages were recorded from reservoir inlets and outlets (Fig. 66 and 67). Capitellida was represented by *Arenicola sp*. with percentage composition (1.76% and

0.08%) for both seasons. *Chironomid sp*. was represented by Diptera with percentage composition (4.31%), highest percentage in inlet and reservoir during rainy and dry seasons was (1.52%) with highest percentage of (5.91%) and (6.96%) from inlet and outlet of the reservoir in the rainy season. Hygrophila was represented by *Lymnae natalensis* (12.67%) with highest abundant in the reservoir and outlet during rainy, while highest abundance were recorded in reservoir inlet and outlet during dry season with (3.55%). Phyllodocida was represented by *Nereis sp.* which had (0.28%) and (1.16%) percentage in reservoir and outlet in rainy season and (0.03%) in the outlet during the dry season.

Pulmonata constituted (4.46%) of the total benthic abundance for the rainy and dry season (1.65%) of which *Indoplarnobis exustus* had highest percentage composition (2.23% and 1.29%), while the least abundant species were *Bulinus truncatus* and *Bulinus globosus* with *Indoplarnobis exustus and B. senegalensis* had the highest abundance by number in rainy and dry season. Order Sorbeoconcha was represented by four species of which *Melanoides tuberculata* had highest relative abundance followed by *Potadoma moerchii* and the least abundant were *Tarabia granifera* and *Potadoma libriensis* for both rainy and dry season. The order Unionidea was represented by two species, where *Anodonta cygnea* had (2.23%) percentage composition followed by *Margaritifera margaritifera* which had 1.35%. They are mostly abundant in the wet season than in the dry season. Decapoda was represented by *Amarinus sp.* and was the least encountered during rainy seasons alone (Fig. 64). *Arenicola sp.* 56 (1.76%) and *Nereis sp*. 18 (0.57%) represented the order Capitellida and Phyllodocida. The two of them are majorly marine organisms but are present in this study. They were more abundant in the raining season than in the dry season.

Generally, *Melanoides tuberculata* were more abundant with 2,433 (61.61%) followed by *Potadoma moerchii* 573 (14.51%), *Viviparus contectus* with 284 (7.20%), *Pomacea bridgesii* 267 (6.76%) *Lymnae natalensis* 140 (3.55%) during dry months. Many encountered species are mostly abundant in the wet season compared to dry season except *M. tuberculata* and *P. Moerchii* that had highest abundance and percentage composition during dry season months (Fig. 67). Other species had lowest abundance. There were more species of insects encountered especially the Hemiptera group than the species of benthic macro-invertebrates (Fig. 60).

Table 4.8a: Percentage composition and abundance of insect macro-invertebrates Encountered during rainy and dry seasons in Erelu Reservoir

	SEASONS															
	Rainy								Dry							
	Sampling Stations								Sampling Stations							
Order/ Species Encountered	**Inlet Species**		**Reservoir Species**		**Outlet Species**		**Sp. Total No**	**%**	**Inlet Species**		**Reservoir Species**		**Outlet Species**		**Sp. Total No**	**%**
	No.	**%**	**No.**	**%**	**No.**	**%**			**No.**	**%**	**No.**	**%**	**No.**	**%**		
COLEOPTERA																
Gyrinus substriatus	286	4.56	245	1.04	581	5.55	1,112	2.75	240	3.66	309	1.52	596	12.17	1145	3.60
Sphaeridium scarabeoides	02	0.03	03	0.01	0.00	0.00	05	0.01	01	0.02	0.00	0.00	01	0.02	02	0.01
Cyphonocerus ruficollis	17	0.27	2685	11.36	30	0.29	2732	6.77	132	2.02	300	1.48	0.00	0.00	432	1.36
Hydaticus sp.	0.00	0.00	01	0.00	0.00	0.00	01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dineutus sp.	0.00	0.00	01	0.00	0.00	0.00	01	0.00	0.00	0.00	01	0.01	27	0.55	28	0.09
Dytiscus sp.	01	0.00	0.00	0.00	03	0.03	04	0.01	0.00	0.00	0.00	0.00		0.00	0.00	0.00
DIPTERA																
Syrphid sp.	01	0.00	0.00	0.00	0.00	0.00	01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tabanid larva	03	0.05	0.00	0.00	0.00	0.00	03	0.01	0.00	0.00	02	0.01	0.00	0.00	02	0.01

HEMIPTERA																
Appasus sp.	18		32	0.14	05	0.05	55	0.14	02	0.03	15	0.07	18	0.37	35	0.11
Gerris sp.	212	3.38	300	1.27	66	0.63	578	1.43	18	0.28	436	2.14	72	1.47	526	1.65
Notonecta sp.	5,215	83.15	16,236	68.67	5,297	50.62	26,748	66.24	1,825	27.85	7,727	37.99	596	12.19	10,148	31.93
Velia caprai	47	0.75	54	0.23	272	2.60	373	0.92	25	0.38	108	0.53	1,087	22.23	1,220	3.84
Ptilomera sp.	53	0.84	20	0.09	43	0.41	116	0.29	10	0.15	05	0.03	50	1.02	65	0.20
Hydrometra sp.	111	1.77	94	0.40	220	2.10	425	1.05	07	0.11	32	0.16	507	10.37	546	1.72
Corixa Sp.	222	3.54	3,711	15.70	3,890	37.17	7,823	19.37	4.197	64.06	11,244	55.28	1,830	37.42	17,271	54.34
Cylindrothetus sp.	39	0.62	13	0.06	15	0.14	67	0.17	54	0.82	03	0.02	57	1.16	114	0.36

Table 4.8a: Percentage composition and abundance of insect macro-invertebrates Encountered during rainy and dry seasons in Erelu Reservoir contd.

	INLET Species		RESERVOIR Species		OUTLET Species		TOTAL	%	INLET Species		RESERVOIR Species		OUTLET Species		Total	%
	No	**%**	**No**	**%**	**No**	**%**	**No**	**%**	**No**	**%**	**No**	**%**	**No**	**%**		
Ranatra sp.	01	0.00	02	0.01	01	0.01	04	0.01	0.00	0.00	02	0.01	01	0.02	03	0.01
Dytiscid larva	01	0.00	01	0.00	0.00	0.00	02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lethocerus sp.	0.00	0.00	0.00	0.00	01	0.01	01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lacotrephes sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	01	0.01	0.00	0.00	01	0.00
ODONATA																
Aeshna sp.	03	0.05	01	0.00	05	0.05	09	0.02	0.00	0.00	07	0.03	0.00	0.00	07	0.02
Libellula sp.	0.00	0.00	20	0.09	0.00	0.00	20	0.05	0.00	0.00	05	0.03	03	0.06	08	0.03
Miathyria sp.	11	0.18	26	0.11	02	0.02	39	0.01	0.00	0.00	04	0.02	0.00	0.00	04	0.01
Ischnura sp. (larva)	09	0.14	25	0.11	11	0.11	45	0.11	07	0.11	06	0.03	06	0.12	19	0.06
Ischnura pumilio	04	06	15	0.06	07	0.07	26	0.06	03	0.05	09	0.04	06	0.12	18	0.06
Sympetrum fonscolombii	01	0.00	22	0.09	0.00	0.00	23	0.06	04	0.06	24	0.12	04	0.08	32	0.10
Ceriagrion glabrum	01	0.00	15	0.06	01	0.00	17	0.04	0.00	0.00	01	0.01	0.00	0.00	01	0.00

Ceriagrion tenellum	0.00	0.00	09	0.04	0.00	0.00	09	0.02	02	0.03	12	0.06	0.00	0.00	14	0.04
Orthetrum Sp.	0.00	0.00	08	0.03	0.00	0.00	08	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ischnura elegan	0.00	0.00	0.00	0.00	01	0.01	01	0.00	01	0.02	01	0.01	02	0.04	04	0.01
Selysiothermis nigra	02	0.03	07	0.03	0.00	0.00	09	0.02	02	0.03	08	0.04	0.00	0.00	10	0.03
Trithemis Kirbyi	01	0.00	37	0.16	03	0.03	41	0.10	14	0.21	36	0.18	13	0.27	63	0.20
Trithemis annulata	07	0.11	49	0.21	09	0.09	65	0.16	02	0.03	14	0.07	03	0.06	19	0.06
Aeshna mixta	03	0.05	03	0.01	01	0.01	07	0.02	03	0.05	18	0.09	03	0.06	24	0.08
Cordulegaster sp.	0.00	0.00	01	0.00	0.00	0.00	01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ischnura verticalis	0.00	0.00	02	0.01	0.00	0.00	02	0.01	0.00	0.00	0.00	0.00	06	0.12	06	0.02
Diplacodes sp.	01	0.00	03	0.01	0.00	0.00	04	0.01	0.00	0.00	08	0.04	02	0.04	10	0.03
Lestes sp.	0.00	0.00	02	0.01	01	0.01	03	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Libellula quadrimaculatus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	03	0.05	02	0.01	0.00	0.00	05	0.02
Total	6,272	100	23,643	100	10,465	100	40,380	100	6,552	100	20,340	100	4,890	100	31,785	100

Table 4.8b: Percentage composition and abundance of benthic macro-invertebrates Encountered during rainy and dry seasons in Erelu Reservoir

	Rainy Seasons								Dry Seasons							
ORDER/ SPECIES	INLET Species		RESERVOIR Species		OUTLET Species		TOTAL	%	INLET Species		RESERVOIR Specie		OUTLET Species		TOTAL	%
	NO	%	NO	%	NO	%	No	%	NO	%	NO	%	NO	%	No	%
ARCHITAE NIGLOSSA																
Lanistes lybiscus	0.00	0.00	01	0.14	0.00	0.00	01	0.03	01	0.09	0.00	0.00	0.00	0.00	01	0.03
Pomacea bridgesii	114	10.53	05	0.70	231	16.74	350	11.00	40	3.48	01	0.18	226	10.07	267	6.75
Viviparus contectus	48	4.43	02	0.28	360	26.09	410	12.89	84	7.30	10	1.81	190	8.47	284	7.20
CAPITELLIDA																
Arenicola sp.	03	0.28	13	1.81	40	2.90	56	1.76	0.00	0.00	03	0.54	0.00	0.00	03	0.08
DIPTERA																
Chironomus sp.	64	5.91	50	6.96	23	1.67	137	4.31	45	3.91	05	0.90	10	0.45	60	1.52
HYGROPHILA																
Lymnae natalensis	26	2.40	168	23.40	209	15.15	403	12.67	89	7.73	19	3.43	32	1.43	140	3.55
PHYLODOCIDA																
Nereis sp.	0.00	0.00	02	0.28	16	1.16	18	0.57	0.00	0.00	0.00	0.00	01	0.05	01	0.03
PULMONATA																
Indoplarnobis exustus	55	5.08	09	1.25	07	0.51	71	2.23	24	2.09	03	0.54	24	1.07	51	1.29
Bulinus truncatus	20	1.85	0.00	0.00	0.00	0.00	20	0.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bulinus senegalensis	09	0.83	28	3.90	01	0.07	38	1.20	03	0.26	04	O.72	02	0.09	09	0.23
Bulinus globosus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	01	0.09	0.00	0.00	04	0.18	05	0.13

SORBEOCONCHA																
Melanoides tuberculata	594	54.85	278	38.72	459	33.26	1331	41.84	517	44.92	223	40.25	1,693	75.45	2,433	61.61
Melanoides granifera	01	0.09	0.00	0.00	0.00	0.00	01	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Potadoma moerchii	61	5.63	146	20.33	24	1.74	231	7.26	316	27.45	254	45.85	03	0.13	573	14.51
Potadoma libriensis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16	2.89	0.00	0.00	16	0.41
UNIONIDEA																
Anodonta cygnea	64	5.91	01	0.14	06	0.44	71	2.23	10	0.87	01	0.18	27	1.20	38	0.96
Margaritifera margaritifera	24	2.22	15	2.09	04	0.29	43	1.35	20	1.74	15	2.71	29	1.29	64	1.62
DECAPODA																
Amarinus sp.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	01	0.09	0.00	0.00	03	0.00	04	0.10
Total	1,083	100	718	100	1,380	100	3,181	100	1,151	100	554	100	2,244	100	3,494	100

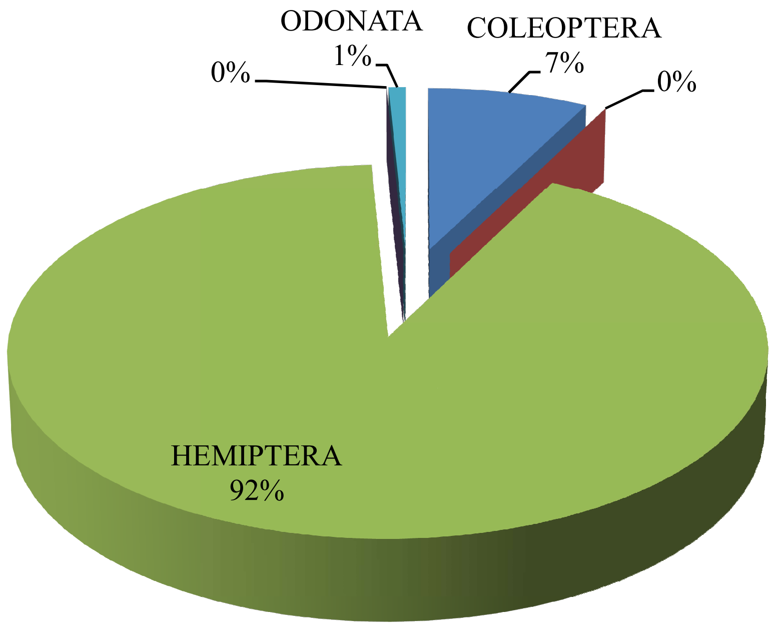

Fig. 60: Relative abundance of insect macro-invertebrates in Erelu reservoir in Oyo Town from 2013 to 2015

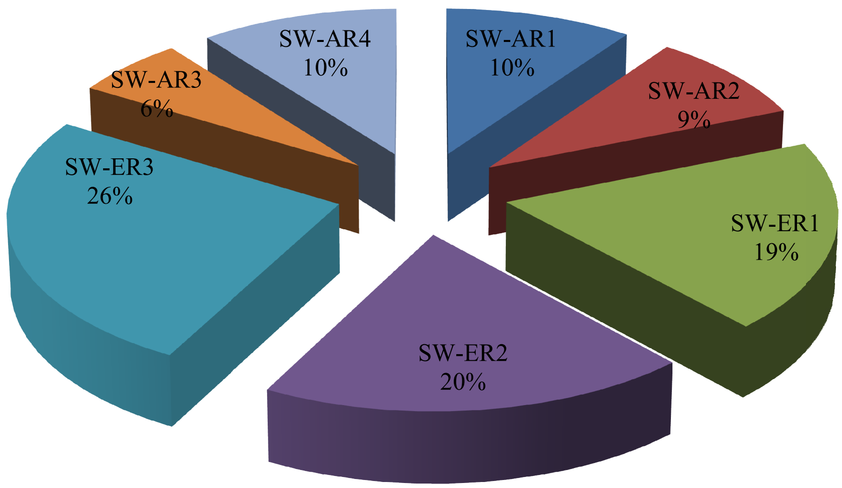

Fig. 61: Relative abundance of insect macro-invertebrates across stations of Erelu reservoir in Oyo Town from 2013 to 2015

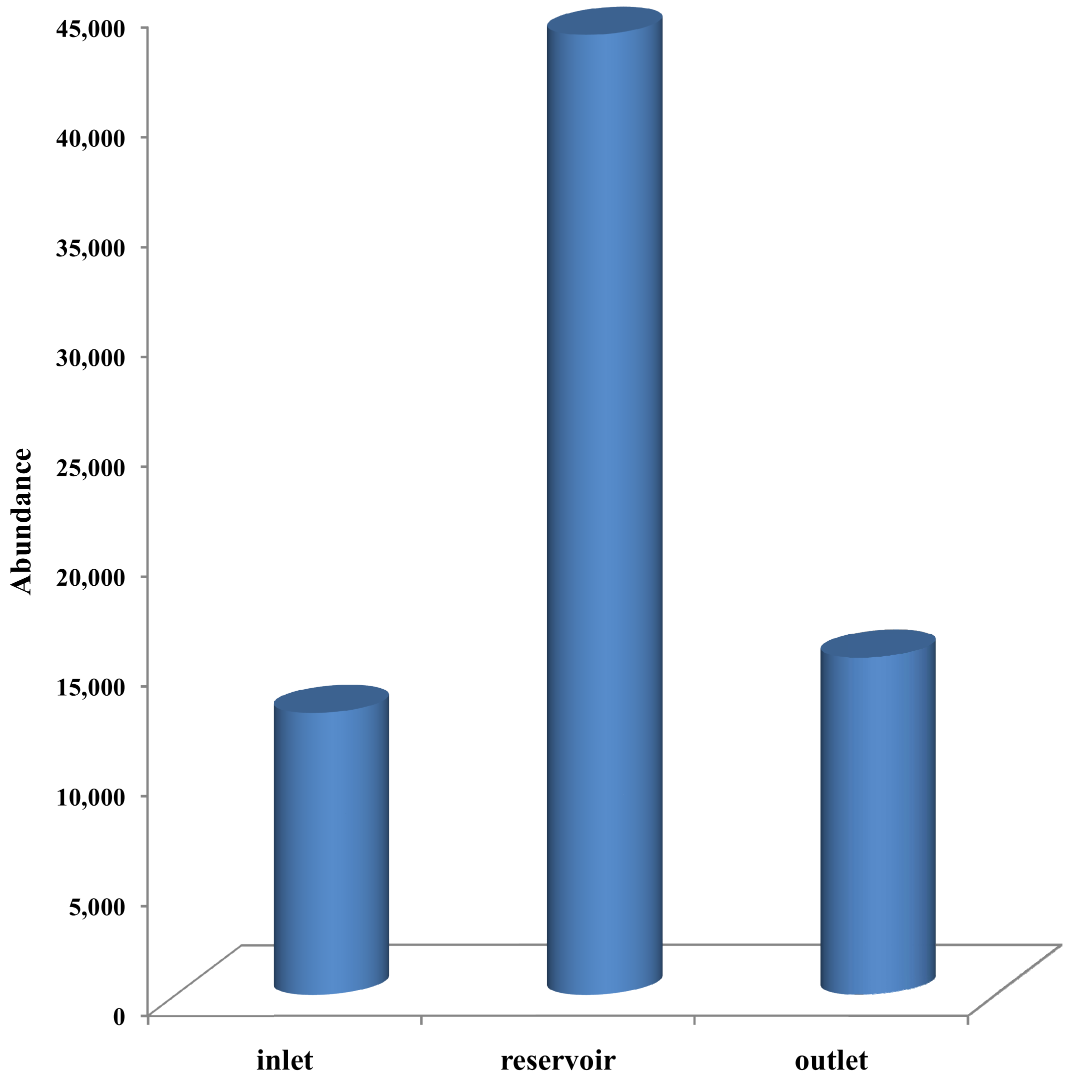

Fig. 62: Numerical values of insect macro-invertebrates across stations of Erelu reservoir between 2013-2015

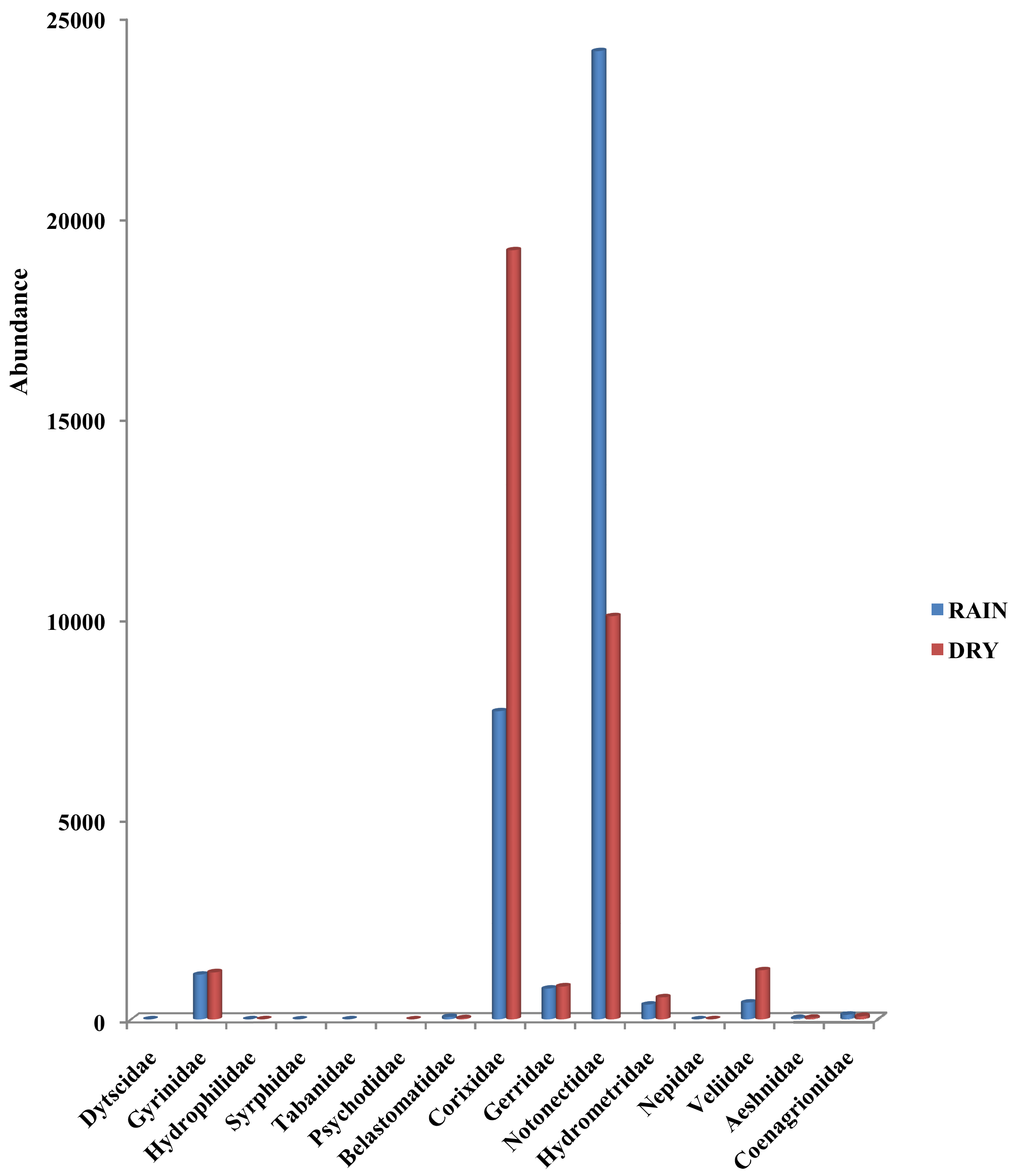

Fig. 63: Seasonal abundance of insect macro invertebrates of Erelu reservoir in Oyo from June 2013-May 2015

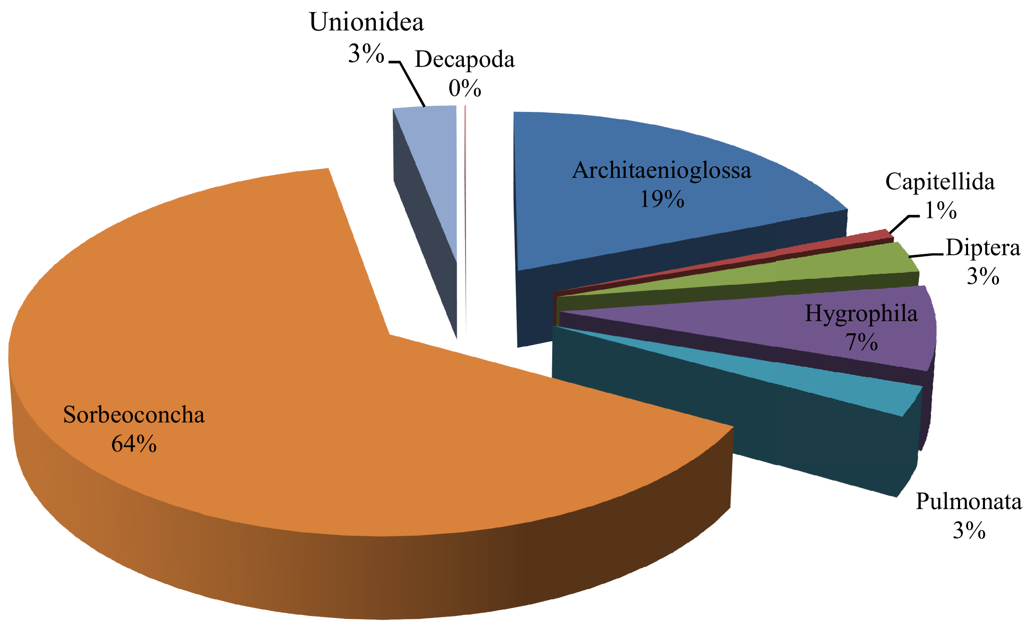

Fig. 64: Relative abundance of benthic macro-invertebrates in Erelu Reservoir in Oyo Town from 2013 to 2015

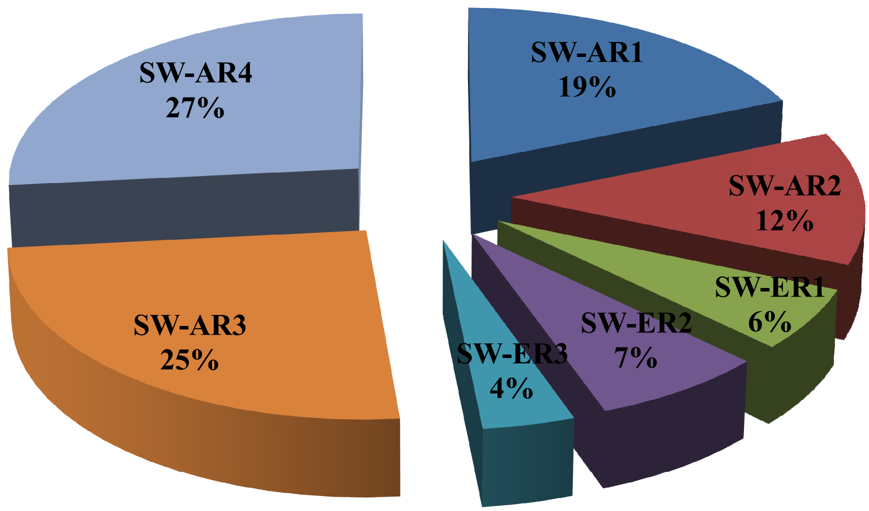

Fig. 65: Relative abundance of benthic macro-invertebrates across stations of Erelu reservoir from 2013 to 2015

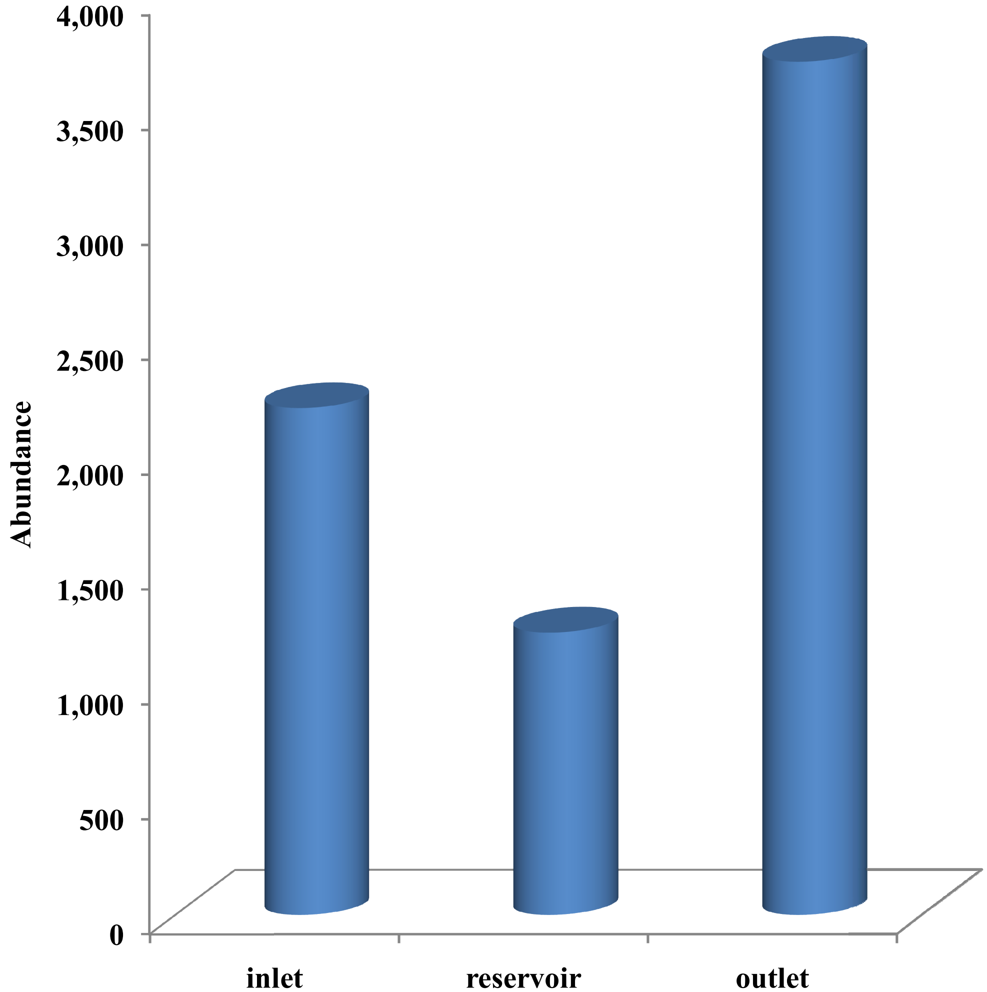

Fig. 66: Numerical abundance of macro-benthic-invertebrates across stations of Erelu reservoir in Oyo Town between 2013-2015

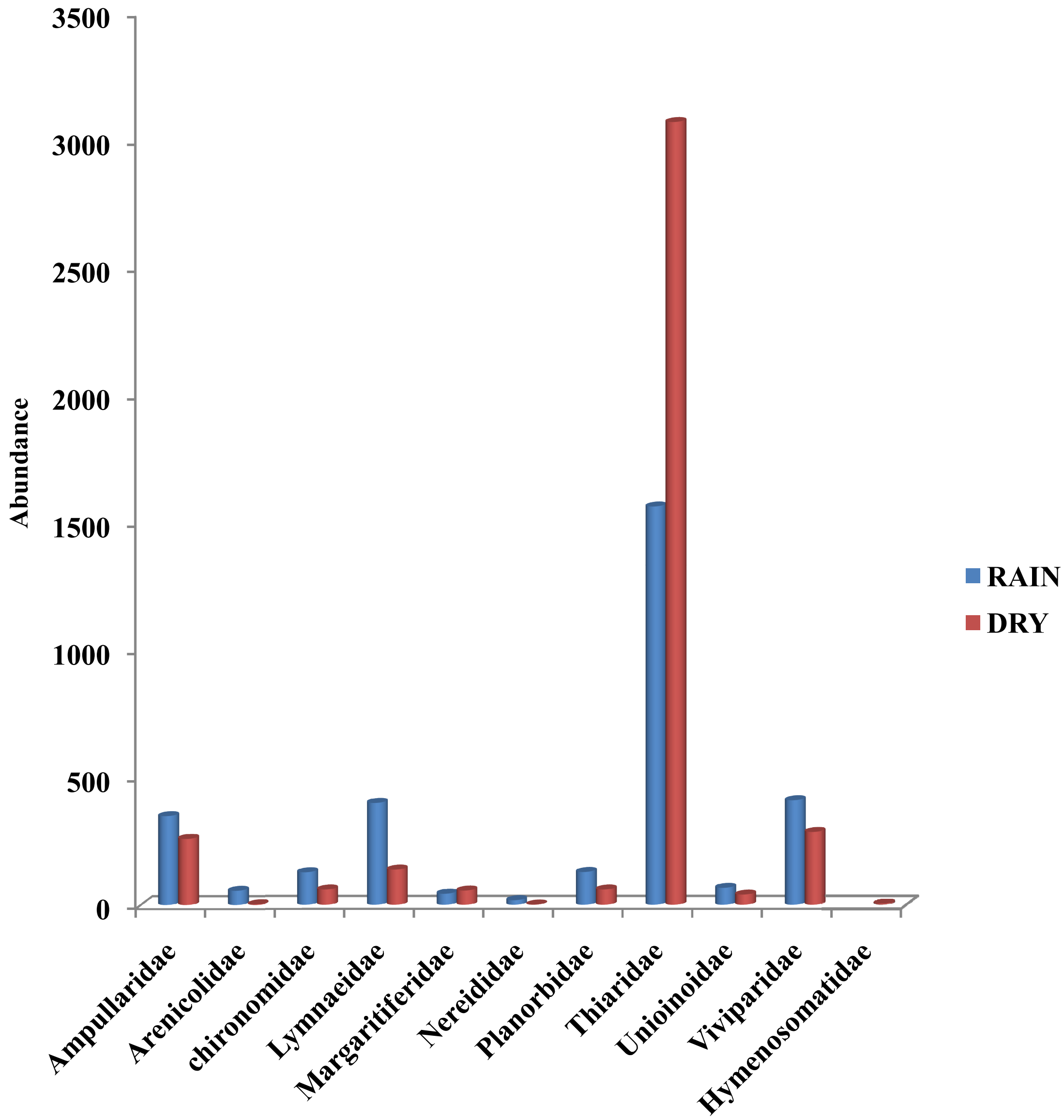

Fig. 67: Seasonal abundance of macro-benthic invertebrates of Erelu reservoir in Oyo from 2013- 2015

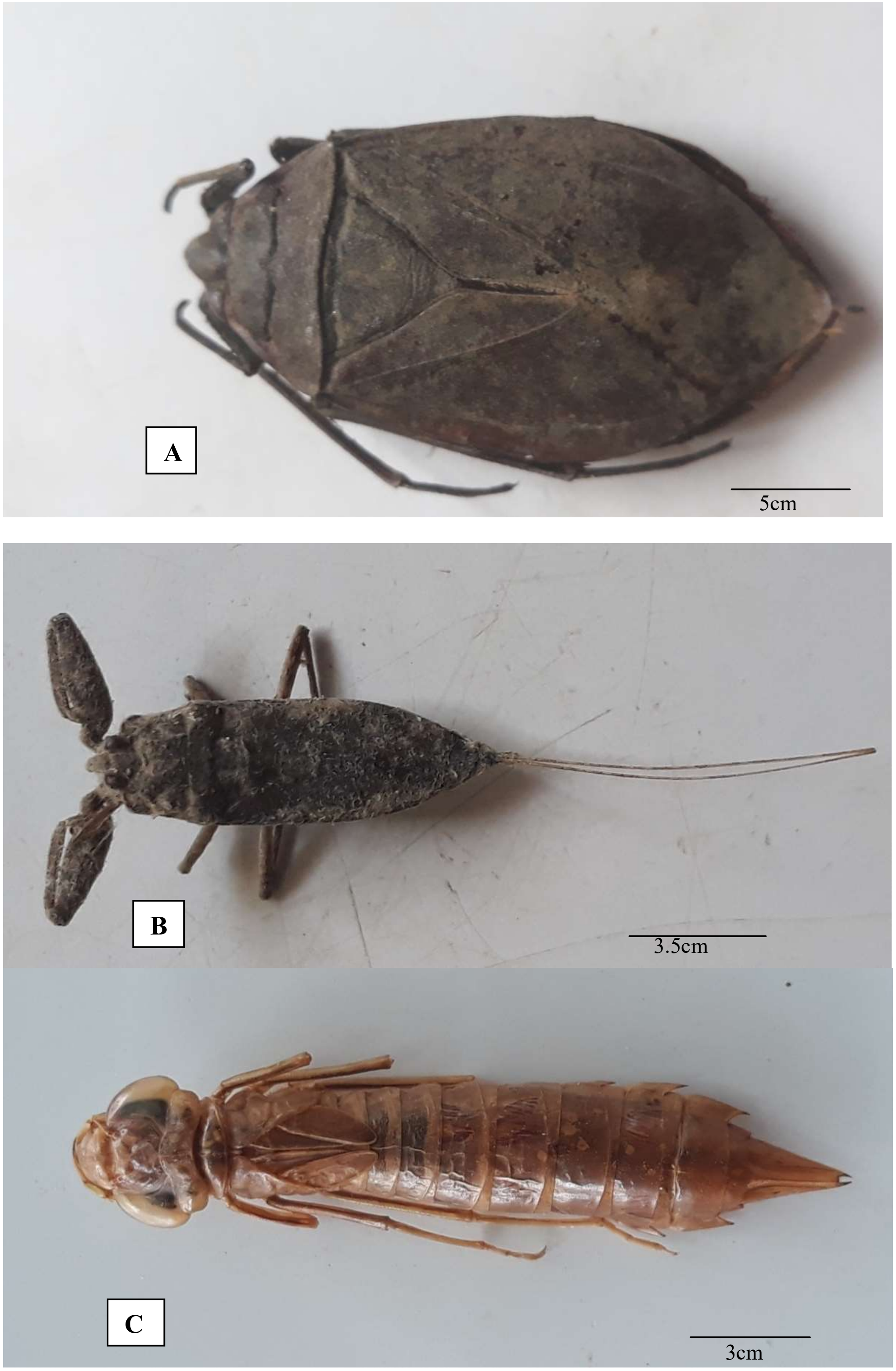

Plate 8: Whole mount of (A) *Lethocerus sp.* (B) *Nepa sp.* and (C) Damsel pupa from Erelu Reservoir in Oyo Town

Plate 9: Whole mount of (D) *Dragonfly larva.* (E) *Dineutus sp.* from Erelu Reservoir in Oyo Town

Plate 10: Whole mount of (F) *Gerris sp.* (G) *Gyrinus sp.* and (H) *Hydrophilus sp*. from Erelu Reservoir in Oyo Town

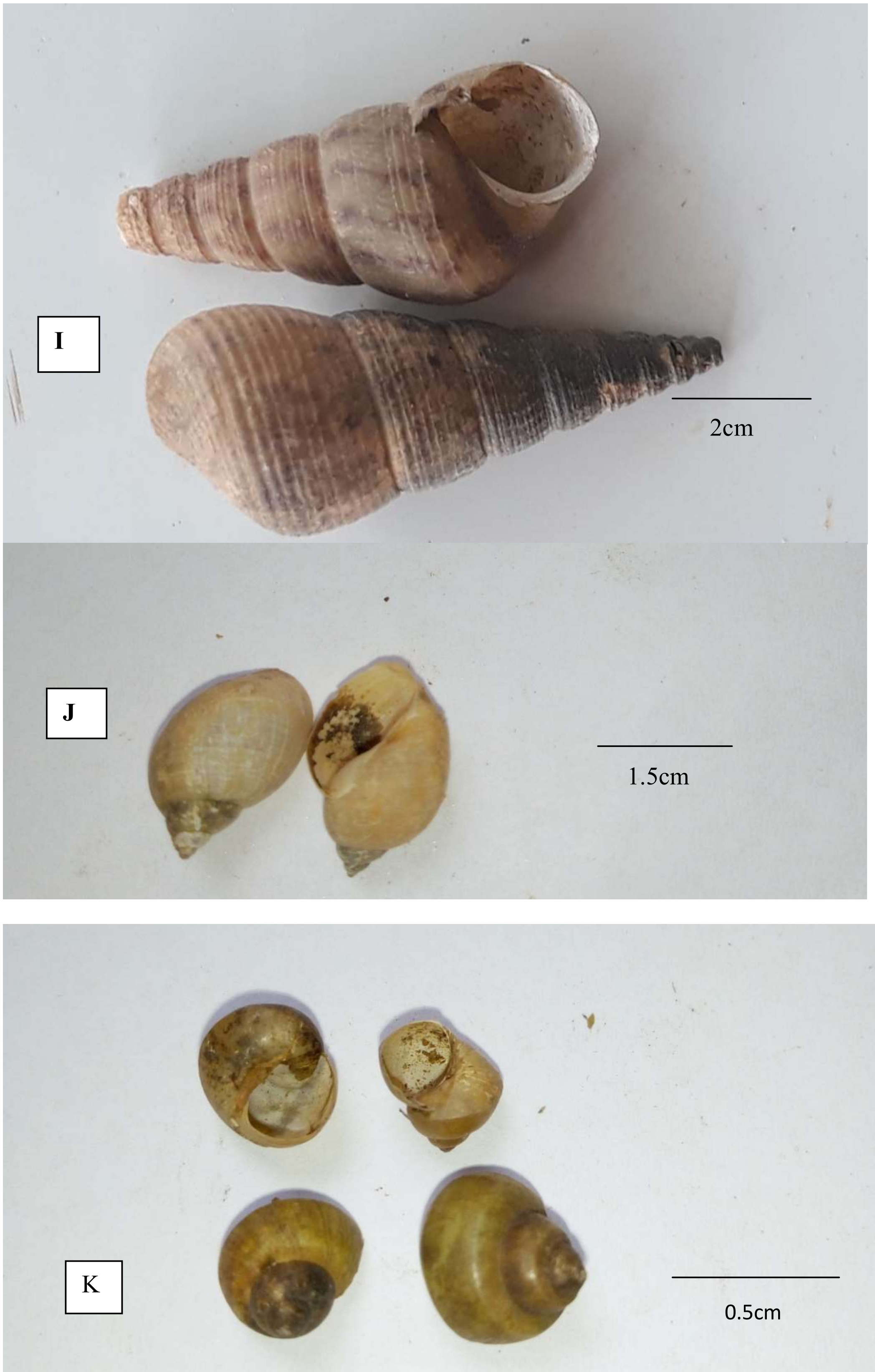

Plate 11: Whole mount of (I) *Melanoides tuberculata* and (J) *Lymnae sp.* and (K) *Pomacea bridgesii* from Erelu Reservoir in Oyo Town

Plate 12: Whole mount of (L) *Indoplarnobis exustus*and (M) *Potadoma moerchii* from Erelu Reservoir in Oyo Town

Plate 13: Whole mount of (N) *Anodonta cygnea* and (O) *Margaritifera margaritifera* from Erelu Reservoir in Oyo Town

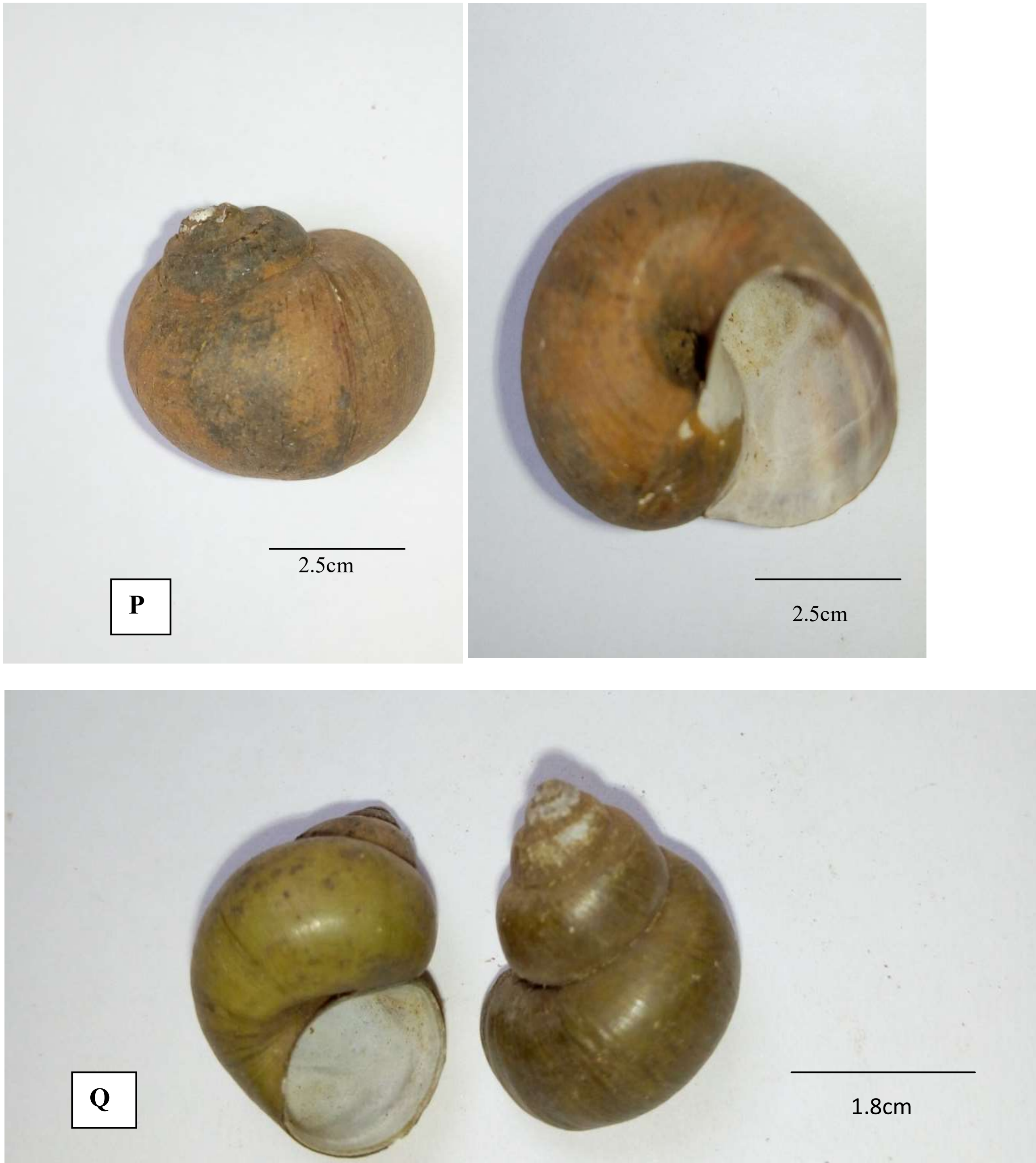

Plate 14: Whole mount of (P) *Lanistes lybicus* and (Q) *Viviparus contectus* from Erelu Reservoir in Oyo Town

4.9. Correlation between physical and chemical parameters in Erelu Reservoir using Pearson's Coefficient (r)

Magnessium ion showed a significant relationship with Calcium ion (r= 0.693*) while Phosphate exhibited negative significant (p<0.05) correlation with Calcium ion (r= -0.755*) and Mg^{2+} (r= -0.840**), respectively. Nitrate had a strong positive significant correlation (p<0.01) with calcium ion, magnesium ion (r=0.831**; r=0.939**) but inverse significant relationship with phosphate (r= -0.864**). DO had positive significant relationship with phosphate (r = 0.828**), however, it revealed negative significant (p<0.01) association with calcium ion, magnesium ion and nitrate where (r= -0.799**; r= -0.952**; r= -0.956**). BOD revealed poitive significant (p<0.05) relationship with turbidity (r=0.774*). TDS had positive significant (p<0.01) relationship with calcium ion (r=0.850**) and also revealed significant inverse association with BOD (r= -0.903**), respectively.

Total alkalinity had significant (p<0.01) positive association with calcium ion, magnesium ion, nitrate and TDS (r=0.847**; r=0.890**; r=0.960**; r=0.743*), respectively, but negative significant (p<0.01) correlation with phosphate and DO where (r= -0.834**; r= -0.949**). Temperature had a negative significant correlation (p<0.01) with turbidity (r= -0.877**) and BOD (r=-0.966**) but strong positive significant relationship with TDS (r=0.906**). There were strong significant (p<0.01) positive correlation of conductivity with calcium ion (r=0.872**), TDS (r=0.999**) temperature (r=0.883**) and TA (r= 0.761*) respectively. However, conductivity revealed an inverse significant (p<0.01) relationship with BOD (r= -0.884**).

4.10 Relationship between physico-chemical parameters and abundance macro-invertebrates insects of Erelu Reservoir using Pearson's Coefficient (r)

Transparency had a strong significant (p<0.01) relationship with order Hemiptera (r=0.880**) and Odonata (r=0.675*) and turbidity exhibited a significant (p<0.05) positive association with order Diptera (r=0.731*), respectively. All other parameters were not significantly (p>0.05) related with the orders of macro-invertebrates.

4.11 Correlation between heavy metals in water samples and insect macro-invertebrates abundance of Erelu Reservoir using Pearson's Coefficient(r)

There were significant (p<0.05) positive association between Lead and Odonata (r= 0.743*), Iron and Lead (r= 0.755*), however, Zinc revealed a strong significant (p<0.01) association with Iron (r= 0.894**), respectively. Chromium showed a strong positive significant (p<0.01) correlation with Lead (r=0.837**) and Iron (r =0.833**), while Cadmium had strong significant (p<0.01) positive relationship with Iron (r= 0.854**) and Zinc (r= 0.951**), respectively.

4.12 Correlation between sediment heavy metals and insect macro-invertebrates abundance of Erelu Reservoir using Pearson's Coefficient(r)

Zinc in sediment samples was observed to have strong (p<0.01) significant relationship with Lead (r= 0.905**) while Chromium (mg/kg) had strong significant (p<0.01) relationship with iron (r= 0.837**). Cadmium exhibited a strong positive significant (p<0.01) relationship with iron and chromium (r= 0.912**; r= 0.839**), respectively. All other parameters were not significantly related.

Table 4.9: Relationship between physical and chemical parameters of Erelu Reservoir using Pearson's Coefficient (r)

Parameters	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
1. Transparency (cm)	1											
2. Turbidity (NTU)	-0.098	1										
3. Calcium ion (mg/L)	-0.033	-0.252	1									
4. Magnesium ion (mg/L)	0.067	0.301	0.693*	1								
5. Phosphate (mg/L)	-0.120	-0.165	-0.755*	-0.840**	1							
6. Nitrate (mg/;)	0.036	0.107	0.831**	0.939**	-0.864**	1						
7. DO (mg/L)	-0.216	-0.182	-0.799**	-0.952**	0.828**	-0.956**	1					
8. BOD (mg/L)	-0.300	0.774*	-0.599	-0.330	0.318	-0.465	0.432	1				
9. TDS (mg/L)	0.152	-0.665	0.850**	0.456	-0.492	0.623	-0.583	-0.903**	1			
10. Total Alkalinity (mg/L)	0.225	-0.087	0.847**	0.890**	-0.834**	0.960**	-0.949**	-0.650	0.743*	1		
11. PH	-0.586	0.345	0.109	0.149	0.132	0.095	-0.076	0.368	-0.094	-0.080	1	
12. Temperature (^{o}C)	0.146	-0.877**	0.578	0.176	-0.178	0.350	-0.287	-0.966**	0.906**	0.524	-0.236	1
13. Conductivity (µs/cm)	0.147	-0.629	0.872**	0.486	-0.522	0.651	-0.613	-0.884**	0.999**	0.761*	-0.074	0.883**

*. Correlation is significant at the (p<0.05).

**. Correlation is significant at the (p< 0.01).

Table 4.10: Relationship between physical and chemical parameters and abundance of macro-invertebrates insect of Erelu Reservoir using Pearson's Coefficient (r)

Parameters	Diptera	Coleoptera	Hemiptera	Odonata
Transparency (cm)	0.300	0.396	0.880**	0.675*
Turbidity (NTU)	0.731*	-0.431	0.201	0.294
Calcium ion (mg/L)	-0.101	0.115	0.158	-0.565
Magnesium ion (mg/L)	0.416	-0.056	0.266	-0.291
Phosphate (mg/L)	-0.358	0.122	-0.382	0.303
Nitrate (mg/L)	0.143	-0.014	0.215	-0.423
DO (mg/L)	-0.316	-0.101	-0.417	0.252
BOD (mg/L)	0.425	-0.524	-0.092	0.366
TDS (mg/L)	-0.393	0.316	0.093	-0.480
Total Alkalinity (mg/L)	0.112	0.166	0.329	-0.344
Ph	0.029	-0.596	-0.475	-0.139
Temperature (^{o}C)	-0.590	0.446	-0.089	-0.428
Conductivity (µs/cm)	-0.372	0.297	0.110	-0.486

*. Correlation is significant at the (p<0.05).

**. Correlation is significant at the (p<0.01).

Table 4.11: Relationship between heavy metals in water samples and macro-invertebrates insect abundance of Erelu Reservoir using Pearson's Coefficient (r)

Parameters/ Orders	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
1.Diptera	1								
2.Coleoptera	-0.222	1							
3.Hemiptera	0.533	0.310	1						
4.Odonata	0.490	-0.155	0.555	1					
5.Lead (mg/L)	-0.185	-0.070	0.212	0.743*	1				
6.Iron (mg/L)	-0.315	-0.060	-0.106	0.518	0.755*	1			
7.Zinc (mg/L)	-0.389	0.089	-0.383	0.239	0.480	0.894**	1		
8.Chromium (mg/L)	-0.438	0.077	0.083	0.489	0.837**	0.833**	0.635	1	
9.Cadmium (mg/L)	-0.335	0.141	-0.326	0.346	0.588	0.854**	0.951**	0.594	1

*. Correlation is significant at the (p<0.05).
**. Correlation is significant at the (p<0.01).

Table 4.12: Correlation between heavy metals in sediment samples and insect macro-invertebrates abundance of Erelu Reservoir using Pearson's Coefficient (r)

Parameters/Orders	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	9
1. Diptera	1								
2. Coleoptera	-0.222	1							
3. Hemiptera	0.533	0.310	1						
4. Odonata	0.490	-0.155	0.555	1					
5. Lead (mg/kg)	0.556	-0.303	0.092	-0.026	1				
6. Iron (mg/kg)	0.168	-0.158	-0.176	0.525	0.102	1			
7. Zinc (mg/kg)	0.620	-0.472	0.061	0.208	0.905**	0.426	1		
8. Chromium (mg/kg)	-0.064	-0.150	-0.313	0.305	-0.227	0.837**	0.151	1	
9. Cadmium (mg/kg)	-0.130	0.032	-0.316	0.400	-0.208	0.912**	0.065	0.839**	1

*. Correlation is significant at the (p<0.05).
**. Correlation is significant at the (p<0.01).

4.13. Correlation between physical and chemical parameters and macro-benthic invertebrate abundance of Erelu Reservoir using Pearson's Coefficient (r)

The results of correlation coefficient between physico-chemical parameters and benthic abundance of Erelu reservoir are shown in table 4.13. Transparency, Calcium ion, TDS, TA, Temperature and Conductivity had non-significant (p>0.05) negative association to all orders of macro-benthic invertebrates. However, turbidity revealed itive posignificant (p>0.05) relationship with Hygrophila where (r= 0.713*). Magnesium had strong significant (p<0.05) negative association with Unionidea where (r= -0.683*), while Phosphate showed positive significant (p<0.01) correlation with capitellida (r= 0.942**). Nitrate exhibited inverse significant (p<0.05) relationship with capitellida and Unionidea, where (r = -0.699*) and (r= -0.684*). Dissolved Oxygen had positive significant (p<0.05) relationship with Unionidea (r= 0.798*). Biological Oxygen Demand exhibited positive and non-significant (p>0.05) relationship with many orders of macro-benthic invertebrates with the exception of Sorbeoconcha that had positive significant (p<0.05) relationship with BOD (r= 0.678*), however, TA had negative significant (p<0.05) association with Unionidea (r= -0.763*), respectively.

4.14. Correlation between water heavy metals and macro-benthic invertebrates abundance of Erelu Reservoir using Pearson's coefficient (r)

Unionidea had strong positive significant (p<0.01) association with Pulmonata (r= 0.808**), Iron also showed positive significant (p<0.01) relationship with lead (r= 0.755**), while Zinc in water samples exhibited a positive significant (p<0.05) association with Unionidea (r= 0.691*) and a strongly significant (p<0.01) positive relationship with iron (r= 0.894**), respectively. However, Chromium in water samples had a strong significant (p<0.01) positive association with lead and iron where (r =0.837**); r = 0.833**), while Cadmium was observed to have a strong significant (p<0.01) and positive relationship with Capitellida (r=0.826**), iron (r=0.854**) and Zinc (r=0.951**), respectively.

4.15. Correlation between sediment heavy metals andmacro-benthic invertebrate abundance of Erelu Reservoir using Pearson's Coefficient (r)

Lead in sediment samples was observed to have a significant (p<0.05)positive association with Pulmonata and Hygrophila (r= 0.808**; r=0.683*), while Iron had positive significant (p<0.05) association with Capitellida (r=0.691*) and Sorbeoconcha (r=0.692*), respectively. Zinc had a significant (p<0.05) positive relationship with Diptera (r=0.680*) and a strongly significant (p<0.01) relationship with Lead (r=0.905**). Chromium in the sediment observed had significant (p<0.05) positive relationship with Pulmonata (r= 0.779*) and highly positive significant (p<0.01) relationship with Unionidea and iron (r=0.878**; r = 0.837**), however, Cadmium revealed a strong significant (p<0.01) positive relationship with Capitellida, Iron and Chromium (r=0.854**; r=0.912**; r = 0.839**), respectively.

Table 4.13: Correlation between physical and chemical properties and macro-benthic invertebrates abundance of Erelu Reservoir using Pearson's coefficient (r)

Parameters	Architaenioglossa	Capitellida	Hygrophila	Diptera	Pulmonata	Sorbeoconcha	Unionidea
Transparency (cm)	-0.520	-0.139	-0.053	-0.374	-0.227	-0.641	-0.505
Turbidity (NTU)	0.421	-0.113	0.713*	0.567	0.199	0.372	0.051
Calcium ion (mg/L)	-0.116	-0.589	-0.141	-0.063	-0.573	-0.450	-0.606
Magnesium ion (mg/L)	0.024	-0.658	0.488	0.045	-0.394	-0.386	-0.683*
Phosphate (mg/L)	0.107	0.942**	-0.171	-0.266	0.138	0.542	0.454
Nitrate (mg/L)	0.024	-0.699*	0.312	0.070	-0.502	-0.536	-0.684*
DO (mg/L)	0.078	0.620	-0.326	0.014	0.585	0.501	0.798*
BOD (mg/L)	0.430	0.257	0.336	0.612	0.463	0.678*	0.536
TDS (mg/L)	-0.266	-0.388	-0.300	-0.491	-0.580	-0.627	-0.628
Total Alkalinity (mg/L)	-0.215	-0.666	0.139	-0.084	-0.576	-0.663	-0.763*
PH	0.527	0.292	0.412	0.057	-0.313	0.499	-0.150
Temperature (^{o}C)	-0.380	-0.123	-0.446	-0.618	-0.478	-0.568	-0.439
Conductivity (mg/L)	-0.237	-0.414	-0.272	-0.469	-0.587	-0.627	-0.643

*. Correlation is significant at the ($p<0.05$).
**. Correlation is significant at the ($p<0.01$).

Table 4.14: Correlation between water heavy metal parameters andmacro-benthic invertebrate abundance of Erelu Reservoir using Pearson's Coefficient (r)

Parameters/Orders	1	2	3	4	5	6	7	8	9	10	11	12
1. Architaenioglossa	1											
2. Capitellida	0.056	1										
3. Diptera	0.083	-0.295	1									
4. Hygrophila	0.637	-0.132	0.005	1								
5. Pulmonata	0.211	-0.134	0.322	0.045	1							
6. Sorbeoconcha	0.324	0.590	0.283	0.050	0.315	1						
7. Unionidea	0.191	0.244	0.464	-0.272	0.808**	0.588	1					
8. Lead (mg/L)	-0.268	0.488	-0.223	-0.230	-0.208	-0.196	-0.066	1				
9. Iron (mg/L)	-0.145	0.494	-0.103	-0.380	0.410	0.086	0.538	0.755*	1			
10 Zinc (mg/L)	-0.126	0.633	-0.173	-0.441	0.494	0.354	0.691*	0.480	0.894**	1		
11 Chromium (mg/L)	-0.338	0.279	-0.377	-0.389	0.034	-0.424	0.072	0.837**	0.833**	0.635	1	
12 Cadmium (mg/L)	-0.130	0.826**	-0.226	-0.394	0.284	0.450	0.560	0.588	0.854**	0.951**	0.594	1

*. Correlation is significant at the ($p<0.05$).

**. Correlation is significant at the ($p<0.01$).

Table 4.15: Relationship between sediment heavy metals andmacro-benthic invertebrate abundance of Erelu Reservoir using Pearson's coefficient (r)

Parameters/Orders	1	2	3	4	5	6	7	8	9	10	11	12
1. Architaenioglossa	1											
2. Capitellida	0.056	1										
3. Diptera	0.083	-0.295	1									
4. Hygrophila	0.637	-0.132	0.005	1								
5. Pulmonata	0.211	-0.134	0.322	0.045	1							
6. Sorbeoconcha	0.324	0.590	0.283	0.050	0.315	1						
7. Unionidae	0.191	0.244	0.464	-0.272	0.808**	0.588	1					
8. Lead (mg/kg)	0.516	-0.110	0.505	0.683*	-0.078	0.389	-0.112	1				
9. Iron (mg/kg)	0.050	0.691*	0.282	-0.041	0.425	0.692*	0.645	0.102	1			
10 Zinc (mg/kg)	0.468	-0.035	0.680*	0.605	0.230	0.499	0.199	0.905**	0.426	1		
11 Chromium (mg/kg)	0.099	0.457	0.202	-0.173	0.779*	0.531	0.878**	-0.227	0.837**	0.151	1	
12 Cadmium (mg/kg)	-0.003	0.854**	-0.057	-0.220	0.346	0.649	0.616	-0.208	0.912**	0.065	0.839**	1

*. Correlation is significant at the ($p<0.05$).
**. Correlation is significant at the ($p<0.01$).

4.16. Ecological Indices of Aquatic insect macro-invertebrates of Erelu Reservoir

The diversity indices of insect macro-invertebrates were shown in table 4.15. Shannon weiner index (H) had elevated value in sampled station 3 (0.643), close to similar value in station 1 (0.625) and station 2 (0.573) while other stations are within the same trend but the stations with the least diverse organisms was station 6 (0.553). The taxa richness (d) showed that stations 5 and 6 had highest taxa richness (0.538 and 0.524) while the station with least richness value was point 1 (0.236) and point 2 (0.241) respectively. Other three stations were along the same trend. Menhinick taxa richness showed highest values in station 6 (0.454), and station 7 (0.544), followed by station 5 (0.375), stations 2 (0.325), station 3 (0.262), station 4 (0.253) while the least richness was in station 1 (0.252).

Evenness/equitability index was higher in station 2 (0.734) and station 1 (0.643) even though, station 2 species were evenly distributed more than station 1, followed by station 3 (0.554), station 6 (0.554), station 4 (0.546), station 5 (0.543) and the station with the least evenly distributed species was station 7 (0.533). Jaccard similarity index had highest index value in station 2 (0.584), station 5 (0.564), station 1 (0.563), station 4 (0.554), station 3(0.545) and the station with the least similar species were station 6 (0.544) and station 7 (0.444) respectively. The result of redundancy index (R) showed that station 5 (0.585) had highest, followed by station 1 (0.475), while station 2 (0.456), station 6 (0.465) and station 7 (0.467) were along the same trend. Berger-parker index showed highest values in station 4 (0.569), station 5 (0.566), while station 2, 6, and 7 are along the same trend of 0.544 with least values in station 1 and 3 with (0.442 and 0.423) respectively.

4.17. Ecological Indices of macro-invertebrates insect order of Erelu Reservoir

Diversity indices of insect taxa were shown in table (4.16). Shannnon index showed that coleopteran were more diverse (H = 0.98), Hemiptera (0.86), Odonata (0.85) and Diptera (0.82) followed. Menhinick index (D) showed highest abundance in Diptera and Odonata with highest value of (0.15) but least value were recorded for coleopteran (0.05) and Hemiptera (0.02) respectively. Margalef taxa richness (d) showed highest species richness in Odonata (0.34) and Diptera (0.33) and least values for coleopteran and Hemipteran (0.24) was recorded.

Equitability (J) showed that coleopteran (0.89) are equally distributed, followed by Odonata (0.79), Diptera (0.74) and Hemipteran (0.66). Redundancy (R) index showed that coleopteran (R= 0.64) were more abundant and represented by many species, while the values for Odonata (0.58), Diptera (0.55) and Hemiptera (0.46) followed. Jaccard similarities D showed that Odonata (0.68) have similar species across station; followed by Diptera (0.64), coleopteran (0.63) and Hemiptera (0.53) respectively. Berger-Parker dominant index revealed that Odonata had highest Berger – Parker dominant index value, followed by Diptera (0.644) and coleopteran (0.553), while Hemiptera were having lowest value (0.50).

4.18. Ecological Indices of benthic macro-invertebrates of Erelu Reservoir

The richness and other indices of aquatic organisms were shown in table 4.17. The Shannon diversity index (H) showed highest diversity value in stations 4 (1.056), 6 (1.052), 5 (0.984), 3 (0.811), 2 (0.796), 7 (0.573) and 1 (0.558). Taxa richness index was highly rich in station 2 (0.478), followed by stations 3 (0.422), 5 (0.382), 1(0.364), 7 (0.363), 6 (0.339) and 4 (0.323). Menhinick taxa index showed the least value in station 5 (0.218), station 3 (0.273) and highest richness value was recorded in station 2 (0.385), other stations were within the same trend. The species are highly distributed in station 5 (0.896), followed by stations 4 (0.855), 6 (0.856), 7 (0.859), 3(0.753), 2 (0.747) and the least values was recorded in station 1 (0.583). The similarity index (D), showed that benthic macro-invertebrates are mostly similar in stations 3 (0.768), 6 (0.752), 7 (0.682), 2 (0.666), 4 (0.658), 5 (0.643), and the least value for similarity index was recorded in station 1 (0.445). Redundancy index (R) showed that highest value were recorded in stations 1 (0.583), 2 (0.583) and 7 (0.584). Other stations were within the same trend which showed that the species were well distributed in the reservoir across stations, since the maximum number is approximately one. The Berger-Parker index (d) showed same trend of species dominant across sampling stations which ranged between (0.446 – 0.655).

4.19: Ecological Indices of benthic macro-invertebrates order of Erelu Reservoir

Diversity and other indices of benthic abundance of Erelu reservoir is shown in table 4.18. Shannon index (H') showed that Sorbeoconcha are more diverse (H = 1.05), followed by Pulmonata (0.98), Unionidea (0.97), Diptera (0.82), Capitellida (0.80) and Architaenioglossa (0.62) respectively. Menhinick index (D) showed highest dominance in Architaenioglossa (0.44), capitellida (0.38) while the least values were recorded for the rest order of benthic macro-invertebrates. The Margalef taxa richness ranged between (0.24 – 0.49), the order with highest richness was capitellida (0.49) and diptera (0.39) while the least was Sorbeoconcha (0.24). Equitability (J) showed the equal distribution of orders with highest recorded for Sorbeoconcha (0.96) and the least was recorded for Architaenioglossa (0.48). Redundancy (R) ranged between 0.38-0.64 with highest dominance recorded for Sorbeoconcha and the least for Architaenioglossa. Jaccard similarity index (D) showed highest similarity index in order Sorbeoconcha (0.95), Unionidea (0.78), Pulmonata and Diptera (0.76), Capitellida (0.64), Hygrophila (0.55) and Architaenioglossa (0.44) respectively. Berger-Parker dominance values across orders are approximately one which showed benthic macro-invertebrates are well distributed across stations.

Table 4.16: Ecological Indices of insect macro-invertebrates in the study points of Erelu Reservoir from June 2013 to May 2015

Diversity Indices	**Sampling Points**						
	1	2	3	4	5	6	7
Shannon Weiner index (H’)	0.6254	0.5732	0.6434	0.5644	0.5545	0.5534	0.5622
Margalef richness index (d)	0.2362	0.2412	0.2914	0.3362	0.5375	0.5244	0.4335
Menhinick index (D)	0.2524	0.3245	0.2622	0.2534	0.3746	0.4544	0.5443
Equitability (J)	0.6434	0.7343	0.5544	0.5456	0.5433	0.5535	0.5333
Jaccard index (D)	0.5633	0.5844	0.5446	0.5538	0.5643	0.5442	0.4442
Redundancy index (R)	0.4753	0.4564	0.5543	0.5434	0.5845	0.4645	0.4665
Berger-parker index (d)	0.4424	0.5444	0.4232	0.5694	0.5658	0.5368	0.5444

Table 4.17: Ecological Indices of order of insect macro-invertebrates in the study points of Erelu Reservoir from June 2013 to May 2015

Diversity Indices	Diptera	Coleoptera	Hemiptera	Odonata
Shannon Wiener index (H')	0.8151	0.9792	0.8553	0.8451
Menhinick index (D)	0.1533	0.04745	0.01613	0.1531
Margalef richness index (d)	0.3322	0.2412	0.2414	0.3361
Equitability (J)	0.7399	0.8913	0.6584	0.7856
Redundancy (R) index	0.5463	0.6442	0.4547	0.5773
Jaccard index (D)	0.6422	0.6342	0.5259	0.6802
Berger-Parker index (d)	0.6444	0.5532	0.4965	0.6693

Table 4.18: Ecological Indices of benthic macro-invertebrates in the study points of Erelu Reservoir fromJune 2013 to May 2015

	Sampling points						
Diversity Indices	1	2	3	4	5	6	7
Shannon Weiner index (H')	0.5578	0.7956	0.8105	1.056	0.9839	1.0522	0.5734
Margalef richness index (d)	0.3643	0.4776	0.4215	0.3234	0.3816	0.3387	0.3627
Menhinick index (D)	0.3435	0.3846	0.3464	0.2734	0.2182	0.3489	0.3051
Equitability (J)	0.5834	0.7467	0.7532	0.8545	0.8956	0.8555	0.8585
Jaccard index (D)	0.4446	0.6656	0.7677	0.6575	0.6432	0.7523	0.6823
Redundancy index (R)	0.5832	0.5834	0.5565	0.5554	0.5646	0.5347	0.5842
Berger-Parker index (d)	0.6558	0.6476	0.6358	0.4845	0.5661	0.4461	0.5624

Table 4.19: Ecological Indices of order of benthic macro-invertebrates in sampled points of Erelu Reservoir from June 2013 to May 2015

Diversity Indices	Architaenioglossa	Capitellida	Diptera	Hygrophila	Pulmonata	Sorbeoconch	Unionidea
Shannon index (H')	0.6206	0.7974	0.8223	1.045	0.9839	1.05	0.9734
Menhinick index (D)	0.4435	0.3841	0.2364	0.1279	0.2182	0.0449	0.2051
Margalef richness index(d)	0.3200	0.4865	0.3936	0.317	0.3816	0.238	0.3727
Equitability (J)	*0.4832*	*0.7259*	*0.7485*	*0.9515*	*0.8956*	*0.9555*	*0.886*
Redundancy (R) index	0.3804	0.4818	0.5685	0.5318	0.4846	0.6348	0.4842
Jaccard index (D)	0.4345	0.6427	0.7586	0.5481	0.7617	0.9523	0.7823
Berger-Parker index (d)	*0.6847*	*0.6393*	*0.6957*	*0.4673*	*0.5661*	*0.461*	*0.5514*

CHAPTER FIVE

5.0 DISCUSSIONS

5.1 Climate

The abundance of organisms in the studied stations during the rainy season may be due to influence of productivity which make food available for the organism survival. This result corroborated that of Ayoade *et al.* (2006) who reported rainfall as one of the factors that influence the amount of discharge into river and lakes and that it affects the water quality (Egborge, 1994). The atmospheric temperatures observed during the study were minimal in the wet season and at peak in dry season and were not different from previous observed result of fresh water bodies. Relative humidity of Oyo that are very low during dry season and high during wet season could be attributed to heavy rainfall pattern during rainy and which lower temperature and improves the Dissolved oxygen level could be a reason for abundance of many organisms encountered during this study (Ayoade *et al*., 2006).

5.1.1 Physical and Chemical Parameters

The variation in values and significant differences of physical and chemical parameters of the water observed at various sampling stations in Erelu reservoir indicated different hydrological qualities. The high transparency observed during dry season and low turbidity indicated reduction of influx into the reservoir. The lower values of transparency and maximum concentrations of turbidity examined during wet season throughout the sampling stations might be related to overflow from the river banks and the reservoir receiving run-off which later reduces light penetration due to suspended particles in the flood water, therefore decreases the quantity of light entering the reservoir body. The present result is in line with the observation reported by Adebisi (1987), Kemdirim (1990), Ugwumba and Ugwumba (1990) Kolo and Oladimeji (2004), Ayoade *et al.* (2006), and Allison *et al.,* (2007), Oso and Fagbuaro (2008) and Ibrahim *et al.* (2009), Garg *et al.* (2010), Priyanka *et al.* (2013), Adeosun *et* *al.* (2014), Ftsum *et al.* (2015) who worked on various manmade waters, reported similar observations.

Low transparency was recorded at inlet and outlet of the reservoir compared with the main reservoir across stations which could be related to reduced level of water in the reservoir inlet and outlets. The turbidity observed during the study were more than the required limit (Ftsum *et al.,* 2015) by NESREA and WHO (1-5NTU) for drinking water across sampling stations during rainy season but fell within the ranges acceptable during dry season in station 3 (4.20 ± 0.98) Station 4 (2.90 ± 0.76) Station 5 (2.68 ± 0.89) and station 6 (3.94 ± 0.97). Comparable result was reported by Offem *et al.* (2011). High level of turbidity do affects Photosynthetic processes due to little or no light penetration into water body and high particulate matter can also clog fish gills. Similar report was documented by Sachidanandamurthy and Yajurvedi (2006) on Bilikire Lake in India.

Temperature is an essential factor that determines primary productivity in water bodies, as water temperature increases, the rate of photosynthesis rises thereby making available sufficient amount of nutrients (Boulton, 2012). Water temperatures for Erelu reservoir were low during the period of rainfall across sampling stations but a bit rise in mean values of temperature between April to June, 2014 which may be due to delay in rainfall, hence cause for warmness of water body. Lowest values of temperature in the rainy season might be ascribed to cool atmosphere as a result of rain and high relative humidity which reduces evaporation of water. Similar observations were reported by Moody (1991), Eghorge (1994), Obiakor *et al.* (2013), Priyanka *et al.* (2013), Sikoki and Anyanwu (2013). High temperature values were reported by Ibrahim *et al.* (2009) during wet period which was associated with effluent and waste water discharge from Benue brewery and abbattoir. The highest water temperature recorded in November, December 2014 and January to March 2015 could be ascribed to the peak of dry season when there is highest sunrise level (Ayoade *et al.,* 2006). Lower temperature recorded for the present study in November and December 2013 might be due to the impact of pleasant weather that cools the water body. Similar reports were observed in Ado- Ekiti reservoir (Adebayo, 1993), Owena reservoir (Oke, 1998), Oyan and Asejire lakes (Ayoade *et al*., 2006) Ero Reservoir (Oso & Fagbuaro, 2008), Ado- Ekiti Reservoir (Idowu *et al.,* 2013), and Opi lake Enugu (Okoro, 2015).

Highest values of temperature recorded during dry season might be related to the intensity of heat as observed by Obiakor *et al*. (2013). Temperatures observed in this study in all stations were similar and this may be linked with same level of the water samples taken. Same observations were reported by Ajao (1990), Emoyan *et al.* (2003), Idowu and Ugwumba (2005). Temperature for this study during dry season which fell within the normal temperature for aquatic organisms survival. The result agreed with the previous report of Sachidanandamurthy and Yajurvedi (2006) who reported temperature range between 28-32^{o}C in Bilikire lake, India, Fafioye *et al*. (2005) in Omi water body 26.5^{o}C-31.5^{o}C, Ago iwoye, Ogun State and Dinowo, 2013 in River Ogun reported 26.9^{o}C -32.1^{o}C, Adeosun *et al.* (2014) also reported 24.00-30.70^{o}C Akomoje river, Ogun State. The present results is also similar to the observation of Kamran *et al.* (2003) and Ayoade *et al.* (2006) who were of the opinion that the temperatures in tropics shift between 21^{o}C-32^{o}C.

Calcium ions (Ca^{2+}) in open water is one out of the major inorganic cations, or positively charged ions in salt water and freshwater. It can be generated from the separation of salts, such as $Cacl_2$ or $CaSO_4$. If the concentration of calcium ion in freshwater is below 5mg/L, it can support few flora and fauna life (Lentech, 2012). Calcium ion concentration of Erelu reservoir were more than 5mg/L across sampling stations both during raining and dry seasons. It was also noted that all the sample stations have values that fall within the acceptable limit of WHO and NESREA, This could be associated with low source of calcium in the reservoir. The present results is in contrast to that of Ftsum *et al.* (2015) who reported higher values more than the required limits for Ca^{2+} in Elala river Ethiopia, which was attributed to influence of waste input into the river. The maximum concentrations of calcium ion in the period of dry season might be attributed to evaporation due to the intensity of sun. This is similar to the observation of Akindele and Adeniyi (2013). The above observation is in contrast to the report of Ayoola and Ajani (2009) in Erelu reservoir who reported low values of Ca^{2+} during dry season. The variation in values of Calcium ion observed at the inlet and outlet sampling points may also be attributed to deposit of faecal material of grazing animals visiting the reservoir to drink water at different stations.

Magnesium ion (Mg^{2+}) result indicated highest values during rainy season compared to the concentration values during dry season, this could be ascribed to influx during the rain which helps in bringing in $MgSO_4$ as a result of flooding and readily dissolved quantity in water body. Mg^{2+} is crucial to all living cells, where it assumes indispensable part in controlling essential organic polyphosphate compounds like ATP, DNA and RNA. Similar observation was reported by was made by Ayoola and Ajani (2009) in Erelu reservoir. The result do not agree with that of Akindele and Adeniyi (2013) who reported higher values of Mg^{2+} during dry season. Majority of enzymes require magnesium ions to perform their role (Lentech, 2012). Mg complexes could be utilised as laxatives and antacids. Magnesium ions are generally within limits in Erelu reservoir. This is in line with the findings of Okoro (2015) in Opi lake, Enugu. Non-significant values of Mg^{2+} observed across sampling stations in Erelu reservoir during rainy and dry seasons might be due to low input of fertilizer as a result of reduction of land to agricultural use because of urbanisation. Magnesium values observed across stations fell with the acceptable limits of WHO and NESREA.

The variation in phosphate concentrations of Erelu reservoir during the wet season and dry season as observed across sampling stations during the period of this study, may be attributed to effect of flood during wet season that washed in fertilizers and detergent nylons from neighbouring villages around the reservoir. This may also be the reason why the reservoir sometimes covered by higher plants (Algal bloom) during the rainy season, hence reducing the availability of dissolved oxygen to the aquatic fauna at night. This result is in agreement with that of Attama (2003), Odo (2004), Adeyemo *et al.* (2008) who reported highest phosphate during rainy season in their study of nutrient load of river sediments in Ibadan city, Ayoola and Ajani (2009) in Erelu reservoir Oyo, Priyanka *et al.* (2013) in India, Khalik *et al.* (2013) in Malaysia and Odo *et al.* (2014) and associated it with flood water from surrounding farmlands. The mean values of phosphate in the present study fall within the standard limits of NESREA (35.0mg/L) and that of SON (100mg/L). Comparable observations were observed by Pawar *et al.* (2006) and Dinowo (2013) who also reported concentrations that were within the normal range. The present study did not agree with the observations reported by Helen *et al*. (1995); Kamal *et al*. (2007), Kavita and Sheela (2012), Akindele and Adeniyi (2013), Adeosun *et al*. (2014) who observed higher concentration values of phosphate in the dry seasons and lower values in the wet season during their study.

Nitrate concentration in Erelu reservoir across sampling stations were below the required limit of WHO, NESREA and SON. This could be attributed to changes in land use, from cultivation to building. The present result is similar to the observation of Patel and Patel (2012). This result is however in contrast to the observation of Akintola and Gbadegesin (1997) who reported 495% Nitrate change between 1977-1992 in Erelu reservoir and attributed the reason to land change pattern from forest vegetation to arable cultivation. Even though, the nitrate reported for Erelu reservoir in 1992 was 5.4 mg/L, Oba reservoir 74 mg/L in Ogbomosho, Opeki in Eruwa had 6.1 mg/L and Saki had 5.1 mg/L of Nitrate. The higher nitrate concentrations in wet season observed in this study may be ascribed to higher inflow of water during wet season that might contained some nutrients which flow into the aquatic environment. Similar results were reported by Sachidanandamurthy and Yajurvedi (2006) of Bilikire Lake in India, Ayoola and Ajani (2009) in Erelu reservoir, Ibraheem *et al.* (2009) in Kotangora reservoir, Patil *et al.* (2011) in India, Agaoru (2012) in Opi lake and the reason for their observation was associated to run-off as well as agitation of water during the rainy season. Kavita and Sheela (2012) opined that bacteria action and bacteria growth could be the cause of increment of Nitrate in their study area.

Similar observation was also made by Adeosun *et al*. (2014) in Ogun State, which was attributed to surface run-off. The low values of nitrate observed in dry season for the present study may be associated with reduction of flood into the water body during the dry seasons. This observation agreed with that of Priyanka *et al.* (2013), Sikoki and Anyanwu (2013). This observation is however in contrast with the findings observed by Adeyemo *et al.* (2008), who reported highest nitrate level during dry season in their study in Ibadan, Khalik *et al.* (2013) in Bertam River Malaysia, Wolfhand and Reinhard (1998), which was attributed to low level of water as a result of evaporation by sun that increases nitrate concentration during dry season.

Dissolved Oxygen in the aquatic environment could be sourced from atmospheric air and photosynthetic activities while losses of oxygen in the same environment are through respiration, decomposition of aerobic bacteria and decaying of dead organisms (Gupta and Gupta, 2006). The values of dissolved oxygen in this study were at peak in the wet season and least concentrations were observed in the dry season, which may be associated to plenty air entering the water body due to cool weather during wet season and too much of heat during dry season which in other hand reduces the amount of air escaping into the reservoir. Dissolved oxygen that recorded high values could also be ascribed to low anthropogenic impact. Related observations were made by Manson

(1991), Idowu and Ugwumba (2005), Ikomi *et al*. (2005) in Ethiope river, Ayoade *et al.* (2006), Idowu (2007), Adeyemo *et al.* (2008), Arimoro and Ikomi (2008) in Warri river, Tiseer *et al.* (2008), Ahmed *et al.* (2011) in Shitalakhya, India, Chakraborty *et al.* (2013) who reported low DO in Buriganga and was associated to very low water flow and concentration of pollutants, Idowu *et al. (*2013), Dinowo (2013), Khalik *et al.* (2013) in Malaysia. The present study do not agree with the findings of Patel and Patel (2012), in two lakes studied in India, Adeosun *et al.* (2014) who attributed their low DO to human habitation which contributed waste water into the system. Offem *et* al., (2011) also reported low DO of 3.0 mg/L in both rainy and dry seasons in Ikwori lake and was attributed to increase organic enrichment of the lake as the probable reason that causes low oxygen values. Also, Ibrahim *et al.* (2009) reported maximum concentrations of DO in the dry season but least concentrations in the wet season which was attributed to cold weather which reduces surface water temperature. Same observations were made by Olatunde and Ayodele (2012) in their study of heavy metal determination in lower River, Niger State and Laurince *et al.* (2013) in Ivory Coast. DO recorded in the study stations of Erelu reservoir are within desirable limits which is an indication of low organic pollution. Related observations were made by Olatunde and Oladele (2012), Akindele and Adeniyi (2013).

The present result showed that BOD recorded low concentrations in the sampled stations in the period of this study which might be due to low input of organic substances. Identical reports were made by Farombi *et al.* (2014) in Osun State. Highest values were recorded in October 2013 which could be associated with run-off (Farombi *et al.,* 2014). Similar observation was reported by Priyanka *et al.* (2013) who reported a range of 1.55-3.26 mg/L and related it to a moderate pollution of Orai pond in India and highest values in January 2014, could be attributed to high temperature that helps in decomposition of organic matter. The high concentrations of BOD observed in the dry season might be attributed to too much heat which leads to increased temperature of water body that may result in high organic decomposition during the period of dry season. Comparative result were observed by Ayoola and Ajani (2009) in Erelu reservoir, Idowu *et al.* (2013) in Ado-Ekiti reservoir, Khalik *et al.* (2013) in Malaysia, Akindele and Adeniyi (2013) in Ile-Ife. In contrary, study in Ogunpa River by Atobatele *et al.* (2005) reported highest range of BOD (15.48-26.78 mg/L) and attributed it to effluent discharge, also indicated that the river is highly polluted during study. Similar observation was made by Fagade *et al.* (1993) and this was related to pollutional stress of the river. Akpan and Akpan (1994), Tyokumbur *et al*. (2002) in Awba stream and reservoir, Abowei and George (2009) in Okpoka creek Niger Delta and Nnaji *et al*. (2011) in River Galma Zaria, Ogidiaka *et al.* (2012) in Ogunpa river Nigeria, they all associated the cause of high concentration of BOD to industrial effluents. The significant deviation (p<0.05) observed at inlet and reservoir during wet season could be due to low temperature during rainy season that lowers the decomposition, hence low BOD level (Fig. 4.3). The BOD across sampling stations fell within the permissible limits of WHO and NESREA and is also in line with the reports of Olatunde and Oladele (2012), Akindele and Adeniyi (2013) who reported variation according to season and levels that fell within limits in lower river, Niger State and Ile-Ife.

Hydrogen ion concentration (pH) refers to the measurements of acidity and alkalinity of a solution. The pH values recorded in this study were higher across sampling stations during dry season and lower values were recorded during wet season. The reason could be due to increased photosynthetic activity during the dry season because of light penetration into water body, thus increasing primary productivity or reduction in water level due to evaporation that results into high concentration of pH. Similar observation was made by Dan *et al.* (2014). This observation disagrees with the findings reported by Akpan *et al.* (1993), Ayoola and Ajani (2009) in Erelu reservoir. Laurince *et al.* (2013) in Ivory Coast. The pH values were acidic to alkaline in Erelu reservoir. Similar reports were made by Ogidiaka *et al.* (2012), Basharat *et al.* (2013), Priyanka *et al.* (2013), Andriaan (2015). The pH of water is essential since majority of metabolic activities can take place just within a short distance, henceforth any disparity more than required limits may be deadly to a particular organism (Idowu *et al.,* 2013).

The pH of the present study fall within an appropriate range of 6.5-9.0 mg/L for fish production and survival of other organisms in the water body, comparable results were observed by Abowei (2010), Adeosun *et al.* (2014), This range had been recorded in many African rivers and reservoirs such as Adebisi 1980 and 1987 for Ogun river, Eyo and Ekwonye (1995), Tyokumbur *et al.* (2002), Atobatele *et al.* (2005), Ayoade *et al.* (2006) in Oyan (6.60-8.30mg/L) and Asejire (6.20-8.50mg/L) Lakes and Ibrahim *et al.* (2009) in Kontagora reservoir. The present result dis in contrast with the report of

Sachdanandamurthy and Yajurvedi (2006) in Bilikire Lake India who reported highest pH value greater than 9.0 mg/L across seasons and attributed it to local determinants such as sewage release, organic debris deposition, discharge of inorganic nutrients, detergents which might be accountable for the increased pH. Offem *et al.* (2011) in Ikwori Lake and Rippey and Rippey (1986) who all reported low pH during dry seasons and were attributed to anthropogenic impacts, acidification of allochtonous organic matter.

Alkalinity measures an ability of water to neutralize its acidic content. Total Alkalinity (TA) mean concentration from this study showed highest values in the rainy seasons months with the exception of station 1 which is lower and can be attributed to surface runoff and alkaline values of pH during wet season, least mean values during dry season were also recorded for all other stations and could be attributed to water level reduction and pH values that are slightly basic. Identical result was observed by Anhwange *et al*. (2012) in Makurdi. Contrasted observation was made by Akindele and Adeniyi (2013) who reported high values of TA in dry season and was associated to the evaporation of water body. The TA values from this study fall within 40-200 mg/L that is suitable for fresh water aquaculture. Highly productive water was reported to have alkalinity values above 100 mg/L (Idowu *et al.,* 2013).

The Erelu reservoir alkalinity values fall within such value. Alkalinity values that are more than 300 ppm have been reported to have adverse impact on the reproduction and hatching of fresh water fishes (Gupta and Gupta, 2006). Similar report was observed by Priyanka *et al.* (2013) in India and was associated to the input and dissolution of $CaCO_3$ in the water column. The present result disagree with the report of Adebisi (1981), Idowu and Ugwumba (2005), Oke (1998) in Owena reservoir Oso and Fagbuaro (2008) in Ero reservoir and Atobatele and Ugwumba in Aiba reservoir, Ibrahim *et al.* (2009) in Kotangora reservoir. Similar Observation were made by Offem *et al.* (2011) in Ikwori Lake South-eastern Nigeria, Nwadiaro *et al.* (1984b) also reported low alkalinity during dry season in Oguta Lake during their study period.

Total Dissolved Solid (TDS) studied in Erelu reservoir showed highest concentration in the dry season months and low concentration in the wet season months which could be attributed to evaporation of water hence resulted in decreasing water level which in turn increases salt concentration during dry season and dilution of water as a consequence of rainfall during wet season. Similar observations were made on manmade lakes and rivers by Ahmed *et al.* (2011) in Shitalakhya, Kavita and Sheela (2012) in Bharawas pond Haryana, Akindele and Adeniyi (2013) in Ile-Ife, Adeosun *et al.* (2014) in Ogun State, Nigeria. Alani *et al.* (2014) reported exceeded limits of TDS in Kara abattoir, Ogun river, Lagos State and was attributed to runoff from agricultural field and release of animal wastes from town. Contrary observation was made by Tiseer *et al.* (2008), Patel and Patel (2012), Priyanka *et al.* (2013) who reported higher concentration values of TDS during rainy season and was attributed to surface runoff.

Conductivity is the ability of water to conduct electicity. It also measures concentration of ions in the water. The more the ions present, the higher the conductivity of water and vice versa. Mean values of conductivity of Erelu reservoir were higher during the dry season and low values were recorded during rainy seasons. Highest concentrations recorded during dry season might be associated to the effect of concentration due to decreased water volume, Ovi and Adeniji (1993) and additionally Kolo and Oladimeji (2004) also observed similar result in Shiroro Lake, Ayoola and Ajani (2009) also reported similar result in Erelu reservoir in Oyo town, Offem *et al.* (2011) in lkwori Lake, Anhwange *et al.* (2012) in Makurdi, Akindele and Adeniyi (2013) in Ile-Ife, Adeosun *et al.* (2014) in Akomoje Ogun river, Rahman *et al.* (2012) in Buriganga and Shitalakhya and was attributed to increased evaporation due to high temperature. Contrary observation were reported by Priyanka *et al.* (2013), Farombi *et al.* (2014) who observed high values of conductivity during wet season. Least values of conductivity during rainy season may be due to dilution effect of the increased water volume within water body and surface runoff or rain water itself that has higher conductivity due to incorporation of gases and dust particles Chapman (1992), Allison *et al.* (2007) in Nun River freshwater, Niger Delta, Ibrahim *et al.* (2009) in Kotangora Reservoir reported related observations. The results across stations were within the required limits of WHO and NESREA. Exceeded values of Electrical conductivity that ranged between 904-2066µs/cm are recorded by Ftsum *et al.* (2015) in Elala River Enugu.

Higher temperature values had also been associated with increase conductivity during dry season because of decreased level of water that results in increased salinity and high concentration of Total Dissolved Solids (Chapman, 1992). Electrical conductivity across stations of the reservoir falls within the class I and class II in accordance with the Talling and Talling (1965) classification of African waters. Higher values of electrical conductivity, Total Dissolved Solids and Nitrates were reported during the rainy season by Kemdirim (2005) in Kangimi reservoir, Tiseer *et al.* (2008) in Samaru stream and was associated to surface runoff or flood which contradicts the present study. Highest mean value of conductivity recorded in Erelu reservoir across sampling stations in April, 2014 and May, 2015 indicated that surface runoff or flood had brought some ionic compounds into the reservoir during early rainfall.

5.1.2. Occurrence of heavy metals in sediment and water samples of Erelu Reservoir

Lead concentration in both water and sediment samples showed the highest values during dry season and lowest values in the rainy months, it can be due to water reduction during dry season that may lead to increase in salt and heavy metal concentrations of the reservoir. Similar observation was reported by Kareem *et al.* (2018). It could be also due to washing of bicycle and tippers with detergents and release of engine oil into the reservoir during washing. Highest value recorded in station 4 for water lead during wet season and highest value recorded in April for sediment lead could be attributed surface runoff that could bring more toxic materials into the reservoir, this is because peak values were recorded in August 2013 and 2015. Similar observation was observed by Mayer *et al.* (2008) who opined that rise in heavy metal concentration in ponds and lakes are associated with increasing road runoff. Comparable observations of highest values of lead that exceeded limits were accounted for by Atobatele *et al.* (2005) in River Ogunpa and Tyokumbur *et al.* (2002) in Awba reservoir, Girgin *et al.* (2010) in urban stream, Turkey, Ahmed *et al.* (2013) who reported highest mean values of lead that exceeded limits in water samples in Egypt, Ebigwai *et al.* (2014) in Kwa River Calabar. Contrary observation was reported by Boyd (1998) who reported heavy metals that that fall within tolerable limits for aquatic lives in their study.

Zinc concentration showed highest values during rainy season across stations in water sample which could be as a result of floods that brought cans and plastic containers of pesticides into the water body and lower values recorded during dry season might be attributed to rock weathering in the dry season due to heat and motor vehicle emission as a result of dust particles particularly at the outlet and inlet of the reservoir. The result is in line with Atobatele *et al.* (2005) who also reported highest mean value of zinc in River Ogunpa and Tyokumbur *et al.* (2002) in Awba stream and reservoir, Obasohan and Egunavoen (2008) in Ogba River, Benin city. Contrary observation was reported by Olatunde and Oladele (2012) who reported highest mean values of Zn, Pb, Cr. and Cd during the dry season in lower River, Girgin *et al.* (2010) also reported high mean concentration values of Cd, Pb and Cu and was associated to the leakage of industrial waste, surface runoff and deposition in urban stream, Turkey, Oyekunle *et al.* (2011) in Osogbo and Ezekiel *et al.* (2012) in Niger State. There were higher concentrations of Zinc in the sediment during dry season and lower values were recorded in the wet season months. This might be attributed to faecal wastes of cow and cattle on grazing in the dry months as results of supplementation of livestock feed with excessive amounts of additional nutrients (Fulton *et al.,* 2002). This may also be associated to low water level during dry season and least concentrations in the wet season may be as a consequence of dilution of the reservoir with rainfall. Similar report was made by Degregori *et al.* (1996) in Chile, Chindah Braide (2003) in Niger Delta, Eja *et al.* (2003) in Calabar, Ayotunde *et al.* (2012) who also reported highest mean value of Zinc in the sediments of cross river freshwater, Nigeria.

Generally, Zn were reported as the only metal that lies within standard range in all water samples examined, this is similar to the observation of Akindele *et al.* (2013) and Saeed *et al.* (2014). Water samples iron concentration showed highest values in stations 4 and 6 during rainy season and lowest values that exceeded limits were also recorded for other stations which may be attributed to surface runoff which may include fertilizers from agricultural fields near the reservoir. Similar reports were observed by Degregori *et al.* (1996) and Fulton *et al.* (2002). Highest mean values recorded across stations in the dry season could also be related to reduction in the water level due to evaporation by sun. Highest values beyond standard limits were as well reported by Girgin *et al.* (2010) in Turkey, Ebigwai *et al.* (2014) in Kwa River Calabar.

Highest mean concentrations of chromium in water samples during wet season and lower mean concentrations during dry season across stations may be due to erosion influx during rainy period while higher values of chromium in the sediment showed bioaccumulation of heavy metals in the sediment and water reduction as a result of evaporation during dry season and dilution effect of rain during wet season could be responsible for low values of chromium that exceeded limits which were obtained in this study. This observation similar with the report made by Olatunji and Osibanjo (2012), Ahmed *et al.* (2013), Ebigwai *et al.* (2014) and Joshua *et al.* (2016), all researcher reported low values which were below permissible limit and the reasons were associated with low solubility of the heavy metals. Cadmium concentration in water and sediment samples showed highest mean values in the period of wet season and least mean concentrations in the period of dry season across sampled stations of Erelu reservoir, which could be due to influx of extraneous materials that might contain heavy metals during rainy season and decrease in water level during dry season with low intake of particles that can increase the heavy metal concentration during dry season (Nriagu, 2007). Comparable result was observed by Amoo *et al.* (2005) in Kanji Lake, Girgin *et al.* (2010) in urban stream, Turkey and also reported that bioavailability of Cd, Cu, Ni, Pb and Zn in freshwater typically decreases with increasing hardness Ebigwai *et al.* (2014), Kakulu and Osibanjo (1992) who reported higher concentration of Cd, Pb, Zn in water samples of Warri River and Calabar River. Different results were reported by Olatunji and Osibanjo (2012) that observed high concentrations in the dry season than in the wet season.

The result obtained from the analysis of water quality of Erelu reservoir revealed that all the measured physical and chemical parameters excluding turbidity were within the permissible limits of World Health Organization (WHO, 2011), Standard Organization of Nigeria (SON, 2007) and National Environmental Standards and Regulations Enforcement Agency (NESREA, 2011) standards for drinking water and aquatic environment with the exception of turbidity values that were higher across sampled stations. Calcium and magnesium ions, phosphate and nitrate were also below limits which indicated low nutrients in the water body, however, some levels of pollution can be observed in the present reservoir under studied. The present study results supported Joshua *et* al. (2016) findings, which reported highest turbidity values across the stations in Mvudi River in South Africa.

All heavy metals studied had concentration mean values that exceeded WHO and NESREA Limits except Zinc in water samples of Erelu Reservoir. This result was supported by Nriagu (2007) and Akindele *et al.* (2013) who also reported that Zinc fell within limits and said Zinc is biologically important, having many physiological functions in living organisms. Garcia and Millan (1998) also reported highest mean values of cadmium and zinc that exceeded limits and was associated with farmyard, car and industrial effluents which discharged great amount of Zn into the aquatic environment. Asides, household products like powder, clothe wash, cleansers, hair wash, tissue papers and other cleansing products may additionally assist in Zinc load. It has unfavourable impacts on human and other creatures when absent or available in an exceeded quantity and thus impacts almost all metabolic processes. Also, iron, zinc and copper are coenzymes which are neccessary for the formation of haemoglobin but very much intake of these metals can be reason for the unfavourable health impacts (Yacoub, 2007). Non-significant deviations (p>0.05) observed in the mean concentrations of heavy metals according to Duncan's Multiple Range Test could be due to the same source of pollution. Similar observations were also reported by Webber *et al.* (2013) and Andriaan (2015).

Elevated concentration values of these heavy metals reported in water and sediment samples of Erelu reservoir might be attributed to dissolve chemicals due to agricultural activities, cassava effluents from local Garri processing industry, Faecal waste of cattle as a result of grazing, engine oils associated with cars and occasionally bicycle wash, detergents from domestic source, ritual baths around the reservoir and pouring of Gammalin 20 (Lindane) into water body for catching fish especially at the reservoir inlet and outlet stations. Similar observations were reported by authors who had studied freshwaters such as Forstner *et al.* (1979) in Germany, Yip *et al.* (1996) in Washington, Broody (1999) in U.S.A reported high concentration of Fe and Pb, Kakulu and Osibanjo (1992) in Warri and Calabar rivers reported highest concentration of Pb, Zn, Cr, Cd, Amoo *et al.* (2005) in Kanji Lake, Ayotunde *et al.* (2012) and Olatunde and Oladele (2012) also reported highest values of Pb, Zn, Cr, Cd, Co, Cu, Fe, in Cross River and lower River Niger respectively. Ezekiel *et al.* (2012) as well reported higher concentrations of heavy metals in water samples and was attributed to indecent deposition of refuse and establishment of wood processing (WEMCO) company very close to the sampling locations at Ikom, area, Cross River. Joshua *et al.* (2016) likewise reported elevated level of Cr in surface water samples and likewise sediment samples of Mvudi River, South Africa.

5.1.3. Significance variation of physico-chemical parameter values across stations and between seasons of Erelu reservoir

The non-significant mean values observed in the Physical and chemical parameters such as Turbidity, Calcium ion, Magnesium ion, Phosphate, Nitrate Dissolved Oxygen, Biological Oxygen Demand (BOD), Total Dissolved Solid (TDS), Total Alkalinity (TA), Hydrogen ion concentration (pH), Temperature and Conductivity, across the inlet, main reservoir and outlets during the rainy and dry seasons according to Duncan's Multiple Range Test which could be attributed to similar sources of pollution to the reservoir. This report is in line with the observation of Olatunde and Oladele (2012) but in contrary to the report observed by Akaahan *et al.* (2014) who reported significant differences in the mean concentration of the physico-chemical parameters across all stations examined except for surface water temperature in river Benue, Markudi. The values of transparency in the reservoir during dry and wet seasons that were significant could be associated with water depth in the reservoir stations. Comparable results were observed by Shahadat *et al.* (2012) in Bangladesh, Adon *et al.* (2011). The significant variation observed in the inlet and reservoir mean values of BOD in the rainy season might be ascribed to different anthropogenic input as a consequence of flood. Similar observations were reported by Emoyan *et al.* (2006), Obasohan and Egunavoen (2008) but contrasted the reports of Obiakor *et al.* (2013) and Adakole and Mbah (2005). The significance variations observed in the reservoir station in lead concentration of water samples during rainy season might be related to flood that brings more input into the reservoir. Non-significant differences in mean concentration values of water and sediment heavy metals across stations in dry and rainy seasons could be attributed to weathering of rocks in water body, hence, cause for the rise in the mean values of the heavy metals especially during dry season as a result of heat generated during hot weather. It may also be due to similar source of pollution which is in accordance with the report of Degregori *et al.* (1996), Olatunde and Oladele (2012).

Transparency and temperature that revealed significant differences between seasons could be associated with different hydrological features across stations. Similar report was observed by Adon *et al.* (2011), Obiakor *et al.* (2013) and Adeosun *et al.* (2014) but deviated from the report of Adakole and Mbah (2005) that reported non-significant concentrations of transparency between seasons. Significant deviations showed in the values of turbidity and calcium ion between seasons in the reservoir and outlet stations may be due to different sources of input that contains calcium and influx due to runoff during rainy season that make water more turbid. This result is in line with Emoyan *et al.* (2006), Adeyemo *et al.* (2008), Adon *et al.* (2011). The concentration values of magnesium ion at inlet and reservoir stations that were significantly varied could be linked with hydrological differences and water levels in these stations. The observed mean values of DO, TDS and EC that were not significant across stations could be related to common origin of anthropogenic input into the reservoir. It can also be linked with values of the parameters not exceeding the critical values. This result accords with the observation of Adakole and Mbah (2005) and Jo-Anne Howell (2010) but digressed from Emoyan *et al.* (2006), Ibraheem *et al.* (2009), Adon *et al.* (2011) Patil *et al.* (2011), Adeosun *et al.* (2014).

The mean values of Phosphate and nitrate that significantly varied in the reservoir and outlet stations between seasons is an indication of differences in hydrological features of the water body. This result agreed with the report of Jo-Anne Howell (2010), Adeosun *et al.* (2014), Akhaan *et al.* (2014) however digressed from the report of Sikoki and Anyanwu (2013) who reported non-significant differences of Phosphate and nitrate between seasons and across stations in Pristine stream Niger Delta. The mean values of BOD across stations between seasons that varied significantly indicated different water quality which is corroborated by the report of Adeyemo *et al.* (2008) Akindele and Adeniyi, (2013). The significant variation observed in the mean values of TA in all stations between seasons could be attributed to water receiving distinctive effluents that brings about variation in bicarbonates between seasons. Similar report were observed by Ibraheem *et al.* (2009), Adon *et al.* (2011), Shahadat *et al.* (2012) but deviated from the report of Adakole and Mbah (2005). The mean concentrations of pH observed at inlet and outlet of the reservoir were significant between seasons and could be associated to diverse hydrological properties and water level that varies with seasons. Departed result was observed by Adeosun *et al.* (2014) who reported non-significant variations between seasons in Ogun State.

Non-significant variation observed in the mean concentrations of lead between seasons in water samples could be attributed to the reservoir having uniform water qualities, this is in line wieh the report observed by Olatunji and Osibanjo (2012), Faith *et al.*

(2013). The observed mean concentrations of Pb in sediment samples that were significantly varied might be related to different sources of human activities and their distribution. Contrary reports were observed by Obasohan and Eguavoen (2008) in Ogba River, Benin City and Kawser *et al.* (2009) in Bangladesh and Faith *et al.* (2013). Significant variation observed in the mean values of zinc in water and sediment samples between seasons indicated no uniform distribution and could be attributed to different pollution levels at each station. Similar observation was made by Emoyan *et al*. (2006). Contrary observation were reported by Li and Zhang (1987) in China, Faith *et al.* (2013), while non-significant deviation observed in sediment iron mean concentrations across sampled stations and between seasons could be associated with the uniform distribution of pollutants across stations. The result is in line with that of Obasohan and Egunavoen (2008). Significant variations observed in the mean concentrations of iron in water samples between seasons might due to varied sources of input into the reservoir. The significant variation in the mean values of Cr and Cd in water and sediment samples between seasons suggests no uniform distribution of the heavy metals in both water and sediment samples. This observation agrees with the report of Kawser *et al.* (2009) in Bamgladesh. The undetected or infinitesimal levels of Cr and Cd in some stations during sampling were also observed by Asiquo *et al.* (1999), Emoyan *et al.* (2006) and Ewa *et al.* (2013).

5.1.4. Biological Assemblage of Erelu Reservoir

The biological checklist of Erelu reservoir encountered during study period were 13 orders, 56 species and 30 families and is said to be more abundant compared to 7 species reported by Nathaniel (2001) in Opa reservoir,13 species reported by Oke (1989) in Owena reservoir, 31 species by Joydeb *et al.* (2013) in Tripura lake, India and 46 species by Olomukoro and Ebehiremhen (2015) in Obazua lake, Bennin but contrary to the report of Edokpayi and Osimen that reported 89 taxa in Ibiekuma river in Ekpoma. However, the present study reported high number of families of macro-invertebrates (30 families) which is high compared to the report of Ogidiaka *et al.* (2012) who reported 4 families and 15 families. The reason for high abundance of macro-invertebrates of Erelu reservoir could be attributed to thick vegetation surrounding the reservoir for attachment and oviposition, food availability, Dissolved oxygen that does not exceeded standard limits and less nutrients that can cause alga growth across sampling stations.

The abundance of *Gyrinus sp. Appasus sp. Notonecta sp.Corixa sp.Velia* species and lot of others may be due to low BOD, high DO and transparency within the reservoir stations that aids photosynthesis which in turn increase food availability. *Hydaticus sp. Syrphid* larva*, Tabanid* larva and *Lethocerus sp., Lacotrephes sp.* that were scantly encountered during sampling period could be due to less polluted status of the reservoir because this group of organisms are found in an heavily polluted waters. Same observation was made by Bristi *et al.* (2016) in Assam India who reported Lethocerus sp. in highly polluted stations of Dikhow River. The frequent occurrence of pollution tolerant macro-invertebrates such as *Chironomus sp., Syrphid* larva and fairly tolerant species like *Melanoides tuberculata, Potadoma moerchii, Bulinus sp*. particularly at the reservoir inlet point and outlet point, which could be associated to the effect of car wash using detergent, cattle faeces and use of Gammalin 20 (Lindane) in catching fishes at those stations. Similar observation were made by Owojori (2004) in Owena reservoir Ile Ife, Nathaniel (2001) in Opa reservoir, Brown (1980), Agbolade and Odaibo (2004) in Omi stream Ago Iwoye where they associated the abundance to being common snails that are widely distributed in West African streams and rivers. The cosmopolitan nature of thiaridae family may be attributed to their survival rate during drought, low mortality rate and long life span (Tan *et al.,* 2012).

Presence and abundance of *Lymnae natalensis* could be associated with luxuriant vegetation that covers the shoreline of the reservoir which is in the same direction with the report of (Tan *et al.,* 2012) in Singapore and Godwin (2015) in Asejire reservoir. High abundance of Mussel (*Margaritifera margaritifera, Anodonta cygnea*) could be due to low phosphate, nitrate, calcium ion and biological oxygen demand recorded in the reservoir, because elevated levels of these parameters have been related with high mortality rate of the mussel (Bauer, 1988). Its abundance is also favoured by high DO, pH and conductivity.

5.1.4.1 Insect macro-invertebrate abundance of Erelu Reservoir

The main aquatic insect order of Ephemeroptera, Plecoptera, and Trichoptera were totally missing in the studied reservoir. The present result is similar to the observation of Frances and Emeka (2006), and they ascribed it with impact of wood mill and waste dumped at Sapele section of Benin River. Insects of order Hemiptera, Coleoptera showed high number of individual species and abundance. The present results is comparable to that recorded in urban fresh water lakes of Tripura, Northeast India by

Joydeb *et al.* (2013). Similar observation of dominance of order Hemiptera was as well reported by Takhelmayum and Gupta (2011) in Loktak lakes of Manipur, Laurince *et al.* (2013) in Ivory coast, Barman *et al.* (2014), Dalal and Gupta (2016) in India. Generally, species composition, abundance and richness revealed that insects of the order Hemiptera were the most dominant and that of Diptera was the least dominant in the Erelu reservoir. Different observations were made by researchers including Mustapha and Omotosho (2005) in Okhuo River, Jana *et al***.** (2009) in West Bengal, Sharma and Rai (1991) in Bhagalpur, Olomukoro and Ebehiremhen (2015) in Benin city Nigeria, they found out insects of order diptera to be the most common organisms encountered, followed by the Hemipteran, while Jana *et al.* (2009) and Ravera (2001) reported Odonata as the most abundant in West Bengal and associated it with macrophyte dominated area (Ruggiero *et al.,* 2003; Arimoro *et al.,* 2007a), Munira *et al.* (2014) in Bangladesh. Okoro (2015) also reported Odonata as the most dominant order of insects with Hemiptera as the diverse with highest number of families in Opi lake Enugu. In this study, Dipteran was found to be the least, indicating low organic enrichment of the reservoir. Amongst the Hemiptera, *Notonecta* and *Corixa sp.* recorded high number of individual. Seasonal variations revealed that Hemiptera recorded highest abundance during dry season which may be attributed to light intensity which in turn aids photosynthesis and make food available for their survival. Coleopteran had high abundance of organisms during rainy season.

Ptilomera sp., *Gyrinus substriatus*, and *Hydrometra sp.* were very abundant at inlets and outlets of the reservoir and the reason might be due to low water speed and vegetations that help in oviposition at the stations. *Gerris sp*., *Notonecta sp*., *Velia sp*. were highly abundant within the reservoir stations and this could be as a result of many of them looking for emergent vegetation and small animals to prey on, their legs are also adapted for water surface tension and adults can also fly even if the velocity is high. It could also be as a result of warmer temperatures that do increase their metabolisms and substratum which provides food like decaying plant, animal matter and suitable shelter which include sandy and stone free environment. This support the report of Allan (1995) who reported that organisms do rise in diversity and abundance when there is stable substrates and the existence of organic detritus. The abundance of insects macro-invertebrates could be attributed to the pH values being within normal range of (6.5-9.00mg/L), this is supported by Willoughby and Mappin (1998) who associated low pH with egg failure and that decrease pH can trigger heavy metals which are toxic to macro-invertebrates. The numerical dominance of *Notonecta sp.* and Odonata species is an indication of fairly clean water body.

5.1.4.2 Macro-benthic invertebrates abundance of Erelu Reservoir

Major orders of benthic macro-invertebrates recorded in Erelu reservoir are unique and comprising dominant groups as Architaenioglossa in rainy season (23.92%) and dry season (13.99%), Sorbeoconcha in the rainy season(49.13%) and dry season (76.53%), Hygrophila in rainy season (12.67%) and dry season (3.55%), Pulmonata (4.06%) and (1.65%). Unionidea (3.58%) in rainy and dry seasons (2.58%). Mollusca which comprises of Architaenioglossa and Sorbeoconcha have higher abundance followed by Hygrophila and pulmonata. This result contradicts that of Chukwu and Nwankwo (2003) who observed annelids as the most predominant organisms encountered and associated it with pollutants from land based source and also substrate unsteadiness, Olomukoro and Ebehiremhen (2015) who also reported low abundance of mollusca in obazua lake Benin, Nigeria. *Viviparus contectus, Pomacea bridgesii, Melanoides tuberculata* were abundant in station 1, 2, 6, and 7 which could be associated to low water velocity and anthropogenic impacts in these stations mentioned unlike that of reservoir, this result could be related to Jobin and Ippen (1964) in their study, who reported that velocities greater than 0.33m/s, aquatic snails became dislodged and swept away. The reason could also be due to physico-chemical parameters that does not exceed limits across stations. *Melanoides sp*. were more abundant in all stations due to their fairly tolerant ability. Similar observation was made by Adebayo (2009) in Eleyele reservoir.

The abundance of these mollusca might be related to the fact that they showed no habitat restriction. Generally, organisms were more abundant in the rainy season than in dry season in the present study. This result is in line with that of Beta (2009) and Olomukoro and Ebehiremhen (2015) who also reported factors responsible for the abundance of snails as vegetation availability, abundance of food, habitat rich in aquatic weeds and moderate temperature that activate life of the snail and that vast majority of these factors are initiated by rainfall. Low abundance of the snails during the dry season could also be ascribed to lack of non-availability of the above factors and decrease in water level which in turn lead to reduction in bacteria which is one of the snail foods (Bengt *et al.,* 2012). The abundance in the rainy season could also be related to little or no pollution, eutrophication which is also observed by Agrueszka (2008) who reported pollution, eutrophication and river regulation as the main factors leading to decline in the occurrence of snails. The abundance of snails during wet season may be attriutted to high mean value of pH. Contrary observation was reported by Thomsen and Friberg (2002) who reported low pH in their study and related it with lower diversity and decrease emergency rate of benthic macro-invertebrates. The high numerical abundance of Arenicolidae (*Arenicola sp*.) and Nereididae (*Nereis sp*.) in the wet season could be attributed to nutrient runoff during the rainy season that serves as food for them. Their occurrence as marine species could be due to their adaptational ability to survive in low salt environment. Similar observation of marine oligochaetes and polychaetes was reported by Mark (2009) in his study and their presence was attributed to the reason not too clear.

5.1.5 Pearson's correlation coefficients between physico-chemical parameters

Correlation coefficient (r) revealed a negative relationship between turbidity and transparency due to the fact that as the turbidity increases, transparency reduces and its positive correlation with benthic and insect abundance is an indication of heavy rainfall, high value of DO that leads to photosynthetic activities, which is in line with Basset (1999) who reported insect abundance as being influenced by rainfall and surrounding vegetation.

The negative correlation of calcium ion with benthic abundance according to Pearson's correlation coefficient suggests that the calcium ion has no effect on the abundance of benthic macro-invertebrates might be due to its low concentrations across sampling stations in this study. Though, calcium was reported as an essential constituent of the skeletal structure of organisms (Patel and Patel, 2012). The strong correlation between calcium and magnesium ions showed the relationship between the two and that the two salts are needed for the functioning of some enzymes in aquatic organisms (Lentech, 2012). The negative correlation observed between phosphate and nitrates indicated a minimal use of fertilizer and that the two of them do not have identical source in the reservoir. The present result contradicts the observation of Otalekor (2009) who reported positive correlation between the two in Awba reservoir and Khalik *et al.* (2013) in Malaysia.

Pearson's correlation coefficient revealed a positive correlation of BOD with turbidity, which indicated relationship with BOD and is a characteristic of organic pollution. The result agreed with Mohan *et al.* (2013) who reported significant relationship between BOD and surface water temperature in River Yamuna and River Tawi, India. TDS and Total alkalinity showed a correlation with Ca^{2+}, Mg^{2+} nitrate and transparency, because as water level reduces, increase in salts occur especially during dry season, but negative correlation of TDS with BOD is an indication of low organic enrichment. The positive correlation of TDS and TA could be attributed to the buffering capacity by total alkalinity (TA) which in turn leads to moderate pH and many aquatic organisms use pH for their growth and metabolism.

According to Pearson's correlation coefficient, total alkalinity that showed a positive correlation with Ca^{2+} Mg^{2+}, NO_3^- and TDS indicated that as total alkalinity increases so also Ca^{2+} Mg^{2+}, TDS increases, which may indicate common sources of the parameters in the reservoir. Similar observation was reported by Fouzia and Amir (2014) in India. The positive correlation of pH with insect abundance showed that insect preferred moderate pH values for their feeding and metabolism (Wahizatul, 2011), since pH of Erelu reservoir fell within 6.0-8.5 mg/L threshold limits which indicated good productivity nature of the reservoir. Comparable observation was made by Garg *et al.* (2010) in India. The positive correlation of pH with turbidity and Ca^{2+}, Mg^{2+}, $PO4^-$, NO_3^- may be due to run-off that might bring more ions into the water body. Negative correlation of temperature within insect abundance showed no effect of temperature on the insect abundance. Departed result was reported by Popoola and Otalekor (2011) who reported great impact of temperature on the abundance and widespread of aquatic insects of Awba reservoir in Ibadan. Conductivity related positively with Ca^{2+}, TDS, TA and temperature, because water that contains moderate salts conduct electricity strongly. Identical result was observed by Khalik *et al.* (2013) who reported strong correlation between conductivity and TDS in Malaysia.

5.1.6 Correlation between physical and chemical parameters and abundance of macro-invertebrates of Erelu Reservoir

The strong positive significant correlation of transparency with Hemiptera and Odonata showed that light penetration had influence on the abundance and diversity of Hemiptera and Odonata, even though greater abundance were recorded during rainy season. The significant positive relationship between turbidity and Diptera might be ascribed to pollution because turbid water always favoured the abundance of Diptera. Deviation was reported by Akhaan *et al.* (2014) where they reported positive significant relationship between Arthropoda and turbidity.

The inverse non-significant relationship exhibited by temperature on most orders of insects indicated no influence on the abundance of these insects, as temperature decreases, so there is increase in the abundance of Coleoptera, Hemiptera and Odonata the reason might be because they prefer waters that is cool for their feeding rate, metabolism and reproduction. Similar observation was made by Pennak (1978). This is so, because larger abundance was recorded during rainy season. This result however digressed from that of Otalekor (2009) who reported most species to be positively correlated with water temperature and related it to some species being temperature dependent for their feeding and metabolism. The present result is in accordance with that of Samweel and Nasir (2014) who observed negative correlation of temperature with the abundance of insects. The positive correlation of phosphate with insect orders shown in this result indicated low nutrient input into the reservoir and it contradicts with the observation of Akaahan *et al.* (2014) who reported inverse relationship of phosphate with insect abundance in Benue State.

The positive non-significant correlation of NO_3^-, TDS, TA, pH, calcium ion and conductivity with insect orders may be associated with the parameters falling within required limits. The result is in line with that of Okoro (2015) who reported non-significant correlation of temperature, transparency, phosphate, Nitrate, Iron TDS, Calcium ion, alkalinity, zinc, pH with insect abundance in his study of ecology of aquatic insects in Opi lake, Enugu, while an inverse relationship between total alkalinity and insects abundance was reported by Popoola and Otalekor (2011).

DO and BOD that positively correlated with Odonata showed that the former has influenced on the later. Similar observation was observed by Anjana and Jankak (2015) who reported positive correlation of DO, BOD and alkalinity with the abundance of Odonata. The positive correlation between Total alkalinity, Coleopteran and Hemiptera indicated strong influence on their abundance. The result agreed with that of Payakka and Prommi (2014) who reported positive correlation of total alkalinity with Diptera and coleopetera but inverse relationship of DO with odonata and coleoptera abundance. The significant relationship between zinc and iron could be linked with similar source of pollution which agrees with the observation of Ewa *et al.* (2013) and Dan *et al.* (2014). The positive significant relationship between the Zinc and Lead in the sediment samples indicated similar source of anthropogenic substances in the sediment, also chromium and Iron, Cadmium and iron that had strong positive relationship with each other indicated identical source of pollution into the sediment and that sediment absorb heavy metals more than water samples because of continous persistence and bioaccumulation of metals in the water sediments. Comparable observations were made by Iwara *et al.* (2012) in Odukpani River, Cross River State, Ewa *et al.* (2013) in Calabar River.

Lead in water samples that had positive significant correlation with odonata implied relationship between the two of them, that is, as the former increases so also the later. Departed report was made by Fredrick and Hudson (2016). Iron in water samples showed no relationship with Coleopteran and Hemiptera but a strong relationship with lead that indicated similar source (Ewa *et al.,* 2013) in Calabar River.

Zinc had a significant strong relationship with iron which indicated similar source into the water body and chromium also relate positively with lead and iron which also indicates identical source of input into the water body. Same results were observed by Ewa *et al.* (2013) in Calabar River, Altaf and Saltanat (2014) in Khasmir. Cadmium also related with iron and zinc in water and sediment samples. The positive correlation of heavy metals in water samples may be attributed to similar sources of pollutants that generated these heavy metals and could be reason why the metals has strong relationship with insects abundance. The present result supported that of Girgin *et al.* (2010) who observed positive correlation of Pb, Cd, Zn, Fe, Boron, manganese, copper with the abundance of insects order during their study in Turkey. Also, Garcia and Millan (1998) in Spain, Ewa *et al.* (2013) in Calabar River, also reported positive relationship among metals and associated it with similar source of anthropogenic pollutant into the water bodies. Deviated result were observed by Iwara *et al.* (2012) where they reported negative correlations among heavy metals and suggested that the metals do not have identical source of pollution.

The non-significant negative correlation between transparency, Calcium ion, Total dissolved Solid, Total alkalinity, Temperature and conductivity and benthic organisms indicates that the abundance of macro benthic fauna is independent of these water quality parameters and the reason could be as a result of these parameters not exceeding the required limits. This result corroborated that of Idowu *et al.* (2013) in Ado Ekiti reservoir and Fouzia and Amir (2014) in River Yamuna India, who reported similar observations. The reason for this observation could be because of relationship between temperature, TDS and Conductivity. This is because when there is high temperature, higher values of TDS, TA and conductivity will be recorded, however, higher abundance of these organisms were recorded in the wet season when low values of these parameters were recorded. The significant positive correlation of turbidity with Hygrophila showed that it has control over its abundance and the reason could be as a result of more nutrients washed into the reservoir that make the water turbid. This result is in contrast with the observation of Akhaan *et al.* (2014). The Mg^{2+} that correlated negatively with Unionidea (Mussel) indicated no association wit the mussel abundance. This result departed from Fouzia and Amir (2014) who reported positive correlation of magnesium iron with benthic organisms.

The positive correlation of phosphate with capitellida (worms) showed its control on the abundance of the organism which is an aquatic worm that usually dwells in a polluted area and may be the reason for its positive correlation. The present report agreed with that of Garg *et al.* (2009). The correlation analysis by Pearson's coefficient (r) that revealed a positive association of phosphate with Unionidea (Mussel) and DO might be associated to photosynthetic activity in the water body and DO values that fall within the required limit for aquatic organisms survival. This present result is in line with Popoola and Otalekor (2011) in Awba reservoir and Idowu *et al.* (2013) in Ado- Ekiti reservoir, Mohan *et al.* (2013) and Akhaan *et al.* (2014).

The significant inverse relationship between nitrate and capitellida (worms) and Unionidea (mussel) may be due to low values of nitrate that is below the limits in the water body. The result supported that of Yap *et al.* (2006) who reported inverse correlation between Oligochaetes and physico-chemical parameters in Malaysia. Deviated results was observed by Garg *et al.* (2009) who reported phosphate and nitrate as being correlated positively with molluscans and that the fluctuation had no significant effect on the richness and population abundance of molluscs in the reservoir in India. The positive significant relationship between BOD and Sorbeoconcha (Gastropoda) revealed that BOD had very intense relationship with the presence of this particular order of benthos and that low concentrations of BOD observed revealed minimal organic perturbation. This work corroborated the reports observed by Mohan *et al*. (2013), Akhaan *et al.* (2014). The inverse significant negative correlation between Total alkalinity and Unionidea (mussel) indicated no relationship between the two, which may be due to the fact that Unionidea do need moderate pH and increase values of TA may reduce the pH as buffering capacity of the reservoir. They are also organisms of purification capable of purifying their environments. Contrary report was observed by Garg *et al.* (2009) who observed positive correlation of TA with mussel.

Lead in the sediment samples that showed positive significant correlation with hygrophila (Lymnae) has influence on its abundance but showed no relationship with other groups of benthic macro-invertebrates. This implies that lead has impacts on *Lymnae sp*. Abundance. Iron in the sediment samples positive correlation within capitellida and sorbeoconcha implied that iron determines their abundance. The positive significant relationship between zinc, lead and Dipteran indicated similar source of pollution in the reservoir and great tolerance of Dipteran as zinc influenced its abundance (Deliz Quinone, 2005). Negative correlation of zinc with Hemiptera was observed by Girgin *et al.* (2010). The positive significant correlation between chromium with Pulmonata, Unionidea and iron may be due to purification of water done by Unionidea. Iron was reported by Okoro (2015) to be correlated with coleopteran, Cr, Iron and Lead, which may have similar source of input into the reservoir. The positive significant correlation between cadmium in the sediment samples with capitellida, iron and chromium showed relationship with the capitellida since it is a worm that dwells directly in the sediment and oxygen depleting environment.

5.1.7 Macro-invertebrates and its Ecological indices

The greater values of Shannon Weinner (H') index observed in station 3,1,2,4 and station 7 indicated low level of anthropogenic activities; this is because many researchers have linked low species abundance and diversity with increased level of human activitie (UNCTAD (2002) who observed that utilization of agrarian chemical additives such as pesticides and other activities that can cause environmental deterioration have been endangering biodiversity all over the world.

The higher values of Margalef and Menhinick diversity index observed in stations 5, 6, and 7 might be related to low movement of water in the stations and lowest values recorded in station 3, 4 and 5 is an indicative of pollution of the sites (Lenat *et al*., 1980). Equitability and Jaccard index that showed greater values in stations1 and 2 might be related to decrease in water level and velocity compared to the main reservoir and that equitability, eveness and similarity values that were within the same trends across other stations showed that organisms are similar and equally distributed in all stations. Olomukoro and Ebehiremhen, (2015), reported similar observation of increase species variation and abundance in Obazua Lake in Benin City and related the abundance to the lake not being influenced by human activities. However, departed observations for temperate streams were reported by Efitre *et al*. (2001) and Furey (2006) where species diversity and distribution were observed to be influenced by agrarian activities and inert contamination.

The highest values of redundancy (R) shown in station 3, 4, 5 may be due to food availability, low water velocity that brings about stable species community and Luxuriant vegetations for insects attachment and oviposition sites (Korkeamaki and Suhonen, 2002), while other stations that showed same trend in values is an indication of dominant species representing the population across the stations (Edward and Ugwumba, 2010). The greater values of diversity index approximately one (1) across stations indicated that the stations are less polluted for benthic organisms to dwell and allowed for diverse species of tolerant organisms like *Melanoides tuberculata* etc. (Lenat *et al*., 1980). The Equitability (J), Jaccard index (D), Redundancy (R) and Berger-parker index (d) are all approximately (1.0) values across stations which indicated that macro-benthic organisms are similar, equally distributed and well dominated across stations (Olomukoro and Ebehiremhen, 2015).

The highest Shannon, Equitability, and redundancy index value for coleopteran of insect orders indicated richness, abundance, equal distribution and dominancy across stations of Erelu reservoir which may be due to high pH that is highly acidic to basic which favours the organism metabolism. This result deviated from that of Wilsey and Stirling (2007) who reported lower acidity and associated it to reduced biodiversity and species composition of various invertebrate communities. It may also be due to abundant luxuriant vegetations, food availability substrate pattern that favours the aquatic biota.

The Margalef, Menhinick, Jaccard and Berger-Parker index that showed higher values with Odonata and Hemiptera indicated that order of insects are abundant, similar and dominant in the stations of Erelu reservoir. This may be due to varieties of Odonata and Hemiptera species encountered during sampling. This result corroborated Wilsey and Stirling (2007) findings, Gallardo *et al*. (2011) and Pettersson (1998) who stated that diversity index increase with increased abundance of species or increasing numerical aggregates of organisms in population, when the population of various species are distributed evenly, diversity index increases as well. The Shannon, Equitability, Redundancy and Jaccard indexes that showed highest values of order sorbeoconcha may be due to richness, abundance and equal distribution of the species of *Melanoides tuberculata*, and *Potadoma moerchii* that dominated all the stations and because of their tolerant ability.

The taxa richness (d) showed that Decapoda, Capitellida were dominant and others with lowest values indicated pollutional stress of some stations during sampling but not all the stations. The greater numbers of individuals in Unionidea (i.e. Mussel) also serve as purifier of water bodies. Berger-Parker index that showed highest values approximately one indicated dominance of macro-benthic invertebrate orders, since the distribution, abundance and dominancy of organisms can be influenced by other factors such as stable habitat, its richness, available substrate, nature of water body, trophic condition etc. (Ogbeibu and Oribhabor, 2001).

CHAPTER SIX

6.0 SUMMARY, CONCLUSION AND RECOMMENDATION

6.1 Summary

This study investigated the physical and chemical parameters, occurrence and abundance of macro-invertebrates of Erelu reservoir in Oyo town, Oyo State. Seven sampling stations were selected from the water body, two stations at the inlet to the reservoir, two stations at the outlets of the reservoir and three stations within the reservoir based on the hydrological characteristics of the water body. Water samples were collected and examined for the period of two years, that is, between June 2013 to May, 2015. The physical and chemical parameters examined include temperature, Hydrogen ion concentration (pH), TDS, EC, DO which were measured using Extech (Model: EC500 and DO600) multimeter kit, transparency and temperature were measured *in-situ* using seechi disc and mercury in glass thermometer. Nitrate was measured using Hannah instrument model (HI83200), phosphate was determined using Vanado- molybdo phosphoric acid method. Total Alkalinity was determined using methyl orange indicator. BOD was determined using 5–days BOD technique or Winkler's titrimetric methods. Turbidity was determined using SX-B26 model turbidometer. Magnesium ion, Calcium ions, all heavy metals both in the water and sediment samples were determined using Atomic Absorption Spectrophotometer (AAS) Model Analyst AIO PGP.

Aquatic insect macro-invertebrates were collected using a dip-net with 500µm mesh size. The net was dipped in water at different stations and swirled for about 2-3 minutes at the surface of water to allowed for the entrance of the aquatic insects and their nymphs and were emptied into pre-labelled plastic bottles according to stations. Adult insects like Dragonflies, Damselflies were as well collected from the surrounding vegetations covering the reservoir with the use of a sweep net of mesh size of 250µm. The net was swept over the vegetation for 2-3 minutes and were emptied into pre-labelled plastic bottles. Aquatic insects were identified using aquatic taxonomic keys, such as (Phyllis *et al.,* 1970*;* Pennak*,* 1978; Merritt and Cummins*,* 1996; Needham *et al.,* 2000; Hechman*,* 2002).

Macro-benthic invertebrates of Erelu reservoir were collected using a Van-veen grab with surface area of 66.6cm^2 to collect sediments from the seven stations and sediment samples collected were subjected to sieving through a mesh size of 0.5mm in order to remove excess sediments. Organisms sorted were preserved in 70% alcohol for onward transfer to laboratory for identification. Aquatic macro-invertebrates collected were identified using aquatic taxonomic keys such as Pennak (1978), Fred (2004), WHO (1978), Hechman*,* 2002, Oscos *et al.* (2011) e.t.c.

Biotic indices such as margalef, Menhinick, Shannon-Weiner index, Evenness, Jaccard similarity index, Berger-Parker index and Redundancy dominance index were used to determined pollution status, abundance and diversity of species of Erelu reservoir.

The results from this research indicated that all physical and chemical parameters examined were within the required limits of WHO, NESREA and SON with the exception of turbidity that had high mean values which exceeded limits across stations examined, calcium ion, magnesium ion, nitrate and phosphate were having low mean values below the critical levels and that the physical and chemical parameters, heavy metals were not significant (p=0.05) according to Duncan's Multiple Range Test (DMRT), except for transparency, BOD and lead in water samples that differs significantly (p<0.05) within stations.

Pearson's correlation coefficient analysis revealed that the physical and chemical parameters such as transparency, Calcium ion, Total Dissolved Solid, Total Alkalinity, Temperature and Conductivity had inverse relationship with benthic macro-invertebrates, while the BOD, DO, Turbidity and pH had positive relationship with macro-invertebrates.

The results also revealed that all heavy metals examined both in the water and sediment samples have concentration values that were above the recommended limits for drinking water and aquatic organism survival except Zn concentration in water samples that were within the required limits of WHO, NESREA and SON.

The study identified absence of sensitive taxa (Ephemeroptera, Plectoptera and Trichoptera) throughout the sampling period which is an indication of pollution. The composition of macro-invertebrates encountered includes: Hemiptera, Coleoptera, Odonata, Gastropoda as the organisms of moderate or fairly tolerant to pollution. The result indicated Diptera (Syrphidae and Chironomidae), Oligochaetes and Polychaetes as the most tolerant organisms.

About 38 species from four (4) orders, nineteen (19) families of aquatic insect macro-invertebrates with 72,165 individuals were collected and of which Hemiptera were the most dominant order comprising 12 species, followed by the Coleoptera, Odonata, etc, while benthos collected were nine (9) orders, eleven (11) families and eighteen (18) species with about 7,130 individuals and the most abundant order was Sorbeoconcha (Gastropoda) ably represented by three species.

The result also revealed that there is an inverse relationship between transparency and turbidity while turbidity had a positive correlation with most orders of macro-invertebrates abundance. There was a direct association between Ca^{2+} and benthic macro-invertebrates abundance and a strong positive correlation was shown between Ca^{2+} and Mg^{2+}. It also revealed a significant negative relationship between phosphate and Nitrate. BOD had a positive significant relationship with macro-invertebrates abundance. It was also revealed that TDS and TA had relationship with Ca^{2+}, Mg^{2+}, nitrate and transparency. TDS and TA also had positive correlation with benthic macro-invertebrates abundance and that TA revealed positive association with Ca^{2+} and Mg^{2+}, TDS and NO_3^-, while transparency associated significantly with Odonata and Hemiptera.

The result also revealed that pH correlated inversely with transparency, DO, TDS. TA had a positive relationship with Ca^{2+}, Mg^{2+}, phosphate and nitrate respectively. Temperature also had negative relationship with insect macro-invertebrates abundance, while conductivity related positively with Ca^{2+}, TDS, TA and temperature. Dissolved oxygen and phosphate were revealed to have a positive correlation with some benthic macro-invertebrate orders. Non-significant negative relationship between temperature and benthic macro-invertebrate orders was revealed, phosphate positively associated with insects macro-invertebrates abundance but non-significant positive correlation of No_3^-, TDS, TA, pH, Ca^{2+} and conductivity with insect macro-invertebrates abundance was revealed.

It was also revealed that DO and BOD had positive relationship with Odonata, and that TA related positively to many orders of insects. Lead in sediments samples related well with hygrophila (*Lymnae natalensis*), iron had positive relationship with capitellida and Sorbeoconcha (*Melanoides tuberculata*, *Potadoma moerchii e.t.c.*) and chromium also related well with pulmonata (*Bulinus sp*.), Unionidea, zinc and iron in water samples related strongly. Zinc in water samples had positive relationship with Unionidea. Chromium in water samples related positively with lead and zinc in water samples respectively. Cadmium had positive relationship with capitellida, iron and zinc respectively.

Zinc related with lead, chromium cadmium associated with iron in the sediments samples and cadmium related with chromium is sediment samples. Lead in water samples had positive significant relationship with Odonata, while iron showed no relationship with insect macro-invertebrates.

Shannon diversity index (H') revealed abundance across stations for benthic macro-invertebrates but diverse observation was shown in station 3, 4, 5, 6. The Margalef''s and Menhinick taxa richness abundance revealed low values across the stations for aquatic macro-invertebrates of Erelu reservoir. The result also revealed that organisms of aquatic insects and benthic macro-invertebrates are evenly/equally distributed and are similar from station to station.

The redundancy and Berger-Parker index revealed abundance across stations of Erelu except stations 1 and 3 for insect macro-invertebrates, Shannon index (H'), Equitability and Redundancy also revealed that coleopteran and sorbeoconcha (Gastropoda) were diverse, equally distributed, well abundant and similarly distributed.

6.2 Conclusions

The results obtained for all the physical and chemical parameter investigated were within the desirable limits for growth, survival and fish production except turbidity values that were found beyond the permissible limits especially during rainy season which implies the effect of runoff or flood. The low values of magnesium ion, calcium ion, phosphate and nitrate mean concentration indicated Erelu reservoir as being oligotrophic in nature and that the variations in values of physical and chemical parameters from this study greatly affected the aquatic macro-invertebrates species composition, distribution and abundance in Erelu reservoir.

All heavy metal mean concentrations both in water and sediment samples were beyond permissible level except zinc in water samples that was within desirable limits which may indicated contamination of the reservoir as at the period of this study.The result revealed that turbidity has the greatest influence on the community structure of Erelu reservoir since the run-off bring more food, nutrients, hence, reason for the abundance of macro-invertebrates during the rainy season. Calcium ion also had strongest influence on the benthic abundance which suggested that it is useful for the formation of their shells. There were significant seasonal variations between physico-chemical parameters and heavy metals concentration in Erelu reservoir.

The fact that the nitrate and phosphorous related negatively and BOD was found to relate positively with insect and benthic macro-invertebrates abundance, indicated less pollutional stress of the reservoir. The result also revealed negative relationship of temperature on the abundance of insects and benthic macro-invertebrates which indicated low temperature with higher abundance of organisms. There was strongest relationship between Ca^{2+}, Mg^{2+}, phosphate and nitrate indicating less nutrient load of the reservoir. It was revealed that DO and PO_4^{3-} has strong influence on the abundance of aquatic insects. It was also revealed that DO and BOD had greater effects on Odonata, while TA had influence on benthic abundance. Lead, iron and chromium also influence the benthic macro-invertebrates abundance which indicated tolerance level of the benthos.

Water quality parameters assume an imperative role in the dynamics, abundance and diversity of macro-invertebrates of Erelu reservoir. The population frequence of coleopteran and hemipteran and resistant order of benthos such as Sorbeoconcha indicated or revealed the moderate pollution of the reservoir and high abundance of apple snails also demonstrated cleanliness of the water body to some extent.

The special reference to Shannon’s index diversity and pollution, the values greater than 3 indicate clean conditions or stable environmental condition, values below one (1) indicates heavy pollution of a stream. The Shannon index for aquatic insects ranged between 0.553 – 0.643 across stations of Erelu reservoir and for benthic is between (0.558 – 1.056) since species diversity, evenness and abundance indices fluctuated across stations, and Shannon H' < 1 in all stations except station 4 and 6 for benthos macro-invertebrates indicated contamination and disturbed environment.

This is further confirmed by the record of high turbidity, low values of calcium ion, magnesium ion, phosphate and nitrate in water samples, absence of EPT (Ephemeroptera, Plecoptera and Tricoptera) species index of clean water and exceeded values of heavy metals in both water and sediment samples of the reservoir, then, the water body could be categorized as Oligotrophic supporting the evidence of moderate pollution status of the reservoir. The study also identified runoff or flood and domestic wastes from residential areas, ritual baths with soap and detergents as sources of contamination in the wet season and waste from grazing animals, Lindane used for catching fishes, engine oils from vehicle wash as major source of pollution of Erelu reservoir during dry seasons. Hence, the health of the primary and secondary users of the reservoir can be put at risk, if the anthropogenic input continues. Generally, Erelu reservoir is more productive in the reservoir stations compared to the inlet and outlet stations. However, rainy season productivity is higher than that of the dry season. The productivity in erelu reservoir is generally low because of low nutrient stability of the reservoir.

6.3 Recommendations

The study of plankton and phytoplankton that serves as indicator of water pollution should be carried out on the reservoir, it is also recommended that heavy metal accumulation in the flesh of macro-invertebrates should be examined by further research so as to determine the influence of these metals on the abundance of the macro-invertebrates and also to get more facts about the healthy status and quality of the reservoir.

The government should place embargo on building of residential houses very close to the reservoir. This is because the anthropogenic activities may later leads to increase in nutrient loads that can cause eutrophication which results in oxygen depletion that can in turn impacts the reservoir quality. If possible, there should be restriction of grazing animals visiting the reservoir, ritual bath activities, washing of bicycles which can leads to increment in heavy metals poisoning that may impair biota and human health leading to diseases like heart attack, cancer of various categories etc. However, occasional pouring of Gammalin 20 (Lindane) into the reservoir for fish catch should be discouraged.

REFERENCES

A.O.A.C. 1996. Method of Analysis of the Association of official Analytical Chemists 15th edition Washinton D.C. 98p.

——— 2000. Official Methods of Analysis of the Association of Official Analytical Chemist.17th Edition .Arington, Virginia USA. 200p.

Abohweyere, P.O. 1990. Study of Limnological Parameters and Potential fish yield in Kigera Reservoir (Extensive System) in Kainji, New Bussa, Nigeria *Journal of aquatic Science* 5: 53-58.

Abowei, J.F.N and George, A.D.I. 2009.Some physical and chemical characteristics in Okpoka Creek, Niger Delta, Nigeria. *Research Journal of Environmental and Earth Sciences* 1.2: 45-53.

Abowei, J.F.N. 2010. Salinity dissolved oxygen, pH and surface water temperature conditions in Nkoro River, Niger Delta, Nigeria. *Advvance Journal of Food Science and Technology*. 2.1: 16-21.

Abowei, J.F.N. and Ukoroije, B. R. 2012. The indentification, Types,Taxonomic, Orders, Biodiversity and Importance of Aquatic Insects. *British Journal of pharmacology and Toxicology* 3.5: 218-229.

Adakole, J. A. and Mbah, C. E. 2005. Seasonal variation of some trace metal concentrations in some fish species on a stretch of River Kubanni, Zaria. In 19th Annual Conference of the Fisheries Society of Nigeria (FISON) held on Nov.03 to Dec. 2004, Ilorin, Nigeria, Pp. 774-780.

Adebayo, T. 2009. The Dynamics of the Macro Benthic invertebrates fauna of Eleyele and Awba reservoir. MSc. Project. Dept. of Zoology. University of Ibadan. 50pp.

Adebayo, W.O. 1993. Weather and Climate in: Ado-Ekiti region, a geographical analysis and master plan (Ed. Ebisemiju F.S.). Alpha Printers, Lagos. Pp.11-14.

Adebisi, A. A. 1981. The physico-chemical hydrology of a tropical seasonal river. Upper Ogun river. *Hydrobiologia* 79: 159-165.

Adebisi, A. A. 1987. The relationship between the fecundities gonadosomatic indices and egg-size of some fishes in ogun River, Nigeria *Arch. Hydrobiol*. 111.1:151-156.

——— 1989. Planktonic and Benthic Organisms in some ponds on the Olupona Fish Farm, Olupona, Oyo state, Nigeria. A report prepared for Agro Team S.R.I. Ibadan, Nigeria.

Adejumoke, O. O., Samuel, O. A. and Ifeanyi, E.O. 2016. Ecology of Schistosoma Snail Vectors in Ado-Ekiti Local Government Area, Ekiti State, Nigeria. *International Journal of Pure and Applied Zoology.* 4.1: 77-84.

Adejuwon, J. O and Adelakun, M. A. 2013. Physico-chemical and bacteriological analysis of surface water in Ewekoro local Government Area of Ogun state, Nigeria case study of Lala, Yobo and Agodo rivers. *International Journal of Water Resources and Environmental Engineering* 4: 66-72 Direct link.

Adekola, J. A., Balogun, J. K. and Lawal, F. A. 1998. The effect of pollution on Benthic fauna in Bindare stream Zaria, Nigeria. *Nigeria. Journal of Chemical Research,* 3:13-16.

Ademoroti, C.M.A. 1996. Standard Method for Water and Effluents Analysis. Foludex Press Ltd. Ibadan 46pp.

Adeniyi, A. A. 1978. Diurnal vertical distribution of zooplankton during stratification in Kanji lake, Nigeria. *Vern, Internal Verein. Limnology*. 20: 1677-1683.

Adewale, J. G. And Ikeola, R. F. 2005. Resettlements coping strategies of woman settlersaround dams in Nigeria. A case study of Erelu dam in Oyo town, Oyo State, Nigeria. *Journal of Human Ecology.* 17.3: 177-181.

Adeosun, F. I., Akin-obasola B. J., Jegede, T., Oyekanmi, F. B. and Kayode, J.O. 2014. Physical and Chemical parameters of lower Ogun River Akomoje, Ogun State, Nigeria. *Fisheries and Aquaculture Journal* 5.1: 1-5

Adeyemo, O. K., Adedokun, O. A., Yusuf, R. K., and Adeleye, E. A. 2008. Seasonal changes in physico-chemical parameters and Nutrient load of River sediments in Ibadan city Nigeria. *Global vest Journal*. 10.3: 326-336

Adeyeye, F.I. and Abulude, F.O. 2004. Analytical assessment of some surface and groundwater resources in Ile-Ife, Nigeria. *Journal of Chemistry Society of Nigeria*. 29: 98-103.

Adon, M.P., Quattara, A. and Gourene, G. 2011. Seasonal variation in the diversity and abundance of Phytoplankton in a small African Tropical reservoir. *African Journal of Microbiology Research* 5.18: 2616-2626.

Agaoru, C.G. 2012. Crustacean Ecology in Opi Lake, Nigeria.MSc. Project.Dept. of Zoology. University of Nssuka. x+65pp.

Agbolade, O.M. and Odaibo, B. 2004. Dockovidia Cookaarum infection and the Prosobranch gastropod *Lanistes lybicus* host in Omi stream, Ago Iwoye. Sub-Western Nigeria. *African Journal of Biotechnology* 3.3: 202-205.

Agniezka, M.K., (2008). The occurrence and distribution of freshwater snails in a heavily industrialized region of Poland (upper silcsia) *Limnological-Ecology and Management of Inland Waters* 38.1:43-55.

Ahmad, N. 1997. Marketing of fish from Selected Floodplains in Bangladesh. In: Open water Fisheries of Bangladesh, Tsai, C.F. and Ali M.Y. (Eds). The University Press Limited, Dhaka, 72pp.

Ahmad, M. K., Das, M and Islam, M. M. 2011. Physico-chemical properties of tannery and textile effluents and surface water of river Buriganga and Karnatoli. *Bangladesh World Application and Sciences.* 12.2: 152-159.

Ahmad, U., Parveen, S., Khan, A. A., Kabir, H. A., Mola, H.R.A and Ganai, A.H., (2011). Zooplankton population in relation to physico-chemical factors of a sewage fed pond of Aligarh (UP), India. *Biology and Medical* 3.1: 336-341.

Ahmed, T. H., Ibrahim, A., Hossam, M. O. 2013. Seasonal variation of Heavy metals accumulation in muscles of the African Catfish *Clarias gariepinus* and in River Nile water and sediment at Assiut Governorate Egypt. *Journal of Biology and Earth Sciences* 3.2: B236-B248.

Ajao, E. A and Fagade, S. O. 2002. The benthic macro-infauna of Lagos Lagoon. The *Zoologist* 1.2: 1-15.

Ajao, E. A. 1990. The influence of Domestic and industrial Effluents on the population of sessile and benthic organisms in Lagos Lagoon. PhD.Thesis. Dept of Zoology University of Ibadan, Ibadan.411pp.

Akaahan, T.J.A., Araoye, P.A. and Olabanji F.M. 2014. Macro-invertebrates fauna group and their relationship with environmental variables in River Benue at Makurdi, Benue State, Nigeria. *Journal of Ecology and the Natural Environment* 6.8: 271- 279.

Akindele, E. O. and Adeniyi, I. F. 2013. A study of the Physico-Chemical water quality, hydrology and zooplankton faun of Opa Reservoir catchment area, Ile-Ife, Nigeria. *African Journal of Environmental Science and Technology* 7.5: 192-203.

Akindele, E. O. and Adeniyi, I. F. and Indabawa, H. 2013. Spatio-temporal Assessment and water characteristics of Lake Tiga, Kano, Nigeria. *Research Journal of Environmental and Earth Sciences.* 5: 67-77.

Akintola, F. O. and Adeniyi, G. 1997. Land-use changes and water quality in impounded water supply dams in Southwest Nigeria. Freshwater contamination. *proceeding of Rabat symposium* S_4 AHS publ. 243, 313-319.

Akpan, A.W. and Akpan, B.E. 1994. Spatial and temporal heterogeneity in plankton distribution in a Nigerian tropical freshwater pond (Southern Nigeria).*Acta Hydrobiol*. 36.2: 201-211.

Akpan, R., Ekom, and John O. O. (1993). Seasonal variation in water quality of the Cross River, Nigeria. *Rev. Hydrobiology Tropical*. 26.2: 96-103.

Atama, C. I. 2003. Studies on the physico-chemical characteristics of effluent from RIMCO vegetable oil Company, Nigeria Breweries limited and their receiving freshwater Ecosystem. MSc. Project. Dept. of Zoology. University of Nigeria. Nsukka. ix +62pp.

Alani, R., Alo, B and Ukpoakonam, F. 2014. Preliminary investigation of the State pollution of Ogun river and Kara Abattoir, near Berger, Lagos. *International Journal of Environmental Science and Toxicology* 2.2: 11-23.

Ali, A., Lobinske, R., Frouz, J., and Leckel, R. J. 2003. Spatial and Temporal influence of environmental conditions on benthic macro-invertebrates in Northeast lake Jessup; Central Florida. *Florida Scientist* 66.2: 69-83.

Aliu, O. O. 2006. Studies of the sediment characteristics and macro-invertebrates fauna of rivers and streams in the Opa River Basin, Ile Ife, Osun State. MSc. Thesis. Dept. of Zoology. Obafemi Awolowo University Ile-Ife. x+70pp.

Allan, J. D., 1995. Stream Ecology-Structure and function of running waters.1st edn. Chapman and Hall. ISBN: 0-412-35530-2 –Xii 388pp

Allison, M. E., Sikoki, F. D., Hart, A. I. and Ansa, E. J. 2007. Some Aspect of physico-chemical Characteristics of the fresh water Reaches of the lower Nun River, Niger Delta, Nigeria. *African Journal of Applied Zoology & Environmental Biology*. 9: 51-58.

Altaf, H.G. and Saltanat, P. 2014. Effect of Physico chemical conditions on the structure and composition of the phytoplankton community in Wular lake at Lankrishipora, Kashmir. *International Journal of Biodiversity and Conservation* 6.1:71-84.

Amoo, I. A., Adebayo, O. T., Lateef, A. J. 2005. Evaluation of heavy metal in fishes, water and sediments of lake kanji, Nigeria. *J. Food Agric Environ.* 3.1: 209 – 212.

Amusat. A. I., Popoola, K.O.K., Adedokun, M. A. and Rafiu R. A. 2015. Composition, Abundance and Diversity of Macro-benthic Fauna of Erelu Reservoir and its Physical Properties. *Journal of Agriculture, Management and Technology.* 1.1: 157-168.

Andriaan Du plessis. 2015. Assessment of Heavy metal concentrations in water and sediment of Dams in central Namibia and bioaccumulation of Copper in locally occurring Crabs and Fish. MSc. project.Dept. of Biological Science.University of Namibia.xi+55-74pp.

Anethekhai, M. A. 1986. Aspects of the bioecology of the African river prawn *Macrobrachium vollen hovenii* (Herklets) in Asejire Lake, Oyo State, Nigeria. PhD. Thesis.Dept. of Zoology.University of Ibadan. 225pp.

Anhwange, B. A., Agbaji, E. B. and Gimba, E. C. 2013. Impact Assessment of Human Activities and Seasonal variation on River Benue, within Markurdi metropolis. *International Journal of Science and Technology* 2.5: 248-254.

Anjana, C. and Janak, A. 2015. Comparison and Relationship between Abundance of Aquatic insects and water parameters of Sagar Lake, Madhya Pradesh India *International Journal of Scientific Research.* 4. 9: 15pp.

APHA, AWWA, WEF. 1992. Standard Methods for the Examination of Water and Waste. American public Health Association, American Water Works. Association, Water Environment Federation, Greenberg, A.E., Clesceri, L.S., and Eaton, A.D., 18th Edition.

Arimoro, F. O., Ikomi, R. B. and Iwegbue, C.M.A. (2007). Water quality changes in relation to Diptera community patterns and Diversity measured at an organic effluent impacted stream in the Niger Delta, Nigeria. *Ecol. Indicators*. 7: 541-552

Arimoro, F. O. and Ikomi, R. B. 2008. Ecological Integrity of upper Warri River, Niger Delta using Aquatic insects as bioindicators. *Ecological indicators* 395: 1-7.

Arimoro, F. O. and Osakwe, E. I. 2006. The influence of sawmill wood wastes on the distribution and population of macro-invertebrates at Benin River, Niger Area, Nigeria. *Chemistry and Biodiversity* 3: 578-592.

Arimoro, F. O., Ikomi, R. B. and Erebe, E. 2007a. Macroinvertebrate community diversity in relation to water quality status of River Ase, Niger Delta, Nigeria. *Journal of Fisheries and Aquatic Science* 2.5: 337-344.

Arslan, N., Ayik, O. and Sahin, Y. 2010. Diversity and structure of Chironomidae (Diptera) Limnofauna of lake Ulabat, a Ramsar site of Turkey and their relation to environmental variables.*Turkish Journal of Fisheries and Aquatic Sciences* 10: 315-322.

Asuquo, F. E., Ogri, O. R. and Bassey, E. S. 1999. Distribution of Heavy Metals and Total Hydrocarbons in Coaster waters and Sediment of Cross River, South-Eastern, Nigeria. *International Journal of Tropical Environment*. 16.2: 1-19

Atobatele, O. E., Morenikeji, O. A., and Ugwumba, O. A. 2005. Spartial variation in physical and chemical parameters and benthic macro-invertebrates fauna of River Ogunpa, Ibadan. *The Zoologist* 3: 58-67.

Atobatele, O. E. and Ugwumba O. A. 2008. Seasonal variation in the physical chemistry of a small tropical reservoir (Aiba Reservoir, Iwo, Nigeria). *African Journal of Biotechnology* 12: 1962-1971.

Ayoade, A. A. Fagade, S. O. and Adebisi, A. A. 2006. Dynamics of limnological features of man-made Lakes in relation to fish production. *African Journal of Biotechnology* 5.10: 1013-1021.

Ayoola, S. O. and Ajani E. K. 2009. Seasonal variations in fish distribution and physico-chemical parameters of wetland areas in Oyo State. *International Journal of Biological and Chemical Sciences* 3.1: 107-116.

Ayodele, I. A. and Ajani, E. K. 1999. Essentials of Fish Farming (Aquaculture), Odufuwa Press, Ibadan, 46p.

Ayotunde, E.O, Offern, B.O and Ada, F.B. 2012. Heavy metal profile of water, sediment and fresh water cat fish *Chrysichthys nigrodigitatus* (Siluriformes: Bagridae) of cross River Nigeria. *Rev Biol Trop*. 60.3: 1289-301.

Balarabe, M. L. 1989. Limnological and Zooplankton distribution of Makwaye, (Ahmadu Bello University farm lake) Samaru, Zaria. M.Sc. Thesis. xi+143pp.

Barbour, M. T., Gerristsen, J., Snyder, B. D. and Stribling, J. B. 1998. USEPA Rapid Bioassessment protocols for use in streams and Wadeable Rivers. Periphyton, Benthic macro-invertebrates and fish. 2nd Edition. EPA/841-B-98-010. U.S.Environmental protection Agency; office of Waters Washington. D.C.

Barman, B., Gupta, P., choudhury, D., Dalal, A., Gupta, S. 2014. Biomonitoring in lentic ecosystems of Irongmara, District Cachar, Assam, India, with special references to aquatic insect community. *International Research Journal of Environmental Sciences* 3: 26-35.

Barr, L. and Hellenthal, D.R. 1996. A review of Aquatic insects as biomonitors of water quality. 11pp.

Battarbee, R.W. 2000. Paleolimnological approaches to climate change, with special regard to the biological record. *Quaternary Science Reviews* 19: 107-124.

Basharat, M., Rajni R., Tabasum, Y., Ashwani, W., and Yousuf, A. R. 2013. Variation in the physico- Chemical properties of Dal Lake, Srinagar. *Kashmir Academic Journals* 7.7: 624-633.

Basset, Y. 1999. Diversity and abundance of insect herbivores collected on *Castanopsis acuminatissima* (Fargaceae) in New Guinea: Relationship with leaf production and surrounding vegetation. *Eupean Journal of Entomology* 96.4: 387-391.

Batiuk, R. A., Orth, R. J., Moore, K. A., Dennison, W. C., Stevenson, J. C., Staver, L.W., Carter, V., Rybicki, N. B., Hickman, R. E., Kollar, S., Bieber, S., Heasly, P. 1992. Chesapeake Bay Submerged Aquatic Vegetation Habitat Requirements and Restoration Targets: A technical synthesis. EPA: Annapolis, MD.

Bauer, G. 1988. Threat to the Freshwater Pearl Mussel (*Margaritifera margaritifera*) in Central Europe. *Biological Conservation*. 45: 239-253.

Bauernfeind, E., Moog, O. 2000. Mayflies (Insecta: Ephemeroptera) and the assessment of ecological intergrity: a methodological approach. *Hydrobiologia* 135: 155-165.

Bengt, H., D.Sc. Curator. 2012. State Museum of Natural History, Stockholm, Sweden. 1072-1080.

Berger W. H and Parker, F. L. 1970. Diversity of Planktonic Foraminifera in deep-sea sediments. *Science* 168: 1345-1348.

Beta Jakubik. 2009. Reproduction of the freshwater snail (*Viviparus contectus*, millet, 1813) (Gastropoda: Architaenioglossa: Viviparidae) *Folia Malacologica* 17.4: 223-230.

Beukemia, J. J. 1984. Zoo-benthos survival during severe winters at high and low tidal flats in the Dutch Wadden Sea. In. J.S.Gray and M.E. Christiansen (eds.); Marine biology of polar regions and effects of stress on marine organisms. John Wiley, Chichester: 351-361.

__________ 1991. Changes in composition of bottom fauna of a tidal-flat area during a period of eutrophication. *Marine Biology* 111: 293-301.

Boesch, D. F., Kraeuter, J. N. and Serafy, D. K. 1997. Distribution and structure of communities of macrobenthos on the outer continental shelf of the middle Atlantic Bight: 1975-1976 investigations. Virginia institute of marine science special report in applied marine science and ocean engineering, No .175.

Bonyton, W. R. and Kemp, W. M. 2000. Influence of river flow and nutrient loads on selected ecosystem processes: A synthesis of Chesapeake Bay data. In: J.E. Hobbie (ed.). Estuarine science: A synthetic approach to Research and practice. Island press, Washington D.C. 56p.

Bouchet, P., Rocroi, J. P., Hausdorf, B., Ponder, W., Valdes, A. and Waren, A. 2005. Classification and Nomenclature of Gastropod families. *Malacologia: International Journal of Malacology*. 47: 1-2. Conch Books: Hacknheim, Germany.

Boulton, A. J. 2012. Temperature impact on stream Ecology, water Encyclopedia, http//www. Water encyclopedia.Com/Re-st/Stream-Ecology-Temperature-imparts –on html.

Brinkhurst, R.O. 1997. The Role of tubificid oligochaetes in Relation to fish disease with special reference to the Myxozoa Annual Review of Fish Diseases. 6: 29-40

Bristi, D., Debojit, B. and Biswas, S. P. 2016. Water Quality Assessment of River Dikhow Assam, India using Biological Water Quality Criteria. *International Journal of Environmental Sciences* 5. 5: 12-17.

Brown, D. S. 1980. Taxonomic keys to freshwater snails of Africa. *Danish Laboratory Manual Serves* 7: 25-98.

Boyd C. E. 1979. Water quality management for pond fish culture Elsevier science publishers B.V. pp.318.in warm water fish ponds. Craft master, Printers inc. Auburn, Alabama, U.S.A, 353p.

———— 1998. Water Quality for pond Aquaculture. Research and Development Series No. 43. International Centre for Aquaculture and Aquatic Environment Alabama. Agriculture Experiment station, Aurburn University Publisher, Alabama, 183pp.

Breitburg, D. L.2002. Effects of hypoxia, and the balances between hypoxia and enrichment, on coastal fishes and fisheries. *Estuaries* 25: 767-781.

Broody, T. 1999. Nutritional biochemistry, 2^{nd} edn. Academic Press San Diego, CA, USA. 697-730pp.

Brusca, R.C., Brusca, G. J. 2003. Invertebrates, 2^{nd} ed. Sinauer Associates, INC., Publishers, Massachusetts.Pages 397, 404, 409, 427, 432.

Cabioch, L. 1991. Evolution, a long term d´ecosysteme benthiques coiters des sediments subtidaux, en relation avec leur variabilite spatiale physique et biologique. Resultats obstenus parle programme COST 647. In BF Keegan (eds.): space and time series data analysis in Coastal benthic ecology. CEE Bruxelles: 237-264.

Campbell, P.C.G. and Tessier, A. 1991. Biological Availability of Metals in Sediments: analytical approaches. In: Venet JP (Ed) Heavy Metals in the Environment. Elsevier Publ. B.V., Amsterdam. 161-173pp.

Carter, J. L., Resh, V. H., Hamaford, M. J., Meyer M. J. 2006. Macro-invertebrates as biotic indicators of environmental quality.Methods in streams Ecology, 2^{nd} Edn. FR Hawer and G.A. Lamberti (Eds.).Academic press, New York. 805-834.

Castelli, A., Lardicci and Tagliapietra, D. 2004. Soft-bottom Macro-benthos, chapter four in M.C. Gambi and M. Dappiano (Eds.). Meditteranean marine Benthos. A manual of methods for its sampling and study, *Biologia marine meditteranean* (SIBM-PATICRAM), 11 (suppl.1), 99-131.

Chae, S.J.N. Purstela, E. Dedrock, S.P. Lawler and Madigan, J.E. 2000. Infection of aquatic insects with trematode metacercaria carrying *Ehrilichi aristicii*, the case of the Potomac house fever. *Journal of Medical Entomol.* 37: 619-625.

Chakraborty, C, Huq, M. M., Ahmed, S., Tabassum, T., and Miah, R. M. 2013. Analysis of the causes and impacts of water pollution of Buriganga river: A critical study. *International Journal of Science and Technological Research* 2.9: 2277-8616.

Chapman, D. and Hall. 1992. Water Quality Assessment: a guide to the use of biota, sediments and water in environmental monitoring London. Pp. 1-11.

Chapman, A. D. 2009. Numbers of living species in Australia and the world, 2^{nd} edition. Australian Biological resources study, Canberra. Accessed 12 January 2010.ISBN 978064256860 (Printed); ISBN 9780642568618 (Online).

Chindah, A. H., Hart, A. P. and Atuzie, B. 1999. A preliminary investigation on the effects of municipal waste Discharge on the Macro fauna associated with macrophytes in a small freshwater stream in Nigeria. *African Journal of applied Zoology* 2: 29-33.

Chindah, A. C., Braide, S. A. 2003.Cadmium and Lead concentration in fish species of a brackish wetland/upper Bonny Estuary, Niger Delta. *Journal of Nigerian Environmental Society* 1: 399-405.

Chinyem, F. I. 2013. Concentration of some trace elements in surface and ground water resources in Agepanu and its Environs. Edo State, Nigeria. *Indian Journal of Science and Technology* 6: 4459-4462 Direct link.

Chowdhary, S., Sharma, K. K. 2013. Evaluation of Macro benthic invertebrates in the longitudinal profile of a river (Tawi) Originating from Shivalik hills *Journal of Global Biosciences* 2.1: 31 -39.

Chukwu, L. O. and Nwankwo, L. O. 2003. The impact of land-based pollution on the Hydrochemistry and Macrobenthic community of a Tropical West African Creek. Diffuse pollution conference Dublin. ECSA4: persistent pollutants. Available from www ucd ie/prep/eccs/theme06/theme06 13.PDF (accessed May, 2013).

Connell, D.W., Miller, G. J. 1984. Chemistry and Ecotoxicology of pollution. John willey & Sons, NY. 444Pp.

Courtney, L. A. and Clement, W. H. 1998. Effects of Acidic pH on benthic macro-invertebrate communities microscosm. *Hydrobiologia* 379: 145p.

Covich, A. P. 1993. Water and Ecosystem in Gluck P.H. ed. Water in crisis. Oxford University press pp. 40-55. In Allan *et al.* (1999).On the role of benthic invertebrates species in freshwater Ecosystem. 1-9pp.

Cummins, K. W. 1973. Trophic Relations of Aquatic Insects. *Annual Review of Entomology*. 18: 183-206.

Dalal, A. and Gupta, S. 2016. A comparative study of aquatic insect diversity of two ponds located in Cachar District, Assam, India. *Turkish Journal of Zoology* 40: 392-401.

Dan, S. F., Umoh, U. U. and Osabor, V.N. 2014. Seasonal variation enrichment and contamination of heavy metals in the surface water of Qua Iboe River Estuary and adjoining creeks, South-South, Nigeria. *Journal of Oceanography and Marine Sci*ences 5.6: 45-54.

Davide, T. and Marco Sigovini. 2010. Benthic fauna: collection and identification of macrobenthic invertebrates instituto di scienze marine consiglio Nationatedeller Ricerche (NR-ISMAR)Riva settemarturi 1364/a 30122, Venice Italy. Near Curricum in National Environmental Science, *Terret Environmental* 88: 253-261.

Davies, O. A., Abowei, J. F. N. and Otene, B. N. 2009. Seasonal abundance and distribution of Plankton of Minichnda Stream Niger Delta, Nigeria. *Animal Journal of Scientific Research* 3: 20-30.

Debbie, H. and Stanislav 2012. Water quality monitoring Using Aquatic macro-invertebrates. 1-3pp.

Dee, A. K. 1989. Environmental Chemistry. New Age International Publisher 2nd edition Pp. 164-272.

Degregori, I., Pinochet, H., Arancibia, M., Vidal, A. 1996. Grain size effects on trace metals distribution in sediments from two coastal areas of Chile. *Bull Environmental Contamination and Toxicology* 57: 163-170.

Deliz-Quinone, K. Y. 2005. Water quality assessment of a tropical fresh waters marsh using Aquatic insects. MSc. Thesis. Dept. of Biology. University of Puerto Rico. xii+ 148pp.

Diaz, R. J. and Rosenberg, M. 1995. Marine benthic hypoxia: A review of its ecological effects and the behavioural of benthic macrofauna. *Oceanography and Marine Biology*: An annual Review 33: 245-305.

Dinowo, B. O. 2013. Assessment of some physico-chemical parameters of River Ogun (Abeokuta, Ogun State, Southern Nigeria) in comparison with National and International Standard. *International Journal of Aquaculture* 3.15:79-84

Doisy, K. E., Rabeni, C. F. 2001. Flow conditions, Benthic food resources, and invertebrate community composition in a low-gradient stream in Missouri. *Journal of North American Benthological Society* 20. 1: 17-32.

Duran, M. 2006. Monitoring water quality using Benthic macro-invertebrates and physico-chemical parameters of Behzat stream in Turkey. *Polish Journal of Environmental Studies*. 15.5: 709-717.

Ebigwai, J. K., Imedimfon, I. E., Bright, H. A., Olowu, C. and Ekanem, F. A. 2014. Physico-chemical parameters and Phytoplankton Assemblage along spatial and temporal gradients in Great kwa River, Calabar, Nigeria. *International Journal of Biological Chemistry* 8: 1-20

Edward, J. B. and Ugwumba, A. A. A. 2010. Physico-chemical parameters and Plankton community of Egbe Reservoir, Ekiti State. *Research Journal of Biological Sciences* 5:356-367.

Ekdopayi, C.A. and Osimen, E.C. 2001. Hydrobiological studies on Ibiekuma River at Ekpoma Southern Nigeria, after impoundment. The faunal characteristics. *African Journal of Science and Technology (AJST) Science and Engineering* Series 2.1: 77-81.

Efitre, J., Chapmaan, J. L and Makanga, B. 2001. The inshore benthic macro-invertebrates of lake Nabugabo, Uganda: seasonal and Spartial Patterns. *African Zoology* 36.2: 205-216.

Egborge, A. B. M. 1970. The hydrology and plankton of River Osun, Western Nigeria. MSc. Project. Dept. of Zoology. University of Ibadan, Nigeria. ix+278PP.

―――――― 1974. The seasonal variations and distribution of phytoplankton in the river Osun, Nigeria. *Freshwater Biology* .4.2: 171-191.

―――――― 1979. The effect of impoundment on the phytoplankton of the River Osun, Nigeria.Nova HEDNIGIA BAND XXX1, 1+2.BRAUNSCHNEIG.407-418.

―――――― 1981. The Composition, Seasonal variation and Distribution of Zooplankton in Lake Asejire, Nigeria. *Revue Zoologie Africaine.* 95: 136-180

―――――― 1994. Water pollution in Nigeria.Biodiversity and Chemistry of Warri River. Ben Miller. Books Nig. Ltd., Warri 331pp.

Eja, M. E., Ogri, ORA.Arikpo, G. E. 2003. Bioconcentration of heavy metals in surfae sediments from the Great Kwa Rivers Estuary, Calabar, South Eastern Nigeria. *J. Nig. Environ. Soc*.2: 247-256.

Emere, M. C. and Nasiru, C. E. 2007. Macro-invertebrates as indicators of the water quality of an Urbanized stream in Kaduna, Nigeria. *Journal of Fisheries International* 2.2: 152-157.

Emoyan, O. O., Ogban, F. E. and Akarah, E. 2006. Evaluation of Heavy metal loading of River Ijana in Ekpan-Warri. Nigeria. *J. Appl. Sci. Environ. Mgt* 10.2: 121-127.

EPA. 1997. National Recommended Water Quality Criteria 1997. Available: http://www.epa.gov/waterscience/pc/revcom.pdf

EPA. 2003. National Recommended Water Quality Criteria 2003. Available: http://www.epa.gov/waterscience/pc/revcom.pdf

Epler, J. H. 2001. Identification Manual for the Larval Chironomidae (Diptera) of North and South Carolina. A guide to the Taxonomy of the Midges of Southeastern United States, Including Florida. Special Publication SJ2001-SP13. North Carolina Department of Environment and Natural Resources, Raleigh NC, andSt. Johns River Water Management District, Palatka, FL. 526pp.

Essien-Ibok, M. A., Akpan, A. W., Udo, M. T., Chude, L. A., Umoh, I. A. and Asuquo, I. E. 2010. Seasonality in the physical and chemical characteristics of Mbo River, Akwa Ibom State, Nigeria, *Nigerian Journal of Agriculture, Food and Environment* 6.1& 2: 60-72

Ewa, E. E., Iwara, A. I., Offiong, V. E., Essoka, P. A. and Njar, G. N. 2013. Seasonal variations in Heavy metal status of the Calabar River, Cross river State, Nigeria. *Journal of Natural Sciences Research* 3.11:78-84.

Eyo, J. E. and Ekwonye, U. C. 1995. The macro-invertebrates fauna of pool in the flood plain (Fadama) of the Anambra River, Nigeria. *Freshwater forum* 5.3: 160-162.

Ezekiel, O. A., Benedict, O. O. and Fidelis, B. A. 2012. Heavy metal profile of water, sediment and freshwater catfish, *Chrysichthys nigrodigitatus* (siluriformes: Bagridae) of cross River. Nigeria. *Revista de Biologia Tropical* 60.3:1-18.

Ezeronye, O. U. and Ubalua, A. O. 2005. Studies in the effect of abattoir and industrial effluents on the heavy metals and microbial quality of Aba River in Nigeria. *African Journal of Biotechnology.* 4.3: 266-272l.

Fafioye, O. O., Olurin, K. B. and Sowunmi, A. A. 2005. Physico-chemical parameters of Omi Water Body, Ago Iwoye, Nigeria. *African Journal of Biotechnology.* 4.9: 749-751

Fagade, S. O. 1970. The food and feeding habit of Tilapia spp. in the Lagos Lagoon. *Journal of Fish Biology.* 3: 151-156.

Fagade, S. O., Adebisi, A. A., Kolo R. J., Elemi, B. F., Adeosun, A. A. and Ja'afru, A. 1993. Urbanisation and Degradation of aquatic resources: The Ibadan experience. National Conference on the Conservation of Aquatic Resources. May, 11-14, 1992. Calabar, Nigeria. (Egborge, A.B.M., Omoloyin, O.J., Olojede, A. and Manu, S.A. (eds), Pp. 208-219.

Fagbola, M. S. 1989. A survey of freshwater snails in Ile-Ife for Helminth Parasites. M.Sc. Thesis. Dept. of Zoology, Obafemi Awolowo University, Ile-Ife, 56p.

Faith, D. E., Erkan, U. and Musa, K. 2013. Temporal variation of metal concentrations of Creek sediment samples. *Pol. J. Environ*. 22.5:1335-1339.

Fakayode, S. O. 2005. Impact assessment of the effect of industrial effluents on the receiving Alaro stream, Ibadan, Nigeria. *Journal of Aquatic sciences* 12.1:7-14.

Farombi, A. G., Adebayo, O. R., Olagunju, E. O. and Oyekanmi, A. M. 2014. Variations in abiotic conditions of water quality of river Osun, Osun State, Nigeria. *African Journal of Environmental Sciences and Technology* 8.5:283-288.

Francis, A. O. and Emeka, O. I. 2006. The influence of sawmill wood wastes on the distribution and population of macro-invertebrates at Benin River, Niger Delta Area, Nigeria. *Chemistry and Biodiversity*. 3.5: 578-592.

Foil, L. D. 1998. Tabanids as vectors of disease agents in Parasitol. *Today*, 5: 88-96.

Forstner, U., Wittmann, G.T.W. 1979. Metal pollution in the aquatic Environment; Springer Verlag: Berlin Germany. 205pp.

Fouzia, I. and Amir, K. 2014. Seasonal Limnological Variation and Macro-benthic Diversity of River Yamuna at Kalsi Dehradun of Uttarakhand. *Middle-East Journal of Scientific Research* 19.2: 206-216.

Fred, G.T. 2004. An Identification Manual for the Freshwater snails of Florida. 1-96pp.

Fredrick, O. and Hudson, L. 2016. Macro-invertebrarates As Bioindicator of water Quality stream in Mbeya, Tanzania. *International Journal of Scientific and Technology Research* 6:211-222

Ftsum, G., Abraha, G., Amanual, H and Samuael E. 2015. Investigation of physico-chemical parameters and its pollution implications of Elala River, Mekelle, Tigray, Ethiopia. *Momona Ethiopian Journal of Science.* 7.2: 240-257.

Fulton, A., Mausberg, B. and Campbell, M. 2002. It's Hitting the Fan: The unchecked Growth of factory farms in Canada; Environmental Defence Canada; Retrieved March 16 2008 from http:// www. educanada. Org.

Fundamental of Environmental Measurement. 2014. Water quality *FONDRIEST ENVIRONMENTAL INC*. Questions Pp. 1-20

Furey, C. P., Nordin, N. R. and Mazmider, A. 2006. Littoral benthic macro-invertebrates under contrasting drawdown in a reservoir and a natural Lake. *Journal of North American Benthological Society.* 25.1: 19-33.

Garllado, B., Gascon, S., Quintana and Comm., F. A. 2011. How to choose a biodiversity indicator-redundancy and Complimentarity of biodiversity metrics in freshwater ecosystems. *Ecological Indicators.* 11: 1177-1184.

Gallep, G. W., Kitchell, J. F. and Bartell, S. M. 1978. Phosphorus release from lake sediments as affected by chironomid, *Ver Inter Vere for Limnologic* 20: 458-465.

Garcia, R. and Millan, E. 1998.Assessment of Cadmium, Lead and Zinc contamination in roadside soils and grasses from Gipuzkoa (Spain).*Chemosphere* 37:1615-1625.

Garg, R. K., Rao, R. J. and Saksena, D. N. 2009. Correlation of molluscan diversity with physico chemical characteristics of water of Ramsagar reservoir, India. *International Journal of Biodiversity and Conservation* 1.6: 202-207.

Garg, R. K., Rao, R. J., Uchchariya, D., Shukla, G. and Saksena, D. N. 2010. Seasonal Variation in water quality and major threats to Ramsagar reservoir , *India African Journal of Environmental Science and Technology* 4.2: 61-76.

Garnier, J. and Billen, G. 1994. Ecological Interractions in a Shallow Sand. Pit Lake (Lake creteil, Paris suburbs, France): a modeling approach. *Hydrobiologia* 276: 97-114.

Geyer, 2010. In Encyclopedia Britannica.Retrieved March 05, 2010 from Encyclopedia Britannica online.

Girgin, S., Nkzanc. and Dugel, M. C. 2010. Relationship between Aquatic insects and heavy metals in an urban stream, Turkey, using multivariate techniques. *International Journal of Environmental Sciences and Technology* 7.4: 653-664.

Godwin, I. A. 2015. Seasonal Biodiversity Assessment of Benthic macro-invertebrates of Asejire Reservoir, Southwest Nigeria. *Journal of Aquatic Sciences* 8.2: 257-269.

Gupta, S. K. and Gupta, R. C. 2006. General and Applied Ichthyology (fish and fisheries) S. Chand and Company Ltd. Ram Niger, New Delhi. 1130pp.

Halse, S. A., Cale, D. J., Jasinska, E. J. and Sheil, R. J. 2002. Monitoring change in aquatic invertebrates biodiversity: Sample size, faunal elements and analytical methods. *Aquatic Ecology.* 36.395pp.

Hassan, A. T. 1974. Studies on the Ecology, Behaviour and Life History of Libelluline Dragonflies. PhD. Thesis. Dept.of Zoology. University of Ibadan. x +150pp.

Heckman, C. W. 2002. Encyclopedia of the South American aquatic insects: Ephemeroptera. Kluwa Academic publishers, Norwell, MA. 419p.

Heleen, J., Danen louwerse, L. and Monique, C. 1995. Co-precipitation of phosphate with calcium carbonate in Lake Velume. *Water Research* 29.7: 1781-1785.

Hem, J. D. 1992. Study and Interpretation of the Chemical Characteristics of natural water. U.S. Geological survey water-supply paper 2254, 263p.

Holdgate, M. W. 1979. A perspective of Environmental Pollution. Cambridge University Press, Cambridge, UK: 278p.

Horne, J. A. and Goldman, C. R. 1994. Phosphorus Cycling in the water Column. In: Limnology, McGraw-Hill inc., New York, 163-164.

Horsfall, M. and Spiff, A. I. 2001. Environmental pollution with Biological, Chemical and Physical emphasis, metro print Ltd, Port Harcourt, Nigeria. 1.110: 138-232.

Ibrahim, B. U., Auta, J. and Balogun, J. K. 2009. An assessment of the physico chemical parameters of Kotangora Reservoir, Niger State, Nigeria. Bayero *Journal of Pure and Applied Science* 2.1: 64-69.

Ideriah, T. J. K., Amachree, O. and Stanley, H. O. 2010. Assessment of water quality along Amadi Creek in Port Harcourt, Nigeria. *Science African* 9:150-162. Direct Link.

Idowu, E. O. 2007. Aspect of the Biology of African pike *Hepsetus odoe* (Osteichthes: Hepsetidae) in Ado-Ekiti Reservoir. PhD. Thesis. University of Ibadan. xii+196pp.

Idowu, E. O. and Ugwumba, A. A. A. 2005. Physical, Chemical and Benthic Faunal Characteristics of a Southern Nigeria Reservoir. *The Zoologist* 3: 15-25.

Idowu, E. O., Ugwumba, A. A. A., Edward, J. B. and Oso J. A. 2013. Study of the seasonal variation in the physico-chemical parameters of a Tropical Reservoir. *Greener Journal of Physical Sciences* 3.4: 142-148.

Ikomi, R. B., Arimoro, F. O. and Odihirin, O. K. 2005.Composition, Distribution, and Abundance of Macro-invertebrates of the upper reaches of River Ethiope, Delta State, Nigeria. *The Zoologist* 3: 68-81.

Ikomi, R. B., Iloba, K. I. and Ekure, M. A. 2003. The Physical and Chemical Hydrology of River Adofi at Utagba-Uno, Delta State, Nigeria. *The Zoologist* 2.2: 84-95.

Imoobe, T. O. and Oboh, I. P. 2003. 'Physical and Chemical Hydrology of River Jamieson, Niger Delta, Nigeria. *Benin Science Digest* 1:105-119.

Iroko, I. A. 2003. Effect of Erelu Water Dam on Livelihood Activities of Settlers in Atiba Local Government Area of Oyo State.B.Sc. Project. Dept. of Agricultural Extension and Rural Development.University of Ibadan. Viii+52pp.

Iwara, A. I., Njar, G. N., Deekor, T. N. and Ita, A. E. 2012. Effects of Adiabo abattoir on the water quality status of Calabar River in Odukpani, Cross river State, Nigeria. *Continental Journal of Environmental Sciences* 6.2:36-43.

Jana, S., Pahari, P. R., Dutta, T. K. and Bhattacharya, T. 2009. Diversity and Community of aquatic insects in a pond in Midnapore town, Pachim Banga, Indian. *Journal of Environmental Biology* 30.2: 283-287.

Jackson, R. B., Carpenter, S. R., Dahm, C. N., Mcknight, D. M. Naiman, R. J., Postel, S. L. and Running S. W. 2001. Water in a Changing World. *Ecological Application* 11.4: 1027-1045.

Jo-Anne Howell. 2010. The distribution of phosphorus in sediment and water downstream from a sewage treatment works. *Bioscience Horizons* 3.2:113-123.

Jobbin, W. I. R. and Ippen, A. I. 1964. Ecological design of irrigation canals for snail control. *Science* 145: 1324-1326.

John De Zuane, P. E. 1981. The Handbook of Drinking water Quality Standards and controls Van Nostrand Reinhold. 523pp.

John, M. 2012. Extramadura keys to the identification of Dragonflies and Damselflies (Odonata) 1-3pp.

Johnson, R., Wiederholm, T. and Rosenberg, D. M. 1993. Freshwater Biomonitoring using Organism population and species Assemblage of Benthic Macro-invertebrates. *Acta Biologica Debreecina Ecological Hungarica* 3: 167-175.

Joshua, N. E., John, O. O., Oluwaseun, E. P. and Titus A. M. M. 2016. Assessment of Trace metals contamination of surface water and sediment: A case study of Mvudi River, South Africa. *Sustainability Article* 8.135: 1-13.

Joydeb, M., Rajib, K. D., Prasanta, M., Ghosh, D. and Agarwala, B. K. 2013. Aquatic insects fauna and diversity in Urban freshwater lakes of Tripura, Northeast India. *Middle-East Journal of Scientific Research* 13.1: 25-32. ISSN 1990-9233. DOI: 10.5829/idosi.mejsr.2013.2013.13.1.66123.

Juarez, F.Y.A and Ibanez, A. 2003.Abundance and First Record of Benthic Macro-invertebrates in lake Metztitlah, Hidalgo, Mexico. *Hydrobiologia* 13.2: 137-144.

Kakulu, S. E. and Osibanjo, O. 1992. Pollution studies of Nigerian rivers: Trace metal levels of surface waters in the Niger Delta. *International Journal of Environmental Studies* 41: 287-292.

Kalff, J. 2002. Limnology: Inland Water Ecosystems. Prentice Hall Inc. 592pp.

Kamal, D. Khan, A. N., Rahman, M. A and Ahamed F. 2007. Study on the physico-chemical properties of water of Mouri River Khulna, Bangladesh. *Pakistan Journal of Biological Sciences* 10. 5: 710-717.

Kamran, T. M Abdus, S., Muhammed, L. and Tasveer, Z. 2003. Study of the seasonal Variation in the physico-chemical and biological aspect of Indus River Pakistan.. *Pakistan Journal of Biological Sciences.* 6.12: 1795-1801.

Kareem, O. K., Ajani, E. K., Omitoyin, B. O., Olanrewaju, A. N., Orisasona, O. and Osho, E.F. 2018. Spatial and Temporal limnological status of Erelu Reservoir, Southwestern Nigeria. *Ife Journal of Science.* 20. 3: 509-518.

Karr, J. R. 1991. Biological integrity: a long neglected aspect of water resource management. *Ecol. Appl*. 166-184.

Karr, J. R. 1996. Ecological Integrity and Ecological Health are not the same. In: Schulze, P.C. (eds), National Academy Engineering, Engineering within Ecological Constraints National Academy Press, Washington, DC. Pp. 97-101.

Kavita, S. and Sheela, Y. 2012. Seasonal variation in Physico-Chemical parameters of Bharawas pond Rewari, Haryana. *Asian Journal of Experimental Sciences.* 26.1: 61-64.

Kawser, A., Sharif A., Safiu, R., Rezaul, H. and Monirul, I. 2009. Heavy metals concentrations in water, sediments and their bioaccumulations in some freshwater fishes and mussel in Daleshwari River, Bangladesh. *Terresrial and Aquatic Environmental Toxicology.* 3.1: 33-41.

Kelly, M. 1988. Mining and the freshwater environment.Elselvier Applied Science, London. In: Leblanc, G. A. 1985 on Effects of Copper on the competitive interractions of two species of Cladocera. *Environmental pollution series A* 37:13-25.

Kemdirim, E. C. 1990. Periodicity and Succession of phytoplankton in an upland and lowland impoundment in plateau State Nigeria. PhD. Thesis. University of Jos. Xii + 484pp.

——————— 2005. Studies on the hydrochemistry of Kangimi Reservoir, Kanduna State Nigeria. *African Journal of Ecology* 43: 7-13.

Kennish, J. R., (1992). Ecology of Estuaries: Anthropogenic Effects. CRC Press, Inc. Boca Raton, FL .74pp.

Khalik, M., Pauzi, A., Nur, A. A. and Norrfaizan, P. 2013. Physico chemical analysis on water quality status of Bertam River in Cameron Highland, Malaysia. *Journal of Material and Environmental Sciences* 4.4: 488-495.

Kolo, R. J. and Oladimeji, A. A., (2004). Water quality and some nutrient levels in Shiroro Lake, Niger State, Nigeria. *Journal of Aquatic Sciences* 19.2: 99-106.

Korkeamaki, F. and Suhonen, J. 2002. Distribution and habitat specialization of species affect local extinction in dragonfly, Odonata population. *Ecography* 25: 459-465.

Laurince, M. Y., Celestin, B. A. and Philippe, K. 2013. Composition, abundance and diversity of aquatic insects in fish ponds of southern Ivory Coast, West Africa. *Entomologie faunistique- Faunistic Entomology* 66: 123-133.

Lenat, D. R., Smock, L. A. and Penrose, D. L. 1980. Use of benthic macro-invertebrates as indicators of environmental quality In: Biological Monitoring for Environmental Effects, Lexinton Books, Toronto, Canada, 7-114pp.

Lenat, D. R. 1988. Water Quality Assessment of Stream using a qualitative collection method for benthic macro-invertebrates. *J. N. am. Benthol. Soc.* 7. 3: 222-233.

Lentech, (2012). Water Treatment solution, Metals in aquatic freshwater. 1-5pp.

Li, C. 2008. Batch and Bench-scale Fixed-bed column evaluations of heavy metal removals from aqueous solution and Synthetic Landfills Leachate using low-cost natural adsorbents. M.Sc Project. Queen's University Kingston. 52pp.

Li, S. and Zhang, Q. 1987. Risk Assessment and Seasonal variation of Dissolved Trace elements and heavy metals in the Upper Han River, China. *J. Hazard. Mater.* 18: 11051pp.

Mandeville, S. M. 2002. Benthic Macro-invertebrates in freshwaters –Taxa Tolerance Values, Metrics, and Protocols.http: //chebucto.ca./Sciences/swcs/.html.

Margalef, R. 1961. Communication of structure in plankton population. *Limnology and Oceanography* 6: 124-128.

Mason, C. F. 1990. Biological Aspects of freshwater pollution. In: Harrison, R. M., Pollution; causes, effects and control 2nd ed. The Royal Society of Chemistry, Cambridge Cb4, 4WF, 99-125 pp.

———————— 1991. Biology of fresh water pollution. Longman Int. New York. 33p.

———————— 1992. Biology of freshwater pollution. 2nd Edition Wiley and Sons Inc.New York, 351 pp.

Mayer, T., Rochfort, Q., Borgmann U., Snodgrass, W. 2008. Geochemistry and toxicity of sediment pore water in a salt impacted urban storm water pond; *Environmental pollution* xx: 1-9.

McArthur, A. G. and Harrasewych, M. G. 2003. Molecular systematics of the major lineages of the Gastropoda. Molecular systematics and phylogeography of Mollusks. Washington: Smithsonian Book. Pp. 140-160.

Menhinick, E. F. 1964. A comparison of some species individuals diversity indices applied to sample of the field insect. *Ecology* 45: 856 – 861.

Merritt, R. W., and Cummins, K. W. 1996. An introduction to the Aquatic insects of North America 3rd Edn'. Dubuque, IOWA: Kendall-Hunt, 862pp.

Mitchell, M. K. and William, B. S. 1996. Field manual for water quality monitoring : An environmental Education program for schools 11th (eds.) Kendall//Hunt Publishing Company. 1-5pp.

Mohan, V.C., Sharma, K. K., Sharma, A. and Watts, P. 2013. Biodiversity and abundance of benthic macro-invertebrates community of river Tawi in vicinity of Udhampar city (J and K). India. *International Research of Environmental Sciences*. 2.5: 17-24.

Moody, F. O. 1991. An Assessment of water quality in River Ona, Ibadan. M.Sc. Thesis. Dept. of Zoology, University of Ibadan. Nigeria. 20-35 pp.

Morton, B. 1994. Hongkong's Coral Communities Status, threats management plans. *Marine pollution Bulletin* 29.3: 74-83.

Munira, N., Mohammed, A. Z., Selim Resa M. D. 2014. Abundance and Diversity of Aquatic insects in two water bodies of Chittagong University campus.*Bangladesh. Journal of Zool*ogy 42.1: 19-33.

Muhammed, A. Z., Sidiq, O. I,. Olayemi, I. K. and Ayanwale, A. V. 2012. Spatial distribution of Lake water insects in Minna North Central Nigeria. Bio-indication of water quality. *International Journal of Advance Biotechnology Research* 4.1&2: 57-64.

Mustapha, M. K. and Omotosho, J. S. 2005. Assessment of the physico-chemical properties of Moro Lake, Kwara State Nigeria. *African Journal of Applied Zoology and Environmental Biology* 7: 73-77

Nathaniel, I. T. 2001. The Macro-invertebrates benthic Fauna and bottom sediment studies of Opa Reservoir in Obafemi Awolowo University, Ile-Ife Nigeria. M.phil. Thesis. Dept. of Zoology, Obafemi Awolowo University, Ile-Ife. Xii+58pp.

Ndaruga, A. M., Ndiritu, G. G., Gichuki, N. M., and Wamicha, W. N. 2004. Impact of water quality on the macro-invertebrate assemblages along a tropical stream in Kenya'. *African Journal of Ecology* 42. 3: 862pp.

Nedeau, E. J. 2006. Quantitative study of the freshwater mussel community downstream of the Surry mountain flood control dam on the Ashuelot River. Unpublished report prepared for U.S. Army Corps of Engineers, Otter Brook /Surry mountain lakes, Keene, NH and U.S fish and wildlife service New England field office, concord, NH Pp.1-10.

Nedeau, E.J., Merritt, R.W. and Kaufman, M. P. 2003. The effect of an industrial effluent on an Urban stream benthic community: Water quality versus habitat quality'. *Environmental pollution* 123.1: 1-13.

Needham, J. G., Westfall, M. J. and May, M. L. 2000. Dragonflies of North America.Revised edition. Scientific Publishers, Inc., Gainesville, FL. 940pp.

Nelson, M. S., Roline, R. A., Thullen, J. S., Sartoris, J. J and Boutwell, J. E. 2000. Invertebrates assemblage and trace element bioaccumulation associated with constructed wetlands. *Wetlands* 20:406-415 Nigeria.Nova HEDNIGIA BAND XXX1, 1+2.BRAUNSCHNEIG. 407-418pp.

Nnaji, J. C., Uzairu, A., Harrision, G. F. S and Balarabe M. L. 2011. Effect of pollution on the physico chemical parameter of water and sediments of River Galma, Zaria, Nigeria .*Research Journal of Environmental and Earth Sciences* 3.4: 314-320.

Nriagu, J. 2007. Zinc Toxicity in Humans. Available online: http:// www. Extranet. elsevier. Com/ homepage about mrud/nvrn/Zinc%20 Toxicity %20 humans Pdf (accessed on 12 April 2015).

NESREA, 2011. National Environmental (*Surface and Groundwater Quality*) Regulations. National Environmental Standards and Regulation Enforcement Agency.

Nwadiaro, C. S. 1984b. The longitudinal Distribution of macro-invertebrates and fish in a lower Niger Delta river- River Sombreiro in Nigeria. *Hydrobiologia* 18.2: 133-140.

Obasohan, E. E. and Eguavoen, O. I. 2008. Seasonal variation of bioaccumulation of heavy metals in a freshwater fish (*Erpetoichthys calabaricus*) from Ogba River, Bennin City. Nigeria. *African Journal of General Agriculture* 4.3:153-163.

Oben, B. O. 2000. Limnological assessment of the impactof agricultural and domestic effluents of three man-made lakes in Ibadan, Nigeria.PhD. Thesis. Dept. of Zoology, University of Ibadan, Nigeria. xii+344pp.

Oben, B. O., Oben, P. M., Ugwumba, A. O., Okorie, T. G. and Pleysier, J. 2003. Trace-metal dynamics in water, sediments and shellfish of a constructed freshwater Wetlands. 22pp.

Obiakor, M. O., Okomkwo, J.C., Ezeonyejiaku, C. D. and Ezenwelu, C.O. 2013. Physico-chemical and heavy metal distribution in freshwater column: Season-location interaction Effects and Public Health Risk. *Journal of Life Sciences and Biomedical* 3.4: 308-317.

Odiete, W.O. 1999. Environmental physiology of Animals and pollution.Diversified Resources Ltd. Surulere, Lagos. 260pp.

Odo, G. E. 2004. Studies on the Ecology of Macro-invertebrates fauna as Fish food in Anambra in River Basin, Nigeria, Ph.D. Thesis. Dept. of Zoology, University of Nigeria, Nssukka. xi+110pp.

Odo, G.E., Avoaja, A.D., Nweze, N.O., Agwu, E.J, Onyishi, G.C., Nzekwe, U, Agaoru, C. G., Nnamonu, E. I. and Haruna, A.S. 2014. Spatial temporal distribution and limnology of crustaceans in tropical freshwater Lake, Nigeria. *Journal of Ecology and the Natural Environment* 6.4: 166-173.

Offem, B. O., Ayotunde E. O., Ikpi; G. U., Ochang; S. N. and Ada, F.B. 2011. Influence of seasons on water quality, Abundance of fish and plankton species of Ikwori Lake, South Eastern Nigeria. *Fisheries and Aquaculture Journal* 13: 1-18.

Ofoezie, I. E. 1999. Distribution of Freshwater snails in the Man-made Oyan Reservoir, Ogun State, Nigeria. *Hydrobiologia*, 416: 181-191.

Ogbeibu, A. E. 2001. Distribution, Density and Diversity of dipterans in a Temporary pond in Okomu Forest Reserve, *Southern Nigeria*. *Journal of Aquatic Science* 16. 1: 43-52.

——————— 2005. Biostatistics: A practical approach to research Data handling Mindex publishing Company Ltd. 153-162pp.

Ogbeibu, A. E. and Egborge, A. B. M. 1995. Hydrobiological studies of water bodies in the Okomu Forest Reserve (Sanctuary) in Southern Nigeria. Distribution and diversity of the invertebrate fauna. *Tropical Freshwater Biology* 4: 1-27.

Ogbeibu, A. E. and Oribhabor, B. J. 2001. Ecological impact of stream regulation using benthic macro-invertebrates as bioindicators. *Journal of Aquatic Science*. 16: 000-0002. Nigeria Association for Aquatic Sciences (ISSN). 0189-8779.

Ogbeibu, A. E. and Oribhabor, B. J. 2002. 'Ecological Impact of River Impoundment using Benthic Macro-invertebrates as indicator'. *Water Research* 36: 2427-2436.

Ogbeibu, A. E., Victor, R. 1995. 'Hydrobiological studies of water bodies in the Okomu forest reserve (Sanctuary) in Southern Nigeria. 2. Physical and Chemical hydrobiology'. *Tropical Freshwater Biology* 4: 83-100.

Ogbogu, S. S. 2001. Assessment of water Quality and Macro-invertebrates Abundance in Opa Stream- Reservoir system, Ile-Ife. *Global Journal of Pure and Applied Sciences* 17.3: 517-521.

Ogbogu, S.S. and Akinya, T.O. 2001. Distribution and Abundance of Insects Orders in relation to Habitat types in Opa stream- Reservoir system, Nigeria. *Journal of Aquatic Sciences* 16. 1: 7-12.

Ogbogu, S.S. and Olajide, S.A. 2002.'Effect of Sewage Oxidation pond effluent on Macro-invertebrare communities of a Tropical forest stream, Nigeria'. *Journal of Aquatic Science* 17.1: 22-27.

Ogidiaka, E., Esenowo, I. K. and Ugwumba, A. A. A. 2013. Physico-chemical parameters and benthic macro-invertebrates fauna of Ogunpa river at Bodija, Ibadan, Oyo State. *European Journal of Scientific Research* 85.1: 89-97.

Oke, O. A. 1989. Studies on the Macro-invertebrate benthic Fauna of Owena Reservoir. *Hydrobiologia.*38: 241-246.

Oke, O. O. 1998. Plankton Diversity, Abundance and Productivity in the Owena Reservoir, South Westhern Nigeria. Ph.D.Thesis.University of Ibadan. x+152pp.

Okogwu, O. I. and Ugwumba, O. A. 2006. The Zooplankton and Environmental Characteristics of Ologe Lagoon, South West, Nigeria. *The Zoologist* 4:86-92.

Okoro, O. J. 2015. Ecology of Aquatic insects in Opi Lake, Enugu .Nigeria. An M.Sc. Project. Dept. of Zoology and Environmental Biology. Faculty of Biological Sciences.University of Nigeria Nsukka. Xii +84-93pp.

Olaniyan, C.I.O. 1969. The seasonal variation in the hydrology and total plankton of the Lagoon of South-West Nigeria. *Journal of Science* 3.2: 101-119.

Olatunde, S. O. and Oladele, O. 2012. Determination of selected heavy metals in inland freshwater of lower River Niger drainage in North Central Nigeria. *AfricanJournal of Environmental Science and Technology* 6. 10: 403-408.

Olatunji, O.S. and Osibanjo, O. 2012. Distribution and Temporal variation of selected heavy metals in sediment of River Osara mainstream drainage in North

Central, Nigeria. *African Journal of Pure and Applied Chemistry* 6.13:188-194.

Olomukoro, J. O. and Ebehiremhen, O. O. 2015. Diversity and Distribution of benthic macroinvertebrate fauna of Obazua lake in Benin city, Nigeria. *Journal of Biology, Agriculture and Health Care*. 5.1: 94-100.

Oniye, S. L., Ega, R.A., Ajanusi, O.J. and Agbede, R.I.S. 2002. Some Aspect of the physico-chemical parameters of Zaria Dam, Nigeria. *Journal of Agriculture and Environment* 11.2: 367-379.

Oscar, O.U., keneth, I. and Sana, M. 2015. Physico-chemical factors affecting Macrobenthic invertebrates distribution in the Bottom sediments of Okhuo river. *Journal of Natural Sciences Research* 5.5: 86-98.

Oscos, J., David, G. and Rafael, M. 2011. Identification Guide of Freshwater Macro-invertebrates of Spain. DOI 10.1007/978-94-007-1554-7, Springer Science+Business Media B.V.

Oso, J. A. and Fagbuaro, O. 2008. An Assessment of the Physico-chemical Properties of a Tropical Reservoir, South westhern, Nigeria. *Journal of Fisheries International* 3.2: 42-45.

Otalekor, A. 2009. Physico-chemical parameters studies and the use of Aquatic Insects as Bioindicators of water quality in Awba stream and Reservoir. M.Sc. Project. Dept. of Zoology. University of Ibadan. x+56pp.

Owojori, O. J. 2004. Ecology of Schistosoma intermediate snail hosts in Opa Reservoir and research ponds at Obafemi Awolowo University, Ile-Ife, Osun State. M.Sc. Thesis. Dept. of Zoology, Obafemi Awolowo University, Ile-Ife. Pp. xi+55pp.

Owojori, O. J., Asaolu, S. O. and Ofoezie, I. E. 2006. Ecology of Freshwater Snails in Opa Reservoir and Research farm ponds at Obafemi Awolowo University Ile-Ife, Nigeria. *Journal of Applied Sciences.* 6: 3004-3015.

Oyekunle, J. A. O., Ogunfowokan, A. O., Akanni, M. S. and Torto, N. 2011. Seasonal mean level of Heavy metals in water and Associated Sediments from Ajawere River in Oke-Osun Farm Settlement, Osogbo, Nigeria. *Environmental Monitoring Asessessment* 177: 51-61.

Ovie, S. I. and Adeniji, H. A. 1993. Zooplankton and Environmental Characteristics of Shiroro Lake at the extremes of its Hydrological Cycle. *Hydrobiologia.* 286: 175-182.

Patel, A. C and Dr. Patel., R. S. 2012. “Comparison of the Physico-chemical parameters of two lakes at Lodra and Nardipur under Biotic stress”.*International Journal of Scientific and Research Publications* 2.9: 1-7.

Patil, J. V., Ekhande, A. P. and Padate, G. S. 2011. Study of Lotus Lake, its abiotic factors, their correlation reference to seasonal changes and altitude. *Annals of Biological Research* 2.4: 44-56.

Pawar, A. C., Naik, J. K., Jadhav, N., Devi V. V. and Pawar S. C. 2006. Physico-Chemical study of ground water samples from Nacharam industrial area, Hydrabad, Ap, Indian. *Journal Aquatic Biology* 21.1: 118-120.

Payakka, A. and Prommi, T. 2014. Aquatic insects biodiversity and water Quality parameters of receiving water body. *International Research Journal of Environmental Science. Current World Environ* 9.1: 1-10.

Pennak, R.W. 1978. Freshwater invertebrates of the United States. Second Edition. John Wiley and Sons, New York. 810pp.

Phyllips, D. J. H. and Rainbow, P. S. 1993. Biomonitoring of trace aquatic contaminants. *Elsevier Applied Science*: New York, NY. *Journal of MarineBiological Association, Elselvier Science Publishers* 74.1: 263-371.

Phyllis, M.M., Miles, H.B. and Graham, V.E. 1970. Tropical Freshwater Ecology.1-33pp.

Pielou, E. C. 1975. Ecological Diversity.Wiley New York.16pp.

Petterson, G. D. 1998. Ecological Resilience, Biodiversity and Scale. *Ecosystems* 1: 6-18

Ponder, W.F. and Linberg, D.R. 1997. Towards a phylogeny of gastropod molluscs: an analysis using morphological characters. *Zoological Journal of the Linnean Society* 119: 83-265.

Popoola, K.O.K. and Otalekor, A. 2011. Analysis of insect communities of Awba Reservoir and its physico-chemical properties. *Research Journal of Environmental and Earth Sciences* 3.4: 422-428.

Poppe, G. T. and Taggaro, S. P. 2006. The new classification of Gastropods according to Bouchet & Rocroi. 2005. Visaya, Fevrier 2006. *Journal of Malacology* 1-10pp.

Priya, J. 2011. Characteristics of Platyhelminthes (flatworms). 1-4pp.

Priyanka, Y, Yadav, V.K., Yadav, A. K. and Khare, P. K. 2013. Physico-chemical characteristics of a fresh water pond of Orai, U.P. Central India. *Octamology Journal of Biosciences* 1.2: 177- 184.

Rader, R. B. 1999. The Florida Everglades : Natural variability, Invertebrate Diversity and food web (eds.) Invertebrates in Freshwater Wetlands of North America. John Wiley and Sons, Inc. 331pp.

Rahman, A., Zafar, M. A and Karim, S. 2012. Analysis and comparison of surface water quality parameters in and around Dhaka city. *Intentional Journal of Civil Engineering and Technology* 3.2: 07-15.

Ravera, O. 2001. 'A comparison between diversity, similarity, and biotic indices applied to the macro-invertebrates community of a small stream: the Ravella River (Como province, N. Italy)'. *Aquatic Ecology*, 35: 97-107.

Reese, J., Voshell, Jr. 2009. Sustaining Americas Aquatic Biodiversity and Conservation Virginia Cooperative Extension pp. 420-531.

Reese, H. L., Heip, C., Vincx, M., and Parker, M. M. 1991. Benthic communities: Use in monitoring point-source discharges. *Techniques in Marine Environmental Sciences*. International Council Exploration Sea. 16: 70pp.

Resh, V. H. and Rosenberg, D. M. 1984. The ecology of aquatic insects. Portsmouth.NH, USA: Praeger Publishers. 42p.

Rippey, I. and Rippey, B. 1986. Chemical Limnology of two artificial lakes. *Hydrobiologia* 139: 234-237.

Robin, A. 2008. Gastropod. *Encyclopedia of Marine*. Verlag Conch Books: Hackenheim. Encyclopedia of Marine. 480pp.

Roland, A. 2013. Understanding the stream monitoring in Winsconsin .Citizen-based stream. 1-12pp.

Rosenberg, D. M. and Resh, V. H. 1993. Introduction to Freshwater biomonitoring and benthic macro-invertebrates, In: D.M. Rosenberg and V.H. Resh (eds.), Freshwater biomonitoring and benthic macro-invertebrates. Chapman and Hall, New York. 195-233pp.

Roy, A. H., Rosemond, A. D., Paul, M.J., Leigh, D. S., and Wallace, J. B. 2003. Stream macro-invertebrate reponse to catchment urbanization (Georgia, USA)'. *Freshwater Biology* 489: 329-346.

Ruggiero, A., Solimini, A.G and Carchini, G. 2003. Nutrient and chlorophyll a temporal patterns in eutrophic maintain ponds with contrasting macrophyte coverage. *Hydrobiologia*, 506-509, 657-663pp.

Sachidanandamurthy, K. L. and Yajurvedi, H. N. 2006. A Study of Physico-chemical parameters of an aquaculture body in Mysore city Karnataka India. *Journal of Environmental Biology* 27.4: 615-618.

Saeed, S., Marzieh, V.D., Akbar, H. and Toba, K. (2014). Heavy metals in water and sediment: A case study of Tembi River. *Journal of Environmental and Public Health* 1-5.

Samweel, N. and Naziri, T. 2014. Diversity of Aquatic insects and function of Fluvial Ecosystem of Song River of Rajaji National Park, India. *Global Journal of science frontier Research Environment & Earth Science* 14.1: 1 -11.

Schindler, D.W. 1990. Natural and Anthropogenically imposed limitations to Biotic Richness in freshwaters in the Earth in Transition: Patterns and processes of Biotic impoverishment. Woodwell, G.M., (ED).Cambridge University Press. 425-462 pp.

Shahadat, M. H., Nani, G. D., Subrata, S., Ziaur, M. R. 2012. Fish Diversity and habitat relationship with environmental variables at Meghna river estuary, Bangladesh. *The Egyptian Journal of Aquatic Research* 38.3: 213-226.

Shannon, C. E. and Weaver, W. 1949. The mathematical theory of communication. The University of Illinois press, Urbana IL. 19-27, 82-83, 104-107.

Sharma, R. C., 1986. Effect of physico-chemical factors on benthic fauna of Bhagirathi river, Garhwal Himalayas. *Journal Industrial Ecology* 13: 133-137.

Sharma, U. P. and Rai, D. N. 1991. Seasonal variations and species diversity of coleopteran insects in a fish pond of Bhagalpur, *Journal Freshwater Biology* 3: 241-246.

Sikoki, F. D. and Anyanwu, I. N. 2013. Spatial and Temporal variation of physico-chemical parameter variables in a small Pristine stream in Niger Delta, Nigeria. *Journal of Fisheries and Aquatic Science* 8:129-135.

Singhal, R. N. S. and Davies R.W. 1986. The physico-chemical environment and Plankton of managed pond in Hariyana, *India. Proc. Indian Academic Animal Science*: 95:353-364. http://dx;doi.org/10.1007/BF03179369.

Sinha, D. K and Roy, S.P. 1991. Species composition and seasonal abundance of predatory insect in some fish culture ponds at Dumka (India). *Journal of freshwater Biology* 3: 99-103.

SON. 2007. Nigerian Standard for drinking water quality.ICS 13.060.20 Approved by SON Governing Council. 1-28pp.

Stirling, H. P. 1985. Chemical and Biological methods of water analysis for aquaculturists.Institution of aquaculture, University of Stirling, Stirling.107-109pp.

Strong, E. E., Gargominy, O., Ponder, W. F. and Bouchet, P. 2008. Global Diversity of gastropods (Gastropoda:Mollusca) in freshwater. *Hydrobiologia* 595: 149-166.http: //hdl.handle.net/10088/7390:10:1007/s 10750-007-9012-6.

Takhelmayum, K. and Gupta, S. 2011. Distribution of aquatic insects in phumdis (floating island) of Loktak lake, Manipur, North –Eastern India. *Journal of Threatened Taxa*. 3: 1856-1861.

Talling J. F. and Talling I. B. 1965. The chemical composition of African Lake water.Int Rev Gesamten. *Hydrobiologia.* 50: 421-463.

Tan, S.K., Chan, S.Y. and Clement, G.R. 2012.A Guide to Snails and other Non-marine Molluscs of Singapore. Science Centre, Singapore 176pp.

Thomsen, A. G. and Friberg, N. 2002. Growth and emergence of the stonefly *Leuctra nigra* in coniferous forest stream with contrasting pH. *Freshwater Biolology* 47: 1159-1172.

Timothy, D. J., Tom, A., Kerry, A.I., Macquarie,T.B., Charles, D.R., Paul, Arp, ANTU Maprani, Richard, A.,C. 2004. Water Striders (Family: Gerridae): Mercury sentinels in small fresh water ecosystems. *Environmental pollution* 134: 165-171.

Tiseer, F.A., Tanimu, Y. and Chia, A. M. 2008. Seasonal occurrence of Algae and physicochemical parameters of Samaru stream, Zaria, Nigeria. *Asian Journal of Earth Sciences.* 1: 31-37.

Tyokumbur, E. T., Okorie, E. T., Ugwumba, O. A. 2002. Limnological assessment of the effects of effluents on macro-invertebrates fauna in Awba stream and Reservoir, Ibadan, Nigeria. *The Zoologist,* 1.2: 59-62.

Ufoegbune, G. C. Oparinde, O. C. and Eruola, A. O. 2011. Municipal Water supply planning in Oyo metropolis, Oyo State, South-western Nigeria. *Journal of Geography and Regional Planning.* 4.7: 392-400.

U.S. Environmental Protection Agency. 2004. Biological indicators of water shed health. Available at http://www.epa.gov.

Ugwumba, A. A.A. 1990. Food and Feeding Ecology of *Oreochromis niloticus*(Pisces: Osteichthyes) in Awba Reservoir, Ibadan. Ph.D. Thesis, University of Ibadan. xv+150pp.

Ugwumba, A.O. and Ugwumba, A.A.A. 1993. A study of the physico-chemical hydrology and plankton community of Awba Lake in Ibadan, Nigeria. *Fish Acadbiz, Comm*.1.1-4: 20-39.

Unanam, A. E. and Akpan, A.W. 2006. Analysis of physic Chemical characteristics of some freshwater bodies in Essien Udim Local Government Area of Akwa Ibom State. Nigeria. In: proceeding of the 21st Annual Conference of the Fisheries Society of Nigeria (FISON) Calabar, 13th-17th November.

UNCTAD, 2002. Use of Biodiversity Resources! The quest for sustainable development.Paper for the G-15 meeting on “Sustainable use of Biodiversity. Traditional knowledge and protection system” *caracas, Venezuela*, 3-5: 37.

Valavanidis, A. and Thomas, T. 2010. Agricultural pesticides: ecotoxicological studies and environmental risks Assessment. *Sci. Adv. Environ. Toxicol. Ecotoxicol.*

Issues. http//:chem..toxicotox.org/wp/wp-content/uoloads/2010/11/07-pesticides-06-11-2010.pdf.

Verneaux, J., Schmitt, V., Verneaux, V., Prouteau, C. 2003. Benthic insects and fish of the Doubs River systems: typological traits and the development of a species. 25pp.

Victor, R. and Onomivbori, O. 1996. The effects of urban pertubations on the benthic macro-invertebrates of a Southern Nigeria stream. *Perspectives in Tropical Limnology* 223-238.

Voshell, J. and Reese, J. R. 2002. A guide to common freshwater invertebrate of North America. The MC Donald and Woodward publishing company. Blackburg, VA. 1-12pp.

Wahizatul, A. A. 2011. Composition and distribution of aquatic insects communities in relation to water Quality in two fresh water streams of Hulu Terengganu. *Malaysia Journal of Sustainability Science and Management* 6.1: 148-155.

Ward, J.V. 1992. 'Aquatic insect ecology'. New York: John Wiley and Sons Inc.438pp.

Water Action Volunteers. 2006. Transparency: A water clarity measure. Factsheets Series. 1-5pp.

Weber, P., Behr, E. R., Knorr, C. D. L., Vendruscolo, D. S., Flores, E.M. M., Dressler, V. L. and Baldisserotto, B. 2013. Metals in the water, sediment and tissues of two fish species from different trophic levels in a subtropical Brazillian river. *Microchemical Journal*. 106: 61-66.

Wilsey, B. and Stirling, G. 2007. Species richness and eveness respond in a different manner to propagule density in developing praire microcosm communities. *Plant Ecology*. 190. 2: 259-273. DOI. 10 .1007/511258-006-9206-4.123.

WHO, 1978. A Field Guide to African Freshwater Snails. West African Species. Pp. 1-32

WHO. 2009. Calcium and Magnessium in Drinking water: Public health significance, Geneva. NLM CLASSIFICATION: QV276.

——— 2011. WHO Guidelines for Drinking-water Quality; fourth Edition, Geneva ISBN 9789241548151, NLM Classification: WA 675.

Wihlm, J. L. 1970. Range of diversity index in benthic macroinvertebrate population. *Journal of Water Pollute*. *Control Fed*. 42: 221-224.

Wilhm, J. H and Dorris, T. C. 1966. Species diversity of benthic macro-invertebrate in a stream receiving domestic and oil refinery effluent. *Amn. Midl. Nat*. 76: 427 – 449. DOI: 10. 2307/2423096.

William, J. S. 1997. Ecological Census Techniques. University of Cambridge, United Kingdom. 281-316pp.

Willoughby, L.G. and Mappin, R.G. 1988. The distribution of *Ephemerella ignita* (Ephemeroptera) in streams: The role of pH and food resources. *Freshwater Biology* 19: 145-155.

Wolfhard, S. and Reinhard, B. 1998. The heterogeneity of run off and its significance for water quality problems. *Hydrological Sciences. Journal des Science Hydrobiologiques*. 43: 103-113.

Yacoub, A., 2007. Study on some heavy metals accumulated in some organs of three River Nile fishes from Cairo and Kalubia Govemocrate. *African Journal of Biological Science* 3: 9-21.

Yakub, A, S. 2004. Assessment of water quality and plankton of Effluent receiving lower Awba stream and Reservoir, Ibadan. *African Journal of Applied Zoology and Environmental Biology.*6: 107-110.

Yakub, A.S. and Ugwumba, A.A.A. 2009. A study of the macro-invertebrate Fauna of Lower Ogun river ar Ishasi, Ogun State, South-West Nigeria. *The Zoologist* 7: 67-74.

Yap, C. k., Rahim, I. A, Azrina, M. Z, Ismail, A. and Tan, S.G. 2006. The influence of physical parameters on the distribution of Oligochaetes at the polluted downstream of the tropical Langat river, peninsula, Malaysia. *Journal of Applied Science and Environmental Management* 10: 135 -140.

Yip, R, Dallman, P.R. and Iron. 1996. In present knowledge in Nutrition 7th ed. Zeigler, E.E filter L.J Eds ILSI press Washington D.C. U.S.A, pp. 277-295.

Zabbey, N. and Hart, A. Z. 2006. Influence of some physico- Chemical parameters on the composition and distribution of benthic fauna in Woji Creek, Niger Delta, Nigeria'. *Global Journal of pure and Applied Sciences*. 12.1: 1-5.

APPENDIX

Appendix 1: Spatial comparison of physico-chemical parameters from Erelu Resevoir water samples during rainy and dry seasons (ANOVA)

Parameters	Stations	Dry	Rainy
		Mean ± SE	
Transparency (cm)	Inlet	59.75 ± 3.54[b]	42.96 ± 2.51 [b]
	Reservoir	94.43 ± 2.35[a]	77.94 ± 0.96 [a]
	Outlet	60.85 ± 3.90 [a]	41.04 ± 2.59 [b]
Turbidity (NTU)	Inlet	8.63 ± 3.49[a]	13.71 ± 2.60[a]
	Reservoir	3.26 ± 0.51 [a]	13.34 ± 2.68 [a]
	Outlet	4.51 ± 1.05 [a]	18.17 ± 4.85 [a]
Temperature (^oC)	Inlet	28.95 ± 0.29 [a]	28.45 ± 0.43 [a]
	Reservoir	28.87 ± 0.20 [a]	28.55 ± 0.32 [a]
	Outlet	29.16 ± 0.34 [a]	28.53 ± 0.41 [a]
Calcium ion (mg/L)	Inlet	18.72 ± 1.65 [a]	17.02 ± 1.58 [a]
	Reservoir	18.43 ± 0.86 [a]	15.18 ± 1.16 [a]
	Outlet	20.08 ± 1.06[a]	15.83 ± 1.42[a]
Magnesium ion (mg/L)	Inlet	5.76 ± 0.80 [a]	8.76 ± 1.39 [a]
	Reservoir	5.30 ± 0.89 [a]	9.91 ± 1.16 [a]
	Outlet	6.24 ± 1.53 [a]	8.51 ± 1.19 [a]
Phosphate (mg/L)	Inlet	0.08 ± 0.03 [a]	0.10 ± 0.02 [a]
	Reservoir	0.09 ± 0.02 [a]	0.16 ± 0.07 [a]
	Outlet	0.10 ± 0.03 [a]	0.29 ± 0.13 [a]
Nitrate (mg/L)	Inlet	0.33 ± 0.16 [a]	0.84 ± 0.14 [a]
	Reservoir	0.63 ± 0.20 [b]	1.50 ± 0.20 [b]
	Outlet	0.28 ± 0.11 [a]	0.82 ± 0.14 [a]
Dissolved Oxygen (mg/L)	Inlet	7.99 ± 0.36 [a]	8.80 ± 0.32 [a]
	Reservoir	7.93 ± 0.23 [a]	8.61 ± 0.22 [a]
	Outlet	8.26 ± 0.28 [a]	8.55 ± 0.26 [a]

Means with same letters along the columns are not significantly different (p=0.05)

Appendix 1: Spatial comparison of physicochemical parametersEreluReservoir water samples duringrainy and dry seasoncontnd. (ANOVA) contd.

Parameters	Stations	Dry	Rainy
		Mean ± SE	
Biological Oxygen Demand (mg/L)	Inlet	1.51 ± 0.45 [a]	1.06 ±0.20 [b]
	Reservoir	1.21 ± 0.31 [a]	1.00 ± 0.15 [b]
	Outlet	1.53 ± 0.45 [a]	1.01 ± 0.17 [a]
Hydrogen ion concentration (mg/L)	Inlet	7.60 ± 0.13 [a]	7.22 ± 0.06 [a]
	Reservoir	7.50 ± 0.11 [a]	7.29 ± 1.78 [a]
	Outlet	7.61 ± 0.11 [a]	7.46 ± 0.08 [a]
Total Alkalinity (mg/L)	Inlet	97.50 ± 6.35 [a]	99.75 ± 7.78 [a]
	Reservoir	99.47 ± 4.74 [a]	102.95 ± 6.37 [a]
	Outlet	93.00 ± 5.58 [a]	94.21 ± 7.29 [a]
Total Dissolved solid (mg/L)	Inlet	159.32 ± 25.92 [a]	119.38 ± 14.41 [a]
	Reservoir	156.88 ± 19.99 [a]	127.75 ± 11.51 [a]
	Outlet	173.77 ± 25.61 [a]	126.14 ± 14.05 [a]
Conductivity (µs/cm)	Inlet	236.64 ± 36.30 [a]	171.63 ± 21.15 [a]
	Reservoir	231.53 ± 28.15 [a]	185.72 ± 17.28 [a]
	Outlet	254.77 ± 35.38 [a]	188.76 ± 22.16 [a]

Means with same letters along the columns are not significantly different (p=0.05)

Appendix 2: Spatial variation of water samples heavy metalsfrom Erelu Reservoir during wet and dry seasons (ANOVA)

Parameters	Stations	Dry	Rainy
		Mean ± SE	
Lead (mg/L)	Inlet	1.02 ± 0.15[a]	0.86 ± 0.13[b]
	Reservoir	1.17 ± 0.13[a]	2.34 ± 1.47[a]
	Outlet	1.18 ± 0.16[a]	0.97 ± 0.15[b]
Iron (mg/L)	Inlet	0.68 ± 0.12[a]	0.52 ± 0..08[a]
	Reservoir	0.69 ± 0.11[a]	0.51 ± 0.08[a]
	Outlet	0.73 ± 0.14[a]	0.47 ± 0.10[a]
Zinc (mg/L)	Inlet	0.52 ± 0.09[a]	1.43 ± 0.51[a]
	Reservoir	0.48 ± 0.08[a]	1.19 ± 0.39[a]
	Outlet	0.47 ± 0.08[a]	1.21 ± 0.45[a]
Chromium (mg/L)	Inlet	0.16 ± 0.03[a]	0.28 ± 0.06[a]
	Reservoir	0.23 ± 0.05[a]	0.35 ± 0.10[a]
	Outlet	0.19 ± 0.03[a]	0.22 ± 0.05[a]
Cadmium (mg/L)	Inlet	0.24 ± 0.05[a]	0.20 ± 0.03[a]
	Reservoir	0.25 ± 0.04[a]	0.25 ± 0.05[a]
	Outlet	0.29 ± 0.06[a]	0.19 ± 0.03[a]

Means with same letters along the columns are not significantly different (*p*=0.05)

Appendix 3: Spatial comparison of sediment sample heavy metals from Erelu Reservoir during wet and dry seasons (ANOVA)

Parameters	Stations	Dry	Rainy
		Mean ± SE	
Lead (mg/kg)	Inlet	34.82±6.67[a]	17.48±2.15[a]
	Reservoir	35.03±5.01[a]	14.18±1.65[a]
	Outlet	38.91±5.95[a]	13.80±1.92[a]
Iron (mg/kg)	Inlet	25.35±6.80[a]	14.92±4.25[a]
	Reservoir	26.72±5.10[a]	20.39±4.74[a]
	Outlet	22.04±6.36[a]	16.57±5.26[a]
Zinc (mg/kg)	Inlet	8.53±2.72[a]	2.00±0.33[a]
	Reservoir	7.14±1.64[a]	1.91±0.27[a]
	Outlet	8.12±2.50[a]	2.25±0.49[a]
Chromium (mg/kg)	Inlet	17.14±5.35[a]	20.70±15.29[a]
	Reservoir	14.95±3.98[a]	12.86±3.66[a]
	Outlet	13.80±4.27[a]	12.88±4.91[a]
Cadmium (mg/kg)	Inlet	3.00±0.39[a]	3.05±0.55[a]
	Reservoir	3.05±0.52[a]	3.38±0.58[a]
	Outlet	3.35±0.40[a]	3.57±0.75[a]

Means with same letters along the columns are not significantly different (p=0.05)

Appendix 4: Seasonal differences of physical and Chemical parameters of water samples of Erelu Reservoir.

Parameters	Seasons	Inlet	Reservoir	Outlet
Transparency (cm)	**Rainy**	42.96±1.76^{a}	77.94±0.68^{a}	41.04±1.82^{a}
	Dry	59.75±2.47	94.43±1.65	60.85±2.72
Turbidity (NTU)	**Rainy**	13.71±1.82^{ab}	13.34±1.88^{a}	18.17±3.40^{a}
	Dry	8.63±2.44	3.26±0.36	4.51±0.74
Temperature (oC)	**Rainy**	27.61±0.19^{a}	27.69±0.14^{a}	27.56±0.17^{a}
	Dry	29.61±0.16	29.60±0.12	30.01±0.13
Calcium ion (mg/L)	**Rainy**	17.02±1.11^{ab}	15.18±0.82^{a}	15.83±0.99^{a}
	Dry	18.72±1.15	18.43±0.61	20.08±0.74
Magnesium ion (mg/L)	**Rainy**	8.76±0.97^{a}	9.91±0.82^{a}	8.51±0.83^{ab}
	Dry	5.76±0.56	5.30±0.62	6.24±1.70
Phosphate (mg/L)	**Rainy**	0.97±0.02^{ab}	0.16±0.05^{a}	0.29±0.09^{a}
	Dry	0.08±0.02	0.09±0.01	0.10±0.02
Nitrate (mg/L)	**Rainy**	0.84±0.10^{ab}	1.50±0.14^{a}	0.82±0.95^{a}
	Dry	0.33±0.11	0.63±0.13	0.28±0.08
Dissolved Oxygen (mg/L)	**Rainy**	8.80±0.23^{ab}	8.61±0.15^{ab}	8.55±0.18^{ab}
	Dry	7.99±0.25	7.93±0.16	8.23±0.19
Biological Oxygen Demand (mg/L)	**Rainy**	1.06±0.14^{a}	0.99±0.11^{a}	1.01±0.12^{a}
	Dry	1.51±0.32	1.21±0.22	1.53±0.32
Hydrogen ion concentration (mg/L)	**Rainy**	7.22±0.04^{a}	7.27±0.04^{ab}	7.46±0.06^{a}
	Dry	7.56±0.08	7.42±0.05	7.50±0.06
Total Alkalinity (mg/L)	**Rainy**	99.75±5.45^{a}	102.95±4.48^{a}	94.21±5.11^{a}
	Dry	97.50±4.43	99.47±3.32	93.00±3.89
Total Dissolved Solid (mg/L)	**Rainy**	119.38±0.10^{ab}	127.76±8.09^{ab}	126.44±9.84^{ab}
	Dry	159.32±18.09	156.89±14.02	173.77±17.87
Conductivity (µscm^{-1})	**Rainy**	171.63±14.82^{ab}	185.72±12.15^{ab}	188.76±15.52^{ab}
	Dry	236.64±25.34	231.50±19.74	254.77±24.70

Means with superscripts (**a**) along rows are significantly different (***p*<0.05**)

Appendix 5: Seasonal differences of water samples heavy metals of Erelu Reservoir.

Parameters (mg/L)	Seasons	Inlet	Reservoir	Outlet
Lead (Pb)	**Rainy**	0.86 ± 0.09^{ab}	0.91 ± 0.08^{ab}	0.97 ± 0.11^{ab}
	Dry	1.02 ± 0.10	1.17 ± 0.09	1.18 ± 0.11
Iron (Fe)	**Rainy**	0.52 ± 0.05^{a}	0.51 ± 0.05^{a}	0.47 ± 0.71^{a}
	Dry	0.68 ± 0.09	0.69 ± 0.08	0.73 ± 0.10
Zinc (Zn)	**Rainy**	1.43 ± 0.36^{a}	1.11 ± 0.33^{a}	1.21 ± 0.31^{a}
	Dry	0.52 ± 0.06	0.49 ± 0.07	0.47 ± 0.06
Chromium (Cr)	**Rainy**	0.28 ± 0.04^{a}	0.35 ± 0.07^{a}	0.22 ± 0.04^{a}
	Dry	0.16 ± 0.02	0.23 ± 0.03	0.19 ± 0.02
Cadmium (Cd)	**Rainy**	0.20 ± 0.02^{a}	0.25 ± 0.03^{ab}	0.19 ± 0.02^{a}
	Dry	0.24 ± 0.04	0.25 ± 0.03	0.29 ± 0.04

Means with superscripts (a) along rows are significantly different (***p*<0.05**)

Appendix 6: Seasonal changes of sediment sample heavy metals of Erelu Reservoir.

Parameters (mg/kg)	**Seasons**	**Inlet**	**Reservoir**	**Outlet**
Lead (Pb)	**Rainy**	17.45 ± 1.50^{a}	14.18 ± 1.16^{a}	13.80 ± 1.34^{a}
	Dry	34.82 ± 4.66	35.03 ± 3.52	38.91 ± 4.16
Iron (Fe)	**Rainy**	17.24 ± 3.92^{ab}	21.82 ± 3.77^{ab}	20.14 ± 5.36^{ab}
	Dry	25.35 ± 4.75	26.72 ± 4.19	22.04 ± 4.44
Zinc (Zn)	**Rainy**	2.18 ± 0.23^{a}	2.01 ± 0.19^{a}	2.29 ± 0.35^{a}
	Dry	8.28 ± 1.92	6.10 ± 1.18	8.07 ± 1.75
Chromium (Cr)	**Rainy**	5.69 ± 1.37^{a}	10.89 ± 2.35^{ab}	12.88 ± 4.91^{ab}
	Dry	16.90 ± 3.75	14.52 ± 2.82	13.80 ± 4.27
Cadmium (Cd)	**Rainy**	3.43 ± 2.69^{ab}	3.71 ± 3.61^{a}	4.03 ± 3.92^{ab}
	Dry	2.63 ± 1.80	2.44 ± 2.12	2.52 ± 1.50

Means with superscripts (a) along rows are significantly different (***p*<0.05**)