CHAPTER ONE

INTRODUCTION

1.1 Overview

Nigeria is naturally blessed with vast expanses of inland waters. The total surface area of water bodies in Nigeria is estimated to be about 14,991,900 hectares (149,919km^2) and this constitutes about 15.9% of the total area of Nigeria (Ita, 1993). Oluwa River is one of the major and important rivers in Nigeria. The river supports major artisanal fisheries, dredging of sand and transportation in Ondo State (Akinwumi *et al.*, 2011). Oluwa River flows through Igbokoda Town.The River provide a daily source of fish and livelihood to the surrounding communities. Owing to the contributions of these communities to the national fish production, the Federal Government of Nigeria built a multimillion naira terminus in Igbokoda. The speed boat workers earn their living by commercializing the speed boats for transporting passengers and their goods to their various destinations on the river. The river is also used for laundry and disposal of excreta. The river receives organic wastes dumped at the shore; this could impact adversely on the physico-chemical characteristics, plankton, benthic macro-invertebrates fish fauna abundance, composition and distribution.

Physico-chemical parameters constitute important abiotic component of aquatic ecosystems and they influence species composition, diversity, stability, abundance, productivity, migration, biodiversity and physiological condition of aquatic organisms (Bagenal, 1978; Adeogun, 2004; Olaniyan 2010). These parameters are used to detect any perturbation in the aquatic environment.

Physico-chemical parameters have been identified to affect plankton abundance (Ayodele and Adeniyi, 2006). Phytoplankton communities are essential components of all aquatic environments.They form the primary producers which all other living organisms in water depend on directly or indirectly for food. Zooplankton plays an important role in the trophic structure of rivers as consumers of phytoplankton and as a source of food for both fin-fish and shell fish (Ayodele and Adeniyi, 2006).

Knowledge of the plankton community of any water body is, therefore, important in assessing its productivity and would permit a better understanding of the population dynamics and life cycles of the fish community (Adebisi, 1981; Abohweyere, 1990; Ugwumba, 1990; Mohammad and Saminu, 2012; Onyema and Popoola, 2013). Planktonic organisms are ideal for theoretical and experimental population ecology owing to several favourable features, such as small size, short generation time and a relatively homogenous habit (Rothhaupt, 2000). They are also good indicators of polluted water (Onyema and Nwankwo, 2007).

Benthic macro-invertebrates play important roles in aquatic community.These include mineralization, mixing of sediments, flux of oxygen into sediments, circulation and recirculation of nutrients and assessment of the quality of inland water (George *et al*., 2009). They also accelerate the breakdown of decaying organic matter into simpler inorganic forms, such as phosphates and nitrates (Gallep *et al.*, 1978). The distribution of benthic macro-invertebrates fauna is determined by a number of factors, like the physical nature of the substratum, depth, nutritive content, degree of stability and oxygen content of the water body. Benthic macro-invertebrates organisms are threatened by changes in their habitats, which are associated with pollution, erosion and siltation (Lydeard *et al.,* 2004). Benthic macro-invertebrates community responses to environmental changes are useful in assessing the impact of industrial oil, agricultural wastes, impacts from other land use on surface waters (APHA, 2005). The use of benthic macro-invertebrates diversity for bioassessment provides a simpler approach and this is due to the fact that they can be sampled quantitatively as well as the known relative sensitivity or tolerance of some of them to contamination (Adakole and Annune, 2003).

Fishes are the most valued living resources in aquatic environments.They are also an important source of food and recreation. Fishing is of great economic value all over the world. Debnath (2009) observes that about one billion human beings worldwide depend on fish as their primary means of animal protein. In Nigeria, fisheries' contribution to the gross domestic product is about 1 billion dollars (Sotolu, 2011). Stressing the importance of fishing to economic development, Osalor (2011) opines that fishing, by itself, has the potential of driving considerable enterprise development, transforming rural economies and generating direct and indirect employment opportunities in the process. Thus, apart from the proteins and other benefits derived from consuming fish, it leads to employment generation of the youths, improved income and reduction in poverty level, and socioeconomic development of communities.

Akinwumi *et al*. (2011), stressed that the fishery of an area could support the stride towards employment generation, poverty alleviation and supply of animal protein to the teeming Nigerian population. For instance, fishing activities are expected to create employment for many peasant fishermen and traders all over the world. In their various communities, they employ male indigenes as canoe paddlers and females as fish processors and as customers in fish trade (Ehinmore, 2007).

Sotolu (2011) notes that, based on the numerous advantages and roles played by fisheries in human existence and nation development, sustainable exploitation of fisheries resources become imperative. Fishes are a key unit in many natural aquatic food webs. They also can serve as environmental indicators of polluted water (APHA, 1998). Fish, the most populous and valued vertebrate in the aquatic environment, are an important source of food and recreation (Sikoki and Kolo, 1993). The inland fisheries sub-sector in Nigeria operates mainly in the remote rural areas where over 3.0 million people are engaged in artisanal fish production which contributes about 86% of the domestic fish production (Federal Department of Fisheries, 2003). Fishes are key units in many natural aquatic food webs and can also serve as environmental indicators of polluted water bodies (Albaret and Lae, 2003). Fish in their habitats also suffer from several organic pollution (Baden *et al*., 1990; Mason, 1991; Sikoki and Kolo, 1993; Oladimeji and Wade, 1994; Arimoro *et al*., 2007; Tyokumbur, 2016). Abundance, species compositions and distributions of fish fauna can serve as a measure of the health–status of water body (Victor and Ogbeibu, 1985; Edokpayi *et al*., 2001; Edoghotu *et al*., 2016).

1.2 Justification

Oluwa River is used for artisanal fishing activities, transportation, domestic purposes, as well as mining of silica and sand. The uncontrolled discharge of domestic wastes has pollution implications, as they may change prevailing conditions and alter the habitats of aquatic organisms and fishing activities are major sources of livelihood, especially for artisanal fisher folks. Oluwa River was eighth (8^{th}) producers in Nigeria's artisanal fisheries, contributing about 4.49% of the total production (FDF, 2007). Assessment of status and changes in the ecosystem is very crucial in order to ensure conservation of the aquatic resources. Despite the increasing anthropogenic influences occasioned by the rapid development of Ilaje communities as one of the Niger Delta areas in Nigeria, no corresponding update in scientific information regarding its limnology, most especially on plankton and benthic macro-invertebrates of the river; hence, the need for this study. This would provide additional information that could be utilized as a platform for impact assessment, planning and proper management of Oluwa River.

1.3 Aim and Objectives

This research aimed at assessing the current status of the physico-chemical parameters, diversity, abundance and distribution of plankton, benthic macro-invertebrates and fish fauna of Oluwa River. The objectives of this study were to measure:

- the physico-chemical parameters of Oluwa River;
- the plankton and benthic macro-invertebrates of the river in quality and quantity.
- the fish diversity and abundance in the river;

- relationship among the physico-chemical parameters, the abundance of plankton, benthic macro-invertebrates and level of pollution.

CHAPTER TWO
LITERATURE REVIEW

2.1 Physico-chemical parameters

An understanding of the physico-chemical variables of a water body is importance when determining its productivity and other characteristics. Adebisi (1981) noted that water used for cultivation of fish will not give maximum production if the conditions are not optimal for fish and for other aquatic organisms. This supposes that physical and chemical factors must be present at their optimum level to determine a good initial production (Jamu and Ayinla, 2003).

The importance of physico-chemical parameters in fishery management has long been recognized and attempts have been made to relate certain limnological factors to inland water productivity. These include the works of Ovie (1995), King and Jonathan, (2003), Adeogun *et al*. (2005), Arimoro *et al*. (2007), Atobatele and Ugwumba (2008), Offem and Akegbejo-Samsons (2009), Davies and Ansa (2010), Ayeni *et al*. (2011), Chinedu *et al*.(2011), Ude *et al*. (2011), Ogbuagu and Ayoade (2012), Ipinmoroti (2013) and Falaye *et al.* (2015).

Ugwu and Wakawa (2012) studied seasonal physico-chemical parameters in River Usma Abuja, Nigeria. The parameters measured included: sodium (Na), potassium (K), Biochemical Oxygen Demand (BOD), Dissolved Oxygen (DO), pH, Temperature, Electrical Conductivity (EC), Total Disssoved Solids (TDS), Total Suspended Solids (TSS), Total alkalinity,Total Phosphate (TP), Total Nitrate (TN), Total Sulphate (TS), and Total Chloride (TC). The mean values of the measured parameters were compared with National Standard for Drinking Water Quality (NSDWQ) and US Environmental Protection Agency (USEPA) standards. The findings showed that all the physico-chemical parameters were within the tolerable values except TSS that exceeded with the mean values of 6.8, 4.9 and 8.4 mg/L for all the stations.

Usoro *et al*. (2013) reported on seasonal variation of physico-chemical parameters of water and sediments from Iko River, Nigeria. Based on the physico-chemical parameters of the water, the pollution index determined for the wet season gave a value of 0.97, which was less than a value 1 for an unpolluted surface water body, but gave a pollution index of 1.34 during the dry season. This could be attributed to reduction in water flow and surface water evaporation. The variation of the dissolved oxygen was not significant in both seasons and was higher than the 5.0mg/L WHO limit for surface waters, and indicated a highly oxidized environment. The phosphate content of the sediment of the river was lower in both seasons than average for soils, whereas, total nitrogen, total organic carbon and sulphur content were higher than average for soils.

The focus of Omaka *et al*.(2014) was the physico-chemical parameters and nutrients variations of streams and rivers in Abakaliki, Ebonyi State, Nigeria. The results obtained showedthe following: temperature (28.60–30.00°C), pH (6.80–7.93), DO (1.40–3.53 mgL^{-1}), turbidity (41.33 –97.67 NTU), conductivity (19.00 –613.30 μScm^{-1}), total acidity (9.17–17.23 mgL^{-1}), total alkalinity (6.43–10.97 mgL^{-1}), BOD (1.20–7.03 mgL^{-1}), COD (16.200–53.533 mgL^{-1}), phosphate (0.11–1.17 mgL^{-1}) and nitrate (0.12–1.45 mgL^{-1}). The turbidity and BOD were well above the prescribed standards. The results suggest that refuse disposal, fertilizer use, and natural phenomena, for example soil erosion and flooding might have contributed in various ways to the impairment of the water quality of the studied sites.

Temperature is one of the most influential environmental factors affecting the physiological activities and behavioural patterns such as growth, feeding, reproduction, distribution and migratory behaviours of aquatic organisms (Suski *et al*., 2006). Temperature affects solubility of gases in water. Gas solubility decreases with increased temperature (Odum, 1971). Guzkowska and Gasse (1990) claim that diatoms seem to grow best at temperature of 15-25°C, green algae at 25-35 °C, and blue-green algae at 30-

40 ^{o}C. The recommended temperature range for fish production, according to Boyd (1982) is 20-33 ^{o}C. Huet (1972) examined the temperature need of fish and the influence of temperature on fish production.He notes that an increase in water temperature of 2^{o}C at the time of production would adversely affect spawning. Temperature over 30^{o}C can cause regression in growth and decay in plant (Kara *et al.,* 2004). The surface temperature for all the rivers ranged between 22.6 and 31^{o}C in the dry seasons and between 21 and 26^{o}C in the wet seasons. These ranges compared well with the ranges reported for other tropical waters (Khan and Ejike, 1984; Ovie and Adeniji, 1993). The highest values in the dry seasons could be attributed to the warming effect of the solar radiation. The temperature recommended for aquatic life in the tropical environment like Nigeria is between 21 and 32^{o}C (Boyd 1981; Ayodele and Ajani, 1999; Olukunle, 2000). NESREA, 2011 recommended a temperature below 40^{o}C for drinking water.

Dissolved oxygen is the dissolved gaseous form of oxygen. Oxygen enters water by diffusion from the atmosphere and as by product of photosynthesis by algae and other plants. Loss of dissolved oxygen is caused by respiration, decay by aerobic bacteria and decomposition of decaying sediment (Gupta and Gupta, 2006). Dissolved oxygen is the most important variable that affect water quality as insufficiency of oxygen will allow aquatic organisms to give in to stress, leading to their death or becoming more susceptible to parasites and diseases (King and Jonathan, 2003). Dissolved oxygen (DO) is probably the most important abiotic parameters because aquatic organisms cannot survive without DO. Oxygen is essential to all forms of aquatic life, including those organisms responsible for the self-purification process in natural water. The DO recommended for the survival of aquatic life in tropical water is between 3 and 5 ppm (Boyd, 1981; Ayodele and Ajani, 1999 and Olukunle, 2000). It varies with temperature, salinity, turbulence, the photosynthetic activity of algae and plants and atmospheric pressure. The solubility of oxygen decreases as temperature and salinity increase. In fresh waters, dissolved oxygen at sea level ranges from 15 mg/l at 0^{o} C to 8 mg/l at 25^{o}C (Chapman and Kamstach, 1992).

The Biological Oxygen Demand (BOD) is the amount of oxygen required by bacteria to decompose the organic matter in the water, while chemical oxygen demand (COD) is the amount of oxygen in water required to oxidize organic matter in the water to carbon dioxide (Moore and Moore, 1976; Chinda *et al*., 1991). As a result, the level of BOD and COD are always closely related. The amount of oxygen needed to completely decompose the organic matter present in the water to simplest molecules, carbon (iv) oxide and water is known as the Biochemical Oxygen Demand (BOD) of the water. The greater the BOD is the higher the degree of pollution. When the organic loading of the aquatic environment becomes abnormally high, the BOD far exceeds the available oxygen. Biochemical oxygen demand is used as a measure of the quantity of oxygen required for oxidation of biodegradable organic matter present in a water sample by aerobic and anaerobic biochemical action. Biochemical Oxygen Demand (BOD) is thus one of the measures of organic loads in an aquatic system as well as an indicator of levels of organic pollution (Odukuma and Okpokwasili, 1990; Bagariano, 1992).

However, low BOD levels water support high organic enrichment. Clerk (1986) asserts that BOD range of $\geq 2 \leq 4$ does not show pollution while levels beyond 5 mg/L are indicative of serious pollution. Water bodies with BOD levels between 1.0 and 2.0 mg/L are considered clean; 3.0 mg/L fairly clean; 5.0 mg/L doubtful and 10.0 mg/L definitely bad and polluted (Moore and Moore, 1976;Chinda *et al*., 1991). The condition of extremely low dissolved oxygen level, high levels of BOD, ammonium nitrogen (NH_3, NH_4^+) and hydrogen sulphide has been observed in organic-rich effluent-receiving water bodies in Nigeria. These include Lagos Lagoon, owing to extensive industrial and domestic wastes discharge (Brown and Ajao, 2004; Onyema and Nwankwo, 2007; Egonmwan, 2008; William *et al*., 2009; Nkwoji *et al*., 2010; Onyema, 2010), Awba Reservoir in Ibadan (Tyokumbur *et al*., 2002 and Yakubu, 2004), Ikpoba River in Benin City,owing to brewering effluent (Ogbeibu and Obanor, 2002),Benin River arising from saw mill wood wastes (Arimoro *et al*., 2007), Owena River as a result of organic wastes (Olaniyan, 2010).

In water, hydrogen ion concentration is measured in terms of pH, which is defined as the negative logarithm of hydrogen ion concentration (Boyd, 1979).This concentration is the pH of neutrality and is equal to 7. When the pH is higher than 7 it indicates increasing alkalinity, while values lower than 7 tend towards acidity,that is increase in hydrogen ion concentration. Accurate measurement of pH may be taken *in situ* using electronic glass electrode.

APHA (1995) observes that pH measurements are affected by temperature in two ways: mechanical effects caused by changes in the properties of the electrode and chemical effects caused by equilibrium changes. The pH higher than 7 but lower than 8.5 is ideal for biological productivity, while pH lower than 4 is detrimental to aquatic life (Abowei, 2010). Most organisms, including shrimps, do not tolerate wide variations of pH over time and, if such conditions persist, death may occur. Therefore, waters with little change in pH are generally more conducive to aquatic life. The pH of natural waters is greatly influenced by the concentration of carbon (IV) oxide, which is an acidic gas (Boyd, 1979).

Phytoplankton and other aquatic vegetation remove carbon (IV) oxide from the water during photosynthesis; so the pH of a water body rises during the day and decreases at night (Boyd and Lichtkoppler, 1979). Rivers flowing through forests have been reported to contain humic acid, which is the result of the decomposition and oxidation of organic matter in them; hence they have low pH (Beadle, 1981).

Abowei and George (2009) reported that the mean pH value of Okpoka Creek, Niger Delta ranged between 6.68 and 7.03, while the spatial and temporal variations were minimal.They also observed seasonal variation in pH between the dry season (6.97) and the wet season (6.81). In the open ocean, the pH of sea water falls within limits of 7.5-8.4 (Riley and Chester, 1971). Waters with low total alkalinity often have pH values of 6.5-7.5 before daybreak, but when phytoplankton growth is high, afternoon pH values may rise to 10 or even more (Swingle, 1969; Beasley, 1983).

Changes in the acidity of water can be caused by acid rain, run-off from surrounding rocks and waste water discharges (Ibiebele *et al*., 1983). Waters with pH values of 6.5 to 9.0 are considered best for fish production, while the acid and alkaline death points are 4.0 and 11, respectively (Swingle, 1969; Boyd, 1982). Low pH values or acidic waters are known to allow toxic elements and compounds, such as heavy metals, to become mobile thus producing conditions that are inimical to aquatic life (Gietema, 1992).

In the Niger Delta, acidity level has been observed as a major limiting factor influencing the distribution of mollusks. Nwadiaro (1987) investigated the longitudinal distribution of macro-invertebrates and fish in the lower Niger Delta (Sombreiro River). He reported that the distribution of mollusks was limited to the neutral slightly alkaline brackish water zone. The acidic nature of the New Calabar River was responsible for the lack of mollusks (Umeozor, 1995). Freshwaters of the Niger Delta tend to be acidic, with pH range of 5.5-7.0 (Hamor and Philip-Howards, 1985; Adeniyi, 1986; Chinda, 2003).

The pH of the water may influence the species composition of an aquatic environment and the availability of nutrients. According to Boyd (1982), the best water for fish cultivation is that which is neutral or slightly alkaline, with a pH between 7.0 and 8.0; at pH range of 3.0 - 3.5, no fish is likely to survive for more than a few hours, although some plants and invertebrates can be found at pH values lower than this. In unpolluted freshwater, suitable pH for most aquatic organisms lies in the range of 6.5 to 9.0.

Conductivity is a measure of the ability of water to conduct an electrical current. Conductivity is said to depend on the ionic strength of water and it is related to the nature of the various dissolved mineral salts, their actual and relative concentrations and the temperature at which the measurement is made (Alabaster and Lloyds, 1982). Increased conductivity could result from low precipitation, higher atmospheric temperatures resulting in higher evaporation rates and higher total ionic concentration and saline intrusions from underground sources (Baird, 2000). It could also be due to a high rate of decomposition and mineralisation by microbes and nutrient regeneration from bottom sediments (Deekay *et al*., 2010). The conductivity of water is dependent on its ionic concentration and temperature. Distilled water has conductivity of about 1mhos/cm and natural waters have conductivity of 20-1500 mhos/cm (Abowei *et al*., 2010).

Conductivity provides good indication of the changes in water composition, particularly its mineral concentration. Variations of dissolved solids in water could affect the relative quantities of the various components. There is a relationship between conductivity and total dissolved solids in water. As more dissolved solids are added, water's conductivity increases (Abowei *et al*., 2010). Conductivity of salt water is usually higher than that of freshwater because the former contains more electrically charged ions than the latter.

Moreover, conductivity is an index of the total ionic content of water and, therefore, indicates freshness or otherwise of the water (Egborge, 1994a; Ogbeibu and Victor, 1995). Conductivity of freshwater varies between 50 and 1500 mhos/cm (Boyd, 1979), but some polluted waters reach 10,000 hs/cm. Seawater has conductivity around 35,000 mhos/cm and above.

The major constituents of the dissolved substances in water are calcium ion (Ca^{2+}), magnesium (Mg^{2+}), hydrogen trioxcarbonate (IV) (HCO_3), trioxocarbonate (iv) (CO_3), trioxonitrate (v) (NO_3) and tetraoxophosphate (vi) (PO_4). They are the necessary constituents of aquatic animals which partly come from their food (Beadle, 1981). Verheust (1997) states that conductivity can be used as indicator of primary production (chemical richness) and, thus, fish production. Sikoki and Veen (2004) observed a conductivity range of 3.8-10 mhos/cm in Shiroro Lake (Imo State) which was described as extremely poor in chemicals. According to them fishes differ in their ability to maintain osmotic pressure; therefore, the optimum conductivity for fish production differ from one species to another.

Total alkalinity is the number of milliequivalents of acid used in titration to combine all the hydroxyl ions. The alkalinity of natural or treated waters is usually due to the presence of bicarbonate, carbonate and hydroxide compounds of calcium, magnesium, sodium, potassium and iron due to the dissolution of carbon dioxide in water (Gupta and Gupta, 2006). Water bodies of the tropics are known to show a wide range of fluctuations in total alkalinity, the values depending on the location, season, plankton population and nature of bottom deposits. Such natural waters which contains 40 $mgCaCO_3/L$ and above of total alkalinity are considered for biological purposes as hard waters, while waters with lower alkalinity are said to be soft (Boyd, 1982). Alkalinity values above 300 $mgCaCO_3/L$ have been reported to adversely affect the spawning and hatching of carps in freshwater aquaculture systems (Kara *et al*., 2004). Alkalinity between 30 and 500 $mgCaCO_3/L$ is generally acceptable for fish and shrimp production (Abowei and George, 2009).Alkalinity between 20 and 50 $mgCaCO_3/L$, according to Boyd (1982), will permit plankton production for fish culture.

Nutrient enrichment of surface waters has generated concern due to the ecological impacts on both freshwater and estuarine systems (Prior and Johnes, 2002). Nitrogen (N) and phosphorus (P) species are notable characteristic pollutants for eutrophication of natural waters (Halliwell *et al.*, 1996; Zanin *et al.*, 1998; Prior and Johnes, 2002; Withers and Lord, 2002; Omaka, 2007). High concentration of nitrate in drinking water sources can be fatal to humans and animals (Zatar *et al.*, 1999; Monteiro *et al.*, 2003), while elevated concentration of phosphorus may result in fouling of natural water and production of toxic cyanobacteria (Omaka, 2007). Polluted river contains large quantities of nutrients, such as nitrogen and phosphorus (Jens *et al.*, 2000) resulting from the use of commercial fertilizers and pesticides applied to crops in nearby farms and animal and human wastes. These nutrients exist mainly as phosphates and nitrates. Nitrogen is quite mobile in soil and can be leached into ground water or washed into the surface waters, thus becoming hazardous to the environment (Ajibola and Baiyewu, 2004). It was reported (David *et al.*, 1997) that 49% of the inorganic pool in a corn and soybean field in Illinois (USA) was leached through drain tiles and seepage and the concentration of nitrate in the tiles were synchronous with the nearby river.

Nitrate may be hazardous to human health as it is a common cause of methe-haemoglobinemia or blue baby syndrome. Methehaemoglobinemia is potentially fatal, usually in infants under six months (Wolfe and Patz, 2002), as concentrations of methehaemoglobin greater than 50% can quickly lead to coma and death (Knobelock *et al.,* 2000). It has also been observed (Wolfe and Patz, 2002) that nitrate endogenously reduced to nitrite and nitrosation reactions produce carcinogenic N-nitroso compounds and that elevated nitrate concentrations in water are associated with both genotoxic and cytogenetic effects. Nitrate has been implicated in organ cancers. Weyer (2001) reported that a cohort study of over 20,000 women in Iowa found a positive association between nitrate water concentrations and bladder and ovarian cancers. Weyer (2001) further reported that Chinese populations exposed to high concentrations of nitrates in drinking water suggested links between nitrate contamination and stomach and liver cancers. High concentrations of nitrates and phosphates lead to eutrophication of water bodies (Taylor *et al.,* 1997). Such environmental problems are increasingly occurring on a worldwide basis and now affect marine as well as freshwater ecosystems (Jens *et al.,* 2000).

As nitrates and phosphates are added to water bodies, they can lead to overgrowth of plant life, which, in turn, leads to depletion of dissolved oxygen; which may, through their effects on the aquatic life and vegetation, be transmitted to humans (Wolfe and Patz, 2002).

In the last several decades there has been a global increase in harm to fish and other aquatic life (Rabalais, 2002). Sulphate is one of the least toxic anions of which WHO does not have any recommended value for drinking water, but catharsis, dehydration and gastrointestinal irritation have been linked to high sulphate concentrations in drinking water. WHO, therefore, suggests an urgent action by health authorities when sulphate in drinking water exceeds 500 mg/L as this could be considered toxic ((Bertram and Balance, 1996).

One of the major anions in natural waters is of importance due to its cathartic effect in some humans when present in excessive amount. Sulphate may occur due to industrial discharge, contaminant from mines, tanneries, paper mills, and so on. Sulphur dioxide from combustion is converted in the atmosphere to sulphuric acid. The sulphuric acid is then driven by wind and eventually comes down to the earth, either directly (dry precipitation) or with rain (wet precipitation, also referred to as acid rain), many miles from its origin. The presence of sulphate in drinking water can result in noticeable bitter taste.

Nitrate and phosphate levels in River Jakara, Kano State, Nigeria was studied by Dike *et al*. (2010).The lowest mean concentration of phosphate (3.80mg/l) was recorded in April and was significantly different ($p<0.05$) from the other months; higher values were obtained in July and August. Higher mean values of both nutrients in most of the sites during the wet seasons were related to surface run offs containing domestic wastes, and fertilizers applied to farmlands. The nitrate value did not exceed the international maximum permissible limit but the phosphate did. It was recommended that sewers and waste treatment facility is of paramount importance in Kano, while the relevant organ of government should find alternative farmlands for the farmers.

Eruola *et al*. (2015) assessed of nutrient concentration in Sokori River, Southwest Nigeria. The result showed that high nutrient concentrations were established at the middle section of the stream. Sulphate has the highest concentration (3.60 mg/L), followed by phosphate (2.13 mg/L), then nitrate (0.89 mg/L). However, the nutrient concentrations in the stream were below the acceptable limit set by the World Health Organization. Where the nutrients concentration (PO_4 = 5.16 mg/L, SO_4 = 9.78 mg/L, NO_2 = 1.46 mg/L) and the BOD_5 (10.24 mg/L) were highest at the midsection of stream, the DO concentration (3.63 mg/L) was lowest, indicating concentrated aquatic life (macro- and micro-organisms) activity. Nutrient enrichment leads to excessive growth of primary producers as well as heterotrophic bacteria and fungi, which increases the metabolic activities of stream water leading to depletion of dissolved oxygen. The low discharge of the stream and its fairly flat terrain also influenced the metabolic activities in the mid section of the stream, although there was no evidence of accumulation of nutrient leading to eutrophication risk.

Iron (Fe) is an important metal in both plants and animals, especially in the cellular processes (Lovell, 1989). Zinc (Zn) is an enzyme co-factor in several enzyme systems, including carbonic anhyrase found in red blood cells. Zinc is rare because salts of alkaline earth element reduce the toxicity of zinc. Zinc toxicity to fish, according to Alabaster and Lloyds (1982) and Reash (1986), can be greatly influenced by both water hardness and pH. It is one of the earliest known trace metals and a common environmental pollutant, which is widely distributed in the aquatic environment. Cadmium (Cd), on the other hand, is one of the most toxic elements with widespread carcinogenic effects in human (Goering *et al*., 1994). The possible accumulation of Cd is mainly in the kidney and liver. Its high concentrations can lead to chronic kidney dysfunction, inducing cell injury and death, by interfering with calcium regulating in biological systems (Woodworth and Pascoe, 1982).

Environmental pollution is a worldwide problem with heavy metals belonging to the most important category of pollutants (Tabari *et al*., 2010). Heavy metals are classified as metallic; they have relatively high atomic weight and are toxic at low concentrations (Butu and Igiusi, 2013). Heavy metals gain access into the river system from both natural and anthropogenic sources and these get distributed into the water body and sediments in the course of their transport. A catchment area containing mineralized rocks will usually have elevated metal levels, as the trace metal content of river water is normally controlled by the abundance of metals in the rocks of the river's catchment area and by their mobility (Olajire and Imeokparia, 2000). These metals are naturally found in the environment but can also be produced anthropogenically to levels high enough to cause disruptions amongst aquatic species, such as impaired metallic functions, changes in distribution and abundance of population (Elder, 1988).

All heavy metals are potentially harmful to most organisms at some levels of exposure and absorption (Adedeji and Okocha, 2011).The ingestion of heavy metals by fish via food and water may affect the productivity and reproductive capabilities of such fish and ultimately affect the health of man that depends on these organisms as a major sources of protein (Fonge *et al*., 2011). Heavy metals are considered very important and highly toxic pollutants in terrestrial and aquatic environments. Atmospheric and river inputs, dredging spoil, direct discharges, industrial dumping and sewage sludge are some of the important contributors to metal pollution in aquatic environments (Valavanidis and Vlachogianni, 2010). In small quantities, certain heavy metals are nutritionally essential for a healthy life. The persistence of heavy metals in the environment may lead to contamination of aquatic organisms (Oshisanya *et al*., 2011).

Davies *et al*. (2006) reported that sediment concentrated more heavy metals than the water, while periwinkles accumulated more of these metals than the sediment from Elechi Creek in the Niger Delta. This process can potentially lead to the bio-magnification of metals up the food chain, thereby threatening many species (Meria, 1991). According to Ajao (1996), the most obvious effects of these pollutants on the benthos of Lagos lagoon was a decline in the number of individuals in some areas of the lagoon and a total elimination of all benthic species from some grossly polluted sites. A similar study by Don-pedro *et al*. (2004) showed the concentration of the metals detected in the Lagos Lagoon sediment. Water and animal samples collected from sites that received most of the industrial effluents had higher concentration than samples collected from site which received fewer or no industrial effluents.

Ayenimo *et al*. (2005) examined the heavy metal pollutants in Warri River, Nigeria and reported highest values of metals at the effluent zone in each industrial location suggesting that industrial activities are responsible for heavy metal pollution of Warri River. The result of this study emphasized the value of constant monitoring of rivers and water bodies receiving effluents in order to forestall the cumulative effects of the metals in the river which may lead to sublethal consequences in the aquatic fauna and ensuing clinical poisoning to man.

Ololade and Ajayi (2009) did a contamination profile of major rivers along the highways in Ondo State, Nigeria. Results from the study revealed that some of the water quality constituents exceeded the World Health Organization (WHO) standards for drinking water and water meant for other recreational uses. Of the four metals (Cd, Cu, Pb and Zn) determined, only Cd was recorded at toxic level in both water and sediment based on WHO and sediment quality guidelines. Elevated concentrations of some pollutants detected in surface sediments and water are attributable to run-off from agricultural sites and commercial activities. The pH, EC, TDS and PO4 3- of the water displayed significant positive correlation with Pb ($p = 0.05$) and Zn ($p = 0.01$), while Cl- equally showed correlation with all the metals. The index of geo accumulation (*Igeo*) seems to be a more objective tool for assessing contamination. Highest and least microbial loads were 439 × 106 cfu/100 ml and 259 × 106 cfu/100 ml respectively. In the fish, the highest and least bioaccumulation factors (BAF) were recorded for Pb and Cu, respectively. The bioaccumulated heavy metals in the tissues of *C. gariepinus* were above the acceptable limits stipulated by international codes of practice, implying critical pollution in the biota.

Olatunde and Oladele (2012), determined selected heavy metals in inland freshwater of lower River Niger drainage in North Central Nigeria The result showed that the mean concentrations (mg/L) of heavy metals were: Mn, 3.85 ± 0.93; Zn, 2.72 ± 0.57; Cu, 2.17 ± 0.73; Cr, 2.08 ± 1.27; Ni, 0.78 ± 0.12; Cd, 0.05 ± 0.02; Pb, 0.03 ± 0.02. The concentration ranges of the metals were given as: Mn, 1.74 to 8.37 mg/L; Cu, 0.58 to 4.50 mg/L; Cd, 0.02 to 0.13 mg/L were variable and inundating. The variations in heavy metal levels between sampling stations were not significant ($P > 0.05$) with relative standard deviation from 2% for Cd and Pb to 12.7% for Cr. The order of dispersion (2 to 14%) showed that the measured metals were nearly homogenously distributed in the water, with Cr, Mn, Cu and Zn having the highest concentration variations in the water samples. The concentrations of the evaluated heavy metals were within the guideline levels for freshwaters, and did not appear to have significant negative impact on the water quality.

Ideriah *et al*. (2012) investigated on the distribution of heavy metals in water and sediment along Abonnema Shoreline, Nigeria. In their reports the concentrations of metals and their pollution index values in sediment were higher than those in water. The mean metal pollution index values for Cu (0.151±0.140 mg/L), Cd (0.007±0.0005 mg/L), and Cr (0.153±0.059 mg/L) at the high activity area higher than Cu (0.132±0.131 mg/L), Cd (0.002±0.001 mg/L) and Cr (0.122±0.0295 mg/L) at the low activity area, while Zn (1.205±1.036 mg/L) high and (1.478±0.6175 mg/L) low as well as Pb (0.009±0.008 mg/L) high and (0.020±0.0185 mg/L) low showed the reverse. They reported that the difference in metal concentrations and metal pollution index values between sediment and water as well as high and low activity areas were not significant ($P>0.05$). The shoreline was considered critically contaminated, as the concentrations of Cr, Zn and Cu exceeded permissible limits set by Rivers State Ministry of Environment, Federal Environmental Protection Agency and World Health Organization and, therefore, poses serious environmental concern. Low pH, high commercial activities, wastes, tidal and wave actions influenced the concentrations of metals in the area.

Matthews-Amune *et al.* (2012) studied the physico-chemical parameters and heavy metals in River Pompom in Okehi Local Government Area of Kogi State, Nigeria. They compared the results obtained with Nigeria (Federal Environmental Protection Agency, FEPA) and WHO permissible guidelines for drinking water.The concentration of Cu, Ni, Pb, Zn, pH, TDS and conductivity were found to be within the WHO safe limits of drinking water.

Akinsorotan (2013) evaluated heavy metals on wetland biodiversity of Oluwa River (Southwest Nigeria) Palm oil polluted area. The results showed varying levels of heavy metals in the fishes, water, bottom sediment and submerged vegetation (biodiversity). The concentrations of Cr, Mn, Cu, and Ni in the fishes were much higher than the WHO and FEPA maximum permissible limits, while the concentrations of Zn and Pb were lower than the standards. Besides pH; chemical oxygen demand (COD), biological oxygen demand (BOD), conductivity and temperature (T^oC) of POME were critical for the survival of aquatic organisms. Water pH, dissolved oxygen (DO), COD, BOD and T^oC were most critical ($P<0.05$) at ZA and improved along ZC, while there was no effect in ZD. There were positively high correlation between DO/pH, COD/pH, BOD/pH, conductivity/pH, T^oC/pH/COD/BOD and conductivity. Negative correlation also existed between COD/DO, BOD/DO, conductivity/DO and T^oC/DO. Regression analyses indicated high coefficient of determination R2 between the water parameters and low R2 between DO/T^oC, which had equation as DO = 72.0 -2.45ToC. Biodiversity mineral concentration was excessively high due to POME pollution, indicating possible subtoxic effect. The results suggest that the lake is polluted with Cr, Mn, Cu and Ni and the consumption of fishes of the lake is life.Threatening to man. This is a confirmation that fish in River Oluwa within the polluted areas must have either migrated out of the zones or died due to POME toxicity.

Ewa *et al.* (2013) worked on the seasonal variations in heavy metal status of the Calabar River, Cross River State, Nigeria. The results showed that the concentrations of iron (Fe), zinc (Zn), manganese (Mn), copper (Cu), lead (Pb) and total hydrocarbon (THC) in the dry and wet seasons were low and within the WHO and FEPA tolerable limits The proportion of copper (Cr), cadmium (Cd), barium (B), nickel (Ni), vanadium (V) and mercury (M) were not detected, indicating the absence of these metals in the sampled stations. The low levels of heavy metal contents across the sampled stations showed that they were not polluted and, as such, suitable for aquatic live.The independent samples test result indicated seasonal difference in the proportion of Fe, Zn, Cu, Pb and THC ($p<0.01$). The study identified run-off from industrial, agricultural and residential areas as sources of heavy metal pollution in the wet season and effluent discharges from industrial and municipal wastes as major sources of pollution of the Calabar River in the dry season.

Ushurhe (2014) assesserd heavy metals and the prevalence of water-borne diseases in rural communities located along River Ase in southern Nigeria. He discovered that parameters such as calcium, sodium, potassium, lead and zinc were within the WHO (2010) and NIS (2007) threshold for drinking water quality. Magnesium and iron were above the recommended threshold for drinking water quality by the WHO (2010) and NIS (2007). The study also discovered that the prevalence of water-borne diseases was influenced by the surface water quality at $R2 = 0.510$ ($P > 0.05$).

Tyokumbur (2016) studied the bioaccumulation of heavy metals in the fish species *Sarotherodon melanotheron* from Alaro stream ecosystem in Ibadan. The results showed that the mean Ni and Se in the organs of *S. melanotheron* were above the World Health Organization (WHO) permissible limit guideline standard of 0.07 and 0.04ppm, respectively. The mean Zn in the organs of *S.melanotheron* did not exceed the permissible limit of 1000ppm. It can be concluded that there is need for moderation in the consumption of fish obtained from Alaro Stream in Ibadan through monitoring of daily intakes even though some heavy metals that have physiological relevance have been found to exceed the recommended permissible limits since there is no massive fisheries output from the aquatic ecosystem that forms a major part of the diet in the populace.

2.2 Plankton groups

Plankton refers to those microscopic aquatic organisms having little or no resistance to currents and living free-floating or suspended in open or pelagic waters (Miller, 2005). Cosmopolitan distribution and the many primitive types of the plankton commonly indicate that their origin is ancient (Mathivanan *et al.*, 2007). Planktonic organisms are ideal subject for theoretical and experimental population ecology due to several favourable features, such as small size, short generation time and relatively homogenous habits (Romhaupt, 2000).

There are many studies on the dynamics of plankton of lakes, large rivers and streams in Nigeria. These include the works of Green (1960), on River Sokoto; Bidwell and Clarke (1977), on Lake Kainji; Donner and Adeniji (1977), on Lake Kainji; Khan and Ejike (1984), on Jos Plateau Reservoir; Jeje and Fernando (1992), on the middle Niger- Sokoto Basin; and Segers (1993), on some lakes in the flood plain of the River Niger. Others are Ovie and Adeniji (1994), on Shiroro Lake; Ovie (1997), on Jebba Lake; Mustapha (2000), on temporary pond in Ilorin; Bala and Bolorunduro (2011), on Sabke Reservoir; Ovie *et al.* (2011), on Omi Dam; Mohammad and Saminu (2012), on Salanta River Kano; Ikhuoriah *et al*. (2015), on River Ossiomo; Akaahan *et al*. (2016), on River Benue; and Wokoma *et al*. (2016), on Sombreiro River, Niger Delta.

Investigations into the physico-chemical parameters of Nigerian freshwater bodies especially in the southwest include those of Egborge (1970), on River Osun; Adebisi (1981), on Upper Ogun River; Oke (1998), on Owena Reservoir; Oben (2000), on three man-made lakes in Ibadan; Akin-Oriola (2003), on Ogunpa and Ona Rivers; Ikenweiwe and Otubusin (2005), on Eleyele Reservoir; Ayoade *et al.* (2006), which is comparative study on the physico-chemical features of Oyan and Asejire Lakes; Olaniyan (2010), on Owena River and Reservoir; and Adeogun and Fafioye (2011), on Awba Stream and Reservoir.

Several works have been done on the diversity and abundance of freshwater species in Ondo State. Some of them are Oke (1990), Olaleye and Adedeji (2005), Fapohunda and Godstate (2007), Olaniyan (2010), Adekunle *et al.* (2010), Akinwumi *et al.* (2011) and Akinsorotan (2013). A checklist of various prawn families has been documented on Igbokoda River (Adebola and Olaniyan, 2012). Work has also been done on the types of fishing gears commonly used by the artisanal fishermen in the coastal Area of Ondo State (Akinwumi *et al.*, 2011). Past works on the artisanal fisheries and dredging activities in the coastal areas of Igbokoda include Steven and Itolima (2009), Akinwumi *et al.* (2011), Tomola (2012), Olawusi-Peters *et al*. (2015) and Alhaji *et al.* (2015).

There studies on the physico-chemical, water quality and plankton in Oluwa Rivers. Olaleye and Adedeji (2005) worked on planktonic and water quality of River Oluwa, Ondo State. They carried out sampling on plankton for six months between (April to September, 2003). Akinsorotan (2013) worked on heavy metals on wetland biodiversity of Oluwa River, Ayandiran *et al*.(2014) focused on microbial assessment and prevalence of antibiotic resistance in polluted Oluwa River, Ayandiran and Dahunsi (2016) did toxicological assessment of fish (*Clarias gariepinus*) from bitumen-polluted River Oluwa.

The phytoplankton in a reservoir is an important biological indicator of the water quality. They play pivotal roles as primary producers and the basis of the food chain in open water. Some species can be harmful to human and other vertebrates by releasing toxic substances (hepatoxin or neurotoxin) into the water. Blue-green algae can degrade recreational value of surface waters, especially by forming thick surface scum. This can cause deoxygenation of the water, leading to fish death (Whitton and Patts, 2000). In many countries, water management is threatened with extensive and persistent noxious blooms of blue-green in surface and near surface mesotrophic and eutrophic waters (Whitton and Patts, 2000). Cyanobacteria blooms lead to some of the most ominous symptoms of water quality degradation, including bottom water anoxia and hypoxia, odour, taste and toxicity problems, destruction of the aesthetic and recreational values of water and structural shifts in plankton communities (Whitton and Patts, 2000). Algae and other aquatic micro-organisms are usually quick to be opportunistic species as they respond quickly to minor perturbation in the physical conditions of their environment (Cole, 1975). Diatoms in water quality analysis is considered adequate as long as the water ranges from oligotrophic to eutrophic and oligosaprobic to strong mesosaprobic (Cole, 1975). Dinoflagellates seem to flourish after diatoms have impoverished the water. This implies that diatom blooms might have reduced one or more of inorganic nutrients to a level favourable for dinoflagellates (Nwankwo, 1995).

Ovie (1993) investigated the composition, seasonal variation and biomass of zooplankton in a small waste water Lagoon. The zooplankton community was very poor, as only four species were identified. These include cyclopoid species *Moina* sp, *Branchionus calyciflorus, Branchionus falcatus and Asplanchna* sp. In terms of numerical abundance, the rotifers dominated the community, with *B. calyciflorus* accounting for 60.9% and 65% in each of the two stations sampled.

Aguigwo (1997) reported the seasonal variability in the water quality parameters, the nutrient levels and plankton abundance of Nnamdi Azikwe University stream, Awka, Anambra State. *Daphnia* and *Macrocyclops* species ranked highest among the zooplankton. Segers (1993) reported a total of 207 species of Monogont rotifers in thirteen lakes in the floodsplains of River Niger, Nigeria, three of which were endemic to Central/West Africa.

While investigating zooplankton asssociations and environmental factors in Ogunpa and Ona Rivers, Nigeria, Akin-Oriola (2003) observed that environmental factors in Ogunpa and Ona Rivers-include buffering capacity, trace metal ions, pH-temperature/transparency-were primarily influenced by rainfall. The dominance of the Rotifera in both rivers was attributed to their short developmental rate and fish predation on larger zooplankton.Two groups of associations were identified in each river a commonly occurring species group exhibiting strong homogenous correlation with environmental factors and a predominant group exhibiting weak correlation with environmental factors and whose abundance/composition may be defined by biotic factors.

Olaleye and Adedeji (2005) studied the water and planktonic quality of a palm oil effluent impacted river in Ondo State, Nigeria. They reported that the dissolved oxygen content of the water rarely went below 3.0 mg L^{-1} and rarely above 7.0 mg L^{-1} irrespective of sampling location. Quantitatively, the levels of Fe and Cu, with mean concentration ranging between 3.07±1.58 and 10.35±3.33 mg L^{-1}, were the major elements in the water sample, while Na, K, Ca, Mg, with mean concentrations between 1.05±0.02 and 4.10±1.65 mg L^{-1}, were the minor elements. Irrespective of the site of sample collection on the river, the concentrations of Cr, Ni, Pb and P (<1.0 mg L^{-1}) occurred in trace amounts.

The study of the plankton and benthos of Ekole River in Bayelsa State, Nigeria by Olaifa and Leilei (2007) identified forty-three and forty-seven species of phytoplankton that belonged to five families in the dry and rainy seasons, respectively. Bacillariophyceae dominated the phytoplankton, while the rotifers dominated the zooplankton species.

The physico-chemical parameters and plankton community of Egbe Reservoir, Ekiti State, Nigeria was studied by Edward and Ugwumba (2010). Diatoms dominated the phytoplankton community, making up 27.2% of the total plankton abundance by number, while the Rotifera dominated the zooplankton, contributing 12.6% of the total plankton abundance. Diatoms showed the highest diversity and were most evenly distributed. The pollution indicator phytoplankton observed included *Microcystics, Anabaena, Synedra, Melosira, Euglena, Phacus* and *Lepocinclis*.

Adekunle *et al.* (2010) examined response of four phytoplankton species found in some sectors of Nigerian coastal waters to crude oil in controlled ecosystem.The four phytoplankton, namely, *Thalassionema frauenfeldii*, *Cosnodiscus centralis, Odontella mobiliensis* and *Ceratium trichoceros,* were subjected to toxicity of crude oil concentration in the range of 6.0 to 50mg/L. In summary, resilience to habitat change from marine environment to laboratory conditions decreased in the order of *C. centralis* > *T.frauenfeldii* >*O.mobiliensis* > *C.trichoceros* but, in relation to crude oil toxicity within 24-h contact time, vulnerability decreased in the order *T.frauenfeldii* > *O.mobiliensis* > *C.centralis* > *T.trichoceros* for the four species. The general reduction of phytoplankton population by the added crude oil was attributed to factors such as, inhibition of food consumption, decrease in cell size, cell number and bio-volume. Others were inhibition of photosynthesis, primary production and respiration mechanisms owing to the presence of hydrocarbons. However, this seemed as a potential danger to phytoplankton species biodiversity conservation.

The diversity and seasonal variation of zooplankton in Okhuo River, a tropical forest river in Edo State, Nigeria was studied by Imoobe (2011). The result of the study indicated that the water was not degraded. The species richness as well as evenness and diversity of the zooplankton in the study area were high and typical of a tropical freshwater river. There was a total of 51 species, made up of 24 rotifers, 15 cladocerans, and 12 copepods and their developing stages in the following order of dominance: Rotifera>Cladocera>Copepoda.

In Ajuonu *et al*. (2011) the abundance and distribution of plankton species in the Bonny Estuary, Nigeria, were investigated. A total population of 2846 plankton was identified, comprising 2172 phytoplankton and 674 zooplankton measured in cells per litre x 10^6. Diatom was the highest in abundance and distribution constituting 48.4% of the entire phytoplankton community and occurring in all the seven stations studied.

Ezekiel *et al*. (2011) studied zooplankton species composition and abundance in Sombreiro River, Niger Delta, Nigeria, They recorded a total of seventeen (17) species belonging to six (6) taxonomic groups from Sombreiro River. The groups Cladocera and Copepoda were represented by five species each consisting of 29.4% by composition. These were followed by three species of Protozoa (17.6%), two species of Rotifera (11.8%), Decapod crustacean (5.9%) and Euphasiacea (5.9%), one specie each. Copepoda was the highest, 46.5%. This was followed by Cladocera (23.3%). The others were Protozoa (11.2%), Euphasiacea (9.6%), Rotifera (7.9%) and Decapod Crustacean (1.5%). The low zooplankton diversity observed in this study is common in tropical waters.

Water quality and phytoplankton of Salanta River Kano, Nigeria were investigated by Mohammad *et al*. (2012). They found that phytoplankton of Salanta River was dominated by the Chlorophyceae both in terms of number of species and number of individuals. The abundance follows the order Chlorophyceae > Bacillariophyceae > Cyanophyceae > Euglenophyceae > Dinophyceae. The phytoplankton composition indicated the increased influence of pollution-tolerant taxa like the Cyanophyceae and Euglenophyceae.The species diversity index showed that the quality of water in Salanta River was undergoing deterioration.

Ogbuagu and Ayoade (2012) studied the seasonal dynamics in plankton abundance and diversity of a freshwater body in Etche, Nigeria. They reported that phytoplankton comprised 43 genera and a mean density of 1859 cells/ml. The dominant phytoplankton was the Bacillariophyceae (53.25%), followed by Cyanophyceae (21.25%), Chlorophyceae (10.33%), Chrysophyceae (4.84%), Pyrrophyceae (4.57%), Xanthophyceae (3.39%) and Euglenophyceae (2.42%). Zooplankton was made up of 7 taxa and a mean density of 433 organisms/ml. The order of dominance was Cladocera (25.87%), Copepoda (20.55%), Protozoans (19.17%), Rotifera (18.71%), fish eggs and larvae (9.24%), Crab larvae (4.62%), and Beetle larvae (0.69%). Phytoplankton species showed oscillating as well as stable seasonal patterns of occurrence. Higher Margalef's diversities were recorded in the dry season (3.655; 57% and 1.273; 61%) than in the wet season (2.732; 43% and 0.810; 39%) for phytoplankton and zooplankton biotypes, respectively.Phytoplankton and zooplankton taxa each showed significant numerical differences between the 2007/2008 and 2008/2009 sampling periods [F(14.39)>Fcrit (4.30) and F (29.08)> Fcrit (4.23), respectively] at $P<0.05$. The observed seasonal peaking in abundance could be attributed to periods of concentration of nutrients and stability in growth factors of plankton biotypes.

In phytoplankton species composition and abundance of Ogun River, Abeokuta, southwestern Nigeria,as studied by Dimowo (2013), Cyanophyta was the highest in abundance, consisting of 41%, while the lowest in abundance was P*yrrophyta* consisting of 1.5%. The low nature of phytoplankton abundance and diversity observed in this study was as a result of polluted nature of the water due to the anthropogenic activities. A total of 41 species of phytoplankton and 16 zooplankton species from 5 classes were recorded. Zooplankton was dominated by Cladocera throughout the study period while phytoplankton was dominated by blue green algae (Cyanophyta or Cyanobacteria). He observed that for the first four months of the study, the dissolved oxygen values were very critically low, that is, less than 5 mg/l. This could have been caused by pollution due to the anthropogenic activities carried out around the water resource.

Ewa *et al*. (2013) studied distribution of phytoplankton in the industrial area of Calabar River, Nigeria. The result showed that a total of 35 phytoplankton species and 35 taxa representing 6 families were recorded. *Chlorophyceae* (green algae) and *Bacillariophyceae* (diatom) were the most abundant phytoplankton families, constituting 57.2% of the total phytoplankton taxa density; the least encountered families were *Cyanophyceae* (blue-green algae), *Chrysophyceae* and *Xanthophyceae*, each with 8.6%.
In his examination of the physico-chemical characteristics, plankton and macrobenthos of Imo River in Etche Local Government Area, Rivers State, Nigeria, reported that bacillariophyceae (53.3%) was the most abundant of the seven families of phytoplankton encountered. Pollution indicator taxa were blue-green algae (*Anabaena gracilis, Oscillatoria tenuis*) diatom (*Cyclotella kutzingiana*) euglenoid (*Euglena gracilis*) and green algae (*Spirogyra* sp).

Mandu and Imaobong (2015) focused on physico-chemical factors influencing zooplankton community structure of a tropical river, in Niger Delta, Nigeria. A total of 45 species of zooplankton in eight (8) taxonomic groups were collected. Crustacea had the highest percentage of 48.0% in the total zooplankton composition in Station I. In the other two stations, Crustaceans contributed 30.0% and 33.3% in Stations II and III, respectively. Other taxonomic groups present in this study included Rotifera, which contributed 20.0%, 50.0% and 55.6% in Stations I, II and III, respectively. Mollusca in Station I contributed 8.0% of the species composition in this station but was absent in Stations II and III. Protozoa, which contributed 9.1% of the total zooplankton composition in Station I, was not recorded in the other two stations. A total percentage of 10.0% and 11.1% were recorded for Ciliates in Stations II and III, in that order.

In the study by Ikhuoriah *et al*. (2015) on zooplankton communities of the River Ossiomo, Ologbo, Niger Delta, Nigeria, a total of 42 taxa were identified, namely 11 species of cladocerans, 6 copepods and 5 rotifers, in the following order of dominance: copepoda > cladocera > rotifera. A total zooplankton population of 1330 individuals was recorded during the study period. Copepods and cladocera represented the predominant species (51.1% and 43.6% of the total zooplankton community, respectively) followed by rofiters (5.3%). Copepods and cladocerans were dominated by both cyclopoid (51.1%) and chydorids (27.8%), respectively. The dominant copepod and cladocera species were *Thermocyclops neglectus* and *Alona eximia*, representing 33.1% and 15.8% of the total zooplankton, respectively. The calculated diversity indices indicated that Station 1 was more diverse, followed by Station 3, while zooplankton species in Station 2 were least diverse. Community composition was similar at both stations 2 and 3, but varied seasonally across the three stations. Higher species number and density was found during the wet season, with a trend of declining proportion towards the dry months.

The phytoplankton species composition and abundance in the lower Sombreiro River, Niger Delta, Nigeria was studied by Wokoma *et al*. (2016). Phytoplankton samples were collected across 10 sampling stations and analyzed in the laboratory following standard methods. One hundred and forty (140) species belonging to 88 genera and 7 classes were recorded. Bacillariophyta was the most dominant class, with 69 species (49.29%), followed by Cyanophyta, with 28 species (20.0%), Chlorophyta, with 21 species (15%), Chrysophyta with 7 species (5.0%), Euglenophyta and Dinophyta with 6 species each (4.29%) and Xanthophyta with 3 species (2.14%). The most occurring genera were Cyclotella, Niztchia and Rhizosolenia, with 7 and 6 species each, respectively. In terms of phytoplankton class abundance, Bacillariophyta dominated the phytoplankton community with 524,680 individuals (77.42%), followed by Cyanophyta with 87,720 individuals (12.94%), Chlorophyta had 50240 individuals (10.04%).

Anyinkeng *et al*. (2016) studied phytoplankton diversity and abundance in water bodies in Buea community in relation to anthropogenic activities and reported a total of 66 phytoplankton belonging to 44 genera, 34 families and six phyla. There were 52, 32, 11 and 38 species recorded for car wash, municipal waste, Car wash + municipal wastes and drinking water sources, respectively. Nine species cut across the four categories, while 22, 3 and 2 species were unique to car wash, municipal wastes and drinking water sources, respectively. *Nitzschia* and *Chlorella* were the most abundant genera in the different water sources. While phytoplankton abundance correlated positively with nutrients, diversity correlated negatively. The highest and lowest organic pollution indices (24 and 8, respectively), were recorded in the drinking water category. Car wash activity did not only encourage the growth and diversity of algae, but also influenced the establishment of some species that are harmful. Human activities in and around water sources in Buea are degrading water quality, putting the population at risk. There is, therefore, the need to protect the water resources of Buea.

The study of Wokoma (2016) focused on zooplankton species composition and abundance in the brackish water axis of Sombreiro River, Niger Delta. Triplicate samples were collected at each station using the filtration technique. Seventy-nine (79) species of zooplankton belonging to four classes were encountered throughout the study, Rotifera had the highest number of species (26), followed by Protozoa, with 20 species and Copeopda and Cladocera, with 19 and 14 species, respectively. Protozoa was the most dominant class in terms of total abundance, accounting for 51% (31,040) of the total number of the enumerated, followed, respectively, by Rotifera, Copepoda and Cladocera, with 24% (14,440), 14% (8880) and 11% (6640). The most encountered zooplankton species was the Protozoa Difflugia constricta, with 6,520 individuals, representing 21.50% of all the Protozoa encountered in the investigation. *Parvocalanus crassirostris*, which accounted for 19.67% and followed closely by *Mytilina ventralis* and *Epiphanies clavuletus* accounting for 10.89% each, were the most abundant Rotiferans. Four species of Copepoda *Neudiaptomus incongruens*, *N. tubgkwariensis*, *Limnothemia sinensis* and *Acantia tosa* were the most encountered Copepods, each accounting for 11.73% of the total number. Chydorus barroisi and Alonella exisa were the most common Cladocerans observed in this study. Variations in zooplankton diversity and abundance were contingent upon the place and time of sampling.

2.3 Benthic macro-invertebrates

Benthic organisms have been defined as those living in or on the substratum of lakes, streams, estuaries and marine waters (APHA, 1985). Benthic macro-invertebrates play vital roles in the circulation and recirculation of nutrients in aquatic environments. They constitute the link between the unavailable nutrients in detritus and useful protein materials in fish (Idowu and Ugwumba, 2005). Most benthic animals feed on debris that settle at the bottom of the water and, in turn, serve as food for a wide range of fishes (Ajao and Fagade, 2002). They also accelerate breakdown of the decaying organic matter into simpler inorganic forms, such as phosphates and nitrates (Gallep *et al*., 1978; Ravera, 2000; Ansa, 2005). The distribution of benthic macro-invertebrates fauna is determined by a number of factors, such as the physical nature of the substratum, depth, nutritive content, degree of stability and oxygen content of the water body. Benthic macro-invertebrates are highly vulnerable and susceptible to environmental stress resulting from pollution and other changes since they have poor mobility, while some are completely sessile (Ajao and Fagade, 2002; Olomukoro and Egborge, 2003; Ikomi *et al*., 2005).

Benthic macro-invertebratesare relatively sedentary, possess ability to tolerate stress and have comparatively long life. These enable their usage for water quality assessment at a single site over a long period of time (Odiete, 1999). Although species composition of plankton community can depict the health status of a water body, distribution of planktonic organisms due to their freely floating nature are greatly influenced by the water movement, especially in a fast-flowing water body (Nwankwo *et al*., 2003). Thus, benthic macro-invertebrates, which are relatively either sedentary or actively mobile, could be considered better than plankton groups for pollution study. The use of bottom dwelling invertebrates for biological assessment of the quality of freshwater is already in practice in Europe, Asia, North America and Nigeria (Odiete, 1999).

Benthic species, especially polychaetes, as indicators of varying degrees of pollution aided the evaluation of pollution in the Los Angeles Long Beach Harbor by Reish (1986). The result showed that grossly polluted zones are riched in polychaetes population, which served as sentinel of pollution. Miserendino and Pizzolon (1999) and Chessman (2003) have classified the families Lumbriculidae, Tubificidae and Naididae (all oligochaetes) as high pollution tolerant species indicative of poor water quality and assigned them the lowest sensitivity grade in the biotic index of macrobenthic invertebrates. Goodherham and Tsyrlin (2002) view macro-invertebrates as useful and convenient indicators of ecological health of a water body or river. As sedentary macro-invertebrate organisms, bivalves are well known for their biological features of concentrating heavy metals and other substances in their tissues. Owing to their exceptional vulnerability to water pollution, bivalves have been used in bio-monitoring studies of heavy metal pollution in aquatic ecosystems (Blassco *et al.*, 1999; Gundaker, 2000; Bonneris *et al.*, 2005). However, they have developed mechanisms to protect themselves from toxic effects of heavy metals. Some bivalves can neutralize the toxicity of heavy metals and store toxic materials at cellular levels of the body tissues (Viarengo, 1995). Bivalves can accumulate Cd in their tissues at levels up to 100,000 times higher than the levels observed in the water in which they live (Avelar *et al.*, 2000).

The work done by Sikoki and Zabbey (2006) on benthic community of the middle reaches of Imo River also showed the macro-invertebrate assemblage of the river. Adakole and Annune (2003) carried out a survey of benthic macro invertebrate fauna of Bindare stream, Zaria, while Emere and Nasiru (2007) conducted a survey on benthic macro-invertebrate fauna of Barnawa stream, Kaduna, in northern Nigeria.These authors contributed immensely to the checklists of the macrobenthic taxa in Nigeria.

The total number of macro-invertebrate fauna of tropical ecosystem in Nigeria has been documented. Ogbeibu (2001) recorded twenty-six taxa of Diptera in Okomu forest ponds in southern Nigeria. Adakole and Annune (2003) and Olomukoro (2007) reported eighty-eight and thirty-seven taxa in an urban stream in Zaria and Warri River, Nigeria. Ogunwenmo and Osuala (2004) reported six species belonging to the Phyla Annelida, Mollusca and Arthropoda in an artificial pond in Lagos.

Victor and Ogbeibu (1986) studied decolonisation of macrobenthic invertebrates in a Nigeria stream after pesticide treatment and associated disruption.They reported that Chironomidae, Baetidae and Naididae were stable during the predistruption phase. The disruption severely reduced the standing crops and the diversity of macro-benthos. The recovery of the habitat was rapid iin spite of low diversity; high densities of invertebrates were recorded in the decolonisation phase. Naideds and chironomids were the most successful recolonisers, while other groups recovered slowly.

Oke (1990) also worked on the limnology and macrobenthos of Owena Reservoir in Ondo State. The author found that the macrobenthos of Owena Reservoir was dominated by *Chaoborid* larva and *Biomphalaria pffeipferi*.

Ogbeibu and Egborge (1995) conducted hydro-biological studies of water bodies in the Okomu Forest Reserve (Sanctuary) in southern Nigeria. Distribution and diversity of the macrobenthic fauna recorded 214 invertebrate taxa. The dominant taxonomic groups were Rotifera, Oligochaeta, Cladocera, Copepoda, Odonata and Diptera. *Brachionus patulus var, Macracanthus, Euchlaris proxima, Lecane hostata, Monostyla unguitata africana, Trichocerca macera, Vonoyella (rotifer)*; *Alona hardingi, Pleuroxus letourneuxi* and *Macrothrix triseralis (*Cladocera*)* were recorded for the first time in Nigeria. Certain groups showed remarkable discontinuity in distribution. Decapoda, Trichoptera, Plecoptera and Simulium were confined to the streams, while Huridinea, Gastropoda, Stratiomyid and Culicid dipterans were restricted to the ponds.

Chukwu and Nwankwo (2003) conducted a study on the impact of land based pollution on the hydrochemistry and macrobenthic community of a tropical West African creek. The macrobenthic fauna abundance and composition were low and the more dominant taxonomic groups were annelids. Fauna similarities upstream were significantly different ($p<0.01$) from stations downstream. The low fauna abundance and diversity were attributed to stress imposed by effluents from land-based sources as well as substrate instability.

A study was carried out by Arimoro *et al*. (2007a) on the ecology and abundance of Oligochaetes as indicators of organic pollution in an urban stream in Southern, Nigeria. A total of 14 species of oligochaetes were identified with 13 (92.8%) occurring in the impacted station. *Tubifex, Dero linmosa* and *Nais communis* were the dominant taxa, less frequent were *Stylaria, Aelosoma* and *Lumbriculus variegates* (Muller). The density of the different taxonomic groups differed among the stations with the impacted station accounting for the greatest abundance and diversity of the organisms. The organic wastes from the abattoir not only altered the water chemistry but also stimulated the abundance of oligochaete worms.

Christopher *et al*. (2007) investigated on use of benthic macro-invertebrate indices to assess aquatic health in a mixed-landuse watershed. Seven family-level metrics were determined from benthic macro-invertebrate samples collected monthly across four different landuse sites in the Cazenovia creek watershed in western New York. The biological impairment designation was highest in the summer at the suburban and agricultural sites. Coefficients of variation were considerably greater at the lower stream order sites.The metrics that were most appropriate and effective in assessing benthic assemblage health in the study were richnes, percentage model affinity, family-level biotic index, and Ephemeroptera-Plecoptera-Trichoptera index. These indices correlated with a low amount of redundancy in a Pearson matrix, had significant discriminatory power in assessing biological impairments across sites and had low variation within site and seasons.

Macro-invertebrates as indicators of the water quality of an urbanized stream, Kaduna, Nigeria were studied by Emere and Nasiru, (2007). A total of 1,304 macro-invertebrates were recovered, and twenty taxa were recorded. The presence of low densities of pollution tolerant macro-invertebrate groups, the deteriorating water quality and the physico-chemical conditions of the water during the dry season months reflected of organic pollution stress caused by decomposing domestic refuse and inorganic fertilizer washed into the stream by irrigation.

George *et al*. (2009) examined on the benthic invertebrate fauna and physico-chemical parameters in Okpoka Creek sediments, Niger Delta, Nigeria. A total of nineteen (19) species, six (6) classes and twelve (12) families were found in the Okpoka creek during the study. A positive relationship existed between salinity and *Notomastus latreila*, biochemical oxygen demand exhibited positive relationship with *Ophidonais serpentine, Eunice harassi, Glycera capitata, Nereis diversicolor, Nereis pelage, Nephthys hombergi, Nototropis laterila, Marphysa sanguine, Glycera convolute, Nereis diversicolor, Nereis pelagea, Nephthys hombergi, Nototropis swamidami* and *Tellina nymphalis.*

Roland (2010) carried out an inventory of the benthic macro-fauna of Epe Lagoon, southwest Nigeria. He identified forty-five species, comprising sixteen species of Arthropoda, twelve species of Mollusca, eleven species of Annelida, two species each of Nemertina and Porifera, and one species each of Chordata and Echinodermata were listed. All the species recorded are endemic to the West African coastal waters.

Adeogun and Fafioye (2011) studied the impact of effluents on water quality and benthic macro-invertebrate fauna of Awba Stream and Resevoir. The abundance of these species and the physico-chemical parameters at the various stations were significantly different ($p<0.05$). The values obtained for the physico-chemical parameters and correlation values with the tested organisms indicated that changes in community structure had occurred as a result of changes in prevailing conditions in the habitat. The levels of trace metals (Zn, Mn, Cu, Pb, Ni and Cr) were analysed and there was no statistically significant difference in the values recorded between stations. The levels of these metals, except zinc and manganese, fell within the limits specified by USEPA, as values recorded for zinc and manganese were higher than the acceptable limits specified by USEPA.

Macro-invertebrate fauna of Tropical Southern Reservoir, Ekiti State, Nigeria was studied by Edward and Ugwumba (2011). Eighteen taxa of macro-invertebrates in two phyla of Mollusca and Arthropoda were identified. Gastropods had the highest numerical abundance (41.8%), Odonata and Ephemeroptera (Insect) had the lowest diversity and numerical abundance (0.4% and 6.3%, respectively). The gastropod, *Melanoides tuberculanta*, which was the most abundant macro-invertebrate, is an indicator of polluted water. This suggests that the reservoir may be tending towards organic pollution. This is further confirmed by the low abundance of Ephemeroptera and Odonata which are indicators of clean water.

An assessment of the environmental conditions and benthic macro-invertebrate communities in two coastal lagoons in Ghana was done byAggrey-Fynn *et al*. (2011).The insects encountered belonged to the orders Diptera and Trichoptera, while the worms present included oligochaetes, leeches and polycheates, with hermit crab and Penaeus shrimps being rare. The conclusion was that the freshwater Amansuri Lagoon supports richer and more diverse macrobenthic fauna than the brackish water Domini Lagoon. Future reduction in invertebrate composition, richness and diversity would imply a change or deterioration in environmental conditions of the lagoon.

Abowei et *al*. (2012) investigated the effects of water pollution on benthic macro fauna species composition in Koluama Area, Niger Delta Area, Nigeria. They recorded a total of 383 species belonging to four major taxonomic groups. These groupings and their percentage contributions to the total macro-benthic collection were Crustaceans (48%), Polychaetes (35%) and Gastropod Moluscs (12%) Bivalve Molluscs (5%). Twenty-eight species belonging to 14 families, 6 classes and 3 phyla of macro-invertebrates were recorded in the study area. The faunal composition was dominated by polychates with 13 species from 7 families (46.4%) in terms of the species richness. Oligochaeta had 2 families and 7 species (25%), Bivalvia had 1 family and 3 species (10.7%). Crustacea was represented by 2 families and 2 species, Gastropoda had one family and 2 species and insecta had 1 family and one species constituting 7.2%, 7.2% and 3.6% of the species, richness respectively.`

In to Composition, distribution and diversity of benthic macro-invertebrates of Ona River, South-west, Nigeria engaged the attention of Andem, *et al*. (2012). Three phyla of macro-benthic invertebrates were encountered in the river. They were Arthropoda, represented by three genera Chironomus (Diptera), Progomphus (Odonata) and Isoperla (Plecoptera); Annelida, represented by only one genus Tubifex (Oligochaeta); and Mollusca, represented by six genera of gastropods with four identified species, namely, Indoplanobis executus, Melanoides tuberculata, Bulinus globosus, Biomphalaria pfferferi, Lymnaea species and Physa species. Chironomus larvae dominated the macrobenthic invertebrates, with a total relative abundance of 59.1% while Isoperla larvae were the least abundant (0.19%) by number. All the macrobenthic invertebrates recorded were pollution-tolerant/clean water species.

A study was carried out by Esenowo (2013) on the physico-chemical characteristics, plankton, macrobenthos and fish fauna of Majidun River, Lagos State, Nigeria. Twenty species of macrobenthos, including pollution-tolerant taxa *Chironomus,* insect larva and *Melanoides tuberculata* (gastropods) were recoreded. Five families of phytoplankton were encountered Bacillariophyceae dominated, with 71.6% of the total number. The pollution-indicator genera recorded were *Navicula, Euglena, Microcystis, Closterium, Oscillatoria, Merismopedia* and *Synedra.* Zooplankton was dominated by rotifers (53.0%) and Copepoda (44.1%). Fish species were encountered, with *Tilapia zillii* (11.4%) dominating. The prevailing conditions revealed thet Majidun River was polluted.

Akindele and Liadi (2014) conducted a research on diversity and response of benthic macro-invertebrates to natural and induced environmental stresses in Aiba Stream, Iwo, southwestern Nigeria. Ninteen taxa of macro-invertebrates were recorded comprising three phyla, four classes and seventeen families,were recorded. The overall Shannon-Weiner diversity and Margalef indices of the stream indicated that the stream was organically polluted,as evidenced by the presence of some pollution-tolerant macro-invertebrates (for example Families Stratiomyidae, Nepidae, Chironomidae and Syrphidae).

An ecological assessment of brewery effluent impact on the macrobenthic invertebrates of Ikpoba River, Edo State, Nigeria was conducted by Albert *et al*. (2016). A total of seven macrobenthic invertebrate species consisting of 803 individuals were identified. These included four species of Diptera and one species each for Hemiptera, Lepidoptera, and Lepidoptera. Among the macrobenthos, Diptera dominated, contributing 61.39% of the total density occurrence, while Lumbriculida, Lepidoptera and Hemiptera, contributed of 33.25%, 3.23% and 0.13, respectively. The highest total number of taxa was observed in Station 1 with a total of seven taxa, with 256 individuals; whereas, Station 2 and Station 3 each hads a total of four taxa, with 71 and 488 individuals, respectively. The changes observed in some of the macrobenthic assemblages of Ikpoba River, notably increased indicating inefficient effluent treatment in the breweries. This study also showed that the quality of receiving water was influenced significantly by the chemical composition of effluents discharged into the river.

Akaahan *et al*. (2016) studied on the variation of benthic fauna composition in River Benue at Makurdi, Benue State, Nigeria. The result of the sediment showed that a total of 4,451 macrobenthic fauna individuals comprising 4 phyla and 21 taxa were obtained. More individuals were recorded during the dry seasons as compared to the rainy seasons. Benue Brewery (570, Individuals) and Mikap Nigeria Ltd (649 Individuals) recorded low population as compared to the other locations: Coca cola (1,177 Individuals), Wadata Market (1,043 Individuals) and Wurukum Abattoir (1,012 Individuals). Arthropoda had the highest population of individuals as compared to Annelida, Mollusca and Platyhelminthes. Mosquito larvae were determined with the highest relative abundance of 10.8% throughout the period of the study at Wadata Market, while the lowest relative abundance of 0% was observed for Stone fly and May fly at Benue Brewery and Mikap Nigeria Ltd stations throughout the period. There was generally low biodiversity of benthic fauna community which indicated the perturbed nature of the study area. Diversity indices results showed a variation in the community structure of River Benue. It was recommended that the discharge of effluents and other waste into the River Benue should be controlled and enforced.

2.4 Fish fauna

The first attempt on the checklists of fishes of the river system in Nigeria was Welman (1948), which had 181 species. This was followed by White (1966) and Reed *et al*. (1970) that gave a total of 161 species in northern Nigeria. Syndeham (1977) studied the qualitative composition and longitudinal zonation of fish fauna of River Ogun, southwest Nigeria and recorded 85 species in the river. According to Olaosebikan and Raji (1998) and Idodo-Umeh (2003), Nigerian freshwaters are the richest in West Africa in terms of fish species. Ita (1993) recorded 293 species during an investigation into the fish diversity of the major rivers in Nigeria. Other works on composition and distribution of fish fauna in Nigerian water bodies include Soyinka and Kassem (2008), in Ologe Lagoon, southern Nigeria; Offem and Akegbejo-Samsons (2009), in Cross River; and Ayoola and Kuton (2009), in Lagos Lagoon. Fish flourish only when the chemical and biological conditions of the water are suitable, such as when the water is fairly free from pollution.

The dominant factors that affect fish distribution in the aquatic environment are often temperature, dissolved oxygen, pH, salinity and water movement (Boyd, 1982). In general, temperature has a pronounced effect on the rate of chemical and biological processes in water. For some processes, such as the rate of oxygen consumption, an increase in temperature causes an increase in these rates until the lethal temperature is reached. So, there is an optimum temperature at which the rate of oxygen consumption is maximum. At temperatures lower or higher than the optimum, the rate of oxygen consumption declines (Shreeder, 1975)

A declined oxygen supply causes rapid breathing of fish and increases the amplitude of respiratory movement (Mason, 1991). Depletion of oxygen, which often result from organic pollution, increase the ventilation volumes of fishes; and, at low levels of oxygen, cardiac output is reduced. This reduces the rate of passage of blood through the gills, thus prolonging the period of time for oxygen and also conserving oxygen by reducing muscular work.

Fapohunda and Godstates (2007) investigated on bimetry and composition of fish species in Owena Reservoir, Ondo State, Nigeria. The results of the survey showed that 14 fish species belonging to seven families were recorded. Two families, namely Characidae and Clariidae, constituted the dominant fish families in the reservoir. Among the Characidae, *Brycinus nurse* (23.1%) and, among the Clariidae family, *Clarias gariepinus* (22.8%) were dominant. Other fish species with significant abundance were *Sarotherodon galilaeus* (9.3%), *Parachanna obscura* (8.0%), *Clarias anguillaris* (7.7%) and *Oreochromis niloticus* (6.4%).

Ipinmoroti's (2013) studies on Ichthyofauna diversity of Lake Asejire.He identified seventeen families grouped into tropic levels. Herbivores were 63.03% and 60.35%; carnivores were 31.05% and 30.65% and omnivores were 5.91% and 8.99% by biomass in the first and second years respectively. The herbivores were dominated by the cichlids, heterotis and cyprinids; carnivores by bagrids, characids, channids and *Lates*; while mormyrids, synodonts and clarids constituted the omnivores. Seasons had no effect on the population and number of the carnivores. The carnivore to herbivore ratio (F/C) was 1.33 and 0.9 by number and 1.7 and 1.33 by biomass; this is of concern, as this could pose a threat to ecological balance.

Assessment of Ichthyofaunal assemblage of Erelu Reservoir, Oyo, Nigeria was studied by Falaye *et al*. (2015).They collected a total of 6,927 samples belonging to 16 species and 8 families were encountered throughout the study period. Seasonally, more fish samples were recorded during the dry season (57.95%) than the wet season. When catches were compared spatially, lower zone recorded 38.89% followed by the upper zone, with 34.29%, and the middle zone, with 26.82%. However, highest catches were recorded at the shore (57.82%). Three families: Cichlidae, Cyprinidae and Clariidae, constituted 72% of the total catches and were dominated by *O.niloticus*, *R.senegalensis*, *C.nigrodigitatus*, *S.melanotheron*, *S.mystus* amd *T.marie*.

Adaka *et al*. (2015) assessed fish landed by artisanal fishers in Imo River at Owerri-Nta, Abia State, Nigeria. They recorded seven fish families made up of nine fish species, with their local names. The fish species *Tilapia zillii*, a cichlid, was the most dominant with a total value of 3,342 and (22.87%) in terms of numbers and percentage abundance. *Chrysichthys nigrodigitatus*, with 13.08% abundance, was the species of the highest market value. Thirty-six artisanal fishers (all part-time) with fourteen canoes, using gill nets, cast nets, basket traps, drum traps, hook and line set and Malian trap as fishing gears were recorded in the river, with a total catch of 14,611 in terms of number and a mean catch of 43 fishes/canoe. Based on the catch composition, the river was productive and comparable with other smaller but productive Nigerian rivers, reservoirs and lakes.

In their study Edoghotu *et al*. (2016) focused on the Ichthyofauna and physico-chemical properties of Kugbo creek in the Niger Delta, Nigeria. They reported that the fish found were of the families Chanidae, Claridae, Gymnachidae, Nandidae, Notopteridae, Osteoglossidae, Polypteridae, Malapteridae and Phractolemidae and were only found in fresh water and not brackish Syngnathidae, Sphyraenidae, Sciaenidae, Pomadasyidae, Polynemidae, Mugilidae, Lutjanidae and Carangidae were caught in the brackish station. Others were caught in all the 3 zones. Mean value range of limnological characteristics were temperature $25.6^oC \pm 1.1:30.8^oC \pm 2.5$; depth profile 110cm ± 113: 479cm ± 160; flow rate $4.3cms^{-1} \pm 0.7:7.6\ cms^{-1} \pm 3.4$; transparency 34.9cm ± 2.7: 265.0cm ± 58.9; TSS 38 mg / l ± 9 : 615 mg / l ± 55; and DO 2.9 mg / l ± 0.9 : 8.2 mg / l ± 4.06.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study area

The study was conducted on Oluwa River at Ilaje Local Government Area (ILGA), Ondo State, Nigeria. The river lies on latitude $4^{o}.40^{/}$-$5^{o}.00^{//}$N and longitude $6^{o}.00^{/}$-$6^{0}.20^{//}$E (Figure 3.1). The annual rainy season occurs from April to October with a characteristic ‘August break’ during which rainfall abates, while the annual dry season occurs from November to March (Adebowale *et al*., 2008). Meteorological conditions within ILGA are as follows: mean daily minimum temperature (22.1-24.4^{o}C); mean daily maximum temperature (24.9-36.8^{o}C); total precipitation (125.2-278.5mm) and mean relative humidity (76-88mm) (Yemi, 2008). Ilaje Local Government Area is in south-south of Ondo State with a coastline of about 80km which runs in a northwest to southeast direction. The coastal area of Ondo State is largely found in ILGA with about 50 settlements scattered around the river tributaries that empty directly into the coast and an increasing population size of 2.2% annually (Adebowale *et al*., 2008).

Babatunde (2010) avers that 80% of the population of the study area engages in fishing and that the area always records the bulk of fish produced in Ondo State. The fishermen operating in the river use wooden/ dug-out canoes. The canoes are either paddled or powered by small outboard engines. Dingies canoes ranges from 25 Tonnage (T)–40Tonnage (T) with engine capacity of 40 horse power (HP) convey 8-10 passengers, work boats ranges from 40T-80T with engine capacity of 80HP convey 10-20 passengers and pleasurable boats ranges from 25T-80T with engine capacity of 80 HP convey 10-25 passengers (NIWA,1998). From these boats the fishermen operate their cast nets, gill nets, fyke nets, hook and line and seine nets; at times, they use traps, such as conical cone trap (Akinwumi *et al.,* 2011). Some of the daily catches are preserved by using the smoke-drying method, while others are sold fresh at the local market.

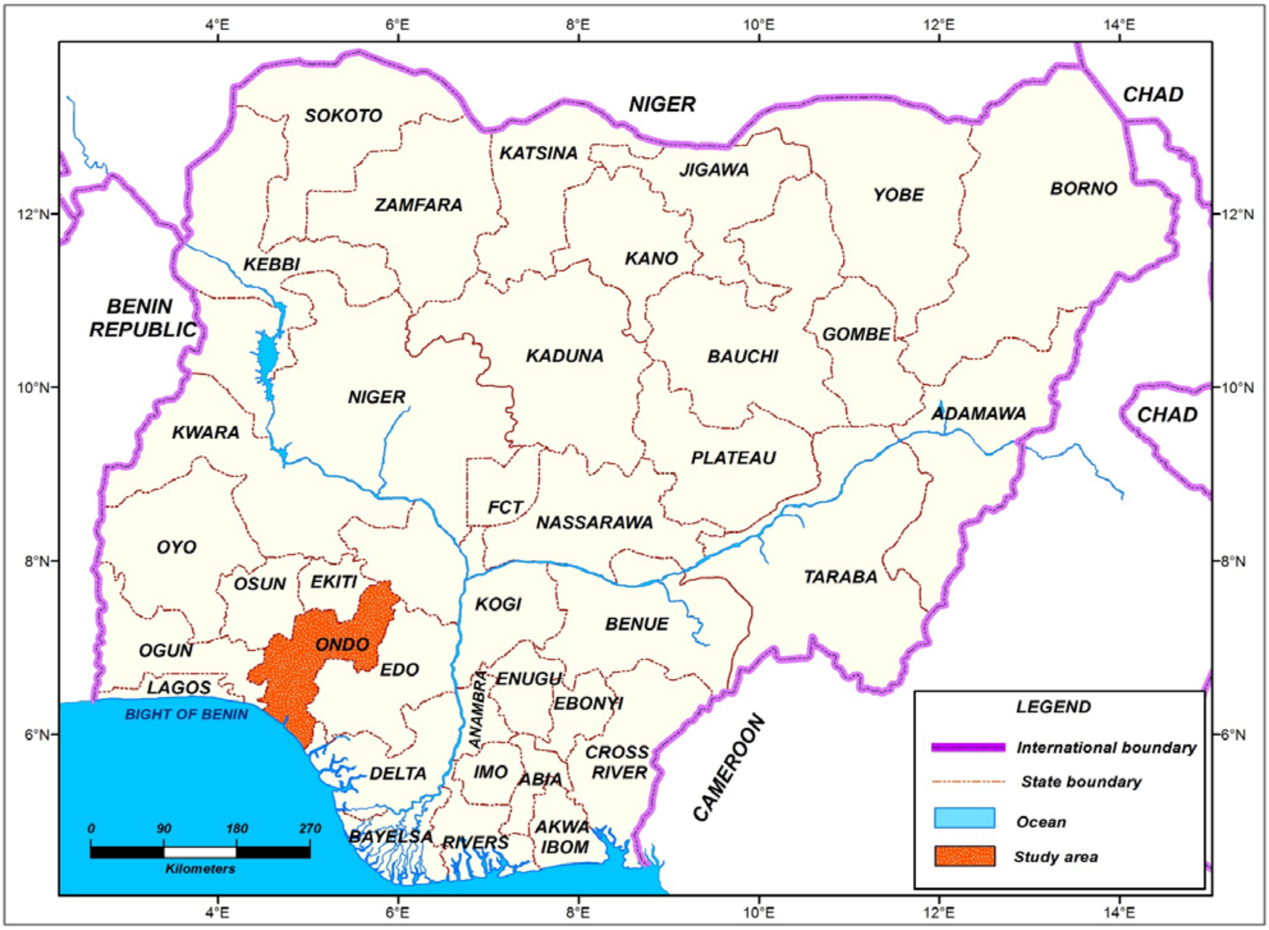


Fig. 3.1: Map of Nigeria showing Ondo State

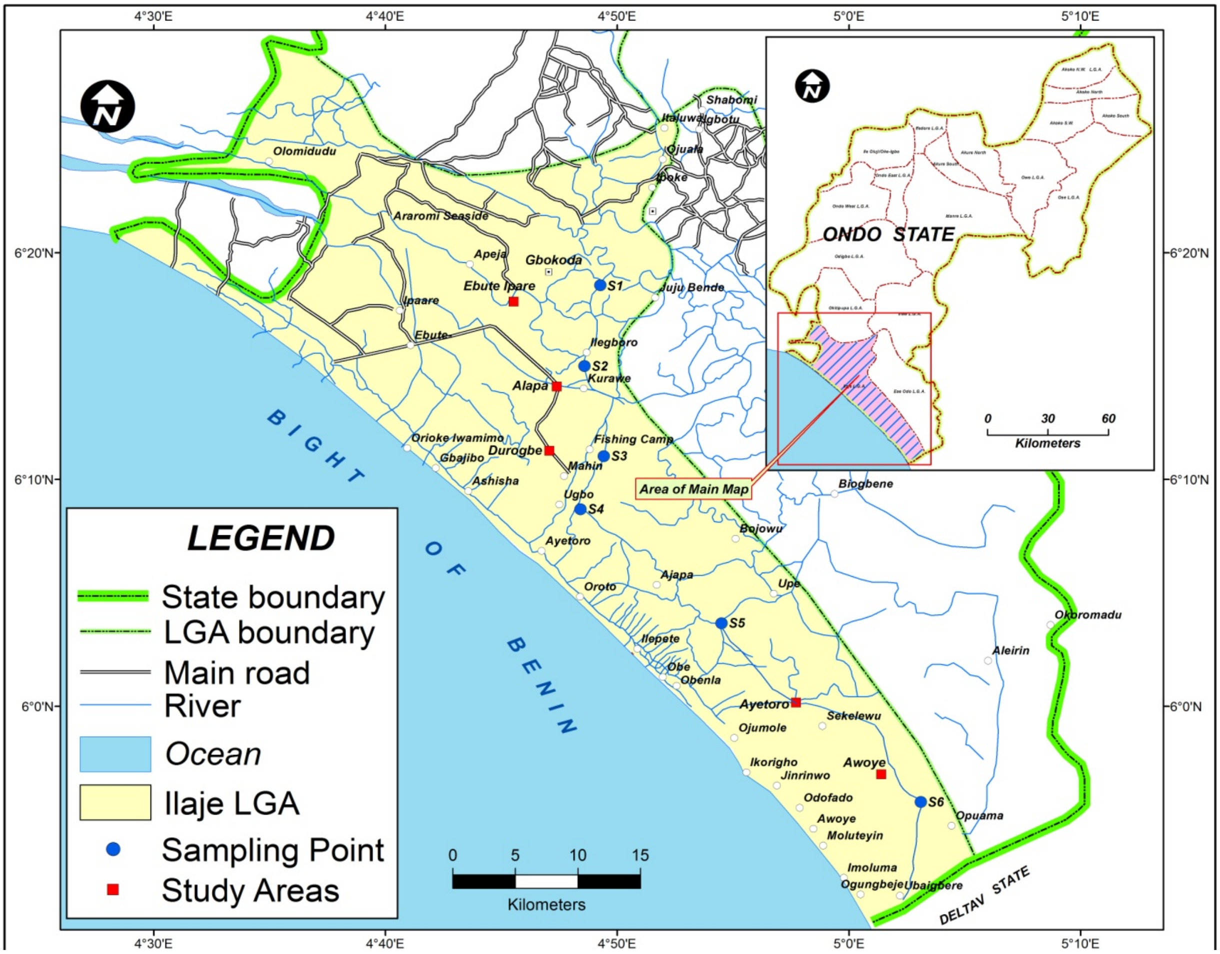


Fig.3.2: Map of Ilaje communities in Ondo State, Nigeria showing River Oluwa

3.1.1 Vegetation

The vegetation of the study area is mangrove forest with small evergreen broad leaves trees. The trees are predominantly woody and stratified. The vegetation is made up of mostly giant trees; the tallest trees are emergent about 40m in height followed by the upper canopy about 20m. Common mangrove trees include: *Avicennia* (White mangrove), *Rhizophora* (Red mangrove), and *Pandanus* (Screw pine) (Babatunde, 2010).

Polychaete worms, oysters, mussels, barnacles, prawns, shrimps and mudskippers are animals found on the roots of mangrove trees. Burrowing animals, such as clams, fiddler crabs and bristle worms are common in the muddy substratum. Animals associated with the parts of the mangrove trees above water include various insects, snakes and aquatic birds, like the kingfisher, sandpipers, black tern and skimmer. Other aquatic birds include waders, duck and herons (Babatunde, 2010).

3.1.2 Land use and Livelihood of Ilaje L.G.A

Land use is basically of two types, rural land (farmland) use and urban land use in Ilaje Local Government Area. Rural land use comprises mainly agricultural activities, like subsistence farming and cash cropping. The major cash crop is oil palm trees. Some commonly cultivated crops are cassava, yam, maize, pawpaw, okro and vegetables. The urban land use could be private land use or government land use. Private land use consists mainly of residential buildings, industries and shops, while government land use is mainly for educational, recreation and transportation.

Fishing is the major occupation of the Ilaje. This is enhanced by about 75% of the area being riverine. Over 85% of the populace earns their living through daily fishing with traps sets, cast and nets, hook and line. Fish species in the river include *Coptodon zillii, Oreochromis niloticus, Channa obscura, Clarias gariepinus, Sarotherodon galilaeus, Mormyrus rume* and *Hepsetus odoe* (Akinwumi *et al*., 2011).

According to the 1991 population figure, the population of the inhabitants was about 54,000 people, with over 85% as fishermen. However a significant proportion of the people engaged in other activities such as hunting, trading and local gin-brewing. The local common industries in the study area include local gin-brewing, iron-smelting, net-fabrication, boat-building and mat-making.

3.1.3 Sampling stations

Six sampling stations (1-6) were purposively selected on the Oluwa River based on the human activities. The distance between the stations was 500-1500m.

Station 1 Ebute-Ipare (Plate3.1a). There were farming activities involving oil palm trees *(Elaeis guineensis)* plantations and planting of cassava crops in the area. Relative to other stations less human activities are on going in this station.

Station 2: Alape, about 500m from Station 1. The major activities in this area were construction of canoes and mat-making (Plate 3.1b). Stations1 and 2 represent the upstream(US).

Station 3: This was at Durogbe Park, which was about 700m from Station 2. Passengers board the canoes and engine boats to their various destinations on the river. Some of the vehicular wastes from engine boats were released into the river (Plate 3.1c). There was a market around this station where the fishermen and fish sellers sold their fishes on the terminus under which were the dumpsites. This served as source of organic wastes into the river. Some of the passengers also used the shores of the river as their public toilets (Plate3.1d).

Station 4: This was at Ugbonla; about 500m from Station 3. There was deposition of wastes in this place. The inhabitants used this water for bathing, washing and also release wastes, such as, cassava peels and palm kernel into the river (Plate 3.1e). Also sand mining activities were not left out around this station (plate 3.1f). Stations 3 and 4 represent the midstream stations(MS).

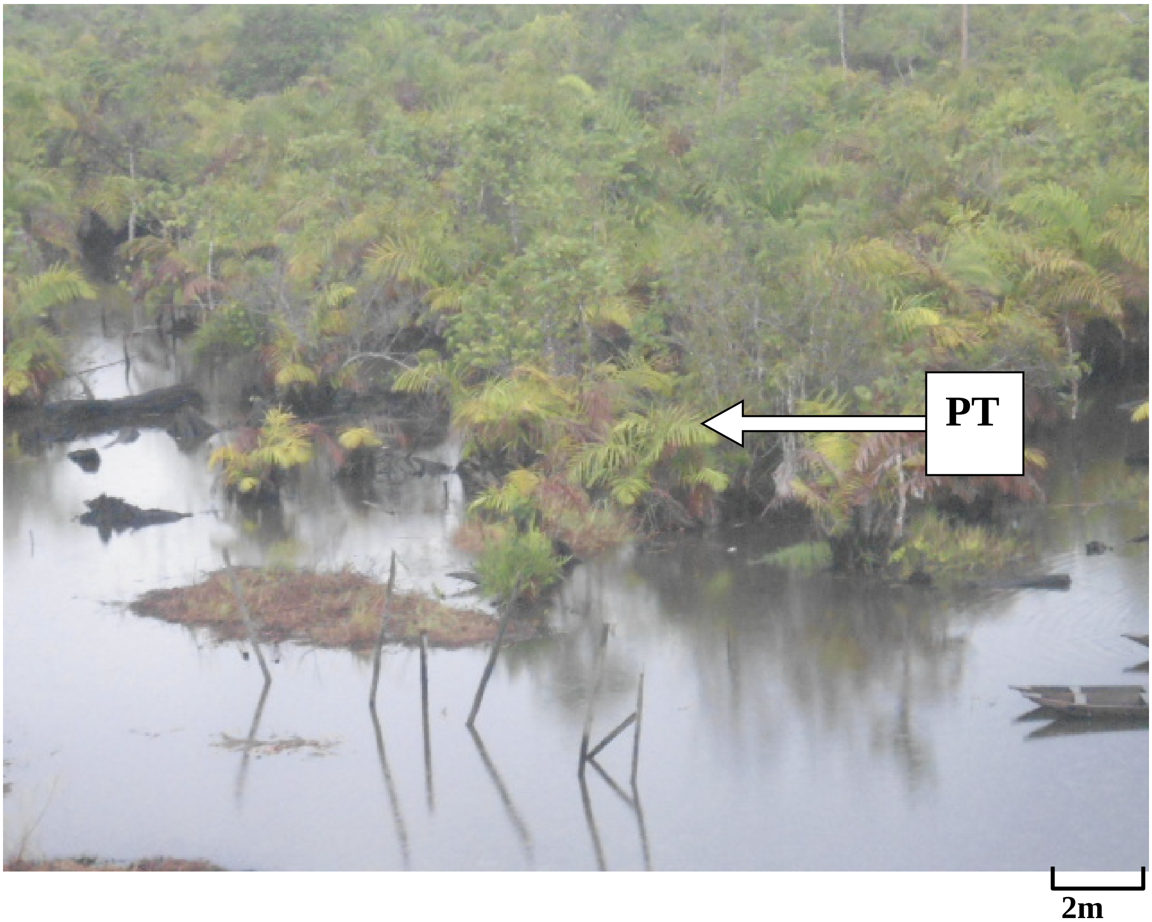


Plate 3.1a: Palm tree (PT) along Oluwa River at Ebute Ipare (upstream Station1).

Plate 3.1b: A Canoe(C) Construction Workshop in Alape, Ilaje community Ondo State (Station 2)

Plate 3.1c: Terminus for Transportation along Oluwa River (Midstream Station 3)

Plate 3.1d: Waste Dumped under (WD) the terminus at Durogbe along Oluwa River (Midstream Station 3)

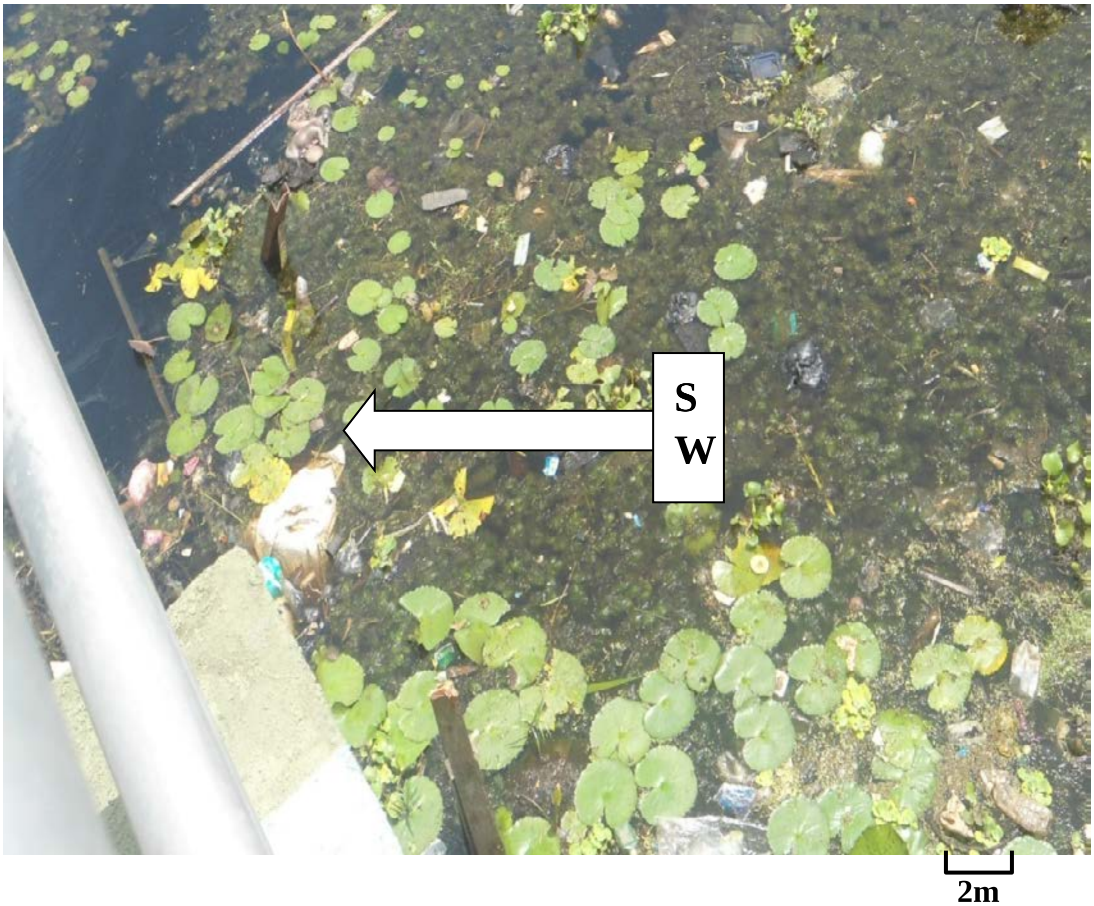


Plate 3.1e: Solid wastes (SW) input along Oluwa River at Ugbonla Town (Midstream Station 4)

Plate3.1 F: Mining activities (MA) along Oluwa River at Ugbonla Town

Plate 3.1g: Transport activities (TA) along Oluwa River in Ayetoro Town (Downstream Station 5)

Station 5: Ayetoro Town is about 600m from Station 4 with residential buildings; business activities such as, selling of fish, baskets, mats and local gins take place. The market men and women use the shore of the river as their public toilets, as most of the houses around this place lacked toilet facilities (Plate3.1g).

Station 6: Awoye was about 1500m from Station 5. There are farming activities and local gin production.Floating plants, such as water lilies, covered the station during the rainy season (Plate3.1h). Stations 5 and 6 represent the downstream stations(DS).

3.2 Collection of samples and analyses

Sampling in the river was done monthly for physico-chemical parameters, plankton, benthic macro-invertebrates and fish fauna from June, 2014 to November, 2015 to cover the main seasons (the rainy and dry seasons) of the year. Stations were sampled within 08.00-14.00 hours throughout to reduce the impact of diurnal variation at each station to the minimum. Analyses were carried out in the Limnology Laboratory, Obafemi Awolowo University and Central Research Laboratory, Obafemi Awolowo University, Ile-Ife, Osun State.

3.2.1 Physico-chemical parameters

The following physical and chemical parameters were determined: air temperature, water temperature, pH, Dissolved Oxygen (DO), total alkalinity, Total Solid (TS), Total Dissolved Solid (TDS), transparency, conductivity, salinity, chloride (Cl), Biochemical Oxygen Demand (BOD), nitrate (NO_3), sulphate (SO_4), phosphate (PO_4), magnesium (Mg), calcium (Ca), potassium (K), and sodium (Na). Apart from temperature and transparency that were measured *in situ*, all other parameters were determined in the laboratory. Two replicate surface water samples were collected in 2L plastic containers from each station; containers were carefully labelled on the field.

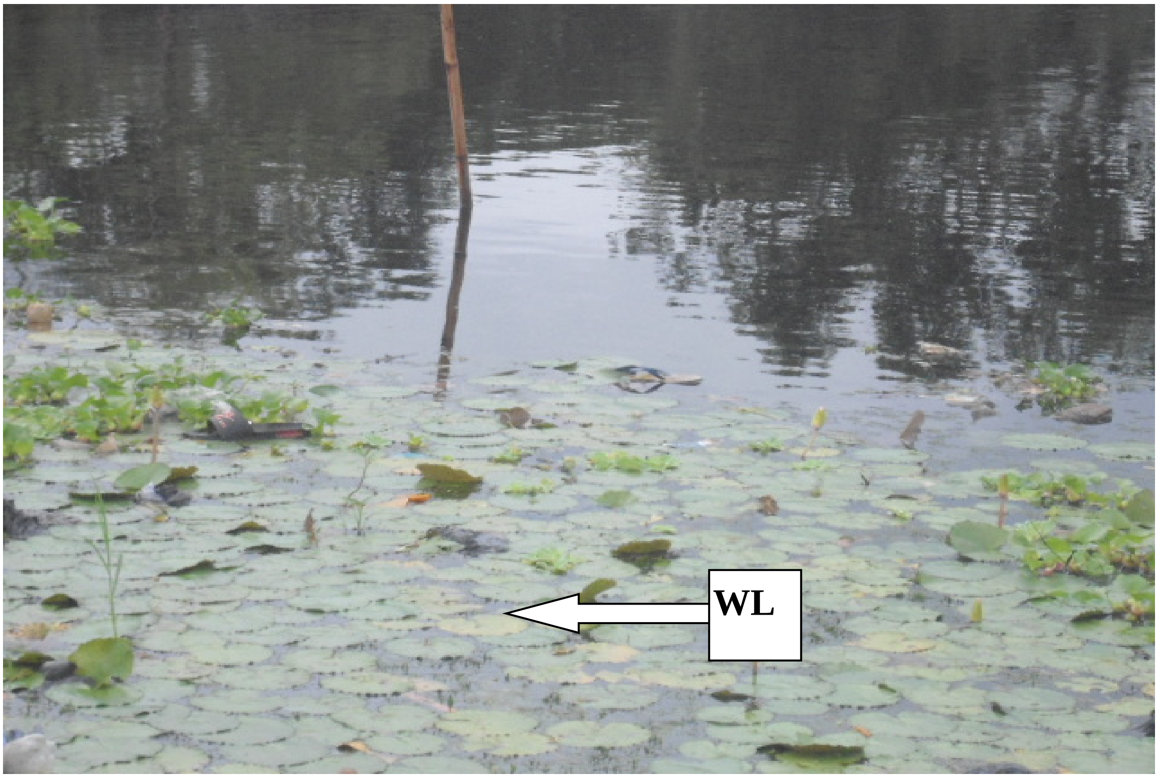


Plate 3.1h: Water lilies (WL) along Oluwa River in Awoye Town (Downstream Station 6)

3.2.1.1 Temperature and transparency

Temperature was determined using a centrigrade mercury in glass thermometer. Air temperature was measured by holding the thermometer in the air for 3 minutes. Water temperature was measured by inserting the thermometer to a depth of 10cm into the water for 3 minutes. Reading was taken and recorded. The results were expressed as degree Celsius (^oC).

Transparency was determined *in situ* by using secchi- disc. The calibrated secchi-disc was suspended into the river at various stations. The length at which the disc could be seen was noted and the length at which the disc could not be seen was equally noted. The average of these two lengths was determined and results expressed in metre..

3.2.1.2 Dissolved Oxygen (DO)

Water samples from each station were collected into 250mL stoppered sampling bottles without air bubbles. Dissolved oxygen was determined by direct probe analysis using dissolved oxygen meter (Extech meter model Exstik EC500). The unit of measurement is mg/L.

3.2.1.3 Biochemical Oxygen Demand (BOD)

Water samples for biochemical oxygen demand from each station were collected without air bubbles into two 250mL dark sampling bottles.The initial DO in the sampling bottles was determined by direct probe analysis using dissolved oxygen meter (Extech meter model Exstik EC500). The dark bottle samples were incubated in the dark at 20^oC for 5days. The DO in the sample was determined after the incubation period and the difference of initial and final DO was the BOD, expressed in mg/L.

3.2.1.4 Hydrogen ion concentrations (pH)

The pH was measured using a pH meter (510pH meter). The pH meter was standardized using prepared buffer solution according to the manufacturer’s instruction. Water sample was put into a beaker after it had been rinsed with distilled water. The glass electrode of the meter was inserted into the water sample and measurement was taken after the reading had stabilized.

3.2.1.5 Total Dissolved Solid, Total Solid, Conductivity and Salinity

Jenway meter 4071 was used to measure total dissolved solid (TDS), total solid (TS), conductivity, and salinity. The meter was caliberated with 3.3mol solution of potassium chloride. The glass electrode of the meter was inserted into the water sample after being rinsed with distilled water and measurement was taken for each parameter after the reading had stabilized. The results for TDS and TS were expressed as mg/Lwhile conductivity and salinity were expressed as µs/cm and part per thousand (‰) respectively.

3.2.1.6 Alkalinity and chloride

Alkalinity and chloride in the water samples collected were measured with LaMotte Freshwater Aquaculture Test Kit Model AQ-2.The results for alkalinity and chloride were expressed as $mgCaCO_3/L$ and mg/L, respectively.

3.2.1.7 Nitrate ion

Nitrate in surface water was determined by colorimetric method, following the method of Golterman *et al.* (1978). 1ml of 1% sodium salicylate solution was added to 25ml of the water sample in a 100ml volumetric flask and evaporated to dryness. The residue was dried for 30 minutes in an oven at 105^oC. The sample was later allowed to cool and 2ml concentrated H_2SO_4 was added. The mixture was swirled quickly to mix well and allowed to stand for 15 minutes, shaking it at intervals to ensure dissolution of all solids. 15ml of distilled water and 15ml sodium hydroxide, potassium or sodium tartate solution were added into the sample residue, swirled again and allowed to stand at room temperature for one hour. A blank sample was prepared in the same manner. Absorbance was measured at 420nm using a corning colorimeter 253. Concentration of nitrate in the surface water was then determined from calibration curve. Calibration curve was prepared as follows 0, 2,4,6,8,10,12,14, and 16 of the standard solution was pipetted into 50ml beaker. The standard solution was also prepared by diluting 10ml of the stock solution to 1ml distilled water to give a solution containing 1mg/l of NO_3-N (1ml=1µg NO_3-N).

The same procedure as for the sample solution was carried out. A reagent blank was also prepared; it contained all the reagents used above. The absorbance of the standard solution against the blank on a colorimeter was measured at 420nm. A calibration curve of absorbance against NO_3-N was drawn to obtain a straight line graph. Concentration of nitrate nitrogen was calculated as follows.

NO_3-N (mg/l) =µgN read from curve x D/ml sample

where, D is dilution factor for the sample.

3.2.1.8 Sulphate and phosphate

The sulphate and phosphate contents of the water were measured by colorimetric method, according to Golterman *et al.* (1978). 25ml of the sample was measured in a 250ml of beaker. 3ml of barium chloride solution was added and stirred then allowed to stay for 30 minutes before being taken to Corning colorimeter 253 for determination of sulphate (SO_4^{2-}) at 425nm wavelength and determination of phosphate at 710nm wavelength, respectively. Blank solutions were prepared in the same manner, then the disposable cuvette was filled and reading was taken on the colorimeter. The concentrations of sulphate and phosphate were determined by extrapolating from the calibration curve.

SO_4 (mg/l) =Mass of SO_4 read from curve x 1000/ ml sample.

PO_4 (mg/l) =Mass of PO_4 read from curve x 1000/ ml sample.

3.2.1.9 Sodium (Na^+) and potassium (K^+)

The two ions were determined with a flame emission spectrophotometer (Corning model 405, Gallenkamp London, UK). Sodium and potassium were determined at different wavelengths 589.0 nm and 766.0 nm, respectively, according to Golterman *et al.* (1978).The unit of measurement is in mg/L.

3.2.1.10 Calcium (Ca^{2+}) and magnesium (Mg^{2+})

The two ions were determined by the complexometric titration method, according to Golterman *et al.* (1978), though; different indicators were used for the ions.

Calcium titration

0.01ml of disodium Ethylene Diamine Tetra- Acetic acid (EDTA) was filled into the burette while; 100ml of the sample was in the conical flask; and spoonful calcon indicator was introduced into the sample. The sample was shaken vigorously; the purple colour of the mixture changed to blue at titrated value.

Magnesium titration

The same procedure of titration was carried out for the determination of magnesium but, Erichrome black-T was used as indicator. The colour changed from purple to blue at end point.

3.2.1.11 Determination of heavy metals

The samples of water for heavy metals concentration were collected with 250 mL plastic bottles and fixed with concentrated nitric acid (APHA, 1998). They were transported to the Central Laboratory, Obafemi Awolowo University, Ile-Ife for determination of heavy metals (Cadmium, Chromium, Lead, Nickel and Iron) with the use of a Varian Spectr AA 600 Atomic Absorption Spectrophotometer (APHA, 1998). The results were expressed in mg/L.

3.3.1 Plankton

The samples for plankton analysis were collected by straining 100 litres of water from each station through plankton net of 55µm mesh size and each concentrated sample was preserved in 4% formalin solution in the field according to Onyema (2007). The samples were transported to the laboratory and kept until needed for analysis. The preserved plankton samples were observed under the microscope. A combination of keys and guides provided by Edmondson (1959), Needham and Needham (1975), Jeje and Fernando (1986), Egborge and Chigbu (1988), APHA (2005) and Nwankwo (2004) were used for identification of the plankton species. The organisms in the concentrated samples were counted in a counting chamber. Pictures of the plankton were taken with a cyber shot DSC-W510 digital camera of 12.5 mega pixel.

3.3.2 Benthic macro-invertebrates sampling

Samples of benthic macro-invertebrates were collected monthly using a $0.6m^2$ (surface area) Van-veen grab from the six sampling stations. Three random replicate hauls of sediments were taken from each station. Each sediment sample was diluted with water and sieved with a 0.5mm mesh size sieve in the field (Holme and McIntyre, 1984; George *et al*., 2009). The residuals retained on the screens of the sieve were washed into a shallow white tray with water for sorting. The sorted benthic macro-invertebrates was preserved in 4% formalin in small glass jars. The individual organisms were identified macroscopically with the following guides and keys: Macan (1959), Edmunds (1978), Pennak (1978), FAO (1981) and WHO (1998).

3.3.3 Fish fauna

Fish specimens were obtained from catches at the landing centre (terminus) of the local fishermen. The fishes were identified using the keys and guides of Reed *et al*. (1970), Olaosebikan and Raji (1998) and Idodo-Umeh (2003), and counted. Pictures of some of the fishes were taken with a cyber shot DSC-W510 Digital camera of 12.5 mega pixel.

3.4 Data analysis

Microsoft Excel 2007 (Microsoft Corporation1985-2007) was used for graphical illustrations. Data analyses were done using descriptive stastistics. Two-tailed correlation coefficient (r) was used to determine the relationships existing between the physico-chemical parameters of the water and plankton and benthic macro-invertebrates abundance. Spatial variations in physico-chemical parameters, plankton and benthic macro-invertebrates abundance were determined using the one way Analysis of Variance (ANOVA). Seasonal variations were determined using student's t-test significance. Shannon-Wierner diversity index and evenness were determined using PAST software

(Hammer and Harper, 2005). The factor analysis procedures, using principal components analysis (PCA) extraction method for data reduction was used to remove redundant (highly correlated) physicochemical variables from the data file and replacing the entire file with a smaller number of uncorrelated variables (factor), and to further examine the underlying (or latent) relationships between the variables.The magnitudes of the eign values and 75% (0.75) rules for variance contribution were used for factor selection (Manly,1986).The cluster analysis (CA) was used to explore and reveal natural groupings (or clusters) within the plankton assemblages that would otherwise not be apparent.

CHAPTER FOUR

RESULTS

4.1. Physico-chemical parameters of Oluwa River in Ilaje Local Government Area (ILGA)

The results of the physico-chemical parameters of Oluwa River in ILGA are presented in Table 4.1. The seasonal variations of physico-chemical parameters for Oluwa River from June, 2014 to November, 2015 are presented in Table 4.2. Profile graphs for physicochemical parameters are illustrated in Figs 4.1-4.23. Guideline values for water quality in drinking water and national guideline values for aquatic life is presented in Appendix 1.

4.1.1 Air temperature

The air temperature ranged between 26 and 32^{o}C (mean=27.6±0.26 ^{o}C) during the study period (Table 4.1). Downstream stations recorded the highest (28.4±0.50 ^{o}C), while the lowest mean air temperature was recorded upstream (26.8±0.37^{o}C). There was significant difference ($p< 0.05$) between the mean air temperature in the rainy (26.7±0.21 ^{o}C) and the dry (29.6±0.36 ^{o}C) seasons (Table 4.2). Temporal variation of air temperature occurred for all the stations (Fig.4.1). The highest value (30.00^{o}C) was recorded during the dry season month (Febuary, 2015) in downstream station (DS) while the lowest value (25.00^{o}C) was recorded during the rainy season month (August, 2015) in midstream station (MS).

4.1.2 Water temperature

The water temperature of Oluwa River in ILGA ranged between 24.00 and 30.00^{o}C (mean =26.8 ± 0.22^{o}C) during the study period (Table 4.1). Downstreams station recorded the highest (27.3 ± 0.39^{o}C), while lower mean water temperature was recorded upstream (26.8±0.37^{o}C) and midstream (26.6±0.38^{o}C) (Table 4.1). There was significant difference ($p<0.05$) between the mean water temperature in the rainy (25.9±0.17 ^{o}C) and the dry (28.6±0.19 ^{o}C) seasons (Table 4.2). Temporal variation in water temperature occurred in all the stations (Fig 4.2).The highest value (29.3^{o}C) was recorded during the dry season month (Febuary, 2015) in downstream station, while the lowest value (24.0^{o}C) was recorded during the rainy season month (August, 2014) in midstream station.

4.1.3 Transparency

Transparency ranged between 1.0m and 8.0m (mean=3.9±0.25m) during the study period (Table4.1). The lowest mean transparency was recorded in DS (3.5 ± 0.42m), while MS recorded the highest (4.6±0.42m) (Table 4.1). There was significant difference ($p<0.05$) between the mean transparency of Oluwa River in rainy (4.49±0.32m) and the dry (2.83±0.23m) seasons (Table 4.2). Temporal variation of transparency was observed in all the stations (Fig 4.3). The highest value (7.9m) was recorded during the rainy season month (September, 2014) in MS, while the lowest value (1.0m) was recorded during the dry season month (March, 2015) in DS.

4.1.4 Dissolved oxygen (DO)

Dissolved oxygen of Oluwa River in ILGA ranged between 1.2 and 4.0 mg/L (mean=2.8±0.10mg/L) during the study period (Table 4.1). The lowest mean DO (2.4± 0.18 mg/L) recorded downstream was significantly different from the highest mean DO (3.1 ± 0.14 mg/L) recorded upstream (Table 4.1). There was no significant difference ($p>0.05$) between the mean DO in the rainy (2.95± 0.11 mg/L) and the dry (2.65± 0.20 mg/L) seasons (Table 4.2). Temporal variation in DO occurred in all the stations (Fig.4.4). The highest value (4.0mg/l) was recorded during the late rainy season month (October, 2015) in midstream station. The lowest value (1.3mg/L) was recorded during the early rainy season month (March, 2015) in DS.

4.1.5 Biochemical Oxygen Demand (BOD)

Biochemical oxygen demand ranged between 1.4 and 3.8 mg/L (mean=2.2±0.10 mg/L) during the study period (Table 4.1). The lowest mean BOD was recorded upstream (2.0 ±0.17mg/L), while DS recorded the highest (2.4 ±0.18mg/L) (Table 4.1)

Table 4. 1. Physico-chemical parameters (Mean±S.Eand Range) of Oluwa River from June, 2014 to November, 2015

S/N	Parameters	Upstream Mean ±SE	Midstream Mean ± SE	Downstream Mean ± SE	OVER ALL Mean ± SE	Range	ANOVA	
							F	P
1.	Air Temperature (^oC)	26.8 ±0.37	27.6 ±0.42	28.4 ±0.50	27.6 ± 0.26	26 – 32	3.145	0.52
2.	Water Temperature (^oC)	26.5 ±0.37	26.6 ±0.38	27.3 ±0.39	26.8 ± 0.22	24 – 30	1.604	0.21
3.	Transparency (m)	3.6 ±0.41	4.6 ±0.42	3.5 ±0.42	3.9 ± 0.25	1.0 – 8.0	2.247	0.116
4.	Dissolved Oxygen (mg/L)	3.1 ±0.14	2.9 ±0.14	2.4 ±0.20[b]	2.8 ± 0.10	1.2 - 4.0	3.844	0.028*
5.	Biochemical Oxygen Demand (mg/L)	2.0 ±0.17	2.2 ±0.16	2.4 ±0.18	2.2 ±0.10	1.4 - 3.8	1.884	0.162
6.	pH	7.0 ±0.24	7.3 ±0.22	7.7 ±0.24	7.3 ± 0.14	6.0 – 9.0	2.439	0.097
7.	Conductivity (µs/cm)	33.5 ±3.94	41.1 ±4.98	48.3 ±6.28	41.0 ±3.01	18 – 105	2.080	0.135
8.	Alkalinity ($mgCaCO_3/L$)	18.9 ±0.46	19.9 ±0.59	21.7 ±0.59	20.2±0.33	14 – 25	7.070	0.002*
9.	Chloride (mg/L)	24.8 ±0.93	26.8 ±1.11	30.6 ±1.00	27.4± 0.66	18 – 36	8.108	0.001*
10.	Total Dissolved Solid (mg/L)	23.6 ±2.11	25.5±3.10	35.1 ±2.73	28.0±1.67	14- 60	5.238	0.009*
11.	Total Solid (mg/L)	52.6 ±5.52	58.0 ±5.19	65.4 ±5.19	58.7 ± 3.14	20 – 100	1.419	0.251
12.	Nitrate (mg/L)	0.01 ±0.002	0.02 ±0.002	0.03 ±0.003	0.02 ±0.001	0.0 – 1.0	10.39	0.00*
13.	Sulphate (mg/L)	1.6 ±0.21	2.2 ±0.32	2.4 ±0.21	2.05±0.15	0.0 – 4.0	2.753	0.73
14.	Phosphate (mg/L)	1.7 ±0.12	2.0 ±0.12	2.5 ±0.19	2.0±0.09	1.0-4.5	6.442	0.003*
15.	Sodium (mg/L)	1.0 ±0.09	1.0 ±0.11	1.2 ±0.61	1.1 ±0.04	0.4-1.6	1.220	0.304
16.	Potassium (mg/L)	1.2 ±0.06	1.0 ±0.06	1.0 ±0.07	1.1±0.04	0.4 – 1.6	3.373	0.042*
17.	Magnesium (mg/L)	2.6 ±0.30	2.2 ±0.23	1.5 ±0.18	2.1±0.15	0.3-5.0	5.100	0.010*
18.	Calcium (mg/L)	2.2 ± 0.10	1.8 ±0.10	1.3 ±0.04	1.8 ±0.07	1.0-2.8	31.388	0.000*
19.	Cadmium (mg/L)	0.01 ±0.001	0.01±0.001	0.02 ±0.001	0.01±0.001	0 - 0.02	9.549	0.000*
20.	Chromium (mg/L)	0.004 ±0.001	0.012 ±0.001	0.018 ±0.004	0.01 ± 0.001	0 - 0.02	33.922	0.000*
21.	Lead (mg/L)	0.006 ±0.001	0.009 ±0.001	0.01 ±0.001	0.01 ±0.001	0 - 0.03	10.304	0.000*
22.	Nickel (mg/L)	0.6 ±0.09	0.5 ±0.09	1.1 ±0.09	0.7 ±0.06	0-1.5	10.221	0.000*
23.	Iron (mg/L)	0.1 ±0.02	0.2 ±0.01	0.2 ±0.01	0.2± 0.01	0.0 -0.3	3.165	0.051*
24	Salinity (‰)	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00 – 0.00	-	-

***** =significant at $p<0.05$

Rainy season=May- November

Dry season=December-April

Table 4. 2. Seasonal Variation (Mean±S.E) of Physico-chemical Parameters of Oluwa River from June, 2014 to November, 2015

S/N	Parameters	Rainy season Mean ±SE	Dry season Mean ± SE	t_{value}	Significance
1.	Air temperature (^oC)	26.7 ±0.21	29.6 ±0.36	-7.07	(.000) Sig
2.	Water temperature (^oC)	25.9 ±0.17	28.6 ±0.19	-9.48	(.000) Sig
3.	Transparency (m)	4.49 ±0.32	2.83 ±0.23	3.39	(.001) Sig
4.	Dissolved Oxygen (mg/L)	2.95 ±0.11	2.65 ±0.20	1.36	(.180) NS
5.	Biochemical Oxygen Demand (mg/L)	1.98±0.09	2.84 ±0.17	-4.66	(.000) Sig
6.	pH	7.86±0.15	6.44±0.07	6.12	(.000) Sig
7.	Conductivity (µs/cm)	48.8 ±3.87	25.3 ±1.27	4.21	(.000) Sig
8.	Alkalinity ($mgCaCO_3/L$)	20.3 ±0.43	20.1 ±0.52	0.19	(.849) NS
9.	Chloride (mg/L)	28.8 ±0.84	24.8 ±0.95	3.06	(.004) Sig
10.	Total Dissolved Solid (mg/L)	31.8±2.23	20.7±0.88	3.44	(.001) Sig
11.	Total Solid (mg/L)	71.08±2.76	33.9 ±2.64	8.54	(.000) Sig
12.	Nitrate (mg/L)	0.03 ±0.002	0.02 ±0.002	2.10	(.040) Sig
13.	Sulphate (mg/L)	2.65 ±0.13	0.86 ±0.13	8.41	(.000) Sig
14.	Phosphate (mg/L)	2.23 ±0.12	1.68 ±0.10	2.88	(.006) Sig
15.	Sodium (mg/L)	1.32 ±0.05	0.78 ±0.13	4.24	(.000) Sig
16.	Potassium (mg/L)	1.17±0.03	1.01 ±0.09	1.82	(.074) NS
17.	Magnesium (mg/L)	2.50 ±0.18	1.32 ±0.12	4.13	(.000) Sig
18.	Calcium (mg/L)	1.90 ± 0.08	1.61±0.12	1.90	(.062) NS
19.	Cadmium (mg/L)	0.02 ±0.01	0.01±0.01	2.69	(.010) Sig
20.	Chromium (mg/L)	0.01 ±0.001	0.01 ±0.001	0.52	(.062) NS
21.	Lead (mg/L)	0.01±0.001	0.01 ±0.001	0.13	(.896) NS
22.	Nickel (mg/L)	0.85 ±0.07	0.40 ±0.05	3.69	(.001) Sig
23.	Iron (mg/L)	0.16 ±0.01	0.17 ±0.002	-7.41	(.462) NS
24	Salinity (‰)	0.00±0.00	0.00±0.00	-	-

NS = Not significant P>0.05   Sig = Significant P<0.05,

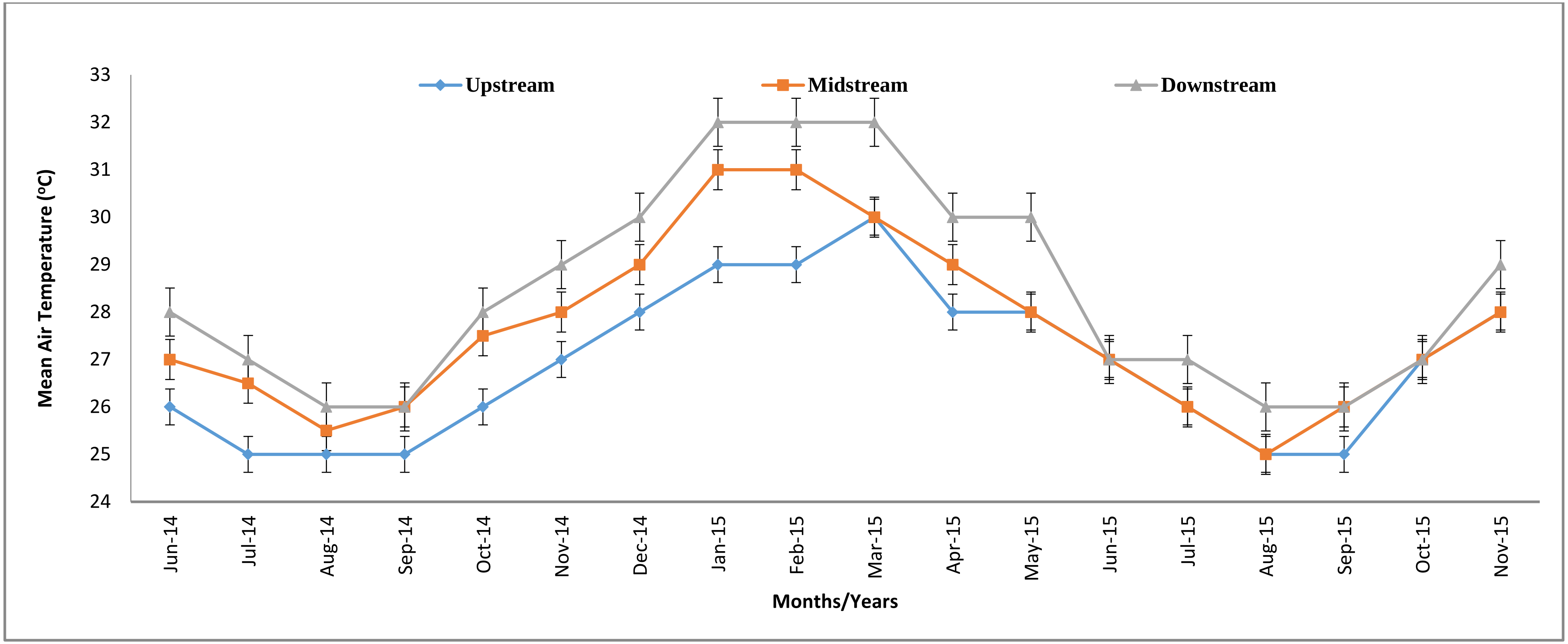


Fig.4.1: Mean Monthly Variation of Air Temperature in Oluwa River from June, 2014 to November, 2015

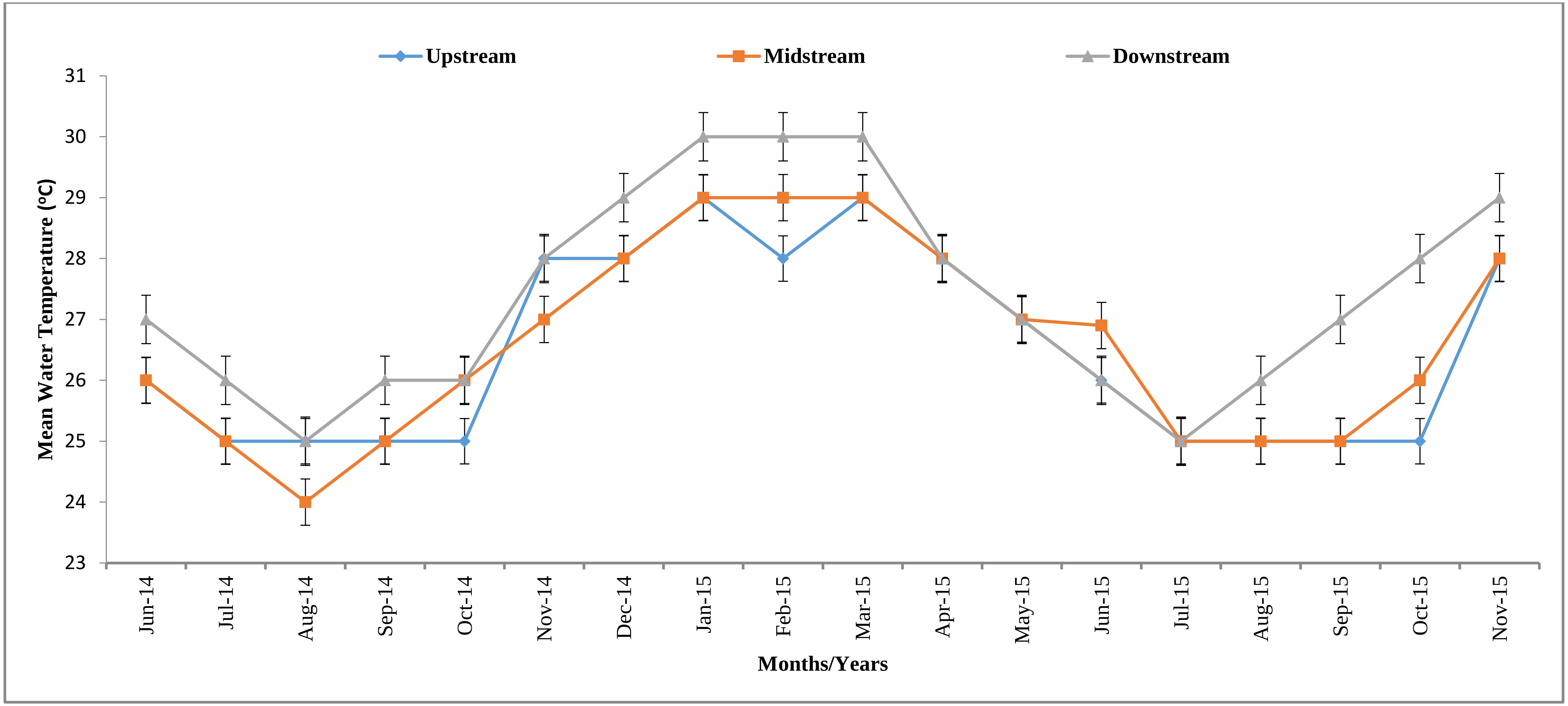


Fig.4.2: Mean Monthly Variation of Water Temperature in Oluwa River from June, 2014 to November, 2015

There was significant difference ($p<0.05$) between the mean biochemical oxygen demand in the rainy (1.98± 0.09 mg/L) and the dry (2.84 ± 0.17 mg/L) seasons (Table 4.2). Temporal variation in biochemical oxygen demand was observed in all the stations (Fig 4.5).The highest value (3.8mg/L) was recorded during the dry season month (Febuary, 2015) in DS, while the lowest value (1.4mg/L) was recorded during the late rainy season month (October, 2014) in US.

4.1.6 pH

pH in Oluwa River ranged between 6.0 and 9.0 (mean=7.3±0.14) during the study period (Table4.1). The lowest mean pH (7.0 ±0.24) was recorded US, while DS recorded the highest (7.7± 0.24) (Table 4.1). There was significant difference ($p<0.05$) between the mean pH in the rainy (7.86± 0.15) and the dry (6.44 ± 3.87) seasons (Table 4.2). Temporal variation in pH occurred in all stations (Fig. 4.6). The highest value (9.0) was recorded during the early rainy season month (June, 2014) in DS.The lowest value (6.0) was during the late rainy season month (September, 2014) recorded US.

4.1.7 Conductivity

Conductivity ranged between 18 and 105µs/cm (mean = 41.0 ± 3.01µs/cm) during the study period (Table 4.1). The lowest mean conductivity was recorded US (33.5 ± 3.94µs/cm), while DS recorded the highest (48.3±6.28µs/cm) (Table 4.1). There was significant difference ($p<0.05$) between the mean value for the rainy (48.8±3.87µs/cm) and the dry (25.3± 1.27µs/cm) seasons (Table 4.2). Temporal variation in conductivity occurred in all the stations (Fig. 4.7).The highest value (100µs/cm) was recorded during the rainy season month (July, 2014) in DS, while the lowest value (18µs/cm) was recorded during the dry season month (July, 2014) in US.

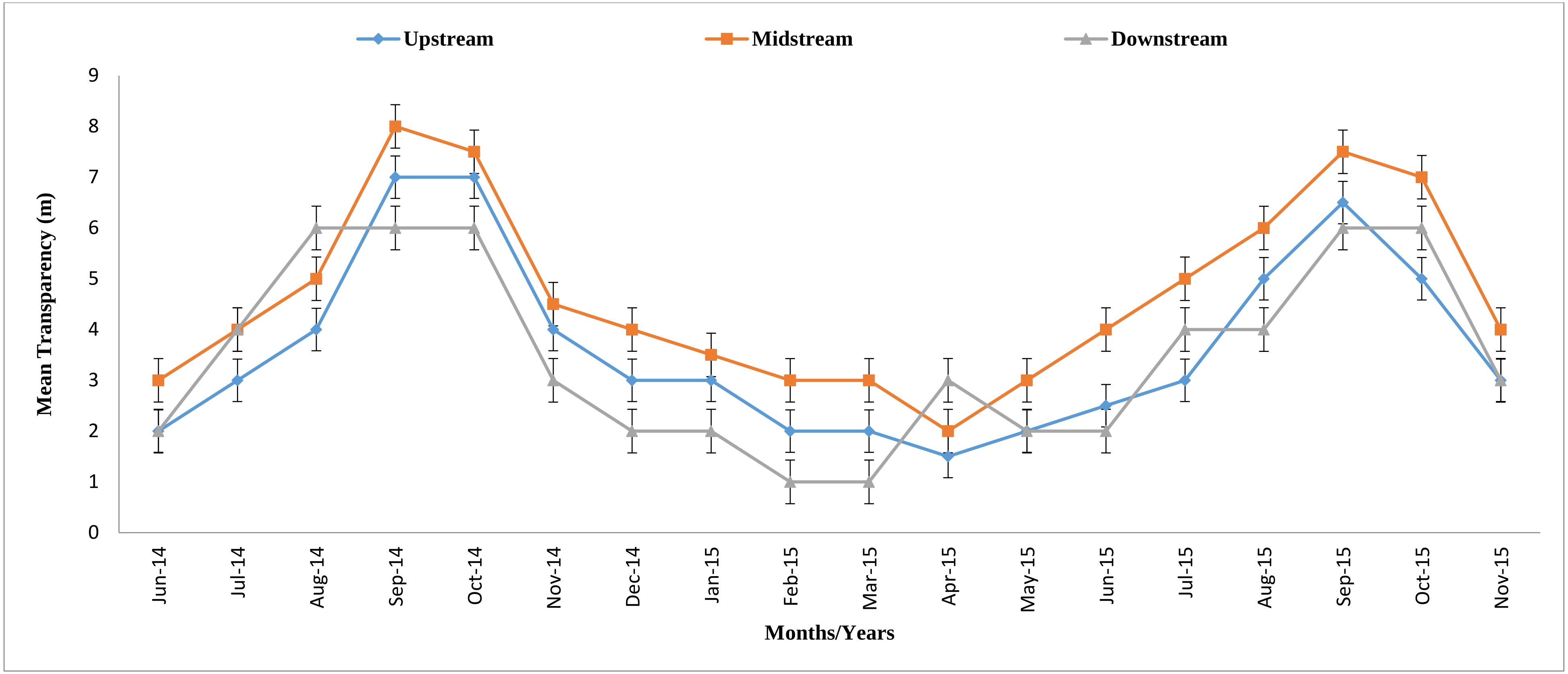


Fig.4.3: Mean Monthly Variation of Transparency in Oluwa River from June, 2014 to November, 2015

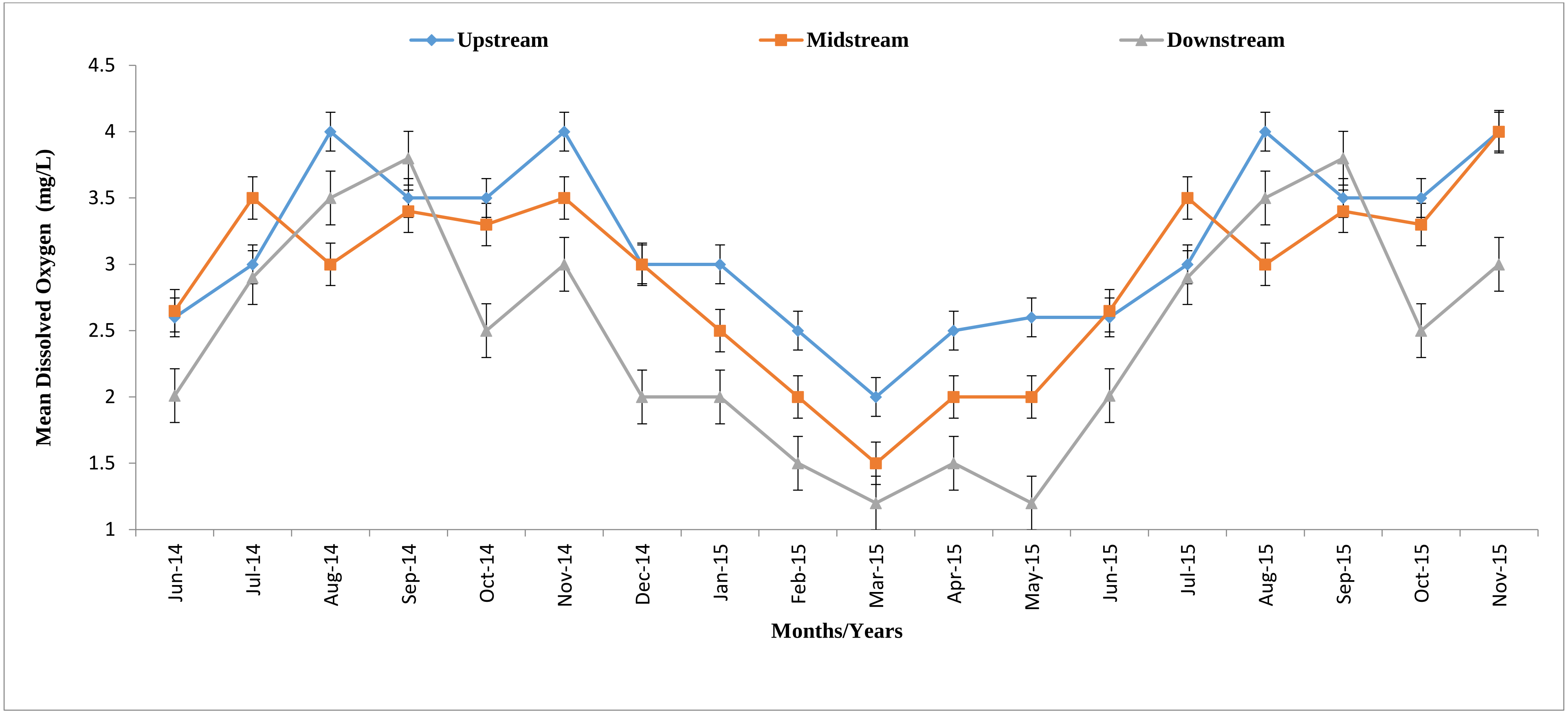


Fig.4.4: Mean Monthly Variation of Dissolved Oxygen in Oluwa River from June, 2014 to November, 2015

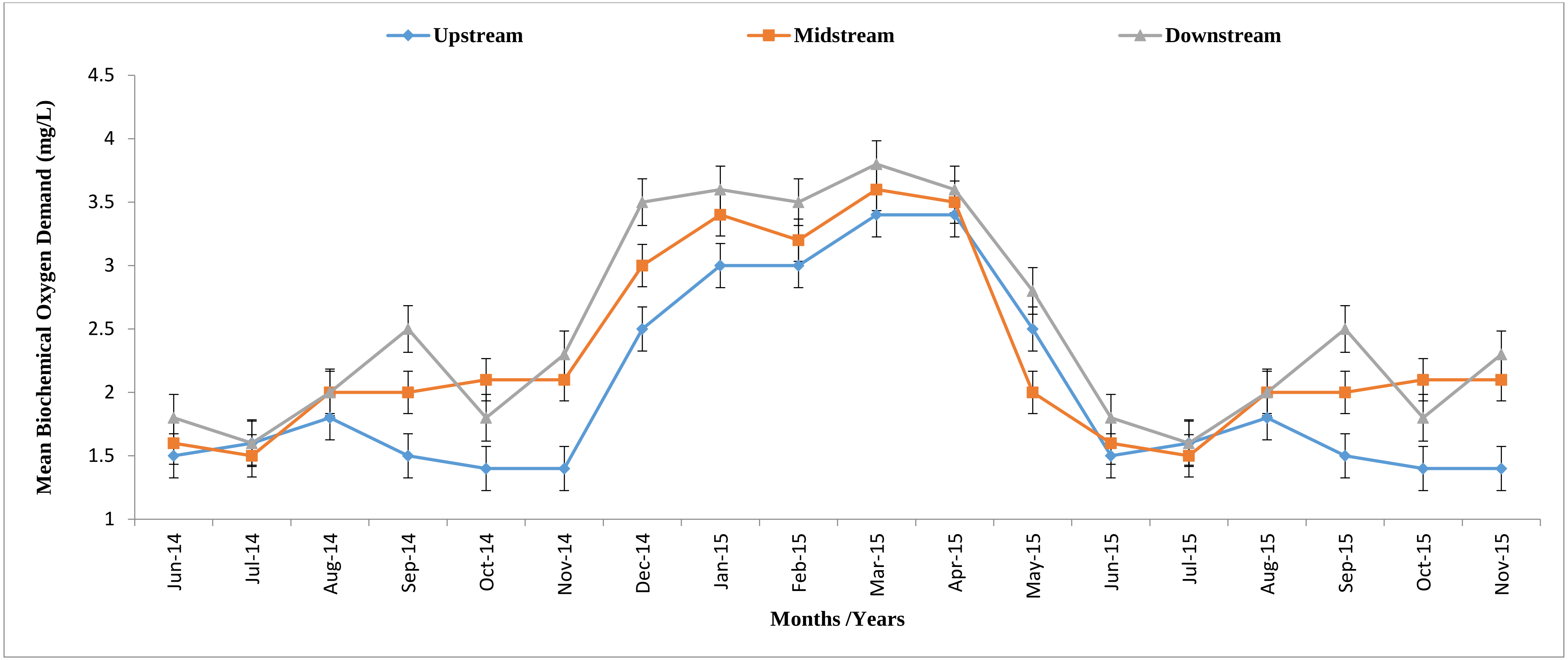


Fig.4.5: Mean Monthly Variation of Biochemical Oxygen Demand in Oluwa River from June, 2014 to November, 2015

4.1.8 Total Alkalinity

Total alkalinity concentration ranged between 14 and 25 $mgCaCO_3/L$ (mean =20.2±0.33 $mgCaCO_3/L$) during the study period (Table 4.1). The lowest mean total alkalinity (18.9± 0.46 $mgCaCO_3/L$) recorded in US was significantly different from the highest (21.7±0.59 $mgCaCO_3/L$) recorded DS (Table 4.1). There was no significant difference ($p>0.05$) between the mean total alkalinity in the rainy (20.3 ±0.43 $mgCaCO_3/L$) and the dry (20.1± 0.52 $mgCaCO_3/L$) seasons (Table 4.2). Temporal variation of total alkalinity occurred in all the stations (Fig.4.8).The highest value (25.00 $mgCaCO_3/L$) was recorded during the late rainy season's months (September and October, 2014) in DS. The lowest value (14.00 $mgCaCO_3/L$) was recorded during the early raining season month (April, 2015) in US.

4.1.9 Chloride ion

Chloride ion concentration in Oluwa River ranged between 18 and 36 mg/L (27.4 ±0.66 mg/L) during the study period (Table 4.1). The lowest mean chloride ion (24.8±0.93mg/L) recorded in US was significantly different from the highest (30.6±1.0mg/L) recorded DS (Table 4.1). There was significant difference ($p<0.05$) between the mean value for rainy (28.8± 0.84) and the dry (24.8± 0.95) seasons (Table4.2). Temporal variation of Chloride ion occurred in upstream, midstream and downstream stations (Fig.4.9). The highest value (36.00mg/L) was recorded during the rainy season month (August, 2015) in DS. The lowest value (18.00mg/L) was recorded during the early raining season month (April, 2015) in US.

4.1.10 Total Dissolved Solids

Total dissolved solid concentration ranged between 14 and 60mg/L (mean= 28.0 ± 1.67mg/L) during the study period (Table 4.1). There was significant difference in the lowest mean TDS (23.6 ± 2.11mg/L) recorded US and the highest mean TDS (35.1 ± 2.73mg/L) recorded DS (Table 4.1).

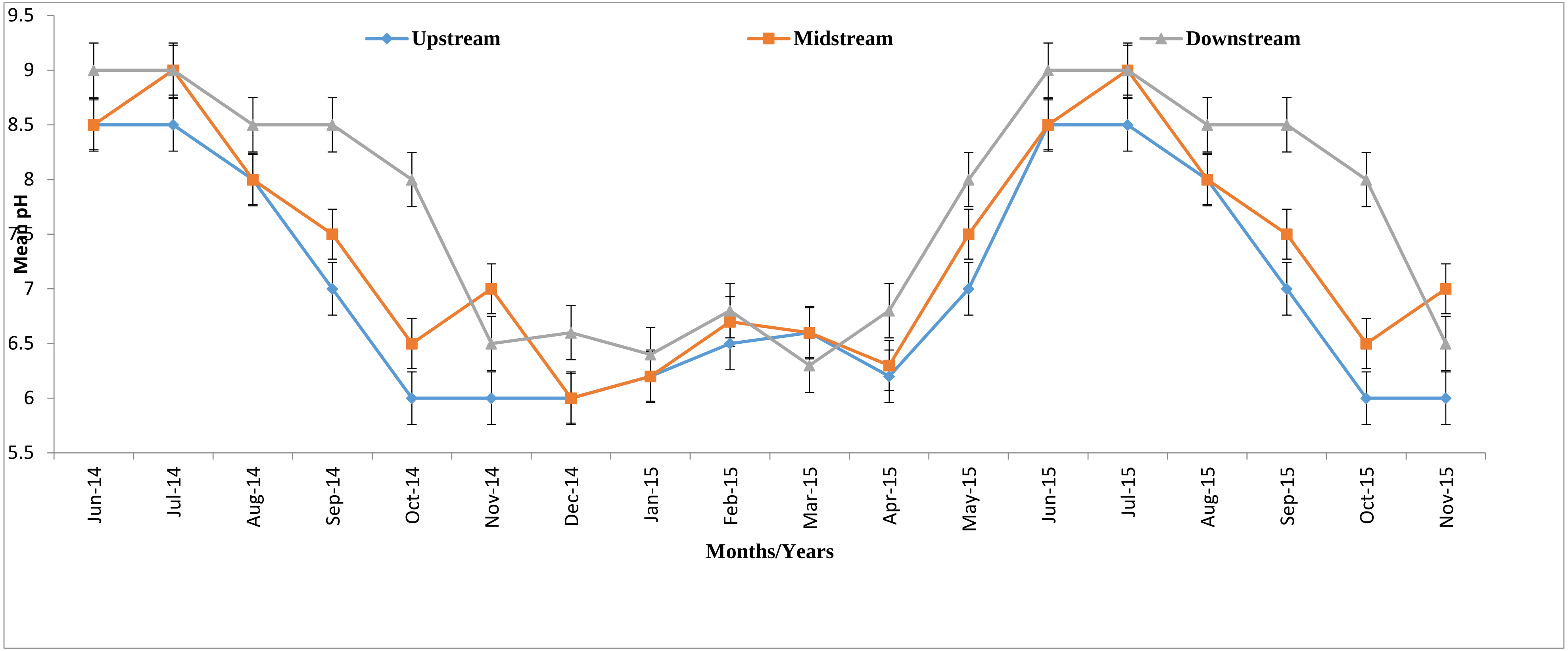


Fig.4.6: Mean Monthly Variation of pH in Oluwa River from June, 2014 to November, 2015

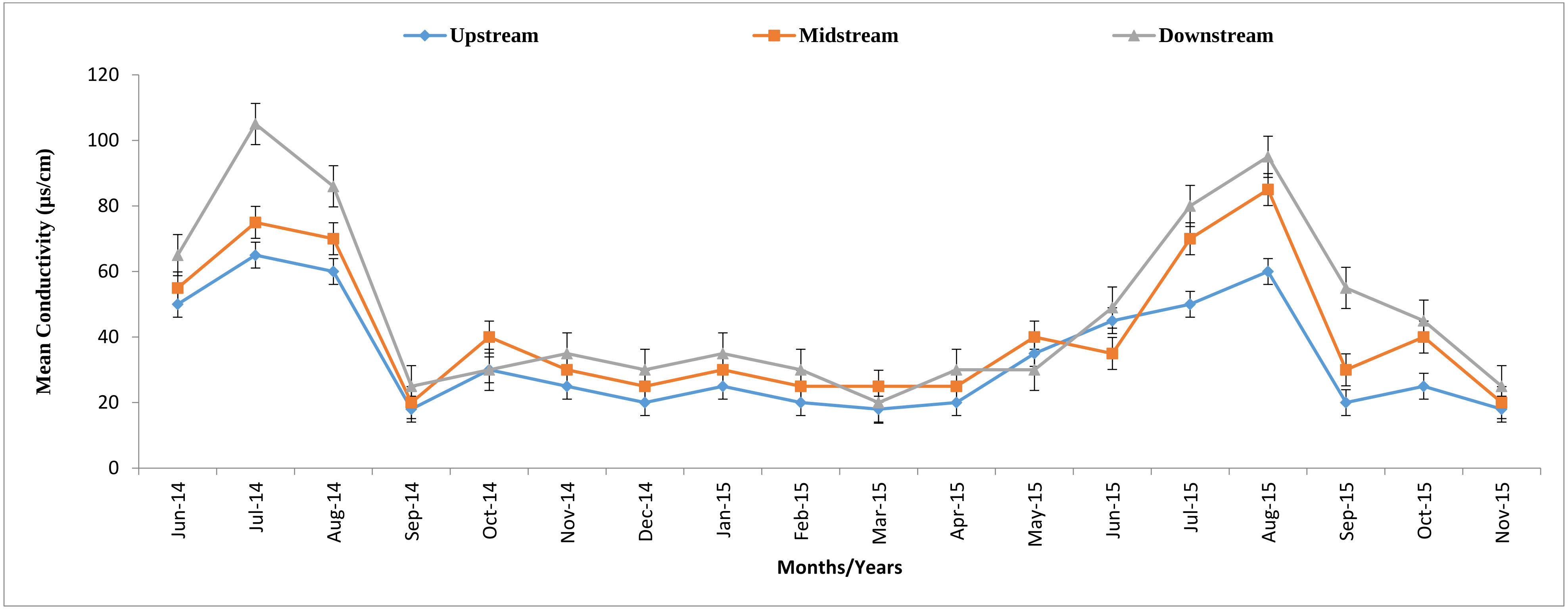


Fig.4.7: Mean Monthly Variation of Conductivity in Oluwa River from June, 2014 to November, 2015

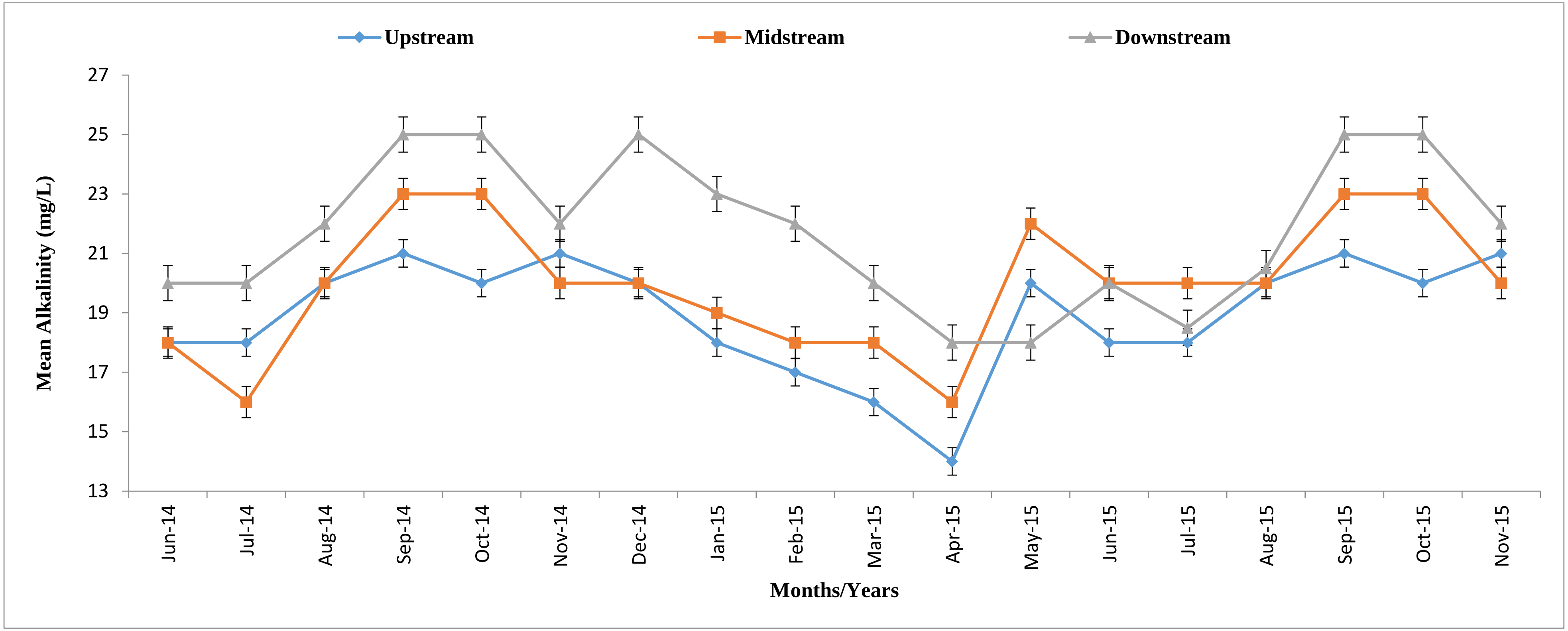


Fig.4.8: Mean Monthly Variation of Total Alkalinity in Oluwa River from June, 2014 to November, 2015

There was significant difference ($p<0.05$) between the mean value for the rainy (31.8± 2.23 mg/L) and for the dry (20.7±0.08 mg/L) seasons (Table 4.2). Temporal variation of total dissolved solids was observed in upstream, midstream and downstream stations (Fig.4.10). The highest value (60.00 mg/L) was recorded during the rainy season month (June, 2014) in DS. The lowest value (15.00mg/L) was recorded during the late rainy season month (September, 2014) in MS.

4.1.11 Total solids

Total solids concentration in Oluwa River ranged between 20 and 100 mg/L (mean = 58.7 ± 3.14mg/L) during the study period (Table 4.1). The lowest mean total solid (52.6 ± 5.52 mg/L) was recorded in upstream, while downstream recorded the highest (65.4 ± 5.19 mg/L) (Table 4.1). There was significant difference ($p<0.05$) in the mean value for the rainy (71.08 ± 2.76 mg/L) and the dry (33.9± 2.64 mg/L) seasons (Table 4.2). Temporal variation in total solids occurred upstream, midstream and downstream (Fig.4.11).The highest value (100.00 mg/L) was recorded during the rainy season month (June, 2014) in DS. The lowest value (22.00mg/L) was recorded during the dry season month (February, 2015) in upstream station.

4.1.12 Nitrate ion

Nitrate ion concentration ranged between 0.0 and 1.0 mg/L (mean = 0.02±0.001mg/L) during the study period (Table 4.1). The lowest mean nitrate ion (0.01 ± 0.002mg/L) recorded US was significantly different from the highest (0.03±0.003mg/L) recorded DS (Table 4.1). The spatial variations in nitrate ions was significantly different ($p<0.05$). There was significant difference in mean nitrate ion for rainy (0.03± 0.002 mg/L) and dry (0.02 ± 0.002 mg/L) seasons (Table 4.2). Temporal variation of nitrate was observed for upstream, midstream and downstream (Fig.4.12).The highest value (0.06mg/L) was recorded during the rainy season month (June, 2014) in DS.The lowest value (0.00 mg/L) was recorded during the late rainy season month (September, 2015) in DS.

4.1.13 Sulphate ion

Sulphate ion concentration ranged between 0.0 and 4.0mg/L (mean=2.05 ± 0.15mg/L) during the study period (Table 4.1). The lowest mean sulphate ion (1.6±0.21mg/L) recorded US was significantly different from the highest (2.4±0.21 mg/L) recorded DS (Table 4.1).

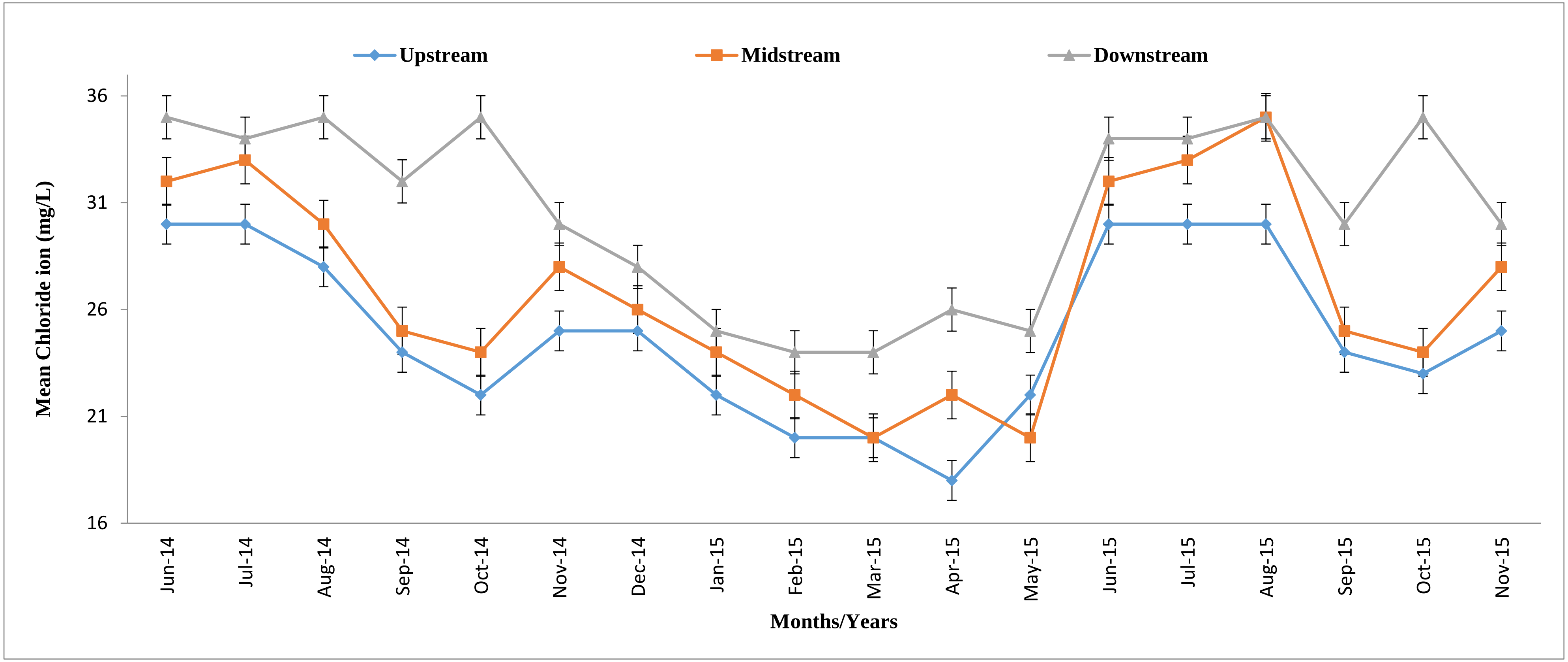


Fig.4.9: Mean Monthly Variation of Chloride Ion in Oluwa River from June, 2014 to November, 2015

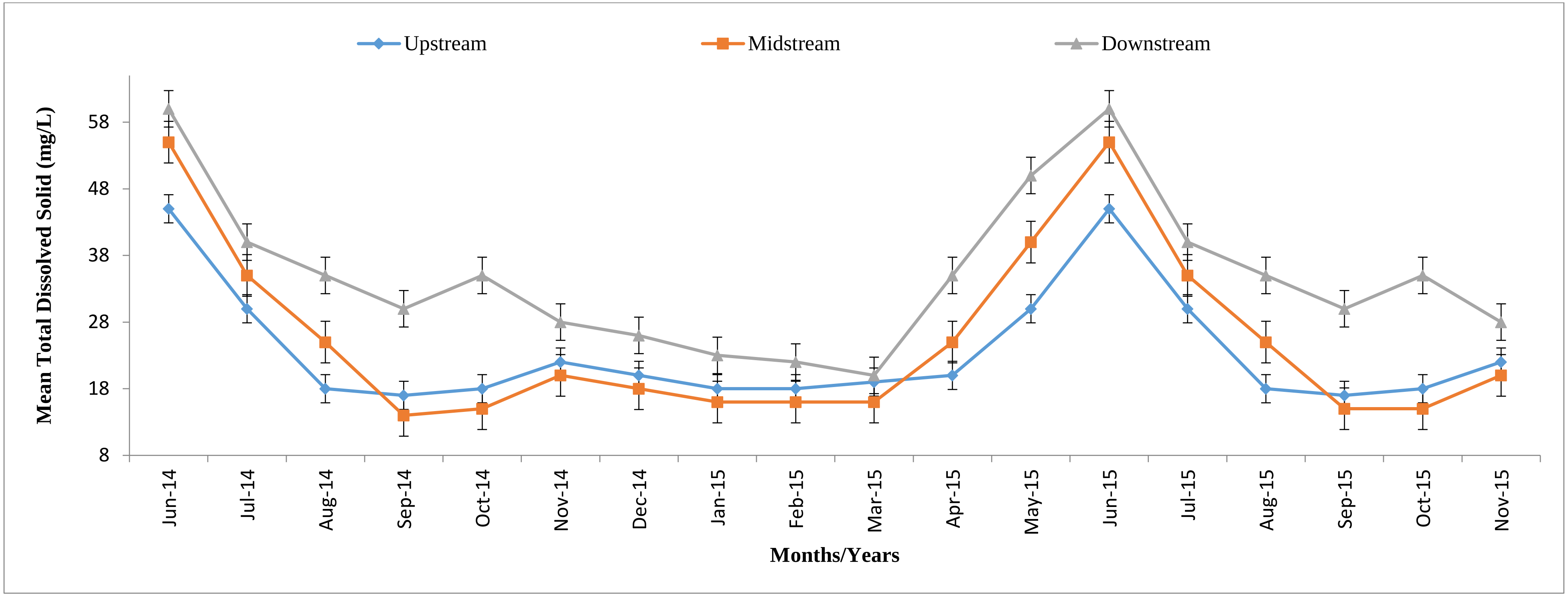


Fig.4.10: Mean Monthly Variation of Total Dissolved Solid in Oluwa River from June, 2014 to November, 2015

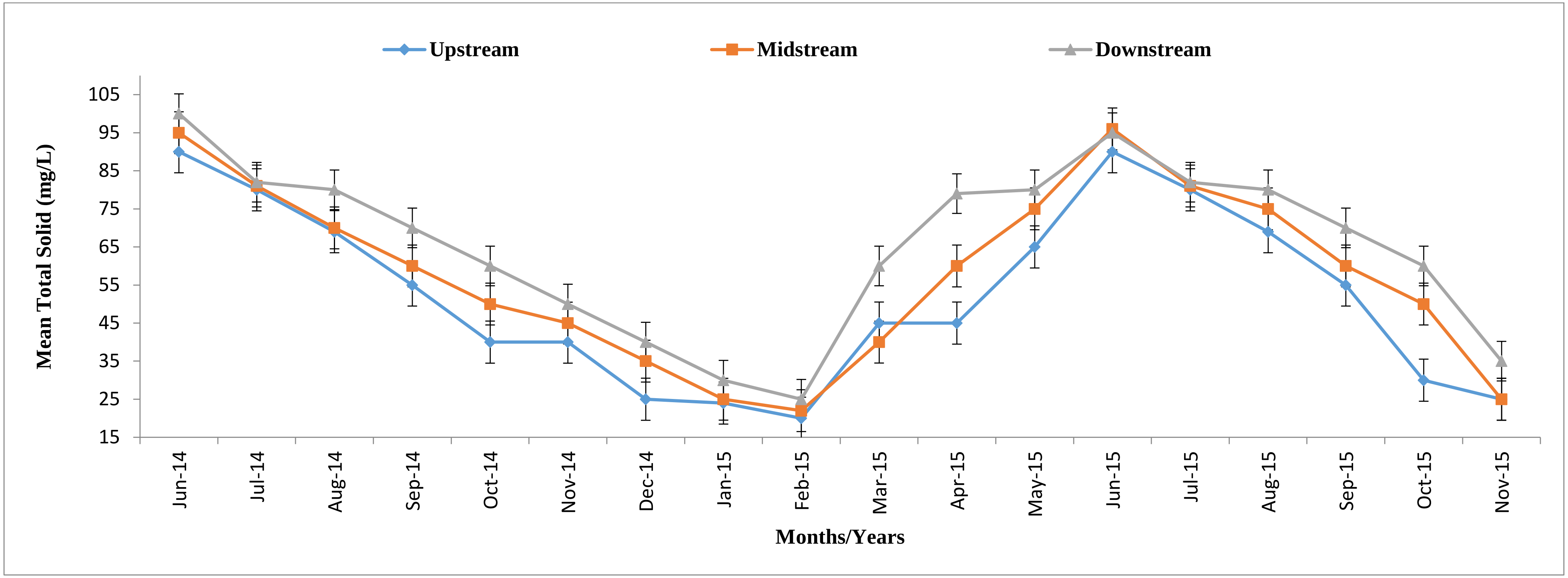


Fig.4.11: Mean Monthly Variation of Total solid in Oluwa River from June, 2014 to November, 2015

There was significant difference ($p<0.05$) between the mean value for rainy (2.65 ±0.13 mg/L) and the dry (0.8± 0.13 mg/L) seasons (Table 4.2). Temporal variation of sulphate ions occurred for all the stations (Fig.4.13).The highest value (4.0mg/L) was recorded during the rainy season month (June, 2014) in MS,. while the lowest value (0.0mg/L) was recorded during the dry season month (November, 2015).

4.1.14 Phosphate ion

Phosphate ion concentration in Oluwa River ranged between 1.0 and 4.5mg/L (mean =2.0±0.09mg/L) during the study period (Table 4.1). The lowest mean phosphate ion (1.7±0.12mg/L) recorded US was significantly different from the highest (2.5±0.19mg/L) recorded DS (Table 4.1). The spatial variations in phosphate ion was significantly different ($p<0.05$). There was significant difference ($p<0.05$) between the mean value for the rainy (2.23± 0.12 mg/L) and the dry (1.68 ±0.10 mg/L) seasons (Table 4.2). Temporal variation of phosphate ion occurred for upstream, midstream and downstream stations (Fig.4.14).The highest value (4.5 mg/L) was recorded during the rainy season month (June, 2014) in DS. The lowest value (0.7mg/L) was recorded during the rainy season month (May, 2015) in US.

4.1.15 Sodium ion

Sodium ion concentration ranged between 0.4 and 1.6 mg/L (mean =1.1±0.04 mg/L) during the study period (Table 4.1). The lowest mean sodium ion (1.0±0.09mg/L) was recorded upstream while, downstream recorded the highest (1.2±0.61mg/L) (Table 4.1). The spatial variations in sodium ion was not significantly different ($p>0.05$). There was significant difference ($p<0.05$) between the mean value for the rainy (1.32± 0.05 mg/L) and the dry (0.78± 0.13 mg/L) seasons (Table4.2). Temporal variation of sodium ions occurred in all stations (Fig.4.15).The highest value (2.2mg/L) was recorded during the rainy season month (June, 2015) in DS, while, the lowest value (0.2mg/L) was recorded during the dry season months February, and March, 2015 in the MS.

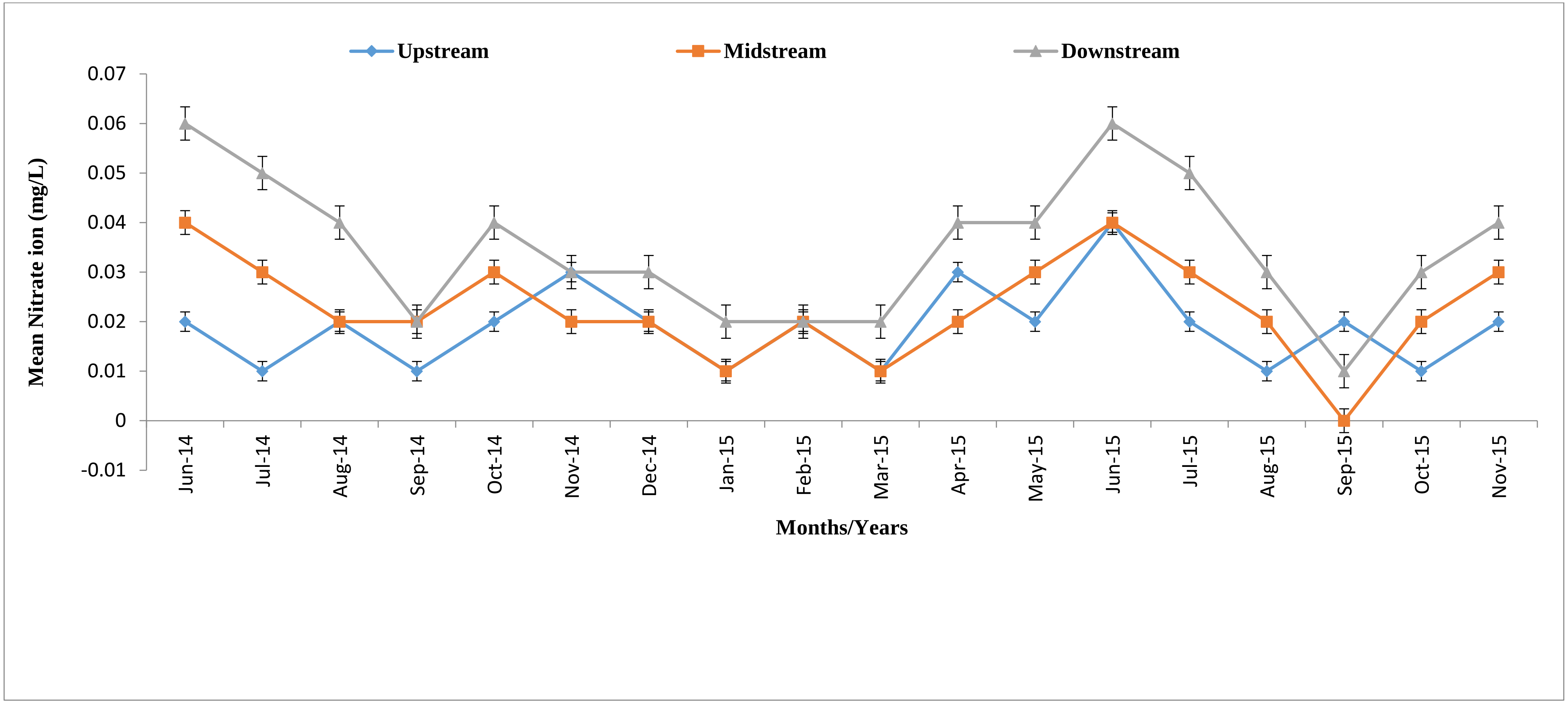


Fig.4.12: Mean Monthly Variation of Nitrate Ion in Oluwa River from June, 2014 to November, 2015

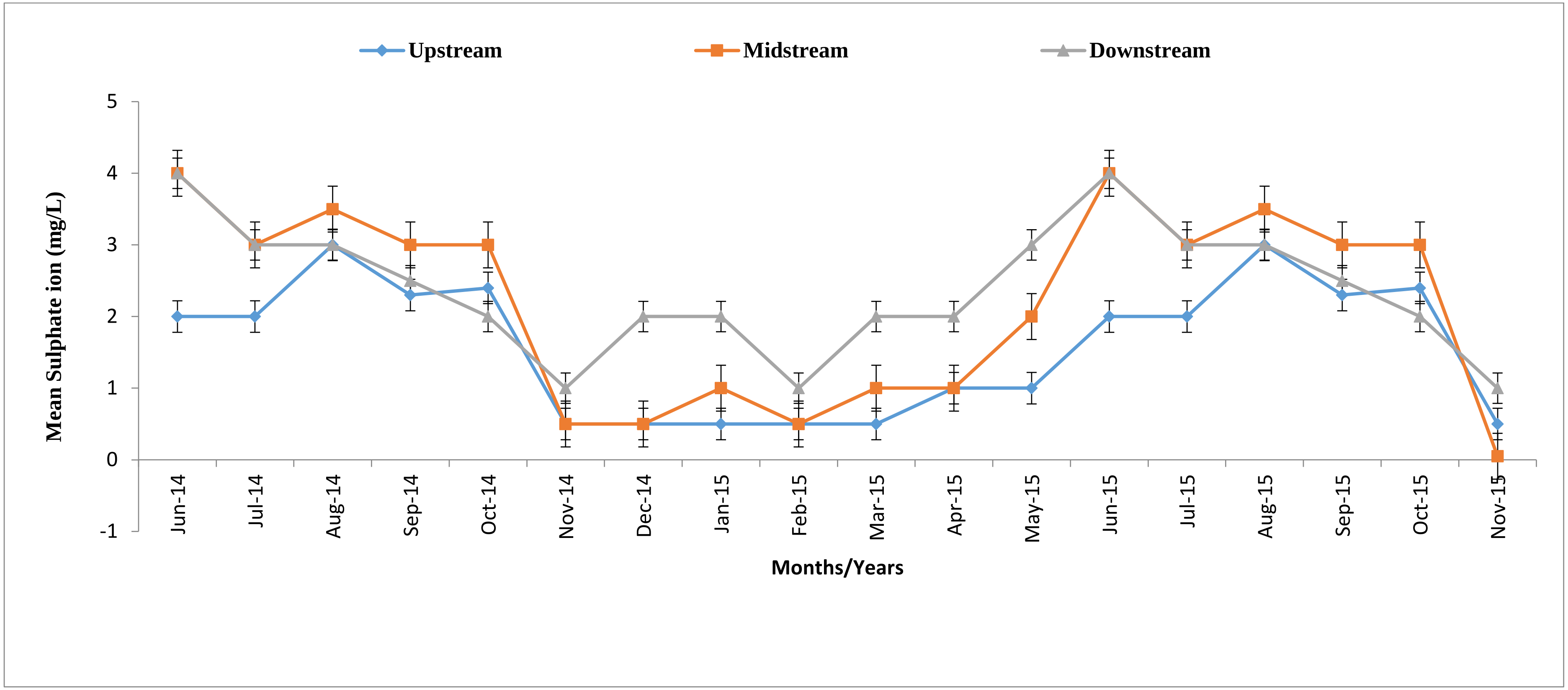


Fig.4.13: Mean Monthly Variation of Sulphate Ion in Oluwa River from June, 2014 to November, 2015

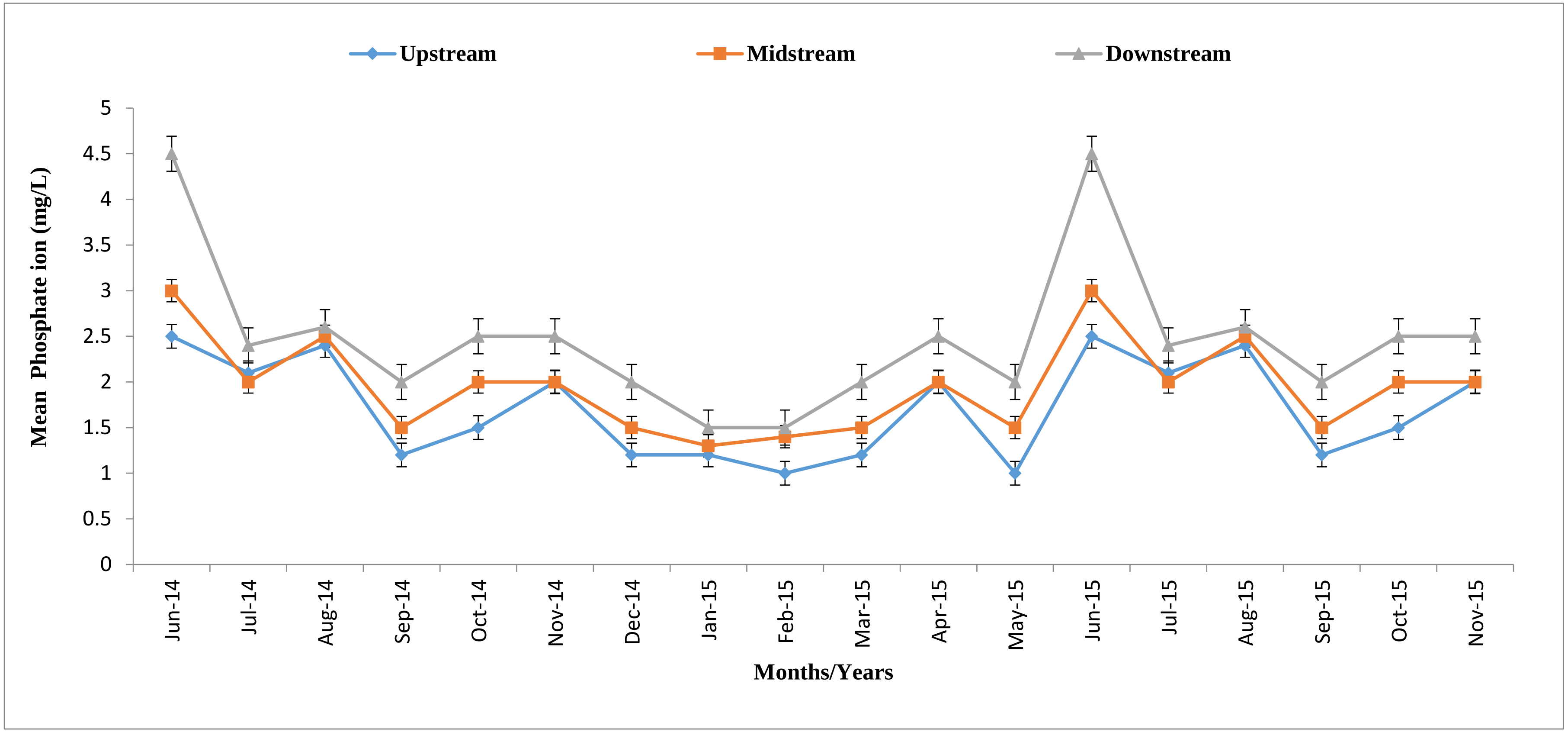


Fig.4.14: Mean Monthly Variation of Phosphate Ion in Oluwa River from June, 2014 to November, 2015

4.1.16 Potassium ion

Potassium ion concentration ranged between 0.4 and 1.6mg/L (mean=1.1±0.04mg/L) during the study period (Table 4.1). The lowest mean potassium ion (1.0±0.06mg/L) recorded in MS was significantly different from the highest (1.2± 0.06mg/L) recorded US (Table 4.1). The spatial variation recorded was significantly different ($p<0.05$). There was no significant difference ($p>0.05$) between the mean value for the rainy (1.17 ±0.03mg/L) and the dry (1.01 ±0.09 mg/L) seasons (Table 4.2). Temporal variation of potassium ions observed in all stations (Fig 4.16). Highest value (1.6mg/L) was recorded during the rainy season month (June,2014) upstream, while the lowest value (0.3mg/L) was recorded during the dry season month (March, 2015) in DS.

4.1.17 Magnesium ion

Magnesium ion concentration ranged between 0.3 and 5.0 mg/L (mean= 2.1 ±0.15 mg/L) during the study period (Table 4.1). The lowest mean magnesium ion (1.5±0.18mg/L) recorded in DS was significantly different from the highest (2.6±0.30mg/L) recorded US (Table 4.1). The spatial variations in magnesium ion was significantly different ($p<0.05$). There was significant difference ($p<0.05$) between the mean value for the rainy (2.50 ±0.18 mg/L) and the dry (1.32 ±0.12 mg/L) seasons (Table 4.2). Temporal variation of magnesium ion was observed for all the stations (Fig.4.17). The highest value (5.0mg/L) was recorded during the rainy season month (June, 2014) in US, while the lowest value (0.5mg/L) was recorded during the dry season month (March, 2015) in DS.

4.1.18 Calcium ion

Calcium ion concentration of Oluwa River ranged between 1.0 and 2.8 mg/L (mean =1.8 ± 0.07 mg/L) during the study period (Table 4.1). The lowest mean calcium ion (1.3± 0.04mg/L) recorded in DS was significantly different from the highest (2.2± 0.10mg/L) recorded US (Table 4.1). The spatial variations in calcium ion was significantly different ($p<0.05$). There was no significant difference ($p>0.05$) between the mean value for rainy (1.90± 0.08 mg/L) and the dry (1.61± 0.12 mg/L) seasons (Table4.2). Temporal variation of calcium ion occurred in all the stations (Fig4.18). The highest value (2.8mg/L) was recorded during the rainy season month (June, 2014) in US, while the lowest value (0.8mg/L) was recorded during the dry season month (February, 2015) in MS.

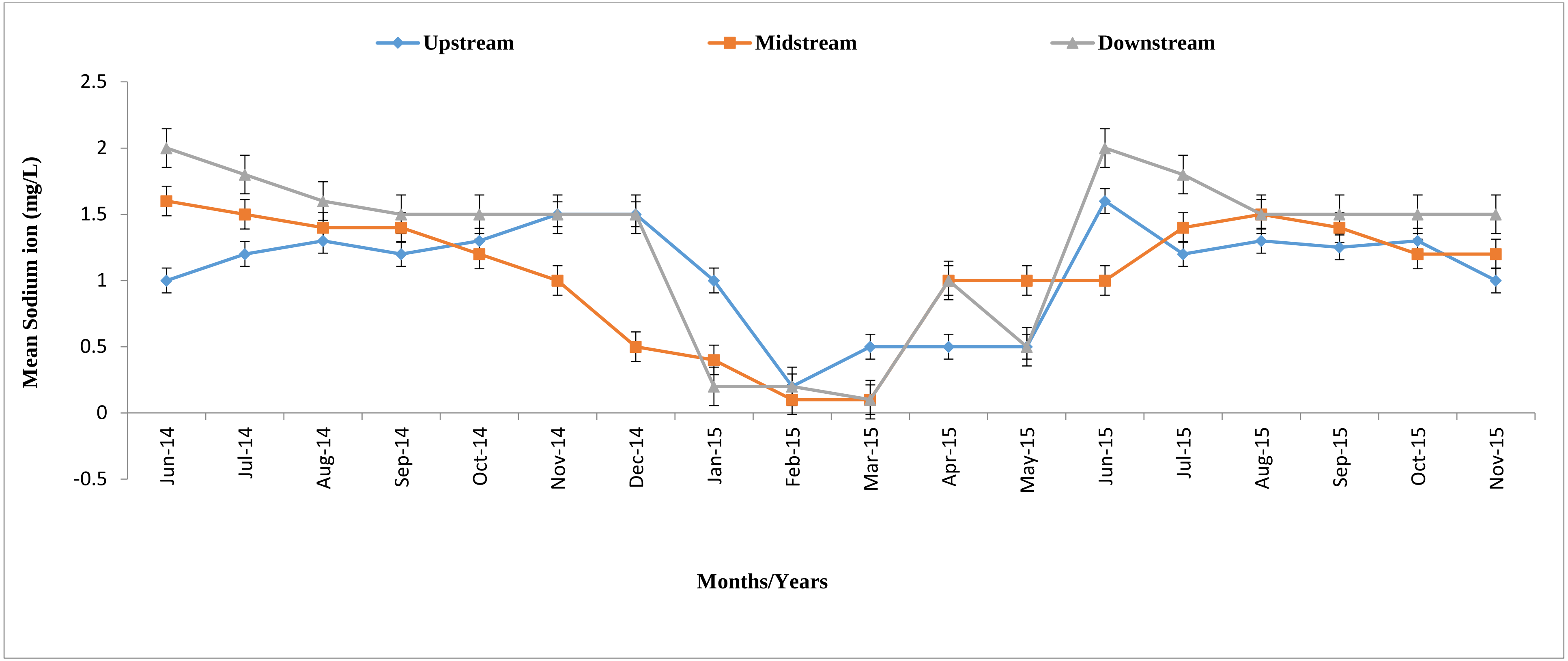


Fig.4.15: Mean Monthly Variation of Sodium Ion in Oluwa River from June, 2014 to November, 2015

Fig.4.16: Mean Monthly Variation in Potassium Ion in Oluwa River from June, 2014 to November, 2015

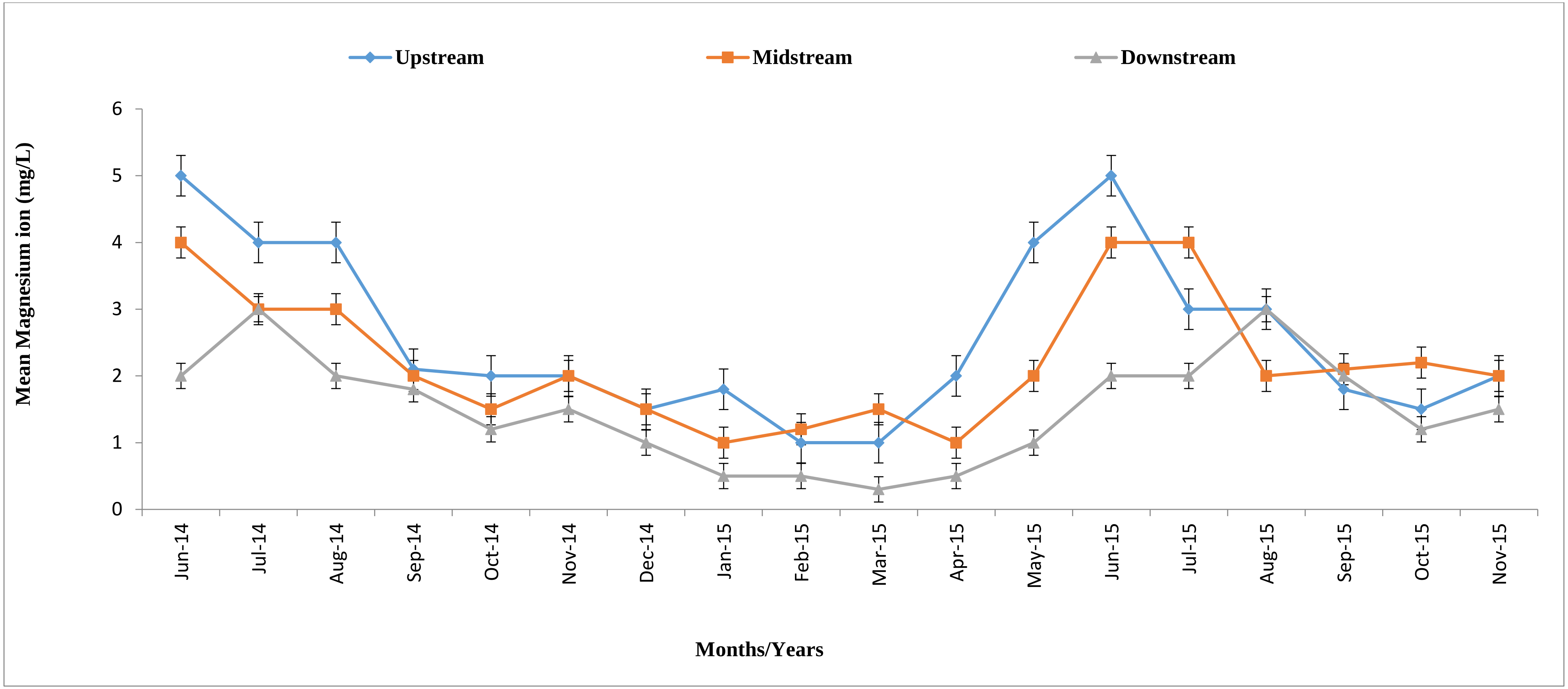


Fig.4.17: Mean Monthly Variation of Magnesium Ion in Oluwa River from June, 2014 to November, 2015

4.1.19 Cadmium ion

Cadmium ion concentration ranged between 0.0 and 0.02mg/L (mean=0.01±0.001mg/L) during the study period (Table 4.1). The lowest mean cadmium ion (0.01 ±0.001mg/L) recorded in US and MS, respectively was significantly different from the highest (0.02±0.001mg/L) recorded DS (Table 4.1). The spatial variations in cadmium ion was significantly different ($p<0.05$). There was significant difference ($p<0.05$) between the mean value for the rainy (0.02± 0.01 mg/L) and the dry (0.01±0.01 mg/L) seasons (Table 4.2). Temporal variation of cadmium ions observed for all the stations (Fig.4.19). The highest value (0.03mg/L) was recorded during the rainy season months (June, July, August, 2014) in DS, while the lowest value (0.0mg/L) was recorded during the dry season months (December, 2014 and March, 2015) in US.

4.1.20 Chromium ion

Chromium ion concentration ranged between 0.0 and 0.02mg/L (mean=0.006 ± 0.002mg/L) during the study period (Table 4.1). The lowest mean chromium ion (0.004 ± 0.001mg/L) recorded in US was significantly different from the highest (0.018 ± 0.004 mg/L) recorded DS (Table 4.1). The spatial variations in chromium ion was significantly different ($p<0.05$). There was no significant difference ($p>0.05$) in mean chromium ion for the rainy (0.01± 0.001 mg/L) and the dry (0.01 ±0.001 mg/L) seasons (Table 4.2). Temporal variation of chromium ions occurred for all the stations (Fig.4.20).The highest value (0.02mg/L) was recorded during the rainy season months (June, July, August, 2014) in DS, while the lowest value (0.0mg/L) was recorded during the rainy season months (June, August, 2014 to November, 2015) in US.

4.1.21 Lead ion

Lead ion concentration of Oluwa River ranged between 0.0 and 0.03mg/L (mean = 0.01 ± 0.001mg/L) during the study period (Table 4.1). The lowest mean lead ion (0.009±0.001mg/L) recorded in MS was significantly different from the highest (0.01 ±0.001mg/L) recorded DS (Table 4.1).

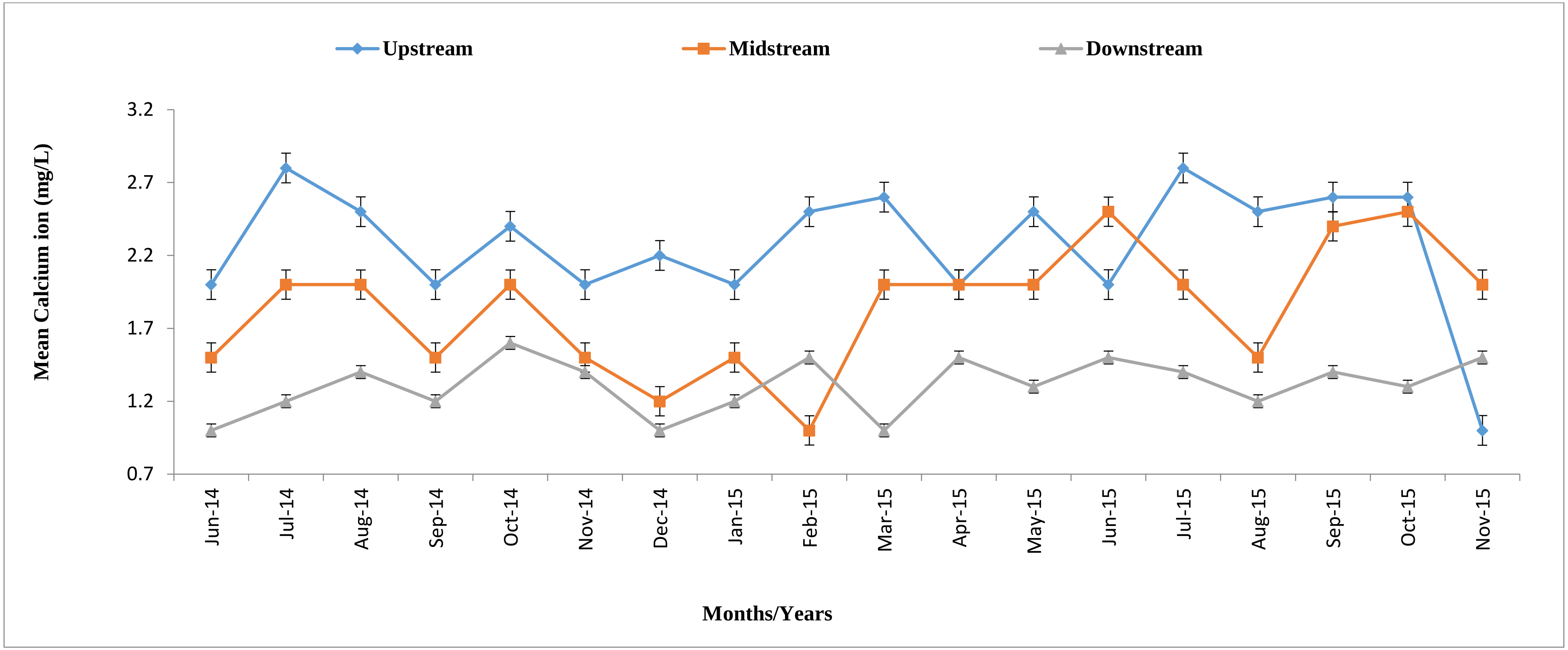


Fig.4.18: Mean Monthly Variation of Calcium Ion in Oluwa River from June, 2014 to November, 2015

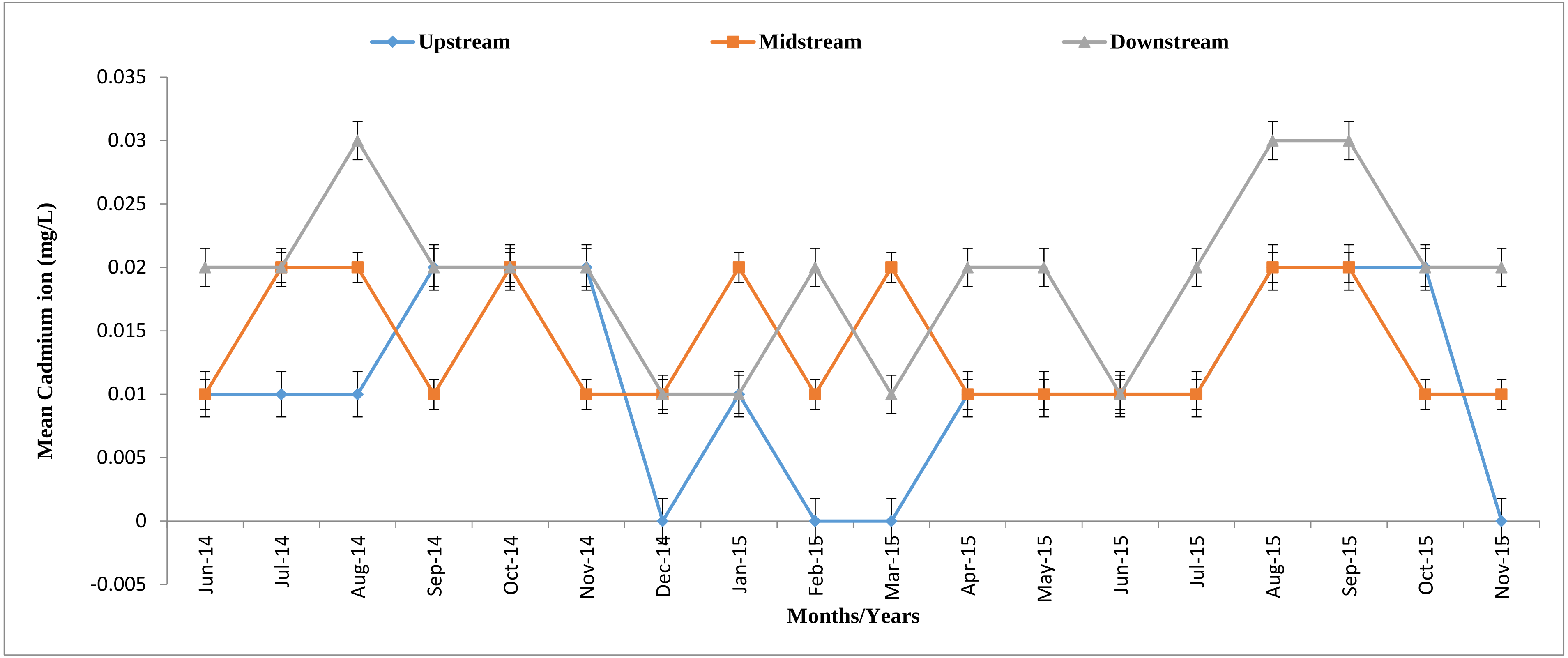


Fig.4.19: Mean Monthly Variation of Cadmium Ion in Oluwa River from June, 2014 to November, 2015

The spatial variations in lead ion was significantly different ($p<0.05$). There was no significant different ($p>0.05$) in mean lead ion for rainy (mean=0.01± 0.001 mg/L) and dry (0.01 ±0.001 mg/L) seasons (Table 4.2). Temporal variation of lead ions was observed for all the stations (Fig. 4.21).The highest value (0.03mg/L) was recorded during the dry season month (September, 2015) in DS. While, the lowest value (0.0mg/L) was recorded during the rainy season months (June, July, 2015) in MS and US recorded lowest value (0.0mg/L) mostly in dry seasons in September, 2014 to March, 2015.

4.1.22 Nickel ion

Nickel ion concentration ranged between 0.0 and 1.5mg/L (mean=0.7 ± 0.06mg/L) during the study period (Table 4.1). The lowest mean nickel ion (0.5 ± 0.09mg/L) recorded in MS was significantly different from the highest (1.1±0.09mg/L) recorded DS (Table 4.1). The spatial variations in nickel ion was significantly different ($p<0.05$). There was significant difference in the nickel for the rainy (0.85±0.07mg/L) and the dry (0.40 ± 0.05 mg/L) seasons (Table 4.2). Temporal variation of nickel ions observed for all the stations (Fig.4.22). The highest value (1.54mg/L) was recorded during the rainy season month (June, 2014) in DS, while the lowest value (0.0mg/L) was recorded during the dry season month (October, 2015) in US.

4.1.23 Ferrous ion

Ferrous ion concentration ranged between 0.0 and 0.3mg/L (mean=0.16 ± 0.01mg/L) during the study period (Table 4.1). The lowest mean ferrous ion (0.1±0.02mg/L) recorded in US was significantly different from the highest (0.2±0.01mg/L) recorded DS (Table 4.1). The spatial variations in ferrous ion was significantly different ($p<0.05$). There was no significant difference ($p>0.05$) in mean ferrous ion for the rainy (0.16±0.01 mg/L) and the dry (0.17 ±0.002 mg/L) seasons (Table 4.2). Temporal variation of ferrous ions occurred for all the stations (Fig 4.23). The highest value (0.32mg/L) was recorded during the rainy season month (October, 2015) in DS, while the lowest value (0.0mg/L) was recorded during the dry season months (February and April, 2015) in US.

4.1.24 **Salinity**

Salinity recorded in US, MS and DS was zero value throught the sampling periods.

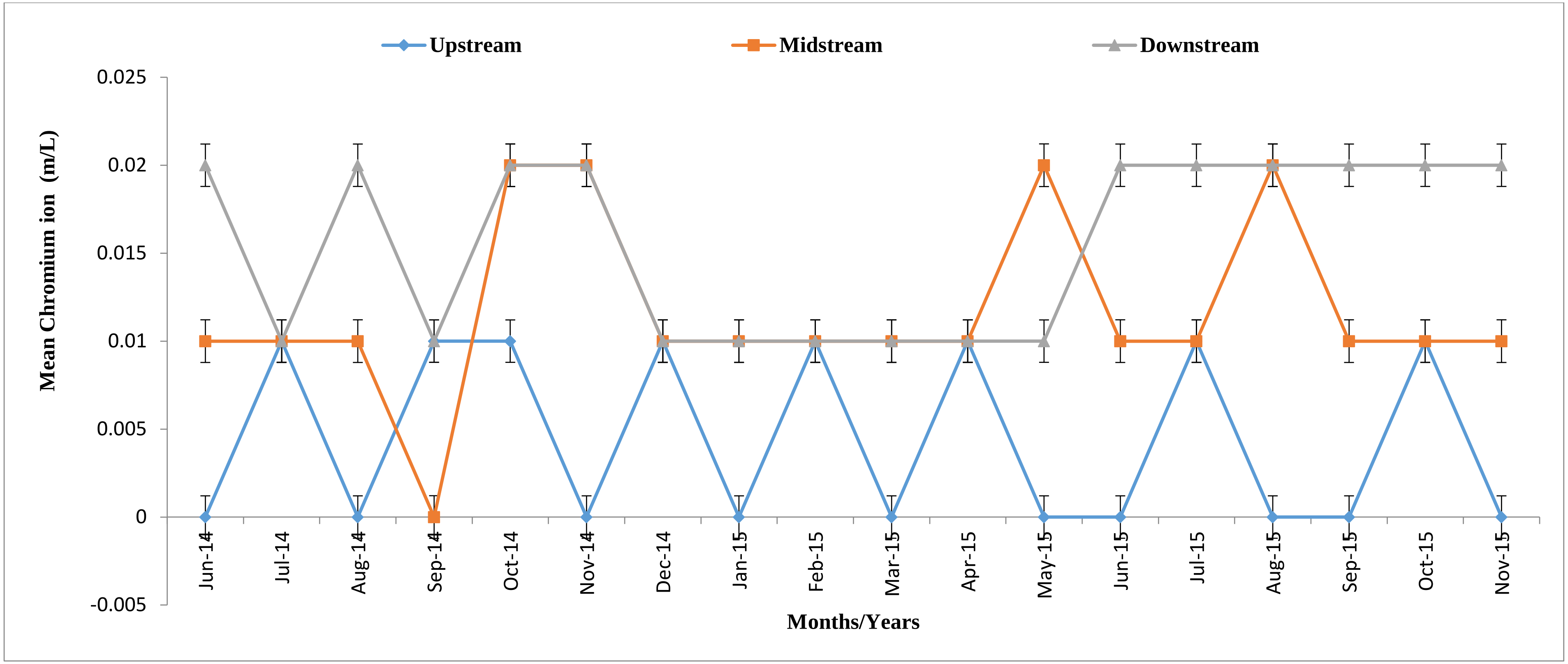


Fig.4.20: Mean Monthly Variation of Chromium Ion in Oluwa River from June, 2014 to November, 2015

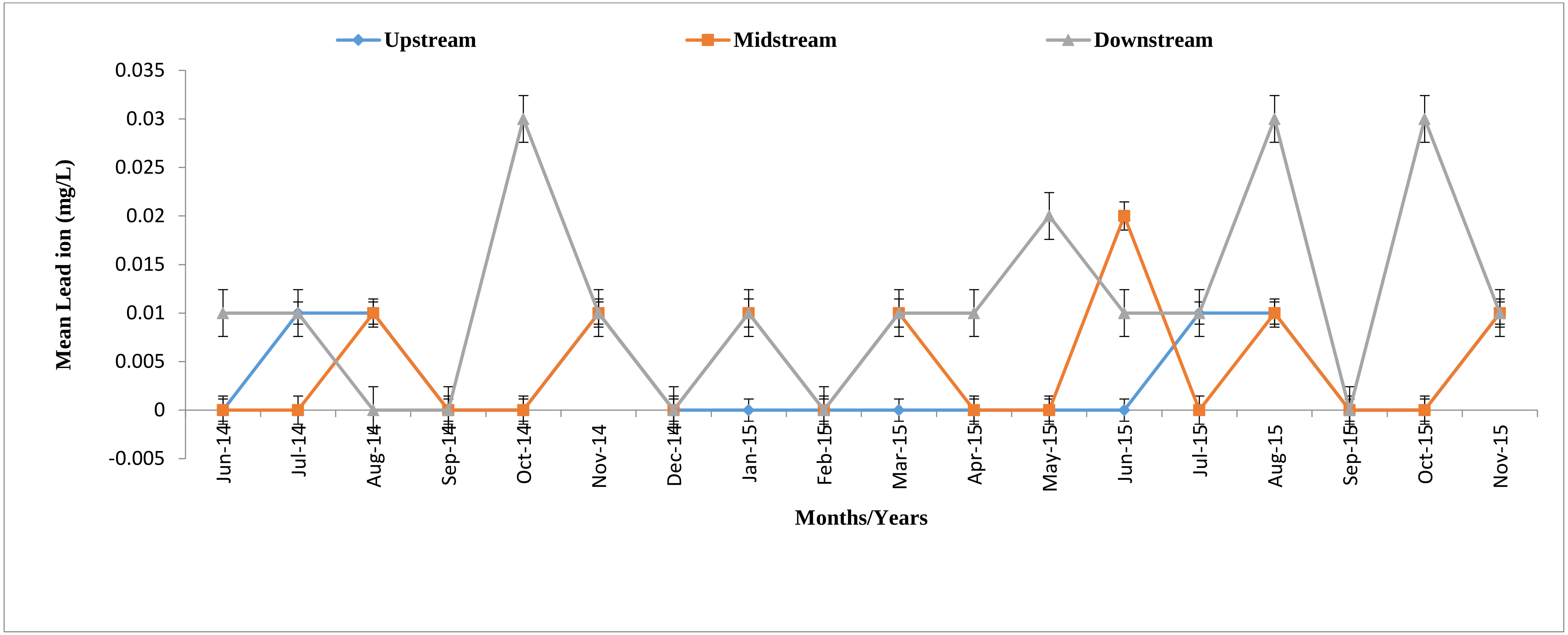


Fig.4.21: Mean Monthly Variation of Lead Ion in Oluwa River from June, 2014 to November, 2015

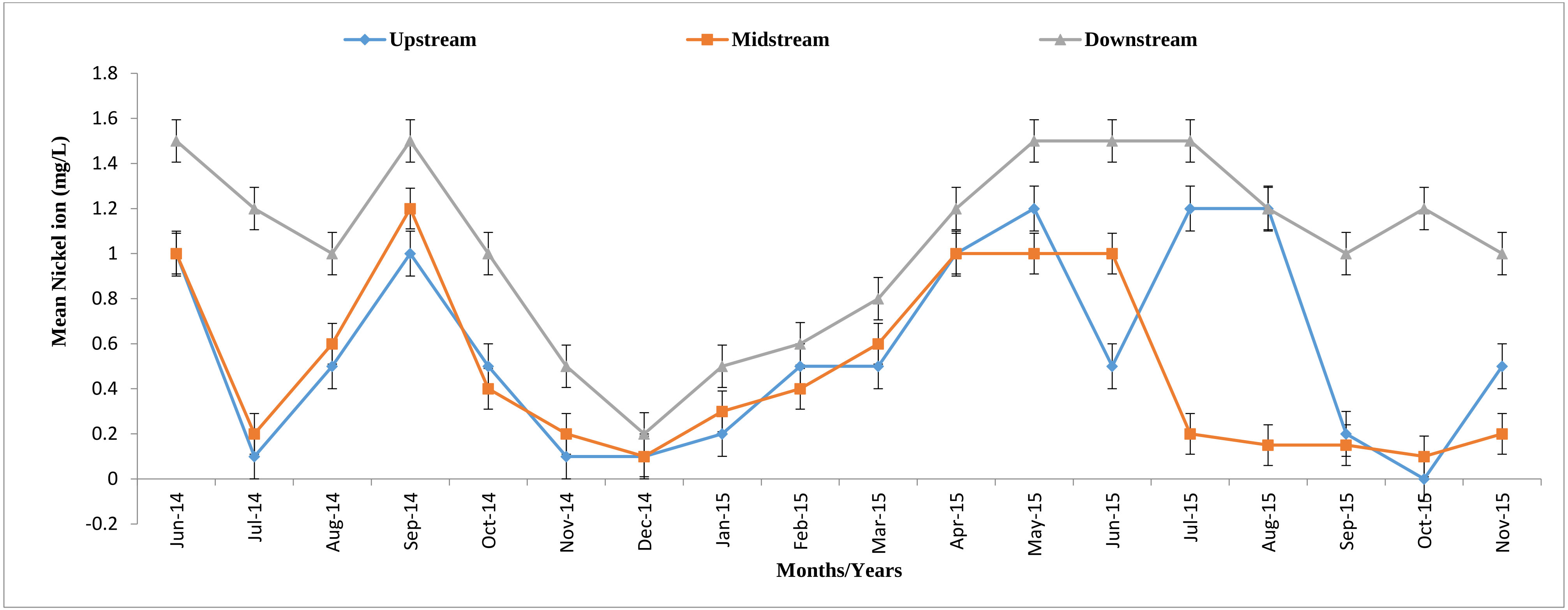


Fig.4.22: Mean Monthly Variation of Nickel Ion in Oluwa River from June, 2014 to November, 2015

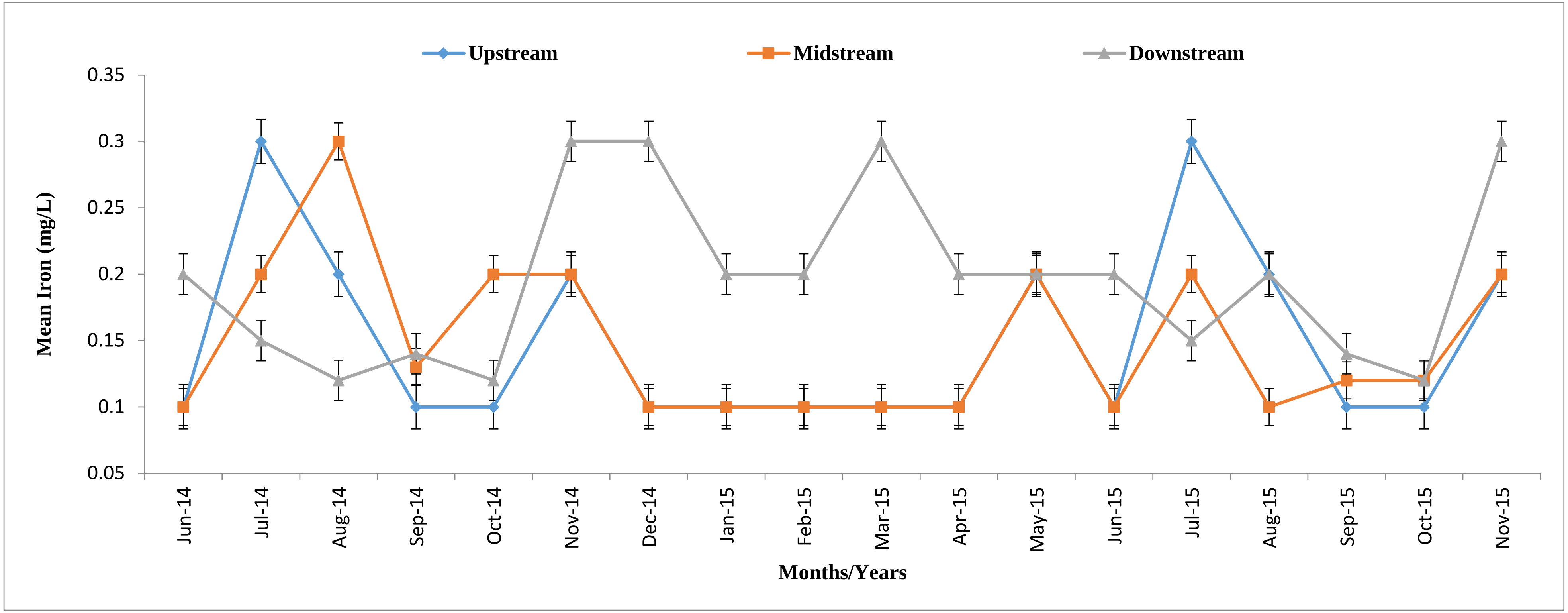


Fig.4.23: Mean Monthly Variation of Ferrous Ion in Oluwa River from June, 2014 to November, 2015

4.2 The relationships among the physico-chemical parameters in Oluwa River.

The output of the PCA extraction on the physico-chemical parameters of the river produced communalities that were all high, indicating that the extracted components represented the physico-chemical parameters well. The initial Eigen value revealed that the first three principal components formed the extraction solution with Eigen value greater than1.The extracted components explained nearly 96% of the variability in the original 23 parameters with only about 4% loss of information. The first component explained about 54.00%, the second 36.00% and third 5.83% of the variability (Table 4.3).

The PCA of the mean values of the physico-chemical parameters (Table 4.4) revealed that the first principal (PC1), which was most highly positive correlated with chloride ion (0.285) and had high positive loadings for pH (0.278), conductivity (0.281), TDS (0.276) and TS (0.273), which were ionic related. PC2, which was most highly negative correlated with dissolved oxygen (-0.344) and had high negative loadings for sodium (-0.319) and calcium ions (-0.319) and positive loadings for biochemical oxygen demand (0.275) and alkalinity (0.297). PC3 had high positive loadings for Iron (0.461) and high negative loadings for lead (-0.485), nickel (-0.448), and sulphate (-0.290), which are metallic related.

Most of the parameters clustered together in both seasons. Total dissolved solids, total solid and conductivity showed peculiar distribution in the PCA diagram in the rainy season, which is an indication of the influence of rain on the concentration of those parameters,conversely water temperature, air temperature and chloride were peculiar during the dry season across the three stations (upstream, midstream and downstream), an indication of impact of dry season on those parameters (Figure 4.24).

The correlation coefficient matrix showing relationship between physico-chemical parameters is presented in Appendix 11. The result of the relationship among physico-chemical parameters based on the mean concentrations of physico-chemical parameters of Oluwa River is indicated in the cluster diagram in Figure .4.25. pH and conductivity formed a cluster at r=0.991; chloride and phosphate formed at r=0.997, chromium and lead formed another cluster at r=0.991, BOD and air temperature formed a cluster at r= 0.996. Altogether, five major clusters were formed in the relationship among the physico-chemical parameters and they were significantly linked / joined at r=0.3515 ($p<0.05$).

4.3 Phytoplankton composition

A checklist of the phytoplankton species identified in Oluwa River in ILGA is in Table 4.5. Plate G shows the photomicrographs of some of the phytoplankton encountered in Oluwa River. Fifty-two phytoplankton species belonging to four classes were recorded during the study period twenty-eight species of Chlorophyceae, ten species of Bacillariophyceae, nine species of Cyanophyceae and five species of Euglenophyceae. The detailed data obtained on composition of phytoplankton from June, 2014 to November, 2015 are presented in Appendix 2.

Chlorophyceae dominated the phytoplankton groups, accounting for 50 % (Figure 4.26). *Closterium ebroracense* dominated among the Chlorophyceae, with 3.16 %; followed by *C. setaceum*, with 2.55 % (Table 4.6). The rainy season abundance (2000 Org/L) was higher than the dry season value (1817 Org/L) (Figure 4.27).

Bacillariophyceae accounted for 22% total phytoplankton (Figure 4.26). *Navicula crucicula* dominated among the Bacillariophyceae with 2.95%; followed by *Fragilaria construens*, with 2.58 % (Table 4.6). The dry season abundance (848 Org/L) was higher than the rainy season abundance (806 Org/L) (Figure 4.27).

Cyanophyceae accounted for 19% of the percentage abundance of phytoplankton (Figure 4.26). *Gomphospharia lacustria* dominated among the Cyanophyceae with 3.41% followed by *Anabaena constricta*, with 2.63% (Table 4.6). The dry season abundance (769 Org/L) was higher than the rainy season value (593 Org/L) (Figure 4.27).

Euglenophyceae accounted for 9% of the percentage abundance of phytoplankton (Figure 4.26). *Phacus brevicauda* dominated among the Euglenophyceae, accounting for 2.25%; followed by *Trachelomonas ensifera* (2.13%) (Table 4.6). The rainy season abundance (374 Org/L) was higher than the dry season value (314 Org/L) (Figure 4.27).

4.3.1 Spatial variations in phytoplankton abundance in Oluwa River

The highest abundance for phytoplankton was recorded in midstream (3246 Org/L) while, the lowest abundance (1613 Org/L) was recorded for upstream station during the study period (Table 4.7).

4.3.2 Diversity of phytoplankton in Oluwa River.

The highest Margalef (6.90), Shannon (3.89) and Evenness (0.94) were recorded for upstream, while lowest values for d (6.30), H (3.89) and E (0.82) were obtained midstream station during the study period (Table 4.8).

4.3.3 The relationships among the phytoplankton species during the seasons

The extracted components represented the phytoplankton species well as the communalities were high. The initial eigen value revealed that the first five principal components formed the extracted solution with eigen value greater than 1.The extracted components explain about 93.02% of the variability in the original 52 species with only about 6.98% loss of information (Table 4.9). The first component explained about 62.50%, the second 17.40%, the third 4.25%, the fourth 4.76% and the fifth 4.11% of the variability.

The PCA (Table 4.10) revealed that the first component (PC1), which was most highly correlated with the *Stenopterobia intermedia* (0.169), also had high positive loading for bacillariophyceace, such as *Asterionella formosa* (0.167), *Cymbella gracilis* (0.167), *Eunotia tautoniensis* (0.167), *Closterium setaceum* (0.168), *C. parvulum* Var (0.167), *C.peracerasum* (0.167) and *Chaetophora attenuate* (0.167). The second PC which was most highly correlated with *Tetraspora cylindrical* (0.226) also had high positive loadings for *Navicula crucicula* (0.181) and *Oscillatoria princeps* Vaucher (0.210).The third PC which was most highly correlated with *Micrasteria radiosa* (0.380), also had high negative loading for *Draparnastrum glomerata* (-0.303) and (-0.227) each for *Gonatozygon aculeatum*, *Micrasterias floridensis* and *M. floridensis Salisbury*.

The fourth PC, which was highly correlated with *Zygema sterile* (0.485) also had high positive loading for *Scutonema crispum* (0.290). The fifth PC which was most highly correlated with *Anabaena constricta* (-0.333) also had high positive loading for *Gomphospharia lacustria* (0.257) and high negative loading for *Spirogyra setiformis* (-0.296) Table 4.10.

The relationship among the phytoplankton species was established using the Principal Component Analysis (PCA), as shown in Figure 4.28. There was no strong relationship among the phytoplankton species in both seasons, as shown in the scattered diagram in Figure 4.28. However, they were mostly spread across the seasons with some more abundant in the dry season and others in the rainy season.

4.3.4 Cluster analysis of the relationships among the phytoplankton of Oluwa River.

Altogether, five clusters showed relationships of the recorded phytoplankton species at varying degree/ level of correlation. Most of the recorded phytoplankton showed positive significant correlation $p<0.05$, where $r=0.275$ with one another, except *Closterium momiliferum*, *Zygnema sterile*, *Lyngbya major*, *C. gracilis* and *Draparnasrum glomerata*, which showed non-significant correlation with the other phytoplankton species. Likewise, *Micrasterias radiosa*, and *Volvox aureus* showed non-significant correlation at $p> 0.05$ with the other phytoplankton species from Oluwa River (Fig 4.29). The correlation coefficient matrix showing relationship between phytoplankton species is presented in Appendix 12

4.3.5 Pollution tolerant species

Some of the phytoplankton species encountered have been used as indicators of aquatic pollution. Table 4.11 shows pollution tolerant phytoplankton species identified over the sampling period. Their occurrences were wide spread in the sampling locations.The Bacillariophyceae were the most abundant group encountered while Euglenophyceae were the least abundant. The Bacillariophyceae included: *Asterionella formosa*, *Fragilaria construens*, *Melosira distans* Var, *Navicula crucicula*,

Table 4.3: Extracted Principal Components of the Physico-chemical Parameters in Oluwa River

Principal Component	Eigen values	% variance	Cumulative%
1	12.42	54.00	54.00
2	8.28	36.00	90.00
3	1.34	5.83	95.83

Table 4.4: Principal Component Analysis (PCA) of the Physico-chemical parameters in Oluwa River

Parameters	PC 1	PC 2	PC 3
Air temperature (ºC)		**0.273**	
Water temperature (ºC)			
Transparency (m)			
Dissolved Oxygen (mg/L)		**-0.344**	
Biochemical Oxygen Demand(mg/L)		**0.275**	
pH	**0.278**		
Conductivity(µs/cm)	**0.281**		
Alkalinity(mg$CaCO_3$/L)		**0.297**	
Chloride (mg/L)	**0.285**		
Total Dissolved Solids(mg/L)	**0.276**		
Total Solids (mg/L)	**0.273**		
Nitrate (mg/L)			
Sulphate (mg/L)			**-0.290**
Phosphate (mg/L)			**-0.305**
Sodium (mg/L)		**-0.319**	
Potassium(mg/L)		**-0.319**	**-0.335**
Magnesium (mg/L)		**-0.289**	
Calcium (mg/L)		**-0.319**	
Cadmium (mg/L)			
Chromium (mg/L)			
Lead (mg/L)			**-0.485**
Nickel (mg/L)			**-0.448**
Iron (mg/L)		**0.285**	**0.461**

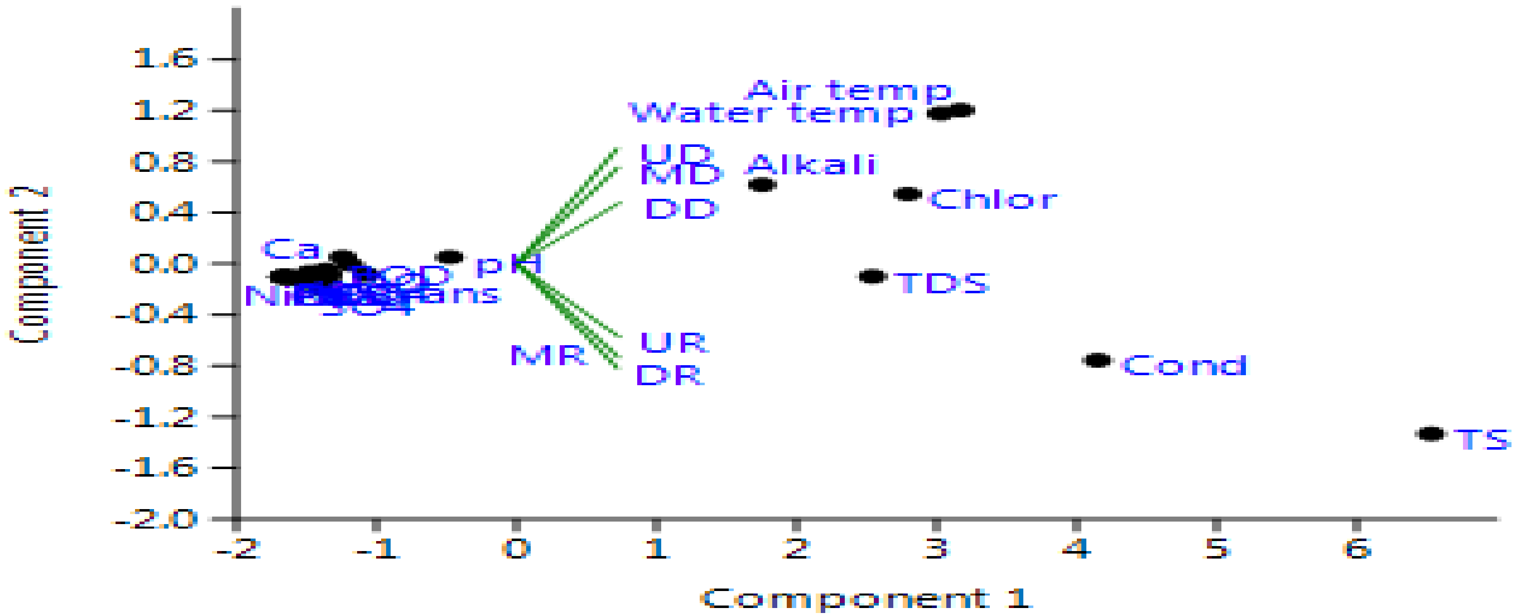


Figure 4.24: The Principal Component Analysis (PCA) Showing theRelationships among Physico-chemical Parameters during the Seasons

Key:

Air temp=Air temperature, W temp=Water temperature, Trans=Transparency, DO=Dissolved oxygen ,pH=pH, Alk=Alkalinity, Cond=Conductivity Chl=Chloride, TDS=Total Dissolved Solids, TS=Total Solids,NO_3=Nitrate, SO_4= Sulphate, Na=Sodium, K=Potassium,Mg=Magnesium, Ca=Calcium, Cd=Cadmium,Cr=Chromium, Pb=Lead, Ni=Nickel, Fe=Iron.

UD = upstream dry season, MD = midstream dry season, DD = downstream dry season, UR= upstream rainy season, MR= midstream rainy season, DR= downstream rainy season**.**

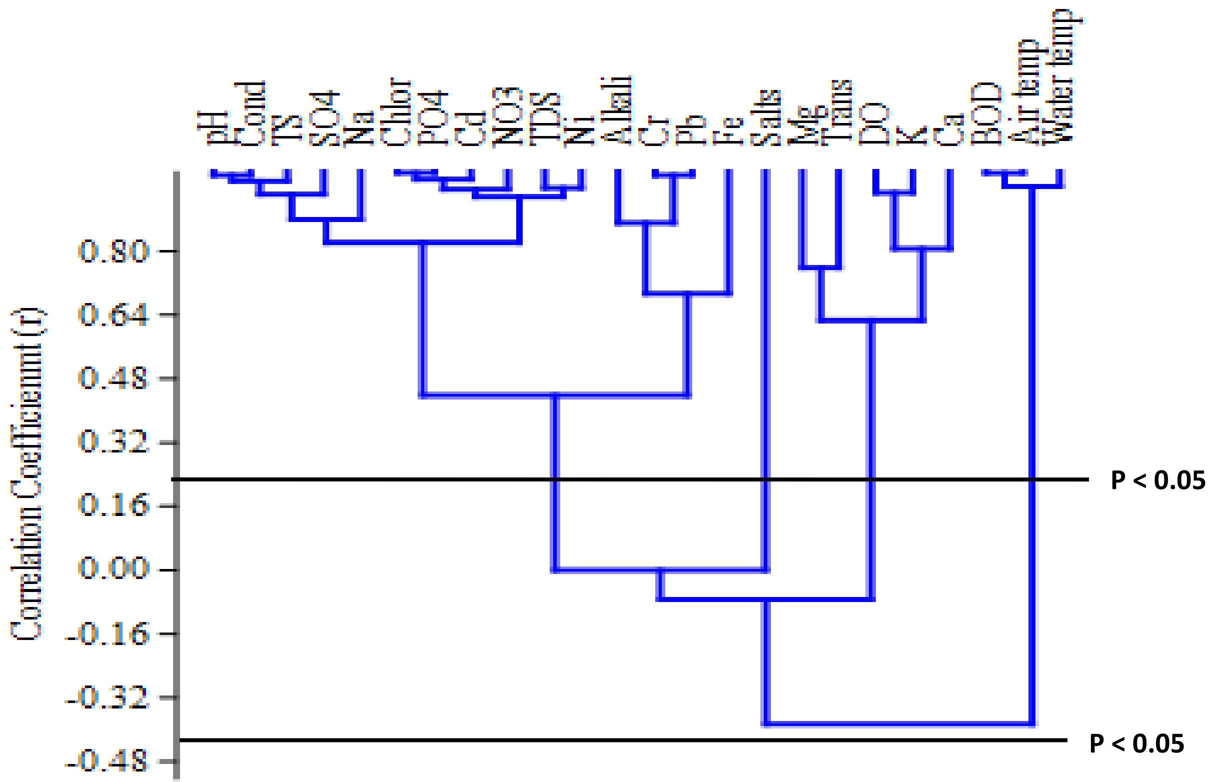


Figure4.25: Cluster Diagram Showing the Relationships between the Physico-chemical Parameters of Oluwa River

Table 4.5: A checklist of phytoplankton in Oluwa River from June, 2014 to November, 2015

Bacillariophyceae

1. *Asterionella formosa* .Hassal
2. *Cymbella gracilis.* Var
3. *Eunotia tautoniensis* Hust
4. *Fragilaria construens.* Var
5. *Melosira distans* Var (Bory, 1822)
6. *Navicula crucicula*. Donkin
7. *Nitzschia acicularis* (Ehr.) W.Sm.
8. *Scutonema crispum*.Ag
9. *Stenopterobia intermedia* Forma
10. *Tabellaria flocculosa*. Roth

Chlorophyceae

11. *Actinastrum hantschii.* Lagerheim
12. *Closterium abruptum.*
13. *C. ebroracense* Turner
14. *C. dianae* Breb
15. *C. gracile* Breb
16. *C. incurvum* Breb
17. *C. kuetzingii* Irenee-Marie
18. *C. lunula* .Var
19. *C. momiliferum.*Ehrenb
20. *C. morus*
21. *C. setaceum* .Ehrenb
22. *C. parvulum.*var
23. *C. peracerosum.Gay*
24. *C. pronum* .Breb
25. *Chaetophora attenu*ates. Hazen
26. *Draparnastrum glomerata* Ag
27. *Gonatozygon aculeatum* Hastings
28. *G.ehrenbergii*. DeBary
29. *Micrasterias floridensis.* Var Prescott and Scott
30. *M. floridensis* Salisbury

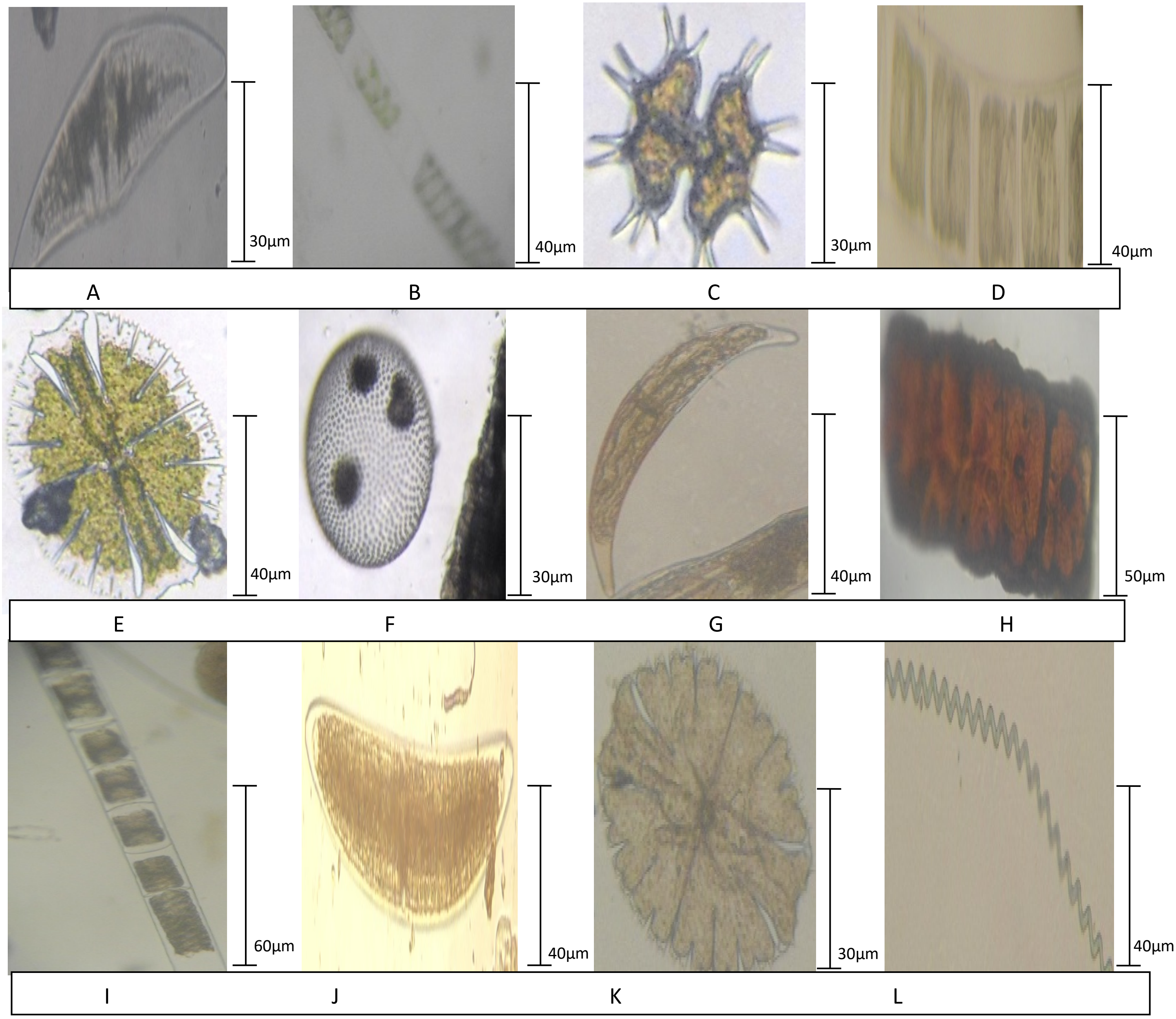
31. *M. fimbriata* Raifa
32. *M. radiosa.* Var Granata
33. *M. sol*
34. *Tetraspora cylindrical*
35. *Spirogyra setiformis*. Kutz
36. *Volvox aureus*
37. *Xanthidium antilopaeum*.Var
38. *Zygnema sterile*. Transeau

Cyanophyceae

39. *Anabaena constricta* (Kutz.) Rabb
40. *Aphanocapsa delilatissima*
41. *A.pulchra*
42. *Chrsococcus taricensis*
43. *Lyngbya major.* Meneghini
44. *Gomphospharia lacustria* (Kutzing, 1836)
45. *Oscillatoria princeps*
46. *O. princeps* .Vaucher
47. *Spirulina subsasa* Oersted

Euglenophyceae

48. *Trachelomonas ensifera* Drez
49. *T. gibberosa*
50. *T. schauinsladii*
51. *Phacus brevicauda*
52. *Synura uvella.* Scale



Key:

A.	*Cymbella gracilis*	**B.**	*Spirogyra setiformis*
C.	*Xanthidium antilopaeum*	**D.**	*Zygnema sterile*
E.	*Micrasterias radiosa*	**F.**	*Volvox* aureus
G.	*Closterium diana*	**H.**	*Eunotia tantoniensis*
I.	*Melosira distans*	**J.**	*Closterium incurvum*
K.	*Micrasterias sol*	**L.**	*Spirulina subsalsa*

Plate G: Some Phytoplankton Encountered in Oluwa River from June, 2014 to November, 2015

Table 4.6. Relative Abundance of Phytoplankton of Oluwa River in ILGA

SPECIES	Number (Org/L)	% Number
Bacillariophyceae		
Asterionella formosa	182	2.44
Cymbella gracilis	124	1.66
Eunotia tautoniensis	132	1.77
Fragilaria construens	192	2.58
Melosira distans var	115	1.54
Navicula crucicula	220	2.95
Nitzschia aciculris	167	2.24
Scutonema crispum	177	2.38
Stenopterobia intermedia Forma	178	2.39
Tabellaria flocculosa	163	2.19
Sub total	**1650**	**22.19**
Chlorophyceae		
Actinastrum hantschii	163	2.19
Closterium abruptum. Var	163	2.19
C. ebroracense Turner	235	3.16
C.dianae	135	1.81
C. gracile	185	2.48
C. incurvum	159	2.13
C. kuetzingii	159	2.13
C. lunula	120	1.61
*C. momiliferum.*Ehrenb	120	1.61
C. morus	120	1.61
C. setaceum	190	2.55
C. parvulum.var	124	1.66
*C. peracerosum.*Gay	88	1.18
C. pronum	111	1.49
Chaetophora attenuate	116	1.55
Draparnastrum glomerata	55	0.73*
Gonatozygon aculeatum	106	1.42
G.ehrenbergii	141	1.89
Micrasterias floridensis	141	1.89
M. floridensis Salisbury	66	0.88

M. fimbriata Raifa	147	1.97
M. radiosa Var	112	1.50
M. sol	83	1.11
Tetraspora cylindrical	182	2.44
Spyrogyra setiformis.Kutz	138	1.85
Volvox aureus	110	1.47
Xanthidium antilopaeum.Var	125	1.68
Zygnema sterile.Transeau	142	1.90
Sub total	**3736**	**50.24**
Cyanophyceae		
Anabaena constricta	196	2.63
Aphanocapsa delilatissima	129	1.73
A. pulchra	114	1.53
Chrsococcus taricensis	111	1.53
Lyngbya major Meneghini	85	1.14
Gomphospharia lacustria	254	3.41**
Oscillatoria princeps	193	2.59
O. princeps .Vaucher	185	2.48
Spirulina subsasa Oersted	95	1.27
Sub total	**1362**	**18.32**
Euglenophyceae		
Trachelomonas ensifera Drez	159	2.13
T. gibberosa	152	2.04
T. schauinsladii	107	1.43
Phacus brevicauda	168	2.25
Synura uvella	102	1.37
Sub total	**688**	**9.25**
GRAND TOTAL	**7,436**	

*= least abundance

**=highest abundance

Table 4.7: Spatial Variations in Phytoplankton Abundance in Oluwa River

Phytoplankton	**Upstream station**	**Midstream station**	**Downstream station**
Bacillariophyceae	320	749	581
Chlorophyceae	907	1549	1250
Cyanophyceae	274	659	429
Euglenophyceae	112	289	287
Total Abundance (Org/L)	1613	3246	2547

Table 4.8: Diversity of Phytoplankton in Oluwa River

Diversity Indices	Upstream station	Midstream station	Downstream station	OVER ALL Mean± SE
Margalef (d)	6.90	6.30	6.50	6.56±0.12
Shannon (H)	3.89	3.87	3.88	3.88±0.23
Evenness (E)	0.94	0.92	0.93	0.93±0.24

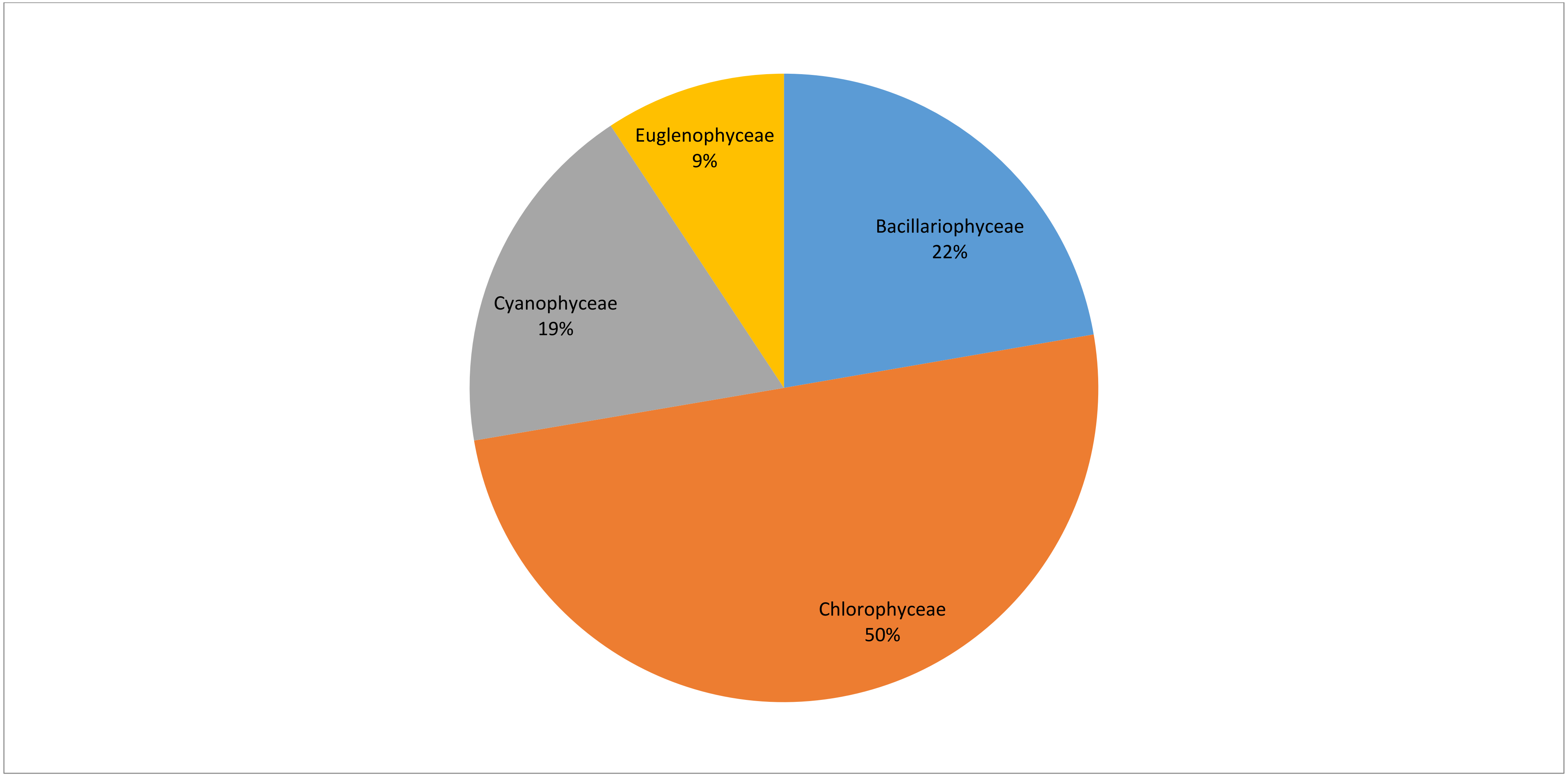


Figure 4.26: Percentage Abundance of Phytoplankton in Oluwa River

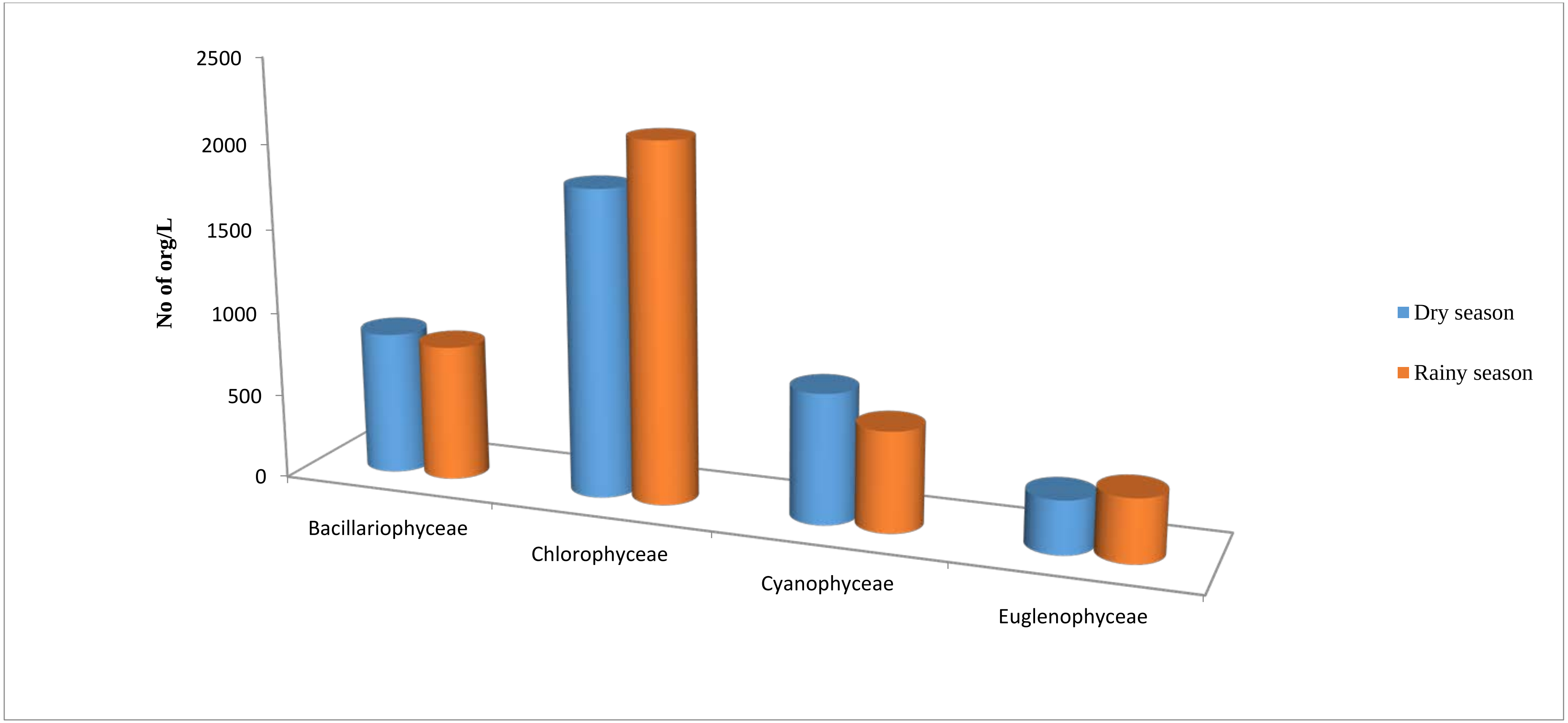


Figure 4.27: Relative Abundance of phytoplankton in the Dry and the Rainy Seasons in Oluwa River

Table: 4.9: Extracted Principal Components of Phytoplankton Species in Oluwa River

PC	Eigen value	% Variance	Cumulative%
1	32.50	62.50	62.50
2	9.05	17.40	79.90
3	5.85	4.25	84.15
4	2.47	4.76	88.91
5	2.14	4.11	93.02

Table 4.10: Principal Component Analysis (PCA) of Phytoplankton Species in Oluwa River

S/NO	Taxon	Comp 1	Comp 2	Comp3	Comp 4	Comp 5
1	*Asterionella formosa*	**0.167**				
2	*Cymbella gracilis*	**0.167**				
3	*Eunotia tautoniensis*	**0.167**				
4	*Fragilaria construens*					**-0.279**
5	*Melosira distans var*					
6	*Navicula crucicula*		**0.181**			
7	*Nitzschia aciculris*					
8	*Scutonema crispum*				**0.290**	
9	*Stenopterobia intermedia*	**0.169**				
10	*Tabellaria flocculosa*					
11	*Actinastrum hantschii*					
12	*Closterium abruptum.*					
13	*C. ebroracense*					
14	*C. dianae*					
15	*C. gracile*					
16	*C. incurvum*					
17	*C. kuetzingii*					
18	*C. lunula*					
19	*C. momiliferum*					
20	*C. morus*					
21	*C. setaceum*	**0.168**				
22	*C. parvulum.*Var	**0.167**				
23	*C. peracerosum.*Gay	**0.167**				
24	*C. pronum*					
25	*Chaetophora attenu*ate	**0.167**				
26	*Draparnastrum glomerata*			**-0.303**		
27	*Gonatozygon aculeatum*			**-0.227**		
28	*G. ehrenbergii*					
29	*Micrasterias floridensis*			**-0.227**		

30	*M. floridensis Salisbury*			**-0.227**		
31	*M. fimbriata Raifa*					
32	*M. radiosa*			**0.380**		
33	*M. sol*					
34	*Tetraspora cylindrical*		**0.226**			
35	*Spirogyra setiformis*					**-0.296**
36	*Volvox aureus*					
37	*Xanthidium antilopaeum*					
38	*Zygnema sterile*				**0.485**	
39	*Anabaena constricta*					**-0.333**
40	*Aphanocapsa delilatissima*					
41	*A. pulchra*					
42	*Chrsococcus taricensis*					
43	*Lyngbya major Meneghini*					
44	*Gomphospharia lacustria*					**0.257**
45	*Oscillatoria princeps*					
46	*O. princeps* .Vaucher		**0.210**			
47	*Spirulina subsasa* Oersted					
48	*Trachelomonas ensifera* Drez					
49	*T. gibberosa*					
50	*T. schauinsladii*					
51	*Phacus brevicauda*					
52	*Synura uvella*					

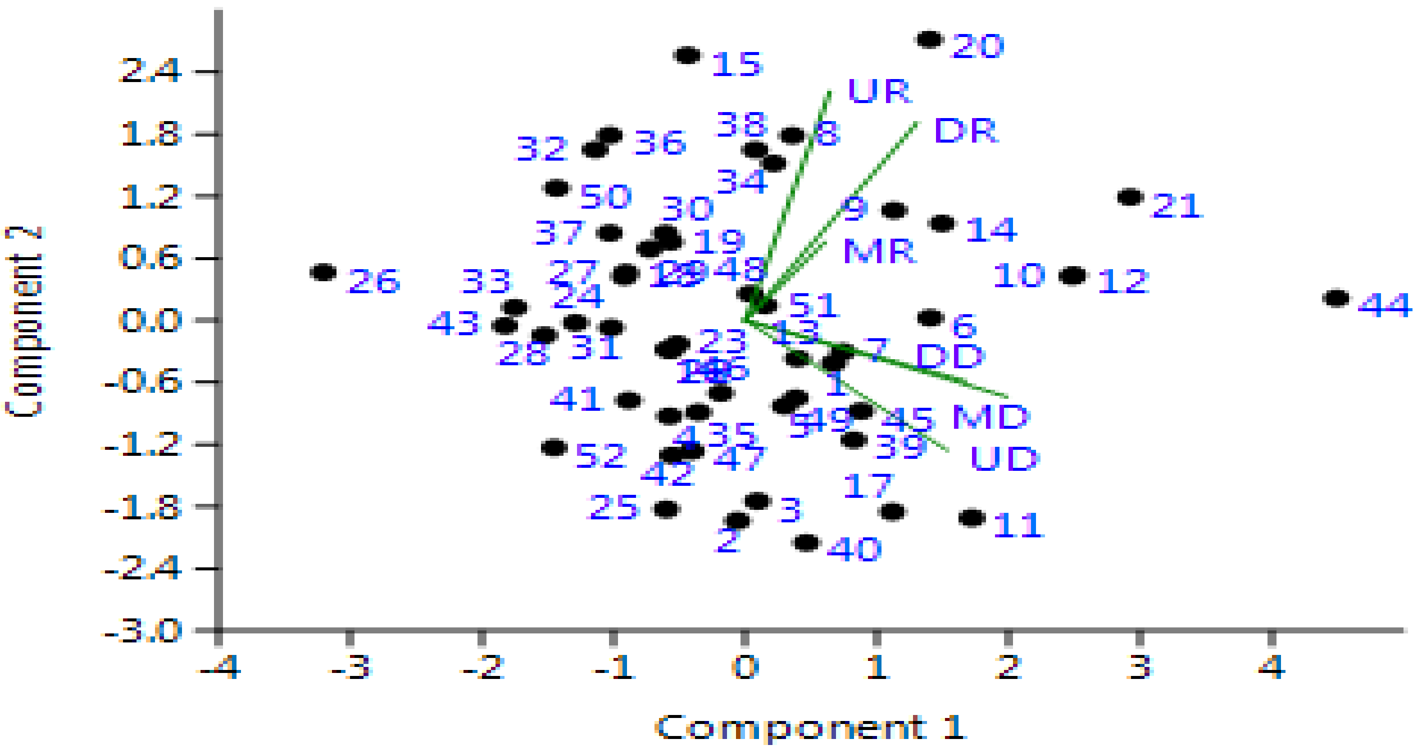
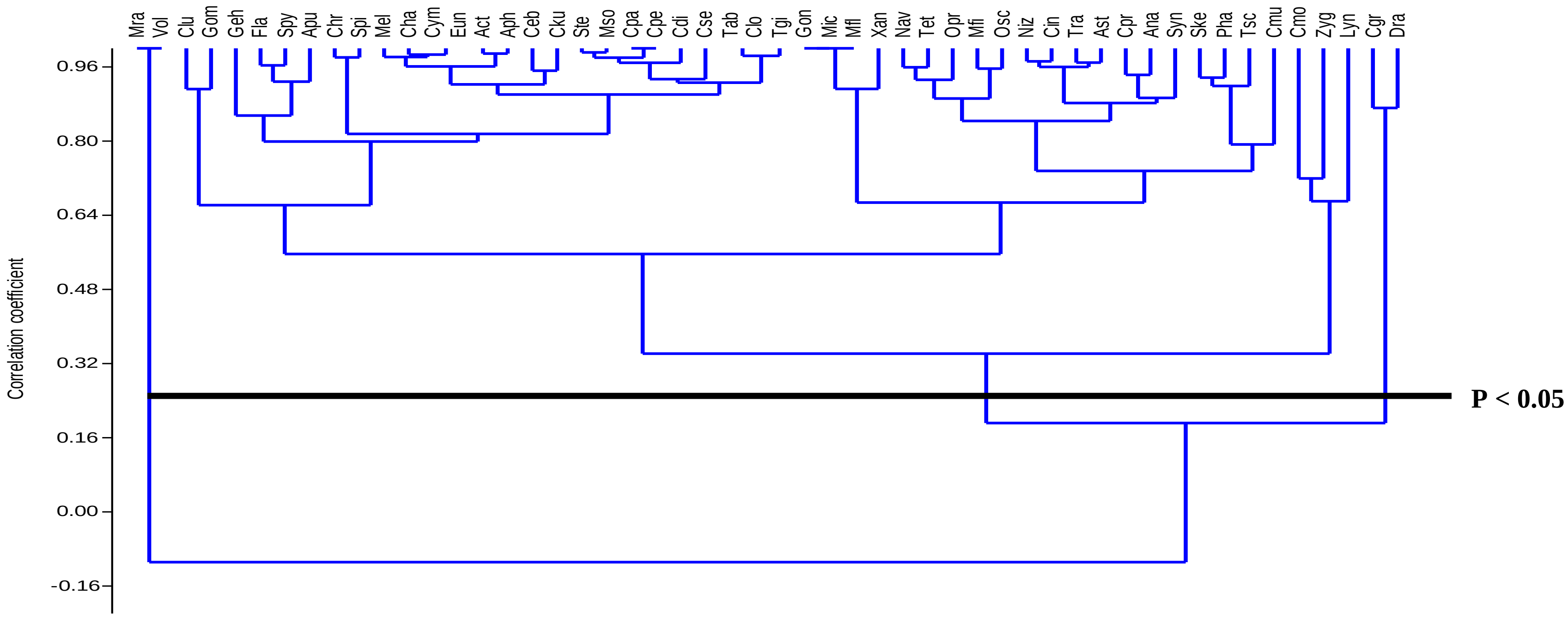


Figure 4.28: The Principal Component Analysis (PCA) Showing the Relationships among Phytoplankton Species during the Seasons

Key:

1=*Asterionella formosa*, 2=*Cymbella gracilis*, 3= *Eunotia tantniensis*, 4=*Flagilaria construens*, 5=*Melosira distans* var, 6=Navicula crucicula, 7=*Nitzschia acicularis*, 8=*Scutonema crispum*, 9=*Stenopterobia intermedia* , 10=Tabellaria flocculosa, 11=*Actinastrum hantschii*, 12=*Closterium abruptum .Var*,13=C.ebroracense Turner,14=C.dianae ,15=C.gracile, 16= *C.incurvum*, 17=*C.kuetzingii*,18=*C.luna*,19=*C.momiliferum.Ehrenb*, 20=*C.morus*,21=*C.setaceum*,22=*C.parvulum var*,23=*C.peracerosum Gay*, 24=*C.proum*, 25= *Chaetophora .attennuate*, 26=*Draparnastrum glomerata*,27=*Gonatozygon aculeatus*,28=G.ehrenbergii,29=*Micrasterias floridensis*,30=*M.floridensis Salisbury*,31=*M.fimbriata Raifa*, 32=*M.radiosa Var*,33=*M. sol*,*34*t=*Tetraspora cylindrical*, 35=*Spyrogyrasetiformisp,36=Volvox aureus,37=Xanthidium* antilopaeum,38=*Zygnema sterile*,39=*Anabaena constricta*,40=*Aphanocapsa delilatissdima*,41= *A.pulchra*, 42=*Chrsococcus taricensis*,43=*Lyngbya major Meneghin*i, 44=*Gomphospharia lacustria*,45=*Oscillatoria princeps*,46=*O.princep vaucher*,47=*Spirulina subsasa Oersted*,48=*Trachelomonas ensifera,49=T.gibberosa,50=T. schauinsladii*,51=*Phacus brevicauda*,52=*Synura uvella*. UD = upstream dry season, MD = midstream dry season, DD = downstream dry season, UR= upstream rainy season, MR= midstream rainy season, DR= downstream rainy season**.**



n=52 , r=0.273, p<0.05

Figure 4.29: Cluster Diagram Showing the Relationships between the Phytoplankton Species of Oluwa River

Key:

Ast=*Asterionella formosa*, Cym=*Cymbella gracilis*, Eun= *Eunotia tantniensis*, Fla=*Flagilaria construens*, Mel=*Melosira distans* var,Nav=Navicula crucicula,Niz=*Nitzschia acicularis*,Ske=*Scutonema crispum*,Ste=*Stenopterobia intermedia* , Tab=Tabellaria flocculosa, Act=*Actinastrum hantschii*, Clo=*Closterium abruptum .Var*,Ceb=C.ebroracense Turner,Cdi=C.dianae ,Cgr=C.gracile, Cin= *C.incurvum*,Cku=*C.kuetzingii*,Clu=*C.luna*,Cmo=*C.momiliferum.Ehrenb*, Cmu=*C.morus*,Cse=*C.setaceum*,Cpa=*C.parvulum var*,Cpe=*C.peracerosum Gay*, Cpr=*C.proum*, Cha= *Chaetophora .attennuate*, Dra=*Draparnastrum glomerata*,Gon=*Gonatozygon aculeatus*,Geh=G.ehrenbergii,Mic=*Micrasterias floridensis*,Mfl=*M.floridensis Salisbury*,Mfi=*M.fimbriata Raifa*, Mra=*M.radiosa Var*,Mso=*M. sol*,*Tet=Tetraspora cylindrical*, Spy=*Spyrogyrasetiformisp,Vol=Volvox aureus,Xa=Xanthidium* antilopaeum,Zyg=*Zygnema sterile*,Ana=*Anabaena constricta*,Aph=*Aphanocapsa delilatissdima*,Apu= *A.pulchra*, Chr=*Chrsococcus taricensis*,Lyn=*Lyngbya major Meneghin*i,Gom=*Gomphospharia lacustria*,Osc=*Oscillatoria princeps*,Opr=*O.princep vaucher*,Spi=*Spirulina subsasa Oersted*,Tra=*Trachelomonas ensifera*,*Tgi=T.gibberosa*,*Tsc=T. schauinsladii*,Pha=*Phacus brevicauda*,Syn=*Synura uvella*.

Table 4.11: List of Pollution-tolerant Phytoplankton Species of Oluwa River in ILGA

Bacillariophyceae

Asterionella formosa

Fragilaria construens

Melosira distans var

Navicula crucicula

Nitzschia acicularis

Scutonema crispum

Chlorophyceae

Closterium abruptum. Var

C.dianae

C. gracile

C. incurvum

*Spirogyra setiformis.*Kutz

Cyanophyceae

Anabaena constricta

Chrsococcus taricensis

Lyngbya major Meneghini

Oscillatoria princeps

O. princeps .Vaucher

Euglenophyceae

Trachelomonas ensifera Drez

Phacus brevicauda

(Source: Palmer, 1969)

Table 4.12: A checklist of Zooplankton in Oluwa River from June, 2014 to November, 2015

Rotifera

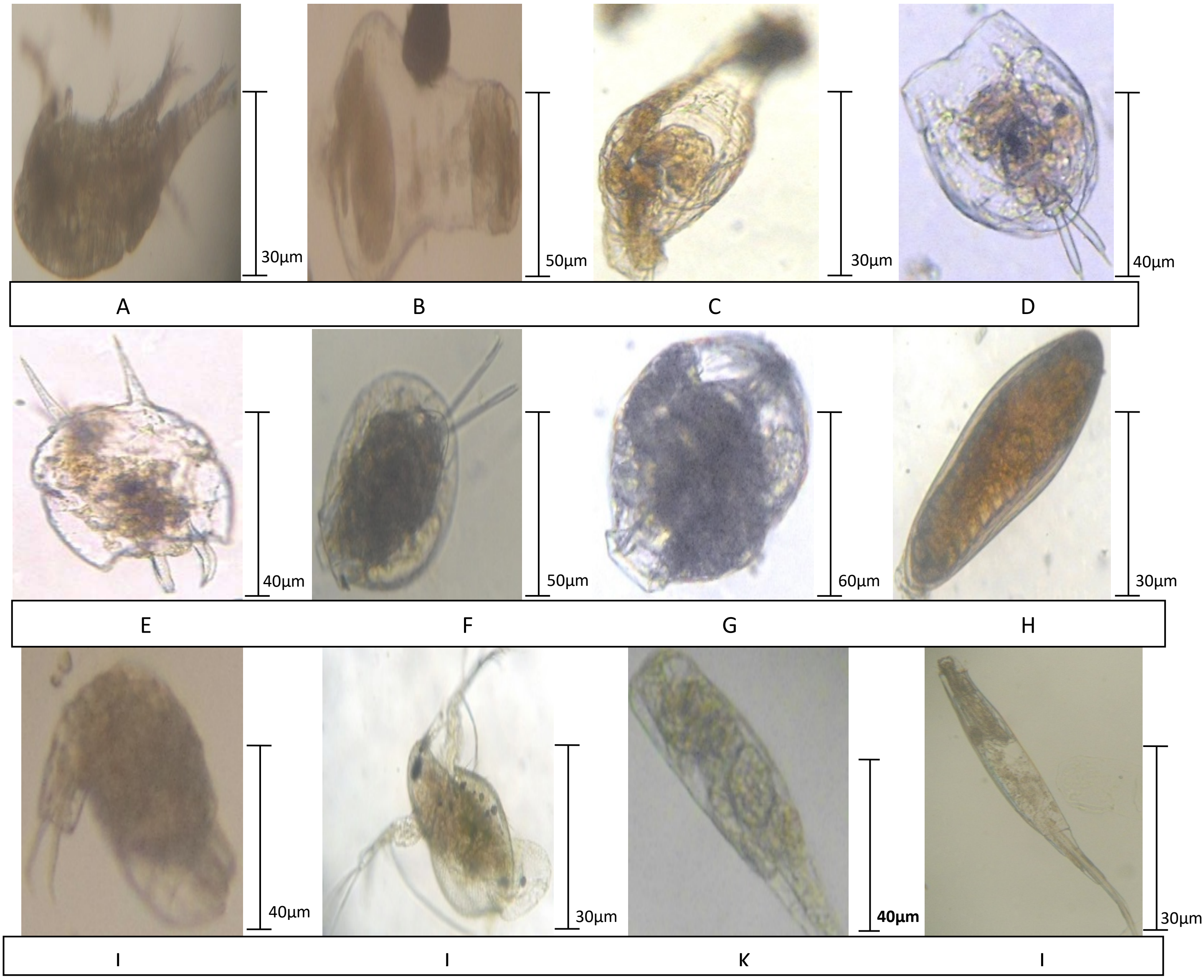
1. *Asplanchna brightwelli* Gosse
2. *A. girodideguerne* Leydig
3. *A. herricki* De Guerne
4. *A. priondonta* Gosse
5. *Brachionus bulla*
6. *B. falcatus. Zacharias*
7. *B. luna.* Pallas
8. *B. quadridentatus.* Hermann
9. *Ceratotrocha cornigera*
10. *Cephalodella parasitica*
11. *Filinia longiseta.* Ehrenberg
12. *F. opoliensis.* Zacharias
13. *F. pejleri*
14. *F. terminalis* Plate
15. *Gloetheca membranacea*
16. *Horaella brehmi Donner*
17. *Lecane tenuiseta.* Turner
18. *L bulla* Gosse
19. *L.luna* Muller
20. *L. tudicola* Murray
21. *Lepadella patella* Muller
22. *Testudinella greeni kosti*
23. *Trichocerca gracilis*
24. *T. iernis*
25. *T. musculus*
26. *Rotaria execulis*
27. *R. hepatica*
28. *R. tridens*
29. *R.neptunia* Ehrenberg
30. *Simocephalus* sp

Copepoda

31. Copepod larva
32. *Euclanis dilatat* Ehrenberg
33. *Eucyclops macrurus*
34. *Pseudocalanus elongatus*

Cladocera

35. *Bosmina longirostris* (O.E Muller)
36. *Podon leucarti*
37. *Ceriodaphinia cornuta*
38. *Moina micrura*



A. Copepod larva
B. *Simocephalus* sp
C. *Asplanchna priodonta*
D. *Lecane tenuiseta*
E *Branchionus quadridentatus*
F. *Euclanis dilatat*
G *Horoella.brehmi*
H. *Asplanchna girodiide guerne*
I *Trichocerca musculus*
J. *Ceriotodaphinia cornuta*
K. *Ceratotracha cornigera*
L. *Trichocerca gracilis*

Plate H: Some Zooplankton Encountered in Oluwa River from June, 2014 to November, 2015

Nitzschia acicularis and *Scutonema crispum*. However, *Trachelomonas ensifera* Drez and *Phacus brevicauda* represented the Euglenophyceae class.

4.4 Zooplankton composition

The zooplankton species encountered in Oluwa River during the period of study was made up of thirty-eight species belonging to three groups; Rotifera, Copepoda and Cladocera (Table 4.12). The Rotifera were represented by thirty species, four species of Copepoda and four species of Cladocera. The zooplankton identified in the study period is illustrated on plate H. The detailed data obtained on composition of zooplankton from June, 2014 to November, 2015 are presented in Appendix 3.

Rotifera dominated the zooplankton groups, accounting for 87% (Figure 4.30). *Asplanchna brightwelli* (3.65%) was the most abundant, followed by *A. girodideguerne* (3.47%) (Table 4.13).The dry season abundance (3373 Org/L) was higher than the rainy season (3025 Org/L) Figure 4.31

Copepoda accounted for 2% of the percentage abundance of zooplankton (Figure 4.30. *Eucyclops macrurus* (3.64%) dominated, followed by *Pseudocalanus elongatus* with 3.57% in the relative abundance (Table 4.13). The rainy season abundance (475 Org/L) was higher than dry season (311 Org/L) Figure 4.31.

Cladocera accounted for 11% of the percentage abundance of zooplankton (Figure 4.30). *Podon leucarti* (3.64%) dominated, followed by *Ceriodaphinia cornuta* (3.57%) in the relative abundance (Table 4.13). The dry season abundance (489 Org/L) was higher than rainy season (476 Org/L) Figure 4.31.

4.4.1 Spatial variations in zooplankton abundance in Oluwa River

The highest abundance for zooplankton was recorded in downstream station (2912 Org/L), while the lowest value (1856 Org/L) was recorded for upstream station during the study period (Table 4.14).

4.4.2 Diversity of zooplankton in Oluwa River.

The highest Margalef (d) value (4.99), Shannon (3.64) and Evenness (0.98) were recorded upstream, while the lowest value for d (4.22) was obtained for downstream. The lowest H (3.61) and E (0.95) were obtained for midstream station during the study period (Table 4.15).

4.4.3 The relationships among the zooplankton species during the seasons.

The extracted components represented the zooplankton species well as the communalities were high. The initial eigen value revealed that the first three principal components formed the extraction solution with eigen value greater than 1.The extracted components explained about 91.7% of the variability in the original 38 species, with only about 8.30% loss of information (Table 4.16). The first component explained about 80.01%, the second 9.34% and the third 2.34% of the variability.

The PCA (Table 4.17) revealed that the first component (PC1), was most highly correlated with the Rotifera and Cladocera, such as *Asplanchnna girodideguene* (0.175), *Lepadella patella* (0.175), *Rotaria hepatica* (0.177) and *Moina macrura* (0.177).The second PC which was most highly correlated with Rotifera, such as *Asplanchna brightwelli* (0.333) and had high negative loadings for *Ceratotracha cornigera* (-0.171). it was also highly correlated with Copepoda, such as *Copepoda* larva (0.511) and *Eucyclops macrurus* (0.511). The third PC which was most highly correlated with *Cephalodella parasitica* (0.281) also had high loading for *Trichocercerca gracilis* (0.197) and high negative loading for *Horaella brehmi* (-0.219) Table 4.17.

Seasonal variation among the zooplankton species was established using the Principal Component Analysis, as shown in Figure 4.32. There was no strong relationship among the zooplankton species recorded in both seasons, as shown in the scattered diagram in Figure 4.32. However, they were mostly spread across the seasons, with some having high loading values in the dry season and others in the rainy season.

4.4.4 Cluster Analysis of the relationships among the zooplankton fauna of Oluwa River

Four clusters showed the relationships of the recorded zooplankton species at varying degrees/levels of correlation. All zooplankton species showed significant positive relationships among themselves at $p<0.05$, where $r=0.304$, except *Fililia terminalis* and *Simocephalus* sp that showed negative non-significant relationship $p>0.05$ with the other zooplankton species (Fig.4.33). The correlation coefficient matrix showing relationship between zooplankton species is presented in Appendix 13.

4.4.5 Correlation coefficient(r) between physico-chemical parameters and plankton fauna of Oluwa River in ILGA

The correlation coefficient (r) value for physico-chemical parameters and plankton fauna is presented in Table 4.18. Copepoda correlated significantly with Mg ($r=-0.913$). Baciliariophyceae correlated with air temperature ($r=0.89$), water temperature ($r=0.81$) and BOD ($r=0.91$). Cyanophyceae correlated with air temperature ($r=0.85$), water temperature (r=0.79), BOD (r=0.88) and Na (r=-0.83), Euglenophyceae correlated with DO (r=-0.86) and BOD (r=0.79).

4.5 Benthic macro-invertebrate composition

The benthic macro-invertebrate species identified in Oluwa River are listed in Table 4.19. The benthic macro-invertebrates organisms identified during the period of study were made up of seventeen species belonging to three phyla; Arthropoda, Annelida and Mollusca.They consisted of five classes: Crustacea, Gastropoda, Insecta, Oligochaetae and Polychaetae (Table 4.19). The gastropoda were the most abundant and constituted 50% of the total benthic macro-invertebrates organisms encountered in Oluwa River (Fig 4.34). *Pachymelanin aurita* had the highest percentage (12.9%). The least amongst this group was *Lanistes varicus* (5.1%) (Table 4.20). Polychaetae accounted for 27% of the total benthic macro-invertebrates organisms in Oluwa River (Fig 4.32). *Glycera capitata* had the highest percentage (8.7%) abundance. The least amongst this group was *G.convolute* (4.1%). The class Insecta accounted for 12% of the benthic macro-invertebrates in Oluwa River (Fig 4.34), *Chironomus* larvae had the highest percentage (4.5%) abundance, while *Chaoborus* larvae accounted for the least value (3.1%) (Table 4.20). The class Crustacea accounted for 7% of the total benthic macro-invertebrates in Oluwa River (Fig 4.32). Amongst the groups, *Nototropis swamidami* accounted for highest percentage (3.8%), while *Iphinoe tripanosa* accounted for the least value (3.4%) of the total composition. Oligochaetae accounted for 4% of the total benthic macro-invertebrates organism in Oluwa River (Fig 4.34). *Ophinidomais serpentina* was the only species recorded and accounted for 3.8% of the abundance (Table 4.20). Some of the benthic macro-invertebrates encountered during the study period are shown in plate I.

4.5.1 Spatial variations in benthic macro-invertebrates abundance in Oluwa River

The highest number of individuals of benthic macro-invertebrates organisms was recorded for upstream (915 individuals), while the lowest value (736 individuals) was recorded for midstream station during the study period (Table 4.21).

4.5.2 Diversity of benthic macro-invertebrates in Oluwa River.

The highest Margalef (d) value (0.61) was recorded for downstream station while, the lowest value (0.58) was recorded for upstream station during the study period. The highest (1.33) Shannon (H) value was recorded for downstream and lowest (1.28) was recorded for upstream station. The highest Eveness (E) (0.75) was recorded in downstream station, while the least value (0.72) was recorded for upstream station (Table 4.22).

4.5.3 Correlation coefficient(r) between Physico-chemical parameters and benthic macro-invertebrates of Oluwa River

Correlation coefficient (r) values for physico-chemical parameters and benthic macro-invertebrates are presented in Table 4.23. Crustacea correlated significantly with chloride (r=-0.80), NO_3 (r=0.87), PO_4 (r=-0.83), Cd (=-0.87) and Cr (r=-0.80). Gastropoda correlated with DO (r=0.85), Alkalinity (r=-0.90), K (r=0.87) and Cr (r=-0.87). Insecta correlated with Cr (r=-0.88); Oligocheate correlated with NO_3(r=0.88), Cd (r=-0.84) and Cr (r=0.84); Polycheate correlated with DO (r=0.81), K (r=-0.81) and Fe

(r=-0.09); Gastropoda correlated with DO (r=0.85), alkalinity (r=-0.90), K (r=0.87) and Cr (r=-0.87); Insecta correlated with Cr (r=-0.88). Oligocheate correlated with NO3 (r=0.88), Cd (r=-0.84) and Cr (r=0.84); Polycheate correlated with DO (r=0.81), K (r=-0.81) and Fe (r= -0.09).

4.6 Fish fauna

A checklist of the composition of fish species that were encountered during the study period is presented in Table 4.24. Some of the fish species identified during the study period are illustrated in Plate J.

Thirty-four species belonging to ten families were recorded during the study period seven species of Cichlidae, four species of Clariidae, four species of Distichodontidae, two species of Bagridae, three species of Characidae, three species of Cyprinidae, two species of Channidae, seven species of Mormyridae, one species of Hepsetidae and Malapteruridae (Table 4.25). *Clarias gariepinus* and *Heterobranchus longifilis* (family: Clariidae) dominated the fish fauna accounting for 7.9% and 7.2% of relative abundance, respectively (Table 4.25). The least abundant was *Marcusenius cyprinoidea* (family: Mormyridae) (0.4%). Clariidae recorded the highest percentage abundance (29%) followed by Cichlidae (20%). The least family was Bagridae (5%) (Figure 4.35). Clariidae recorded the highest abundance for the rainy season and the dry season (33.4%), while Malapteruridae recorded the least (15%) for the dry season and Channidae the least abundance (6%) for the rainy season Figure 4.36. High relative abundance of fish was observed in the dry season months, while low relative abundance was noticed in the rainy season months (Figure 4.37).

Table 4.13: Relative Abundance of Zooplankton organisms encountered in Oluwa River

SPECIES	Number of Org/L	Percentage Abundance (%)
Rotifera		
Asplanchna brightwelli	267	3.36**
A. girodideguerne	254	3.20
A. herricki	171	2.15
A. priondonta	205	2.58
Branchionus bulla	233	2.93
B. falcatus	226	2.85
B. luna	198	2.50
B quadridentatus	215	2.71
Ceratotrocha cornigera	204	2.57
Cephalodella parasitica	190	2.39
Filinia longiseta	245	3.09
F. opoliensis	182	2.29
F. pejleri	171	2.15
F. terminalis	163	2.05
Gloetheca membranacea	139	1.75*
Horaella brehmi Donner	171	2.15
Lecane tenuiseta	243	3.06
L. bulla	194	2.44
L.luna	219	2.76
L. tudicola	212	2.67
Lepadella patella	233	2.93
Testudinella greeni kosti	251	3.16
Trichocerca gracilis	246	3.10
T .iernis	231	2.91
T. musculus	198	2.49
Rotaria execulis	201	2.53
R. hepatica	201	2.53
R. tridens	244	3.07
R.neptunia	157	1.98
Simocephalus sp	196	2.47
Sub total	6,260	78.97
Copepoda		
Copepod larva	143	1.80
Euclanis dilatat Ehrenberg	157	1.98
Eucyclops macrurus	266	3.35
Pseudocalanus elongates	261	3.29

Sub total	827	10.43
Cladocera		
Bosmina longirostris (O.E Muller)	157	1.98
Podon leucarti	266	3.35
Ceriodaphinia cornuta	261	3.29
Moina micrura	156	1.96
Sub total	840	10.59
GRAND TOTAL	7,927	

***= least abundance**

****=highest abundance**

Table 4.14: Spatial Variations in Zooplankton Abundance in Oluwa River

Zooplankton	Upstream station	Midstream station	Downstream station
Rotifera	1614	2306	2493
Copepoda	44	45	54
Cladocera	198	277	365
Total Abundance (Org/L)	1856	2628	2912

Table 4.15: Diversity of Zooplankton in Oluwa River

Diversity Indices	Upstream station	Midstream station	Downstream station	OVER ALL Mean± SE
Margalef (d)	4.99	4.77	4.22	4.66 ± 1.23
Shannon (H)	3.64	3.61	3.63	3.62 ± 0.25
Evenness (E)	0.98	0.95	0.97	0.96 ± 1.31

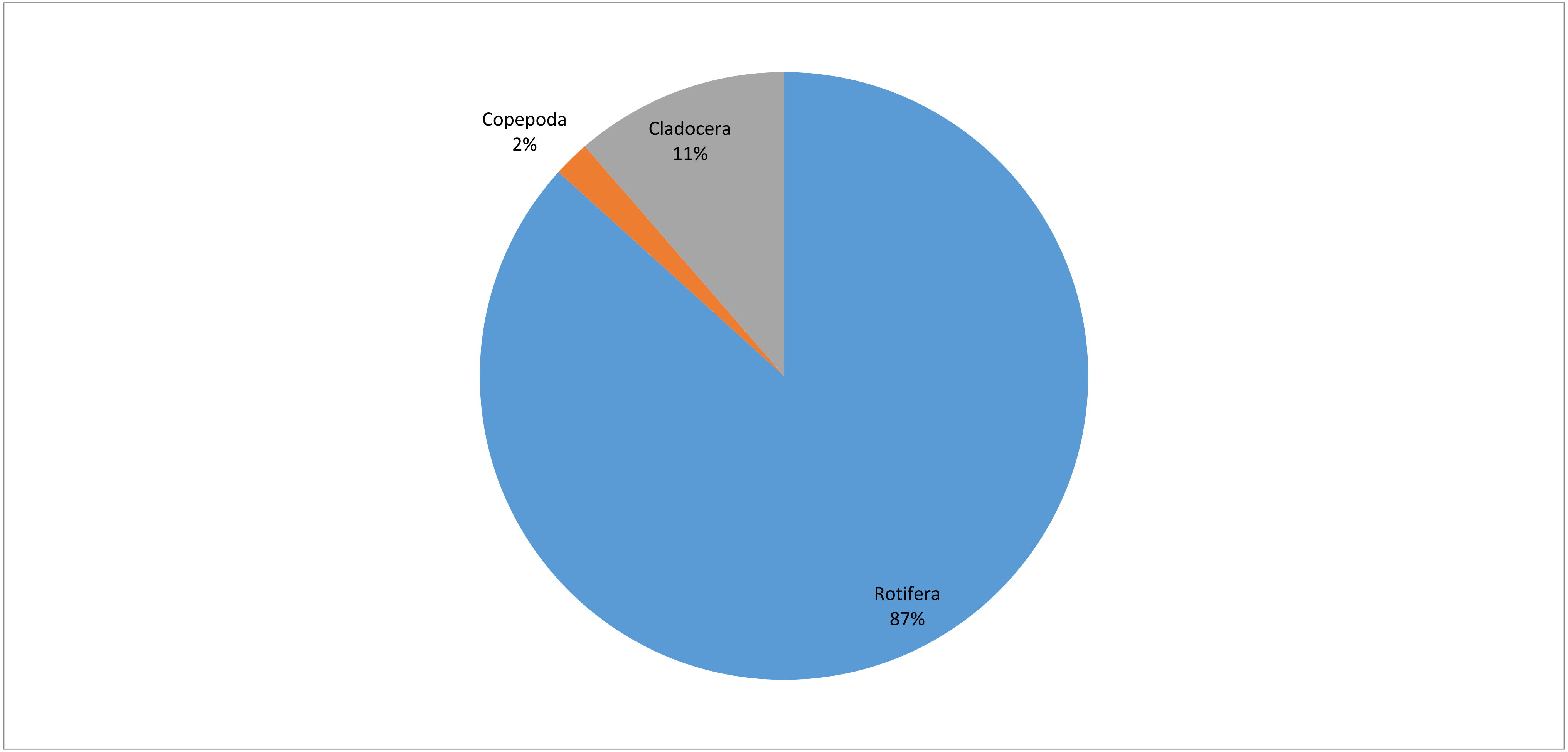


Figure 4.30: Percentage Abundance of Zooplankton in Oluwa River

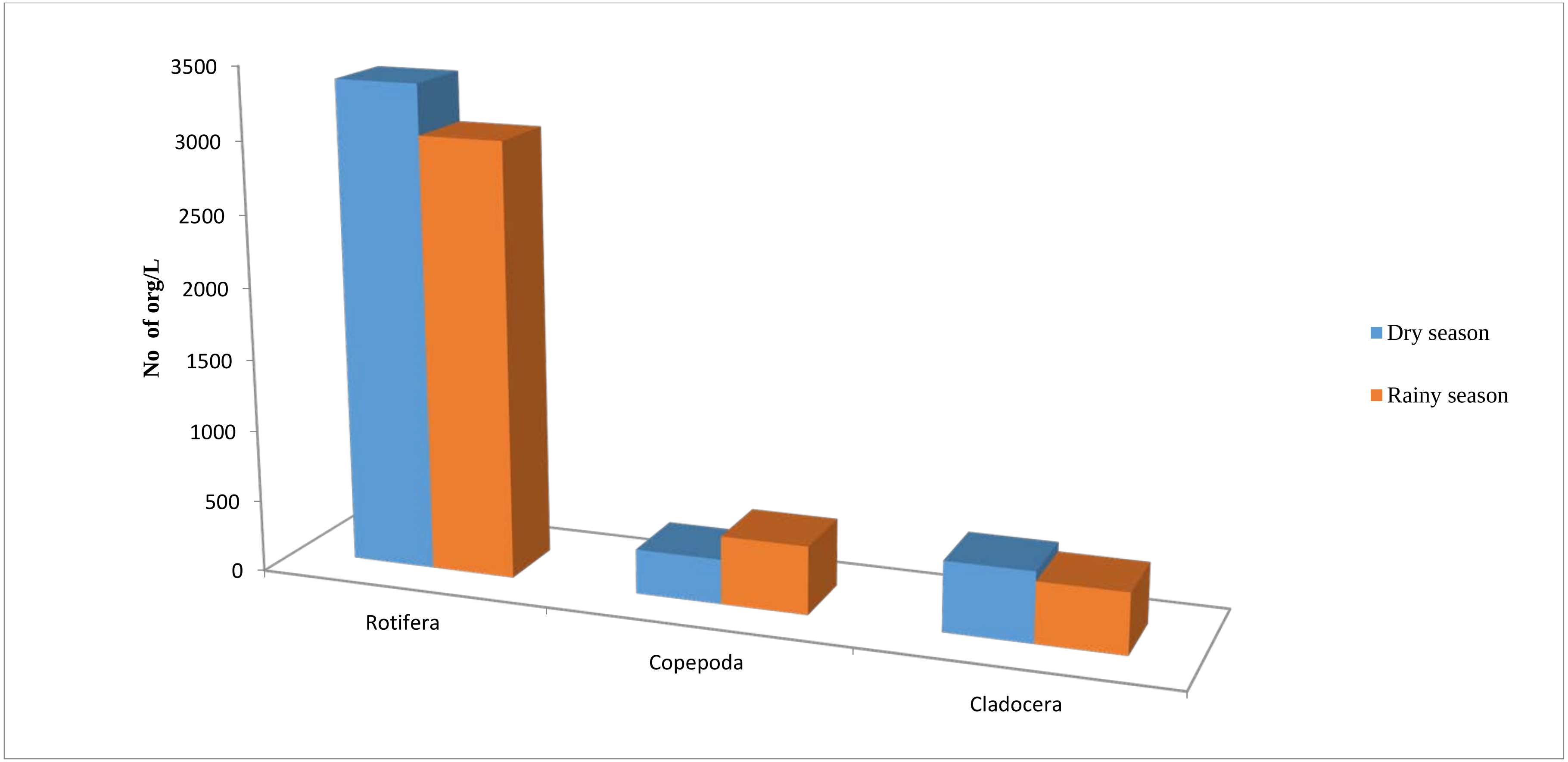


Figure 4.31: Relative Abundance of zooplankton in the dry and rainy season in Oluwa River

Table 4.16: Extracted Principal Components of Zooplankton Species in Oluwa River

PC	Eigen value	% Variance	Cumulative%
1	31.20	80.01	80.01
2	3.65	9.34	89.35
3	2.35	2.34	91.69

Table 4.17: Principal Component Analysis (PCA) of Zooplankton species in Oluwa River

S/N	Taxon	Comp 1	Comp 2	Comp 3
1	*Asplanchna brightwelli*		**0.333**	
2	*A. girodideguerne*	**0.175**		
3	*A. herricki*			
4	*A. priondonta*			
5	*Branchionus bulla*			
6	*B. falcatus*			
7	*B. luna*			
8	*B. quadridentatus*			
9	*Ceratotrocha cornigera*		**-0.171**	
10	*Cephalodella parasitica*			**0.281**
11	*Filinia longiseta*			
12	*F. opoliensis*			
13	*F. pejleri*			
14	*F. terminalis*			
15	*Gloetheca membranacea*			
16	*Horaella brehmi*			**-0.219**
17	*Lecane tenuiseta*			
18	*L. bulla*			
19	*L.luna*			
20	*L. tudicola*			
21	*Lepadella patella*	**0.175**		
22	*Testudinella greeni*			
23	*Trichocerca gracilis*			**0.197**
24	*T . iernis*			
25	*T. musculus*			
26	*Rotaria execulis*			
27	*R. hepatica*	**0.177**		
28	*R. tridens*			
29	*R.neptunia*			
30	*Simocephalus* sp			
31	Copepod larva		**0.511**	
32	*Euclanis dilatat*		**0.511**	
33	*Eucyclops macrurus*			
34	*Pseudocalanus elongates*			
35	*Bosmina longirostris*			
36	*Podon leucarti*			
37	*Ceriodaphinia cornuta*			
38	*Moina macrura*	**0.177**		

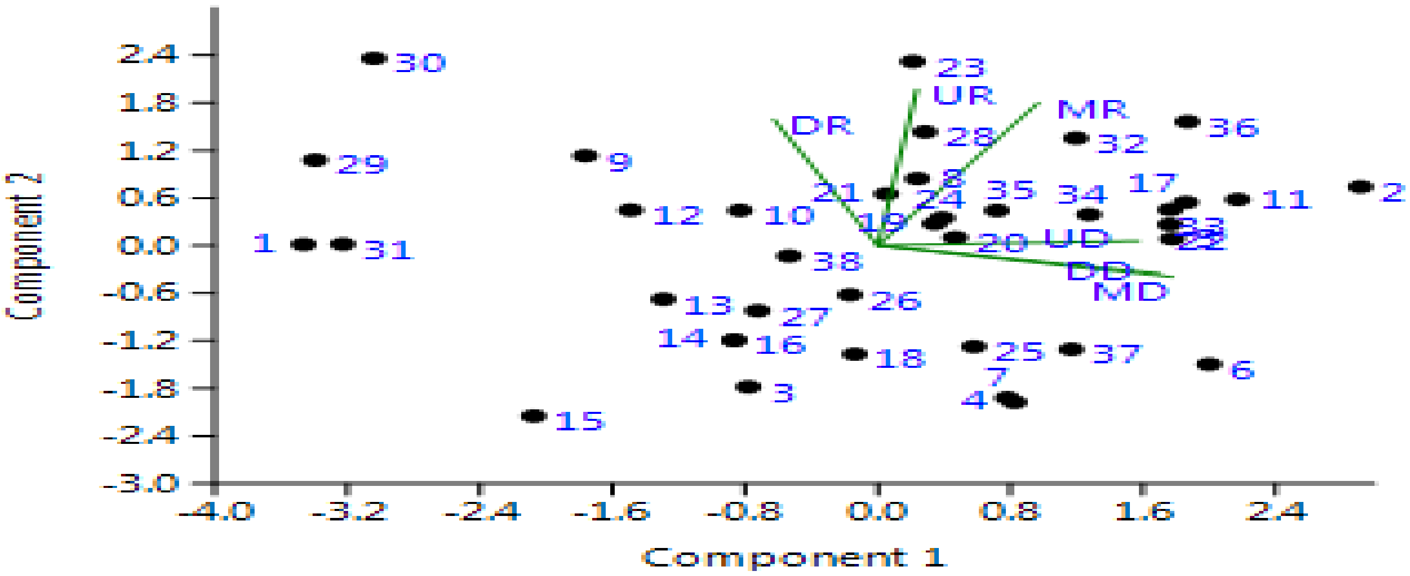
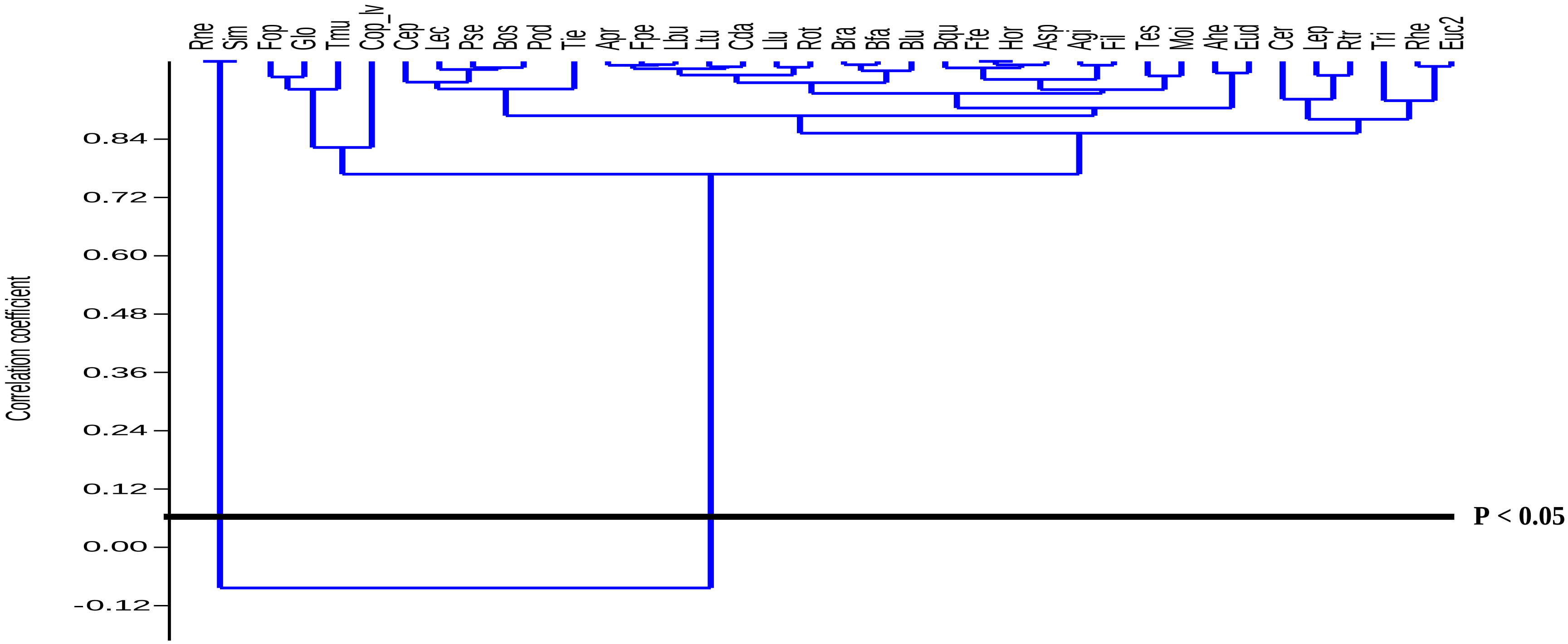


Figure 4.32: The Principal Component Analysis (PCA) Showing the Relationships among Zooplankton Species during the Sseasons

Key:

UR=upstream rainy season, MR=midstream rainy season, DR=downstream rainy season, UD=upstream dry season, MD=Midstream dry season, DD=downstream dry season.

1=*Ascomorpha* sp,2=*Asplanchna brightwelli*,3=*A.giradideguerne*, 4=*A.herricki 5=A.priondonta*,6=*Branchionus bulla*, 7=*B.falcatus*, 8=*B.luna* 9=*B.quadridentatus*, 10=*Ceratotrocha cornigera*,11=*Cephalodella parasitica*,12=*Filinia longiseta*, 13=*F.opoliensis*, 14=*F.pejleri*, 15=*F.terminalis*,16=*Glotheca membranacea*,17=*Horaella brehmi Donner*,18=*Lecane tenuseta*,19=*L.bulla*.20=*L.luna*,21=*L.tudicola*,22=*Lepadella patella*,23=*Testudinella green Kosti*, 24=*Trichocerca gracilis*,25=*T.iernis*,26=*T.musculus*,27=*Rotaria execulis*,28=*R.hepatica*, 29 r=*R.tridens*,30 =*R.neptunia*, 31=*Simocephalus* sp,32=*Copepoda larva*,33=*Euclanis dilatat*,34=*Eucylops macrurus*,35=*Bosmina* sp,36=*Podon leucarti*, 37= *Ceriodaphninia cornuta*, 38=*Moina micrura.*



N=38, r=0.304, p<0.05

Figure 4.33: Cluster Diagram Showing the Relationships between the Zooplankton Species of Oluwa River

Asp=*Asplanchna brightwelli*,*Agi*=*A.giradideguerne*, Ahe=*A.herricki Apr*=*A.priondonta*,Bra=*Branchionus bulla*, Bfa=*B.falcatus*, Blu=*B.luna* Bqu=*B.quadridentatus*, Cer=*Ceratotrocha cornigera*,Cep=*Cephalodella parasitica*,Fil=*Filinia longiseta*, Fop=*F.opoliensis*, Fpe=*F.pejleri*, Fte=*F.terminalis*,Glo=*Glotheca membranacea*,Hor=*Horaella brehmi Donner*,Lec=*Lecane tenuseta*,Lbu=*L.bulla*.Llu=*L.luna*,Ltu=*L.tudicola*,Lep=*Lepadella patella*,Tes=*Testudinella green Kosti*, Tri=*Trichocerca gracilis*,Tie=*T.iernis*,Tmu=*T.musculus*,Rot=*Rotaria execulis*,Rhe=*R.hepatica*, Rtr=*R.tridens*,Rne =*R.neptunia*, Sim=*Simocephalus* sp,Coplu=*Copepoda larva*,Euc^2=*Euclanis dilatat*,Eud=*Eucylops macrurus*,Pse=*Pseudocalamus elongates*,Bos=*Bosmina* sp,Pod=*Podon leucarti*, Cda= *Ceriodaphninia cornuta*, Moi=*Moina micrura*.

Table 4.18: Correlation coefficient (r) between Physico-chemical Parameters and Plankton Fauna of Oluwa River

	Physico-Chemical Parameters																						
Plankton grp	Air temp	Water temp	Transp	DO	BOD	pH	Cond	Alka	Chlo	TDS	TS	$N0_3$	SO_4	PO_4	Na	K	Mg	Ca	Cd	Cr	Pb	Ni	Fe
Rotifera	**0.986***																**-0.909***						
Copepoda	**0.968***	**0.919***															**-0.913***						
Cladocera					**0.827***											**-0.839***							
Bacillariophycea	**0.898***	**0.812***			**0.919***																		
Chlorophyceae	**0.876***	**0.796***			**0.904***																		
Cyanophyceae	**0.857***																						
Euglenophyceae				**0.864***	**0.799***																		

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

KEY:

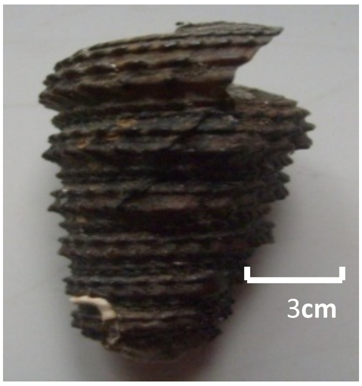
Air temp=Air temperature, W temp=Water temperature, Trans=Transparency, DO=Dissolved oxygen, pH=pH, Alk=Alkalinity, Cond=Conductivity Chl=Chloride, TDS=Total Dissolved Solids, TS=Total Solids,NO_3=Nitrate, SO_4= Sulphate, Na=Sodium, K=Potassium,Mg=Magnesium, Ca=Calcium, Cd=Cadmium,Cr=Chromium, Pb=Lead, Ni=Nickel, Fe=Iron.

Table 4.19: A checklist of Benthic Macro-invertebrates recorded from Oluwa River from June, 2014 to November, 2015

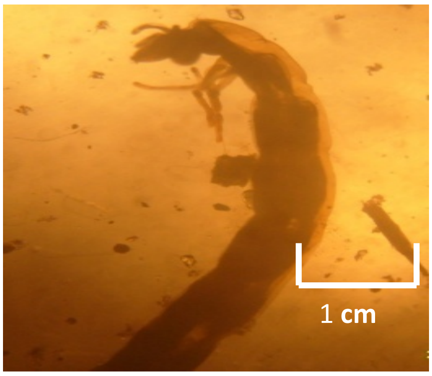
Phylum	**Arthropoda**	
Class	Insecta	
		Chironomus larvae
		Chaoborus larvae
		Phrganea.larvae (caddis fly)
Class	Crustacea	
		Nototropis swamidami
		Iphinoe tripanosa
Phylum	**Annelida**	
Class	Oligochaeta	
		Ophidonais serpentina
Class	Polychaeta	
		Arenicula maina
		Eunice haressi
		Glycera capitata
		G. convoluta
		Nereis diversicolor
Phylum	**Mollusca**	
Class	Gastropoda	
		Pachymelania aurita
		P. fuscatus
		P. fuscatus.var.quard
		Tympanotomus fusca
		Melanoides tuberculata
		Lanistes varicus

A

B



C



D

E

Keys: A. *Melanoides tuberculata* B. *Tympanotomus fuscatus*

C. *Pachymelania fusca* D. *Chironomus* larvae

E. *Lanistes varicus*

Plate I: Some Benthic Macro-invertebrates Encountered in Oluwa River from June, 2014 to November, 2015

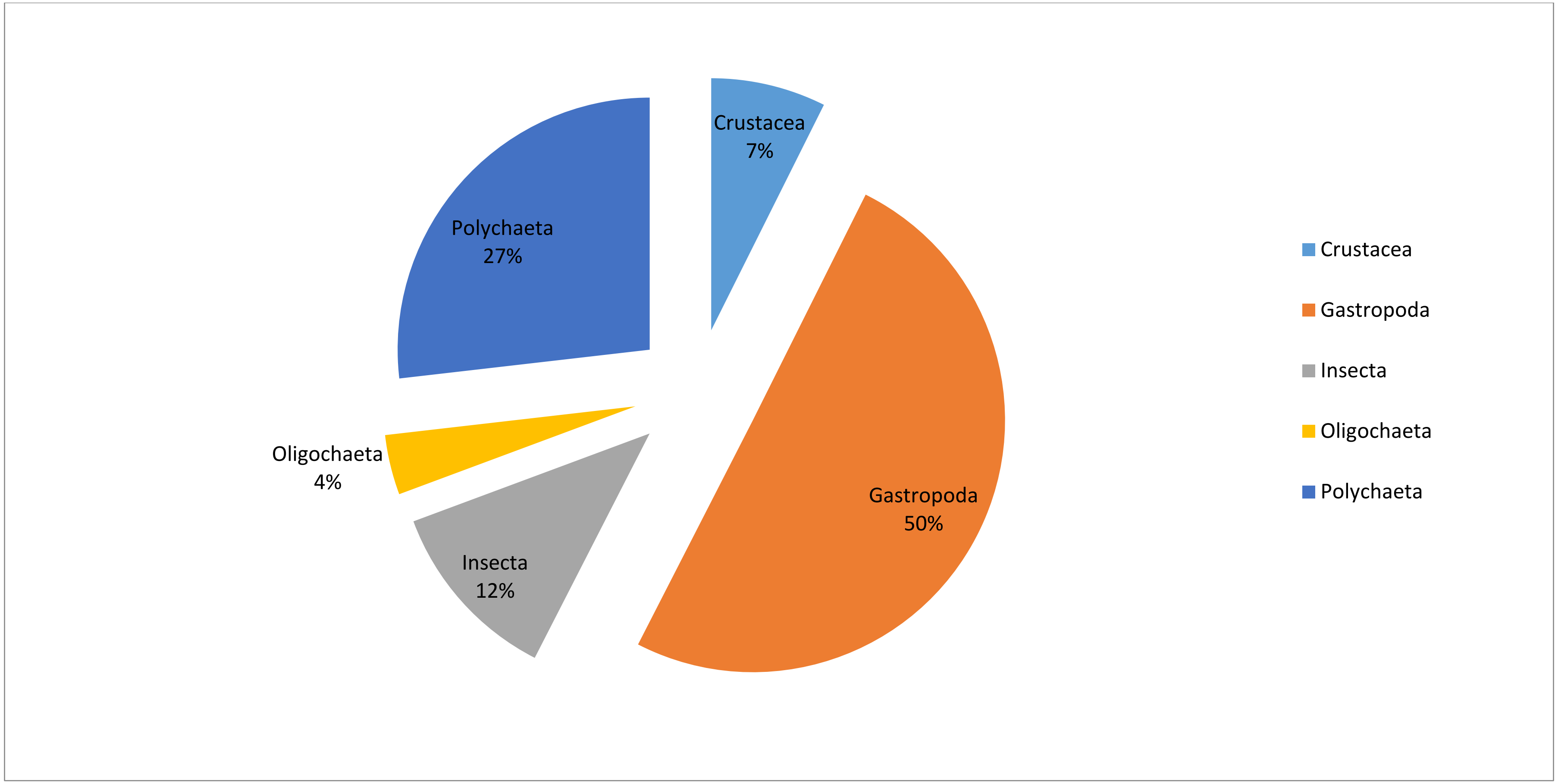


Figure 4.34: Composition(%) of Benthic Macro-invertebrates in Oluwa River

Table 4.20: Relative Abundance of Benthic Macro-invertebrates in Oluwa River

SPECIES	Total number	Percentage abundance
Insecta		
**Chironomus* larvae	103	4.5
Chaoborus larvae	72	3.1
*Phrganeap.*larvae (caddis fly)	95	4.1
Sub total	**270**	**11.9**
Crustacea		
Nototropis swamidami	88	3.8
Iphinoe tripanosa	79	3.4
Sub total	**167**	**7.3**
Oligochaeta		
**Ophidonais serpentine*	87	3.8
Polychaeta		
Arenicula maina	105	4.6
Eunice haressi	107	4.7
**Glycera capitata*	197	8.7
**Glycera convolute*	94	4.1
**Nereis diversicolor*	102	4.5
Sub total	**605**	**26.7**
Gastropoda		
**Pachymelania aurita*	294	12.9
P.fuscatus	213	9.4
P.fuscatus.var.quard	148	6.5
Tympanotomus fusca	182	8.0
Melanoides tuberculata	182	8.0
Lanistes varicus	116	5.1
Sub total	**1135**	**50.1**
GRAND TOTAL	**2,264**	

***pollution indicators species**

Table 4.21: Spatial Variations in Benthic Macro-invertebrates Abundance in Oluwa River

Family	**Upstream station**	**Midstream station**	**Downstream station**
Crustacea	60	57	70
Gastropoda	455	353	327
Insecta	161	92	57
Oligochaeta	34	31	52
Polychaeta	205	203	237
Total Abundance	915	736	743

Table 4.22: Diversity of Benthic Macro-invertebrates in Oluwa River

Diversity indices	Upstream station	Midstream station	Downstream station
Margalef (d)	0.58	0.60	0.61
Shannon (H)	1.28	1.29	1.33
Evenness(E)	0.72	0.73	0.75

Table 4.23: Correlation Coefficient(r) between Physico-chemical Parameters and Benthic Macro-invertebrates of Oluwa River

Physico-Chemical Parameters																							
Benthso groups	Air temp	Water temp	Transp	DO	BOD	pH	Cond	Alka	Chlo	TDS	TS	$N0_3$	SO_4	PO_4	Na	K	Mg	Ca	Cd	Cr	Pb	Ni	Fe
Crustacea								**-0.881***	**-0.809***			**-0.871***		**-0.835***					**-0.871***	**-0.803***			
Gastropoda				**0.851***				**-0.905***								**0.877***				**-0.878***			
Insecta																				**-0.882***			
Oligocheate												**-0.886***							**-0.886***	**-0.845***			
Polycheate				**0.819***												**0.810***							**-0.897***

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

KEY:

Air temp=Air temperature, W temp=Water temperature, Trans=Transparency, DO=Dissolved oxygen, pH=pH, Alk=Alkalinity, Cond=Conductivity Chl=Chloride, TDS=Total Dissolved Solids, TS=Total Solids, NO_3=Nitrate, SO_4= Sulphate, Na=Sodium, K=Potassium,Mg=Magnesium, Ca=Calcium, Cd=Cadmium,Cr=Chromium, Pb=Lead, Ni=Nickel, Fe=Iron.

Table 4.24: A Checklist of Fish fauna recorded from Oluwa River from June, 2014 to November, 2015

Bagridae

1. *Chrysichthys. nigrogiditatus*

2 *Auchenoglanis occidentalis*

Channidae

3. *Parachanna obscura*

4. *Parachanna africana*

Characidae

5. *Brycinus brevis*

6. *B. nurse*

7. *Micralestes occidentalis*

Cichlidae

8. *Hemichromis fasciatus*

9. *Oreochromis* sp

10. *O. niloticus*

11. *Sarotherodon. galilaeus*

12. *S. melanotheron*

13. *Coptodon. guineensis*

14. *Coptodon. zillii*

Clariidae

15. *Clarias anguillaris*

16. *C. gariepinus*

17. *Heterobranchus bidorsalis*

18. *H. longifilis*

Cyprinidae

19. *Barbus bynni occidentalus*

20. *B. lagoensis*

21. *Labeo senegalensis*

Distichodontidae

22. *Distichodus rostratus*

23. *D. engycephalus*

24. *Nannocharax ansorgii*

25. *N. latifasciatus*

Hepsetidae

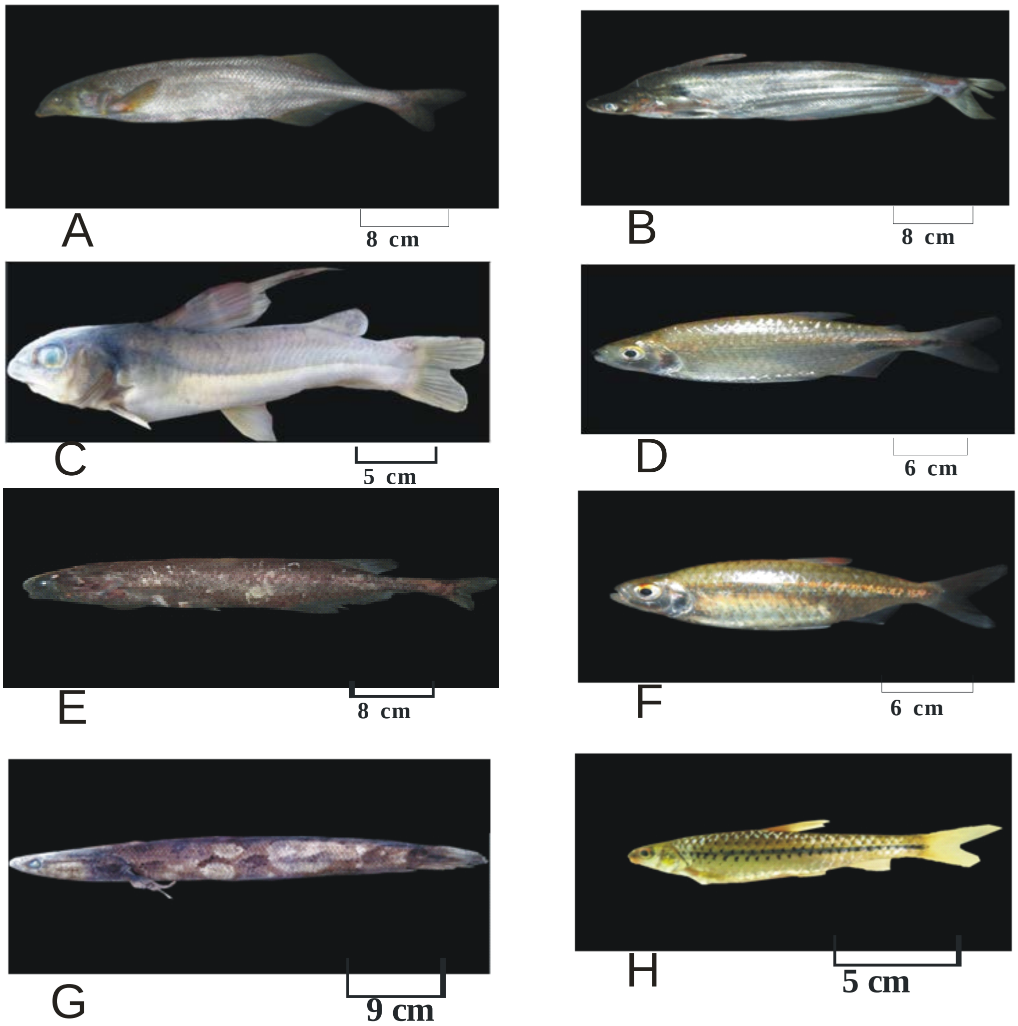
26. *Hepsetus odoe*

Malapteruridae

27. *Malapterurus electricus*

Mormyridae

28. *Mormyrus hasselquistic*
29. *M. macrophthalamus*
30. *M. rume*
31. *M. senegalensis*
32. *Marcusenius abadii*
33. *M. brucii*
34. *M. cyprinoidea*



Key:

A=*Mormyrus rume*

B= *Micralestes occidentalis*

C= *Chrysichthys nigrogiditatus*

D= *Labeo senegalensis*

E=*Distichodus rostratus*

F= *Brycinus brevis*

G= *Parachanna obscura*

H= *Hepsetus odoe*

Plate J: Some fin fishes in Oluwa River

Table 4.25: Numerical Abundance of Fish Species in Oluwa River from June, 2014 to November, 2015

	TOTAL NO	RELATIVE ABUNDANCE (%)
Bagridae		
Chrysichthys nigrodigitatus	66	3.8
Auchenoglaris occidentalis.	29	1.6
Sub total	**95**	**5.5**
Channidae		
Parachanna obscura	30	1.7
Parachanna africana	19	1.0
Sub total	**49**	**2.8**
Characidae		
Brycinus brevis	21	1.2
B. nurse	24	1.3
Micralestes occidentalis	21	1.2
Sub total	**66**	**3.8**
Cichlidae		
Hemichromis fasciatus	59	3.4
Oreochromis sp	42	2.4
O. niloticus	61	3.5
Sarotherodon galilaeus	63	3.6
S. melanotheron	51	2.9
Coptodon guineensis	26	1.5
Coptodon zillii	40	2.3
Sub total	**342**	**19.7**
Clariidae		
Clarias anguillaris	115	6.6
C. gariepinus	137	7.9**
Heterobranchus bidorsalis	122	7.0
H. longifilis	128	7.2
Sub total	**502**	**28.9**
Cyprinidae		
Barbus bynni occidentalus	47	2.7
B. lagoensis	71	4.0
Labeo senegalensis	67	3.8
Sub total	**185**	**10.7**
Distichodontidae		
Distichodus rostratus	35	2.0
D. engycephalus	34	1.9
Nannocharax ansorgii	49	2.8

N. latifasciatus	26	1.5
Sub total	**144**	**8.3**
Hepsetidae		
Hepsetus odoe	57	3.2
Malapteruridae		
Malapterurus electricus	22	1.2
Mormyridae		
Mormyrus hasselquistic	55	3.1
M. macrophthalamus	63	3.6
M. rume	76	4.3
M. senegalensis	48	2.7
Marcusenius abadii	12	0.6
M. brucii	9	0.5
M. cyprinoidea	8	0.4*
Sub total	**271**	**15.6**
GRAND TOTAL	**1,733**	

** Highest abundance

* Least abundance

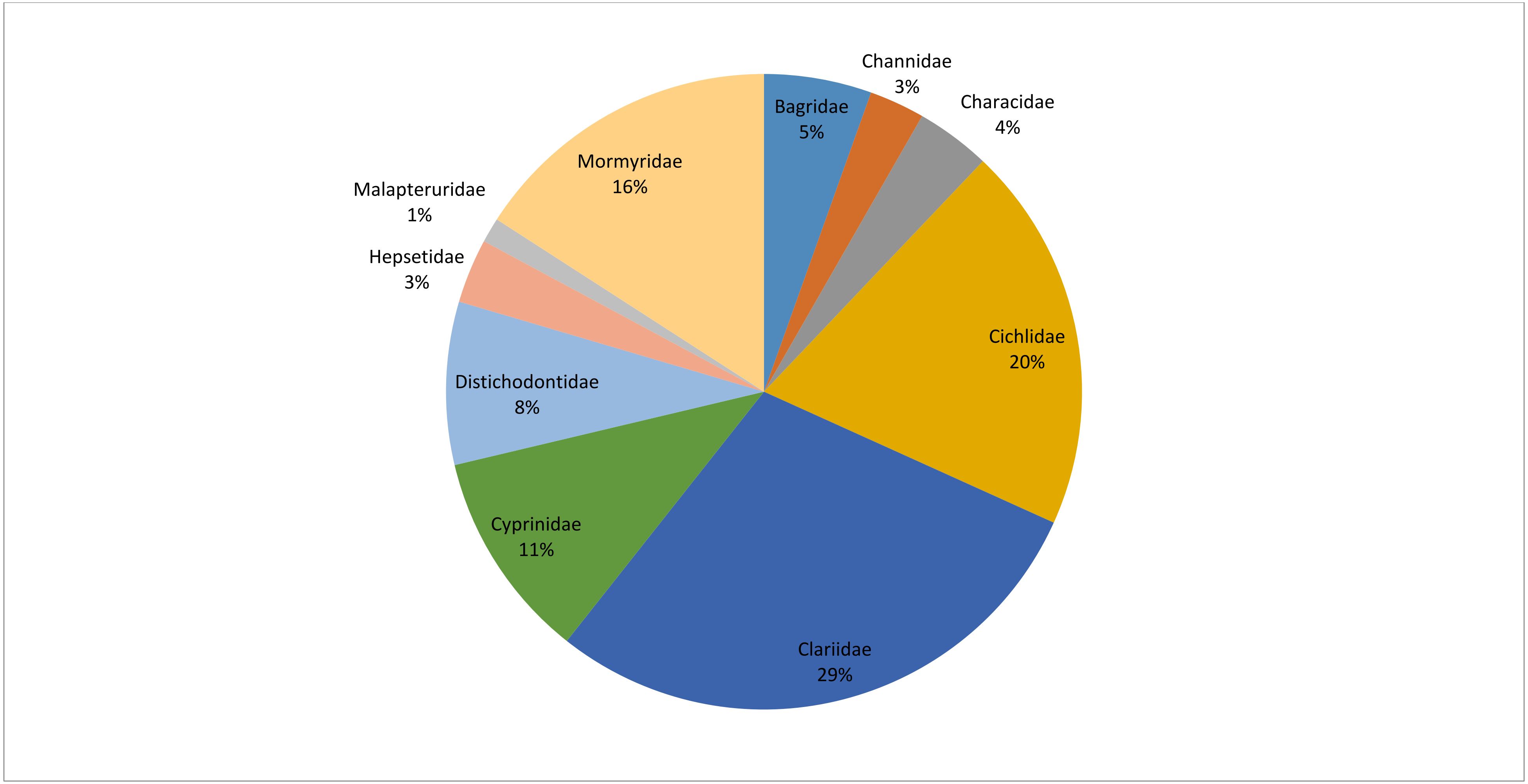


Figure 4.35: The Percentage Abundance of Fish Family in Oluwa River

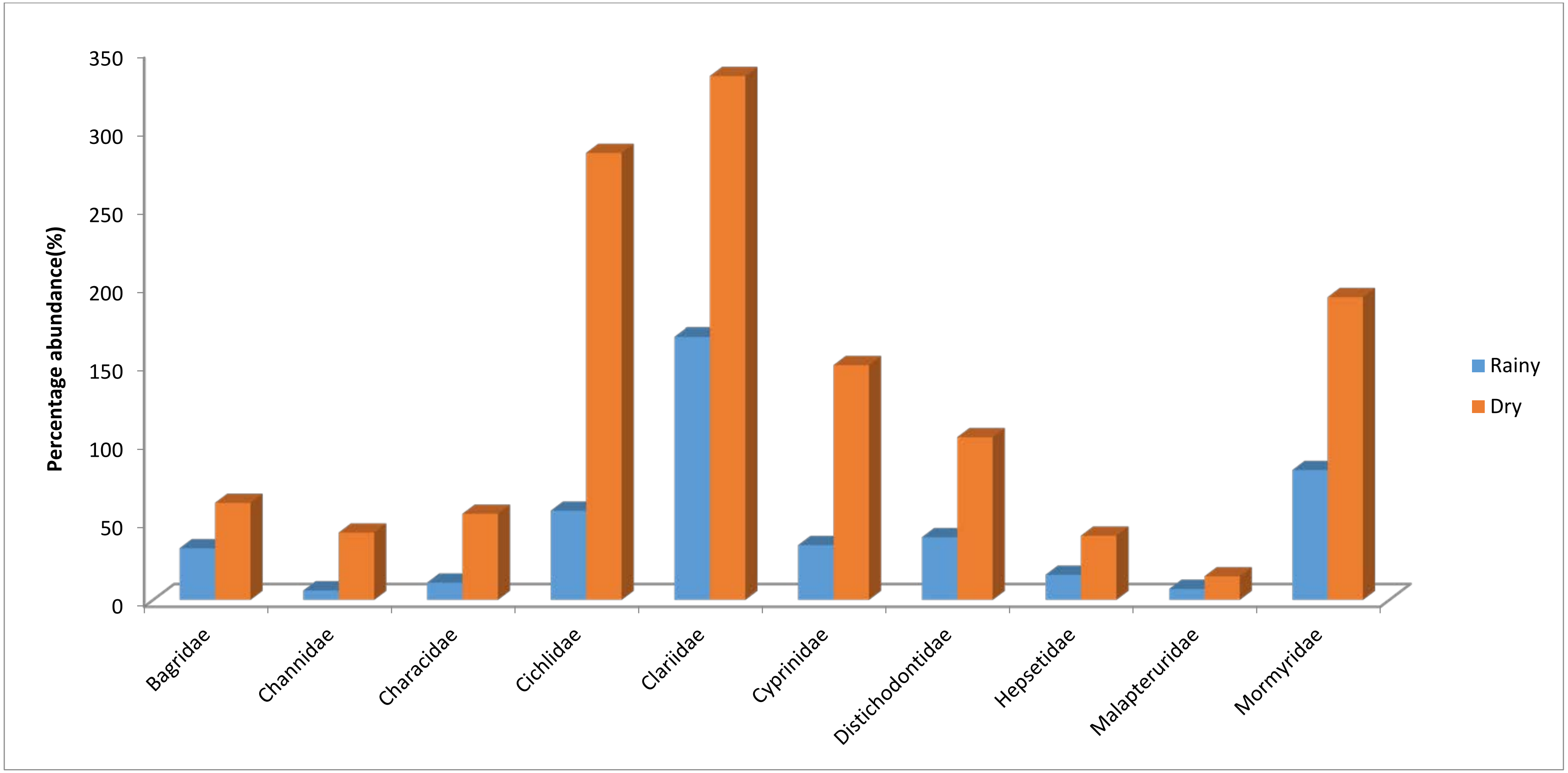


Figure 4.36: Seasonal Variation in Fish Abundance (%) in Oluwa River

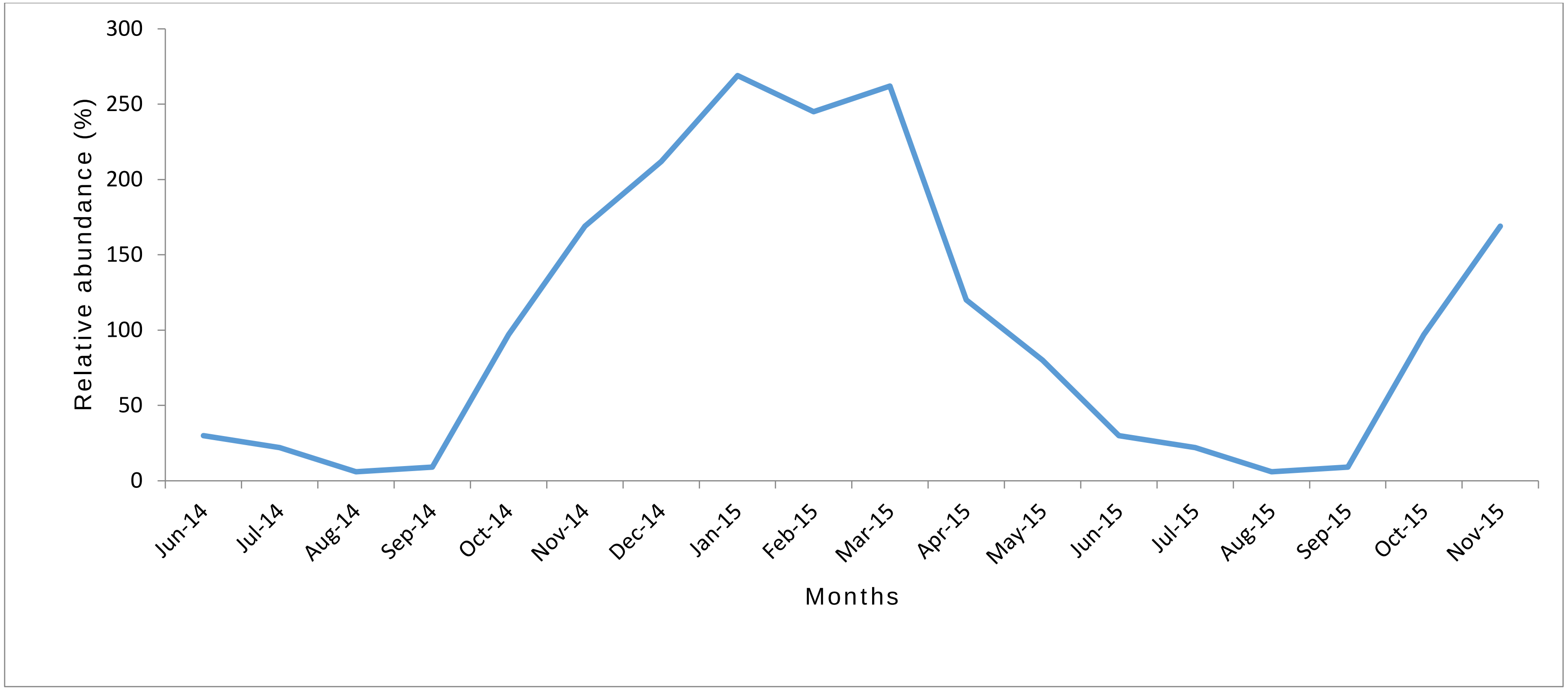


Figure 4.37: Monthly Relative Abundance of Fish Fauna in Oluwa River

CHAPTER FIVE

DISCUSSION

5.1 Physico-chemical parameters

The temporal variations in the physico-chemical parameters indicate the influence of season on the physico-chemical hydrology of Oluwa River. Egborge (1970) and Adebisi (1981) cited the rainfall pattern of an area as an important climatic factor governing the physico-chemical dynamics of the water bodies of that locality. The spatial variations recorded in the physico-chemical parameters of Oluwa River could be due to different degrees in anthropogenic activities across the stations.

The water temperature of Oluwa River fluctuated throughout the study-period in relation to the air temperature but they were within the acceptable levels for survival, metabolism and physiology of aquatic organisms. Generally, the surface water temperature follows the ambient temperature and it is influenced by latitude, altitude, season, time of day, air circulation, cloud cover, substrate composition, turbidity, vegetation cover, water current and depth of the water body (Awachie, 1981; Ikusemiju, 1981; Leman, 1985; Umeham, 1989). The higher water temperature in downstream station could be as a result of sampling time. As most of the sampling times in the downstream were in the afternoon it has been confirmed that time of the day influence the water temperature. Usually there is more insolation during the noon period of the day than in the morning in this region of the world (that is tropical region). Lack of vegetation cover at the downstream station was another contributory factor of higher temperature, though not significantly different across the stations. Nwankwo (1986) and Esenowo and Ugwumba (2010) assert that high water temperature could be associated with reduction in river flow and attendant insolation. The mean water temperature of Oluwa River during the study period fell within the normal temperature range (20-33 ^oC) as suitable for aquatic life in the tropical region (WHO, 1998 and NESREA, 2011).

According to USDA (1992), the level of oxygen depletion depends primarily on the amount of wastes added, the size, velocity and turbulence of the stream and the temperature of the water. The higher level of DO in the upstream station than the other two stations could be attributed to the organic matter discharge in midstream and downstream stations, since oxidation of organic matter in aquatic ecosystem by aerobic micro-organisms involves consumption of DO available in the water. The lower temperature in upstream stations could also lead to higher oxygen concentration. The DO values reported in this study at different periods were below the W.H.O (1998) and NESREA (2011) threshold for aquatic life. This could be attributed to waste input and biological activities (Cole, 1975; Boyd 1979, Chapman and Kimstach, 1992). Abowei and Sikoki (2005) reported organic pollution with similar marked reduction in DO levels. Tyokumbur *et al.* (2002) and Yakubu (2004) found that where human sewage discharged into Awba stream caused reduction in the DO level. The same observation was made by Chindah *et al.* (1999) at the municipal waste receiving end of a freshwater stream in Port-Harcourt, while anthropogenic wastes discharge was reported to be responsible for DO decline in Owena River by Olaniyan (2010). Similar higher rainy DO was observed in River Ogun (Adebisi, 1981), Nun River (Yakubu *et al.,* 1998) and Aiba Reservoir (Atobatele and Ugwumba, 2008). High dissolved oxygen in the rainy season was associated with run-off and turbulence (Chapman and Kimstarch, 1992).

Biochemical Oxygen Demand provides a measure of the level of organic pollution as a result of consumption of oxygen during biological process of breaking down of organic molecules into inorganic form (Abowei and Sikoki, 2005). Waters with BOD level less than 4mg/L are regarded as clean, while those with levels greater than 10 mg/L are considered polluted as they contain large amount of degradable organic materials (Boyd, 1982). The mean BOD in this study was below the 4.0 mg/L limit recommended as suitable for aquatic life by the NESREA. However, the BOD range in this study (1.4-3.8mg/L) was close to the limit (4.0mg/L) for aquatic life and could pose a threat to aquatic organisms if not put under control. Higher BOD in downstream station could be attributed to the different organic wastes received from the residents. Similar elevated level was recorded at human sewage discharge point of Awba Stream by Yakubu (2004) and Olaniyan (2010) for Owena Reservoir. The significantly higher BOD in the dry season than the rainy season indicates decrease in the volume of the water level that brought about poor water current that could initiate the required dissolved oxygen that are necessary for biodegradation processes.

The mean pH of Oluwa River fell within the acceptable limit (6.0-9.0) recommended by NESREA (2011) for aquatic life. The significantly lower pH level during the dry season indicates poor water condition due to lack of rain which could have facilitated the necessary dilution processes on the water body.

According to Adeleke (1982), conductivity levels below 50µs/cm are regarded as low; those between 50µs/cm to 600µs/cm are medium, while those above 600µs/cm are high conductivity levels. The mean conductivity in this study fell within the range for many inland waters. The mean and highest electrical conductivity in the study sites were similar to 31-131µmhos/cm recorded by Adebisi (1981) in Upper Ogun River. The monthly variation pattern of rising in the rainy season months could be attributed to the run-off gained during the period. The higher conductivity downstream could be due to decomposed organic matter increasing the conductivity and reducing the dissolved oxygen concentration, as suggested by Chapman and Kinstach (1992).

Water bodies in the tropics usually show a wide range of fluctuations in total alkalinity, the values depending on the location, season, plankton population and nature of the bottom deposits. However, the mean alkalinity recorded in this study was within the 20-200mg/L optimal range for fish production as classified by Boyd (1982). Oluwa River can be grouped as soft waters since none of the stations in the river had alkalinity levels of above 50mg/L. Sawyer (1966) describes hard waters as more productive than soft water, greater productivity does not result directly from higher concentrations of alkalinity but from higher levels of phosphorus and other elements, which increases along with alkalinity. Many trace metals including copper, lead, manganese, cadmium and zinc, are readily complexed into non-toxic chemical in hard water. The alkalinity of waters also often reflects carbonate contents of rocks and soils of water sheds and bottom muds. Mairs (1966) notes that waters of high total alkalinity are associated with carbonate deposits in surrounding soils. The seasonal varaiations in alkalinity recorded in this study with lowest mean in the rainy season could be due to the effect of dilution of the water during the rainy season. This is in contrast to earlier studies on other inland fresh water bodies (Adebisi 1981; Ogbeibu and Egborge, 1995). The higher alkalinity in the rainy season reported in these works was attributed to increased activities of micro-organisms on organic matters from the influx of flood water, resulting in increased carbon dioxide production and consequently impacting on the alkalinity of the river (Egborge, 1970).

Chloride contaminates rivers and ground water and makes it unsuitable for humans and aquatic life. The normal range, according to WHO (1993), is 50 - 250 mg/L for river. The mean chloride value of Oluwa River was below the acceptable limit of 200-250mg/L for aquatic life as recommended by the NESREA,(2011).This signifies that chloride is not a threat in the river. The significantly higher chloride in the rainy season could be explained by the effect of run-offs during the rains. Similar works by Chindah and Braide (2005) in tropical estuary, and Esenowo *et al*.(2010) in Majidun River reported higher chloride in the rainy season, which could be attributed to the effect of run-offs containing domestic wastes, as well as fertilizers, herbicides, fungicides and other agrochemicals from surrounding farmlands.

Total dissolved solid had regimes similar to conductivity for upstream, midstream and downstream stations. Total dissolved solid, total solid and conductivity are higher downstream due to unidirectional flow of river; it carries sediment from upstream to downstream. Total dissolved solids and conductivity values of the Oluwa River were within the national and international limits for aquatic life ≤ 200mg/L and 1000 µs/cm, respectively (NESREA, 2011).

Presence of nitrate in the natural water seldom exceeds 0.1mg/L (Chapman and Kimstach, 1992). The nitrate concentrations observed during the study were below 5mg/L suggested by Chapman and Kimstach (1992);this indicates pollution. The higher values of nitrate and phosphates in the rainy season might be due to the presence of the organic nutrients from the drainage areas by run-offs created from decaying plants and animals' materials, agricultural fertilizers and domestic sewage. Similar observations have been made by Ajao (1991) and Nwankwo and Amuda (2003) in Lagos Lagoon and surrounding coastal waters in southwest, Nigeria. The significantly higher concentrations of nitrate and phosphate at the downstream region of Oluwa River could be as a result of definite flow of the nutrients downstream of the river. Charles (1973) found a definite increase in nitrate concentration of the White River as it flew downstream.

The highest sulphate concentration in Oluwa River was observed during the rainy season. The sulphate content of the water samples fell within the maximum acceptable limit (≤ 200mg/L W.H.O 1998 and SON, 2007). However, the large quantities of nutrients were from faecal deposition use of manure and synthetic fertilizers from adjoining farmlands.They were brought into the main body of Oluwa River by run-off water. Sulphate occurs naturally in water as a result of leaching from gypsum and other common minerals and discharge of industrial wastes and domestic sewage tends to increase its concentration (Shrinivasa and Venkateswaralu, 2000). The sulphate content of the water samples may be regarded as high in comparison with most other inland waters in Nigeria. For instance Oke (1998) recorded values ranging from 0.2 to 1.2 mg/L in Owena Reservoir, Ikomi et *al.*, 2005 recorded mean values of 0.3mg/L in River Adofi, Delta State; while Atobatele and Ugwumba, (2006) recorded higher mean value of 36.6mg/L in Ogunpa River, Ibadan.

The levels of sodium and potassium recorded in this study were within the maximum acceptable levels of 200mg/L, according to WHO (1998). Adeniyi and Adedeji (2007) observed higher levels of sodium and potassium in both ground and surface water resources in Ile-Ife, Osun State, Nigeria. The mean values of sodium for ground waters ranged from 18.7± 0.06 to 40.8±6.1mg/L and from 15.9 ± 1.0 to 26.8±1.4 mg/L for potassium. The low aqueous solubility of sodium and potassium salts might have contributed to their relatively low concentration in Oluwa River. The level of these elements / ions in the soil would be enhanced by dead plants residues and this would enrich the associated waters.

Metal concentrations in the environment are controlled by various processes, such as particulate surface adsorption and micronutrient cycles (Chapman and Kimstach, 1992). Higher metals detected during the rainy season could be as a result of run-off containing domestic wastes, as well as fertilizers, herbicides, fungicides and other agrochemicals from surrounding farmlands or soil erosion. This agreed with Gaur *et al.* (2005), who asserted that higher concentration of metal in water during the rainy season could be due to the industrial/agricultural/domestic run-off coming into the river. High level of metal concentrations downstream of Oluwa River might be due to inputs from agro-chemicals used in farmlands around the area and domestic wastes discharged into the surroundings as well as input from their direct inflow from the other regions (upstream and midstream) of the river. The concentrations of Pb, Fe, Cr, Ni and Cd in this study were within the threshold level for aquatic life as recommended by NESREA (2011).

Principal Components Analysis (PCA)

The PC test verified that the physico-chemical parameters were successfully sorted into distinct categories that exhibited similar trends representing all of the other parameters. According to Simmons *et al.* (2004), though PCA is useful for detecting possible groupings of related parameters in a large multivariate data sets, it is important to note that the derived PCs are strictly hypothetical and that a PC that is significantly correlated with another may or may not represent an actual causal factor.

The PCA extracted three major components among the original 23 physico-chemical parameters. The PCs comprised essentially ionic (for example chloride and conductivity) and turbidity (TDS and TS) factors, with facor 1 alone contributing as high variability as 54% in the river. Two components (PC2 and PC3) exhibited mostly positive correlations, while one (PC1) exhibited negative correlation. This extraction clearly revealed three major groups of parameters (conductivity, TDS and TS) which are key drivers in ecosystem productivity. Increasing TDS and TS have also been observed to impair aquatic productivity (Ogbuagu *et a.*, 2011).

Among the other parameters with high loadings for factor 2 (that accounted for 36.00%), dissoved oxygen (DO) was prominent. DO is the most important parameter that affects water quality, as insufficiency of oxygen will allow aquatic organisms to give in to stress, thereby leading to dealth or becoming more susceptible to parasites and diseases (King and Jonathan, 2003).

The third component was most negatively correlated with Fe, Pb and Ni, which are metallic factors with about 5.85% variability. Metals are important to plants and animals, especially in the cellular processes (Lovell, 1989).

During the dry season, air temperature, water temperature and chloride recorded high positive loading on the first component. This could be an indication of the impact of the dry season on these parameters. Conversely, TDS,TS and conductivity showed peculiar distribution in the rainy season, an indication of the influence of rain on the concentration of these parameters.

5.2 Phytoplankton composition of Oluwa River

The phytoplankton taxa, namely, Chlorophyceae, Bacillariophyceae, Cyanophyceae and Euglenophyceae, identified in Oluwa River are similar to the assemblages previously identified from different Nigerian rivers (Imevbore, 1965; Egborge, 1970; Abohweyere, 1990; Aguigwo, 1997; Yakubu *et al.*, 1998; Adeogun *et al.*, 2005; Mustapha and Omotosho, 2005; Onyema and Nwankwo, 2007; Adakole *et al*., 2008; Atobatele and Ugwumba, 2008; Adesalu and Nwankwo, 2008; Agbaire and Obi, 2009; Bwala *et al*., 2010; Chinedu *et al*., 2011; Ezekiel *et al*., 2011; Adejuwon and Adelakun, 2012; Ogbuagu and Ayoade, 2012; and Esenowo, 2013). The species richness of Oluwa River was relatively higher than those encountered by Olaleye and Adedeji (2005), who recorded 19 phytoplankton species in palm oil effluent-impacted area of Oluwa River in Ondo State; Akoma and Imoobe (2009), recorded 46 phytoplankton species in Bahir Dar Gulf of Lake Tana. Ethiopia; Esenowo and Ugwumba (2010) recorded 50 species of phytoplankton in Majidun River in Lagos State and Ogbuagu and Ayoade (2012) recorded a total of 42 phytoplankton in Imo River. This higher phytoplankton taxa (52) in Oluwa River could be as a result of nutrient availability in the water body (Kumar, 1990). The observation of Chlorophyceae as the most abundant phytoplankton in this study is similar to the finding of Solomon *et al.* (2011) that Chlorophyceae are more obvious representative of the phytoplankton in the tropics. The higher phytoplankton relative abundance during the dry season was possibly induced by high photosynthetic activity (Chapman and Kimstach, 1992; Meybeck *et al.,* 1992).

Bacillariophyceae were relatively more abundant in the dry season than the rainy season. This observation was in contrast to the study of Edward and Ugwumba (2010), where Bacilariophyceae were relatively more abundant in the rainy season than the dry season in Egbe Resevoir, Ekiti. Cyanophyceae in Oluwa River being abundant in the dry season agreed with findings of Nwankwo (1995) and Akpata *et al*., (1993). This observation was in contrast to the report of Oduwole (1997), in which Cyanophyceae were higher in the rainy season than the dry season in River Ona. The Euglenoids identified in the Oluwa River generally had higher relative abundance in the dry season than in the rainy season. Similar observation was made by Ugwumba (1990).

The complexity of ecosystems has forced conservation biologists to develop alternative methods to monitor change that would be too costly or difficult to measure directly (Landres *et al*., 1988; Meffe and Carroll, 1997). One such method is the use of indicator taxa, which are species or higher taxonomic groups whose parameters, such as density, presence or absence, or infant survivorship, are used as proxy measures of ecosystem conditions. For example, indicator taxa have been used to evaluate toxicity levels, abundance of species resources, levels of biodiversity, target taxa status, endemism levels, and ecosystem health (Temple and Wines, 1989; Wilcove, 1989; Nyholm, 1995; Faith and Walker, 1996). Phytoplankton is considered as a good indicator of water quality (Onyema and Nwankwo, 2007).

The presence of 18 indicator species out of the total of 52 individual species of phytoplankton suggests that Oluwa River may be polluted. *Navicula crucicula*, *Nitzchia acicularis, Oscillatoria princeps, O. princeps vaucher, Melosira distans* and *Anabaena constrica* observed in Oluwa River during the period of study have been implicated to be found in organically polluted water (Palmer, 1969). It has also been reported that excessive growth of certain algae belonging to the genera, viz: *Scenedesmus, Anabaena, Oscillatoria* and *Melosira* indicate nutrient enrichment of aquatic bodies (Kumar, 1990). Some euglenoid species can tolerate various levels of organically polluted waters and, therefore, can be used as indicators of organic pollution (Nwankwo, 1995). Such species include *Euglena* and *Phacus.* Egborge (1990) avers that the euglenoids are not only planktonic but good indicators of pollution in freshwater bodies.

5.3 Hierarchical Cluster Analysis (HCA)

The HCA is an exploratory tool designed to reveal natural groupings within a data set that would otherwise not be apparently revealed clustered that did not depend on numerical nor apparently assumed criteria.

The clustering showed relationships among phytoplankton species at varying levesl of correlation. Most of the phytoplankton showed positive significant correlation in terms of abundance, with the organisms closer together being more related. However, this implies that environmental factors give similar effects on their abundance.

5.4 Zooplankton

The zooplankton taxa, namely Rotifera, Copepoda and Cladocera, identified in Oluwa River have been variously reported from different Nigerian Rivers (Olaniyan, 1957; Imevbore, 1965; Egborge 1970; Bidwell and Clark, 1977; Jeje and Fernado 1992; Egborge 1994a, Ovie, 1995; Akinbuwa, 1999; Aguigwo 1997; Ovie 1997; Imoobe and Egborge, 1997; Yakubu *et al.*, 1998; Ogbeibu and Obanor, 2002; Ibrahim, 2009; Nkwoji *et al.,* 2010; Olaniyan, 2010; Nkwoji *et al.,* 2010; Ayeni *et al*., 2011; Ude *et al.,* 2011; Ladipo *et al*., 2011; and Ezeribe *et al*., 2012). This study recorded 38 species of zooplankton, which is higher than 6 species recorded by Olaleye and Adedeji (2005) in palm oil effluent-impacted area in Oluwa River, Ondo State; 19 species recorded by Ogbuagu and Ayoade (2012) in Imo River; 30 species reported by Nkwoji *et al*. (2010) in Lagos Lagoon, but less than 39 species recorded by Esenowo and Ugwumba (2010) in Majidun River in Lagos State. This present observation of higher zooplankton species possibly indicates the presence of organic wastes deposition in Oluwa River, which results in increase in phytoplankton production, consequently, zooplankton productivity.

The predominance of rotifers in the river in terms of species number and numerical abundance has been attributed to the fact that rotifers evolved from fresh waters (Green, 1960; Egborge, 1977 and Segers, 1993). Rotifers generally are adapted to warm water, occurring mostly in tropical water bodies, with high temperatures. The predominance of rotifers in some inland freshwaters has also been reported by Egborge (1990), in Osun River; Jeje and Fernando (1992), in Sokoto River; and Ayodele and Adeniyi (2006), in River Osun. The abundance of the genera *Brachionus, Asplanchna* and *Filinia* showed that the rotifer-fauna was made up of a tropical assemblage (Jeje and Fernando, 1986). The predominance of the Brachionidae could, however, be attributed to their widespread geographical distribution and omnivorous nutrition of most of the members (Goldman and Hornes, 1983).

The increasing order of diversity and evenness are Rotifera > Copepoda > Cladocera in the upstream, midstream and downstream, respectively. This same order was observed in both seasons. This observation is similar to those of Oben (2000) in three man-made lakes in Ibadan, Nigeria.

Seasonal variation in the abundance of zooplankton from Oluwa River in this study showed higher abundance of Rotifera and Cladocera during the dry season. Most rotifers species have been found to thrive well in warm-water conditions with high temperatures, which is usually characteristic of most Afro-tropical waters in the dry season (Segers, 1993; Kutikova, 2002)

5.5 Benthic macro-invertebrate Composition of Oluwa River

Seventeen species and 14 genera of benthic macro-invertebrates belonging to five families reported in this study are low compared to benthic macro-invertebrates abundance and diversity of some Nigerian environment. For example; Emere and Nasiru (2007) recorded 1,304 organisms belonging to 8 classes and 27 species in the urbanized Bamawa Stream in Kaduna; George *et al*. (2009) recorded 19 species belonging to 6 classes in Okpoka Creek in the Niger Delta area; Esenowo and Ugwumba (2010) recorded 10,799 organisms belonging to 18 species in Majidun River in Lagos State, Adeogun and Fafioye (2011) recorded 1,013 macro-invertebrates belonging to 4 taxa in Awba Stream and Resesrvoir in Ibadan; and Akindele and Liadi (2014) recorded 19 taxa of macro-invertebrates in Aiba Stream, Iwo, south-western Nigeria. However, the taxa richness of Oluwa River is relatively higher than those of the works of Chukwu and Nwankwo (2003), who recorded 8 species in Port Novo Creek; and Nkwoji *et al.* (2010), who reported 13 species in Lagos Lagoon and attributed the low abundance to organic pollution and dredging activities.

Higher relative abundance of pollution indicator species (*Pachymelanin aurita* and *P. fusca*) encountered in Oluwa River could be attributed to organic pollution from dump sites along the shore of the river. Perhaps, these are not unconnected with decline in the water qualities observed in the area, such as low DO. The organic pollution tolerant species found in this river are morphologically and physiologically adapted to surviving conditions of low water quality. This forms of include possession of pigment haemoglobin, which gives affinity for oxygen even at very low concentration (Pertet *et al.,* 1999). Gastropods are known to be relatively tolerant of physical and chemical variations in the environment and are usually present in a broad range of habitats (Brown and Ajao, 2004). Ajao and Fagade (2002) also recorded gastropods as the dominant benthic fauna in Lagos Lagoon. *Pachymelania aurita* recorded the highest percentage abundance during the study period. Similar observation was made by Chukwu and Nwankwo (2003) in Port Novo Creek. This is not unconnected with their ability to cope with decline water quality.

Species abundance and diversity were low, especially when compared with the other studies in Nigerian inland water. This study recorded the lowest Margalef index of 0.58 in the study area. Conversely, Sikoki and Zabbey (2006) recorded Margalef index of 2.39 and Ogbuagu (2014) recoded 1.13 in the same Imo River; also Akindele and Liadi (2014) recorded Margalef index of 2.89 for macro-invertebrates in Aiba Stream, Iwo, South-western Nigeria. Other than from natural processes, anthropogenic perturbation has been known to threaten and exacerbate biological diversity losses (Spaak and Bauchrowitz, 2010). Global biodiversity in freshwaters has also been reported to be on the decline (Jokela, 2010). Harrison and Stiassny (1999) have identified habitat modification as exerting the most influence on aquatic biodiversity richness. Spaak and Bauchrowitz, (2010) view sand mining as a major habitat modifier for aquatic biota. In-stream sand mining could improverish aquatic sediment of essential nutrients necessary for a healthy and thriving biological community. The sand-mining activity could have contributed to the low value recorded in this study area.

Shannon-Weiner diversity index values above 3.0 indicate that the structure of the habitat is stable, while values less than 1.0 indicate that there are pollution and degradation of the habitat structure (Shannon, 1948; Mandaville, 2002). Margalef's water quality index values less than 1.0 indicate severe pollution and intermediate values indicate moderate pollution (Lenat *et al*., 1980). Based on the diversity indices values (0.58, 0.60 and 0.61) obtained in this study, Oluwa River can be regarded as being slightly polluted.

Some important factors governing the abundance and distribution of macrobenthic communities include, water quality, immediate substrates for occupation and food availability (Dance and Hynes, 1980). Any ecological imbalance arising from any severe alterations of these factors may affect the macrobenthos. Therefore, it appears that the macrobenthic community abundance, composition and diversity might have been greatly affected by stress imposed by land-based pollutants, as well as substrate instability possibly arising from frequent deposition of organic wastes in the river. The low diversity of benthic macro-invertebrates recorded midstream could be attributed to sand mining activities taking place in that area.

One important macro-invertebrate community indicator is EPT richness, or the total number of Ephemeroptera (mayfly), Plecoptera (stonefly) and Trichoptera (caddisfly) taxa in a sample. An increasing EPT richness value correlates with increasing water quality

(Rothrock *et al.*,1998) and many studies have indicated that Ephemeroptera, Plecoptera and Trichoptera show a strong negative response to anthropogenic disturbances in aquatic ecosystems (Ode *et al.*, 2005). Although, caddisfly was present in all the stations with low abundance, the absence of Ephemeroptera and Plecoptera throughout this study period is an indication that the river is of low biological water quality.

5.6 Relationship between the physico-chemical parameters and the abundance of plankton and benthic macro-invertebrates

The positive significant relationship of air and water temperatures with Rotifera abundance in Oluwa River is an indication that most species rotifers thrive well in warm-water, as suggested by Segers (1993). Many investigators have shown that water temperature is important for rotifer development (Heesen *et al.*, 1995; Pinel-Alloul *et al.*, 1995; Pociecha, 2002; Michaloudi and Kostecka, 2004). Air temperature was also observed to have showed positive significant relationship with Copepoda during the study period, which is in line with the suggestion of Jackson *et al.* (1989) that life cycles and population densities of many stream organisms are temperature-dependent and alteration of the average stream temperature by a few degrees could alter the flora and fauna of the river. Air temperature, water temperature and BOD showed positive significant relationship with most of the major groups of phytoplankton (Bacillariophyceae, Chlorophyceae, and Cyanophyceae).

The largest percentage of heat input into the atmosphere which in turn, influences air and water temperature in any location on the earth is from sunlight (solar energy). This solar energy is the major energy required for photosynthetic activities by phytoplankton which, in turn, brings about increase in their abundance and blooms (Chapman and Kimstach, 1992, and Meybeck *et al.,* 1992). The significant relationship between BOD and the major phytoplankton group, as mentioned above, could be as a result of the level of organic pollution of Oluwa River (Egborge 1990; Chapman and Kimstach, 1992 and Meybeck *et al.,* 1992). The negative significant of Copepoda with magnesium as well as that of Cyanophyceae with sodium could be as a result of the influence of total salinity (ion contents) on the metabolism of the organisms. According to Wetzel (2001), proportional concentrations of major cations (Ca, Mg, Na and K) can influence the metabolisms of many organisms, particularly certain phytoplankton (algae) as well as the absolute concentrations do.

Dissolved oxygen showed significantly positive relationship with Gastropoda in Oluwa River. This is an indication that oxygen is essential for the metabolic processes and respiration of most aquatic organisms and affects the solubility and availability of many nutrients for organisms in aquatic ecosystem and, in turn, enhances their productivity (Wetzel, 2001). Gilled snails rely on high concentrations of dissolved oxygen; they tend to be sensitive to pollution (Voshell and Reese, 2002). Negative relationships between chlorides, nitrate with crustacea could probably be due to the influence of anthropogenic activities on Oluwa River, as anthropogenic actions have been suggested to significantly alter directly or indirectly the composition and distribution of benthic organisms (Beghelli *et al*., 2012).

All the benthic macro-invertebrates showed negative correlations with the investigated heavy metals and were significant in their correlations with Cadmium, Chromium, and Iron.This could be as a result of the fact that elevated concentrations or increase in concentrations of heavy metals has been linked to toxicity in aquatic macro-invertebrates (Hartman *et al*., 2004).

5.7 Fish composition of Oluwa River

A total of thirty-four species of fish belonging to ten families encountered in the present study have been earlier reported to occur in Nigerian water bodies (Reed *et al.,* 1970; Idodo-Umeh, 2003; Olaniran, 2003; Obasohan and Oronsaye, 2006; Fapohunda and Godstates 2007 and Falaye *et al*., 2015). Babatunde and Raji (1998) reported occurrence and distribution of most of these species in Ogun River. However, distribution and abundance of fish in tropical water bodies have been variously attributed to several factors but principally water depth (Chapman and Kimstach,1992), water temperature (Agremier and Kar,1983), water transparency (Fagade and Olaniyan, 1974) and migratory behaviour of some of the fish species (Adebisi, 1988). The fish in Oluwa River were more than 14 species reported by Fapohunda and Godstates (2007) in Owena River and nineteen species identified by Esenowo (2013) in Majidun River in which the low number was attributed to sand-mining activities in the river because sand-mining degrades, destroys spawning, breeding, feeding or growth to maturity of fish (Odun 1995). The dominance of the member of the families Clariidae and Cichlidae in Oluwa River was similar to the finding of Fapohunda and Godstates (2007), that Clariidae constituted the dominant fish families in the reservoir. This confirms that Clariidae and Cichlidae dominated the fish under uncontrolled conditions in most Nigerian water (Ita and Balogun, 1983; Ita, 1993).

The higher abundance of the fish species during the dry season than the rainy in Oluwa River is similar to the report of Falaye *et al*. (2015), that the catch composition differed seasonally with highest number of fish obtained in the dry season, while the lowest was observed in rainy season. The percentage abundance of fish observed to be significantly higher in the dry season could be attributed to low water level during the dry season. Ayoola and Kuton (2009) and Esenowo (2013) found higher abundance of fish species at low level of water in Lagos Lagoon and Majidun River during the dry season.

CHAPTER SIX

SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

6.1. Summary of findings

Allochthonous materials brought in during the rainy season possibly played a major role in the limnology of the river since the physico-chemical parameters of Oluwa River showed seasonality for water temperature, conductivity, alkalinity, chloride, DO, BOD, pH, TDS, TS, NO_3, SO_4^{2-}, PO_4^{3-}, Na, Mg,Cd and Ni. Most of the metals analysed had concentrations below the recommended limit for aquatic biota on the scale of hierarchy the concentrations of the major cations analysed was Mg>Ca>Na>K, while that of anions was Cl^- >SO_4 and that of heavy metals was Ni > Fe > Pb> Cd > Cr. Most parameters recorded were significantly higher in downstream station due to unidirectional flow of the river. Physico-chemical parameters: air temperature, water temperature, BOD, magnesium and potassium, showed wide range of both positive and negative significant relationships with major zooplankton groups; while air temperature, water temperature, DO and BOD showed positive significant relationship with the major phytoplankton groups. Physico-chemical parameters: DO, Alk, Cl, K, NO_3, PO_4, Cd, Cr, and Fe showed significant relationships with benthic macro-invertebrates groups from Oluwa River.

The phytoplankton composition of Oluwa River showed similarity with previous studies from Afro-tropical water bodies. Chlorophyceae was the dominant taxa throughout the study in number, occurrence and abundance. The increasing order of dominance values was: Chlorophyceae>Bacillariophyceae>Cyanophyceae>Euglenophyceae. The zooplankton composition of the study area also revealed a marked similarity with the recorded of most studies from Nigeria water bodies. Rotifers were the predominant taxa. The increasing order of diversity and evenness were Rotifera > Copepoda > Cladocera. Most of the recorded taxa had the highest value at the downstream. Most of the taxa were higher in the dry season than the rainy season, except Copepoda. Benthic macro-invertebrates of Oluwa River comprised seventeen different species belonging to five families (Crustacea, Gastropoda, Insecta, Oligochaeta and Polychaeta) with a total abundance of 2,394 individuals. Gastropoda were the predominant taxa at Oluwa River during the period of study; followed by Polychaeta > Insecta > Crustacea > Oligochaeta. Pollution indicators species, such as *Chironomus* larvae, *Glycera capitata*, *Nereis diversicolor* and *Pachymelania aurita,* were encountered in all the stations, suggesting pollution in the stations. The low diversity of benthic macro-invertebrates recorded midstream could be attributed to sand mining activities taking place in that area. The higher abundance of fishes recorded in the dry season than the rainy season could be attributed to low water volume during the period.

6.2. Conclusions

In conclusion, on going livelihood activities in River Oluwa are unregulated resulting in increase in temperature, low dissolved oxygen and presence of pollution indicator organisms. The comparism of some nutrient parameters (NO_3 and SO_4) concentrations in most of the investigated stations with the recommendations of standard regulatory bodies such as, NESREA, SON and WHO were slightly elevated shown the presence of oganic pollution. Moreover, the presence of pollution indicator species suggests that the river is slightly polluted.

6.3. Recommendations

The following regulatory measures are therefore recommended:

1. Public enlightment

There should be enlightment and awareness programmes organized through public workers for local residents on the environmental devastation that could result from dumping of untreated wastes into the natural water bodies as well as the benefit of adequate waste management measures.

2. Waste utilization

The concept of waste-to-wealth should be put in place. Some waste could be utilized as source of organic fertilizer for agricultural purposes rather than being discharged into the natural water bodies and proper collection facilities, such as waste bin, waste bag collectors and incinerators should be made available for the market people at Durogbe Market. So as to prevent the habit of saddling the water bodies with their waste..

3. A**dequate monitoring**

There should be regular monitoring of the discharge of anthropogenic wastes as well as the health status of the water bodies using physico-chemical study and biomonitoring by the environmental agencies, such as, Nigeria Inland Water Ways Authority (NIWA). This will ensure compliance with the standard for discharging effluents as well as early detection of any devastation in the aquatic environment.

REFERENCES

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 Sciences* 5:53-58.

Abowei, J.F.N. 2010. Salinity, dissolved oxygen, pH andsurface water temperature Conditions in Nkoro River, Niger Delta, Nigeria. *Adv. J. Food Sci. Technol.,* 2(1): 16-21.

________, and Sikoki, F.D. 2005. *Water pollution; management and control* Port Harcourt, Double Trust Publishers.

________, and George, A.D.I., 2009. Some physicochemical characteristics of Okpoka Creek, Niger Delta, Niger, Nigeria. *Res. J. Environ. Earth Sci*. 1(2): 45-53.

________, Davies, O.A. and Eli. A. 2010. Physicochemistry, morphology and abundance of fin fish in Nkoro River Niger Delta, Nigeria. *Int. J.Pharm. Bio. Sci*., 6(2). 54-68.

________, Ezekiel E.N. and Hansen.U. 2012, Effects of water pollution on benthic macro fauna species Composition in Koluama Area, Niger Delta Area, Nigeria. *International Journal of Fisheries and Aquatic Sciences* 1(2): 140-146.

Adaka, G.S. Etim, I.N., Nlewadim, A.A ,Olele N.F and Ezefulukwe, C.F. 2015. Assessment of fish landed by artisanal fishers in Imo River at Owerri-Nta, Abia State, Nigeria Nigeria. *Journal of Fisheries and Aquatic Science,* 10: 587-591.

Adakole, J.A. and Anunne, P.A.2003. Benthic Macro-invertebrates as indicators of environmental quality of an urban stream. Zaria, Northern Nigeria, *Journal of Aquatic Science* 18.1: 85-92.

________, Abulode DS and Balarabe ML 2008. Assessment of water quality of a man-made lake in Zaria Nigeria; *Proceedings of Taal, 2007: The 12th World Lake Conference*: 1373-1382.

Adebisi, A.A .1981. The physico-chemical hydrology of a tropical seasonal river –Upper Ogun River, *Hydrobiologia* 79:157-165.

________, 1988. Changes in the structural and functional components of the fish community of a seasonal river. *Archive fur Hydrobiology* 113: 457-463.

Adebola O.T and Olaniyan, R.F. 2012. Relative abundance and Identification of Paelaemoniid prawns at Oluwa Creek, Igbokoda, Southwest, Nigeria. *Journal of Science and Science Education, Ondo.* 3 (1) 118-124, 24.

Adebowale K.O, Agunbiade F.O, Olu-owolabi, B.I. 2008. Impacts of natural and anthropogenic multiple source of pollution on the environmental conditions of Ondo state coastal water. *Nig .J.Environ Agric.Food Chem*.2 (1) 2798-2810.

Adedeji, O.B and Okocha, R.C. 2011. Assessment level of heavy metals in prawns (*Macrobrachium macrobrachion*) and water from Epe Lagoon. *Adv.Env.Biol*.5 (6) 1342-1345.

Adekunle, I.M, Ajijo, M.R, Adeofun, C.O and Omoniyi, I.T. 2010. Response of four phytoplankton species found in some sectors of Nigeria coastal waters to crude oil in controlled ecosystem. *Int. J.Environ.Res.4* (1):65-74.

Adejuwon J.O and Adelakun, M.O. 2012. Physico-chemical and bacteriological analysis of surface water in Ewekoro Local Government Area of Ogun State, Nigeria:Case study of Lala,Yobo and Agdo Rivers,*Int.J.Water Res.Environ*.Eng 4(3).66-72.

Adeleke, C.A. 1982. Studies on the ecology and feeding habits of Lymnea natalensis(Krauss) intermediate host of cattle liverfluke in Ibadan area.Ph.D Thesis.University of Ibadan.p25-46.

Adeniyi, I.F. 1986. The ecology of bonny estuary: the chemical composition of the Rivers and Creeks. Paper presented at the Man and Biosphere (MAB) Workshop held at Federal Secretariat, Port Harcourt, August, 2006, pp: 27.

________, and Adedeji, A.A. 2007. The rotifera fauna of Gongola River Basin, Northeast Nigeria. *Ife Journal of Science* 9(1): 1-15.

Adeogun, A.O. 2004. Effects of methanolic extracts of *Raphia hookeri* (Mann and Wend 1804) on life stage of *Claria gariepinus* (Burchell, 1862) Ph.D. thesis, University of Ibadan.p45-80.

________, Fafioye O.O, Olaleye B.A and Ngobili G.O. 2005. The relationship between some physico-chemical parameters and plankton composition on fish production in Ponds. In the 19th annual conference of the Fisheries Society of Nigeria (FISON), Ilorin, Nigeria.p6-12.

________, and Fafioye O.O. 2011. Impact of effluents on water quality and benthic macro invertebrate fauna of Awba Stream and Reservoir *J. Appl. Sci. Environ. Manage.*vol 15(1) 105-113.

Adesalu, T. A and Nwankwo D.I. 2008. Effect of water quality Indices on Phytoplankton of a Sluggish Tidal Creek in Lagos, Nigeria. *Pak. J. Biol. Sci.* 11(6): 836-844.

Agbaire, P.O, and Obi, C.G. 2009. Seasonal variations of some physico-chemical properties of River Ethiope water in Abraka, Nigeria. *J. Appl. Sci. Environ. Manage*. 13(1): 55–57.

Agremier, P.L and Karr, J. R. 1983. Fish Communities along environmental gradients in a system of trophical streams, *Environmental Biology and Fisheries* 9:117-135.

Aguigwo, J.N. 1997. Studies on Plankton productivity in relation to water quality parameters and Nutrient levels. *Journal of Aquatic Sciences* 12:15-22.

Aggrey-Fynn, J, Galyuon, I, Aheto, D.W and Okyere, I. 2011. Assessment of the environmental conditions and benthic macroinvertebrate communities in two coastal lagoons in Ghana.*Annals of Biological Research*. 2(5) :413-424.

Ajao, E.A. 1991. A study of sediment and communities in Lagos Lagoon, Nigeria, *Oil and Chemical Pollution*. Vol.1 (2):15-25.

______, 1996. Review of the state of pollution at the Lagos Lagoon, *Nigerian Institute for Oceanography and Marine Research* (NIOMR) Tech,paper 106:1-15.

______, and Fagade, S.O. 2002. The benthic macro-In fauna of Lagos Lagoon. *The Zoologist* Vol.1 (2):1-15.

Ajibola, V.O. and Baiyewu, O.O. 2004. Dynamics of Nitrates and Phosphates in some selected farm soils around Zaria. *Chem Class Journal*, 1:174-176.

Ajuonu N, Ukaonu S.U, Oluwajoba E.O, Mbawuike, B.E, Williams, A.B, and Myade, E.F. 2011. The abundance and distribution of plankton species in the bonny estuary; Nigeria. *Agriculture and Biology Journal of North America*.vol 2 (3) 1033-1037.

Akaahan, T.J.A, Manyi M .M, and Azua E.T. 2016. Variation of benthic fauna composition in River Benue at Makurdi, Benue State, Nigeria. *International Journal of Fauna and Biological Studies* 2016; 3(2): 71-76

Akegbejo-Samsons.2009. Practical suggestions for the commercialization of fishery Production in Ondo State.

Akinbuwa, O. 1999. The rotifera fauna and physicochemical condition of Erinle Lake and its major inflow at Ede, Osun State, Nigeria.Ph.D Thesis, Obafemi Awolowo University, Ile-Ife.

Akindele, E.O and Liadi, A.A. 2014. Diversity and response of benthic Macroinvertebrates to natural and induced envirnmental stresses in Aiba Stream, Iwo Southwestern Nigeria. *West African Journal of Applied Ecology*.Vol 22 (1):101-111.

Akin-Oriola, G.A. 2003. Zooplankton associations and environmental factors in Ogunpa and Ona Rivers, Nigeria. *Rev. Biol. Trop.* 51(2): 391-398.

Akinsorotan, A. M. 2013. Evaluation of heavy metals on wetland biodiversity of Oluwa River (Southwest Nigeria) POME Polluted Area. *International Journal of Scientific & Engineering Research* Volume 4, Issue3:1-10.

Akinwumi F.O, Akinwumi I.O and Ogundahunsi, O.A. 2011. Characterization of artisanal fishery in the Coastal Area of Ondo State, Nigeria. *International Research Journal of Agricultural Science and Soil Science* vol.1 (3):083-089.

Akoma, O.C and Imoobe, T.O.T. 2009. Limnological and phytoplankton survey of Bahir Dar Gulf of Lake Tana, Ethopia, *African Journal of Science and Technology (AJST) Science and Engineering Series*, 10(2):91-98.

Akpata, T.V.I., Oyenekan, J. A and Nwankwo, D.I. 1993. Impacts of organic pollution on the Bacterial, plankton and benthic populations of Lagos Lagoon, Nigeria. *Int. J. Ecol. African Experience.* Vol 1(2) 166.

Alabaster, J. S. and Lloyds R. 1982. *Water quality criteria for fresh water fish* 2nd edition. Butterworts Scientific 127-142

Albaret. J and Lae, R. 2003. Impact of fishing on fish assemblages in tropical Lagoons. the example of the Ebrie Lagoon, West Africa, *Aquatic Living Resources* 16:1-9.

Albert C. Ibezute, Godwin, I. Asibor, and Sandra U. Ibezute . 2016. Ecological Assessment of Brewery Effluent Impact on the Macrobenthic Invertebrates of Ikpoba River, Edo State, Nigeria. *International Journal of Ecosystem* 6(3): 47-54

Alhaji T.A., Jim-Saiki L.O., Giwa J.K., Adedeji A.K., and Obasi, E.U. 2015. Infrastructure Constraints in Artsanal Fish Production in the Coastal Area of Ondo State, Nigeria. *International Journal of Research in Humanities and Social studies.* Vol 2, Issue 5 22-29.

Andem, A. B.1; Okorafor, K. A.1; Udofia, U.1; Okete, J. A.and Ugwumba, A.A.A. 2012. Composition, distribution and diversity of benthic macroinvertebrates of Ona River, South-west, Nigeria. *European Journal of Zoological Research*, 2012, 1 (2):47-53 *(http://scholarsresearchlibrary.com/archive.html).*

Ansa, E. J. 2005. Studies of the benthic macro fauna of the Andoni flats in the Niger Delta Area of Nigeria. Ph.D. Thesis, University of Port Harcourt, Port Harcourt, Nigeria.

Anyinkeng N, Afui M. Mih, Tening A. Suh and Che. C. Awah. 2016. Phytoplankton diversity and abundance in water bodies as affected by anthropogenic activities within the Buea municipality, Cameroon. *Journal of Ecology and The Natural Environment* Vol. 8(7): 99-114,

APHA. 1985. *Standard methods for the examination of water and wastes water*. 16th Edn, American Public Health Association Washington D.C. USA.16th edn. 1268p

_____, 1995. *Standard methods for the examination of waste water*. 14th Edn., APHA, AWIWAWPCHCF, Washington.

______, 1998. *Standard methods for the examination of water and wastewater*. 20th Edn. American Public Health Association, American Water Works Association, Water Environment Federation. Greenberg, A.E., Clesceri, L.S., and Eaton, A.D Washington D.C. USA. 1213p.

_____, 2005. *Standard methods for examination of water and waste water*. American Public Health Association. Washington D.C.

Arimoro, F.O. Ikoms, R.B. and Osalor, E.C. 2007a. The impact of sawmill wood wastes on water quality and fish communities of Benin River, Nigeria Delta Area, Nigeria *International Journal of Sciences and Tech*. 2(1) 1-12.

______, ______ and Iwegbue, M.A. 2007. Ecology and abundance of Oligochaetes Indicators of organic pollution in an urban stream in southern Nigeria. *Pakistan Jounal of Biological Sciences* 10(3):446-453.

Atobatele, O.E and Ugwumba, O.A. 2006. Seasonal variation in the physico-chemistry of a small tropical reservoir (Aiba Reservoir, Iwo Osun, Nigeria) *African Journal of Biotechnology* Vol 7(12) 1962-1971.

_______ and _______, 2008. Seasonal variation in the physico-chemistry of a small tropical reservoir (Aiba Reservoir, Iwo, Osun, Nigeria). *Afr.J. Biotechnol*.7 (12):1962-1971.

Avelar, W, E, P., Mantelatto, F.L.M., Tomaazelli, A.C, Siva, D.M.L., Shuhaama,T. and Lopes, J.L.C. 2000. The marine mussel *perna perna* (Mollusca, Bivalvia, Mytilidae) as an indicator of contamination by heay metals in the Ubatuba bay,Sao Paula,Brazil, *Water ,Air and Soil Poll*.118:65-72.

Awachie, J.B.E. 1981. Running Water Ecology in Africa In: Lock, Perspectives in running water ecology. Williams (Eds.), Plenum Press, New York, plenum press:339-366.

Ayandiran, T.A., Ayandele, A.A., Dahunsi, S.O. and Ajala O.O. 2014. Microbial assessment and prevalence of antibiotic resistance in polluted Oluwa River, Nigeria. *Egyptian Journal of Aquatic Research* 40, 291–299.

_______, and Dahunsi, S.O. 2016. Toxicological assessment of fish (*Clarias gariepinus*) from bitumen-polluted River Oluwa, Nigeria. *Environ Monit Assess* 188: 71-90.

Ayeni, A.O, Balogun I.I., and Soneye A.S.2011. Seasonal assessment of physico-chemical concentration of polluted urban river: a case of Ala River in southwestern, Nigeria. *Res.J.Enviorn.Sci*. 5:22-35.

Ayenimo, J. G. Adeeyinwo C. E. and Amoo I. A.2005. Heavy metal polutantsin Warri River, Nigeria, *Kragujevac J. Sci.* 27 43-50.

Ayoade, A. A. Fagade, S. O. and Adebisi, A. A. 2006. Dynamics of limnological features of two man-made lakes in relation to fish production. *Afr. J. Biotechnol*. 5(10): 1020-1021.

Ayodele, H.A. and Adeniyi, I.F. 2006. The zooplankton fauna of six impoundments on River Osun, Southwest Nigeria. *The Zoologist*, 1(4): 49-67.

_______, and Ajani E.K. 1999. *Essential of fish Farming*. Ibadan. Odua Printing Co. Ltd. Ibadan.

Ayoola, S.O. and Kuton, M.P. 2009. Seasonal variations in fish abundance and physicochemical parameters of Lagos Lagoon Nigeria. *African Journal of Environmental Science and Technology* Vol. 3 (5) 149-156.

Babatunde, A. 2010. Impact of Oil exploitation on the socioeconomic life of the Ugbo people of Ondo State, Nigeria*. J.Sust.Dev.Afr*. 12(5):61-84.

Babatunde, D.O and Raji, A. 1998. *Field guide to Nigeria freshwaters fishes*. Federal College of Freshwater Fisheries Technology, New Bussa.

Baden, S.P., Loo, L.O., Pihi. L., and Rosenberg, R. 1990. Effects of eutrophication on benthic communities including fish. *Swedish West coast Ambio* 19.113-122.

Bagariano, T. 1992. Sulphide as an environmental factor and toxicants tolerance and adaptations in aquatic organisms. Aquac. *Toxicol.*, 24: 21-62.

Bagenal T.B. 1978. Fecundity in eggs and early life. *Methods for assessment of fish production in freshwater*. Bagenal, T.B (Ed).3rd edition, 66-178.

Bala U and Bolorunduro P.I. 2011. Limnological survey and nutrient load of Sabke Reservoir, Katsina State, Nigeria.*African Scientist* Vol 11, No 3.163-168.

Baird, C. 2000. *Environmental Chemistry* 2nd edn. W. H. Freeman and Company New York.557p.

Battin, T.L, Luyssaert S. Kaplan L.A, Aufdenkampe A.K,.Richter A, Trannvik L.I. 2009. The bundless carbon cycle *Nature Geoscience* 2:598-600.

Beadle, L.C. 1981. The inland waters of tropical Africa: *an Introduction to tropical limnology*. London Longman Publishers. pp: 475.

Beasley, P.G.1983. The penetration of light and the concentration of dissolve oxygen in fertilized pond water infested with mycrocystis. *Prol. Ann. Conf.Southeastern Assoc. Game Fish Comm.* 17:222-226.

Beghelli, F.G.S; Dos-Santos, A.C.A, Urso-Guimaraes, M.V and Calijuri, M.C. 2012. Relationship between space distribution of the Benthic Macro-invertebrates community and tropic state in a neotrophical Reservior (Itupararanga, Brazil). *Biota Neotropica* 12(2):1-11.

Benstead J.P and Leigh, D.S. 2012. An expanded role of river networks, *Nature Geoscience* 5:678-679.

Bertram J, and Balance R. 1996. A *practical guide to the design and implementation of freshwater, quality studies and monitoring programmes*. Published on behalf of United Nations Environmental Programme (UNEP) and World Health Organization (WHO), E and FN spoon publishers.

Bidwell, A. and Clark, N.V. 1977. The invertebrate fauna of Lake Kainji, Nigeria. *Nigeria Field*, 42(3); 104-110.

Blassco, J.,Arias, A.M and Saenz,V. 1999. Heay metals in organisms of River Guadalquivir estuary, possible incidence of the Aznale Ollar Disaster. *Sci.Tot Enviro.,* 242:249-259.

Bonneris, E., Giguere, A.Perceval, O., Buronfosse, TMasson, Share, L and Campbell, P.G.C. 2005. Subcellular portioning of metals (CD, Cu,Zn in the gills of a fresh water bivalve, *Pgganodon grandis*, role of calcium concentrations).*Aquat Toxicl.,*71:319-334.

Boyd, C.E. 1979. *Water quality in warm water fish ponds. agricultural experimental station* Auburn University. Craft master printers Inc. Alabama.

______, and Lichtkoppler. F. 1979. Water quality management in fish ponds. Research and Development Series No. 22 International Centre for Aquaculture (J.C.A.A) Experimental Station AuburnUniversity, Alabama, pp; 45-47.

______, 1981. *Water quality in warm-water fish pond.Auburn*; Auburn University.

______, 1982. *Water quality management for pond fish culture*. Elsevier Scruneh Publishers, pp: 249.

______, and Tucker, C.S. 1998. *Pond aquaculture water quality management*. London. Kluwer Academic publishers.

Brown, C.A. and Ajao, E.A. 2004. Effects of topographic modification on the composition and abundance of macro fauna in Southern Lagos lagoon. *West Afr. J. Applied Ecol.* 5: 41-50.

Butu, A.W, and Iguisi, E.O. 2013. Concentration of heavy metals in sediment of river Kubami Zaria, Nigeria.Comp. *J.Env.Earth. Sci* 2(1):10-17.

Bwala, R.L., Ovie, S.I., Ajayi, O., and Haruna, A. 2010. Preliminary study on the limnology and plankton abundance In relation to fish production in some NIFFR Reservoirs; Report and Opinion 2 (6). http://www.sciencepub.net/report.

Cave Cristi. 2015. *How a river Flows'* Stream Biology and Ecology. Archived from the original on 1, January, 2015.

Chapman, D., and Kimstach, V. 1992. *The selection of water quality variables*. w*ater quality assessments; a guide to the use of biota, sediments and water in environmental monitoring*.Chapman, D, Ed.London: Chapman and Hall.50-199.

Charles, E. Baker. 1973. Indicate a definite increase in nitrate concentration of the White River as it flows downstream. University of Nebraska – Lincoln Digital Commons@ University of Nebraska – Lincoln. Transactions of the Nebraska Academy of Sciences and Affiliated Societies Nebraska Academy of Science

Chessman, B. C. 2003. New sensitive grades for Australian River Macro invertebrates. *Marine Fresh Water Res*. 54: 95-103.

Chinda, A.C. 2003. The physico-chemical, phytoplankton and periphyton of swamp forest stream in the Lower Niger Delta. *J. Sci. Afr*.,1(2): 1-4.

______, Hart, A.I., and Atuzi, B. 1991. A preliminary investigation on the effects of municipal wastes discharge on the macrofauna associated with macrophytes in small freshwater stream in Nigeria. *J.Ecol*, 2: 23-29.

______, and Braide, S.A. 2005. Epidemic algal of tropical estuary: case of stable and invariable seasonally community. *Polish Journal Ecology* 50:91-99.

_______, Hart, A.I, Briade, S.A and Atuzie, B 1999. A preliminary investigation on the effects of municipal waste discharge on the Macrofauna associated Macrophytes in a small fresh water stream in Nigeria.*Afr.Journal of Applied Zoology* 2.29-33.

Chinedu, S.N, Nwinyi, O.C, Adetayo, Y.O., and Eze, V.N. 2011. Assessment of water quality in Canaanland, Ota Southwest Nigeria. *Agric.Biol.J North Ame*. 1(3). 2151-7517

Christopher, R., Shreeram, I., and Christopher, P. 2007. Use of Benthic macroinvertebrate indices to assess aquatic health in a mixed-landuse watershed. *Journal of Freshwater Ecology*, Volume 22, Number 4: 539-551.

Chukwu, I.O and Nwankwo, D.I. 2003. The impacts of land based pollution on the hydrochemistry and macrobenthic community of a trophican West African Creek *Ecologia* 2(1-2):1-9.

Clerk, R.B. 1986. Marine pollution. Oxford: Clarandon Press.

Cole, G.A. 1975. *Textbook of limnology*. The C.V Mosby company.283pp.

Dance, K.W., and Hynes, H.B.N. 1980. Some effects of Agricultural land use on stream insect communities .*Environ.pollut .Ser A* :22:19-28.

David, M. B., Gentry, L.E., Kovacic, D.A and Smith, K. M. 1997. Nitrogen Balance in and export from an agricultural watershed.*Journal of Environmental Quality*, 26:10-38.

Davies, O.A., Allision, M.E and Uyi, H.S. 2006. Speciation of heavy metals in floodplain in eastern England.*The Science of the Total Environment* 226:139-156.

_______, and Ansa, E. 2010. Comparative assessment of water quality parameters of freshwater tidal earthen ponds and stagnant concerete tanks for for fish production in Port Harcourt, Nigeria. *I.J.S.N*. (1(1):34-37.

Debnath, S. 2009. Fishing business for sustainable development current senario in Indo-Asia Retrieved on 14th May, 2012 from http//aquafind.com/articles/Indo-Asia-Fishing-business php.

Deekay, S.N., Abowei, J.F.N. and Alfred-Ockiya, J.F. 2010. Seasonal variation of some physical and chemical parameters of Lubara Creek, Ogoni Landl, Niger Delta, Nigeria, *Research. J. Environmental and Earth Sci*. 2(4): 207-215.

Dike,N.I, Oniye,S.J, Ajibola V.O and Ezealor, A.U. 2010. Nitrate and phosphate Levels in River.Jakara,Kano State,*Nigeria. Science World Journal* .Vol 5 (3) 23-27.

Dimowo, Benjamin Onozeyi. 2013. Monthly spatial occurrence of phytoplankton and zooplankton in River Ogun, Abeokuta, Ogun State, Southwest *Nigeria International Journal of Fisheries and Aquaculture* Vol. 5(8),193-203. ©2013Academic Journals http://www.academicjournals.org/IJFA

Dinar. A, Seidl.P, Olem.H, Jorden, Dada. A, and Johnson.R. 2005. Restoring and protecting the world’s lakes and reservoirs, *World Bank Technical Paper*. No 289.The World Bank. Washington D.C, page 85.

Donner, J and Adeniji, H.A. 1977. Annual succession of plankton rotifers in Kainji Lake. Nigeria. *Internationale Revue de Hydrologie* 62(1):109-132.

Don-pedro, K.N., Oyewole, E.O and Otitiloju A.A. 2004. Trend of heavy metal concentration in Lagos Lagoon ecosystem, Nigeria. *West African Journal of Applied Ecology* 5:103-144.

Edmonson, W.T. 1959. Rotifera. *Fresh water Biology*.2nd ed. Edmonson, W.T. (Ed.) 421-494.

Edmunds, J. 1978. Sea *shells and other Molluscs found on West African coast and Estuaries,* Accra, Ghana University Press.146pp.

Edoghotu, A. J., George, U. U. and Hart, A. I. 2016. The Ichthyofauna and physico-chemical properties of Kugbo Creek in the Niger Delta, Nigeria. *New York Science Journal* 9(4) 65-74.

Edokpayi, C. A, Okeniyi, J.C, Ogbeibu, A.E, and Osimen, E.C. 2001.The effect of human on the Macrobenthic invertebrates of Ibiekuma stream,Ekpoma,Nigeria.*Biosci.Res Common*. 12:79-87.

Edward, J.B and Ugwumba, A.A.A. 2010. Physico-chemical parameters and Plankton community of Egbe Reservoir, Ekiti State, *Nigeria.Journal of Biological Science* 2 (5) 356-367.

_________, and________, 2011. Macroinvertebrate fauna of a Tropical Southern Reservoir, Ekiti State, Nigeria. *Continental J. Biological Science* 4(1):30-40.

Egborge, A.B. 1970. The Chemical Hydro biological studies on Ibiekuma River at Ekpoma, Southern Nigeria After impoundment: the fauna characteristic *African Journal of Science and Techn*. 2.72-81.

Egborge, A.B.M. 1977. The seasonal variation and distribution of phytoplankton of the lake Asejire. A new impoundment in Nigeria: *Proceedings of International conference on Kainji Lake. Universityof Ife.* The Ecology of Lake Kainji. University of Ife, Ile-Ife Nigeria.136-145

_______, 1990. The composition, seasonal variation and distribution of zooplankton in Lake Asejire, Nigeria. *La Revue de Zoologic Africaine*Vol.'95. FASC. (1-1981). 137-165.

_______, 1994a. Salinity and the distribution of rotifers in the lagos harbour - badagry creek system, Nigeria. *Hydrobiologia*, 272: 95-104.

________, and Chigbu, P. 1988. The rotifers of Ikpoba River, Bendel State *The Nigerian Field* 53:117-132.

Egonmwan, R.I. 2008. The ecology and habits of *Tympanotonus fuscatus* var. *radula* (L.) (Prosobranchia: Potamididae). *J. Boil. Sci.,* 8: 186-190.

Ehinmore, O.M. 2007. Migration and fishing among the Ilaje people of Coastal Yoruba Land During the 20th Century IRORO-*Journal of Arts.* 12(1,2),241-251.

Elder J.F. 1988. Metal Biochemistry in surface water systems. A review of principle and concepts .United States Geological Survey Circular 1013.

Emere, M.C. and Nasiru, C. E. 2007. Macro-invertebrates as indicators of the water quality of an urbanized stream Kaduna Nigeria. *Journal of Fisheries International* 2(2): 152-157.

Eruola, A.O., Ojekunle, ZO; Amori, A.A; Awomeso, J.A; Amole O.E; and Anthony, D.E. 2015. Assessment of nutrient concentration in Sokori River, Southwest Nigeria. *J Appl. Sci. Environ. Manage*. Vol. 19 (3) 447 - 450

Esenowo, I. K. 2013. Physico-chemical characteristics, plankton, macrobenthos and fish fauna of Majidun River, Lagos state, Nigeria. Ph.D. Thesis University of Ibadan.

________, and Ugwunba A.A.A. 2010. Composition and abundance of macrobenthos in Majidun River Ikorodu Lagos State. Nigeria. *Research Journals of Biological Science* 5(8): 556-560

_________, Ugwumba, A.O and Ugwunba A.A.A. 2010. Composition and abundance of macrobenthos in Majidun River Ikorodu Lagos State. Nigeria. *Research Journals of Biological Science* 5(8): 556-560.

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* www.iiste.org Vol.3, No.11:78-82.

______, ______, Alade, A.O., and Adeyemi, J.A. 2013. Spatio-temporal distribution to phytoplankton in the industrial area of Calabar River, Nigeria. *Advances in Environmental Biology*, 7(3): 466-470.

Ezekiel, E.N, Ogamba, E.N, and Abowei, J.F.N. 2011. The zooplankton Species Composition and Abundance in Sombreiro River, Niger Delta, Nigeria. *Asian J. Agric. Sci.* 3(3):200- 204.

Ezeribe, A.I, Oshieke, K.C, and Jauro, A. 2012. Physico-chemical properties of well water samples from some villages in Nigeria with cases of stained and mottle teeth. *Sci. World J*. 7 (1); 43-54.

Fagade S.O. and Olaniyan, C.I.O. 1972. The biology of the West Africa shad *Ethmalosa fimbriata* (Bow fish) in the Lagos Lagoon. *Nigeria Journal of Fish Biology* 4: 519-534

________, and________, 1974. Seasonal distribution of the fish fauna in Lagos Lagoon.*Bull Institution for Africa Noire Series A* 36:245-252.

Fakayode, S.O. 2005. Impact assessment of industrial effluent on water quality of the receiving Alara stream in Ibadan, Nigeria, *Journal of AJEAM-RAGEE*.10:1-13.

Faith, D.P., and Walker, P.A. 1996. Environmental diversity: on the best-possible use of surrogate data for assessing the relative biodiversity of sets of areas. *Biodiversity and Conservation* 5, 399-415.

Falaye, A.E. Ajani, E.K. Kareem, O.K., and Olanrewaju, A.N. 2015. Assessment of ichthyofaunal assemblage of Erelu Reservoir, Oyo, Nigeria. *Ecologia*, 5: 43-53.

Fapohunda, O.O., and Godstates, R. 2007. Biometry and composition of fish species in Owena Reservoir, Ondo State, Nigeria. *Journal Central European Agriculture* Vol 8, No 1: 99-104.

Federal Department of Fisheries. 2003. Presentation on the fisheries sub-sector at the Presidential Forum Lagos, *Fisheries Society of Nigeria*.34-56.

________, 2007. *Fisheries Statistics of Nigeria*. Federal Department of Fisheries Area11, Garki, Abuja, FCT, Nigeria, Fourth Edition.

Food and Agriculture Organization (FAO). 1981. Methods of collection and analyzing size and age data for fish stock assessment.*FAO Fish Circular* 736:1-100.

Fonge, B.A, Tening, A.S, Egbe, A.E, Awo, E.M, Focho, D.A Oben, P.M, Asongwe G.A, and Zoneziwoh, R.M. 2011. Fish (*Arius heudelotii valenciennes* 1840) as bio-indicator of heavy metals in Douls Estuary of Cameroon.*Afr.J.Biotechnol*.10 (73) 16581-16588.

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

Gaur, V.K., Gupta, S.K., Pandey, S.D., Gopal, K., and Misra, V. 2005. Distribution of Heavy metals in sediment and water of river Gomti. *Environ Monit Assess*. 102 (1-3):419-33.

George, A.D.I., Abowei, J.F.N., and Daka, E.R. 2009. Benthic macro-invertebrate fauna and physico-chemical parameters in Okpoka Creek sediments Niger Delta, Nigeria. *Int.J. Anim. Vet.Adv*.1:59-65.

Gietema, B. 1992. Fish farm (fish farming) in ponds and Integrated farming Abeokuta Gbemi Sodipo Press Ltd

Goering, P.L, Waalkes, M.P and Klaassen, C.D. 1994. Toxicology of metals. In zinc supplement overdose can have toxic effects. *Haematol/Oncol*.24:528-584.

Goldman, C.E and Hornes, A.J. 1983. Limnology, New Yolk Mc Graw-Hill Book Company.

Golterman, R I, Clymo, R.S. and Ohnstad, M.A.M. 1978. *Methods for physical and chemical analysis of freshwater.* IBP Handbook No.8.Oxford: Blackwell Scientific Publication.

Goodherham, J and Tsyrlin, E. 2002. *The water bug book*: *a guide to the freshwater macroinvertebrates of temperate Australia*. Collings wood; Victoria: CSIRO Publishing: Australia.

Green, J. 1960. Zooplankton of the River Sokoto; the Rotifera. *Proc .Zool .Soc. Lond.* 135:491-523.

Gundaker, C. 2000. Comparison of heavy metals bio-accumulations in fresh water molluscs of urban river habitat in Vienna.*Environ.Poll*.110; 61-71.

Gupta, S.K., and Gupta, R.C. 2006. *General and applied Ichthyology* (f*ish and fisheries*).New Delhi: S. Chand and Company Limited. 1130p.

Guzkowska, M.A.J and Gasse, F. 1990. Diatoms Indications of water in some English urban lakes. *Freshwaters Biology*. 23:233-250.

Halliwell, D.J., McKelvie, I.D., Hart B.T. and Dunhill, R.H. 1996. Separation and detection of condensedpPhosphates in waste waters by Ion chromatography coupled with flow Injection, *Analyst*, 121, 1089-1093.

Hammer, O and Harper, D.A.T. 2005. PAST: Palaeontogical statistics software packages for education and data analysis *palaeontologia electronic*, 4(1):9

Hamor, T. and Philip-Howard, K. 1985. Water quality measurement in the Niger Delta Area.: The managrove ecosystem of the Niger Delta.B.H.R. Wilcox, and C.B. Powell, (Eds), Publications Committee University of Port Harcourt, 24-25.

Harrison, I.J and Stiassny. M.I.J. 1999. The quiet crisis missing in action:.*Extinctions in Near Time*: Causes, contexts and consequences. R.D.E MacPhee (ed) New York Plenum Press,,271-331.

Hartman, K.J, Kaller, M.D; Howell, J.W and Sweka, J.A. 2004. How much valley fills influences head water,Stream? Proceedings of the 2004 National Meeting of the American Society of Mining and Reclamation and the 25th West Varginia Surface more Drainage Task Force.April 18-24, 2004.822-846.

Heesen, D.O., Faafeng, B.A., Anders, T. 1995. Replacement of herbivore zooplankton species along gradients of ecosystem productivity and fish predation pressure. *Can. J. Fish. Aquat. Sci., 52*: 733–742.

Herschy, R.W. 1999. *Hydrometry principles and practices* 2nd Edn.John Wiley and Sons. Chichester international joint Commission (I.Y.C). 1977. New and revised specific water quality objectives Vol.41 Great Llake Water Quality Board Report.

Holme, N. A and McIntyre, A.D. 1984. *Methods for the study of Marine benthos.* Blackwell Scientific Pub. Huet, M. 1972. *Textbook of fish culture breeding and cultivation of fish* (Norwich) Ltd.Norwich, 311p.

Huet, M 1972. *Textbook of fish culture breeding and cultivation of fish* (Norwich) Ltd.Norwich, 311p.

Ibiebele, D.D., Powell, C.B. Shou, P.M., Murday, M., and Selema,M.D. 1983. Establishment of baseline data for complete monitoring of petroleum related aquatic pollution in Nigeria. *Proceeding of the Seminar on, The Petroleum Industry and the Nigerian Environment*, Port Harcourt. NNPC Publication, pp: 159-164.

Ibrahim, S. 2009. A survey of zooplankton diversity of challawa River, Kano and evaluation of some of its physico-chemical conditions; *Bayero J. Pure Appl. Sci*. 2(1):19–26.

Ideriah, T. J., David-Omiema K.1, and Ogbonna, D. N. 2012. Distribution of heavy metals in water and sediment along abonnema Shoreline, Nigeria, *Resources and Environment*, 2 (1): 33-40

Idodo-Umeh, G. 2003. *Freshwater fishes of Nigeria* (t*axonomy, ecological notes, diets and utilization*).Benin City: Idodo-Umeh Publ. Ltd..

Idowu, E.G. and Ugwumba, A.A.A. 2005. Physical, chemical and benthic fauna characteristics of a southern Nigerian reservoir. *The Zoologist*, 3: 15-25.

Ikenweiwe, N.B and Otubusin, S.O. 2005. An evaluation of the pelagic primary productivity and potential fish yield of Oyan Lake, Southwestern, Nigeria. The *Zoologist*, 3:46-57.

Ikhuorial, S. O., Oronsaye, C.G. and Adebanjo, I.A. 2015. Zooplankton communities of the River Ossiomo, Ologbo, Niger Delta, Nigeria. *Animal Research International* 12(3): 2249-2259

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

Ikusemiju, K. 1981. The Hydrology and fishes of the Lekki Lagoon, Nigeria. *Nig. J. Nat. Sci.*, 3(1-2):135-146.

Imevbore, A.M.A. 1965. A Preliminary checklist of the planktonic organisms of Eleyele Reservoir, Ibadan, Nigeria. *Journal of West African Science* 10:56-60.

Imoobe, T.O.T and Egborge, A.B.M. 1997. The composition, distribution and seasonal variation of Crustacea in Jamieson River, Southwest Nigeria. *Tropical Freshwater Biology* 6:49-63.

_______, 2011. Diversity and seasonal variation of zooplankton in Okhuo River,a Tropical Forest River in Edo State, Nigeria.*Centrepoint Journal (Science Edition*) Vol.17, No.1:Page37-51.

Ipinmoroti, M.O. 2013. Icthyofauna diversity of Lake Asejire: Ecological implications. *International Journal of Fisheries and Aquaculture* Vol 5 (10) pp. 248-252.

Ita, E. O. and Balogun, J. K. 1983. *A report of fishing survey of Oguta Lake, Imo State*. A report prepared for the Anambra-Imo River Basin Development Authority 37p.

_____, 1993. Inland fishery resources of Nigeria.*CIFA Occasional paper* No 20.F.A.O pg. 120

Jackson, L. S., Morris,G. P.and Smith, P.G.1989. *Environmental health,* London Butterworth, London, 961 pp.

Jamiu, D.M. and Ayinla, O.A. 2003. Potential for the development of aquaculture in Africa. *NAGA* 693: 9-13.

Jeje, C.Y. and Fernando, C.H. 1986. *A practical guide to the identification of Nigeria Zooplankton* (Cladocera,Copepoda and Rotifera) New Bussa: KLRI.

_______ and ______, 1992. *A practical guide to the identification of Nigerian*

Jens, S., Per, L., Rutger, R., Per, J., Mats, O. and Dag, M. 2000. Eutrophication and contaminants in aquatic Ecosystems. *Ambio;* 29(4-5): 184-194.

Jokela, J. 2010. *Cause for concern: silent loss of freshwater diversity*.Eawag. News swiss Federal Institute of Aquatic Science and Technology.

Kara, Y., Kara. I and Basaran, D. 2004. Investigation of some physical and chemical parameters of water in the Lake Isykli in Denizil, Yurkey. *International Journal Agriculture and Biol.* 6(2):275-277.

Khan, M.A and Ejike, C. 1984. Limnology and plankton periodicity of Jos plateau water reservoir, Nigeria, *West Africa.Hydrobiologia*, 114,189-199.

King, R.P, and Jonathan, G.E. 2003. *Aquatic environmental perturbations and monitoring. African Experience,*

Kitto, R.1996. *Composting the Organic Natural Way*. Pub. By Thorsons, 1988, ISBN- 0-7225-1588.

Knobelock, L., Salna, B., Hogan, A., Postle, J. and Anderson, H. 2000. Blue babies and nitrate-contaminated well water. *Environ Health Perspective*, 108, 675-678.

Kolo, A.I. 1996. The Assessment of physico-chemical parameters of Shiroro Lake and its major tributries. *Proceedings of 1996 FISON Conference*. pp 260-268.

Kumar, B.M. 1990. Macrobenthos in relation to sediment characteristics of Near Shore waters of Chtrapur, West Coast of India receiving industrial effluents.*Asian Fisheries Science* 17:21-28.

Kutikova, L.A. 2002. Rotifera. In: Fernando CH (ed.), A guide to tropical freshwater Zooplankton: Identification, ecology and impact on fisheries.London Leiden Backhuys Publishers,pp. 23-68.

Ladipo, M.K, Ajibola, V.O, Oniye, S.J. 2011. Seasonal variations in physicochemical properties of water in selected locations of the Lagos Lagoon. *Sci.World J.* 6 (4):1597-6343.

Landres, P.B., Verner, J., and Thomas, J.W. 1988. Critique of vertebrate indicator species. *Conservation Biology* 2, 316-328.

Lawson, E.O. 2011. Physico-chemical parameters and heavy metal content of water from the mangrove swamps of Lagos Lagoon, Lagos Nigeria..*Advances in Biological Research* 5(1):8-21.

Leman, M. 1985. Marine biology environment, diversity and ecology. California: The Beryamin/Cummings Publishing Company, Inc.

Lenat, D.R., Smock, L.A and Penrose, D.L. 1980. Use of Benthic macro-invertebrates as indicators of environmental quality. *Biological monitoring for environmental effects* L.W.Douglass, (Ed). Lexington Books, Toronto. 97-114.

Lovell, R.T. 1989. *Nutrition and feeding of fish*.Nostrand, Reinhold, New-York.

Lydeard, C., Cowies, R.H, Ponder W.F, Bogan, A.E and Bouchet, P. 2004. The global decline of Non marine mollusks, *Bioscience*, 54:321-330.

Macan, T.T. 1959. A guide to freshwater invertebrate animals.London: Longman Group.

Mahre, N.Y, Moses, E.A., and Ogugbuaja V.O. 2007. Pollution Indicators in River Kaduna, Kaduna State, Nigeria.*Trends in Applied Science Research*,2:304-311.

Mairs D.F. 1966. A total alkalinity atlas for Maine Lake waters.*Limnology and Oceanography* 11:68-72.

Mandaville, S.M. 2002. Benthic macroinvertebrate in *Freshwater-taxa tolerance values metrics and protocols, project* H-1-(Nova Scotia:Soil & Water Conservation Society of Metro Halifax).

Mandu Essien-Ibok and Imaobong, E. 2015. Physico-chemical factors influencing zooplankton community structure of a tropical river, Niger Delta, Nigeria *Journal of Environment and Earth Science.*Vol.5, 17-22.

Manly, F.J. 1986. *Multivariate statistical methods: a primer.* London Chapman and Hall, London,

Mason, C.F. 1991. *Biology of fresh water pollution*.2nd ed.Essex longman Scientific and Technical.

Matthews-Amune, O.C. Macan, T., and Kakulu, S. 2012. Physico-chemical parameters and heavy metals in River Pompom in Okehi Local Government Area of Kogi State, Nigeria *International Research Journal of Biotechnology* (ISSN: 2141-5153) Vol.3(8) pp.134-40, Available online http://www.interesjournals.org/IRJOB

Mathivanan, V., Vijayan, P., Sabhanayakam S. and Jeyachitra O. 2007. An assessment of plankton population of Cauvery River with Reference to Polution. *Journal of Environmental Biology* 28(2) 523-526.

Meffe, G.K.,and Carroll, C.R., 1997. Principles of conservation biology, 2nd Ed. Sinauer Associates Sunderland, MA.

Meria, E. 1991. *Metals and their compounds in the environment occurrence, analysis and biological relevance* UCH,Wunkeim-New-York- Basel: Cambridge.

Meybeck, M, Friedrich, A, Thomas, R and Chpman,D. 1992. Rivers in water qulity assessment:.a guide to use of biota, sediments and water in environmental monitoring Chapman D, Ed Chapam and Hall. 23(9) 3-16pp.

Michaloudi, E., and Kostecka, M. 2004. Zooplankton of Lake Koroneia (Macedonia Greece). *Biologia (Bratislava), 59*, 2: 165-172.

Miserendino, M.L., and Pizzolon. L.A. 1999. Rapid assessment of river water Quality using macro-invertebrates: a family level biotic index for the Patagonia-Andean zone.*Acta limnol.Brasitrensia* 11:137-148.

Miller, J.G. 2005. The flow of energy primary production to higher trophic levels Retrieved Jan.14.2012 from http//www//imno.feien.edu.up/research/rochabst. Html.

Mohammad, M.A and Saminu M.Y.2012. A water quality and phytoplankton of Salanta River Kano, Nigeria. *Journal of Biological Science and Bioconservation* Vol 4: 65-70.

Monteiro, M.I.C., Ferreira F.N., De Oliveira, N.M.M and Ávila A.K. 2003. Simplified Version of Sodium Salicylate Method for Analysis of Nitrate in Drinking Waters, *Analytica Chimica Acta*, 47**7**, 125-129.

Moore, J.W. and E.A. Moore. 1976. *Environmental chemistry*. London Academic Press, 360-363 (Cited in) Odokuma, L.O. and G.C. Okpokwasillii, 1996. Seasonal influence on the organic pollution monitoring of the New Calabar River. Niger. *Environ. Monitor. Assess*., 5: 1-14.

Mustapha, M.K. 2000. Species composition and abundance in a temporary pond in Ilorin, Kwara State, Nigeria.*Nig. J.Pure and Appl.Sci.* Vol, 15.1065-1071.

________, and Omotosho, J .S. 2005. An Assessment of the physico-chemical properties of Moro Lake; *Afr. J. Appl. Zool. Environ. Biol.* 7: 73–77.

Needham, J.G and Needham, P.R. 1975. *A guide to the study of freshwater Biology.* san Francisco: Holden Day Publi.

National Environmental Standards and Regulation Enforcement Agency (NESREA). 2011. National Environmental (Surface and Groundwater Quality Control) Regulations. *Federal Rebulic of Nigeria Office Gazette* No.49, Vol 98, Government Notice No 136.The Federal Government Printer, Lagos, Nigeria. FGP 71/72011/400 (OL46).

NIWA, 1998.National Inland Waterways Authority, Regulation for Dues, Rates and Charges (TARIFF). In Accordance with Establishment Decree NO.13 of 1997.

Nkwoji, J.A, Onyema, I.C, and Igbo, J. K. 2010. Wet season spatial occurrence of phytoplankton and zooplankton in Lagos Lagoon,*Nigeria. Sci. World J.* 5(2). ISSN 1597-6343.

______, Yakub, A., Ajani, G. Z., Balogun K. J., Rnner, K. O., Igbo, J. K., Ariyo, A. A., and Bello, B. O. 2010. Seasonal variations in the water chemistry and Benthic macro invertebrates of a South Western Lagos, Lagos Nigeria. *Journal of American Science* 6: (3) 85-92.

Nwadiaro, C.S.1987. The longitudinal distribution of macroinvertebrates and fish in the lower Niger Delta River (Sombreiro River) in Nigeria. *J. Aquat. Sci*., 7(1): 18-25.

Nwankwo, D.I. 1986. Phytoplankton of a sewage disposal site in Lagos Lagoon, Nigerian *Journal of Biological Sciences* 1(2) 89-96.

______, 1995. Euglenoids of some polluted storm-waters channels in Lagos, *Nigeria Tropical Freshwater Biology* 4:29-39.

______, and Amuda S.A. 2003. Epiphytic diatoms on three flouting aquatic marcophytes in a polluted South-West Nigerian Greek. *International Journal of Ecology and Environmental Sciences* 19:10-10.

______, Chukwu.A and Amuda S.A. 2003. Epiphytic diatoms on three flouting aquatic marcophytes in a polluted South-West Nigerian Greek. *International Journal of Ecology and Environmental Sciences* 19:10-10.

______, 2004. *A practical guide to the study of algae in Nigeria*. Lagos JAS Publishers, Pp 90.

Nyholm, N.E. 1995. Monitoring of terrestrial environmental metal pollution by means of free- living insectivorous birds.85:343-351.

Obasohan, E.E and Oronsaye, J.A.O. 2006. Biodiversity and sustainability of fresh water fishes of Nigeria.*Proceeding of the 20th Annual Conference of the Fisheries Society of Nigeria,* Port Harcourt 14th -18th Nov, 2005, Deckai,S.N(Eds). 230-237.

Oben B.O. 2000. Limnological assessment of the impact of Agricultural and domestic effluent of three man–made lakes in Ibadan, Nigeria Ph.D. thesis.University of Ibadan.

Ode, P.R, Rehn A.C and May J.T. 2005. A qualitative tool for assessing the integrity of Southern Coastal California stream.*Environ.Mgmt* 35:493-504.

Odiete, W.O. 1999. *Environmental physiology of animals and pollution*. Lagos Diversified Resources Ltd.

Odukuma, L.O. and Okpokwosili. G.C. 1990. Seasonal influence on the organic pollution monitoring of the New Calabar River. *Nig. Environ. Monitor. Assess*., 5:1-14.

Odun, E.P. 1971. *Fundamentals of Ecology* 3rd Edn, W.B Saundaers, Philadelphia.574p.

Odun, O. 1995. Fish distribution in Ethiope River Southern Nigeria.*Tropical freshwater biology*.4:53-64.

Oduwole, G.A. 1997. Indices of pollution in Ogunpa and Ona Rrivers,Ibadan physico-chemical trace metal and plankton studies Ph.D thesis Department of Zoology , University of Ibadan 152pp.

Offem, B. Y. and Akegbejo-Samsons Y. 2009. Fish composition and abundance in the wetlands of Cross Rivers, *Nigeria Aqual Ecol*.2 (3):23-34.

Ogbeibu, A.E. 2001. Distribution density and diversity of Dipterans in a temporary pond in Okomu Forest Reservoir, Southern Nigeria. *J. Aqu.Sci*.16:43-52.

_______, and Egborge, A.B.M. 1995. Hydro biological studies of water bodies in the Okomu Forest Reserve (Sanctuary) in southern Nigeria: distribution and diversity of invertebrate fauna. *J.Tropical Freshwater, Biology* 4, 1-27.

_______, and Obanor, B.J. 2002. Ecological Impact of river impoundment using benthic macro-invertebrates as indicator. *Water Research* 36:2427-2436.

_______, and R. Victor. 1995. Hydrological studies of water bodies in the Okomu Forest Reserves (Santuary) in Southern Nigeria: 2 physico-chemical hydrology. *Trop. Freshwater Biol*.,4: 83-100.

Ogbuagu, D.H., Chukwuocha, N.A.C, Okoli, C.G and Njoku-Tony, R.F. 2011.Physico-chemical gradients and *in situ* yields in pelagia primary production of the middle reaches of Imo River in Etche, Southern-eastern,Nigeria.*Journal of Ecology and the Natural Environment*.3(2):47-53.

_______, and Ayoade, A.A. Seasonal dynamics in plankton abundance and diversity of a freshwater body in Etche, Nigeria.*Environment and Natural Resources Research* Vol. 2, No. 2; 48-59.

_______, 2014. Physico-chemical characteristics, plankton and macrobenthos of Imo River in Etche Local Government Area, River State, Nigeria. Ph.D Thesis, University of Ibadan. pp115-122.

Ogunwenmo, C. A and Osuala, I. A. 2004. Physico-chemical parameters and macrobenthos of an estuarine creek and an artificial pond in Lagos, Southwestern, Nigeria. *Acta Satech* 1(2):128-132.

Oke, O.O. 1990. Limnology and macrobenthos of Owena Reservoir Nigeria.M.phil thesis, Zoology Department, University of Ibadan.

______, 1998. Plankton diversity, abundance and productivity in the Owena Reservoir, Southwest Nigeria.Ph.D.Thesis University of Ibadan.

Oladimeji, A.A and Wade, A. 1994. Effects of effluents from sewage treatment plant on Aquatic Organism. *Water, Air and Soil Pollution* 23.3:309-316.

Olaifa, F.O and Leilei, K.E. 2007. A study of the plankton and Benthic of Ekole River in Bayelsa State, Nigeria. *Asset International Journal.Vol* 7(1):144-150.

Olajire, A.A., and Imeokparia, F.E. 2000. A study of the water quality of the Osun River: Metal monitoring and geochemistry.*Bulletin of the Chemical Society Ethiopian,* 14(1): 1-8.

Olaleye V.F. and Adedeji , A.A. 2005. Water and planktonic quality of a palm oil effluent impacted river in Ondo State, Nigeria. *International Journal of Zoological Research.* 1: 15-20.

Olaniran, T.S. 2003. Fishing activities and fish species diversity assessment in Eleyele Lake, Ibadan, Nigeria, Nigeria *Journal of Livestock Extension* 2:72-74.

Olaniyan, C.I.O. 1957. The seasonal variation in plankton population in the Lagos Harbour Nigeria Ph.D thesis University of London.

Olaniyan, R.F. 2010. Physico-chemical characteristics and Phytoplankton flora of Owena Reservoir, Southwest, Nigeria. *African Journal of Medical Science,* 3(1): 6-10.

Olaosebikan, B.D and Raji, A. 1998. *Field guide to Nigeria freshwater fishes.* Federal College of freshwater fisheries Techn. New Bussa, Nigeria,.*Proceedings of the 20th Annual Conference of the Fisheries Society of Nigeria, Port Harcourt* 14th -18th Nov.2005. Ansa ,E.J., Anyanwu, P.E., Ayonadu,B.W., Eronde, E.S.,Deekae ,S.N (Eds) 423-428.

Olatunde, S.O. and Oladele, O. 2012. Determination of selected heavy metals in inland fresh water of lower River Niger drainage in North Central Nigeria *African Journal of Environmental Science and Technology* Vol. 6(10): 403-408.Available online at http://www.academicjournals.org/AJEST

Olawusi-peters, O.O, Ajibare, A.O and Ajetunmobi, O.A. 2015. Gillnet fishing in Igbokoda Coastline Area of Ondo State, Nigeria.*Nigeria Journal of Agriculture, Food and Environment* 11(1) 13-18.

Ololade, I. A., and Ajayi A. O. 2009. Contamination profile of major rivers along the Highways in Ondo State, Nigeria. *Journal of Toxicology and Environmental Health Sciences* Vol. 1(3):038-053,

Olomukoro, J.O. 2007. Salinity and Macrobenthic community structure in *Eichhrnia crassipes* of Warri River, Nigeria. *Journal of Biological Science* 7(2):309-314.

________, and Egborge, A. B. M. 2003. Hydro biological studies on Warri, River, Nigeria Part 1: The Composition, distribution and diversity of macrobenthic fauna. *Biose. Res. Commun.* 15: 279-296.

Olukunle, O. 2000. Homestead Pond Management. Ibadan by John Archers (Publishers) Ltd

Omaka, O.N. 2007. Phosphorus in the environment, effects of eutrophication, cycle, fractionation, determination and procedures for sampling and storage-a review, *Journal of Applied and Natural Sciences*, 1(1), 27-36.

______, Nwabue F.I, Itumoh, E.J, Orokke, E.C and Igwe, D.O. 2014. Physico-chemical parameters and nutrients variations of streams and rivers in Abakaliki Ebonyi State, Nigeria.*Global NEST Journal* .Vol.16, NO11: 114 -123.

Onyema, I.C. 2007. The phytoplankton composition abundance and temporal variation of a polluted estuarine Creek in Lagos, Nigeria. *Turkish Journal of Fisheries and Aquatic Science* 7:89-96.

______, and Nwankwo D. I. 2007. The epipelic assemblage of a polluted estuarine Creek in Lagos, Nigeria. *Pollution Research* 25(3): 459-468.

______, 2010. The phytoplankton composition abundance and temporal variation of a polluted estuarine Creek in Lagos, Nigeria. *Turkish Journal of Fisheries and Aquatic*

Science 7: 89-96.

______, and Popoola R.T. 2013. The physico-chemical characteristics, Chlorophylla levels and phytoplankton dynamics of the East Mole Area of the Lagos Harbour, Lagos. *Journal of Asian Science Research*, 3(10): 995-1010.

Osalor, P.O. 2011. *Fishing and Nigeria 2020 Goals* Retrieved on 15th May,2012 from http//ezinearticles.com/ Fishing and Nigerias-2020- Goals and id=3474882.

Oshisanya,K.I.,Unyimadu,J.P.,Shelle,R.O.D.,Nubi,A.O.,Ladigbolu,O.N.M., Olumodeji,O.O., Adeleye, A.O and Fashade, A.O. 2011. Seasonal variation of heavy metals in sediment and water of Lagos Lagoon, *Journal of American Science*,7(3) :384-387.

Ovie, S.I. 1993. Composition, Seasonal variation and Biomass Lagoon. *J. Tropical Freshwater Biology*.3:397-412.

_____, and Adeniji, R.A. 1993. Zooplankton and environmental characteristics of Shiroro Lake at the Extremes of Hydrological Cycle.*Hydrobiologia*. 286: 175-18

_____, 1995. Zooplankton species riches and Sorensons index of similarity for Asa Lake and some other freshwater ecosystem in Nigeria.*National Institute for Freshwater Fisheries: Annual Report*. Pp 57-62.

______, 1997. The Ecology and Culture of the zooplankton of Jebba Lake, Nigeria. Ph.D. Thesis, University of Benin, Benin City, Nigeria. 240pp.

______, and Adeniji, H.A. 1994. Further studies on the mass production zooplankton; water level and secchi disc manipulation and biomass estimates. *National Institute for Freshwater Fisheries Research Annual Report 1994*, Federal Ministry of Agriculture, Water Resources and Rural Development.

_______, Bwala R. L and Ajayi. O. 2011. A preliminary study on limnological stock assessment, productivity and potential fish yield of Omi Dam, Nigeria. *Africa Journal of Environment Science and Technology* Vol 5(11):956-963.

Palmer, C.M. 1969. A composite rating of algae tolerating organic pollution. *J. Phycol.* 5:78-82.

Pennak, R.W. 1978. *Freshwater invertebrates of the United States*. 2nd Edn. California, John Wiley and Sons.

Pertet, F.O, Aman, R and Devos, I. 1999. The impacts of pollution on aquatic living resources (with special reference to Kenya). *Proceedings of the 5th Conference on Oceanography Sea and Inland Fisheries,Mobasa Kenya.* 6-8 May, 1998, Ndoye M (Ed) 103-108.

Pinel-Alloul, B., Niyonsenga, T., Legendre, P. 1995. Spatial and environmental components of freshwater zooplankton structure. *Ecoscience*, 2: 1-19.

Pociecha, A. 2002. Impact of abiotic and biotic variables on dynamic and structure of zooplankton communityin dam reservoir (Dobczycki Dam reservoir, southern Poland)(in Polish). PhD thesis, Uniwersytet Łodzki,Łodź, 106 pp.

Prior, H. and Johnes, P.J. 2002. Regulation of surface water quality in a cretaceous chalk catchment, UK: an assessment of the relative importance of instream and wetland processes. *The Science of the Total Environment*, 282-283, 159-174.

Rabalais, N. 2002. Nitrogen in aquatic ecosystems. *Ambio*. 31,102-112

Ravera, O. 2000. Ecological monitoring for water body management proceedings of monitoring Taulor-made III. International Workshop on Information for Sustainable Water Management. 157-167p.

Reash, O 1986. Fecundity and trace metals content of Creek chubs from metals contained Stream.*Trans American Fisheries Society*.115:346-351.

Reed W., Benchand J., Hopson, A. J. Jennies, J. and Yaro, I. 1970. *Fish and fisheries of northern Nigeria*. Ministry of Agriculture, Northern Nigeria, Zaria 226p.

Reish, R. J. 1986. Fecundity and trace metals content of creek chubs from metals contaminated Stream. *Trans American Fisheries Society*. 115: 346 – 351

Riley, J.P. and R. Chester. 1971. *Introduction to marine chemistry*. London, New York London, New York Academic Press. 465.

Roland, E.U. 2010. An inventory of the Benthic Macrofauna of Epe Lagoon,South-West Nigeria. *Journal of Sci.Res.Dev*.Vol.12,161-171.

Romhaupt, K.O. 2000. Plankton population dynamics: food web interactions and abiotic constraints. *Freshwater Biology* 45: 105 - 109.

Rothrock J.A,.Barten P.K and Ingman G.L. 1998. Land use and aquatic biointegrity in the Blackfoot River water watershed, Montana. *J.Am.Wat Resour.Ass* 34:565-583.

Sawyer, C.N. 1966. Basic concept of *eutrophication Journal of Water Pollution Control Federal*. (WPCF), 38,727-744.

Segers, H. 1993. Rotifera in some lakes in the flood plain of the River Niger (Imo state, Nigeria). New species and other taxonomical considerations. *Hydrobiologia* 250: 39-61.

Shannon, C. 1948. A mathematical theory of communication. *Bell Systems Technol. J* 27:379-423.

Shreeder, G.I. 1975. Night time material balance for oxygen in fish ponds receiving organic waste. *Bamidgeh* 27:65-74.

Shrinivasa, R.B and Venkateswaralu, P. 2000. Physicochemical analysis of selected groundwater sample. *Indian J.Environ Prot.* 20(3):161.

Sikoki, F.D and Kolo, R.J. 1993. Perspectives in alter pollution and their Implications for Conservation of Aquatic Resources. *Proceedings of Conference on Nigeria Aquatic Resources Conservation. 185-187.*

_______, and Veen, J.V. 2004. Aspects of water quality and the potential for fish production of shiroro reservoir *Nigeria. Liv. Sys*. Dev., 2: 7-15.

_______, and Zabbey, N. 2006. Environmental gradients and Benthic community of the middle reaches of Imo River, South-Eastern Nigeria. *Environment and Ecology* 24.1:32-36.

Simmons J.A, Long, J.M and Ray, J.W 2004.What limits the productivity of acid mine drainage treatment ponds? *Mine water and the Environment*, 23:44-53.

Solomon. I.O. Richard, L.B., and Olarewaju,A. 2011. A preliminary study on limnological stock assessment, productivity and potential fish yield of Omi Dam, Nigeria. *Africa Journal of Environment Science and Technology* Vol 5(11), 956-963.

SON, 2007. *Nigerian standard for drinking water quality*. Standard Organisation of Nigeria. ICS 13.060.20.

Sotolu, A.O. 2011. Sustainanble fisheries management through efficient fisheries resources data statistics. *Journal of Fisheries and Aquatic Science.* 6:202-211.

Soyinka O.O. and Kassem, A.O. 2008. Seasonal variation in the distribution: fish species diversity of a tropical Lagoon in South-West Nigeria *Journal of Fisheries and Aquatic Science* 3(6): 375-383.

Sowumi, A.A. 2001. The hydrology of Ologe Lagoon Owo at Agbara,South west Nigeria.M.Phil.Thesis,Department of Zoology,University of Ibadan,Nigeria. 180pp.

Spaak, P and Bauchrowitz, M. 2010. Environmental influences and plankton dynamics, Eawag: *Swiss Federal Institute of Aquatic Science and Technology*,69e:25-27.

Steven,O.O.,and Itolima, O. 2009. Environmental aspects of dredging intra-coastal navigation channels in muddy coastlines: the case of Awoye, Ondo State,Nigeria.*Journal of Food Agriculture and Environment* Vol. 7(2):764-768.

Suski, C.D., Killen, S.S, Keiffer, J.D and Tufts, B.L. 2006. The Influence of environmental temperature and oxygen concentration on the recovery of largemouth bass from exercise implication for live-release angling tournaments.*J. Fish.Biology* 68:120–136.

Swingle, H.S. 1969. *Methods of analysis for waters organic matter and pond bottom soils used in fisheries research*. Auburn, Auburn University.

Syndeham, D.H.J. 1977. The qualitative composition and longitudinal zonation of the Fish fauna of River Ogun, Western Nigeria. *Rev. Zool.Afr*. 91.4:974-976.

Tabari S, Saravi SSS, Bandy, G.A, Dehghan, A.and Shokizadeh .M. 2010. Heavy metals (Zn, Pb, Cd and Cr) in fish water and sediment sampled from Southern Caspian Sea, Iran.*Tox. Ind. Health*. 26 (10):649-656.

Taylor, D. J., Green, N. P.O. and Stout, G.W. 1997. *Biological science* Cambridge. Cambridge University Press.

Temple, S.A., and Wines, J.A. 1989. Bird populations and environmental changes: can birds be bio-indicators. *American Birds* 43, 260-270.

Tomola, M.O. 2012. Financial predicament in the midst of abundant natural resources: a study of the fishing business in the coastal area of Ondo State, Nigeria. *International Business and Management* Vol5, No1: 113-119.

Tyokunbur, E.T, Okorie, T.G and Ugwunmba, O.A. 2002. Limnological assessment of the effects of effluents on Macro invertebrate fauna in Awba stream and reservoir, Ibadan, Nigeria. *The zoology* 1.2:59-69.

______, 2016. Bioaccumulation of heavy metals in the fish species *Sarotherodon melanotheron* from Alaro Stream Ecosystem in Ibadan. *New York Science Journal* 2016; 9(2):83-88.(online). http://www.sciencepub.net/newyork. 14. doi:10.7537/ marsnys 09021614.

Ude, E.F, Ugwu, L.L.C, and Mgbenka B.O. 2011. Evaluation of zooplankton diversity in Echara River, Nigeria. *Continental. J.Biol.Sci* 4(1)1-5.

Ugwu, A.I and Wakawa R.J. 2012. A study of seasonal physicochemical parameters in River Usma.*American Journal of Environmental Science*, 8(5),569-576.

Ugwumba A.A.A. 1990. Food and feeding habit of *Oreochromis niloticus*, *Sarotherodon melanotheron* and *Heterotis niloticus*. (Pieces Osteichthyes) in Awba Reservoir Ibadan. Ph.D Thesis, University of Ibadan, Ibadan.

Umeham, S.N. 1989. Some aspects of the physicochemical limnology of Lake Chad (Southern Sector) *J. Aquat. Sci.*, 4: 21-26.

Umeozor, O.C. 1995. Benthic fauna of new Calabar River, *Nigeria. Trop. Fresh. W. Biol.*, 4: 41-51.

United State Department of Agriculture (USDA)-1992. Agricultural wastes management building design handbook.Soil Conservation Service, Washington, D.C

Ushurhe, O. 2014. Assessment of heavy metals and the prevalence of water borne diseases in rural communities located along River Ase in southern Nigeria.

Journal of Environment and Earth Science Vol.4, No.7, 34-56.

Usoro, E. E.U., Thomas, H. and Victor. R .2013. Seasonal variations of physico- chemical parameters of water and sediments from Iko River, Nigeria. *Journal of Environment and Earth Science,* Vol 3.(8): 22-32.

Valavanidis, A. and Vlachogianni, T. 2010. Metal pollution in ecosystem snail: Ecotoxicology studies and risk assessment in the marine environment. *Science Advances on Environment, Toxicology and Ecotoxicology Issues*.1(2):34-54.

Verheust, L. 1997. Obtaining basic information for the enhancement of small water body fisheries. A regional project view point. Aquatic Resources Management Programme for Local Comities, ALCOM/ FAO, Havare, Zimbabwe, pp: 22.

Viarengo, V. 1995. Biochemical effects of trace metals. *Marine Pollution Bulletin,* 16 40:153-158.

Victor, R., and Ogbeibu, A.E. 1985. Macrobenthic invertebrates of a stream flowing through Farmlands in Southern Nigeria.*J.Environmental Pollution* (series A) 39:339-349. Wastes *Bamidgeh* 27: 65-74

______ and _____, 1986. Recolonisation of macrobenthic invertebrates in a Nigerian stream after pesticide treatment and association distruption. *J. Environmental Pollution*. (Series A) 41.125-137.

Voshell, J., and Reese, J. 2002. *A Guide to common freshwater invertebrates of North America.* Blacksburg (VA). The MeDonald and Wood ward Publishing Company. 442pp.

Walker, P. 1996. Sensitive skates or resilient rays? Spatial and temporal shifts in ray species composition in the central and northwester North Sea. ICES, C.M. 1996/Mini: 4.

Welman, J.B. 1948. *Preliminary survey of the freshwater fisheries of Nigeria*. Lagos The Government Press,. Pp 5-40.

Wetzel, R.G. 1998. Encyclopedia on environmental biology.Vol.2: F-N: 433-441.

______, 2001. *Limnology lake and river ecosystems* (3rd Edition). California Academic Press; San Diego.

Weyer, P. 2001. Municipal drinking water nitrate level and cancer risk in older women: the Iowa women's health study. *Epidemolog.* 12: 327-338.

White, E. 1966. *The first scientific report of the Kainji Biological Research Team*.Ife: University of Ife.

Whitton, B.A and Patts, M. 2000. The ecology of Cyanobacteria. Netherlands. Kluwer Academic Publishers.

Wilcove, D.S. 1989. Protecting biodiversity in multiple-use lands: lessons from the US Forest Service. *TREE* 4: 385-388.

William A.B., Ajuonu, N., Abohweyere P. O. and Olawusi–Peters, O.O. 2009. Macrobenthic fauna of snake island area of Lagos Lagoon Nigeria. *Research Journal of Biological Science* 4(3): 272-276.

Withers, P.J.A., and Lord, E.I. 2002. Agricultural nutrients inputs to rivers and ground waters in the UK: Policy, environmental management and research needs, *The Science of the Total Environment*, 282- 283, 9-24.

Wokoma, O.A.F. 2016. Zooplankton apecies composition and abundance in the brackish water axis of Sombreiro River, Niger Delta. *Applied Science Reports*, 15 (1): 31-34.

_____, Nwaogu, V.O., Chima, G.N. and Gbosidom, V.I. 2016. Phytoplankton species composition and abundance in the lower sombreiro River, Niger Delta, Nigeria. *Journal of Environmental Science, Computer Science and Engineering & Technology*.; Vol.5. No.2: 223-229.

Wolfe, A. H. and Patz, J. A. 2002. Reactive nitrogen and human health: Acute and long term implications *Ambio: A journal of the human environment*; 23 (2):120-125.

World Health Organization 1966. GEMS/WATER Operational Guide. Third Edition, World Health Organization Geneva.

________, 1993. Guildeline values for contaminants in water Guidelines for Drinking –water Quality.2nd Ed.Vol.1- Recmmendations 208pp.

________, 1998. Guidelines for drinking water quality, (W.H.O, Geneva, 1993).

________, 2010. *Guildlines for drinking water quality*.First Addendum to the Third Edition Volume 1 Recommendations, 491-493.

Woodworth, J.C and Pascoe V. 1982. Cadmuim toxicity to rainbow trout, Salmo gardneri R.A study of eggs and alevins.*Journal Fish.Biol*.21:47-57.

Yakubu, A.S, Sikoko, F.D, and Horsfall, Jr.M. 1998. An investigation into physicochemical condition and planktonic organisms of the lower reaches of the Nun River, *Nigeria Journal of Applied Science and Environmental management*.1:38-42.

______, Ajani, G.E. and Oshisanya, K.I. 2010. Impacts of Shrimp farming on coastal ecosystems: The need for Eco-friendly Approach in Nigeria. *Book of Abstracts of the papers presented at the 6th Annual Conference of the Zoological Society of Nigeria,* Ibadan 1st -5th March 2010.71p.

______, 2004. Assessment of water quality and plankton of effluents receiving Awba stream and reservoir in Ibadan, Nigeria.*African journal of Applied Zoology and Environmental Biology* 6.107-110.

Yemi, A.D. 2008. Urban agriculture, water, local reconomies in Igbokoda, Ondo State. *African Journal of Food Agriculture Nutrition and Development* Vol 8, No 1: 48-62.

Zabbey, N. 2006. Environmental gradients and benthic community of the middle reaches of Imo River, South-Eastern Nigeria. *Environment and Ecology* 24.1:32-36.

Zanin L., Robertson W.D., Ptacek C.J. and Schiff S.L. 1998. Phosphorus characterization in sediments impacted by septic effluent at four sites in Central Canada. *Journal of Contaminant Hydrolog* , 33:405-429.

Zatar, N.A., Abu-Eid, M.A. and Eid, A.F. 1999. Spectrophotometric Determination of Nitrite and Nitrate Using Phosphomolybdenum Blue Complex, *Talanta,* 50: 819-826.

APPENDIX 1: Guideline Values for Water Quality and Trace Metals in Drinking Water and National Guideline Values for Aquatic life

Quality characteristics	**NESREA (2011)**	**WHO Values (1966)**	**WHO (1998)**
pH	6.5-8.5	6.5-9.0	6.5-8.5
Temperature		30^oC-32^oC	
Conductivity	<1000µs/cm		
Transparency	NS		150-75
Alkalinity	NS		500mg/L
Total suspended solids	0.25mg/L	3omg/L	
Total Dissolved Demand	NS		
Dissolved oxygen	Not <6.0 mg/L	75mg/L	15mg/L
Biochemical oxygen Demand	3.0mg/L	<40	10mg/L
Nitrate	9.1mg/L		10mg/L
Phosphate	3.5mg/L		400mg/L
Sulphate	NS		
Sodium	120.0		
Potassium	50		0.3mg/L
Magnessium	40	0.10-0.50mg/l	0.3mg/L

APPENDIX 2: Numeric Abundance of Phytoplankton Family in Igbokoda River from June, 2014 to November, 2015

PHYTOPLANKTON FAMILY	SPECIES	UPSTREAM	RIVERINE	DOWNSTREAM	TOTAL
Bacillariophyceae	*Asterionella formosa*	33	86	63	182
	Cymbella gracilis	26	56	42	124
	Eunotia tautoniensis	45	59	28	132
	Fragilaria construens	34	109	49	192
	Melosira distans var	31	49	35	115
	Navicula crucicula	16	115	89	220
	Nitzschia aciculris	20	77	70	167
	Scutonema crispum	27	66	84	177
	Stenopterobia intermedia Forma	46	74	58	178
	Tabellaria flocculosa	42	58	63	163
	TOTAL	**320**	**749**	**581**	**1650**
Chlorophyceae	*Actinastrum hantschii*	42	58	63	163
	Closterium abruptum. Var	42	58	63	163
	C. ebroracense Turner	58	95	82	235
	C. dianae	35	51	49	135
	C. gracile	45	73	67	185
	C. incurvum	24	53	52	159
	C. kuetzingii	44	75	40	159
	C. lunula	40	52	28	120
	C. momiliferum.Ehrenb	40	52	28	120
	C. morus	39	36	45	120
	C. setaceum	49	62	79	190
	C. parvulum.var	27	52	45	124
	C. peracerosum.Gay	21	39	28	88
	C. pronum	25	43	43	111
	Chaetophora attenuate	24	58	34	116
	Draparnastrum glomerata	11	28	16	55
	Gonatozygon aculeatum	29	53	24	106
	G. ehrenbergii	22	72	47	141
	Micrasterias floridensis	22	72	47	141
	M. floridensis Salisbury	22	22	22	66
	M. fimbriata Raifa	29	81	37	147
	M. radiosa Var	20	60	32	112
	M. sol	19	37	27	83
	Tetraspora cylindrical	34	83	65	182

	Spirogyra setiformis	41	62	35	138
	Volvox aureus	40	21	49	110
	Xanthidium antilopaeum	24	53	48	125
	Zygnema sterile	39	48	55	142
	TOTAL	**907**	**1549**	**1250**	**3706**
Cyanophyceae	*Anabaena constricta*	32	95	69	196
	Aphanocapsa delilatissima	39	54	36	129
	A. pulchra	36	46	32	114
	Chrsococcus taricensis	30	43	38	111
	Lyngbya major Meneghini	30	30	25	85
	Gomphospharia lacustria	46	147	61	254
	Oscillatoria princeps	19	115	59	193
	O. princeps .vaucher	17	98	70	185
	Spirulina subsasa Oersted	25	31	39	95
	TOTAL	**274**	**659**	**429**	**1362**
Euglenophyceae	*Trachelomonas ensifera*	29	69	61	159
	T. gibberosa	31	64	57	152
	T. schauinsladii	22	41	44	107
	Phacus brevicauda	13	68	87	168
	Synura uvella	17	47	38	102
	TOTAL	**112**	**289**	**287**	**688**
	GRAND TOTAL	**1,613**	**3,246**	**2,547**	**7,406**

APPENDIX 3: Numeric Abundance of Zooplankton Family in Igbokoda River from June, 2014 to November, 2015

ZOOPLANKTON FAMILY	SPECIES	UPSTREAM	RIVERINE	DOWNSTREAM	TOTAL
Rotifera	*Ascomorpha* sp	30	50	73	153
	Asplanchna brightwelli	55	96	116	267
	A. girodideguerne	72	105	77	254
	A. herricki	37	71	63	171
	A. priondonta	44	73	88	205
	Branchionus bulla	71	83	79	233
	B. falcatus	61	79	86	226
	B. luna	55	60	83	198
	B quadridentatus	54	86	75	215
	Ceratotrocha cornigera	45	69	90	204
	Cephalodella parasitica	57	70	63	190
	Filinia longiseta	68	96	81	245
	F. opoliensis	56	61	65	182
	F. pejleri	48	55	68	171ee
	F. terminalis	41	48	74	163
	Gloetheca membranacea	43	39	57	139
	Horaella brehmi Donner	38	71	62	171
	Lecane tenuiseta	64	101	78	243
	L. bulla	47	62	85	194
	L.luna	55	77	87	219
	L. tudicola	58	76	78	212
	Lepadella patella	52	71	110	233
	Testudinella greeni kosti	54	101	96	251
	Trichocerca gracilis	58	99	89	246
	T .iernis	55	88	88	231
	T. musculus	56	78	64	198
	Rotaria execulis	47	74	80	201
	R. hepatica	32	83	86	201

	R. tridens	60	84	100	244
	R.neptunia	47	42	68	157
	Simocephalus sp	54	58	84	196
	TOTAL	**1614**	**2306**	**2493**	**6413**
Copepoda	Copepod larva	44	45	54	143
	Euclanis sp	47	42	68	157
	Eucyclops macrurus	48	113	105	266
	Pseudocalanus elongatus	60	98	103	261
	TOTAL	**44**	**45**	**54**	**143**
Cladocera	*Bosmina* sp	47	42	68	157
	Podon leucarti	48	113	105	266
	Ceriodaphinia cornuta	60	98	103	261
	Moina micrura	43	24	89	156
	TOTAL	**198**	**277**	**365**	**840**
	GRAND TOTAL	**1,856**	**2,628**	**2,912**	**7,396**

APPENDIX 4: Numeric Abundance of Macrobenthic Family in Igbokoda River from June, 2014 to November, 2015

PHYTOPLANKTON FAMILY	SPECIES	UPSTREAM	RIVERINE	DOWNSTREAM	TOTAL
Crustacea	*Nototropis swamidami*	40	20	28	88
	Iphinoe tripanosa	20	37	22	79
	TOTAL	**60**	**57**	**50**	**167**
Gastropoda	*Pachymelania aurita*	28	99	167	294
	P.fusca	100	71	42	213
	P.fusca.var.quard	89	37	22	148
	Tympanotomus fusca	89	53	40	182
	Melanoides tuberculata	89	53	40	182
	Lanistes varicus	60	40	16	116
	TOTAL	**455**	**353**	**327**	**1135**
Insecta	*Chironomus* . larvae	60	39	4	103
	Chaoborus .larvae	45	21	6	72
	Phrganeap.larvae *(caddis fly)*	56	32	7	95
	TOTAL	**161**	**92**	**17**	**270**
Oligochaeta	*Ophidonais serpentina*	34	31	22	87
	TOTAL	**34**	**31**	**22**	**87**
Polychaeta	*Arenicula maina*	36	41	28	105
	Eunice haressi	42	33	32	107
	Glycera capitata	64	65	68	197
	Glycera convolute	29	30	35	94
	Nereis diversicolor	34	34	34	102
	TOTAL	**205**	**203**	**197**	**605**
	GRAND TOTAL	**915**	**736**	**613**	**2,264**

Appendix 5: Average Monthly Values of Physico-chemical Parameters of Upstream Station Measured during the Study Period

Upstream station	Air temp (ºC)	Water temp (ºC)	Trans (m)	DO (mg/L)	BOD (mg/L)	pH	Cond (µs/cm)	Alk (mg/L)	Cl (mg/L)	TDS (mg/L	TS (mg/L)	NO_3 (mg/L)	SO_4 (mg/L)	PO_4 (mg/L)	Na (mg/L)	K (mg/L)	Mg (mg/L)	Ca (mg/L)	Sal ‰	Pb	Cr	Fe	Ni
5-Jun-2014	26	26	2	2.6	1.5	8.5	50	18	30	45	90	0.02	2	2.5	1.6	1.6	5	2	0	0	0	0.1	1
5-Jul-2014	25	25	3	3	1.6	8.5	65	18	30	30	80	0.01	2	2.1	1.2	1.2	4	2.8	0	0.01	0.01	0.3	0.1
5-Aug-2014	25	25	4	4	1.8	8	60	20	28	18	69	0.02	3	1.2	1.3	1.3	4	2.5	0	0.01	0	0.2	0.5
5-Sep-2014	25	25	7	3.5	1.5	7	18	21	24	17	55	0.01	2.3	1.5	1.2	1.2	2.1	2	0	0	0.01	0.1	1
5-Oct-2014	26	25	7	3.5	1.4	6	30	20	22	18	40	0.01	2.4	2	1.3	1.3	2	2.4	0	0	0.01	0.2	0.5
5-Nov-2014	27	28	4	4	1.4	6	25	21	25	22	40	0.02	0.5	1.2	1.5	1.5	2	2	0	0.01	0	0.1	0.1
5-Dec -2014	28	28	3	3	2.5	6	20	18	25	20	25	0.01	0.5	1.2	1.5	1.5	1.5	2.2	0	0	0.01	0.1	0.1
5-Jan-2015	29	29	3	3	3	6.2	25	17	22	18	24	0.03	0.5	1	1	1	1.8	2	0	0.01	0	0.1	0.2
5-Feb-2015	29	28	2	2.5	3	6.5	20	16	20	18	20	0.02	0.5	1.2	1.5	1.5	1	2.5	0	0	0.01	0	0.5
5-Mar-2015	30	29	2	2	3.4	6.6	18	14	20	19	45	0.01	0.5	2	0.5	0.5	1	2.6	0	0	0	0.1	0.5
5-Apr-2015	28	28	1.5	2.5	3.4	6.2	20	20	18	20	45	0.02	1	1	1	1	2	2	0	0.01	0.01	0	1
5-May-2015	28	27	2	2.6	2.5	7	35	18	22	30	65	0.01	1`	2.5	1	1	4	2.5	0	0	0	0.1	1.2
5-Jun-2015	27	26	2.5	2.6	1.5	8.5	45	18	30	45	90	0.03	2	2.1	1.6	1.6	5	2	0	0	0	0	0.5
5-Jul-2015	26	25	3	3	1.6	8.5	50	20	30	30	80	0.02	2	2.4	1.2	1.2	3	2.8	0	0.01	0.01	0.2	1.2
5-Aug-2015	25	25	5	4	1.8	8	60	21	30	18	69	0.04	3	1.2	1.3	1.3	3	2.5	0	0.01	0	0.1	1.2
5-Sep-2015	25	25	6.5	3.5	1.5	7	20	203	24	17	55	0.02	2.3	1.5	1.2	1.2	1.8	2.6	0	0	0	0.3	1.2
5-Oct-2015	27	27	5	3.5	1.4	6	25	20	23	18	30	0.01	2.4	1.5	1.3	1.3	1.5	2.6	0	0.01	0.01	0.2	0.2
5-Nov-2015	28	28	3	4	1.4	6	18	21	25	22	25	0.02	0.5	2	1.5	1.5	2	1	0	0.01	0	0.1	0

Key: Air temp = Air Temperature, Water Temp = Water Temperature, Trans = Transparency, TDS = Total Dissolved Solids, Cond = Conductivity, Sal = Salinity, Alk = Alkalinity, PO_4 =Phosphate, NO3= Nitrate, DO = Dissolved Oxygen, BOD = Biochemical Oxygen Demand, Chl = Chloride, K=Potassium, Na=Sodium, Mg=Magnesium,Cr = Chromium, Cd = Cadmium, Ni = Nickel, Fe = Iron, Pb = Lead

Appendix 6: Average Monthly Values ofPphysico-chemical Parameters of Midstream Sstation Measured during the Study Period

Upstream station	Air temp (ºC)	Water temp (ºC)	Trans (m)	DO (mg/L)	BOD (mg/L)	pH	Cond (µs/cm)	Alk (mg/L)	Cl (mg/L)	TDS (mg/L	TS (mg/L)	NO_3 (mg/L)	SO_4 (mg/L)	PO_4 (mg/L)	Na (mg/L)	K (mg/L)	Mg (mg/L)	Ca (mg/L)	Sal ‰	Pb	Cr	Fe	Ni
5-Jun-2014	27	26	3	2.65	1.6	8.5	55	18	32	55	95	0.04	4	3	1.6	1.2	4	1.5	0	0	0.01	0.1	1
5-Jul-2014	26.5	25	4	3.5	1.5	9	75	16	33	35	81	0.03	3	2	1.5	1.3	3	2	0	0	0.01	0.2	0.2
5-Aug-2014	25.5	24	5	3	2	8	70	20	30	25	70	0.02	3.5	2.5	1.4	1.2	3	2	0	0.01	0.01	0.3	0.6
5-Sep-2014	26	25	8	3.4	2	7.5	20	23	25	14	60	0.02	3	1.5	1.4	1.2	2	1.5	0	0.01	0	0.1	1.2
5-Oct-2014	27.5	26	7.5	3.3	2.1	6.5	40	23	24	15	50	0.03	3	2	1.2	1.1	1.5	2	0	0.01	0.02	0.3	0.4
5-Nov-2014	28	27	4.5	3.5	2.1	7	30	20	28	20	45	0.02	0.5	2	1	1.4	2	1.5	0	0.01	0.02	0.2	0.2
5-Dec -2014	29	28	4	3	3	6	25	20	26	18	35	0.02	0.5	1.5	0.5	1.5	1.5	1.2	0	0.01	0.01	0.02	0.1
5-Jan-2015	31	29	3.5	2.5	3.4	6.2	30	19	24	16	25	0.01	1	1.3	0.4	0.8	1	1.5	0	0.01	0.01	0.1	0.3
5-Feb-2015	31	29	3	2	3.2	6.7	25	18	22	16	22	0.02	0.5	1.4	0.1	0.5	1.2	1	0	0.01	0.01	0.1	0.4
5-Mar-2015	30	29	3	1.5	3.6	6.6	25	18	20	16	40	0.01	1	1.5	0.1	0.5	1.5	2	0	0.01	0.01	0.2	0.6
5-Apr-2015	29	28	2	2	3.5	6.3	25	16	22	25	60	0.02	1	2	1	0.5	1	2	0	0.01	0.01	0.1	1
5-May-2015	28	27	3	2	2	7.5	40	22	20	40	75	0.03	2	1.5	1	0.5	2	2	0	0	0.02	0.2	1
5-Jun-2015	27	26.9	4	2.65	1.6	8.5	35	20	32	55	96	0.04	4	3	1	0.8	4	2.5	0	0.01	0.01	0.1	1
5-Jul-2015	26	25	5	3.5	1.5	9	70	20	33	35	81	0.03	3	2	1.4	1.3	4	2	0	0	0.01	0.2	0.2
5-Aug-2015	25	25	6	3	2	8	85	20	35	25	75	0.02	3.5	2.5	1.5	1.2	2	1.5	0	0.02	0.02	0.1	0.1
5-Sep-2015	26	25	7.5	3.4	2	7.5	30	23	25	15	60	0.01	3	1.5	1.4	1.2	2.1	2.4	0	0.02	0.01	0.12	0.1
5-Oct-2015	27	26	7	3.3	2.1	6.5	40	23	24	15	50	0.02	3	2	1.2	1.1	2.2	2.5	0	0.02	0.01	0.12	0.1
5-Nov-2015	28	28	4	4	2.1	7	20	20	28	20	25	0.03	0.05	2	1.2	1.4	2	2	0	0.01	0.01	0.2	0.2

Key: : Air temp = Air Temperature, Water Temp = Water Temperature, Trans = Transparency, TDS = Total Dissolved Solids, Cond = Conductivity, Sal = Salinity, Alk = Alkalinity, PO_4 =Phosphate, NO3= Nitrate, DO = Dissolved Oxygen, BOD = Biochemical Oxygen Demand, Chl = Chloride, K=Potassium, Na=Sodium,Mg=Magnesium,Cr = Chromium, Cd = Cadmium, Ni = Nickel, Fe = Iron, Pb = Lead

Appendix 7: Average Monthly Values of Physico-chemical Parameters of Downstream Station Measured during the Study Period

Downstream station	Air temp (ºC)	Water temp (ºC)	Trans (m)	DO (mg/L)	BOD (mg/L)	pH	Cond (µs/cm)	Alk (mg/L)	Cl (mg/L)	TDS (mg/L	TS (mg/L)	NO_3 (mg/L)	SO_4 (mg/L)	PO_4 (mg/L)	Na (mg/L)	K (mg/L)	Mg (mg/L)	Ca (mg/L)	Sal ‰	Pb	Cr	Fe	Ni
5-Jun-2014	28	27	2	2.0	1.8	9	65	20	35	60	100	0.06	4	4.5	2	1.3	2	1	0	0.01	0.02	0.2	1.5
5-Jul-2014	27	26	4	2.9	1.6	9	105	20	34	40	82	0.05	3	2.4	1.8	1.4	3	1.2	0	0.01	0.02	0.15	1.2
5-Aug-2014	26	25	6	3.5	2	8.5	86	22	35	35	80	0.04	3	2.6	1.6	1.2	2	1.4	0	0.02	0.01	0.12	1
5-Sep-2014	26	26	6	3.8	2.5	8	25	25	32	30	70	0.02	2.5	2	1.5	1.2	1.8	1.2	0	0.02	0.02	0.14	1.5
5-Oct-2014	28	26	6	2.5	1.8	6.5	30	25	35	35	60	0.04	2	2.5	1.5	1	1.2	1.6	0	0.02	0.02	0.12	1
5-Nov-2014	29	28	3	3	2.3	6.6	35	22	30	28	50	0.03	1	2.5	1.5	1	1.5	1.4	0	0.01	0.02	0.3	0.5
5-Dec -2014	30	29	2	2	3.5	6.4	30	25	28	26	40	0.03	2	2	1.5	1	1	1	0	0.02	0.01	0.3	0.2
5-Jan-2015	32	30	2	2	3.6	6.8	35	23	25	23	30	0.02	2	1.5	0.2	0.5	0.5	1.2	0	0.01	0.02	0.2	0.5
5-Feb-2015	32	30	1	1.5	3.5	6.3	30	22	24	22	25	0.02	1	1.5	0.2	0.5	0.5	1.5	0	0.01	0.01	0.2	0.6
5-Mar-2015	32	30	1	1.2	3.8	6.8	30	20	24	20	60	0.02	2	2	0.1	0.4	0.3	1	0	0.02	0.02	0.3	0.8
5-Apr-2015	30	28	3	1.5	3.6	8	20	18	26	35	79	0.04	2	2.5	1	0.6	0.5	1.5	0	0.01	0.01	0.2	1.2
5-May-2015	30	27	2	1.2	2.8	9	30	18	25	50	80	0.04	3	2	0.5	1	1	1.3	0	0.01	0.02	0.2	1.5
5-Jun-2015	27	26	2	2.0	1.8	9	30	20	34	60	95	0.06	4	4.5	2	1.3	2	1.5	0	0.01	0.02	0.2	1.5
5-Jul-2015	27	25	4	2.9	1.6	8.5	49	18	34	40	82	0.05	3	2.4	1.8	1.4	2	1.4	0	0.01	0.02	0.15	1.5
5-Aug-2015	26	26	4	3.5	2	8.5	80	20	35	35	80	0.03	3	2.6	1.5	1.2	3	1.2	0	0.02	0.02	0.2	1.2
5-Sep-2015	26	27	6	3.8	2.5	8.5	95	25	30	30	70	0.01	2.5	2	1.5	1.2	2	1.4	0	0	0,.02	0.14	12
5-Oct-2015	27	28	6	2.5	1.8	8	55	25	35	35	60	0.03	2	2.5	1.5	1	1.2	1.3	0	0.03	0.02	0.12	1.2
5-Nov-2015	29	29	3	3	2.3	6.5	45	22	30	28	35	0.04	1	2.5	1.5	1	1.5	1.5	0	0.01	0.02	0.3	1

Key: Air temp = Air Temperature, Water Temp = Water Temperature, Trans = Transparency, TDS = Total Dissolved Solids, Cond = Conductivity, Sal = Salinity, Alk = Alkalinity, PO_4 =Phosphate, NO3= Nitrate, DO = Dissolved Oxygen, BOD = Biochemical Oxygen Demand, Chl = Chloride, K=Potassium, Na=Sodium,Mg=Magnesium,Cr = Chromium, Cd = Cadmium, Ni = Nickel, Fe = Iron, Pb = Lead

Appendix 8: Seasonal Variation in physico-chemical Parameters of Oluwa River during the Study Period

	Season	N	Mean	Std. Deviation	Std. Error Mean
air.w	Rainy	36	26.708	1.3168	.2195
	Dry	18	29.556	1.5424	.3636
w.tem	Rainy	36	25.914	1.0763	.1794
	Dry	18	28.667	.8402	.1980
Transp	Rainy	36	4.4861	1.93275	.32212
	Dry	18	2.8333	1.00000	.23570
DO	Rainy	36	2.948	.6892	.1149
	Dry	18	2.650	.8840	.2084
BOD	Rainy	36	1.978	.5753	.0959
	Dry	18	2.839	.7563	.1783
pH	Rainy	36	7.856	.9497	.1583
	Dry	18	6.439	.3274	.0772
Cond	Rainy	36	48.833	23.2668	3.8778
	Dry	18	25.333	5.4015	1.2732
Alkal	Rainy	36	20.250	2.6309	.4385
	Dry	18	20.111	2.2463	.5295
Chlo	Rainy	36	28.778	5.0659	.8443
	Dry	18	24.778	3.1911	.7521
TDS	Rainy	36	31.806	13.3926	2.2321
	Dry	18	20.667	3.7417	.8819
TS	Rainy	36	71.083	16.6019	2.7670
	Dry	18	33.944	11.2327	2.6476
NO3	Rainy	35	.029	.0138	.0023
	Dry	18	.021	.0083	.0020

SO4	Rainy	36	2.650	.7980	.1330
	Dry	18	.864	.5851	.1379
PO4	Rainy	36	2.233	.7407	.1234
	Dry	18	1.683	.4515	.1064
Na	Rainy	36	1.318	.3578	.0596
	Dry	18	.778	.5745	.1354
K	Rainy	36	1.175	.2196	.0366
	Dry	18	1.017	.4204	.0991
Mg	Rainy	36	2.497	1.1373	.1895
	Dry	18	1.322	.5451	.1285
Ca	Rainy	36	1.906	.5248	.0875
	Dry	18	1.617	.5227	.1232
Cd	Rainy	36	.018	.0074	.0012
	Dry	18	.013	.0067	.0016
Cr	Rainy	36	.012	.0074	.0012
	Dry	18	.011	.0073	.0017
Pb	Rainy	36	.010	.0081	.0014
	Dry	18	.009	.0054	.0013
Ni	Rainy	36	.853	.4794	.0799
	Dry	18	.406	.2532	.0597
Fe	Rainy	36	.157	.0645	.0108
	Dry	18	.173	.0938	.0221
Salts	Rainy	36	.000	.0000[a]	.0000
	Dry	18	.000	.0000[a]	.0000

Correlation is significant at ($p<0.05$)

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
air.w	Equal variances assumed	1.131	.293	-7.072	52	.000	-2.8472	.4026	-3.6551	-2.0394
	Equal variances not assumed			-6.705	29.730	.000	-2.8472	.4247	-3.7148	-1.9796
w.tem	Equal variances assumed	1.019	.317	-9.486	52	.000	-2.7528	.2902	-3.3351	-2.1705
	Equal variances not assumed			-10.303	42.459	.000	-2.7528	.2672	-3.2918	-2.2137
Transp	Equal variances assumed	14.393	.000	3.397	52	.001	1.65278	.48659	.67637	2.62919
	Equal variances not assumed			4.141	51.888	.000	1.65278	.39915	.85179	2.45377
DO	Equal variances assumed	2.300	.135	1.360	52	.180	.2978	.2189	-.1416	.7371
	Equal variances not assumed			1.252	27.664	.221	.2978	.2379	-.1899	.7854
BOD	Equal variances assumed	4.283	.043	-4.660	52	.000	-.8611	.1848	-1.2319	-.4903
	Equal variances not assumed			-4.254	27.155	.000	-.8611	.2024	-1.2763	-.4459
pH	Equal variances assumed	18.674	.000	6.124	52	.000	1.4167	.2313	.9525	1.8809
	Equal variances not assumed			8.045	48.031	.000	1.4167	.1761	1.0626	1.7707

Cond	Equal variances assumed	23.552	.000	4.210	52	.000	23.5000	5.5820	12.2989	34.7011
	Equal variances not assumed			5.758	41.949	.000	23.5000	4.0814	15.2630	31.7370
Alkal	Equal variances assumed	.321	.573	.192	52	.849	.1389	.7250	-1.3160	1.5938
	Equal variances not assumed			.202	39.330	.841	.1389	.6874	-1.2512	1.5290
Chlo	Equal variances assumed	9.319	.004	3.053	52	.004	4.0000	1.3103	1.3707	6.6293
	Equal variances not assumed			3.537	49.026	.001	4.0000	1.1308	1.7277	6.2723
TDS	Equal variances assumed	17.833	.000	3.447	52	.001	11.1389	3.2314	4.6547	17.6231
	Equal variances not assumed			4.641	44.546	.000	11.1389	2.4000	6.3037	15.9741
TS	Equal variances assumed	2.718	.105	8.543	52	.000	37.1389	4.3471	28.4159	45.8619
	Equal variances not assumed			9.698	47.116	.000	37.1389	3.8296	29.4352	44.8425
NO3	Equal variances assumed	6.218	.016	2.106	51	.040	.0075	.0035	.0003	.0146
	Equal variances not assumed			2.453	49.477	.018	.0075	.0030	.0013	.0136
SO4	Equal variances assumed	2.493	.120	8.415	52	.000	1.7861	.2122	1.3602	2.2120
	Equal variances not assumed			9.323	44.596	.000	1.7861	.1916	1.4001	2.1721
PO4	Equal variances assumed	.969	.329	2.886	52	.006	.5500	.1906	.1676	.9324
	Equal variances not assumed			3.375	49.766	.001	.5500	.1630	.2226	.8774

Na	Equal variances assumed	15.548	.000	4.248	52	.000	.5403	.1272	.2851	.7955
	Equal variances not assumed			3.651	23.798	.001	.5403	.1480	.2348	.8458
K	Equal variances assumed	16.024	.000	1.826	52	.074	.1583	.0867	-.0157	.3323
	Equal variances not assumed			1.499	21.757	.148	.1583	.1056	-.0609	.3776
Mg	Equal variances assumed	10.578	.002	4.138	52	.000	1.1750	.2840	.6052	1.7448
	Equal variances not assumed			5.131	51.965	.000	1.1750	.2290	.7155	1.6345
Ca	Equal variances assumed	.007	.931	1.909	52	.062	.2889	.1513	-.0147	.5925
	Equal variances not assumed			1.912	34.230	.064	.2889	.1511	-.0181	.5959
Cd	Equal variances assumed	.127	.723	2.690	52	.010	.0056	.0021	.0014	.0097
	Equal variances not assumed			2.779	37.217	.008	.0056	.0020	.0015	.0096
Cr	Equal variances assumed	.373	.544	.525	52	.602	.0011	.0021	-.0031	.0054
	Equal variances not assumed			.528	34.593	.601	.0011	.0021	-.0032	.0054
Pb	Equal variances assumed	3.626	.062	.131	52	.896	.0003	.0021	-.0040	.0045
	Equal variances not assumed			.150	47.583	.882	.0003	.0019	-.0035	.0040
Ni	Equal variances assumed	12.860	.001	3.696	52	.001	.4472	.1210	.2044	.6900
	Equal variances not assumed			4.485	51.773	.000	.4472	.0997	.2471	.6474
Fe	Equal variances assumed	4.239	.045	-.741	52	.462	-.0161	.0218	-.0598	.0275
	Equal variances not assumed			-.655	25.307	.518	-.0161	.0246	-.0667	.0345

Appendix 9:Spatial Variation in Phytoplankton Abundance during the Study Period (ANOVA Table)

		Sum of Squares	Df	Mean Square	F	Sig.
Aster	Between Groups	78.481	2	39.241	4.856	.012
	Within Groups	412.111	51	8.081		
	Total	490.593	53			
Cym	Between Groups	25.037	2	12.519	1.491	.235
	Within Groups	428.222	51	8.397		
	Total	453.259	53			
Eunt	Between Groups	25.037	2	12.519	1.491	.235
	Within Groups	428.222	51	8.397		
	Total	453.259	53			
Flag	Between Groups	26.778	2	13.389	2.469	.095
	Within Groups	276.556	51	5.423		
	Total	303.333	53			
Melo	Between Groups	9.926	2	4.963	.575	.566
	Within Groups	440.167	51	8.631		
	Total	450.093	53			
Nav	Between Groups	292.704	2	146.352	11.395	.000
	Within Groups	655.000	51	12.843		
	Total	947.704	53			
Nitz	Between Groups	107.370	2	53.685	4.663	.014
	Within Groups	587.167	51	11.513		
	Total	694.537	53			

Skele	Between Groups	94.333	2	47.167	5.588	.006
	Within Groups	430.500	51	8.441		
	Total	524.833	53			
Steno	Between Groups	21.926	2	10.963	1.290	.284
	Within Groups	433.333	51	8.497		
	Total	455.259	53			
Tabel	Between Groups	39.148	2	19.574	2.165	.125
	Within Groups	461.167	51	9.042		
	Total	500.315	53			
Act.ht	Between Groups	9.148	2	4.574	.404	.669
	Within Groups	576.722	51	11.308		
	Total	585.870	53			
Clost	Between Groups	39.148	2	19.574	2.165	.125
	Within Groups	461.167	51	9.042		
	Total	500.315	53			
C.ebro	Between Groups	8.444	2	4.222	.482	.621
	Within Groups	447.056	51	8.766		
	Total	455.500	53			
C.diana	Between Groups	24.148	2	12.074	1.449	.244
	Within Groups	425.056	51	8.334		
	Total	449.204	53			
C.gra	Between Groups	26.778	2	13.389	1.137	.329
	Within Groups	600.722	51	11.779		
	Total	627.500	53			

C.incu	Between Groups	30.111	2	15.056	2.049	.139
	Within Groups	374.722	51	7.347		
	Total	404.833	53			
C.kur	Between Groups	40.778	2	20.389	1.843	.169
	Within Groups	564.056	51	11.060		
	Total	604.833	53			
C.lun	Between Groups	16.000	2	8.000	1.328	.274
	Within Groups	307.333	51	6.026		
	Total	323.333	53			
C.momi	Between Groups	2.333	2	1.167	.191	.826
	Within Groups	311.000	51	6.098		
	Total	313.333	53			
C.morus	Between Groups	25.148	2	12.574	1.144	.326
	Within Groups	560.333	51	10.987		
	Total	585.481	53			
C.seta	Between Groups	88.111	2	44.056	2.792	.071
	Within Groups	804.722	51	15.779		
	Total	892.833	53			
C.paru	Between Groups	18.481	2	9.241	1.251	.295
	Within Groups	376.778	51	7.388		
	Total	395.259	53			
C.pera	Between Groups	18.481	2	9.241	1.251	.295
	Within Groups	376.778	51	7.388		
	Total	395.259	53			

C.pron	Between Groups	12.000	2	6.000	1.250	.295
	Within Groups	244.833	51	4.801		
	Total	256.833	53			
Chaet.att	Between Groups	33.926	2	16.963	2.271	.114
	Within Groups	380.889	51	7.468		
	Total	414.815	53			
Drap.glo	Between Groups	8.481	2	4.241	2.289	.112
	Within Groups	94.500	51	1.853		
	Total	102.981	53			
Gonat	Between Groups	69.444	2	34.722	4.768	.013
	Within Groups	371.389	51	7.282		
	Total	440.833	53			
G.ehren	Between Groups	19.370	2	9.685	1.601	.212
	Within Groups	308.500	51	6.049		
	Total	327.870	53			
Micra	Between Groups	69.444	2	34.722	4.768	.013
	Within Groups	371.389	51	7.282		
	Total	440.833	53			
micra.flo .v	Between Groups	69.444	2	34.722	4.768	.013
	Within Groups	371.389	51	7.282		
	Total	440.833	53			
M.fib	Between Groups	87.111	2	43.556	6.041	.004
	Within Groups	367.722	51	7.210		
	Total	454.833	53			

M.rad	Between Groups	26.322	2	13.161	4.181	.021
	Within Groups	157.376	50	3.148		
	Total	183.698	52			
M.sol	Between Groups	9.037	2	4.519	.596	.555
	Within Groups	386.389	51	7.576		
	Total	395.426	53			
Tetra	Between Groups	68.259	2	34.130	3.221	.048
	Within Groups	540.333	51	10.595		
	Total	608.593	53			
Spyr	Between Groups	22.333	2	11.167	.932	.400
	Within Groups	611.000	51	11.980		
	Total	633.333	53			
Volvox	Between Groups	26.322	2	13.161	4.181	.021
	Within Groups	157.376	50	3.148		
	Total	183.698	52			
Xanth	Between Groups	26.704	2	13.352	3.389	.042
	Within Groups	200.944	51	3.940		
	Total	227.648	53			
Zygo	Between Groups	7.148	2	3.574	.621	.541
	Within Groups	293.444	51	5.754		
	Total	300.593	53			
Anae	Between Groups	111.370	2	55.685	4.708	.013
	Within Groups	603.222	51	11.828		
	Total	714.593	53			

Aphan	Between Groups	10.333	2	5.167	.604	.551
	Within Groups	436.500	51	8.559		
	Total	446.833	53			
A.pun	Between Groups	5.778	2	2.889	.539	.587
	Within Groups	273.556	51	5.364		
	Total	279.333	53			
Chro	Between Groups	4.778	2	2.389	.216	.806
	Within Groups	564.056	51	11.060		
	Total	568.833	53			
Lym.m	Between Groups	.926	2	.463	.085	.919
	Within Groups	278.278	51	5.456		
	Total	279.204	53			
Gom.lac	Between Groups	330.037	2	165.019	.921	.405
	Within Groups	9139.222	51	179.200		
	Total	9469.259	53			
Osc.pri	Between Groups	258.370	2	129.185	17.671	.000
	Within Groups	372.833	51	7.310		
	Total	631.204	53			
O.p.var	Between Groups	188.037	2	94.019	9.530	.000
	Within Groups	503.167	51	9.866		
	Total	691.204	53			
Spiru	Between Groups	5.481	2	2.741	.272	.763
	Within Groups	514.389	51	10.086		
	Total	519.870	53			

Trach	Between Groups	49.778	2	24.889	3.384	.042
	Within Groups	375.056	51	7.354		
	Total	424.833	53			
T.gib	Between Groups	33.593	2	16.796	2.097	.133
	Within Groups	408.556	51	8.011		
	Total	442.148	53			
T.sch	Between Groups	15.815	2	7.907	.906	.411
	Within Groups	445.167	51	8.729		
	Total	460.981	53			
Phacus	Between Groups	164.111	2	82.056	7.326	.002
	Within Groups	571.222	51	11.200		
	Total	735.333	53			
Syn.uv	Between Groups	26.333	2	13.167	1.709	.191
	Within Groups	393.000	51	7.706		
	Total	419.333	53			

Correlation is significant at ($p<0.05$)

Appendix 10:Spatial Variation in Zooplankton Abundance during the Study Period (ANOVA Table)

		Sum of Squares	df	Mean Square	F	Sig.
Asco	Between Groups	44.778	2	22.389	16.656	.000
	Within Groups	68.556	51	1.344		
	Total	113.333	53			
Asp	Between Groups	50.778	2	25.389	3.720	.031
	Within Groups	348.056	51	6.825		
	Total	398.833	53			
A.gir	Between Groups	35.148	2	17.574	1.350	.268
	Within Groups	664.111	51	13.022		
	Total	699.259	53			
A.her	Between Groups	35.111	2	17.556	1.633	.205
	Within Groups	548.389	51	10.753		
	Total	583.500	53			
A.pri	Between Groups	55.593	2	27.796	2.028	.142
	Within Groups	699.167	51	13.709		
	Total	754.759	53			
Bran	Between Groups	4.148	2	2.074	.216	.806
	Within Groups	489.500	51	9.598		
	Total	493.648	53			
B.fa	Between Groups	18.481	2	9.241	.668	.517
	Within Groups	705.667	51	13.837		
	Total	724.148	53			

B.lu	Between Groups	24.778	2	12.389	.979	.383
	Within Groups	645.222	51	12.651		
	Total	670.000	53			
B.qu	Between Groups	29.370	2	14.685	1.735	.187
	Within Groups	431.611	51	8.463		
	Total	460.981	53			
Cer.c	Between Groups	56.333	2	28.167	4.447	.017
	Within Groups	323.000	51	6.333		
	Total	379.333	53			
Ceph	Between Groups	4.704	2	2.352	.460	.634
	Within Groups	260.778	51	5.113		
	Total	265.481	53			
F.lo	Between Groups	21.815	2	10.907	.828	.443
	Within Groups	671.611	51	13.169		
	Total	693.426	53			
F.op	Between Groups	2.259	2	1.130	.160	.853
	Within Groups	360.333	51	z7.065		
	Total	362.593	53			
F.pej	Between Groups	11.444	2	5.722	.591	.558
	Within Groups	494.056	51	9.687		
	Total	505.500	53			
F.ter	Between Groups	32.333	2	16.167	1.665	.199
	Within Groups	495.167	51	9.709		
	Total	527.500	53			

Glo	Between Groups	9.926	2	4.963	.546	.582
	Within Groups	463.278	51	9.084		
	Total	473.204	53			
Hor	Between Groups	32.333	2	16.167	1.665	.199
	Within Groups	495.167	51	9.709		
	Total	527.500	53			
Lec	Between Groups	38.778	2	19.389	1.668	.199
	Within Groups	592.722	51	11.622		
	Total	631.500	53			
L.bu	Between Groups	40.704	2	20.352	1.893	.161
	Within Groups	548.333	51	10.752		
	Total	589.037	53			
L.lu	Between Groups	29.778	2	14.889	1.403	.255
	Within Groups	541.056	51	10.609		
	Total	570.833	53			
L.tu	Between Groups	13.481	2	6.741	.605	.550
	Within Groups	568.222	51	11.142		
	Total	581.704	53			
Lep	Between Groups	94.778	2	47.389	4.776	.013
	Within Groups	506.056	51	9.923		
	Total	600.833	53			
Tes	Between Groups	74.037	2	37.019	2.751	.073
	Within Groups	686.278	51	13.456		
	Total	760.315	53			

Trich	Between Groups	50.778	2	25.389	1.972	.150
	Within Groups	656.556	51	12.874		
	Total	707.333	53			
T.ie	Between Groups	40.333	2	20.167	1.784	.178
	Within Groups	576.500	51	11.304		
	Total	616.833	53			
T.mu	Between Groups	13.778	2	6.889	.480	.622
	Within Groups	732.222	51	14.357		
	Total	746.000	53			
Rot	Between Groups	34.333	2	17.167	1.573	.217
	Within Groups	556.500	51	10.912		
	Total	590.833	53			
R.he	Between Groups	102.333	2	51.167	6.858	.002
	Within Groups	380.500	51	7.461		
	Total	482.833	53			
R.tri	Between Groups	45.037	2	22.519	1.678	.197
	Within Groups	684.444	51	13.420		
	Total	729.481	53			
Euc	Between Groups	21.148	2	10.574	5.426	.007
	Within Groups	99.389	51	1.949		
	Total	120.537	53			
R.nep	Between Groups	29.481	2	14.741	1.075	.349
	Within Groups	699.111	51	13.708		
	Total	728.593	53			

Sim	Between Groups	29.481	2	14.741	1.075	.349
	Within Groups	699.111	51	13.708		
	Total	728.593	53			
Cope	Between Groups	3.370	2	1.685	.677	.513
	Within Groups	126.944	51	2.489		
	Total	130.315	53			
Eucl	Between Groups	122.399	2	61.200	6.883	.002
	Within Groups	444.582	50	8.892		
	Total	566.981	52			
Eud	Between Groups	61.444	2	30.722	3.184	.050
	Within Groups	492.056	51	9.648		
	Total	553.500	53			
Bos	Between Groups	34.111	2	17.056	1.102	.340
	Within Groups	789.389	51	15.478		
	Total	823.500	53			
Pod	Between Groups	39.593	2	19.796	1.558	.220
	Within Groups	648.111	51	12.708		
	Total	687.704	53			
Cerio	Between Groups	34.778	2	17.389	1.341	.271
	Within Groups	661.222	51	12.965		
	Total	696.000	53			
Moi	Between Groups	61.148	2	30.574	3.794	.029
	Within Groups	411.000	51	8.059		
	Total	472.148	53			

Correlation is significant at ($p<0.05$)

Appendix10: Raw Values of Fish Encountered during the Study Period in O luwa River

Species	Jun-2014	Jul	Aug	Sep	Oct	Nov	Dec	Jan-2015	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Chrysichthys nigrodigitatus	1	-	-	-	6	8	10	8	6	5	3	2	2	2	-	-	-	6
C . occidentalis	1	-	-	-	4	2	2	4	5	2	1	1	1	-	-	-	4	2
Parachanna obscura	-	-	-	-	-	5	4	3	4	5	3	1	-	-	-	-	-	5
Parachanna africana	-	-	-	-	-	3	3	2	4	2	1	1	-	-	-	-	-	3
Brycinus brevis	1	-	-	-	-	-	4	2	6	4	2	1	1	-	-	-	-	-
B .nurse	-		-	-	-	4	6	2	1	4	2	1	-	--	-	-	-	4
Micralestes occidentalis	-	-	-	-	-	2	5	4	2	3	2	1	-	-	-	-	-	2
Hemichromis fasciatus	1	-	-	-	2	4	8	10	11	12	3	1	1	-	-	-	2	4
Oreochromis aureus	2	-	-	-	2	5	6	4	5	6	2	1	2	-	-	-	2	5
O. niloticus	-	-	-	-	-	6	7	8	14	13	5	2	-	-	-	-	-	6
Sarotherodon galilaeus	-	-	-	-	2	6	7	8	12	13	5	2	-	-	-	-	2	6
S. melanotheron	-	-	-	-	-	4	6	10	14	10	2	1	-	-	-	-	-	4
Tilapia guineensis	1	-	-	-	-	1	2	3	4	10	2	1	1	-	-	-	-	1
T. zillii	2	-	-	-	-	2	3	4	4	15	5	1	2	-	-	-	-	2
Clarias anguillaris	2	3	2	4	6	10	15	14	14	15	2	1	2	3	2	4	6	10
C. gariepinus	4	5	-	5	8	12	14	15	16	15	5	4	4	5	-	5	8	12
Heterobranchus bidorsalis	2	3	-	-	8	13	18	17	18	10	5	2	2	3	-	-	8	13
H. longifilis	2	5	4	-	8	11	12	18	20	11	5	2	2	5	4	-	8	11
Barbus bynni occidentalus	-	-	-	-	2	4	-	8	11	12	3	1	-	-	-	-	2	4
B. lagoensis	-	-	-	-	4	6	10	12	12	13	3	1	-	-	-	-	4	6
Labeo senegalensis	-	-	-	-	5	8	10	12	10	4	3	2	-	-	-	-	5	8
Distichodus rostratus	1	-	-	-	2	2	3	5	5	8	3	1	1	-	-	-	2	2
D. engycephalus	-	-	-	-	3	3	3	6	7	3	2	1	-	-	-	-	3	3
Nannocharax ansorgiii	-	-	-	-	3	3	3	6	7	3	2	1	-	-	-	-	3	3

N. latifasciatus	-	-	-	-	4	4	5	6	7	8	2	1	-	2	-	-	4	4
Hepsetus. Odoe	3	-	-	-	2	2	6	10	11	10	4	2	3	-	-	-	2	2
Malapterurus electricus	2	-	-	-	-	-	4	4	3	4	2	1	2	-	-	-	-	-
Mormyrus hasselquistic	2	-	-	-	5	5	6	7	8	8	1	1	2	-	-	-	5	5
M. macrophthalamus	1	-	-	-	6	6	8	8	9	10	1	1	1	-	-	-	6	6
M. rume	2	-	-	-	8	8	8	10	10	10	1	1	2	-	-	-	8	8
M. senegalensis	-	-	-	-	6	6	2	8	10	2	1	1	-	-	-	-	6	6
Marcusenius abadii	1	-	-	-	-	-	2	3	-	2	2	1	1	-	-	-	-	-
M. brucii	-	-	-	-	-	-	1	2	3	1	1	1	-	-	-	-	-	-
M. cyprinoidea	2	1	-	-	-	-	-	2	-	3	1	1	2	1	-	-	-	-

*--not encountered

Appendix 11: Correlation Coefficient Matrix Showing Relationships between Physico-chemical Parameters

	Air temp	Water temp	Trans	DO	BOD	pH	Cond	Alkali	Chlor	TDS	TS	NO3	SO4	PO4	Na	K	Mg	Ca	Cd	Cr	Pb	Ni	Fe
Air temp																							
Water temp	0.971																						
Trans	-0.811	-0.882																					
DO	-0.783	-0.651	0.575																				
BOD	0.996	0.953	-0.772	-0.784																			
pH	-0.694	-0.801	0.752	0.156	-0.678																		
Cond	-0.641	-0.759	0.718	0.071	-0.628	0.991																	
Alkali	0.379	0.231	-0.243	-0.856	0.367	0.290	0.390																
Chlor	-0.298	-0.441	0.429	-0.296	-0.291	0.887	0.915	0.663															
TDS	-0.464	-0.552	0.467	-0.106	-0.476	0.913	0.937	0.554	0.958														
TS	-0.751	-0.850	0.739	0.189	-0.741	0.973	0.978	0.298	0.831	0.885													
NO3	-0.112	-0.223	0.224	-0.421	-0.125	0.746	0.792	0.752	0.954	0.930	0.680												
SO4	-0.643	-0.767	0.682	0.049	-0.634	0.912	0.947	0.438	0.820	0.856	0.969	0.686											
PO4	-0.309	-0.449	0.412	-0.301	-0.305	0.884	0.917	0.685	0.997	0.965	0.844	0.953	0.843										
Na	-0.722	-0.740	0.585	0.247	-0.749	0.869	0.884	0.276	0.756	0.905	0.903	0.714	0.863	0.778									
K	-0.774	-0.633	0.546	0.946	-0.783	0.275	0.177	-0.779	-0.121	0.073	0.255	-0.211	0.065	-0.137	0.362								
Mg	-0.937	-0.925	0.758	0.784	-0.915	0.529	0.470	-0.482	0.097	0.219	0.616	-0.146	0.529	0.110	0.483	0.689							
Ca	-0.695	-0.565	0.365	0.885	-0.703	-0.026	-0.082	-0.757	-0.458	-0.264	0.102	-0.593	0.034	-0.433	0.136	0.728	0.800						
Cd	-0.247	-0.382	0.417	-0.295	-0.238	0.859	0.878	0.622	0.987	0.935	0.769	0.959	0.739	0.974	0.710	-0.089	0.024	-0.521					
Cr	0.341	0.149	-0.001	-0.790	0.361	0.434	0.498	0.876	0.772	0.589	0.347	0.805	0.429	0.759	0.219	-0.663	-0.449	-0.880	0.785				
Pb	0.388	0.216	-0.070	-0.801	0.401	0.394	0.454	0.865	0.757	0.583	0.291	0.820	0.356	0.741	0.204	-0.640	-0.524	-0.920	0.785	0.991			
Ni	-0.398	-0.480	0.325	-0.163	-0.408	0.864	0.868	0.546	0.937	0.959	0.820	0.901	0.754	0.942	0.813	0.054	0.180	-0.304	0.919	0.588	0.595		
Fe	0.527	0.397	-0.494	-0.868	0.522	-0.066	0.033	0.860	0.282	0.152	0.010	0.339	0.185	0.320	-0.079	-0.910	-0.463	-0.568	0.202	0.627	0.593	0.198	

$P<0.05$, $r= 0.3515$, $n= 23$

Appendix 12: Correlation coefficient matrix showing relationships between zooplankton fauna