PHYSICO-CHEMICAL PARAMETERS, PLANKTON, MACROZOOBENTHOS AND FISH FAUNA OF IBUYA RIVER, SEPETERI, SOUTH-WESTERN NIGERIA

BY

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ABSTRACT

Ibuya River runs across the Old Oyo National Park, a wildlife and recreational park. There is paucity of information on the limnology of the river which will provide information on the ecological status relevant for sustainable management. Therefore, this study was carried out to investigate the physico-chemical parameters, diversity and abundance of plankton, macrozoobenthos and fish fauna of Ibuya River.

Surface water (72), plankton (72) and macrozoobenthic (72) samples were collected monthly from September 2012 to February 2014 at randomly selected stations (i-iv) along the river. Water temperature, pH and Dissolved Oxygen (DO) were measured *in situ*, while hardness, turbidity, phosphate (PO_4^{3-}), sulphate (SO_4^{2-}), heavy metals including cadmium (Cd), Iron (Fe) and lead (Pb), were determined in the laboratory according to APHA method. Plankton samples were collected with plankton net (mesh size, 55 µm), identified and counted microscopically. Macrozoobenthos were collected with Van-Veen grab (0.086 m^2), identified and counted macroscopically. Fish samples were collected with gill net (mesh size 45 mm), identified and counted. All identifications including pollution indicator species were done using standard identification keys. Species diversity was determined with Shannon-Wiener index H^I. Descriptive statistics, student t-test, one-way ANOVA, Pearson correlation coefficient and Principal Component Analysis (PCA) were used for analysis of data at $\alpha_{0.05}$.

Water temperature was 24.8±0.2 °C; pH, 7.60±0.04; DO, 4.4±0.2 mg/L; hardness, 39.6±2.1 mg/L $CaCO_3$; turbidity, 19.4±0.9 FTU; Cd, 0.2±0.1 mg/L; Pb, 0.7±0.1 mg/L; Fe, 2.1±0.2 mg/L; PO_4^{3-}, 24.3±2.8 mg/L; and SO_4^{2-}, 31.8±3.1 mg/L. Turbidity had significant spatial and seasonal variation at $p<0.001$ while pH and SO_4^{2-} had significant spatial and seasonal variation at $p<0.04$ and $p<0.002$, respectively. Cadmium, Pb, and PO_4^{3-} exceeded the NESREA permissible limits for surface water (0.003, 0.01 and 3.5 mg/L, respectively). Turbidity correlated significantly with Fe ($r = 0.6$) and SO_4^{2-} ($r = 0.7$). The PCA revealed high positive loading for water temperature (0.7 °C), hardness (0.6 mg/L $CaCO_3$) and turbidity (0.6 FTU). Forty-five species of phytoplankton belonging to four Classes: Bacillariophyceae (25 species), Chlorophyceae (Nine species), Euglenophyceae (Eight species) and Cyanophyceae (Three species) were recorded. *Merismopedia punctata* (52.1%) dominated the phytoplankton population. Zooplankton from three groups: rotifers (15 species), crustaceans (five species) and insects (one species) were encountered. *Mesocyclops leuckarti* (11.6%) was the most abundant zooplankton. Diversity index for phytoplankton was highest in station iv; stations ii and iii recorded highest H^I for zooplankton. Eight species of macrozoobenthos were recorded with the gastropod, *Indoplanorbis exustus* (30.9%) dominating and the insect, *Chironomus* species (11.8%) was the least abundant. Twenty-four fish species were recorded. Family Cichlidae (22.6%) was the most abundant. Pollution indicator species were abundant and included the phytoplankton, *Merismopedia punctata* (52.1%) and the macrozoobenthos, *Melanoides tuberculata* (24.7%).

This study provided baseline information on the ecological status of Ibuya River. However, the composition and diversity of both plankton and macrozoobenthos could be potentially used as bio-indicators for assessing and monitoring Ibuya River.

Keywords: Water quality, Plankton and Macrozoobenthos diversity, Fish fauna, Ibuya River

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CERTIFICATION

I certify that this research work was carried out by Juliet A. Akponine in the Department of Zoology, University of Ibadan.

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DEDICATION

This research work is dedicated to the Almighty God, my dearly beloved husband, daughter and family.

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CHAPTER ONE

INTRODUCTION

Water is essential for the survival of life on earth and when polluted, its value is lost and can become a threat to our health as well as organisms living in it. Boyd (1981) described water qualities as those physical, chemical and biological factors that influence species composition, diversity, stability, production and physiological conditions of indigenous populations. The physico-chemical parameters of water bodies vary in concentration on a seasonal, daily or even hourly basis. These variations may be related to pattern of water use and rainfall (Akin-Oriola, 2003). The quality of the river systems often fall below acceptable levels for many uses. Rivers due to their role in carrying off the municipal and industrial wastewater and run off from agricultural land in their vast drainage basins are among the most vulnerable water bodies to pollution (Yerel, 2010). Availability of safe and reliable source of water is an essential prerequisite for sustained development.

Water pollution is of grave consequences because both terrestrial and aquatic life may be affected. It may cause disease due to the presence of some hazardous substances, with distortion of the water quality, impose physiological stress on biotic community, add odour and significantly hinder economic activities (Asonye *et al.*, 2007). A pressing need has therefore emerged for a comprehensive and accurate study of these water bodies in order to raise awareness of the urgent needs to address the consequences of present and future threats of contamination and degradation and their likely effect on our overall goals of poverty alleviation among fisher folks.

The use of invertebrates and fish as bio-indicators of water quality has been advocated by several investigators (Adakole *et al.*, 1998; Adakole, 2000; Ogbeibu and Ezeunara, 2002; Emere and Nasiru, 2009; Nkwoji *et al.*, 2010; and Joydas and Damodaran, 2009). For example an aquatic community dominated by *Tubifex tubifex* or *Chrironomus* species reflect an area with low oxygen concentrations and high organic enrichment (Lenat, *et al.*, 1980; Moss, 1993). While an association of mayflies, stoneflies and caddis flies in a stream is indicative of clean water conditions (Adakole *et al.*, 1998).

Species vary in their degree of tolerance with the result that under polluted condition, a reduction in species diversity is the most obvious effect. Fish, the most populous and valued vertebrate in the aquatic environment, which occupy the highest trophic levels of food chains in the ecosystem also suffer from severe organic pollution (Sikoki and Kolo, 1993). The adverse effects of pollution on water quality which in turn affect the abundance, species composition, diversity of macro-invertebrate and fish fauna pose a great threat to the sustained existence and preservation of water bodies in Nigeria.

1.1 Justification

Water quality is a major economic and environmental issue in developing countries and in the world at large. However, it has been observed that most inland waters become threatened by pollutants from various human activities, siltation, drought and effective management practices are usually not given due attention. It is in line with these that this research work was initiated.

Human and wildlife interaction within and outside the park involves the use of Ibuya river for drinking, domestic and recreational purposes. Untreated wastes such as sewage, detergents and agricultural effluents from anthropogenic activities in the surrounding communities enter into the river. These inputs can render the water unsafe for humans and also adversely affect the resident biota. Despite these, there is paucity of information on the limnology of the river.

The study will provide vital conservation information for the relevant agencies in formulating appropriate measures for the conservation of the river. It will undoubtedly provide the necessary baseline data on the ecological status relevant for sustainable management.

1.2 Aim and Objectives

This study investigates the physico-chemical parameters, Plankton, Macrozoobenthos and Fish Fauna of Ibuya River in the old Oyo National Park, Sepeteri, South-Western

Nigeria. It is also an opportunity to provide necessary information to highlight the peculiar features of Ibuya River.

The objectives of this study therefore are to:

- Determine spatial and seasonal variation in the physicochemical parameters of Ibuya River.
- Determine spatial and seasonal variations in the abundance, diversity and evenness of the plankton, macrozoobenthos.
- Investigate the fish abundance and diversity.
- Determine seasonal variations in the abundance, diversity and evenness of fish species.
- Determine the relationships between measured physicochemical parameters with the abundance of plankton and macrozoobenthos
- Use the information obtained from the above to provide an index of environmental quality of Ibuya River and prescribe conservation action(s) to protect the biota and their habitat

CHAPTER TWO

LITERATURE REVIEW

2.1. Physico-chemical parameters

2.1.1. Fresh water physico-chemistery

Water is an extraordinary substance, which exist in the three states of matter (gaseous, liquid and solid states). It is a very simple chemical compound composed of two atoms of hydrogen and one atom of oxygen, which bond covalently to form one molecule. In its pure state, water is colourless, odourless, and insipid, freezes at 0 °C, and has boiling point of 100 °C at a pressure of 760 mm Hg. Chemically, it is a substance, which is thermally stable at temperatures as high as 2,700 °C. It is neutral to litmus, with a pH of 7 and undergoes a very slight but important reversible self-ionization (Wilson, 1990).

The general desire to protect fresh water fisheries has led to an expansion of research into their water quality requirements, in terms of their physicochemical parameters such pH, temperature, dissolve oxygen, transparency, total alkalinity, total hardness, electrical conductivity, total dissolved matter, e.t.c. These factors serve as a basis for the richness or otherwise biological productivity of any aquatic environment (Imevbore, 1970). The physical and chemical properties of water immensely influenced its uses, the distribution and richness of the biota (Courtney and Clement, 1998; Unanam and Akpan, 2006).

The water quality of rivers and lakes is largely affected by natural processes (weathering and soil erosion) as well as anthropogenic inputs (municipal and industrial wastewater discharge). The anthropogenic discharges represent a constant polluting source; whereas surface runoff is a seasonal phenomenon, largely affected by climatic conditions (Vega, *et al.*, 1998). Water quality guidelines provide basic scientific information about water quality parameters and ecologically relevant toxicological threshold values to protect specific water uses (Chitmanat and Traichaiyaporn, 2010).

Assessment of water resource quality of any region is an important aspect of developmental activities of the region, because rivers, lakes and manmade reservoirs are used for water supply to domestic, industrial, agricultural and fish culture (Jackher and Rawat, 2003). Several of these physicochemical parameters have been studied on large man-made lakes in Northern Nigeria by Adeniji and Ita (1977) and Adeniji (1981). Other works on physicochemical parameters include that of Balarabe (1989), on Makwaye Lake, Zaria, Oniye *et al.* (2002), on Zaria Dam, Ugwumba and Ugwumba (1993), on Awba Lake in Ibadan, Kolo and Oladimeji (2004), studied water quality and some nutrient levels in Shiroro Lake, Niger State.

2.1.2. Temperature

Water temperature is one of the major environmental factors that affect and control food utilization at all levels and stages of fish growth (Dupree and Hunner, 1993). Fish are poikilothermic and water plays an important role in their feeding as it affects their metabolic activities, feeding potential, growth, reproduction and efficiency of food conversion (Martinez-Placious *et al.*, 1993). Dupree and Hunner (1993) suggested temperature range of 20 ºC to 30 ºC for fish, while the lethal levels are from less than 2 ºC and higher than 42 ºC for tropical fishes but cold water fishes can survive a temperature range of 5 ºC-15 ºC. Temperature has a pronounced effect on the rate of chemical and biological processes in water; for instance, fish require twice oxygen at 30 ºC than at 20 ºC (Adeniji and Ovie, 1990). It is recommended that fish in the tropics be kept in water whose temperature range is between 25 ºC and 30 ºC (Auta, 1993). Sudden increase in temperature will stress or kill fish (Adeniji and Ovie, 1990). Temperature affects the dominance and distribution of phytoplankton in water as it influences the growth rate and mortality of zooplankton and other organisms (Orchutt and Porter, 1983). Temperature influences other factors such as Dissolved Oxygen and may affect organisms to varying degrees, depending on their sensitivity (Countant, 1987). The physiology of aquatic organisms is such that they can tolerate only narrow ranges of temperatures, outside which they cannot function normally (Willoughby, 1976; Orchutt and Porter, 1983). Guzkowska and Gasse (1990) reported that diatoms seem to grow best at temperature of 15-25 °C, green algae at 25-35 °C, while blue green algae at 30-40 °C. The recommended temperature range for fish production according to Boyd (1982) is 20-33 °C. Huet (1972) examined the temperature need of fish and the influence of temperature on fish production. The author noted that an increase in water temperature of 2 °C at the time of production would adversely affect spawning. Other studies reported temperatue range of 19.5 to 21 ^{o}C (Patil *et al.*, 2012), 10.18 to 19.73 ^{o}C (Kar *et al.*, 2008), 20.5 to 22 ^{o}C (Chiroma *et al.*, 2012), 19.01 to 23.93 ^{o}C (Okweye, 2013).

2.1.3 Hydrogen-ion concentration (pH)

The hydrogen-ion concentration (pH) of any water is the measurement of the acidity or alkalinity of that water body. It is usually measured on a scale of 0-14 with 7 being neutral (Branco and Senna, 1996). The effects of pH on the chemical, biological and physical properties of a water system makes its study very crucial to the lives of the organisms in the medium. Freshwater with a pH of 6.5-9.0 is known to be productive and recommended as suitable for fish culture (Adeniji, 1981; Auta, 1993). Increase in acidity and alkalinity of any water body may increase or decrease the toxicity of that water. Solar radiation and temperature accelerates photosynthesis, which in turn increase carbon dioxide‟s absorption, altering the Bicarbonate equilibrium and producing hydroxide (OH-) thus raising the pH (Branco and Senna, 1996). Hynes (1974) observed that pH values of below 5 or above 9 were harmful to most aquatic animals. Chronic pH levels may reduce fish reproduction and are associated with fish die-offs (Stone and Thomforde, 2006). Adeniji and Ovie (1990) reported that acid and alkaline death points are approximately at pH 4 and 11 respectively. Ramanathan *et al*. (2005) recommended optimum range of pH 6.8-8.7 for maximum growth and production of shrimp and carp. pH higher than 7 but lower than 8.5 according to Abowei (2010) is ideal for biological productivity, but pH at <4 is detrimental to aquatic life.

2.1.4 Dissolved Oxygen (DO)

Dissolved oxygen is very essential to life in aquatic environment as it affects the physiology and distribution of the aquatic organisms. Nearly all aquatic organisms, with the exception of some bacteria, must have oxygen to survive and most of these organisms must extract their oxygen from water. The two main sources of oxygen into the aquatic environment are the atmosphere and photosynthetic activities of aquatic plants. The ideal range of dissolved oxygen in water which must be at least 5 mg/L is required to sustain fish and other aquatic life (FDF, 2003). Insufficient dissolved oxygen (DO) in a water system causes/results in anaerobic decomposition of organic material thereby leading to the production of obnoxious gases such as carbon dioxide, hydrogen sulphide and methane which bubble to the surface. Kutty (1968) reported that Atlantic salmon stopped swimming when dissolved oxygen concentration remained below 5 ppm, but that goldfish, Tilapia and carp swim at oxygen levels of 1-2 ppm. Inadequate dissolved oxygen has many effects on fish such as reduced feeding leading to impaired growth, which results in fish becoming more susceptible to disease. Cold water fish require large amounts of dissolved oxygen, while warm water fish are able to survive with low oxygen content.

2.1.5 Conductivity

Electrical conductivity is the ability of a water body to receive and conduct electrical current correlating with its salt content. It is an indicator of the type and number of ions present or dissolved in water or in solution, which are almost proportional to the amount of dissolved matter. Freshwater fish thrive over a wide range of electrical conductivity. The desirable range is 100-2,000 µS/cm and the acceptable range is 30-5,000 µS/cm (Stone and Thomforde, 2006). Sikoki and Veen (2004) observed a conductivity range of 3.8-10 µS/cm in Shiroro Lake (Imo State) which was described as extremely poor in chemicals. They were of the view that fishes differ in their ability to maintain osmotic pressure, therefore the optimum conductivity for fish production differ from one species to another. High conductivity is an indication of the presence of large amount of dissolved salts, while at low level major ions may be determined by the nature of the fauna (Moss, 1993). Electrical conductivity is affected by temperature, it is thus important to report temperature data along with conductivity values. In unpolluted waters, conductance increases by 2 to 3 % per ^{o}C. The international standard temperature to which conductivity measurements are corrected is 25 ^{o}C. This measurement is expressed in microsiemens per centimeter (uS/cm) at 25 degrees Celsius. Conductivity values can be used to estimate the total concentration of dissolved solids (commonly referred to as total dissolved solids, or TDS) (WHO, 2004).

2.1.6 Total Dissolved Solids (TDS)

Total Dissolved Solids (TDS) are the total amount of mobile charged ions, including minerals, salts or metals dissolved in a given volume of water, expressed in units of mg per unit volume of water (mg/L), also referred to as parts per million (ppm). TDS is directly related to the purity of water and the quality of water purification systems and affects everything that consumes, lives in or uses water, whether organic or inorganic, either for better or for worse (Dallas and Day, 1993). When some of these substances are in suspension, they cause turbidity in the water thus reducing photosynthesis and the amount of dissolved oxygen, which in turn affect the feeding of aquatic organisms that depend on sight to catch prey. A certain level of TDS in water is necessary for aquatic life (Stone and Thomforde, 2006). TDS is one of the parameters used in measuring the fitness factor of fish and as a general measure of edaphic relationship that contributes to productivity within a water body (Ryder, 1965). Dallas and Day (1993) stated that the tolerance of fish species to variations in TDS concentrations is dependent on physiological adaptations.

2.1.7 Water Hardness

Hardness may be defined as the concentration of all multivalent metallic cations in solution. The principal ions causing hardness in natural water are calcium and magnesium. Others, which may be present though in much smaller quantities, are iron, manganese, strontium and aluminum (Nsi, 2007). Hardness of natural water is not harmful to the health of man; on the contrary, calcium promotes removal of cadmium; an element that can adversely affect the cardiovascular system (Nikoladze and Mints, 1989). Waters having hardness values of 15 mg/L $CaCO_3$ or above are satisfactory for the growth of fish while values less than 5 mg/L $CaCO_3$ equivalent cause slow growth, distress and eventual death of fish (Gupta and Gupta, 2006).

2.1.8 Alkalinity

Alkalinity of water is the capacity to neutralize strong acid. It is expressed as mg/L $CaCO_3$ or as mEq/L — the number of milli-equivalents of hydrogen ions which are released by 1 kg of water when an excess of acid is added (Strickland and Parsons, 1968). The chemical composition of rocks and soils strongly influences the natural alkalinity of water, which can range from very low values to several hundred mg/L $CaCO_3$ (DWAF, 1996; Zweig *et al.,* 1999). Waters with moderate to high alkalinity tend to be more strongly buffered than waters with low alkalinity. Alkalinity in natural freshwater systems ranges from 5 mg L^{-1} to 500 mg L^{-1}. In natural waters, the alkalinity is usually due to calcium because it forms the major constituent of carbonates and bicarbonates (Department of the Environment, 1972; Gupta and Gupta, 2006). Natural waters which contain 40 mg/L or more total alkalinity as equivalent $CaCO_3$ are considered for biological purposes by limnologists as "hard" waters, while waters with lower alkalinity are said to be "soft" (Boyd, 1990). Alkalinity values above 300 ppm have been reported to adversely affect the spawning and hatching of carps in freshwater aquaculture systems (Gupta and Gupta, 2006). However, extremes of pH and alkalinity are more likely to affect plants than animals (Beadle, 1974). A minimum level of alkalinity is desirable because it is considered a "buffer" that prevents large variations in pH (Anon., 2006). Chapman and Kimstach (1996) showed that water with low alkalinity (<24 mg/L $CaCO_3$) have low buffering capacity and can therefore be susceptible to alteration in pH.

2.1.9 Transparency

Transparency can vary significantly due to a number of management strategies particularly in aquaculture ponds (Boyd, 1990). Thus transparency is often measured in centimeters using a secchi disc (i.e. it is the distance (cm) into the water at which a black and white disc becomes visible to the naked eye). For silver perch, the preferred secchi disc reading is 30 to 45 cm (Rowland, 1995), < 200 cm for snapper (Ogburn, 1996), < 30 cm for barramundi, 30 to 40 cm for freshwater crayfish (O'Sullivan, 2001), and < 20 cm for prawns (Anderson *et al.,* 2006). Typically, if the secchi disk reading is below 10 cm water turbidity is excessive. If turbidity is due to the presence of phytoplankton, there is likely to be a problem with dissolved oxygen concentrations when the light level decreases below the photosynthetic compensation level. Conversely, if turbidity is due to silt/clay or organic matter, planktonic productivity will be low. Much of the photosynthetic activities of phytoplankton take place in the presence of light, therefore the amount of light that penetrates the aquatic ecosystem is of importance to the overall abundance of other members on the higher levels of the food chain (Adeniji, 1981).

2.1.10 Turbidity

Turbidity of water is an important parameter for characterizing water quality. Turbidity is a measure of the lack of clarity or transparency of water caused by biotic and abiotic suspended or dissolved substances. The higher the concentration of these substances in water, the more turbid the water becomes. Technically, when passing light through a water sample, turbidity is an expression of the optical properties of substances that causes light to be scattered and absorbed rather than transmitted in straight lines through the sample (Wetzel, 1975). The most reliable method for determining turbidity is nephelometry (light scattering by suspended particles), which is measured by means of a turbidity meter giving nephelometric turbidity units (NTU). Environmental samples vary within the normal range of 1 to 1000 NTU (Chapman, 1997). Plankton and bacterial blooms, suspended organic and humic acids, suspension of silt and clay particles all influence the level of turbidity (turbidity increases with suspended solids) and scatter light, restricting penetration into water. Turbidity affects reservoir productivity and fish life because decreased penetration of light reduces primary production (Chapman, 1997).

2.1.11 Heavy Metals and Nutrient Parameters

A number of chemicals can occur in surface waters as a result of human activities. These can be of inorganic or organic origin. A wide range of heavy metals can be a problem in freshwater, brackish water and inshore marine aquaculture, especially in areas of human habitation. Trace quantities of metals are present in natural waters; however, their concentrations are generally greater where pollution from industrial processes (ore mining and processing, textile and leather industries) as well as exhaust gases of motor vehicles and burning of other fossil fuels occur. The metals of greatest concern to fisheries (and aquaculture) include aluminium, arsenic, cadmium, chromium, copper, iron, lead, mercury, nickel and zinc (Svobodova *et al.*, 1993). Other inorganic toxicants include ammonia, chlorine, cyanide, fluoride, hydrogen sulphide, nitrite, nitrate and phosphates (Svobodova *et al.*, 1993).

Manganese

Manganese is used in a number of industries, producing alloys, pigments, glass, fertilizers and herbicides. It is an essential micronutrient for vertebrates but is neurotoxic in excessive amounts. Manganese has aesthetic rather than toxic effects as it produces a slight green discolouration of the water (DWAF, 1996). The oxidized form, Mn^{4+}, is far less soluble than the reduced form, Mn^{2+}. If high concentrations of reduced manganese are present in source water, it will oxidize and precipitate causing similar problems as iron (Zweig *et al.*, 1999). Typically, the median concentration of manganese in freshwater is 8 µg/L (range 0.02 to130 µg/L) and 2 µg/L in sea water. However, DWAF (1996) noted that manganese concentrations in the mg/L range can be found in anaerobic bottom waters where manganese has been mobilized from the sediments. High concentrations of manganese interfere with the central nervous system of vertebrates by inhibiting dopamine (a neurotransmitter) formation as well as interfering with other metabolic pathways. Sodium regulation in fish is disrupted by manganese and may ultimately cause death. Sub lethal gill damage has been observed in some fish exposed to 0.1 - 0.5 mg/L. Manganese is lethal to stickleback (*Gasterosteus aculeatus*) when exposed to 40 mg/L Mn^{2+} (DWAF, 1996). Tolerance to manganese depends on total water chemistry, such as pH. DWAF (1996) suggested < 0.1 mg/L of Mn for freshwater aquaculture. Meade (1989) and Zweig *et al.* (1999) recommended that manganese should not exceed 0.01 mg/L for all aquaculture species.

Copper

Copper is a micronutrient, forming an essential component of many enzymes involved in redox reactions, and is an essential trace element for plants and animals. Copper (Cu) is used in antifouling paints, applied to boats and submerged structures. In addition, copper is used as fungicides and algaecides. These uses, as well as copper mining activities are the major source of copper contamination in the aquatic environment (Zweig *et al.*, 1999). The most common copper species in natural waters are the free (cupric) ion (Cu^{2+}), copper hydroxide and carbonate complexes, while it also forms strong complexes with dissolved organic matter. The latter complexes usually control the aqueous copper and/or cupric ion concentration in freshwater systems. Free cupric copper ions (Cu^{2+}) are considered most toxic and complex forms least toxic to aquatic organisms. (Zweig *et al.*, 1999). DWAF (1996) stated that the toxicity of copper depends on the solubility and chemical species of the copper present in the water. Its toxicity is strongly influenced by the physico-chemical properties of the water. In water with high dissolved organic content, copper can become bound in soluble and insoluble complexes, with reduced toxicities. Svobodova *et al.* (1993) noted that compounds that are slow to dissolve or are insoluble are unlikely to be taken up to any extent into the fish body, so their toxicity to fish is low. Although copper is highly toxic to aquatic organisms, its compounds are used in fish culture and fisheries as algaecides and in the prevention and therapy of some fish diseases (Svobodova *et al.* 1993).

Iron

Iron is an essential element in human nutrition. The most common sources of iron in groundwater are naturally occurring, for example from weathering of iron bearing minerals and rocks. Industrial effluent, acid-mine drainage, sewage and landfill leachate may also contribute iron to local groundwater. Estimates of the minimum daily requirement for iron depend on age, sex, physiological status and iron bioavailability and range from about 10 to 50 mg/day (Asklund and Eldvall, 2005). In drinking-water supplies, Fe (II) salts are unstable and are precipitated as insoluble Fe (III) hydroxide, which settles out as a rust-coloured silt. Anaerobic groundwater may contain Fe (II) at concentrations of up to several milligrams per litre without discolouration or turbidity in the water when directly pumped from a well. Turbidity and discolouration may develop in piped systems at Fe levels above 0.05-0.1 mg/L, whereas levels of 0.3-3 mg/L are usually found acceptable. As a precaution against storage of excessive iron in the body a provisional maximum tolerable daily intake was calculated to about 2 mg/L drinking water, (WHO, 1996). That level does not present a hazard to health, although iron concentrations of 1-3 mg/L can be acceptable for people drinking anaerobic well-water (WHO, 1996). The WHO (2004) prescribes 0.3 mg/L as the limited Fe level allowable in water for drinking and domestic purposes.

Cadmium

Cadmium (Cd) is a highly toxic metal that is used in a variety of industrial processes including electroplating, nickel plating, smelting, engraving and battery manufacturing (Zweig *et al.*, 1999). Inorganic (e.g. phosphate) fertilizers, reclaimed sewage sludge, municipal sewage effluents, and zinc are important sources of cadmium contamination (Zweig *et al.*, 1999). Cadmium is usually associated with zinc in surface waters, but at much lower concentrations (Svobodova *et al.*, 1993). Background levels of cadmium in natural freshwaters are usually very low, generally ranging from 0.0 to 0.13 ppb (0.00013 mg/L) (Zweig *et al.*, 1999). According to Svobodova *et al.* (1993), of the dissolved forms, those which may be toxic to fish include the free ion and various inorganic and organic complex ions. Cadmium is of particular concern to aquaculture as it bio-accumulates (DWAF, 1996). Apart from an acute toxic action which is similar to that of other toxic metals (damage to the nervous system); very small concentrations of cadmium may produce specific effects after a long exposure period, especially on the reproductive organs (Svobodova *et al.*, 1993). Cadmium toxicity is reduced with increasing levels of calcium and magnesium in the water (i.e. the harder the water the lower the toxicity). A similar relationship exists between cadmium and alkalinity. At high water temperatures, cadmium levels increase and fish survival decreases under low dissolved oxygen conditions. Additive (synergistic) effects have been found with cadmium and copper and with cadmium and mercury, while cadmium toxicity is lowered in the presence of sub-lethal concentrations of zinc (DWAF, 1996).

Lead

Major sources of lead (Pb) to aquatic systems include atmospheric deposition of exhaust emissions, improper disposal of batteries, lead ore mine wastes and lead smelters, sewage discharge, storm water runoff, and agricultural runoff from fields fertilized with sewage sludge (Zweig *et al.*, 1999). Lead forms sulphate and carbonate precipitates, while it also complexes with organic and particulate matter (Zweig *et al.*, 1999). Concentrations of dissolved lead are generally low due to either precipitation of carbonate species or adsorption to particulates, and natural background concentrations rarely exceed 20 ppb (0.020 mg/L) (Dojlido and Best, 1993). Chronic lead toxicity in aquatic organisms leads to nervous system damage while acute toxicity causes gill damage and suffocation (Svobodova *et al.*, 1993). Chronic lead toxicity is easily identified in fish by the blackening of the fins (Dojlido and Best, 1993). The toxicity of lead is dependent on the alkalinity, hardness and pH of the water. Toxicity is decreased by high alkalinity (that is, high calcium carbonate) because calcium carbonate competes for uptake at the gill surface (Lloyd, 1992). The solubility of lead and thus its toxicity is lower in hard waters than in soft waters (Dojlido and Best, 1993). For the same reason, lead toxicity is higher at lower pH levels which would be common particularly at pond bottoms and among benthos and nutrients (Svobodova *et al.*, 1993).

Zinc

Zinc (Zn) enters surface waters primarily as a result of discharges from metal treatment plants, chemical plants and foundries (Dojlido and Best, 1993), while mining can also be a major source (Zweig *et al.*, 1999). In low alkalinity waters, the predominant forms of zinc are the free ion (Zn^{2+}) and hydroxide complexes, while carbonate and sulphate complexes dominate in high alkalinity waters (Zweig *et al.*, 1999). At high pH Zinc can precipitate as zinc hydroxide and co-precipitate with calcium carbonate (Dojlido and Best, 1993). Zinc forms complexes with organic and particulate matter. Natural background concentrations of zinc are generally low, ranging from 5 to 15 ppb (0.005 to 0.015 mg/L) (Moore and Ramamoorthy, 1984). Zinc toxicity is synergistic with copper, and zinc is more toxic in soft water (Lloyd, 1992). Svobodova *et al.* (1993) considered that avoiding the use of galvanized pipes, containers and equipments for the supply of water especially in soft and acid waters, is the best remedy to avoid frequent occurrences of zinc toxicity in rainbow trout culture. The clinical symptoms of zinc poisoning in fish are similar to those found for copper (i.e. gill damage, reduced growth and kidney damage). There is very little evidence to indicate any significant human health effect of zinc. Zinc concentrations less than 100 ppb had little effect on oyster larvae *(Ostrea edulis)*, but concentrations of 300 ppb considerably reduced larval growth, and at concentrations of 500 ppb larvae either died or failed to metamorphose (Milne, 1972). The LC_{50} (48-96 hours) varies between 0.5 and 5 mg L^{-1}

for fish (Moore and Ramamoorthy, 1984). The USEPA (1993) suggested for freshwater aquaculture a level of < 0.11 mg/L, and < 0.086 mg/L for saltwater aquaculture. Meade (1989), on the other hand, suggested a conservative level below 0.005 mg/L for aquaculture species.

Phosphates

Phosphate is not generally recognized as toxic to aquatic organisms, however, it is an important plant nutrient which can assist in stimulating the growth of nuisance organisms, particularly algae in fresh and brackish waters (DWAF, 1996). High levels may be present in ponds or tanks through the addition of inorganic fertilizers to assist in promoting micro-algal growth as food for zooplankton which, in turn, acts as a feed source for larval fish, molluscs and crustaceans (SECL, 1983). Phosphorus is a major component of nucleic acids and molecules involved in the storage and use of energy in cells, it is an essential dietary requirement of all organisms (SECL, 1983). Symptoms of phosphorus deficiency include poor appetite accompanied by depression of growth. Decreased bone calcification and cranial and skeletal deformities have been noted in some species (Viola *et al.*, 1986). The source of dietary phosphorus is important as phosphorus of plant origin is not as available as that from animal sources. Natural dissolved phosphates are considered to be largely non-toxic, although certain manmade organophosphates do have toxic effects. It is, however, likely that high concentrations of dissolved phosphate may lead to osmotic stress, as is the case with high nitrate concentrations (Viola *et al.*, 1986). DWAF (1996) recommended a guideline of < 0.1 mg/L for freshwater farm species.

Nitrate

Nitrate is the least toxic of the major inorganic nitrogen compounds (Zweig *et al.*, 1999). As it is the end-product of the nitrification process, the concentration of nitrate is generally higher than both ammonia and nitrite (Zweig *et al.*, 1999). The main sources of nitrate pollution in surface waters are the use of nitrogenous fertilizers and manures on arable land leading to diffuse inputs, and the discharge of sewage effluents from treatment works (Svobodova *et al.*, 1993). Nitrate is not recognized generally as being toxic to aquatic animals (SECL, 1983). However, high nitrate concentrations (i.e. much higher than toxic concentrations of ammonia or nitrites) can impair osmo-regulation and oxygen transport (Lawson, 1995). High nitrate levels can result in eutrophication and excessive nuisance algal and plant growth (Zweig *et al.*, 1999). This can have negative effects on culture species and can result in deaths due to changes in oxygen/carbon dioxide levels. CCME (2006) recommended that nitrate levels that stimulate prolific weed growth should be avoided. High nitrate levels can be a sign that nitrification (conversion of ammonia to nitrate by certain bacteria of the genus *Nitrobacter*) is occurring which is helping to reduce the levels of toxic ammonia. Nitrate is known to accumulate to high levels in recirculation systems as an end-product of nitrification. Through the process of de-nitrification it can be converted to N_2 gas, so high nitrate levels can indicate that de-nitrification is not occurring. High nitrate levels (e.g. > 50 mg/L) could be a potential problem under conditions of low dissolved oxygen and high pH, both of which could be further lowered by an algal bloom stimulated by the excess nitrate (Zweig *et al.*, 1999). Meade (1989) recommended on a species-specific level, and suggested a level of < 3.0 mg/L for aquaculture.

2.2. Plankton

Plankton refers to those microscopic aquatic organisms having little or no resistance to currents and living free-floating or suspended in open or pelagic water (APHA, 2005). Planktonic organisms are ideal subject for theoretical and experimental population ecology due to several favourable features such as small size, short generation time and a relatively homogenous habitat (Rothhaupt, 2000). The photoautotrophic microscopic plants make up the phytoplankton while the nutritionally dependent microscopic animals make up the zooplankton (Boney, 1989; Gupta and Gupta, 2006). The productivity of any water body is determined by the amount of plankton it contains as they are the major primary and secondary producers (Davies *et al.*, 2009). The study of plankton (phytoplankton and zooplankton) is very important because they serve as a base upon which the aquatic ecosystem is supported. Phytoplankton (singular, phytoplankter) are primary producers while zooplankton (singular, zooplankter) are secondary producers. Phytoplankton serve as food to zooplankton which in turn serve as food to almost all larval forms in natural surface water. Many scientists including Adeogun *et al.* (2005); Fafioye *et al*. (2005); Onyema (2007); Adesalu and Nwankwo (2008); Atobatele and Ugwumba (2008); Davies and Ansa (2010); Nkwoji *et al*. (2010); Adejuwon and Adelakun (2012) and Ogbuagu and Ayoade (2012) have worked on the various aspects of ecosystem studies of rivers, reservoirs, lakes, creeks and estuaries in Nigeria.

Phytoplankton are plants (microscopic), drifting at the mercy of water current (Anene, 2003). Walmsley and Reynod (1980) reported that although phytoplankton are at the mercy of water current, most are slightly heavier or lighter than water and therefore show some vertical movement relative to the surrounding media. They also respond quickly to environmental changes because of their short life cycle. Phytoplankton communities are essential components of all aquatic environments because primary production by phytoplankton forms the base of food chains and webs in water. Therefore, they are of great importance in aquaculture and fisheries (Oben, 2000; Davies *et al.,* 2009). They convert incident radiant energy of the sun to chemical energy in the presence of nutrients like phosphorous, nitrogen, iron, manganese, molybdenum and zinc. Their distribution, abundance and diversity reflect the physico-chemical conditions of aquatic ecosystem in general and its nutrient status in particular (Anene, 2003). Davies *et al*. (2009) reported that phytoplankton communities are major producers of organic carbon in large rivers, a food source for planktonic consumers and may represent the primary oxygen source in low-gradient rivers. They also said that phytoplankton is of great importance in bio-monitoring of pollution. The distributions, abundance, species diversity, species composition of phytoplankton are used to assess the biological integrity of the water body (Townsend *et al*., 2000). They are also important in estimating potential fish yield (Hecky and Kling, 1981), productivity (Park *et al.*, 2003), water quality (Walsh *et al.,* 2001), energy flow (Simciv, 2005), trophic status (Reynolds, 1999) and management (Beyruth, 2000).

Oben (2000) reported that the phytoplankton communities of three man-made lakes in Ibadan was dominated by blue-green algae which are indicative of a high pollution load followed by green algae while diatoms were least abundant. The freshwater zone of Warri has been reported to contain a rich and diverse flora of tropical desmids. The major sectors in which the desmids were found were limited largely to water with conductivities below 100 µS/cm (Opute, 2000). The Desmidaceae (a family of green algae) are typically characteristic of acidic water and oligotrophic waters (Opute, 2000). Adeniji (1991), in his study of the limnological and biological production of Jebba Lake observed five major groups of phytoplankton; Chlorophyta, Euglenophtyta, Chrysophyta, Pyrrophyta and Cyanophyta. These groups were made up of 42 species. He observed that most of the phytoplankton groups studied showed seasonal variation with peak abundance in April and May.

Zooplankton communities of fresh water bodies constitute an extremely diverse assemblage of organisms represented by most of the invertebrate phyla, however, the dominant zooplankton includes rotifers, cladocerans, copepods and ostracods and their distribution and diversity are influenced by seasonal variations of physicochemical properties, biotic factors including feeding ecology and predation pressure (Edmonson, 1965; Egborge, 1994). Zooplankton as a biotic component of the aquatic ecosystems play a key role in cycling of organic materials, helping in regulating algal and microbial productivity through grazing, as suspension feeders and predators in the transfer of primary productivity to fish and other consumers (Dejen *et al*., 2004). They often exhibit dramatic changes in response to the changes in the physicochemical and biotic properties of the aquatic environment hence are good bio-indicators for the assessment of trophic state of water (Vilela *et al*., 2003; Imoobe and Adeyinka, 2010).

Zooplankton actually or potentially exerts both subtle and gross effects on phytoplankton populations, which in turn have a prime bearing on water quality (Mavuti, 1990). Clarke (1978) found out that Kainji Lake was richer in zooplankton population than the rivers flowing into it and concluded that the poor zooplankton fauna of rivers could be attributed to low nutrient concentration and poor sunlight penetration. Owili (1999) reported that cladocerans are more vulnerable to fish predation than copepods and rotifers due to their large size and slow mobility. Among zooplankton species, calanoid crustacean species richness has been reported to be lower in eutrophic water than in oligotrophic waters. However, higher abundance of Cladocerans found in tropical eutrophic water might be as a result of their shorter developmental times when compared with copepods that enable them to exploit unstable and changing environments. These systems often experience bloom of cyanobacteria and floating macrophytes. The increase in macrophytes beds creates a variety of new habitats favourable to zooplankton (Pinto-Coelho *et al.*, 2005). In tropical lakes and reservoirs, fish predation is known to be a key factor structuring zooplankton communities and the strong dominance of small copepods and cladocerans in tropical lakes and the disappearance of large cladocerans may be due to high densities of zooplanktivorous fish (Pinto-Coelho *et al.*, 2005).

Studies on the identification of Nigerian planktonic organisms include those of Oke (1998) who reported the presence of 60 species of plankton in the Owena Reservoir: *Gonatozygon*, *Plueroteanium* and *Richterella* dominated the Chlorophyceae; *Nitzchia* and *Synedra* dominatied the Bacillariophyceae; *Oscillatoria* and *Phormidium* dominated the Cyanophyceae; *Keratella* and *Copelopagis* dominated the Rotifera while *Mayorella* and *Trinema* dominated the Protozoa. He also reported significant correlation of seasonal variations of the abundance of the major groups of phytoplankton and zooplankton and suggested that this was an indication of similarity in the distribution pattern and abundance of both plankton communities. Therefore, information on plankton as indicator is interpreted best in conjunction with concurrently collected physicochemical and other biological data.

2.3 Benthic Macroivertebrates

The benthic environment has been defined as the bottom environment with distinct physical and biological characteristics (Walsh, *et al.*, 2001). Benthic organisms have been defined as those living in or on the substratum of lakes, streams, estuaries and marine waters (Hutchinson, 1967; APHA, 1992). Macrobenthic invertebrates are important components of the ecosystems, directly processing a significant portion of system-wide primary production, and providing an important food resource for crustaceans, fish and birds (Herman *et al.*, 1999). According to Wilson (1994) benthic organisms can be described as bio-indicators in three ways:

1) Indicators of a defined set of environmental conditions;

2) Indicators of contaminant loads on the system; and

3) Indicators of the overall health of the system.

Currie and Small (2006) summarized the multiple biotic, abiotic and human-induced factors that affect macrobenthic invertebrates:

1) Physical influences include water depth, sediment structure, salinity and hydrology;

2) Biological factors include predation, competition and recruitment;

3) Human-induced factors include organic enrichment, chemical pollution and commercial fishing activity.

As a result of these influencing factors, macrobenthic invertebrate distribution often exhibits high spatial variability (Ysebaert *et al.*, 1998; Dittmann *et al.*, 2006). Precipitates and chemical substances in suspension or dissolved in freshwater eventually gets deposited on sediments through sedimentation, bio-turbation, diffusion, adsorption and re-suspension processes. Consequently, sediments serve as a sink and a source of organic and inorganic materials in the body of water. These substances therefore become highly concentrated in the benthic area (Miller, 1998; Odiete, 1999). Benthic macro-invertebrate assemblages are structured according to physical and chemical parameters that define microhabitats, including food supply, shelter to escape predators and other biological parameters that influence reproductive success (Silveria *et al.*, 2006). Benthic macro-invertebrates play an integral role in the aquatic food web and are useful indicators of ecosystem health of lakes (Sekiranda *et al.*, 2004; Moreno and Callisto, 2006). The composition and abundance of benthic macro-invetebrate have been noted to depend on substratum, depth, vegetation, distance from shore, season and trophic status of lakes (Sekiranda *et al.*, 2004). According to APHA (2005), three situations for which patterns of macro-invertebrate community structure changes are organic loading, substrate alteration and toxic chemical pollution. Severe organic pollution usually results in a restriction in the variety of macro-invertebrates to only the most tolerant ones and a corresponding increase in density of those tolerating the pollution condition.

Over several decades, many investigators including Oladimeji and Wade (1984), Mason (1992) and Odiete (1999) have found that there is a good relation between water quality and the presence or absence of certain benthic invertebrates depending on their sensitivities. Sekiranda *et al.* (2004) suggested that taxonomic and structural compositions of benthic macro-invertebrates are good predictors of water quality status. Moreno and Callisto (2006) reported that benthic macro-invertebrate richness and diversity are high during the rainy season than the dry season and attributed it to organic pollutant, sewage and runoffs from industrial and agricultural lands.

Freshwater benthic macroinvertebrates include representatives of many insect orders, as well as crustaceans, gastropods, bivalves and oligochaetes (Merritt, *et al.*, 2008), and they contribute to many important ecological functions, such as decomposition, nutrient cycling, as well as serve an important role in aquatic food webs as both consumers and prey (Moore, 2006). However insects are often the dominant group of benthic macroinvertebrates in both absolute numbers and species diversity, which is not surprising given that the juvenile stages of many terrestrial insects are typically aquatic (Merritt *et al.*, 2008). Tubificid worms and the larva of the midge, *Chironomus* tolerate organically polluted waters while *Eristalis* larva (the rat-tailed maggot) inhabits places most highly polluted with organic matter (Odiete, 1999). *Tubifex* is known to survive anaerobic conditions for weeks because they have a high affinity respiratory pigment adapted for respiration in oxygen-deficient condition called myoglobin. *Chironomus* larva has blood gills in addition to myoglobin. *Eristalis* can tolerate anaerobic conditions by extending its very long tail, an air breathing tube to reach the surface of the water. In a like manner, Psychoda and Telmatoscopus larvae have negative phototaxis, ability to migrate vertically in the water column in addition to the ability to alternate from a planktonic to a benthic life habit. These characteristic allow them to easily relocate in search of food and better oxygen conditions, which enrich their survival conditions (Moreno and Callisto, 2006). Chaoborus larvae are predacious and feed largely on crustaceans and rotifers and migrate between the mud and upper water. Chironomid larvae are often important as feeder on the bottom sediments. Their pupae rise to the surface and become temporarily planktonic (Beadle, 1981).

2.4 Fish Fauna

Fishes, the most popular and valued living resources in the aquatic environment are an important source of food and recreation. They are key unit in many natural aquatic food webs and can also serve as environmental indicators of polluted water (APHA, 1998). According to Idodo-Umeh (2003), Nigeria fresh water are the richest in West Africa in terms of fish species. Other works on composition and distributions of fauna in Nigeria water bodies include Offem and Akegbejo-Samsons (2009) in Cross River, Ayoola and Kuton (2009) in Lagos Lagoon and Soyinka and Kassem (2008) in Ologe Lagos Lagoon, Southern Nigeria.

The dominant factors that affect fish distribution in the aquatic environment are often temperature, dissolved oxygen, pH, salinity and water movement (Boyd, 1982). Nevertheless, temperature has effect on the rate of metabolism and consequently on the rate of feeding, growth and reproductive activities (Crillet and Quetin, 2006). In order to obtain a maximum fish yield from a body of water using the minimum effort and without depleting adversely the available stock, a knowledge of the general biology of resident fishes is essential (Fawole, 2002). This is because fish species are often conspicuous primary indicators of the toxification of streams and lakes (APHA, 2005). Lawson and Olusanya (2010) were of the view that fisheries resources are on the decline in Nigeria due to over exploitation and inadequate management of the waters. For sustainability of these resources, an adequate knowledge of species composition, diversity and relative abundance in the water bodies must be understood and vigorously pursued.

2.4.1 Fish Species Diversity

Ita (1993) reported that Nigerian fish fauna reveals about 511 families. About 34% of these species are restricted to EEZ while approximately 44% are freshwater fisheries inhabiting water of very low salinities (below 1 part per thousand or conductivity of 1000µs/cm). The presence of *Potamotrygeon garouensis* in the waters of northern Nigeria (Obasohan and Oronsaye, 2006) and river Ase in Delta State of Nigeria (Idodo-Umeh, 2003) are of scientific interest because *P. garouensis* is a ray fish of the family Dasyatidae. These species which occur in both the brackish and freshwaters are unique and so require protection. The most important fishes in terms of species diversity are the teleosts (Obasohan and Oronsaye, 2006). The families Carangidae and Characidae are the most abundant with 22 and 20 species respectively (Egborge, 1994); the majority of the Carangidae are marine while the Characidae are mostly freshwater except species of Myletes (*M. guile and M. nurse*) which are brackish (Obasohan and Oronsaye, 2006). Among the Carangidae only *Trachinotus goreensis*, a marine species has been reported in southern freshwaters in Lekki lagoon (Ikusemiju and Olaniyan, 1977) and Oguta Lake (Nwadiaro, 1984). These species appear restricted in distribution and therefore need to be protected. The Mudskipper, *Periopthalmus papillio* (Family Periopthalmidae) is a fish of great biological and evolutionary significance. The continued existence of these fish is seriously threatened by pollution (Obasohan and Oronsaye, 2006).

Welman (1948) identified 181 species of fish from the major river systems and Lake Chad including some estuarine and marine species which are frequent in the rivers. Banks *et al.* (1965) identified and described about 139 species of fish in River Niger within the then proposed Kainji Reservoir Basin. Reed *et al*. (1967) reported about 160 species within the Northern region of Nigeria. Since then numerous studies have been undertaken in Kainji Lake and other freshwater bodies leading to the description of many species (Ita, 1978: Idodo-Umeh, 2003). Obasohan and Oronsaye (2006) recorded 239 fish species and there are at least 18 of such freshwater species which are endangered (Table 2.1). A drastic decline has been observed among larger species such as *Gymnarchus niloticus, Lates niloticus, Heterobranchus bidorsalis and Protopterus annectus* as reported by Obasohan and Oronsaye (2006). Members of the Cichlidae are generally widespread in Nigerian freshwaters, but a few are however of restricted distribution. *Barbus nigeriensis, Barilius ogunesis* and *Labeo ogunensis* appear endemic having only been reported in Nigeria (Obasohan and Oransoye, 2006). For this reason and their restricted distribution, they need to be protected. Several studies suggest that after disturbances, species composition can recover to levels similar to the pre-disturbances, but it all depends on the colonization of the affected area by natural recruitment through reproduction (Meffe and Sheldon, 1990).

Table 2.1: List of some of the Endangered Freshwater Fishes in Nigeria.

S/No	Family	Species	Water body
1.	Albulidae	*Albula vulpes*	Warri River
2.	Amphilidae	*Phractura clauseni*	Ogun River
3.	Carangidae	*Trachinotus goreensis*	Niger/Benue
4.	Centropomidae	*Lates niloticus*	Widespread
5.	Cromeridae	*Cromeria nilotica*	Niger/Benue
6.	Gymnarchidae	*Gymnarchus niloticus*	Widespread
7.	Hepsetidae	*Hepsetus odoe*	Widespread
8.	Lepidosireniidae	*Protopterus annectens*	Fair Distribution
9.	Lutjanidae	*Lutjanus sp*	Cross River
10.	Mastacembelidae	*Mastacembelius loennbergii*	Fair Distribution
11.	Malapteruridae	*Malapterurus electricus*	Widespread
12.	Nandidae	*Polycentropsis abbreviata*	Fair Distribution
13.	Ophiocephalidae	*Paraophiocephalus africana*	Oguta Lake
14.	Osteoglossidae	*Heterotis niloticus*	Widespread
15.	Pantodontidae	*Pantodon butcholzi*	Fair Distribution
16.	Phractolaemidae	*Phractolaemus ansorgii*	Fair Distribution
17.	Synbranchidae	*Synbramchus afer*	Ethiope River
18.	Trigonidae	*Trigon margrarita*	Epe Lagoon
Estuarine and marine moving up rivers			
19.	Pristidae	*Pristis perrottetis*	Niger/Benue

20.	Trigonidae	*Potamotrygon garouensis*	Niger/Benue
21.	Monodactylidae	*Monodactylus sebae*	Niger/Benue

Source: Obasohan and Oransoye (2006)

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study area

Ibuya River is located in the Old Oyo National Park. The park is in Sepeteri in Oyo in the southwestern Nigeria. It covers a land area of approximately 2,512 sq. km making it the fourth largest park in Nigeria. It lies between North latitude $8^0.10'$ - $9^0.05'$N and longitude $3^0.00'$ - $4^0.20'$E (Fig. 3.1). The park is about 120 km long from the southwest to the northeast and about 50 km at its widest in the south (Plate 3.1). Most parts of the park are lowland plains, undulating and vegetative from 300 m to 500 m above sea level. A sizeable portion of the park is the Ibuya River (Plate 3.2) ajoining two river systems; the Ogun River flowing to the Atlantic Ocean (Plate 3.3) and the Tessi flowing to the River Niger (Plate 3.4). Several tributaries flows to join these two main rivers respectively. Annual rainfall in the Park range between 900 mm and 1500 mm and main annual temperature is between 12 ^{0}C and 37 ^{0}C. The park has diverse wildlife and cultural/historical settings. The abundance of cultural features both within and outside the park makes it a combination of an ecological, cultural/historical park.

3.2 Sampling stations

Four sampling stations with distance of 5.40 km part were chosen for the studies on physico-chemical parameters, plankton and macrobenthos.

Station 1: Area around the entrance of the Ogun River within the southwest part of the river where activities like fishing, bathing, cloth washing, sales of fuel (petrol station), block moulding and cassava processing takes place.

Station 2: Vegetative area around the central basin of the river within the park where wild life, tourist and research activities takess place

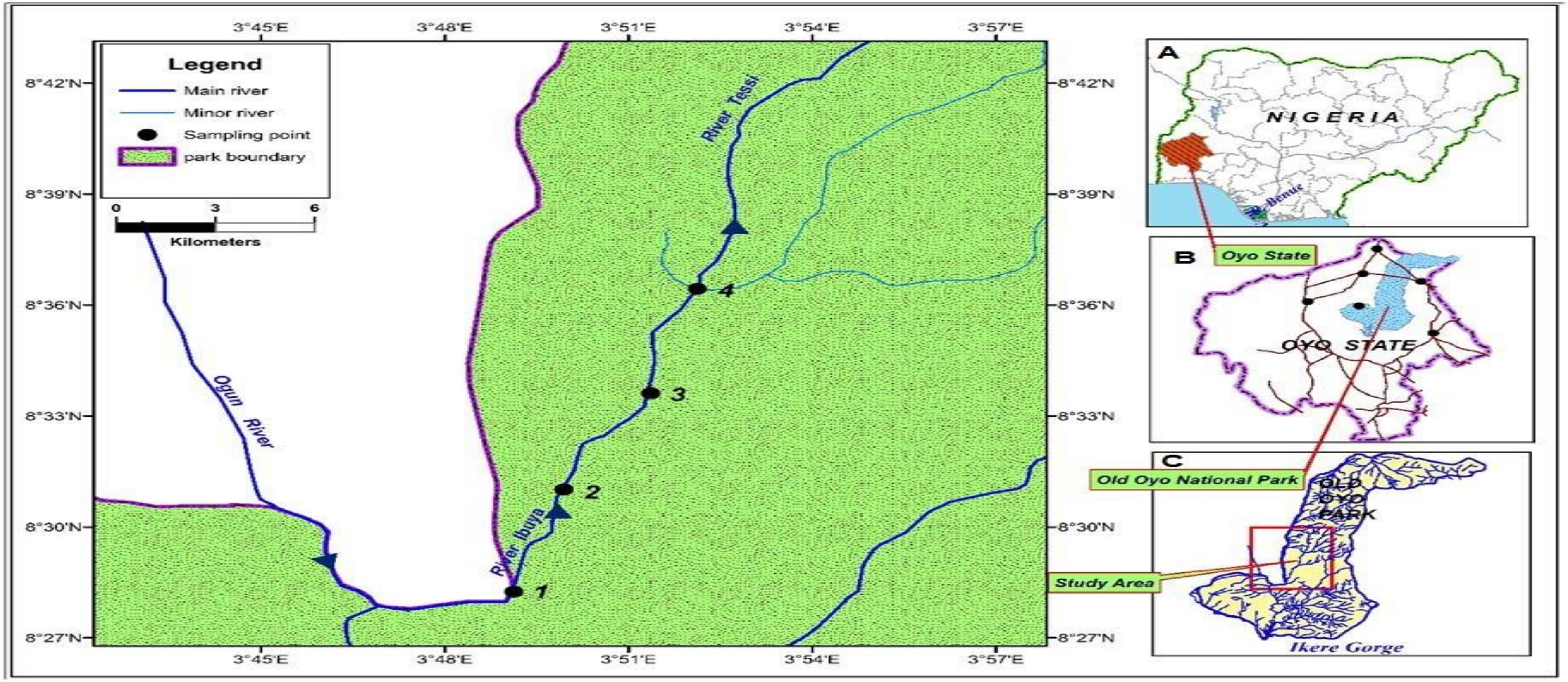


Fig. 3.1: Map of Ibuya River showing sampling stations

Key: Point 1 – 4 are stations 1 - 4

A = Map of Nigeria;

B = Map of Oyo State;

C = Map of Old Oyo National Park

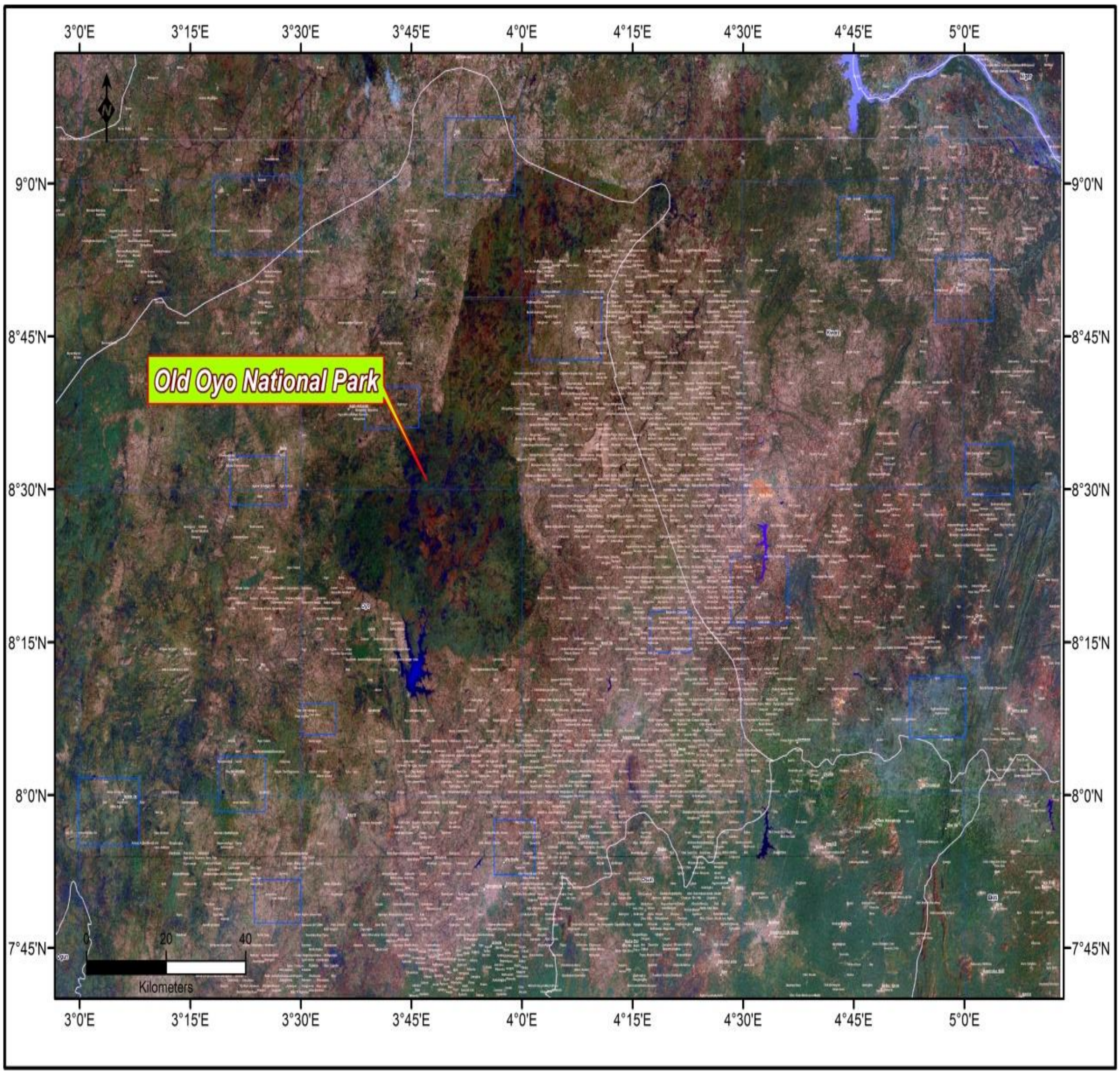


Plate 3.1: Satellite Image of Old Oyo National Park showing mangrove vegetations and Ibuya River

Plate 3.2: Central basin of Ibuya River showing vegetation

Plate 3.3: Entrance of Ogun River into River Ibuya showing vegetation

Plate 3.4: Rocky part of River Ibuya joining River Tessi

Station 3: Vegetative area around the central basin of the river within the park, wild life tourist and research activities also takes place here

Station 4: Rocky part of the park where the River joins River Tessi

3.3. Sample collection and analysis

Samples were collected for 18 months between September 2012 and February 2014 in the morning hours between 7 and 10 am covering the wet and dry season. One-liter containers were used to collect water samples for physico-chemical parameters at each station. Samples for plankton and macrozoobenthos analysis were collected from each sampling station along with survey of fish fauna. A total of twenty-one parameters were measured in-situ (Water temperature, pH, Dissolved Oxygen (DO), Transparency and Conductivity) and in the laboratory (hardness, turbidity, alkalinity, heavy metals and nutrients).

3.3.1. Physicochemical Parameters

The physicochemical parameters was determined following standard protocols (APHA, 2005).

Temperature:

The atmospheric air and water temperatures were determined using a mercury-in-glass thermometer which was held in the air for 3 minutes. Reading was taken, recorded and expressed in °C. The thermometer was also inserted to a depth of 5 cm into water for 3 minutes as described by Hira (1966).

pH

The pH was determined with portable pH meter (model pH-012). The pH meter was standardized using prepared buffer solutions of pH 4.00, 7.00 and 9.00. The probe was inserted into the water and readings taken immediately after stabilization of the meter.

Dissolved oxygen:

Portable dissolved oxygen meter (model: ExStik DO600) was used to determine the dissolved oxygen concentration in the different stations. The meter was standardized using prepared buffer solutions. The meter was set at zero point, inserted in the water and readings taken and recorded.

Conductivity:

Conductivity was determined with portable pH/TDS/Conductivity measuring instrument (model: ExStik EC500). The meter was standardized using prepared buffer solutions. The meter was set at zero point, lowered into the water body and reading taken immediately the timer stabilized.

Total dissolved solids (TDS):

Total dissolved solid was also determined with portable pH/TDS/Conductivity measuring instrument (model: ExStik EC500). The meter was standardized using prepared buffer solutions. The meter was set at zero point, lowered into the water body and reading taken immediately the timer stabilized.

Total hardness:

- For Total Hardness, 50 ml of water sample was measured into a conical flask and 4 ml of ammonium chloride buffer solution was added to achieve pH 10. Two drops of eriochrome black -T- indicator was added to the solution. The colour of the resulting solution turns red indicating the presences of Ca and Mg ions. Immediately, it was titrated with 0.01M EDTA solution with continuous stirring to a light blue colour as the end point.

Calculations:

- **Total hardness (mg/L)** = $\frac{\text{Vol. (ml) of 0.01M EDTA x 1000}}{\text{Vol. of Sample (ml)}}$

Alkalinity:

100 ml of water sample was measured into a conical flask, few drops of phenolphthalein indicator was added and the colour turns pink. The solution was titrated against 0.02 N sulphuric acid till the pink colour disappears. Two drops of Methyl organe indicator was

added to the solution and continue the titration till the solution becomes red for total alkalinity.

Calculations:

- **Alkalinity (mg/L $CaCO_3$)** = A x M x 50000/Volume of sample (ml)

Where A = volume (ml) of standard acid used and

M = Molarity of standard acid.

Transparency:

Transparency was determined by the use of a 25 cm diameter Secchi disc. The procedure involves lowering the disc down into the water until it is no longer visible, noting the depth on the calibrated line, pulling the disc up until it is visible again, and noting the depth a second time. The Secchi disc transparency is the average of these two depths, rounded to the nearest cm and recorded.

Turbidity:

Turbidity determination was carried out using UV visible absorption spectrophotometer (model: Jenway 6305). Blank solution was prepared without the addition of the sample. The absorbance of blank and FTU working solutions were measured with visible spectrophotometer at a wave length of 580 nm. The absorbance of water sample to which no reagent was added was also measured. The sample was thoroughly mixed to disperse the solids and waited till the air bubbles disappear, then the sample was poured into the turbidimeter tube. Turbidity was directly read from the instrument scale or the calibration curve.

Determination of heavy metals

Water samples were digested in triplicates according to the method described by (APHA, 2005). 10 ml of the filtered water were digested with 3 ml of concentrated nitric acid at 100°C with the addition of 3 drops of hydrogen peroxide until there was no brown fumes. The mixture was filtered using whatman 0.45µm filter paper in a 100 ml volumetric flask and topped with distilled water for aspiration into the flame atomic absorption spectrophotometer. The sample solutions were then introduced into the flame and their absorbance values were used to calculate the concentration. The concentrations of Magnesium (Mg), Manganese (Mn), Iron (Fe), Copper (Cu), Zinc (Zn), Cadmium (Cd), and Lead (Pb) in the samples of water were determined with Buck Scientific Atomic Absorption Spectrophotometer (AAS) (model 210/211 VGP) with wave length (nm) of (285.2, 279.5, 248.3, 324.8, 213.9, 228.9 and 217.0); detection limit (mg/L) of (0.005, 0.003, 0.003, 0.001, 0.006, 0.004 and 0.004); and sensitivity check (mg/L) of (0.75, 1.25, 2.50, 2.0, 0.5, 0.75 and 5.0) respectively according to the standard method of AOAC (2010).

3.3.2 Plankton sampling and analysis

Plankton net of mesh size 55µm was used to collect plankton samples from just below the water surface, towing was for 30 minutes. The content was emptied into plastic container and fixed immediately with 4 % formalin in the field (Onyema, 2007). The samples were transported to the Hydrobiology and Fisheries Laboratory, University of Ibadan for plankton analysis. After 48 hrs in the laboratory, the preserved plankton samples were concentrated to 10 ml (Nwankwo, 1984). The plankton sample was then agitated and 1 ml subsample was withdrawn into a petri dish using a bulb pipette and observed under the microscope at different magnifications (X100 and X400). Appropriate text were used to aid identification (Prescott, 1954; Whitford and Schumacher, 1973; Jeje and Fernando, 1986; Needham and Needham, 1969; and Nguetsop, 1990). The drop count method described by NIO (2004) was used for plankton calculation.

3.3.3 Macrozoobenthic sampling and analysis

The benthic samples were collected using Van-Veen grab with surface area of 0.086 m^2 from each station. At each station, sediment was collected and diluted with water and sieved with 2.0 mm and 3.18 mm mesh size sieves (Holme and Mclntyre, 1984; George *et al.*, 2009). The residuals retained on the screens of the sieves were washed into a shallow white tray with water for sorting. The sorted macrobenthos were preserved in 4% formalin in glass jars. The individual organisms were identified macroscopically using identification guides (Macan, 1959; FAO, 1981; Brown, 1994; Edmunds, 1978; and APHA, 2005).

3.3.4 Fish fauna

Fish species caught with gill net of mesh size 45 mm were identified and counted in the field to the lowest possible taxonomic level using Reed *et al.* (1967); Ita (1993);

FAO (1992), Holden and Reed (1972) Idodo-Umeh (2003) and Olaosebikan and Raji (2013).

3.4 Quality assurance/Quality control

- All glasses and plastic containers were washed with detergents and thoroughly rinsed.
- Meters were properly calibrated with calibration solution before reading was taken
- Triplicate of water samples were collected consecutively from the water body in order to increase precision.
- Samples for plankton analysis were immediately fixed with 4 % formalin for preservation
- All samples containers were labelled with time, date and site of collection
- Samples were transported to the laboratory for analysis
- Standard laboratory procedures were ensured
- Water used for analytical purposes were deionized (distilled water).
- Purity of reagents was ensured to protect against contamination by glassware cleaning, water purity and technical procedures in the preparations.

3.5 Data and statistical analysis

Microsoft Excel was used for graphical illustrations. Shannon-Wiener diversity index and evenness were determined (Shannon and Wiener, 1949). Data analysis was done using descriptive statistics. Correlation coefficient (r) was used to determine the relationships existing between the variable of physicochemical parameters of the water and plankton and macrobenthos abundance. Factors were extracted using the Principal Component Analysis (PCA) (STATISTICA software version 7, USA Inc.). The software was also used for two-tailed parametric and non parametric correlation, which was used to determine interrelationships between measured variables. Spatial and seasonal variations in physicochemical parameters, plankton and macrobenthos abundance were determined using Analysis of Variance (ANOVA) on Genstat_Discovery 4.103 and Student t-test on SPSS software. Mean values of physicochemical parameters were compared to water quality standards and guidelines specified by NESREA, USEPA, WHO and SON.

CHAPTER FOUR

RESULTS

4.1. Physico-chemical parameters

The result of the Physico-chemical parameters measured and expressed as mean values, standard error and range are presented in Table 4.1. Detailed data are shown in Appendices 1-5.

4.1.1. Air temperature

The air temperatures ranged from 21.70 °C to 32. 00 °C with a mean value of 26.04 ± 0.23 °C. The lowest air temperature of 21.70 °C was recorded in December, 2013 in station 4 while the highest air temperature of 32.00 °C was recorded in station 3 in the month of April, 2013. The mean monthly variations in air temperature of Ibuya River for all stations are presented in Fig 4.1. The mean air temperature for the wet season 25.82±0.49°C was lower than the dry season value 26.22±0.43 °C (Table 4.2) and there was no significant difference between season ($p>0.05$). Spatial variations in air temperature were not significantly different ($p>0.05$).

4.1.2. Water temperature

The water temperatures ranged from 20.30 °C to 29.70 °C with a mean value of 24.73 ± 0.21 °C during the study period. The lowest water temperature of 20.30 °C was recorded in December, 2013 in station 4 while the highest air temperature of 29.70 °C was recorded in station 3 in the month of April, 2013. The mean monthly variations in water temperatures of Ibuya River for all stations are as presented in Fig 4.2. The mean water temperature for the wet season 24.69±0.47 °C was lower than the dry season value 24.76±0.43 °C and there was no significant difference between season ($p>0.05$). Spatial variations in water temperature were not significantly different ($p>0.05$).

Table 4.1: Physico-chemical parameters of Ibuya River from September 2012 to February 2014

Parameters	Range	Mean ± Standard error
Air temperature (°C)	21.70 – 32.00	26.04 ± 0.23
Water temperature (°C)	20.30 - 29.70	24.73 ± 0.21
pH	6.88 - 8.39	7.57 ± 0.04
DO (mg/L)	2.68 - 8.89	4.43 ± 0.15
Conductivity (µS/cm)	69.90 - 272.00	140.83 ± 5.60
TDS (mg/L)	48.80 - 188.00	98.11 ± 3.80
Hardness (mg/L $CaCO_3$)	21.40 - 111.40	39.55 ± 2.14
Alkalinity (mg/L $CaCO_3$)	4.50 – 27.00	9.72 ± 0.57
Transparency (cm)	5.50 - 56.00	16.02 ± 1.28
Turbidity (FTU)	6.55 - 36.20	19.36 ± 0.91
Mg (mg/L)	0.19 - 6.95	2.10 ± 0.18
Mn (mg/L)	0.00 - 0.69	0.21 ± 0.02
Cu (mg/L)	0.0 - 0.49	0.14 ± 0.02
Fe (mg/L)	0.03 - 8.32	2.10 ± 0.21
Cd (mg/L)	0.00 - 1.64	0.24 ± 0.05
Pb (mg/L)	0.00 - 2.11	0.68 ± 0.07
Zn (mg/L)	0.00 - 1.21	0.16 ± 0.02
Cl^- (mg/L)	14.40 - 168.00	77.00 ± 4.10
PO_4^{3-} (mg/L)	0.00 - 68.50	24.25 ± 2.84
SO_4^{2-} (mg/L)	0.00 - 96.45	31.80 ± 3.06
NO_3^- (mg/L)	0.00 - 97.60	32.00 ± 3.60

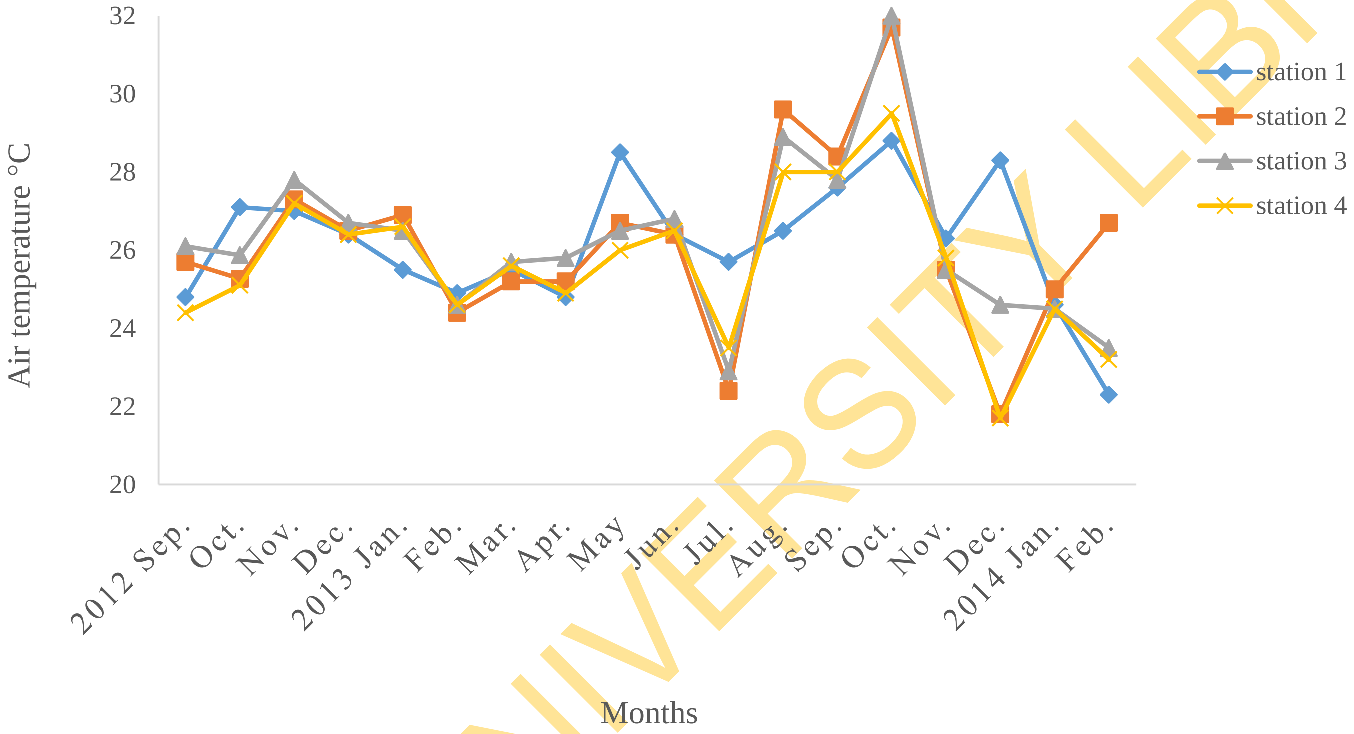


Fig. 4.1: Mean monthly variation of air temperature in Ibuya River

Table 4.2: Analysis of variance of the physico-chemical parameters of Ibuya River from September 2012 to February 2014

PARAMETERS	**SEASON**		**STATIONS**					**SEASONS*STATIONS**							
Season/Station	**Dry**	**Wet**	**1**	**2**	**3**	**4**	**LSD**	**Dry*Wet**							
								1	2	3	4	1	2	3	4
Air temp (^{0}c)	26.22	25.82	26.17	26.15	26.23	25.64		26.50	26.42	26.30	25.67	25.75	25.81	26.13	25.60
Water temp (^{0}c)	24.76	24.69	24.63	24.98	24.70	24.61		24.57	25.22	24.62	24.63	24.70	24.67	24.79	24.59
pH	7.58	7.56	7.41*	7.58	7.59	7.69*	0.19	7.41	7.63	7.61	7.66	7.416	7.52	7.57	7.73
DO (mg/L)	4.36	4.53	4.29	4.59	4.47	4.38		4.01	4.53	4.50	4.39	4.65	4.67	4.43	4.36
Cond (µS/cm)	163.00***	113.10***	143.70	144.00	142.00	133.60		166.30	161.10	167.60	157.00	115.5	122.70	109.90	104.30
TDS (mg/L)	112.60***	80.00***	99.70	100.00	98.80	94.00		115.90	110.70	115.00	108.60	79.4	86.50	78.50	75.70
Hard(mg/L $CaCO_3$)	40.60	38.30	41.70	38.10	40.20	38.20		43.20	39.70	40.30	39.00	39.8	36.10	40.00	37.30
Alka(mg/L $CaCO_3$)	9.12	10.46	10.07	9.53	10.28	8.98		8.93	9.26	9.90	8.39	11.49	9.87	10.77	9.71
Trans (cm)	20.50***	10.40***	15.10	15.60	15.50	17.90		19.60	19.70	19.20	23.50	9.5	10.40	11.00	10.80
Turb (FTU)	15.35***	24.36***	20.14	19.02	17.88	20.38		17.40	15.32	12.58	16.10	23.57	23.65	24.49	25.74
Mg (mg/L)	2.44*	1.66*	2.16	2.23	2.09	1.91		2.35	2.58	2.47	2.37	1.91	1.80	1.62	1.33
Mn (mg/L)	0.19	0.24	0.22	0.22	0.22	0.18		0.25	0.18	0.16	0.15	0.184	0.27	0.29	0.22
Cu (mg/L)	0.12	0.17	0.15	0.13	0.15	0.14		0.13	0.12	0.11	0.11	0.163	0.15	0.19	0.19
Fe (mg/L)	1.25***	3.16***	2.44	2.27	2.08	1.62		1.81	1.32	1.01	0.86	3.22	3.46	3.42	2.56
Cd (mg/L)	0.20	0.29	0.17	0.24	0.27	0.27		0.19	0.20	0.19	0.21	0.161	0.28	0.36	0.36
Pb (mg/L)	0.67	0.70	0.71	0.74	0.61	0.67		0.65	0.76	0.62	0.63	0.78	0.72	0.60	0.72
Zn (mg/L)	0.22**	0.07**	0.20	0.16	0.15	0.12		0.31	0.24	0.20	0.16	0.067	0.07	0.09	0.07
Cl^{-} (mg/L)	83.40	69.00	78.30	77.10	78.00	74.70		87.10	81.30	84.90	80.20	67.3	71.80	69.20	67.70
Po$_4^{3-}$ (mg/L)	19.80	29.80	22.00	23.00	26.20	25.80		17.30	19.80	20.00	22.20	27.8	27.00	34.10	30.30
So$_4^{2-}$ (mg/L)	21.10***	45.20***	30.20	32.00	35.90	29.10		21.80	22.40	21.50	18.70	40.8	43.90	53.80	42.20
No$_3^-$ (mg/L)	36.10	26.80	35.80	25.50	34.20	32.40		43.80	29.60	35.90	35.20	25.8	20.30	32.10	29.00

* Significant P<0.05 level, **Significant P<0.01 level, ***Significant P<0.001 level

Key: Air temp = Air Temperature, Water temp = Water Temperature, Cond = Conductivity, Hard = Hardness, Alka = Alkalinity, Trans = Transparency, Turb = Turbidity, LSD = Least significant difference.

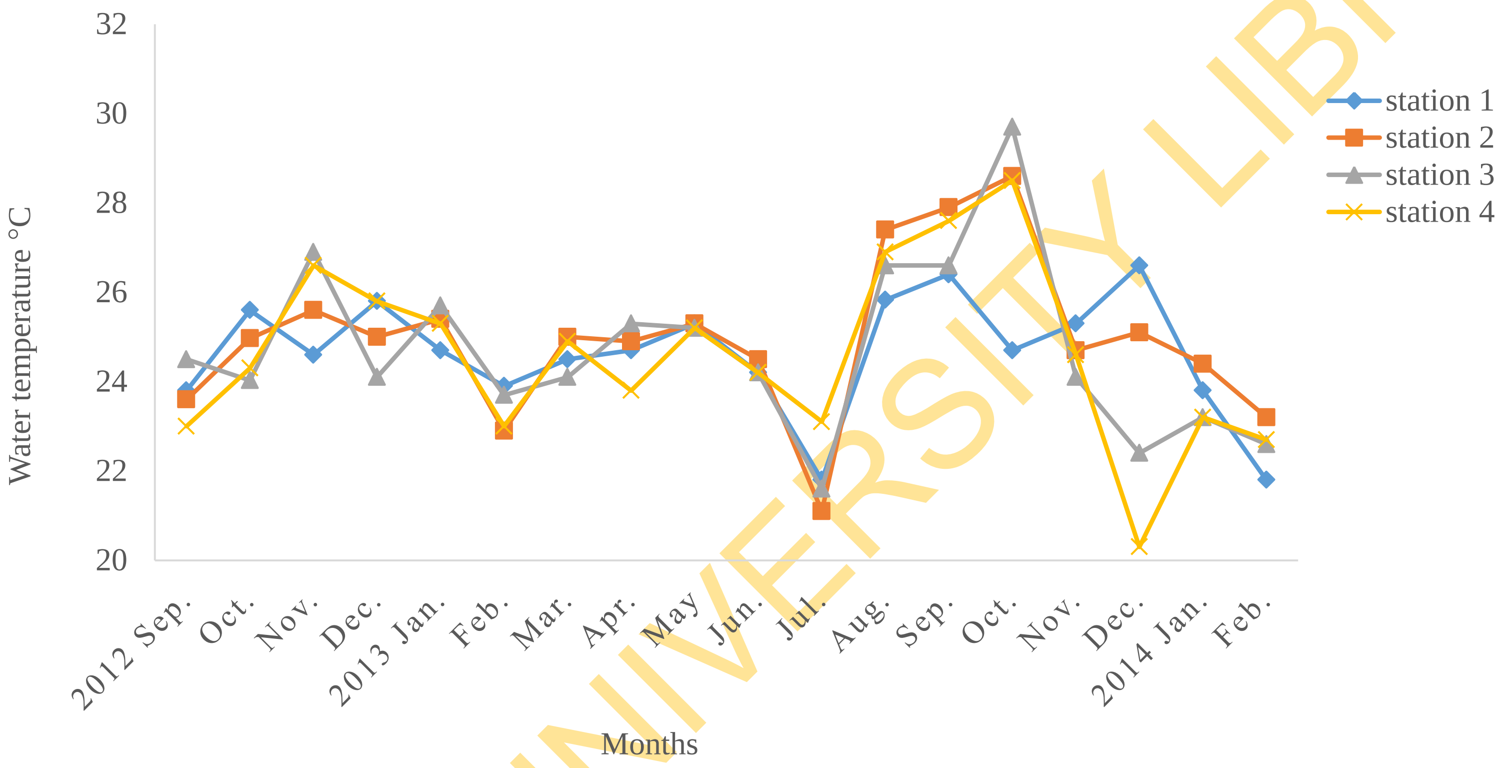


Fig.4.2: Mean monthly variation of water temperature in Ibuya River

4.1.3. pH

The mean monthly variations in the hydrogen ion concentration (pH) for Ibuya River are presented in Fig. 4.3. The river was mostly in the neutral/alkaline range of 6.88 to 8.39 with a mean of 7.57 ± 0.04 (Table 4.1). The lowest pH 6.88 was recorded in station 1 in April, 2013 while the highest 8.39 was recorded in December, 2012 in the same station. The pH for the wet season 7.56±0.09 was lower than the dry season value of 7.58±0.15 and there was no significant difference between season ($p>0.05$). Spatial variations showed significant different in pH ($p<0.05$) (Table 4.2).

4.1.4. Dissolved Oxygen (DO)

The Dissolved Oxygen fluctuated between 2.68 mg/L and 8.89 mg/L with a mean of 4.432 ± 0.15 mg/L throughout the study period (Table 4.1). The lowest DO concentration was in the month of July, 2013 (2.61 mg/L) in station 4 while the highest was in September, 2013 (8.89 mg/L) in station 1. The mean monthly variation in DO is shown in Fig. 4.4. There were no significant difference ($p>0.05$) between the DO concentration (4.53 ± 0.12 mg/L) for the wet season and the dry season (4.36±0.14 mg/L). Spatial variations in DO were not significantly different ($p>0.05$) (Table 4.2).

4.1.5. Conductivity

The mean monthly values of conductivity are shown in Fig. 4.5. The conductivity ranged from 69.90 µS/cm to 272.00 µS/cm with a mean of 140.83 ± 5.60 µS/cm. The lowest value (69.90 µS/cm) was recorded in station 1 in the month of September, 2012 while the highest (272.00 µS/cm) was recorded in February, 2013 in the same station. The mean conductivity of the river was lower during the wet season (113.10±5.87 µS/cm), than the dry season (163.00±8.89 µS/cm) with a very high significant difference ($p<0.001$) between seasons. Spatial variations in conductivity were not significantly different ($p>0.05$) (Table 4.2).

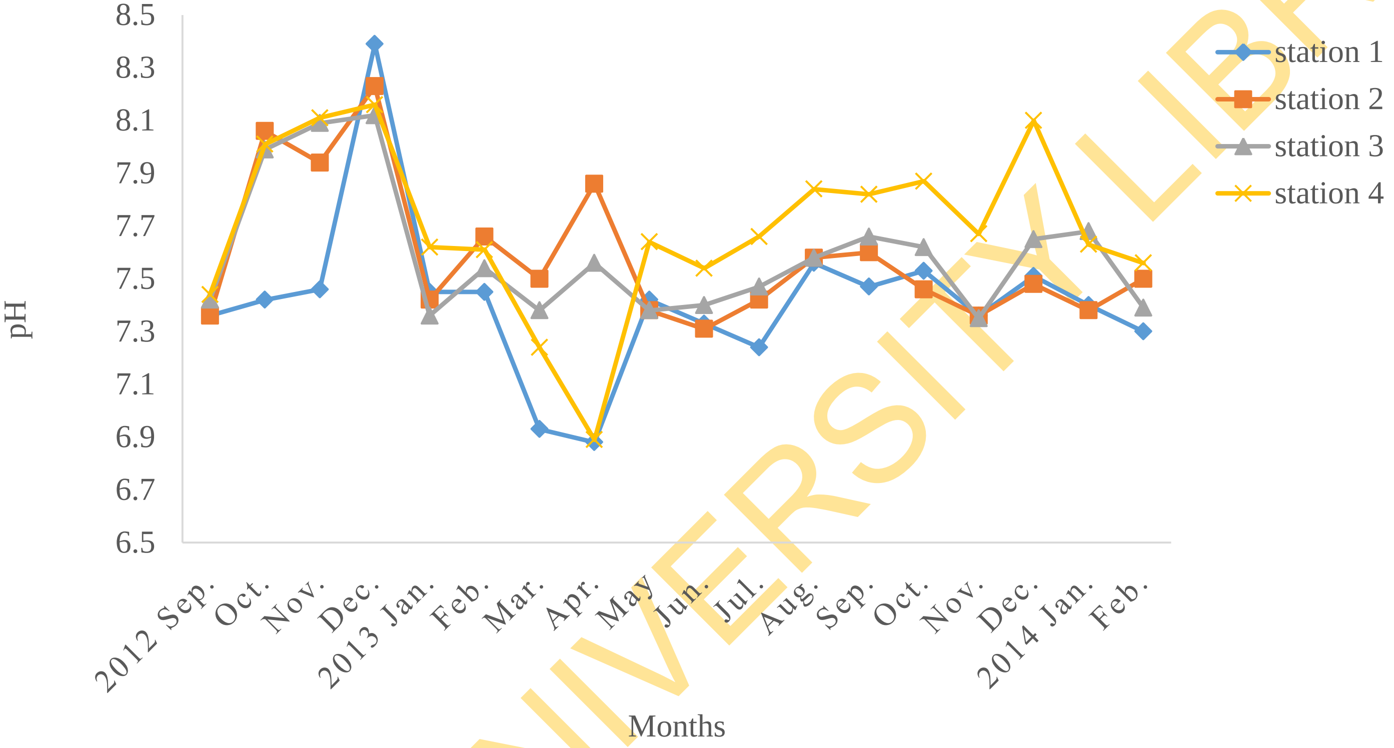


Fig 4.3: Mean monthly variation of pH in Ibuya River

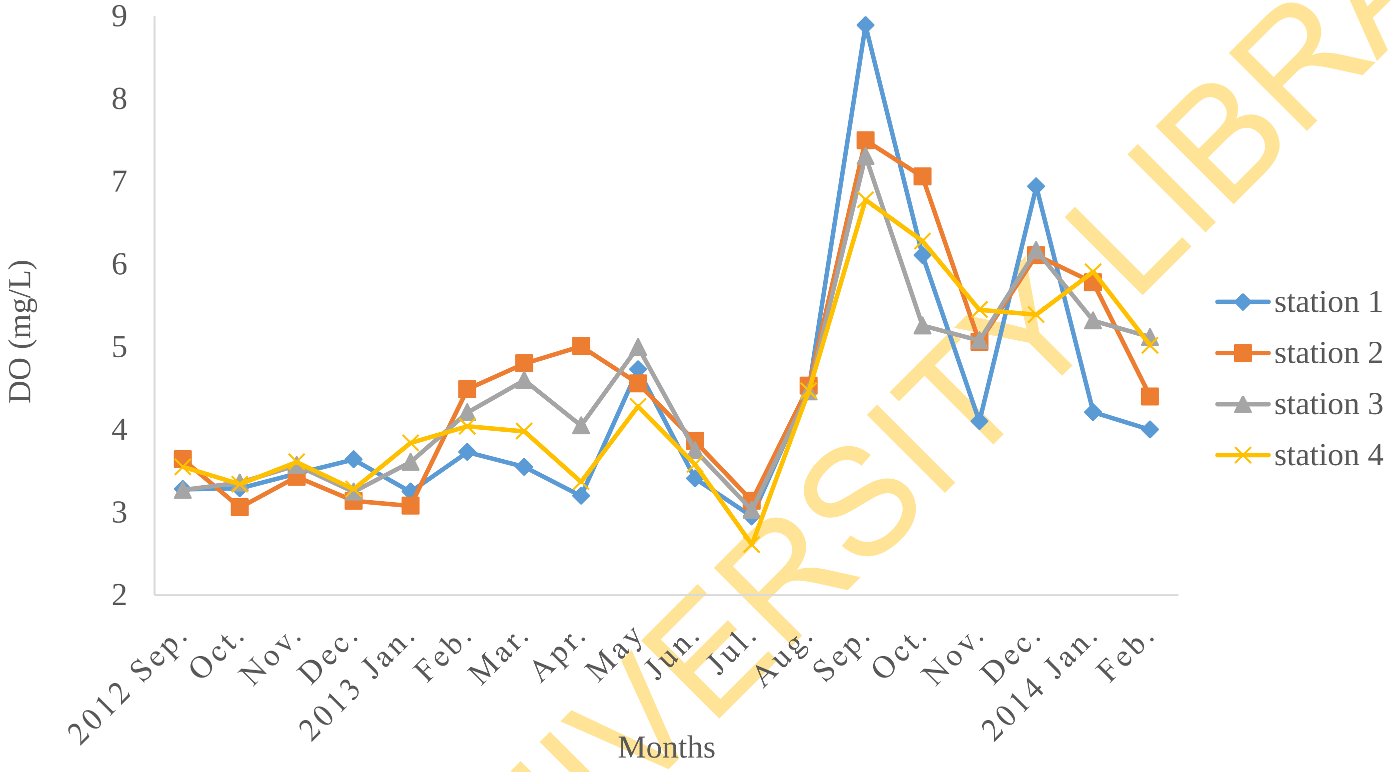


Fig 4.4: Mean monthly variation of Dissolved Oxygen in Ibuya River

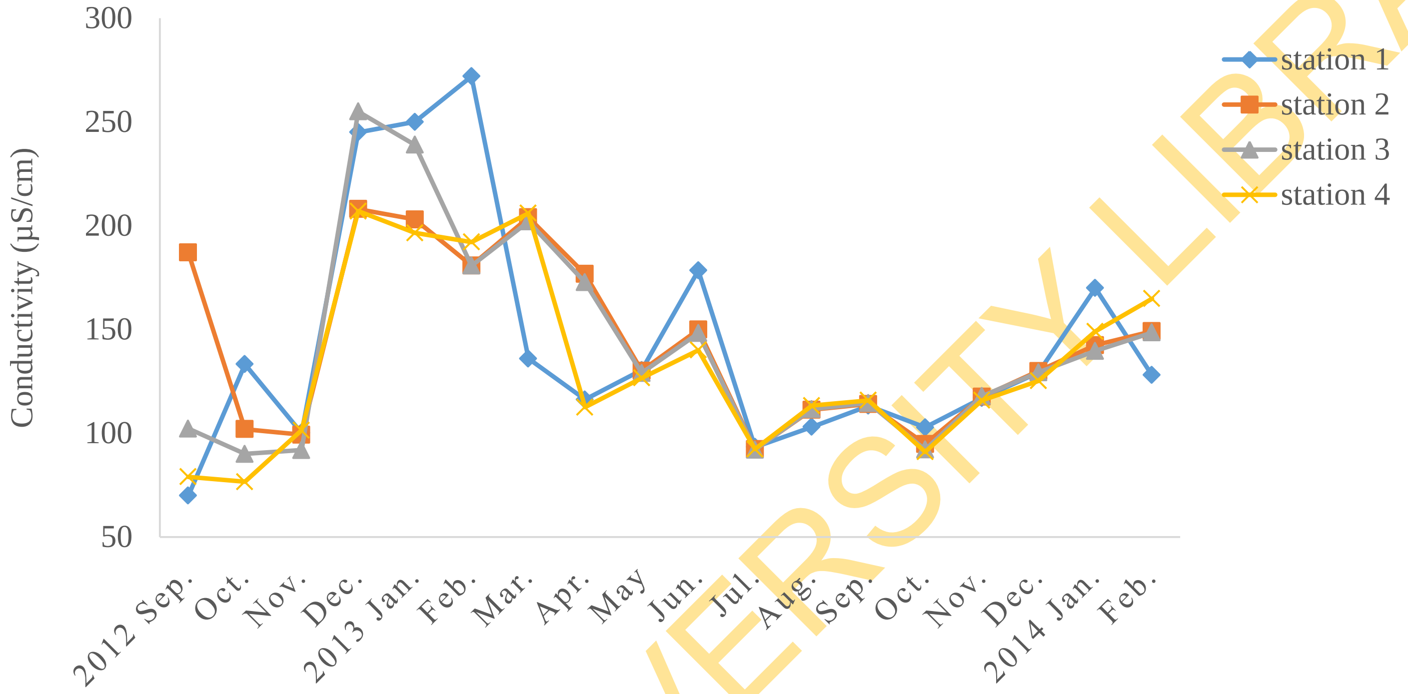


Fig 4.5: Mean monthly variation of Conductivity in Ibuya River

4.1.6. Total Dissolved Solids (TDS)

The TDS values measured at Ibuya River ranged from 48.80 mg/L to 188.00 mg/L with a mean of 98.11 ± 3.80 mg/L during the study period (Table 4.1). The lowest TDS value of 48.80 mg/L was recorded in September, 2012 in station 1 while the highest value of 188.00 mg/L was recorded in February, 2013 in same station. The variations in TDS of Ibuya River for all stations are as presented in Fig 4.6. The mean TDS for the wet season 80.00±7.48 mg/L was lower than the dry season value 112.60±6.83 mg/L which showed significant difference at $p<0.001$ level. Spatial variations in TDS were not significantly different ($p>0.05$) (Table 4.2).

4.1.7. Hardness

The mean monthly variations in water hardness is shown in Fig. 4.7. Hardness ranged from 21.40 mg/L $CaCO_3$ to 111.40 mg/L $CaCO_3$ with a mean of 39.55 ± 2.14 mg/L $CaCO_3$ during the study period (Table 4.1). The month of July, 2013 recorded the lowest value of 21.40 mg/L $CaCO_3$ for station 4, while the highest value of 111.40 mg/L $CaCO_3$ was recorded in station 3 in the month of October, 2012. The mean hardness for the wet season 38.30 ± 3.86 mg/L $CaCO_3$ was lower than the dry season value of 40.55 ± 2.33 mg/L $CaCO_3$ and there were no significant difference ($p>0.05$) between seasons. Spatial variations in hardness were not significantly different ($p>0.05$).

4.1.8. Alkalinity

The mean monthly variations in alkalinity for Ibuya River was presented in Fig. 4.8. The alkalinity ranged from 4.50 mg/L $CaCO_3$ to 27.00 mg/L $CaCO_3$ with an overall mean of 9.72 ± 0.57 mg/L $CaCO_3$. October, 2012 recorded the highest value of 27.00 mg/L $CaCO_3$ in station 3 and August, 2013 recorded the lowest value of 4.50 mg/L $CaCO_3$ in station 1. The mean value for the wet season 10.46±1.14 mg/L $CaCO_3$ was higher than the dry season 9.12±1.04 mg/L $CaCO_3$ and the variations showed no significant difference ($p>0.05$) between seasons. Spatial variations in alkalinity were not significantly different ($p>0.05$) (Table 4.2).

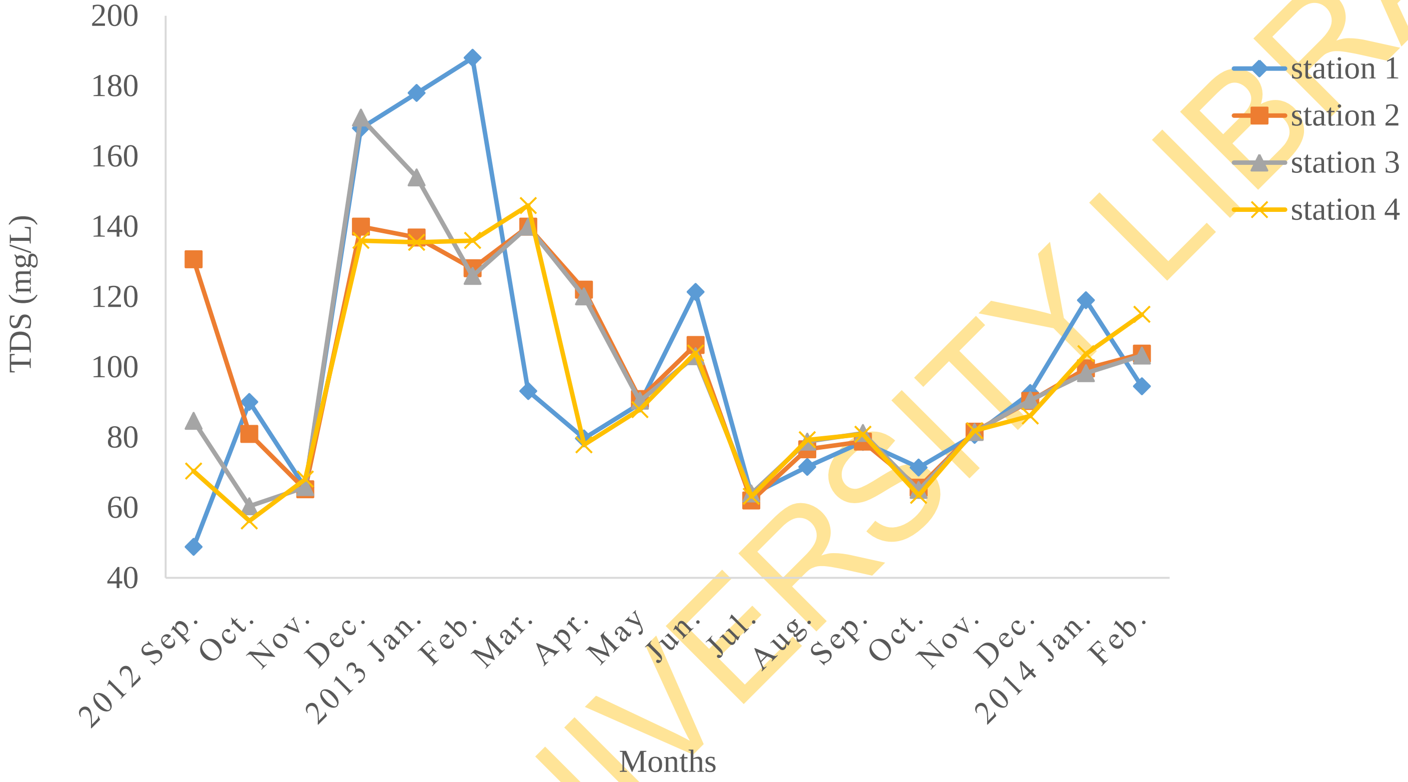


Fig 4.6: Mean monthly variation of TDS in Ibuya River

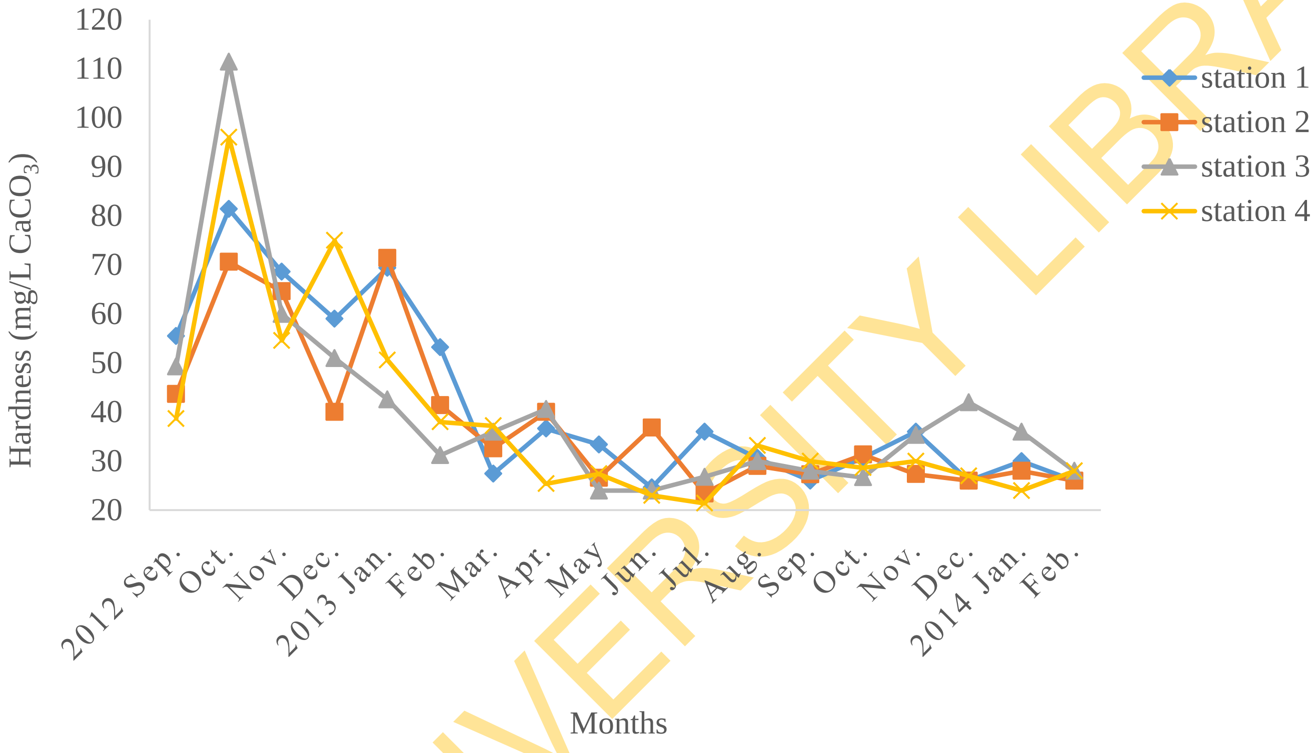


Fig 4.7: Mean monthly variation of Hardness in Ibuya River

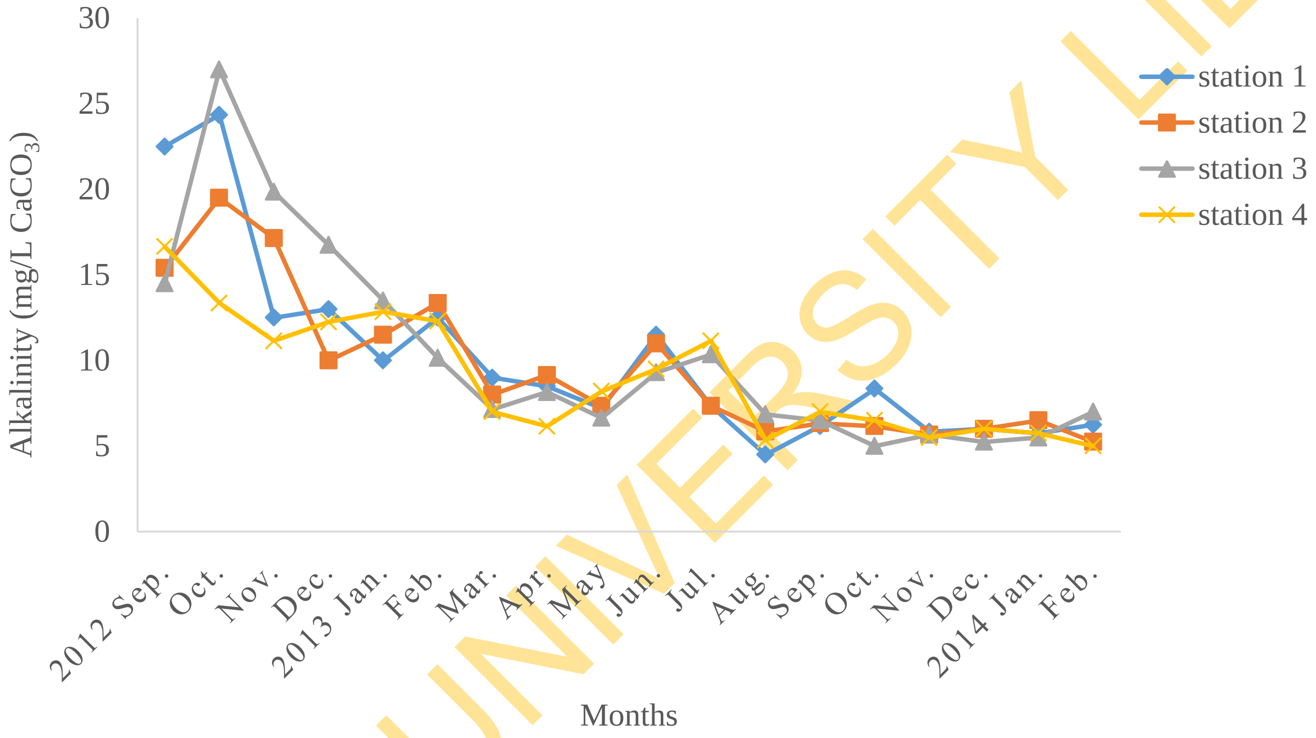


Fig 4.8: Mean monthly variation of Alkalinity in Ibuya River

4.1.9. Transparency

The Transparency values at Ibuya River ranged from 5.50 cm to 56.00 cm with a mean of 16.02 ± 1.28 cm (Table 4.1). The lowest value of 5.50 cm was recorded in October, 2013 in station 4 while the highest value of 56.00 cm was recorded in January, 2014 in same station. The mean monthly variations in the transparency of Ibuya River are presented in Fig 4.9. The mean transparency for the wet season 10.40±0.89 cm was lower than the dry season value 20.50±0.82 cm which showed significant difference between seasons at $p<0.001$. Spatial variations in transparency were not significantly different ($p>0.05$) (Table 4.2).

4.1.10. Turbidity

The Turbidity values at Ibuya River ranged from 6.55 FTU to 35.26 FTU with a mean of 19.36 ± 0.91 FTU (Table 4.1). The lowest value of 6.55 FTU was recorded in February, 2013 in station 3 while the highest value of 35.26 FTU was recorded in July, 2013 in the same station. The mean monthly variations in turbidity of Ibuya River is presented in Fig 4.10. The mean turbidity for the wet season 24.36±1.11 FTU was higher than the dry season value 15.35±1.01 FTU which showed significant difference between seasons at $p<0.001$. Spatial variations in turbidity were not significantly different ($p>0.05$) (Table 4.2).

4.1.11. Magnesium (Mg)

The mean monthly variations in Mg values at Ibuya River is presented in Fig. 4.11. The Mg values range from 0.199 mg/L to 6.95 mg/L with a mean of 2.097 ± 0.1 `81 mg/L (Table 4.1). The lowest value of 0.199 mg/L was recorded in station 1 in March, 2013 while the highest 6.95 mg/L was recorded in January, 2013 in station 2. The values for the wet season 1.66±0.38 mg/L was lower than the dry season values (2.44±0.35 mg/L) and the variations were significantly different at $p<0.05$. Spatial variations in Mg were not significantly different ($p>0.05$) (Table 4.2).

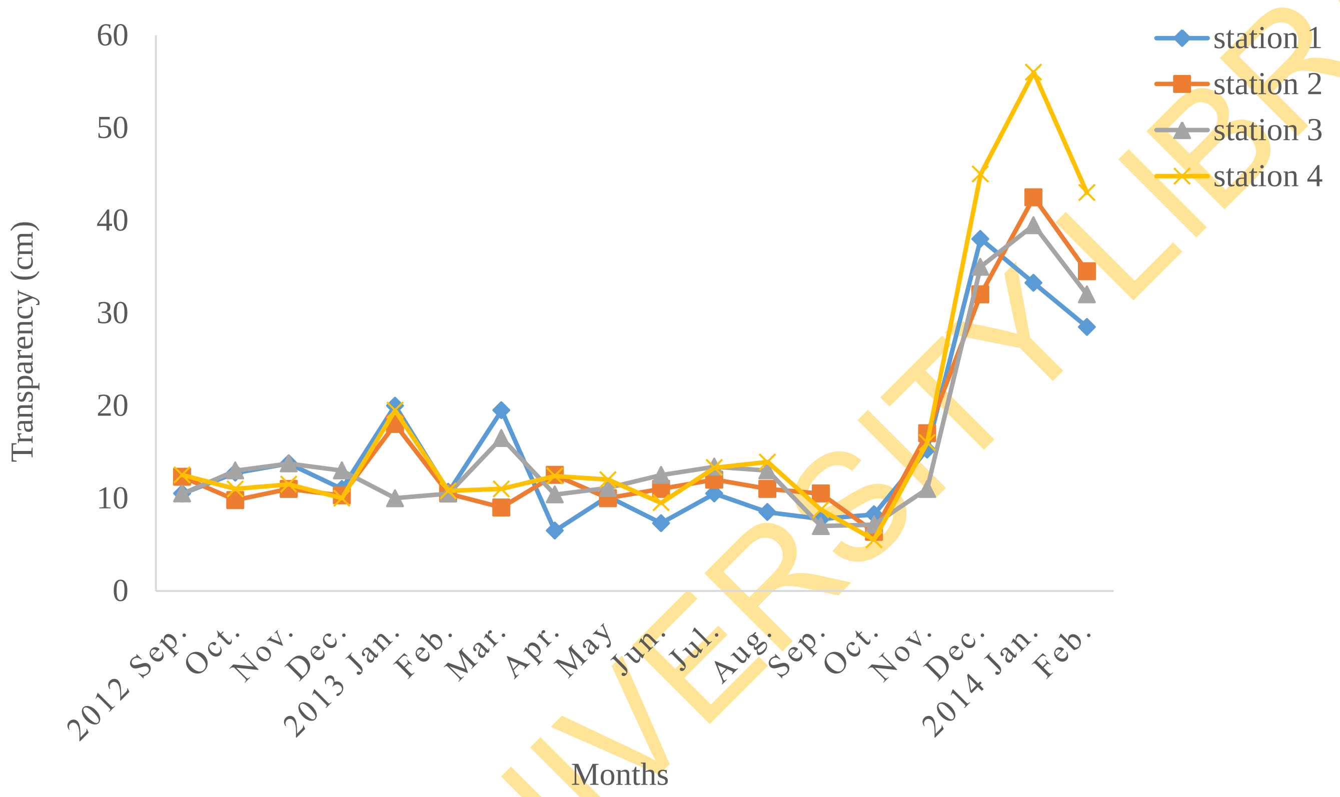


Fig 4.9: Mean monthly variation of transparency in Ibuya River

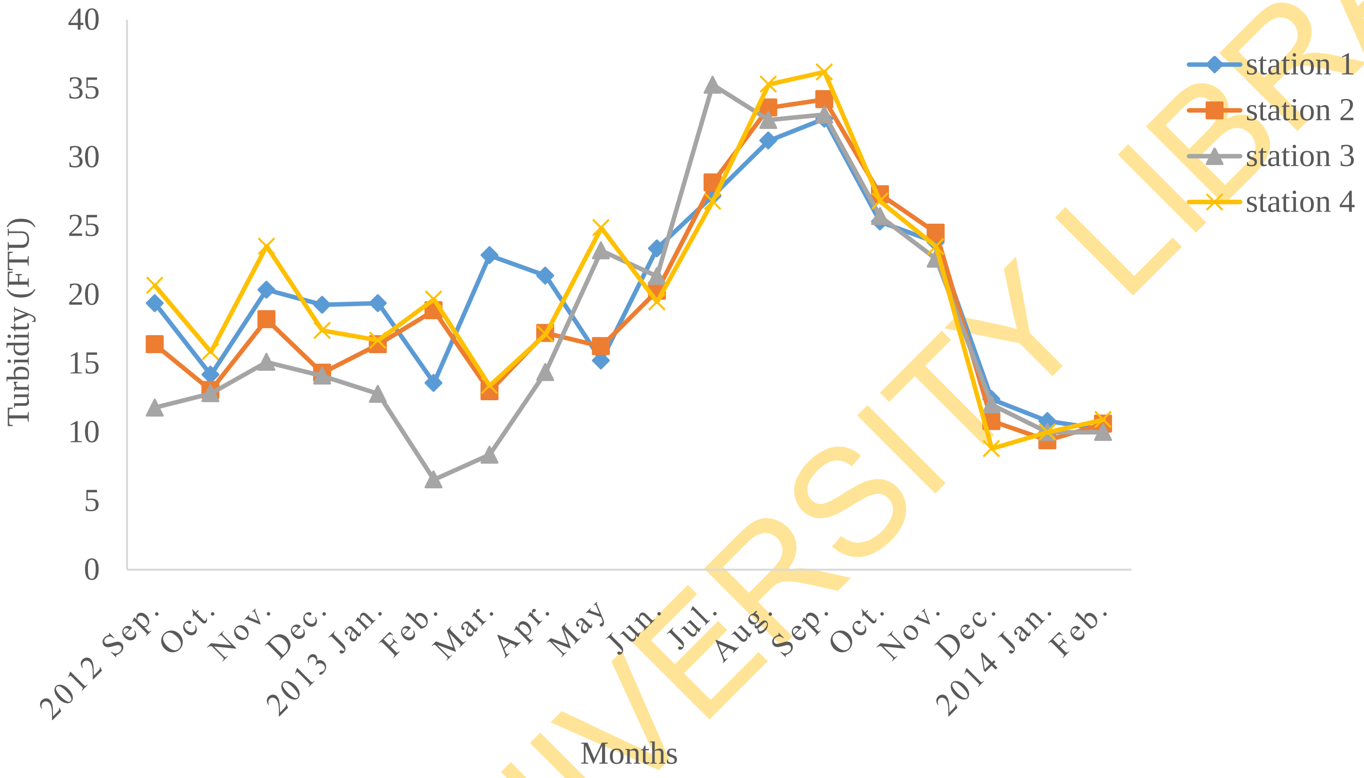


Fig 4.10: Mean monthly variation of turbidity in Ibuya River

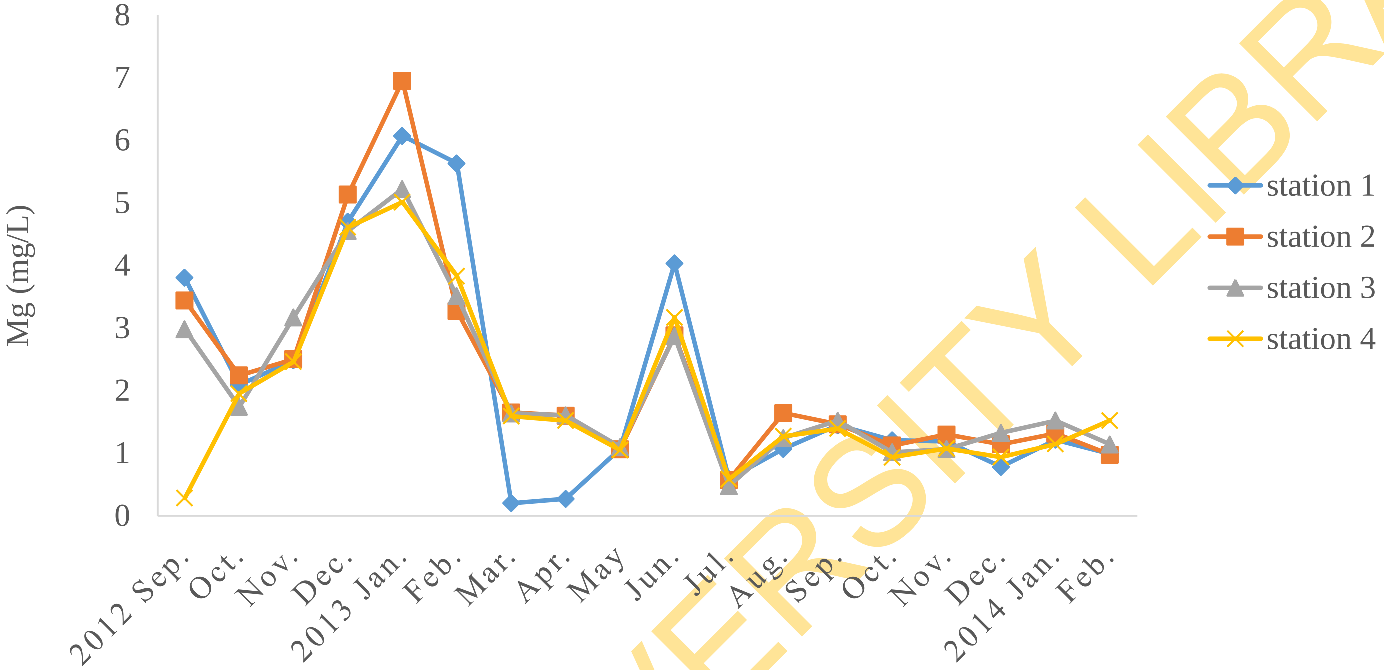


Fig 4.11: Mean monthly variation of Mg in Ibuya River

4.1.12. Manganese (Mn)

The mean monthly variations in Mn are represented in Fig. 4.12. The Mn value ranged from 0.00 mg/L to 0.69 mg/L. The month of February, 2013 recorded the lowest value of 0.00 mg/L for both stations 2 and 3, while the highest value of 0.69 mg/L was recorded in station 2 in the month of August, 2013 (Fig. 4.12). The mean value for the wet season 0.24±0.03 mg/L was higher than the dry season 0.19±0.03 mg/L and there were no significant difference (p>0.05) between seasons. Spatial variations in Mn were not significantly different (p>0.05) (Table 4.2).

4.1.13. Copper (Cu)

The mean monthly variations in Cu are presented in Fig. 4.13. The Cu value ranged from 0.00 mg/L to 0.497mg/L (Table 4.1). The month of September, 2012 recorded the lowest value of 0.00 mg/L for all stations while the highest value of 0.497 mg/l was recorded in station 4 in the month of August, 2013 (Fig. 4.13). The mean value for the wet season 0.17±0.02 mg/L was higher than the dry season 0.12±0.01 mg/L which showed no significant difference (p>0.05) between seasons. Spatial variations in Cu were not significantly different (p>0.05) (Table 4.2).

4.1.14. Iron (Fe)

The mean monthly values of Fe are shown in Fig. 4.14. The Fe values ranged from 0.03 mg/L to 8.32 mg/L with an overall mean of 2.10 ± 0.21mg/L. The lowest Fe value of 0.03 mg/L was recorded in station 3 in the month of February, 2013 while the highest value of .32 mg/L was recorded in July, 2013 in the same station. The mean value for the wet season (3.16±0.37 mg/L) was higher than the dry season value of 1.25±0.17 mg/L and this variation showed significant difference at p<0.001. Spatial variations in Fe were not significantly different (p>0.05) (Table 4.2).

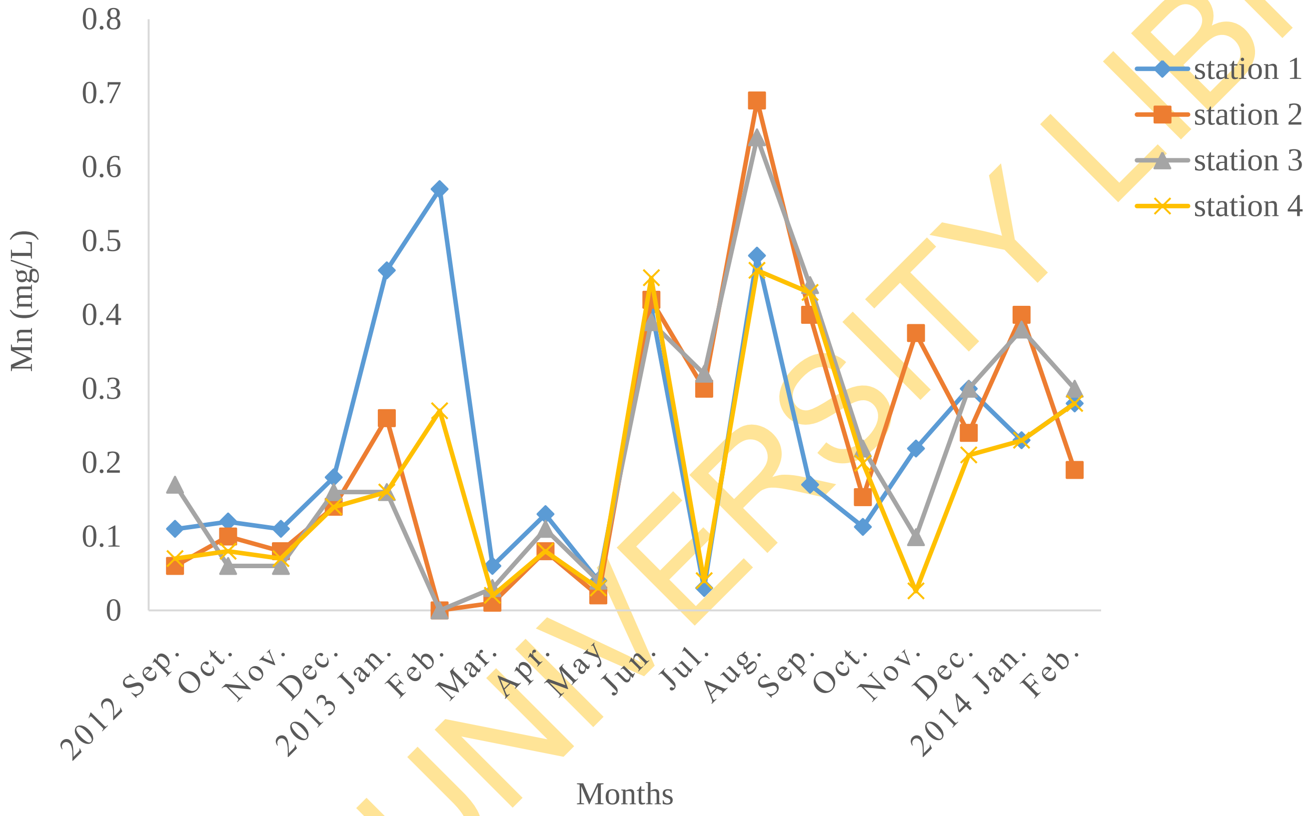


Fig 4.12: Mean monthly variation of Mn in Ibuya River

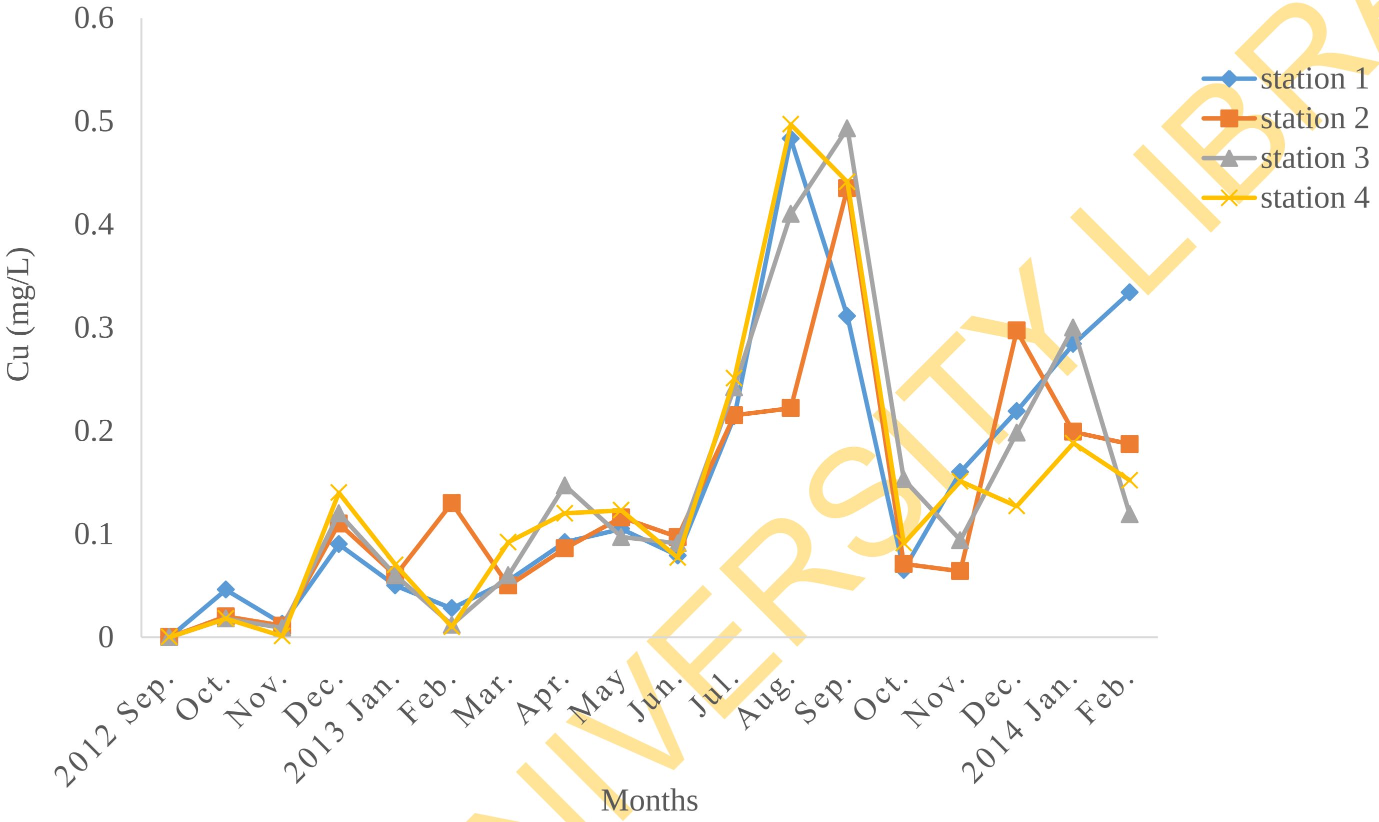


Fig 4.13 Mean monthly variation of Cu in Ibuya River

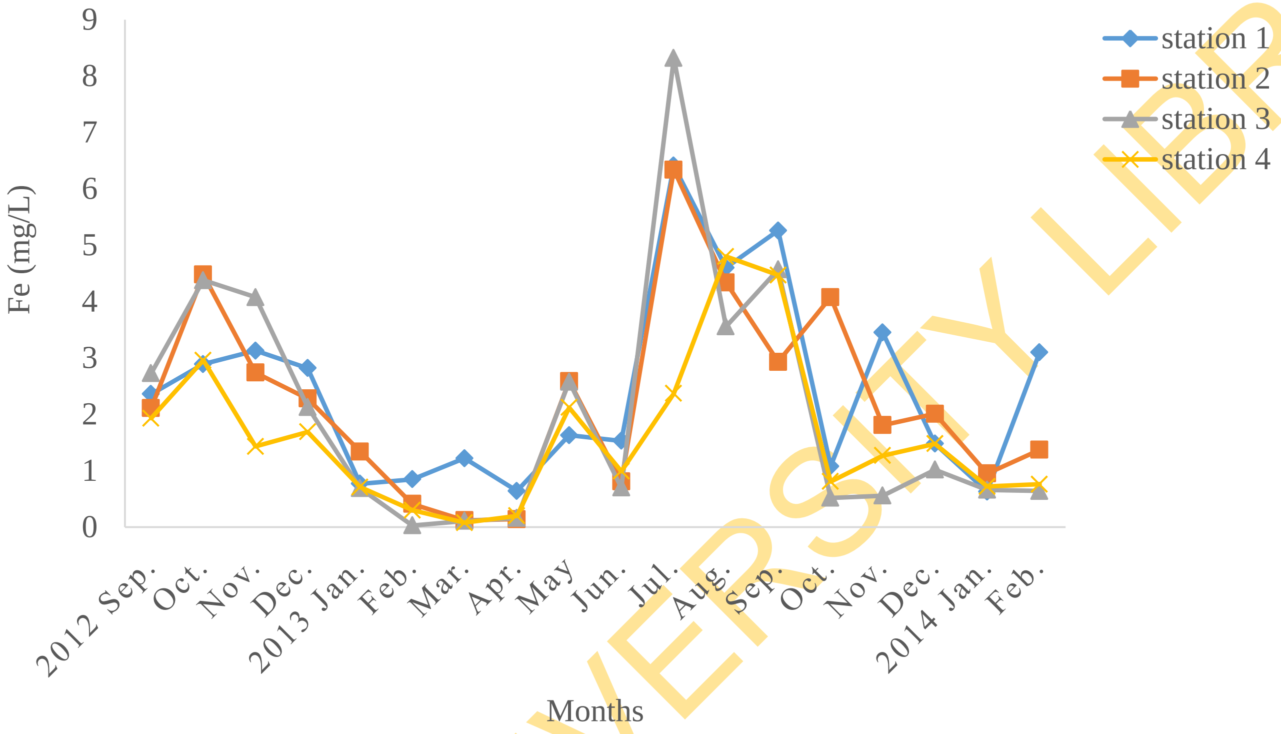


Fig 4.14: Mean monthly variation of Fe in Ibuya River

4.1.15. Cadmium (Cd)

The Cd values measured at Ibuya River ranged from 0.00 mg/L to1.638 mg/L with a mean of 0.24 ± 0.05mg/L during the study period (Table 4.1). The lowest Cd value of 0.00 mg/L was recorded in the first six months (September 2012 to February 2013) in all stations, while the highest value of 0.096 mg/L was recorded in August 2013 in station 2. The variations in Cd of Ibuya River for all stations is presented in Fig 4.15. The figure showed initial progressive decrease in Cd for all stations and then a peak in the month of August 2013. The mean Cd for the wet season 0.29±0.01 mg/L was higher than the dry season value 0.20±0.01 mg/L and there were no significant difference between seasons (p>0.05). Spatial variations in Cd were not significantly different (p>0.05) (Table 4.2).

4.1.16. Lead (Pb)

The Pb values measured at Ibuya River ranged from 0.00 mg/L to 2.113mg/L with a mean of 0.68±0.07mg/L during the study period (Table 4.1). The lowest Pb value of 0.00 mg/L was recorded in the first two months (September and October 2012) for all stations, while the highest value of 2.113 mg/L was recorded in November 2012 in station 1. The variations in Pb of Ibuya River for all stations is presented in Fig 4.16. The Pb level in the river exhibited two major peaks for all stations in the month of November 2012 and March 2013 respectively (Fig. 4.16). The mean Pb for the wet season (0.70±0.16 mg/L) was higher than the dry season value 0.67±0.14 mg/L with no significant difference between seasons (p>0.05). Spatial variations in Pb were not significantly different (p>0.05) (Table 4.2).

4.1.17. Zinc (Zn)

The mean monthly variations in Zn are presented in Fig. 4.17. The Zn value ranged from 0.00 mg/L to 1.219 mg/L with a mean of 0.16±0.02mg/L (Table 4.1). The month of November 2012 and September 2013 recorded the lowest value of 0.00 mg/L in each of stations 4, 1 and 2 while the highest value of 1.219 mg/L was recorded in station 1 in the month of December 2013 (Fig. 4.17). The mean value for the wet season 0.07±0.03 mg/L was lower than the dry season 0.22±0.03 mg/L with no significant difference between seasons (p<0.01). Spatial variations in Zn were not significantly different (p>0.05) (Table 4.2).

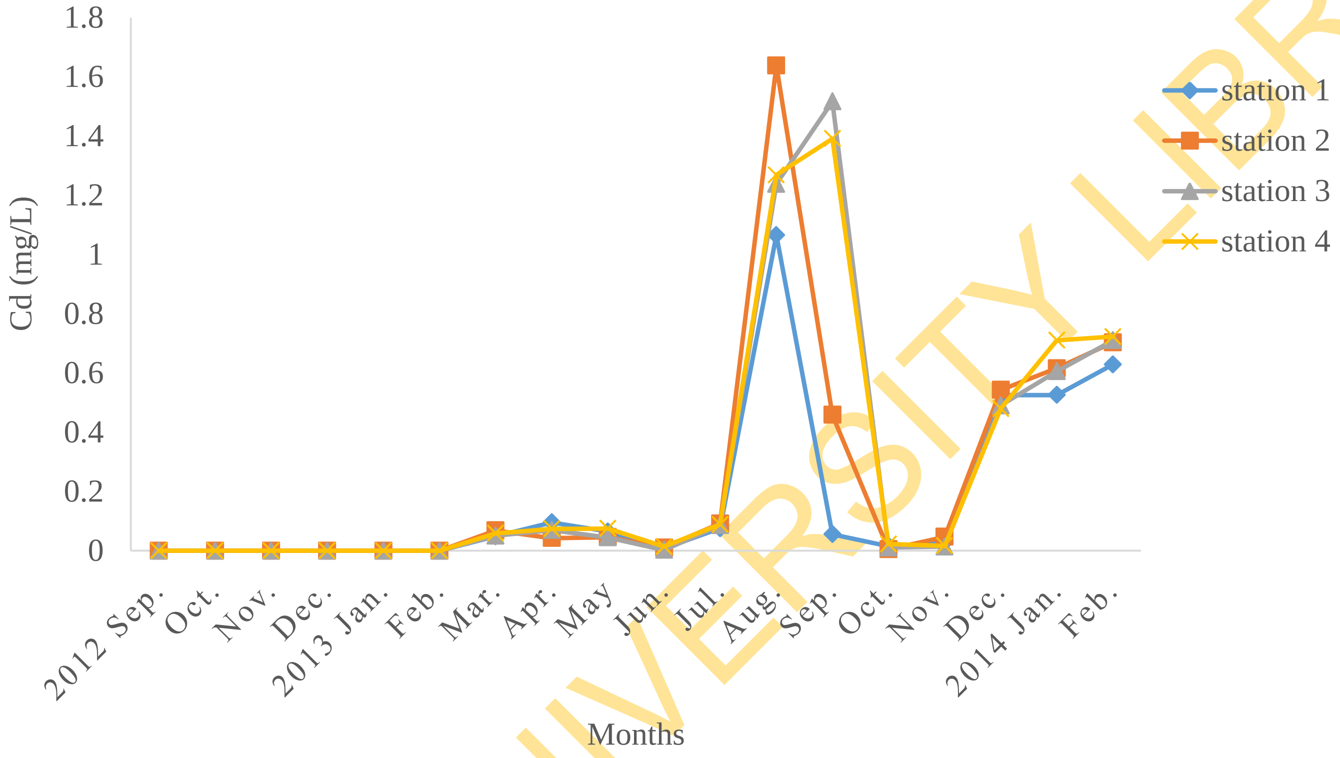


Fig 4.15: Mean monthly variation of Cd in Ibuya River

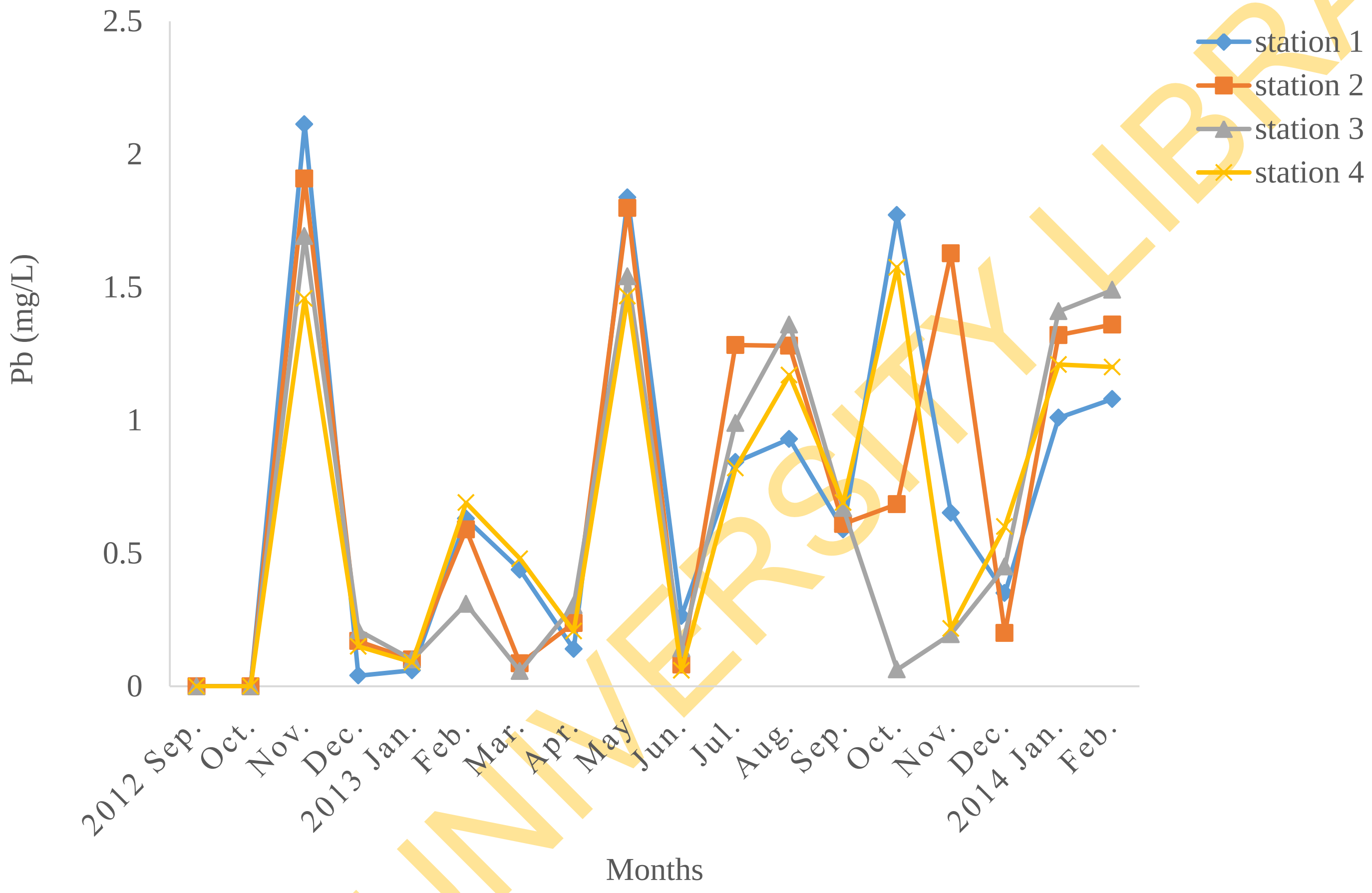


Fig 4.16: Mean monthly variation of Pb in Ibuya River

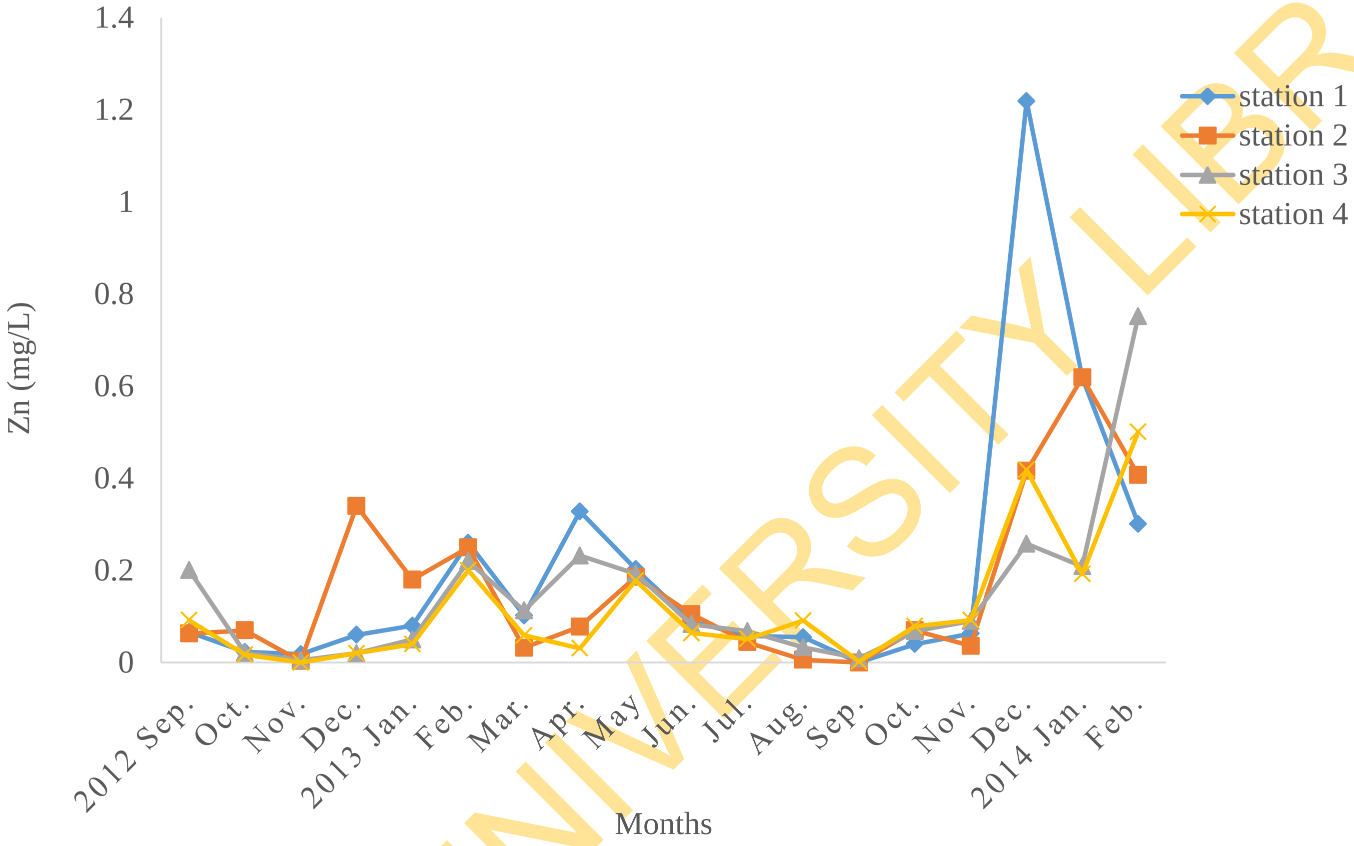


Fig 4.17: Mean monthly variation of Zn in Ibuya River

4.1.18. Chloride (Cl^-)

The value for Chloride in Ibuya River fluctuated throughout the study period and it ranged from 14.40 mg/L to 168.00 mg/L with a mean of 77.00 ± 4.10 mg/L (Table 4.1). The lowest value of 14.40 mg/L was recorded in station 2 in the month of October, 2012 while the highest value of 168.00 mg/L was recorded in station 3 in the month of January, 2013. The mean monthly variations in chloride in Ibuya River are presented in Fig. 4.18. The mean value of Cl^- for the wet season (69.0±4.44 mg/L) was lower than the dry season value of 83.40±7.07 mg/L with no significant difference ($p>0.05$) between seasons. Spatial variations in Cl^- were not significantly different ($p>0.05$) (Table 4.2).

4.1.19. Phosphate (PO_4^{3-})

The mean monthly variations in Phosphate in Ibuya River are presented in Fig. 4.19. The PO_4^{3-} value ranged from 0.00 mg/L to 68.5mg/L with a mean of 24.25 ± 2.84mg/L (Table 4.1). The month of February, 2013 recorded the lowest value of 0.00 mg/L in stations 2 while the highest value of 68.5 mg/L was recorded in station 4 in the month of February, 2014. The mean value for the wet season 29.8±2.65 mg/L was higher than the dry season 19.8±0.02 mg/L and there were no significant difference ($p>0.05$) between seasons. Spatial variations in PO_4^{3-} were not significantly different ($p>0.05$) (Table 4.2).

4.1.20. Sulphate (SO_4^{2-})

The mean monthly variations of Sulphate in Ibuya River are presented in Fig. 4.20. The SO_4^{2-} values ranged from 0.00 mg/L to 96.45 mg/L with a mean of 31.80 ± 3.06 mg/L (Table 4.1). The month of February, 2013 recorded the lowest value of 0.00 mg/L in stations 2 and 3 while the highest value of 96.45 mg/L was recorded in station 3 in the month of July, 2013. The mean value for the wet season 45.20±4.17 mg/L was higher than the dry season value of 21.10±3.81 mg/L which showed significant difference between seasons ($p<0.001$). Spatial variations in SO_4^{2-} were not significantly different ($p>0.05$) (Table 4.2).

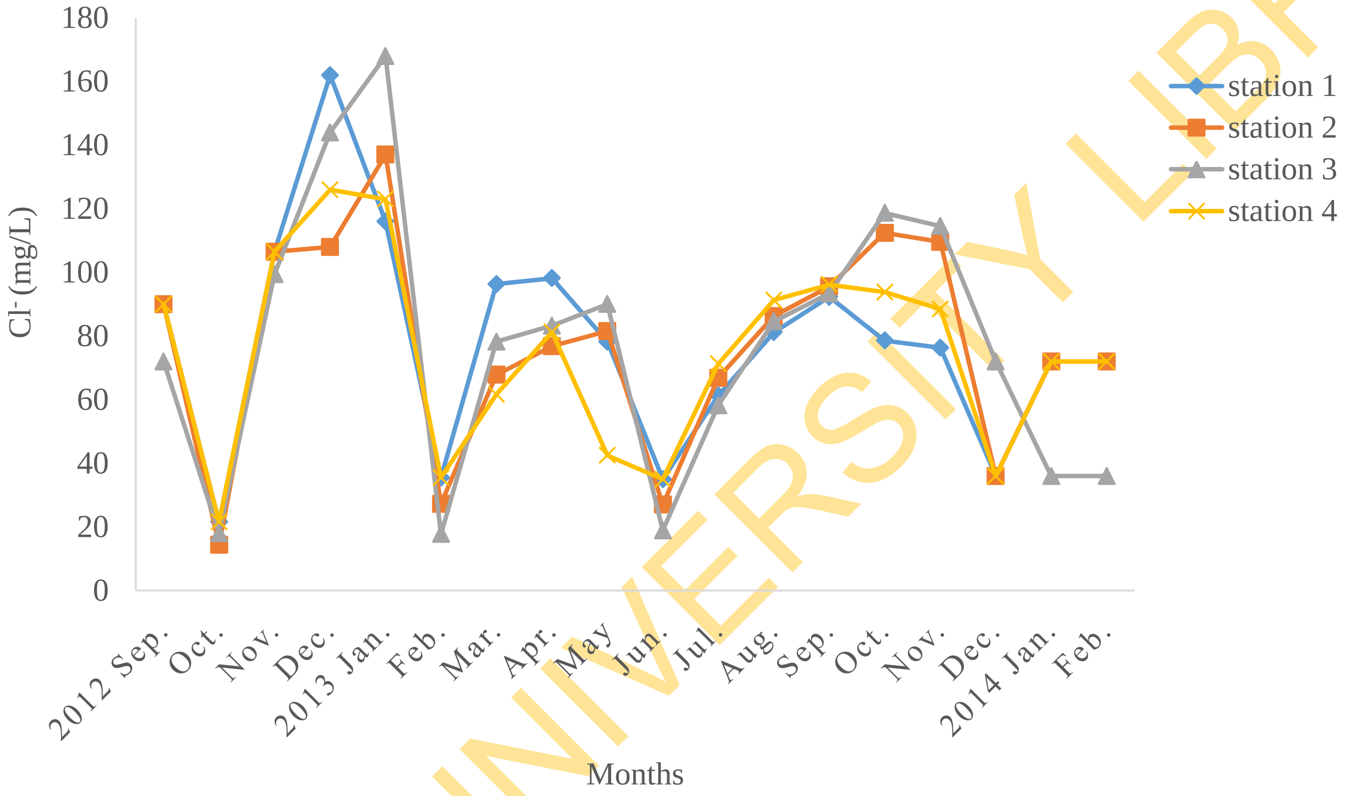


Fig 4.18: Mean monthly variation of Cl¯ Ibuya River

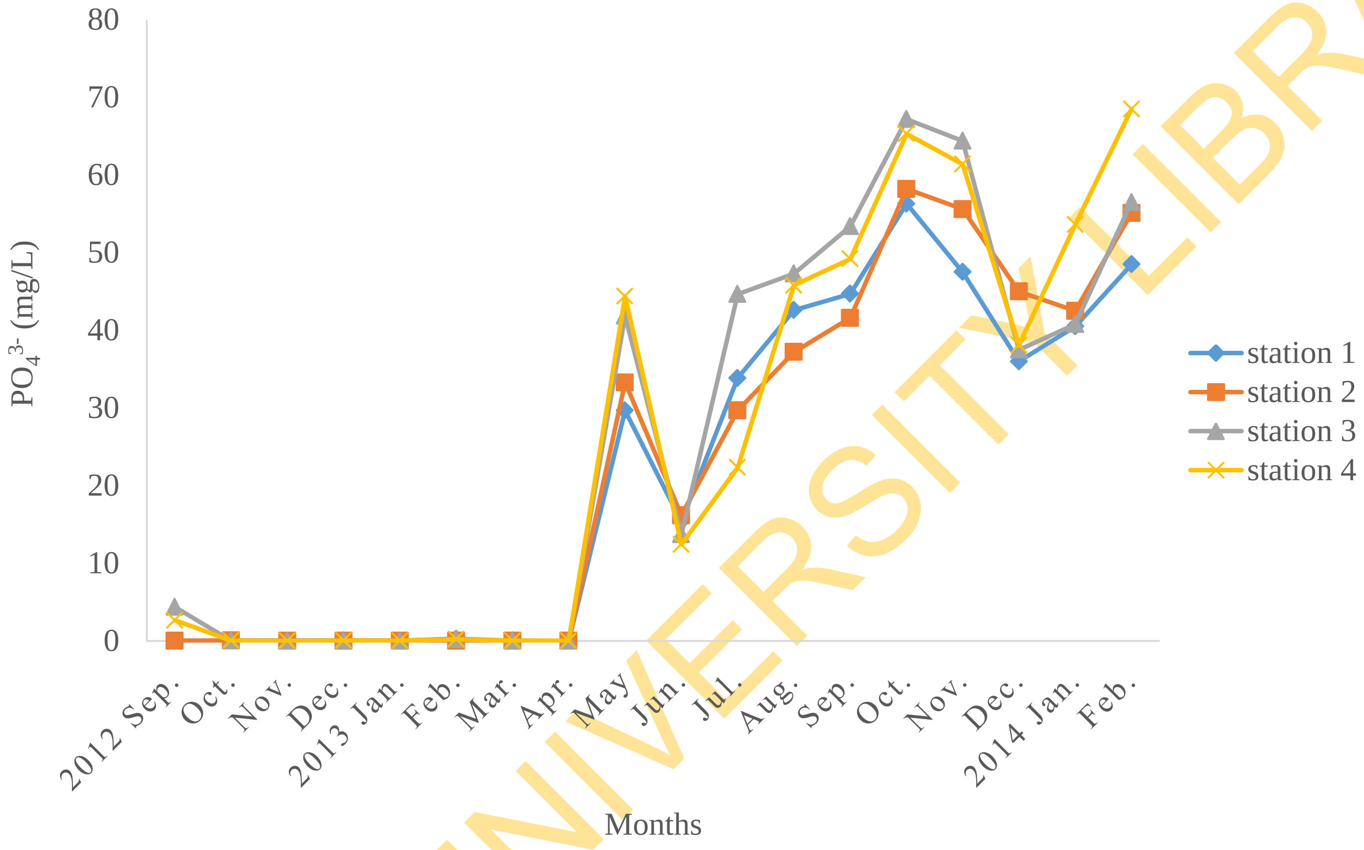


Fig 4.19: Mean monthly variation of PO_4^{3-} in Ibuya River

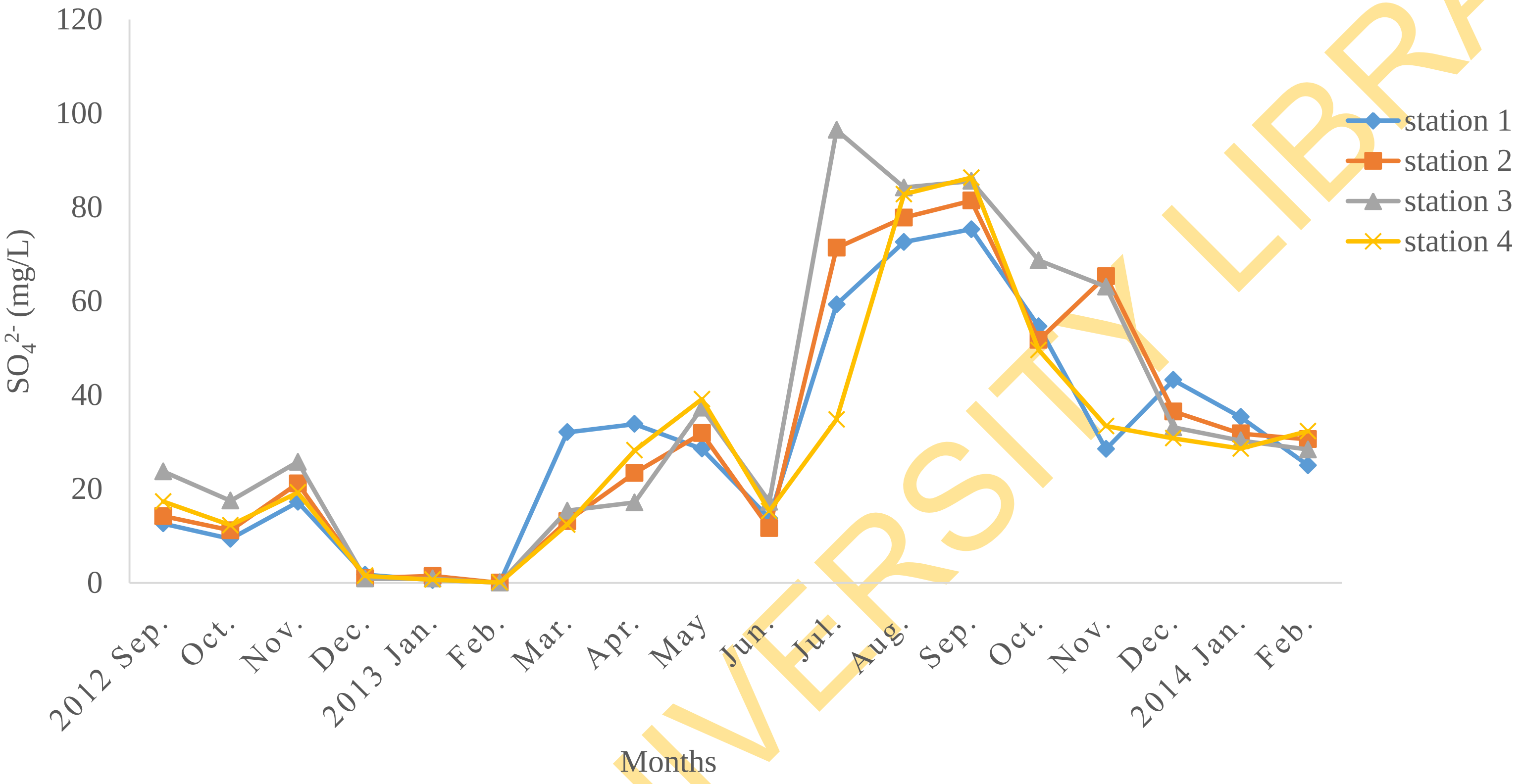


Fig 4.20: Mean monthly variation of SO_4^{2-} in Ibuya River

4.1.21. Nitrate (NO_3^-)

The value for Nitrate in Ibuya River fluctuated throughout the study period and it ranged from 0.00 mg/L to 97.60 mg/L with a mean of 32.00 ± 3.60 mg/L (Table 4.1). The lowest value of 0.00 mg/L was recorded in station 2 in the month of February, 2013 while the highest value of 97.60 mg/L was recorded in station 1 in the month of November, 2013. The mean monthly variations of nitrate in Ibuya River are presented in Fig. 4.21. The mean value for NO_3^- during the wet season (26.80±5.10 mg/L) 3 was lower than the dry season (36.1±4.68 mg/L) with no significant difference ($p>0.05$) between seasons. Spatial variations in NO_3^- were not significantly different ($p>0.05$) (Table 4.2).

4.1.22 Correlation between physico-chemical parameters

Correlation coefficient (r) values for physico-chemical parameters are presented in Table 4.3. There was significant correlation between air temperature and water temperature at $p<0.01$; air temperature negatively correlated with DO, Cu, NO_3^- at $p<0.05$; transparency, Mn, Cd, Zn and PO_4^{3-} at $p<0.01$. pH correlated significantly with hardness at $p<0.01$; alkalinity and magnesium at $p<0.05$ levels respectively; negatively correlated with NO_3^- at $p<0.05$. Dissolved oxygen correlated significantly with transparency at $p<0.05$, Cu, Cd, PO_4^{3-}, SO_4^{2-} and NO_3^- at $p<0.01$ respectively; negatively correlated with TDS, Hardness, and turbidity at $p<0.01$. Conductivity correlated significantly with TDS and magnesium at $p<0.01$; negatively correlated with transparency, Fe, Pb, PO_4^{3-}, SO_4^{2-} at $p<0.01$ and NO_3^- at $p<0.05$. TDS correlated significantly with magnesium at $p<0.01$; negatively correlated with transparency, Fe, Pb, PO_4^{3-}, SO_4^{2-} at $p<0.01$ and NO_3^- at $p<0.05$. Hardness correlated significantly with alkalinity and magnesium at $p<0.01$; negatively correlated with turbidity, Pb, Zn, at $p<0.05$; Cu, Cd, PO_4^{3-}, SO_4^{2-} and NO_3^- at $p<0.01$. Alkalinity correlated significantly with magnesium at $p<0.01$; negatively correlated with transparency, Mn, Cu, Cd, Pb, PO_4^{3-}, SO_4^{2-} and NO_3^- at $p<0.01$; Zn at $p<0.05$. Transparency correlated significantly with Cd, Zn, PO_4^{3-} and NO_3^- at $p<0.01$; negatively correlated with turbidity at $p<0.01$ and Fe at $p<0.05$. Turbidity correlated significantly with Cd at $p<0.05$; Mn, Cu, Fe, PO_4^{3-} and SO_4^{2-} at $p<0.01$ respectively; negatively correlated with Mg at $p<0.05$, and

Zn at $p<0.01$. Mg correlated significantly with Cl^{-} at $p<0.05$; negatively correlated with Cu, Cd, Pb, PO_4^{3-}, SO_4^{2-} and NO_3^{-} at $p<0.01$.

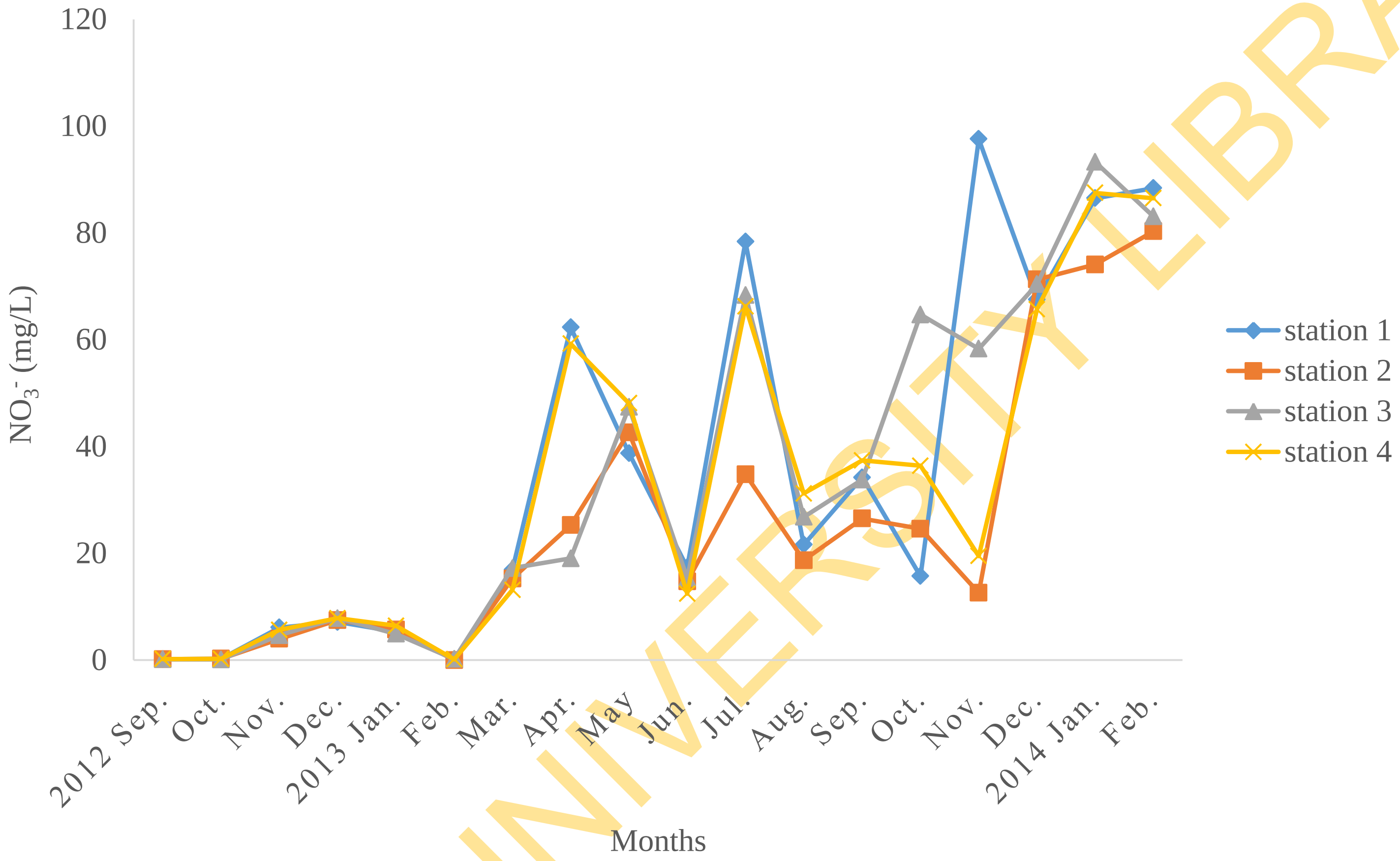


Fig 4.21: Mean monthly variation of NO_3^- in Ibuya River

Table 4.3: Correlation coefficient values for Physico-Chemical parameters of Ibuya River from September 2012 to February 2014

	Air temp.	Water temp.	pH	DO	Cond.	TDS	Hard.	Alk.	Trans	Turb.	Mg	Mn	Cu	Fe	Cd	Pb	Zn	Cl$^-$	PO$_4^{3-}$	SO$_4^{2-}$
Water temp.	.944**																			
pH	-0.094	-0.175																		
DO	-.256*	-0.107	0.007																	
Cond.	0.054	-0.038	0.078	-0.183																
TDS	0.045	-0.041	0.066	-0.184	.994**															
Hard.	0.005	-0.108	.409**	-.440**	0.102	0.093														
Alk.	0.155	0.042	.283*	-.542**	0.033	0.037	.760**													
Trans	-.550**	-.494**	-0.016	.239*	0.071	0.081	-0.192	-.304**												
Turb.	0.105	0.109	-0.026	0.213	-.423**	-.442**	-.249*	-0.214	-.524**											
Mg	-0.067	-0.216	.267*	-.385**	.689**	.680**	.477**	.446**	-0.194	-.245*										
Mn	-.385**	-.363**	-0.041	0.206	0.054	0.063	-0.229	-.308**	0.168	.345**	0.096									
Cu	-.238*	-0.186	0.005	.475**	-0.207	-0.217	-.446**	-.545**	0.177	.478**	-.386**	.526**								
Fe	-0.085	-0.121	0.165	-0.015	-.487**	-.499**	0.096	0.131	-.248*	.580**	-0.230	0.183	.400**							
Cd	-.354**	-.328**	0.044	.415**	-0.178	-0.177	-.332**	-.439**	.344**	.281*	-.319**	.640**	.780**	.256*						
Pb	-0.012	0.009	0.018	0.204	-.329**	-.354**	-.278*	-.315**	0.190	0.188	-.371**	0.106	0.211	0.208	.293*					
Zn	-.372**	-.324**	-0.137	0.228	0.124	0.142	-.267*	-.292*	.649**	-.485**	-0.158	0.096	0.094	-.299*	0.210	0.089				
Cl$^-$	-0.061	-0.189	0.115	0.016	0.198	0.158	0.037	-0.081	-0.197	.245*	.264*	-0.063	0.028	0.023	-0.033	0.040	-.294*			
PO$_4^{3-}$	-.385**	-.253*	-0.101	.648**	-.408**	-.413**	-.585**	-.674**	.335**	.341**	-.587**	.333**	.575**	0.198	.509**	.458**	.238*	-0.003		
SO$_4^{2-}$	-0.131	-0.041	-0.123	.516**	-.589**	-.602**	-.478**	-.509**	-0.054	.737**	-.635**	.406**	.712**	.574**	.584**	.383**	-0.089	0.086	.721**	
NO$_3^-$	-.301*	-0.178	-.262*	.324**	-.237*	-.244*	-.532**	-.623**	.629**	-0.077	-.582**	0.130	.475**	0.019	.378**	.320**	.502**	-0.134	.677**	.387**

**Correlation is significant at the 0.01 level (2-tailed); *Correlation is significant at the 0.05 level (2-tailed)

Key: Air temp = Air Temperature, Water temp = Water Temperature, Cond = Conductivity, Hard = Hardness, Alka = Alkalinity, Trans = Transparency, Turb = Turbidit

Mn correlated significantly with Cu, Cd, PO_4^{3-} and SO_4^{2-} at $p<0.01$. Cu correlated significantly with Fe, Cd, PO_4^{3-}, SO_4^{2-} and NO_3^{-} at $p<0.01$. Fe correlated significantly with Cd at $p<0.05$ and SO_4^{2-} at $p<0.01$; negatively correlated with Zn at $p<0.05$. Cd correlated significantly with Pb at $p<0.05$, PO_4^{3-}, SO_4^{2-} and NO_3^{-} at $p<0.01$. Pb correlated significantly with PO_4^{3-}, SO_4^{2-} and NO_3^{-} at $p<0.01$. Zn correlated significantly PO_4^{3-} and NO_3^{-} at $p<0.05$; negatively correlated Cl^{-} at $p<0.05$. PO_4^{3-} correlated significantly with SO_4^{2-} and NO_3^{-} at $p<0.01$. SO_4^{2-} correlated significantly with NO_3^{-} at $p<0.01$.

4.1.23 Principal component analysis (PCA) of physico-chemical parameters

The first three components for the dry season accounted for 70.69 % of the total variation. The first component accounted for 40.98 % of the explained variance. Hardness, alkalinity and magnesium recorded high positive loadings of 0.74, 0.79 and 0.73 respectively (Fig. 4.22). The second component accounted for 16.77 % of the explained variance. Air and water temperatures recorded high positive loadings of 0.60 and 0.68 respectively while turbidity recorded a positive loading of 0.51. The third component accounted for 12.94 % of the explained variance. Iron and phosphate recorded high positive loading of 0.84 and 0.55 respectively. The first two components for the wet season accounted for 54.75 % of the total variation. The first component accounted for 35.90 % of the explained variance. Hardness, alkalinity and magnesium recorded high positive loadings of 0.60, 0.78 and 0.61 respectively (Fig. 4.23). The second component accounted for 18.85 % of the explained variance. Air and water temperatures recorded high positive loading of 0.73 and 0.78 respectively while conductivity, TDS and zinc recorded positive loadings of 0.61, 0.57 and 0.64 respectively. The first three component for the annual variability accounted for 52.20 % of the total variation. The first component accounted for 26.77 % of the explained variance. Conductivity, TDS, hardness and alkalinity recorded high positive loadings of 0.62, 0.62, 0.60 and 0.63 respectively (Fig. 4.24). The second component accounted for 14.80 % of the explained variance. Turbidity and iron recorded high positive loadings of 0.60 and 0.54 respectively. The third component accounted for 10.63 % of the explained variance. Air and water temperature recorded high positive loading of 0.60 and 0.73 respectively.

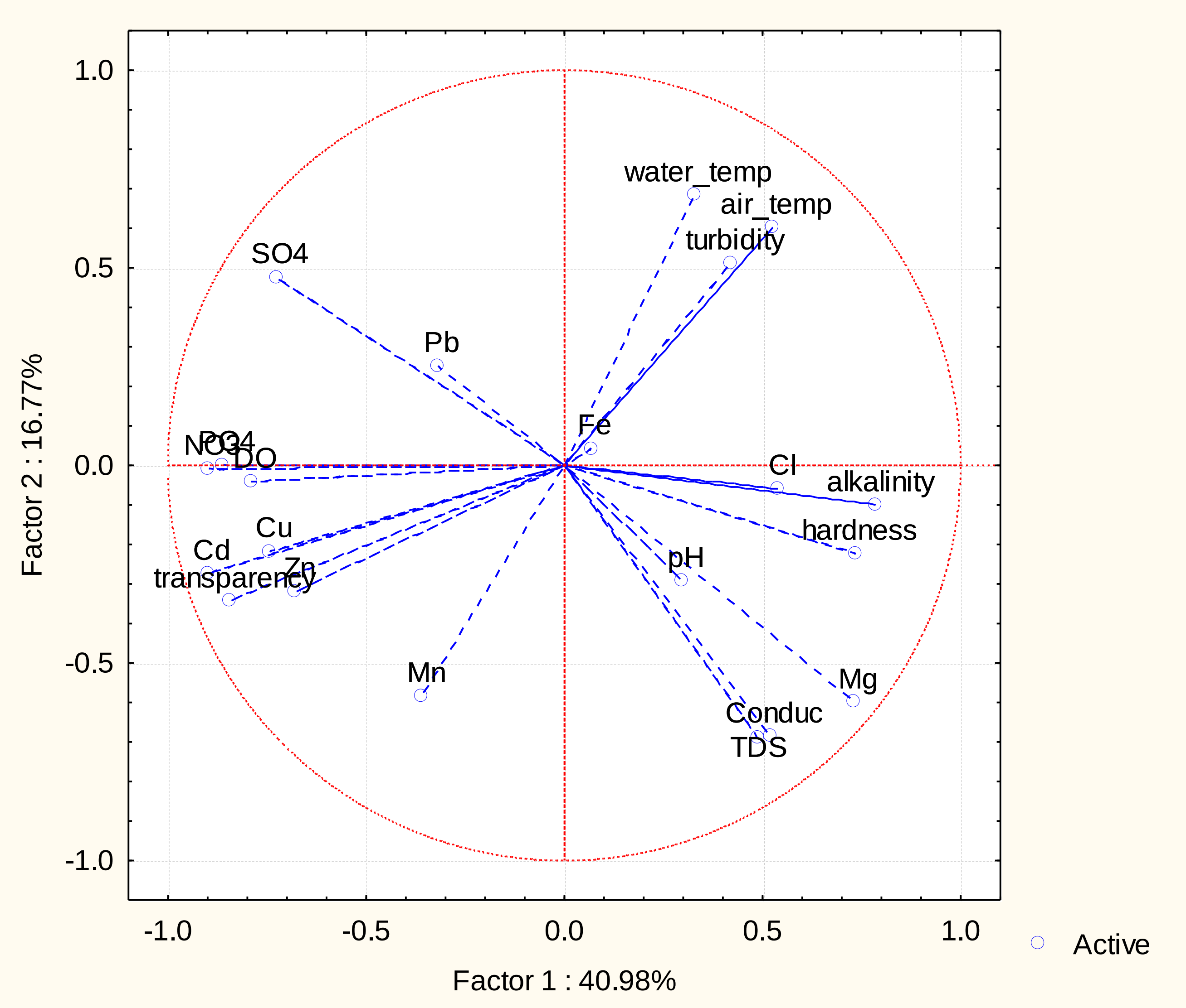


Fig. 4.22. Principal Component Analysis (PCA) plot of Physico-chemical parameters for dry season.

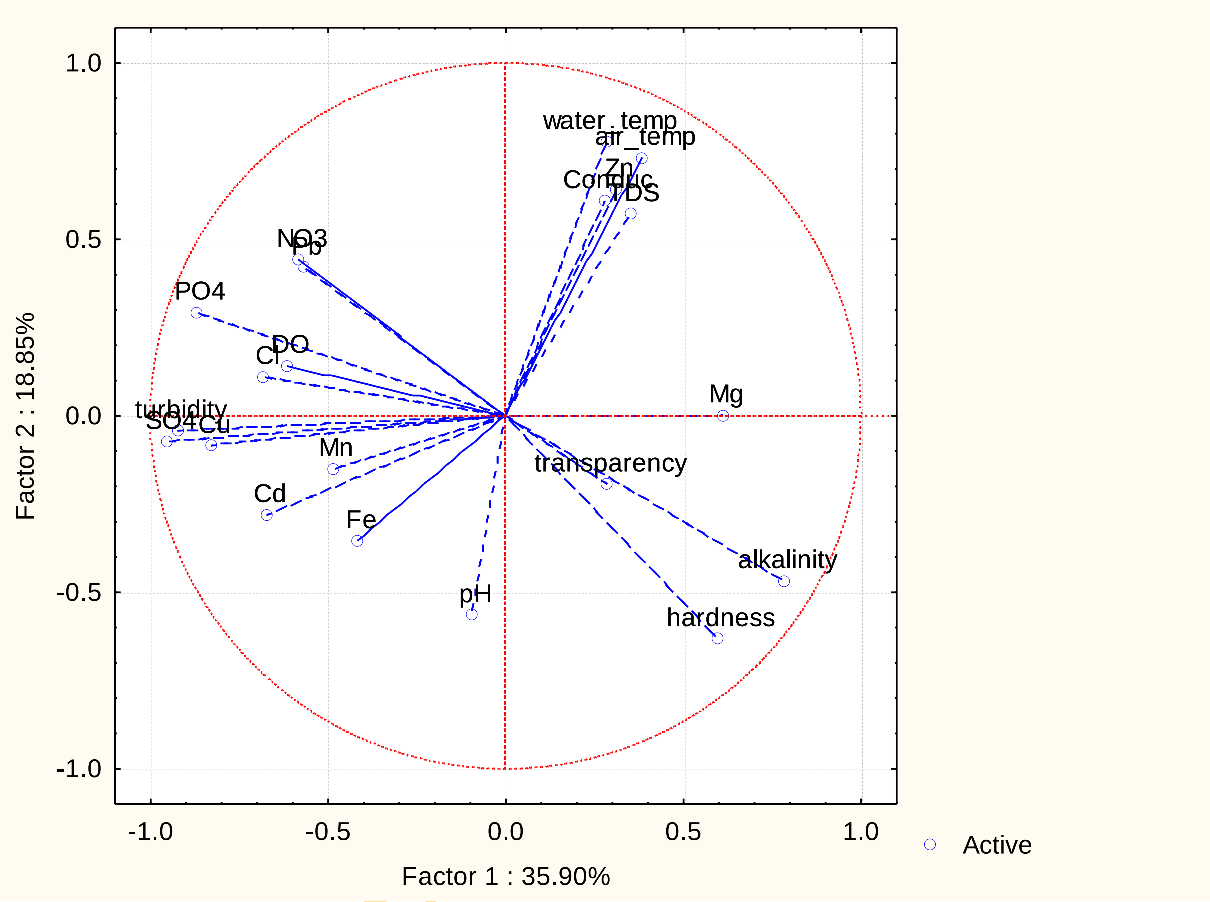


Fig. 4.23. Principal Component Analysis (PCA) plot of Physico-chemical parameters for wet season.

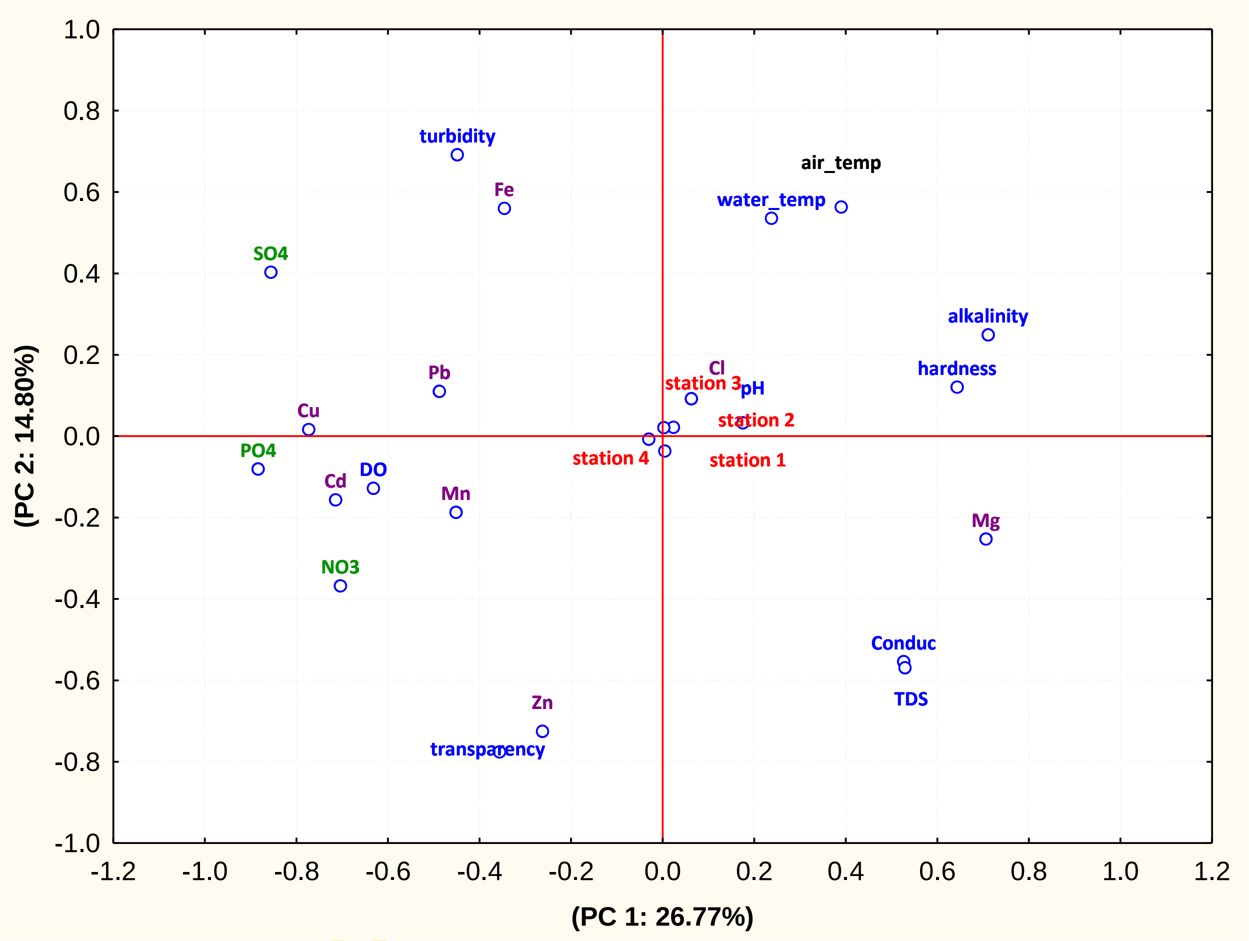


Fig. 4.24. Principal Component Analysis (PCA) plot of physico-chemical parameters for combined seasons.

4.2. Plankton

4.2.1 Phytoplankton composition and abundance

Table 4.4 shows the checklist of phytoplankton species encountered during the study period. Four families, comprising 29 genera and 45 species of phytoplankton were identified in Ibuya River during the period of study. Bacillariophyceae (diatoms) had 25 species, Chlorophyceae (green algae), 9 species, Euglenophyceae (euglenoids), 8 species and Cyanophyceae (blue-green algae), 3 species (Table 4.5). Phytoplankton encountered are shown in Plates 4.1-4.4. Detailed data obtained on compositon of phytoplankton from September 2012 to February 2014 are presented in appendices 6-9.

Bacillariophyceae accounted for 38.82 % of the total phytoplankton of which *Aulacoseira granulata* dominated and accounted for 14.35 %. This is followed by *Fragilaria construens* and *F. oceanica* with 10.87 % and 7.56 % respectively (Table 4.5). Stations 2 and 1 had the highest percentage abundance of diatoms (27.17 % and 27.12 % respectively) while station 4 had the lowest value of 20.85 % (Table 4.6). The variations of diatoms across the four stations were not significantly different ($p>0.05$) (Fig. 4.25). The wet season value of diatoms (1791.56±272.67 cells/ml) was higher than the dry season value of 1541.65±216.34 cells/ml with no significant difference ($p>0.05$) (Table 4.7).

Chlorophyceae accounted for 3.14 % of the relative abundance of phytoplankton. *Spirogyra dubra* dominated the green algae species and accounted for 1.77 %. This is followed by *Scenedesmus protuberans* with 0.24 % (Table 4.5). The highest percentage abundance of green algae was recorded in station 1 (32.79 %) while the lowest value was recorded in station 3 (21.24 %) (Table 4.6). Spatial variations of green algae were not significantly different ($p>0.05$) (Fig. 4.25). The wet season value of green algae was lower than the dry season value and the difference was not significant ($p>0.05$) (Table 4.7).

Euglenophyceae accounted for 1.91 % of the relative abundance of phytoplankton. *Euglena spirogyra* dominated the euglenoids with 0.40 % followed by *E. ehrenbergii* and *Prorocentrum gracile* with 0.35 % and 0.30 % respectively (Table 4.5). The highest percentage abundance of euglenoids was recorded in station 1 (34.56 %) while the

Table 4.4: A Checklist of phytoplankton species in Ibuya River

DIVISION: BACILLARIOPHYTA

Class: Bacillariophyceae

Order: Centrales

Family: Thalassiosiraceae

Genus: Aulacoseira Thwaites

Aulacoseira granulata (Ehr.) Simonsen v. *valida* (Hustedt) Simonsen, (1979)
Family: Coscinodiscacea
Genus: Coscinodiscus Ehrenberg
Coscinodiscus lineatus Grunow
Family: Melosiraceae
Genus: Cyclotella Kutz.
Cyclotella stelligera (Kütz.) (Brébisson, 1838)
Family: Lithodesmiaceae
Genus: Ditylum Bailey
Ditylum brightwellii (T.West) Grunow

Order: Pennales

Family: Cymbellaceae (Greville, 1833)
Genus: Cymbella (Agardh, 1830)
Cymbella sp.
Family: Diatomaceae
Diatoma elongatum (Rawlence 1987)
Genus: Fragillaria (Hustedt, 1930)
Fragilaria construens Ehr. v. *construens* f. *venter* (Ehr.) Hustedt.
F. oceanica
Genus: Synedra Ehrenberg
Synedra acus (Kutzing) Hustedt
S. crystallina
S. ulna (W.Smith) Brun
Genus: Tabellaria Ehrenberg
Tabellaria fenestrate (Lyng) Kutzing
Family: Naviculaceae Kutz.
Genus: Frustulia Rabenh
Frustulia rhomboids (Ross, 1947)
F. weinholdii (Rabenhorst, 1853)
Genus: Gyrosigma Agardh
Gyrosigma fasciola (Ehr.) Griffith and Henfrey
Genus: Navicula Bory
Navicula mutica (Kützing, 1844)

Genus: Pinnularia Ehrenberg

Pinnularia biceps

P. cardinalis

P. gibba (Krammer, 1992)

P. nobilis Ehr.

Family: Nitzschiaceae Grunow

Genus: Nitzschia Hass.

Nitzschia sigmoidea

Nitzschia sp. (Hassall, 1845)

N. spiculum

Family: Gomphonemataceae (Kützing, 1844)

Gomphonema dubravicense

Family: Bacillariaceae (Ehrenberg, 1840)

Peridinium sp.

DIVISION: CHLOROPHYTA

Class: Chlorophyceae

Order: Desmidiales

Family: Closteriaceae

Genus: Closterium (Nitzsch) Ralf

Closterium acerosum var. elongatum (Schr) Ehr.

C. ehrenbergii Menegh

C. lineatum var. africanum (Ehr.)

Genus: Cosmarium Corda

Cosmarium granatum var. concavum

Genus: Spirogyra Link

Spirogyra dubra Kutz.

Family: Scenedesmaceae

Genus: Scenedesmus Meyen

Scenedesmus opoliensis

S. protuberans

Family: Hydrodictyaceae

Genus: Pediastrum Meyen

Pediastrum duplex Meyen

Order: Volvocales

Family: Volvocaceae
Genus: Pandorina Bory

Pandorina morum

DIVISION: EUGLENOPHYTA

Class: Euglenophyceae

Order: Euglenales

Family: Euglenaceae

Genus: Euglena Ehrenberg
Euglena Ehrenbergii

E. oxyuris Schmarda

E. spirogyra Ehrenbergii

E. tripteris Dujardin

Genus: Phacus Dujardin

Phacus longicauda var. *torta*

P. pleuronectes

Prorocentrum gracile

Genus: Trachelomonas Ehrenberg

Trachelomonas planctonia

DIVISION: CYANOPHYTA

Class: Cyanophyceae

Order: Chroococcales

Family: Chroococacceae

Genus: Merismepodia Meyen

Merismopedia punctate

Genus: Microcystis Kutzing

Microcystis aeruginosa Kutz.

Family: Oscillatoriaceae

Genus: Oscillatoria Vaucher

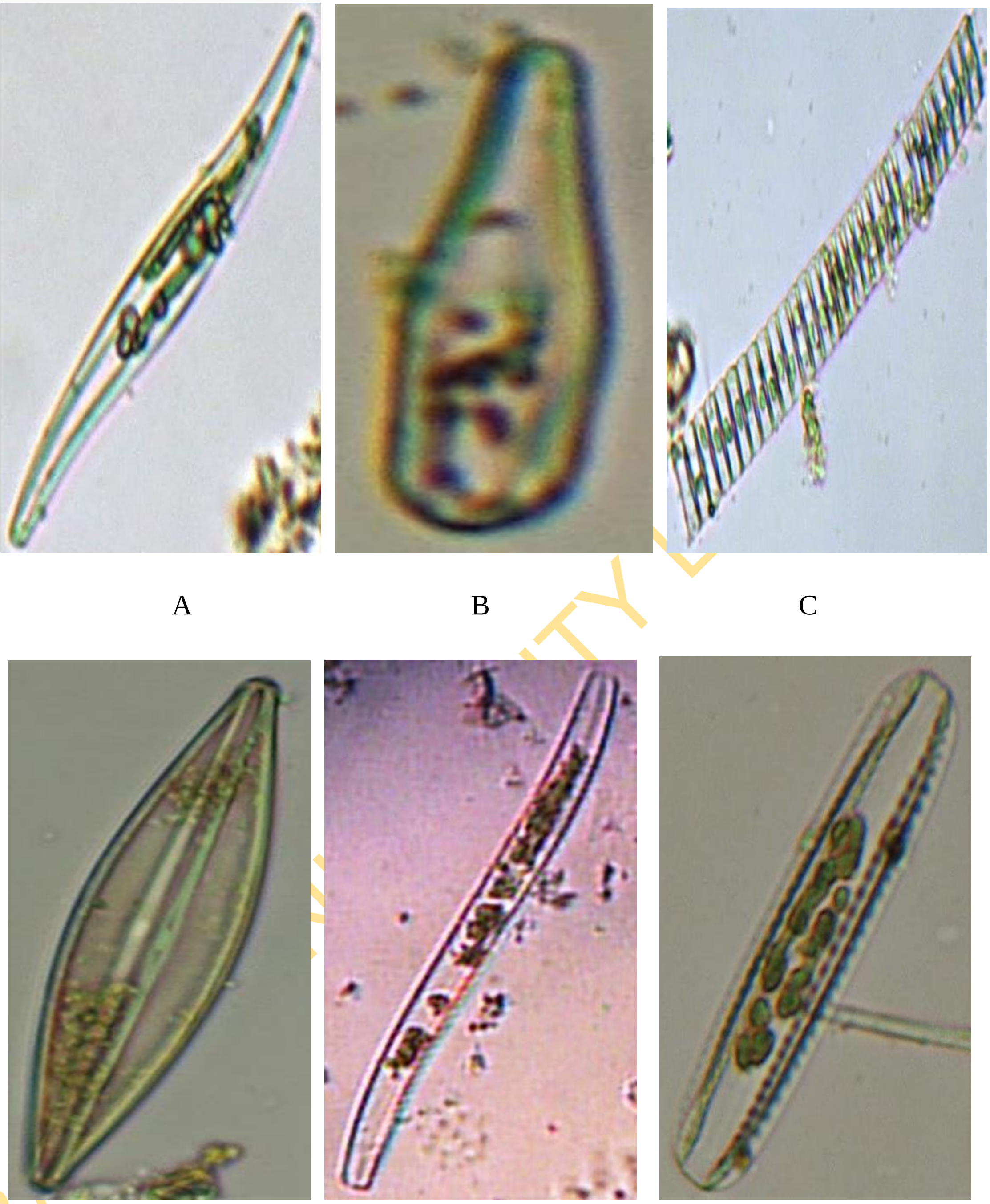
Oscillatoria princeps Vaucher

Table 4.5: Relative Abundance of Phytoplankton organisms in Ibuya River.

Bacillariophyceae	No of cells/ml	Percentage (%) number of phytoplankton
**Aulacoseira granulata*	43978	14.35
**Coscinodiscus lineatus*	1235	0.40
**Cymbella sp.*	338	0.11
**Cyclotella stelligera*	429	0.14
Diatoma elongatum	676	0.22
Ditylum brightwellii	325	0.11
**Fragilaria construens*	33332	10.87
**F. oceanica*	23166	7.56
**Frustulia rhomboides*	442	0.14
**F. weinholdii*	585	0.19
**Gomphonema dubravicense*	741	0.24
Gyrosigma fasciola	507	0.17
**Navicula mutica*	507	0.17
Nitzschia sigmoidea	1079	0.35
Nitzschia sp.	1535	0.50
N. spiculum	1995	0.65
Peridinium sp.	533	0.17
**Pinnularia biceps*	403	0.13
**P. cardinalis*	1326	0.43
**P. gibba*	494	0.16
P. nobilis*	364	0.12
**Synedra acus*	1456	0.48
**S. crystallina*	794	0.26
**S. ulna*	1612	0.53
Tabellaria fenestrata	1144	0.37
Subtotal	**118996**	**38.82**
Chlorophyceae		
**Closterium acerosum var. elongatum*	702	0.23

**C. ehrenbergii menegh*	351	0.11
**C. lineatum var. africanum*	468	0.15
**Cosmarium granatum var. concavum*	390	0.13
Pandorina morum	286	0.09
**Pediastrum duplex*	442	0.14
Scenedesmus opoliensis	611	0.20
S. protuberans	949	0.24
Spirogyra dubra	5421	1.77
Subtotal	**9620**	**3.12**
Euglenophyceae		
Euglena ehrenbergii	1066	0.35
E. oxyuris	624	0.20
E. spirogyra ehrenbergii	1235	0.40
E. tripteris dujardin	533	0.17
**Phacus longicauda var. torta*	520	0.17
**P. pleuronectes*	598	0.20
**Prorocentrum gracile*	910	0.30
**Trachelomonas planctonia*	364	0.12
Subtotal	**5850**	**1.91**
Cyanophyceae		
**Microcystis aeruginosa*	600	0.20
**Merismopedia punctata*	159744	52.12
**Oscillatoria princeps*	11710	3.82
Subtotal	**172054**	**56.13**

* Pollution indicator species

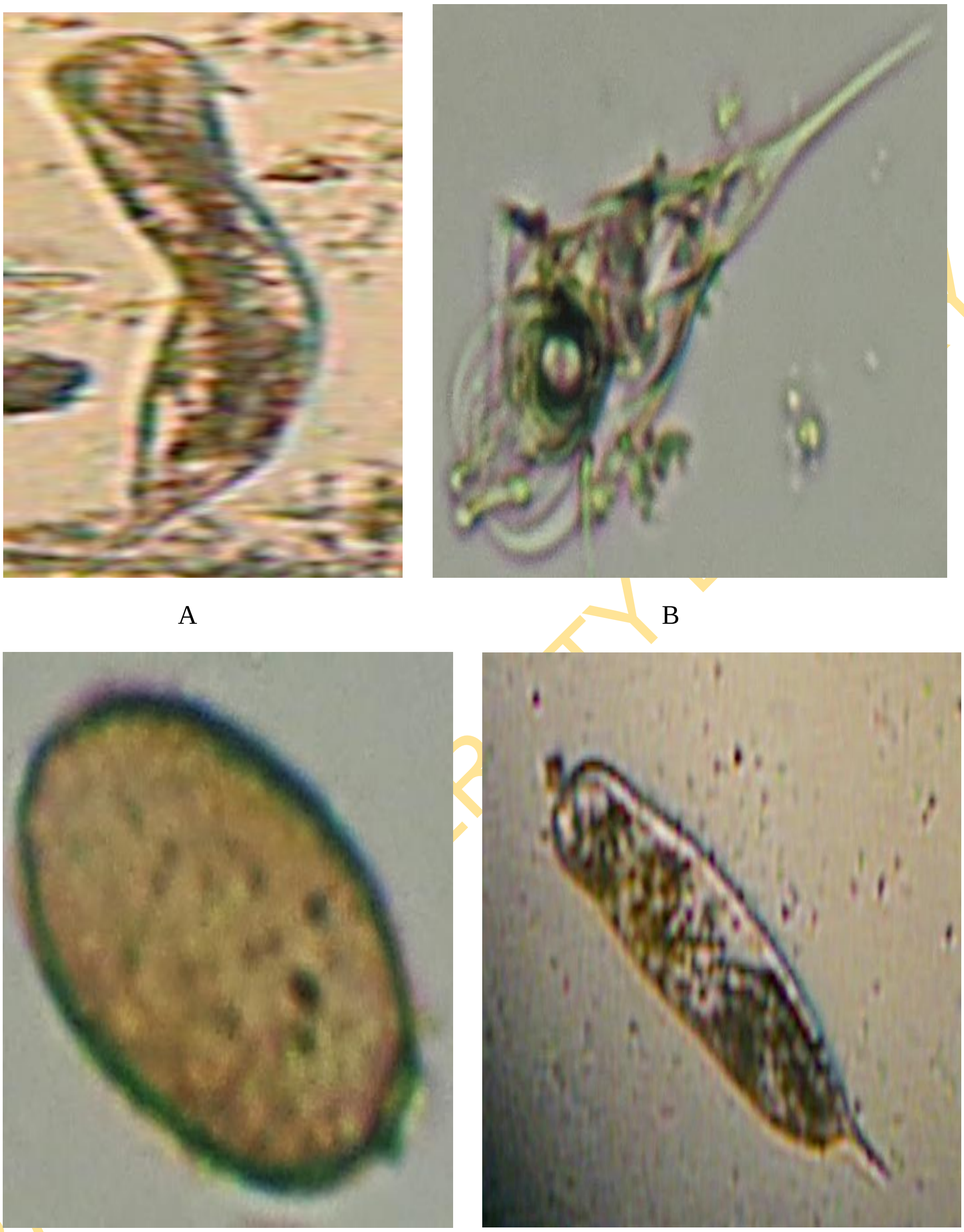


A B C

D E F

Key: A = *Gyrosigma fasciola* x100 B = *Gomphonema dubravicense* x400
C = *Fragilaria construens* x100 D = *Frustulia rhomboids* x100
E = *Nitzschia sigmoidea* x100 F = *Pinnularia cardinal* x100

Plate 4.1: Phytoplankton (Bacillariophyceae) encountered in Ibuya River



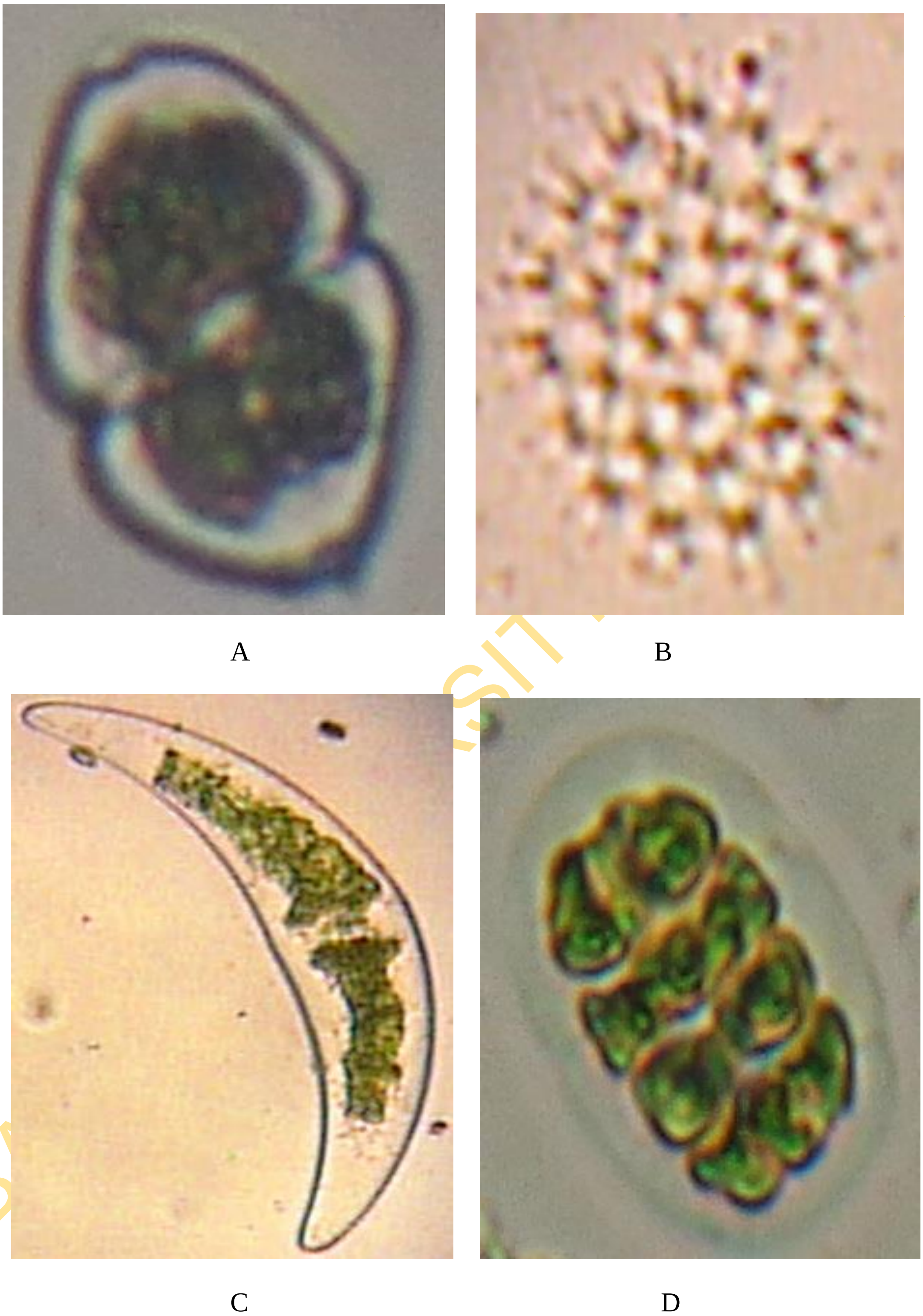
A B

C D

Key: A = *Euglena spirogyra* x400 B = *Phacus longicauda* x100

C = *Trachelomonas planctonica* x400 D = *E. oxyuris* x400

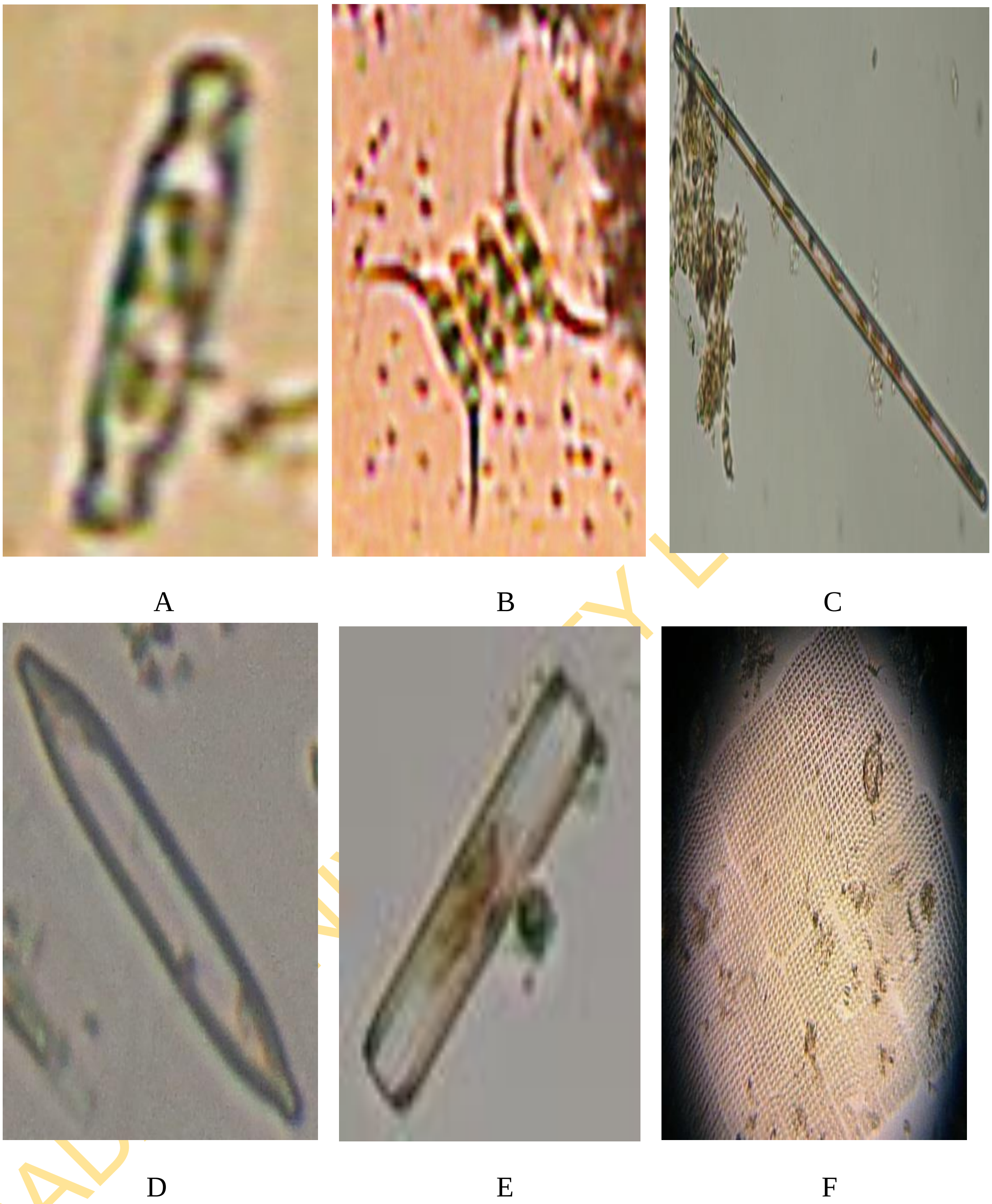
Plate 4.2: Phytoplankton (Euglenophyceae) encountered in Ibuya River



Key: A = *Cosmarium pyramidatum* x400 B = *Pediastrum duplex* x400

C = *Closterium ehrenbergii menegh* x100 D = *Pandorina morum* x100

Plate 4.3: Phytoplankton (Chlorophyceae) encountered in Ibuya River



Key: Bacillerophyceae: A = *Pinnularia biceps* x400
B = *Scenedesmus protuberans* x100
C = *Synedra acus* x100
D = *S. ulna* x100
E = *Tabellaria fenestrate* x100
Cyanophyceae: F = *Merismopedia punctata* x400

Plate 4.4: Phytoplankton (Bacillerophyceae and Cyanophyceae) encountered in Ibuya River

Table 4.6: Percentage abundance of phytoplankton in various sampling stations in Ibuya River

Phytoplankton	Station 1 (inlet)		Station 2 (middle)		Station 3 (middle)		Station 4 (outlet)	
Bacillariophyceae	32272	27.12%	32332	27.17%	29582	24.86%	24811	20.85%
Euglecophyceae	2022	34.56%	1478	25.26%	997	17.04%	1353	23.13%
Chlorophyceae	3155	32.79%	2285	23.75%	2044	21.24%	2139	22.23%
Cyanophyceae	64369	37.41%	53430	31.05%	33703	19.59%	20552	11.95%
Total	**101818**		**89525**		**66326**		**48855**	

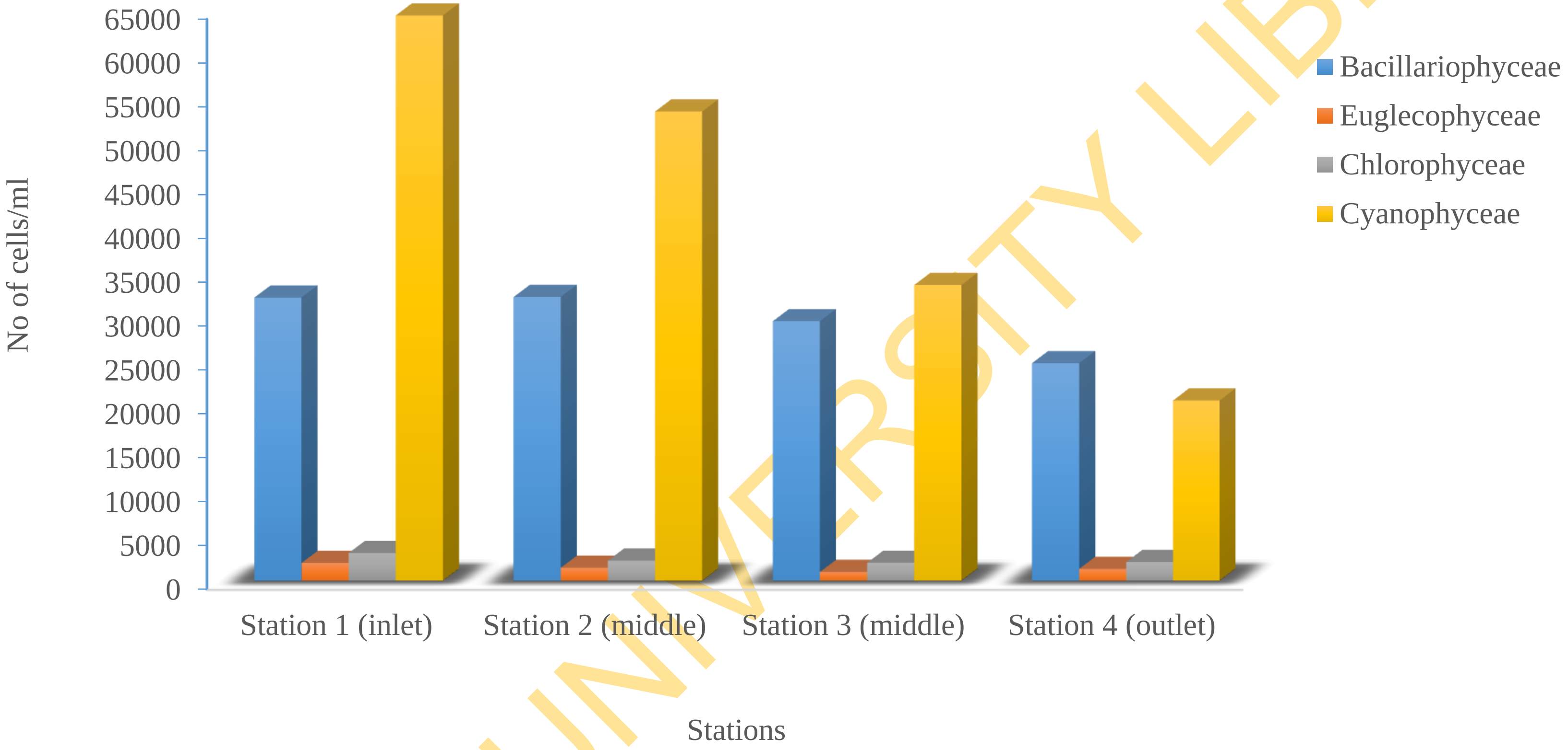


Fig. 4. 25: Spatial variation of Phytoplankton Abundance in Ibuya River

Table 4.7: Mean phytoplankton value for the wet and dry season in Ibuya River

Phytoplankton	**Season**	
	Wet	**Dry**
Bacillariophyceae	1791.56±272.67	1541.65±216.34
Euglecophyceae	82.06±13.29	80.60±11.65
Chlorophyceae	126.84±26.64	120.93±19.12
Cyanophyceae	2612.31±1774.38	2211.50±1366.50

lowest value was recorded in station 3 (17.04 %) (Table 4.6). Spatial variations of diatoms were not significantly different ($p>0.05$) (Fig. 4.25). The wet season value was higher than the dry season value with no significant difference ($p>0.05$) (Table 4.7).

Cyanophyceae accounted for 56.13 % of the relative abundance of phytoplankton. *Merismopedia punctata* dominated the blue-green algae and accounted for 52.12 %; followed by *Oscillatoria princeps* with 3.82 % while *Microcystis aeruginosa* was the least with 0.20 % (Table 4.5). Station 1 had the highest percentage abundance of blue-green algae (37.41 %) while station 4 had the lowest value of (11.95 %) (Table 4.6). Spatial variations of blue-green algae were not significantly different ($p>0.05$) (Fig. 25). The wet season value of blue-green algae was not significantly higher than the dry season value ($p>0.05$) (Table 4.7).

4.2.2 Phytoplankton diversity

Diversity (H) for Bacillariophyceae was higher in station 4 (2.63) and lowest in station 3 (2.49). Evenness (E) ranged from 0.86 in station 3 to 0.91 in station 4 (Table 4.8). Higher diversity (H) value for Euglenophyceae was recorded in station 4 (2.92) and lower in station 2 (2.47). Evenness (E) ranged from 0.85 in station 2 to 1.01 in station 4 (Table 4.8). The diversity (H) for Chlorophyceae was highest in station 2 (3.75) and lowest in station 4 (2.38). Evenness (E) ranged from 0.82 in station 4 to 1.3 in station 2 (Table 4.8). Divesity (H) for Cyanophyceae was highest in station 3 (1.66) and lowest in station 2 (0.03). Evenness was highest in station 3 (0.69) and lowest in station 2 (0.02) (Table 4.8).

4.2.3 Correlation of physico-chemical parameters and phytoplankton abundance

Correlation coefficient values for Physico-chemical parameters and phytoplankton abundance are presented in Table 4.9. Bacillariophyceae had a significant positive correlation with conductivity ($r = 0.35$), TDS ($r = 0.36$), hardness ($r= 0.31$), alkalinity ($r= 0.39$) and Mg ($r=0.62$); negative significant correlation with DO ($r= -0.31$), Cu ($r= -0.37$), Cd ($r= -0.43$), Pb ($r= -0.34$), PO_4^{3-} ($r= -0.44$), SO_4^{3-} ($r= -0.45$), NO_3^- ($r= -0.45$) at $p<0.01$ and transparency ($r= -0.29$) at $p<0.05$ level. Chlorophyceae had a significant negative correlation with pH ($r= -0.48$) at $p<0.01$, DO ($r= -0.24$) and Pb ($r= -0.29$) at $p<0.05$.

Table 4.8: Diversity and evenness of phytoplankton in the different sampling stations in Ibuya River.

Stations	**Bacillariophyceae**		**Euglecophyceae**		**Chlorophyceae**		**Cyanophyceae**	
	Diversity (H)	Evenness	Diversity (H)	Evenness	Diversity (H)	Evenness	Diversity (H)	Evenness
1	2.60	0.90	2.73	0.94	2.68	0.93	0.47	0.34
2	2.57	0.89	2.47	0.85	3.75	1.30	0.03	0.02
3	2.49	0.86	2.74	0.95	2.44	0.84	1.66	0.69
4	2.63	0.91	2.92	1.01	2.38	0.82	1.54	0.67

Table 4.9: Correlation coefficient between physico-chemical parameters and phytoplankton abundance in Ibuya River

	Air Temp.	Water Temp.	pH	DO	Cond.	TDS	Hard.	Alk.	Trans	Turb.	Mg	Mn	Cu	Fe	Cd	Pb	Zn	Cl^{-}	PO$_4^{3-}$	SO$_4^{2-}$	NO$_3^{-}$
Bacil	.000	-.093	-.023	-.310**	**.347****	**.362****	**.307****	**.396****	**-.290****	-.089	**.616****	-.120	**-.373****	-.062	**-.425****	**-.343****	-.209	.191	**-.441****	**-.449****	**-.454****
Eugl	.014	.028	-.150	.096	-.193	-.191	-.042	.070	.049	.015	-.031	.009	-.059	-.014	.048	.142	.097	.093	-.062	.029	.010
Chlor	-.014	-.026	**-.478****	**-.237***	-.022	-.003	-.142	.076	.020	-.132	-.012	-.142	-.211	-.213	-.168	**-.287***	-.013	.123	-.162	-.186	-.017
Cyan	.006	.014	-.135	-.053	-.104	-.115	-.067	-.142	-.024	.119	-.131	-.054	.002	.169	-.082	.179	-.053	.060	.160	.178	.110

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlationn is significant at the 0.05 level (2-tailed)

Key: Air temp = Air Temperature, Water temp = Water Temperature, Cond = Conductivity, Hard = Hardness, Alka = Alkalinity, Trans = Transparency, Turb = Turbidity, Bacil = Bacillerophyceae, Eugl = Euglenophyceae, Chlor = Chlorophyceae, Cyan = Cyanophyceae

Euglenophyceae and Cyanophyceae had no significant relationships with the physico-chemical parameters.

4.2.4 Zooplankton composition and abundance

Three classes made up of fifteen genera and twenty one zooplankton species were identified during the study period. Rotifera encountered during the study period were fifteen species, Crustacea were five species while Insecta was one species (Table 4. 10). Zooplankton encountered during the study period are shown in Plates 4.5-4.7. Detailed data on composition of zooplankton from September 2012 to February 2014 are presented in appendices 10-12

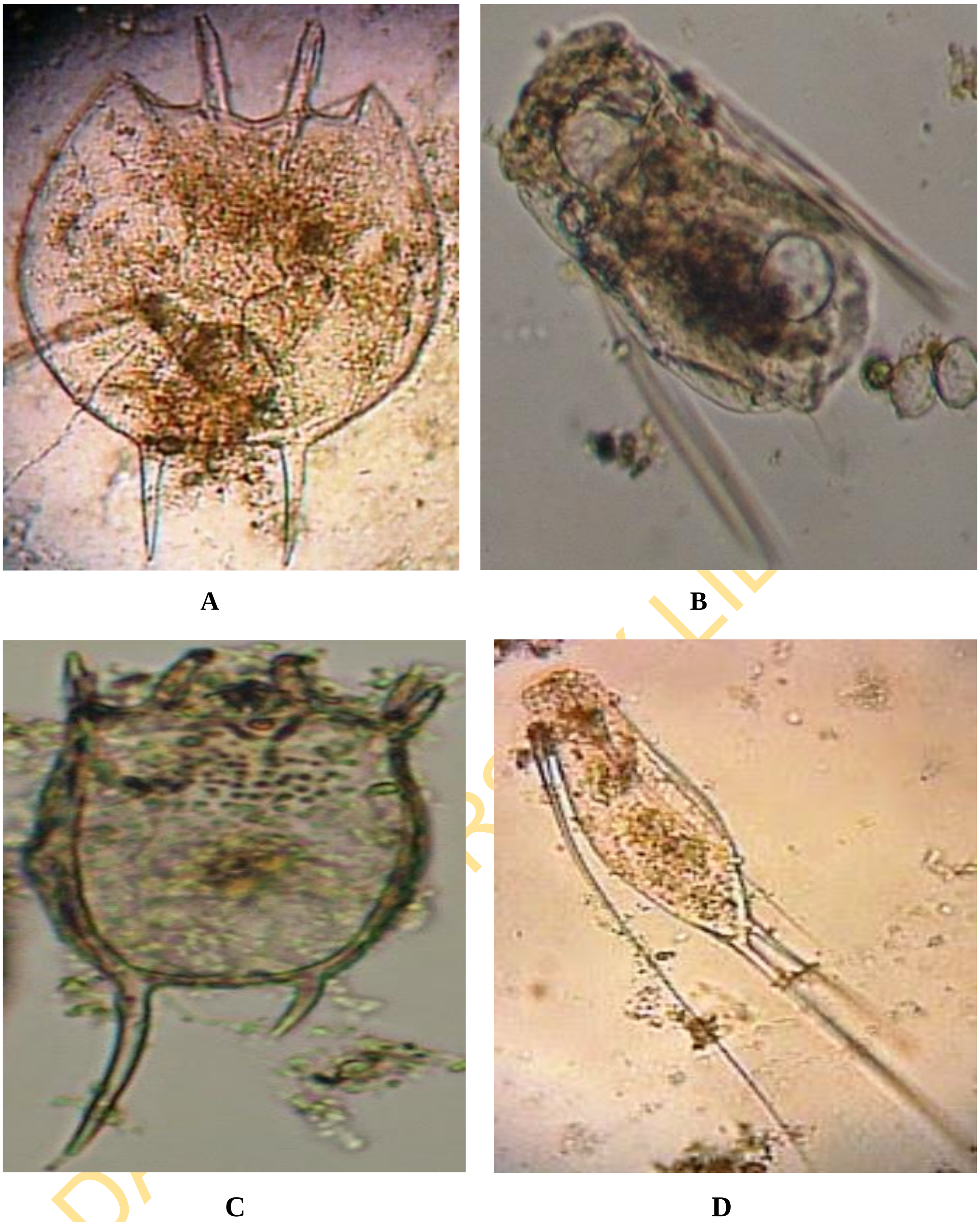
Rotifera accounted for 62.6 % of the relative abundance of zooplankton, followed by Crustacea with 32.9 % while Insecta accounted for 4.5 % (Table 4.10). *Mesocyclops leuckarti* had the highest value (11.64 %) followed by *Trichocerca elongate* and *Diaphanosoma paucispinosum* (7.45%) while the lowest is *Keratella valga* (1.87 %). Figure 4.26 shows the spatial variations of the zooplankton encountered. It demonstrated that Rotifera and Crustacea had highest number of individuals in station 2 and lowest in station 4 respectively while Insecta had highest number of individuals in station 1 and lowest in station 3 and 4. The wet and dry season value for Rotifera were not significantly different ($p>0.05$). The wet season value for Crustacea was lower than the dry season value (Table 4.11), the difference were significant ($p<0.05$). Insecta value for the wet season was higher than the dry season with no significant difference ($p>0.05$) (Table 4.11).

4.2.5 Zooplankton diversity

Highest diversity (H) of Rotifera was encountered in station 2 while lowest (H) was encountered in station 1. Evenness (E) ranged from 0.82 in station 1 to 0.98 in station 2 (Table 4.12). Crustacea had higher (H) in station 3 and lower in station 1. Evenness (E) ranged from 0.78 in station 1 to 0.82 in station 3 (Table 4.12).

Table 4.10: Relative abundance of zooplankton organisms of Ibuya River

Zooplankton	No of organisms/ml	Relative abundance %
Rotifera		
Anuraeopsis fissa	260	2.87
Brachionus angularis	299	3.30
B. falcatus	520	5.75
B. calyciflorus	338	3.74
Chromogaster ovalis	208	2.30
Filinia terminalis	338	3.74
F. opoliensis	234	2.59
Keratella quadrata	377	4.17
K. valga	169	1.87
Lecane bulla	546	6.03
L. luna	403	4.45
Platyias quadricornis	416	4.60
Polyarthra dolicoptera	442	4.89
P. vulgaris	442	4.89
Trichocerca elongate	676	7.47
Subtotal	**5668**	**62.6**
Crustacea		
Mesocyclops leuckarti	1053	11.64
Harpacticoid sp.	624	6.90
Diaphanosoma paucispinosum	676	7.47
Arachnactis larva	299	3.30
Nauplius larva	325	3.59
Subtotal	**2977**	**32.9**
Insecta		
Chironomus riparius	403	4.45

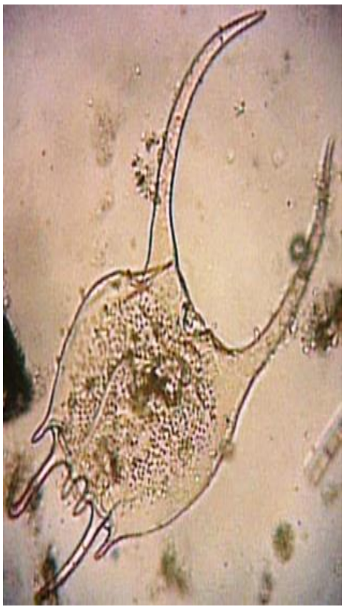


Key: **A**. *Platyias quadricornis* x100 **C.** *Keratella valga* x100

B. *Polyarthra vulgaris carlin* x100 **D**. *Filinia opoliensis* x100

Plate 4.5: Zooplankton (Rotifera) encountered in Ibuya River

A



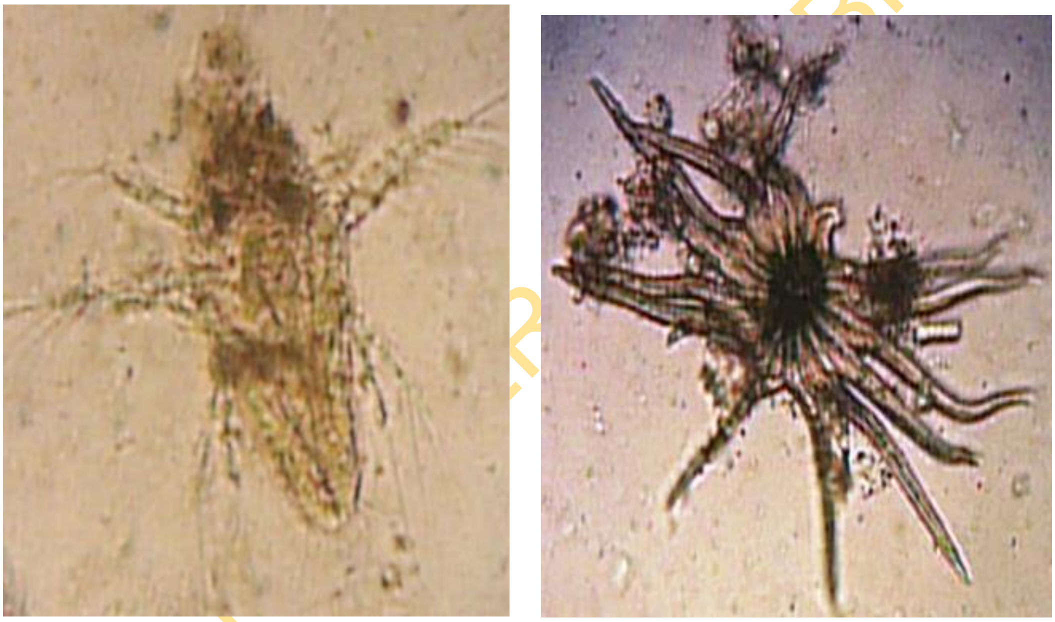
B

C

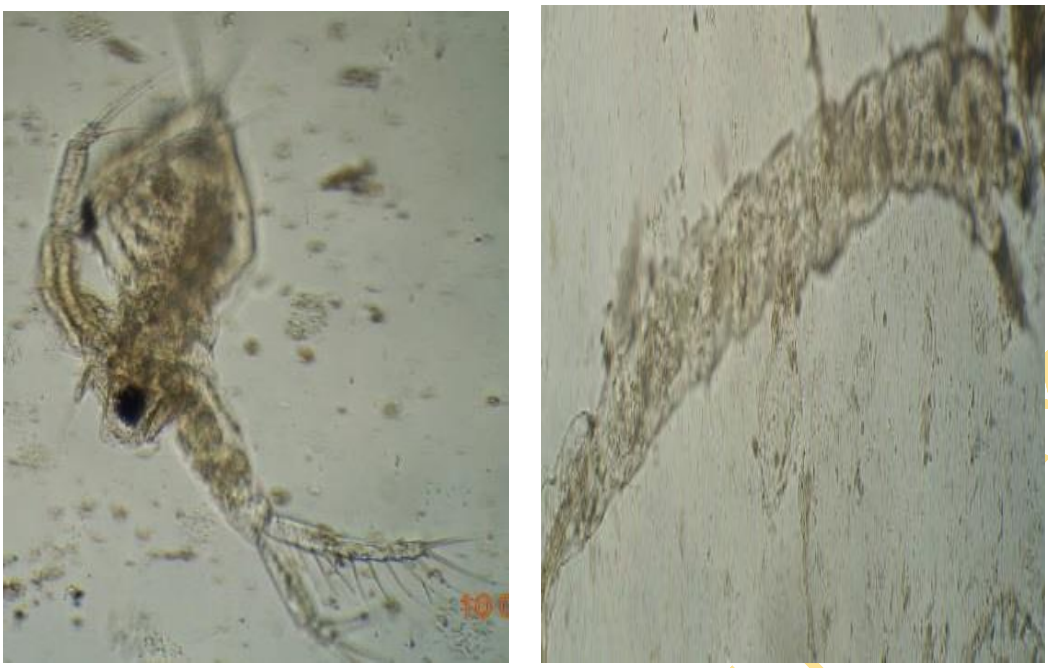
D **E** **F**

Key: A. *Brachionus calyciflorus* x100 **D.** *Anuraeopsis fissa* x100
B. *Brachionus falcatus* x100 **E.** *Lecane luna* x100
C. *Keratella quadrata* x100 **F.** *L. bulla* x100

Plate 4.6: Zooplankton (Rotifera) encountered in Ibuya River



A B



C D

Key: Crustacea: **A.** *Nauplius larva* x100

B. *Arachnactis larva* x100

C. *Diaphanosoma paucispinosum* x100 .

Insecta: **D.** *Chironomus riparius* x100

Plate 4.7: Zooplankton (Crustacea and Insecta) encountered in Ibuya River

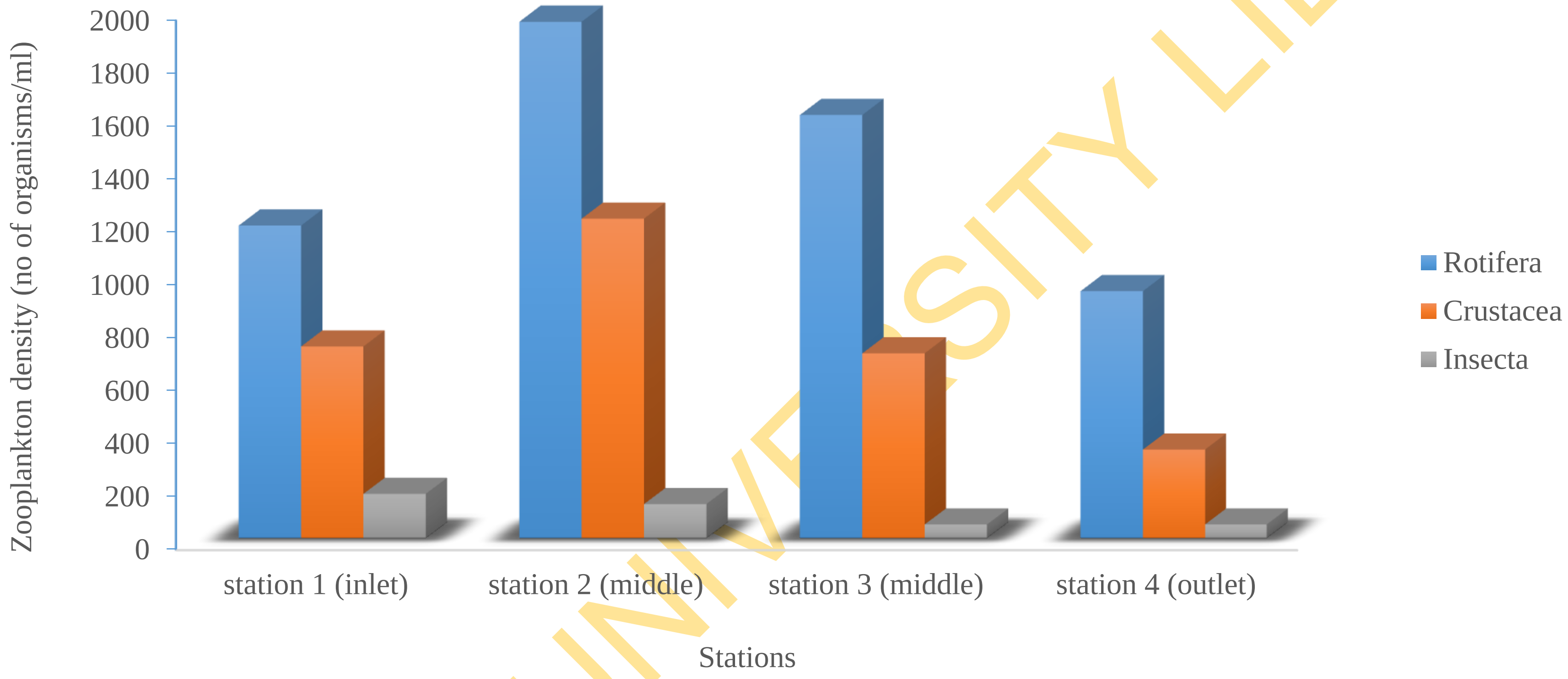


Fig. 4. 26: Spatial variation of zooplankton abundance in Ibuya River

Table 4.11: Mean zooplankton values for the wet and dry season in Ibuya River

Zooplankton	Season	
	Wet	Dry
Rotifera	88.56±11.4	70.85±11.5
Crustacea	26.81±3.5	52.98±11.7*
Insecta	6.50±1.5	4.88±1.4

***** Significant at p<0.05 level

Table 4.12: Diversity and evenness of zooplankton in the different sampling stations in Ibuya River.

Stations	**Rotiferea**		**Crustacea**	
	Diversity (H)	**Evenness**	**Diversity (H)**	**Evenness**
1	2.37	0.82	2.27	0.78
2	2.83	0.98	2.35	0.81
3	2.66	0.92	2.36	0.82
4	2.45	0.85	2.29	0.79

4.2.6 Correlation between physico-chemical parameters and zooplankton abundance

Correlation coefficient (r) values for physico-chemical parameters and zooplankton abundance are presented in Table 4.13. Crustacea had a significant positive correlation with air and water temperature (r = 0.48 and r = 0.44) respectively and a significant negative correlation with PO_4^{3-} (r = -0.31) at $p<0.01$ level. Rotifera and Insecta did not show any significant relationships with physico-chemical parameters.

4.3. Macrozoobenthos

4.3.1 Macrozoobenthos composition and abundance

The relative abundance of macrozoobenthos are shown in Table 4.14. A total of 8 macrozoobenthos genera belonging to two phyla, Mollusca and Arthropoda were encountered. Mollusca were represented by gastropods which accounted for 80.42 % and bivalves 4.94 %, Arthropoda was represented by Crustaceans and Insecta which accounted for 2.82 % and 11.82 % respectively of macrozoobenthos encountered (Fig. 4.27). The gastropod *Indoplanobis exustus* was the most abundant species accounting for 30.86 % and the least *Cardisoma sp*. a crustacean accounted for 2.82 % of the total number of individuals. Plate 4.8 showed the macrozoobenthos encountered during the study period. Detailed data obtained on composition of macrozoobenthos from September 2012 to February 2014 are presented in appendices 13-31.

Gastropoda had highest population density in stations 4 (206 organisms/m^2) and 1 (139 organisms/m^2); Bivalvia in station 4 (15 organisms/m^2); Insecta in station 1 (40 organisms/m^2); and Crustacea in station 4 (10 organisms/m^2) while the lowest density for gastropods, bivalves and insect were recorded in station 3 (47 organisms/m^2), (5 organisms/m^2), and (3 organisms/m^2) respectively and station 2 recorded zero population density for crustacean (Fig. 4.28). *Indoplanorbis exustus*, and *Melanoides tuberculata* were more abundant in stations 4 and 1 while *Donax vittatus*, *Cardisoma sp*. and *Gabbiella sp*. were the least abundant in these stations. *Cardisoma sp.* was not encountered in station 2.

Table 4.13: Correlation coefficient between physico-chemical parameters and zooplankton abundance in Ibuya River

	Air temp	Water temp	pH	DO	Cond	TDS	Hard	Alk	Trans	Turb	Mg	Mn	Cu	Fe	Cd	Pb	Zn	Cl^-	PO_4^{3-}	SO_4^{2-}	NO_3^-
Roti.	.113	.083	.095	.004	.032	.040	.024	.063	-.222	.168	.099	-.050	-.013	.062	-.052	-.190	-.088	.135	-.058	.055	-.166
Crust	**.477****	**.440****	-.124	-.040	.157	.156	-.030	-.038	-.135	-.107	-.089	-.157	-.091	-.192	-.081	-.228	.013	.027	**-.310****	-.100	-.045
Insec	.114	.021	.075	-.040	-.022	-.034	-.059	-.016	-.176	.069	.101	.035	-.014	.043	.032	.123	-.039	.041	.025	-.076	-.096

**. Correlation is significant at the 0.01 level (2-tailed).

Key: Air temp = Air Temperature, Water temp = Water Temperature, Cond = Conductivity, Hard = Hardness, Alk = Alkalinity, Trans = Transparency, Turb = Turbidity, Roti = Rotifera, Crust = Crustacea, Insec = Insecta

Table 4.14: Relative abundance of macrozoobenthos encountered in Ibuya River

Phylum	Class	Species	No of organisms/ m^2	Relative Abundance (%)
Mollusca	Gastropoda	*Lanistes libycus*	70	12.35
		Indoplanorbis exustus	175	30.86
		Melanoides tuberculata	140	24.69
		Potadoma moerchi	47	8.29
		Gabbiella sp.	24	4.23
	Bivalvia	*Donax vittatus*	28	4.94
Arthropoda	Insecta	*Chironomus sp.*	67	11.82
	Crustacea	*Cardisoma sp.*	16	2.82

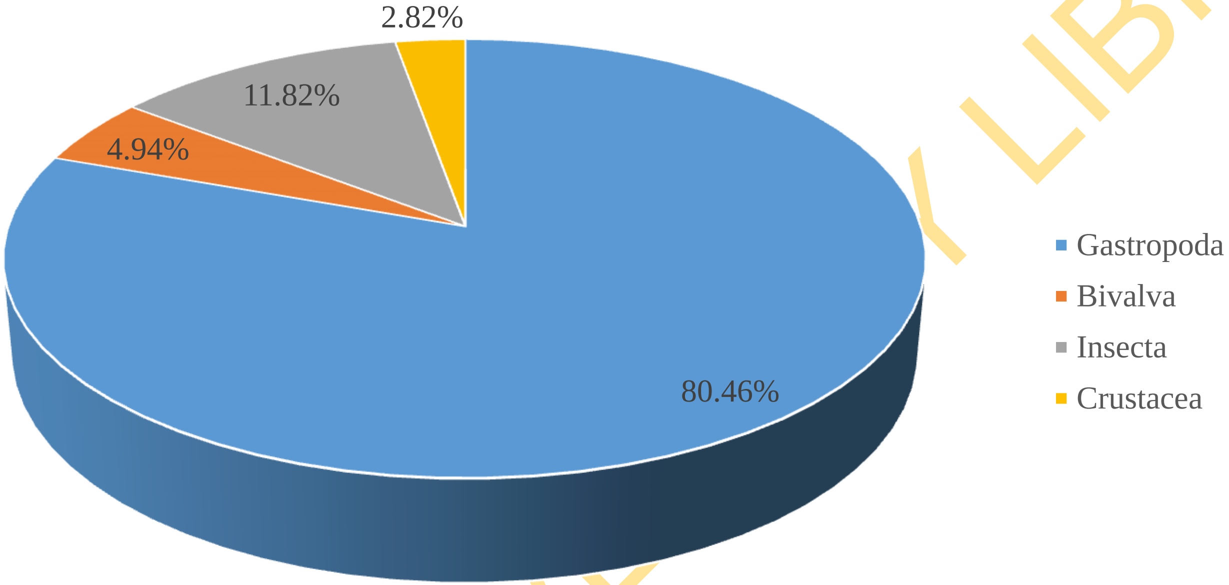
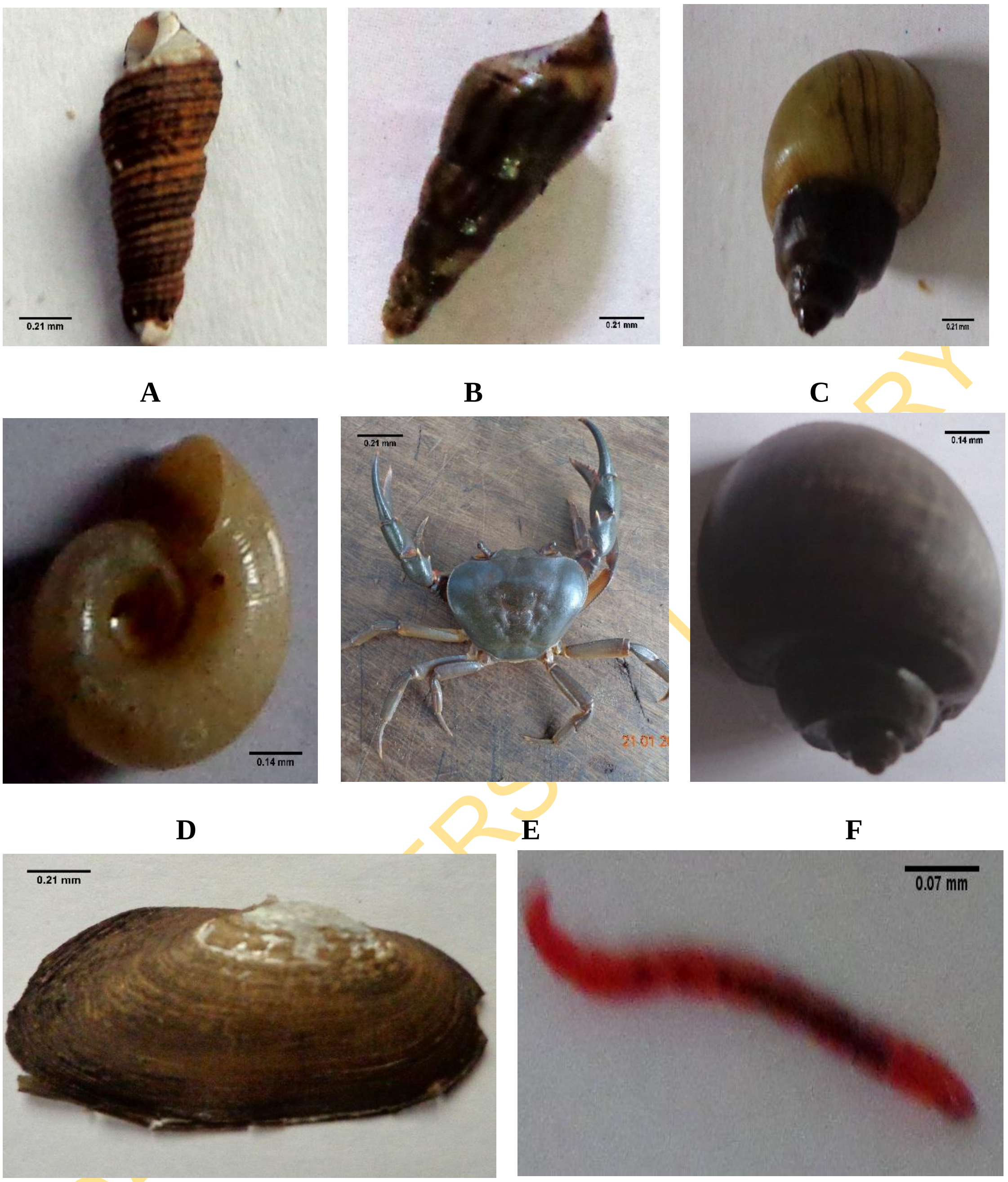


Fig. 4.27: Percentage abundance of macrozoobenthos in Ibuya River from September 2012 to February 2014.



A B C

D E F

G H

Keys: A. *Potadoma moerchi*
B. *Melanoides tuberculata*
C. *Lanistes libycus*
D. *Indoplanorbis exustus*

E. *Cardisoma sp.*
F. *Gabbiella sp*
G. *Donax vittatus*
H. *Chironomus sp.*

Plate 4.8: Macrozoobenthos encountered in Ibuya River

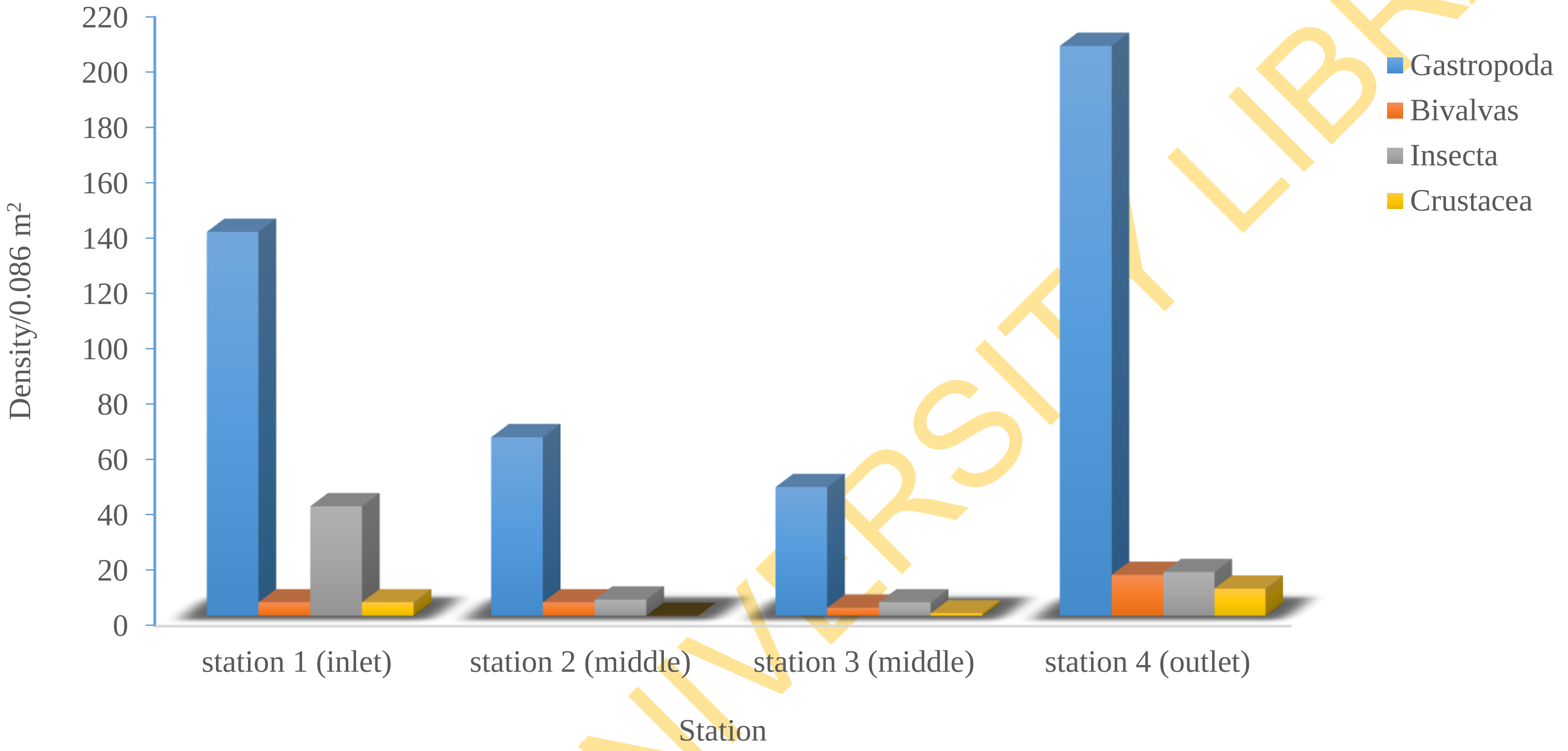


Fig. 4.28: Spatial variation of macrozoobenthos population density in Ibuya River from September 2012 to February 2014.

Monthly distribution shows highest density of macrozoobenthos in November 2012 while September 2013 had the lowest density of macrozoobenthos (Fig. 4.29). Gastropods, bivalves, insect and crustaceans all had higher density in the dry season than the wet season. These values were not significantly different ($p>0.05$) except for crustacean that was significantly different at $p<0.05$ (Fig.4.30).

4.3.2 Macrozoobenthos diversity

Shannon-Wiener diversity index (H) for Gastropods was higher and the same for station 1 and 2 (1.43) and lower in station 4 (1.4) while Evenness ranged from 0.87 in station 4 to 0.89 in station 1 and 2 (Fig. 4.15).

4.3.3 Correlation between physicochemical parameters and macrozoobenthos abundance

Correlation coefficient (r) values between physicochemical parameters and macrozoobenthos abundance are presented in Table 4.16. *Lanistes libycus* significantly correlated positively with Pb ($r = 0.27$; $p<0.05$) and PO_4^- ($r = 0.29$; $p<0.05$) respectively. *Gabbiella sp.* significantly correlated positively with Transparency ($r = 0.30$; $p<0.01$), Zn ($r = 0.28$; $p<0.05$) and NO_3^- ($r = 0.27$; $p<0.05$) respectively. *Cardisoma sp.* significantly correlated positively with PO_4^{3-} ($r = 0.29$; $p<0.05$) and SO_4^{2-} ($r = 0.24$; $p<0.05$) respectively. *Melanoides tuberculate* had a significant negative correlation with conductivity ($r = -0.27$; $p<0.05$), TDS ($r = -0.24$; $p<0.05$). *Potadoma moerchi* had significant negative correlation with conductivity ($r = -0.26$; $p<0.05$), TDS ($r = -0.26$; $p<0.05$) and Mg ($r = -0.24$; $p<0.05$). *Gabbiella sp* negatively correlated with Mg ($r = -0.26$; $p<0.05$) and Fe ($r = -0.29$; $p<0.05$). *Donax vitatus* negatively correlated with conductivity ($r = -0.27$; $p<0.0$), TDS ($r = -0.26$; $p<0.05$), alkalinity ($r = -0.24$; $p<0.05$) and Mg ($r = -0.29$). *Cardisoma sp* negatively correlated with conductivity ($r = -0.24$; $p<0.05$), TDS ($r = -0.25$; $p<0.05$), alkalinity ($r = -0.30$; $p<0.05$) and Mg ($r = -0.28$; $p<0.05$).

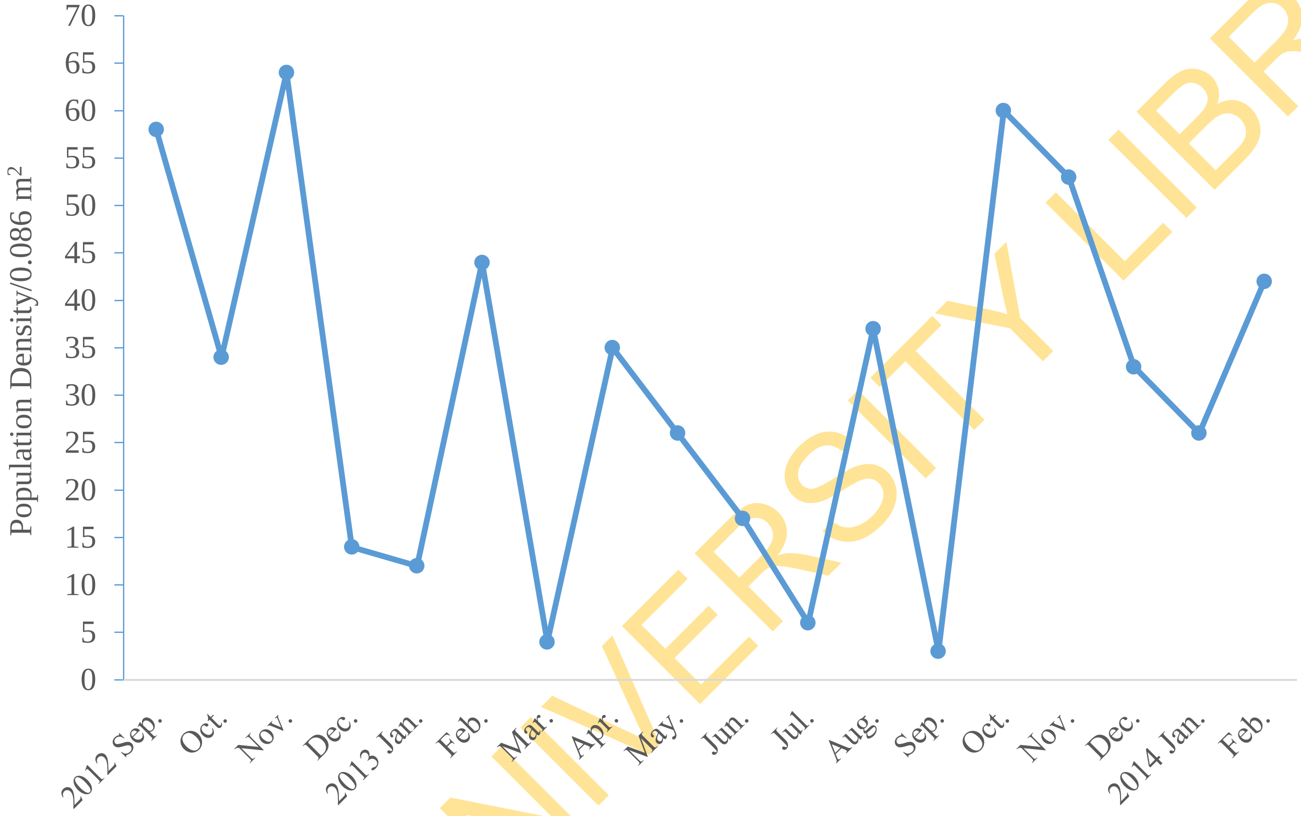


Fig. 4.29: Monthly distribution of macrozoobenthos population density in Ibuya River

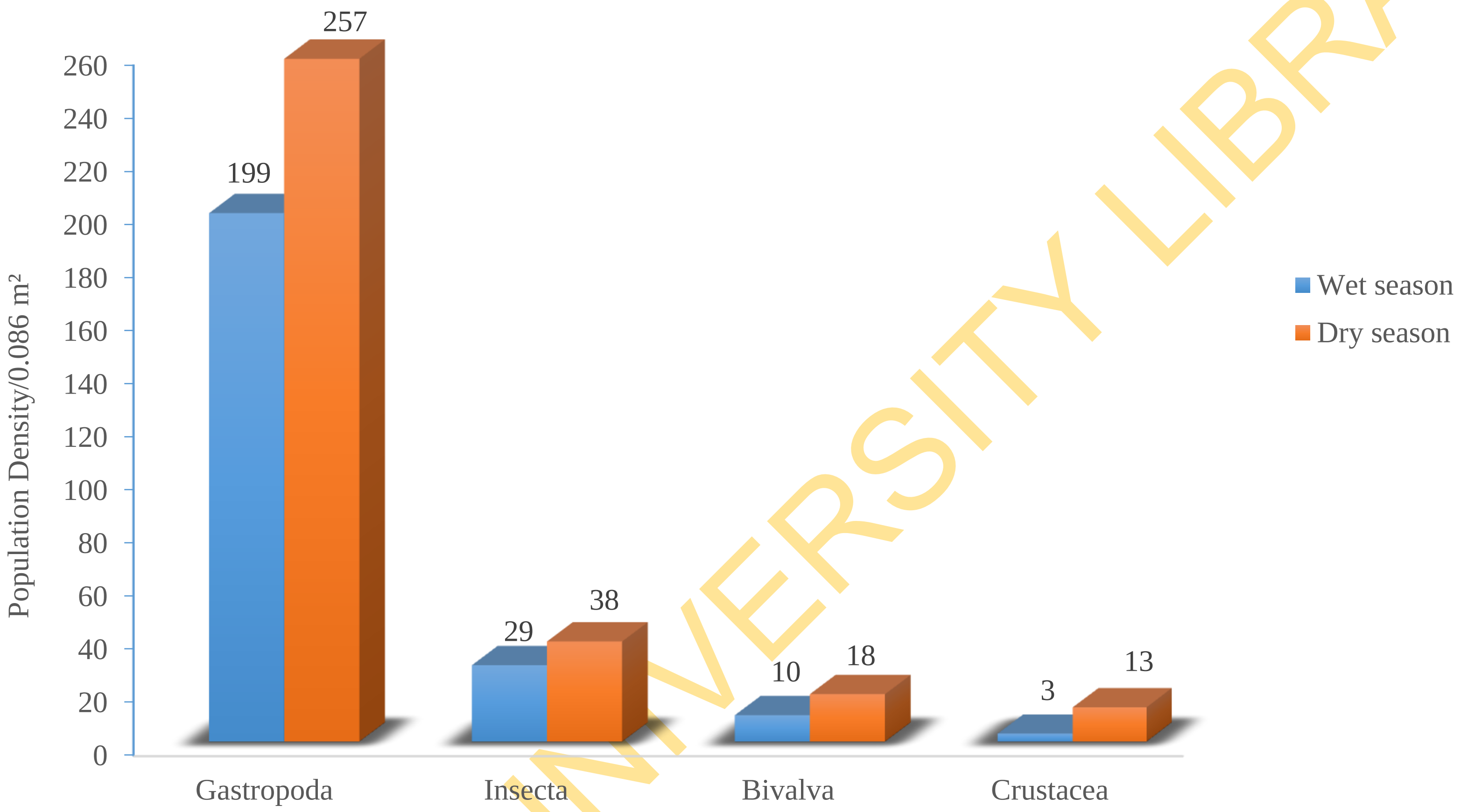


Fig. 4.30: Population density of macrozoobenthos for the wet and dry season in Ibuya River

Table 4.15: Diversity and evenness of macrozoobenthos in the different sampling stations in Ibuya River.

Stations	Gastropoda	
	Diversity (H)	Evenness
1	1.43	0.89
2	1.43	0.89
3	1.42	0.88
4	1.40	0.87

Table 4.16: Correlation between Physicochemical Parameters and Macrozoobenthos Abundance in Ibuya River

	Air temp	Water	pH	DO	Cond	TDS	Hard	Alka	Trans	Turb	Mg	Mn	Cu	Fe	Cd	Pb	Zn	Cl^{-}	PO_4^{3}	SO_4^{2}	NO_3^{-}

		temp																			
Lanistes libycus	-0.071	-0.023	-0.122	0.063	-0.202	-0.181	-0.198	-0.083	0.194	-0.045	-0.231	-0.222	-0.157	-0.062	-0.139	**.270***	0.208	-0.086	**.294***	0.025	0.224
Indoplanorbis exustus	0.093	0.085	-0.105	-0.104	-0.177	-0.157	-0.017	-0.024	0.033	0.008	-0.157	-0.076	-0.065	-0.123	0.038	0.114	0.076	-0.063	0.061	-0.065	0.069
Melanoides tuberculata	0.031	0.032	0.027	-0.175	**-.267***	**-.244***	0.117	0.112	-0.110	0.034	-0.174	-0.179	-0.136	0.012	-0.090	0.048	-0.051	-0.162	-0.025	-0.094	-0.054
Potadoma moerchi	0.035	0.043	-0.057	0.103	**-.263***	**-.256***	-0.131	-0.067	-0.025	0.049	**-.244***	-0.051	-0.115	-0.177	0.059	0.110	0.166	0.006	0.013	0.078	0.064
Gabbiella sp.	0.008	0.018	-0.135	-0.006	**-0.084**	-0.059	-0.165	-0.099	**.304****	-0.180	**-.260***	-0.151	-0.055	**-.254***	0.008	-0.036	**.284***	-0.037	0.083	-0.081	**.268***
Donax vittatus	-0.096	-0.101	0.064	0.085	**-.266***	**-.260***	-0.102	**-.237***	0.070	0.169	**-.288***	0.038	0.175	-0.018	0.156	-0.043	0.002	0.045	0.149	0.213	0.055
Chironomus sp.	0.004	0.028	-0.083	-0.015	-0.050	-0.053	0.097	0.024	0.007	-0.050	-0.087	-0.072	-0.079	-0.097	-0.078	0.103	0.197	-0.083	0.035	-0.094	0.117
Cardisoma sp.	-0.019	0.021	-0.053	0.123	**-.244***	**-.252***	-0.229	**-.295***	-0.033	0.230	**-.280***	-0.045	0.187	-0.042	0.083	0.054	0.072	-0.005	**.292***	**.242***	0.205

**Correlation is significant at the 0.01 level (2-tailed); *Correlation is significant at the 0.05 level (2-tailed)

Key: Air temp = Air Temperature, Water temp = Water Temperature, Cond = Conductivity, Hard = Hardness, Alka = Alkalinity, Trans = Transparency, Turb = Turbidity

4.4. Fish fauna

Table 4.17 shows the checklist of fish species recorded during the study period. Detailed data obtained on composition of fish is presented in Appendix 32. The fish fauna included 24 species belonging to 11 families. The families Cichlidae and Cyprinidae dominated the fish fauna accounting for 22.63 % and 17.37 % of the relative abundance respectively (Table 4.18), while the least abundant family, Channidae had only 2.37 %. Apart from Cichlidae and Cyprinidae, Clariidae (12.11%), Alestidae (9.21%) and Mormyridae (9.21%) also contributed well to the catch. The highest relative abundance of fish was recorded in January 2013 and lowest in October 2013 (Fig. 4.31). The Shannon-Wiener diversity index had higher value of 2.82 in January 2013 and lower (1.34) in October 2013. Evenness ranged from 0.84 in December 2013 to 1.02 in May 2013 (Table 4.19). Plate 4.9 shows the fish species encountered in Ibuya River.

Table 4.17: A Checklist of fish species at Ibuya River from September 2012 to February 2014

Family Cichlidae

Hemichromis fasciatus (Peters, 1857)

Oreochromis niloticus (Linnaeus, 1758)

Coptodon dageti (Dunz and Schliewen, 2013) (Formerly *Tilapia dageti*; Thy Van den Audenaerde, 1971)

C. guineensis (Dunz and Schliewen, 2013) (Formerly *T. guineensis*; Bleeker, 1862)

C. zillii (Dunz and Schliewen, 2013) (Formerly *T. zilli*; Gervais, 1848)

Family Cyprinidae

Labeo brachypoma (Gunther, 1868)

L. parvus (Boulenger, 1902)

Raiamas senegalensis (Steindachner, 1870)

Family Clariidae

Clarias gariepinus (Burchell, 1822)

Heterobranchus bidorsalis (Geoffrey Saint-Hilaire, 1809)

H. longifilis (Valenciennes, 1840)

Family Alestidae (Formerly Characidae; Cuvier, 1817)

Brycinus nurse (Ruppell, 1832)

Micralestes elongatus (Daget, 1957)

M. occidentalis (Gunther, 1899)

Family Mormyridae

Marcusenius senegalensis (Steindachner, 1870)

Mormyrus rume rume (Valenciennes, 1846)

Family Bagridae

Bagrus docmak niger (Daget, 1954)

Family Claroteidae

Chrysichthys aluuensis (Risch, 1985)
C. nigridigitatus (Lacepede, 1803)

Family Hepsetidae

Hepsetus akawo (Decru, Vreven and Snoeks, 2011) (Formerly *H. odoe*; Bloch, 1794)

Family Mochokidae

Synodontis budgetti (Boulenger, 1911)
S. gambiensis (Gunther, 1864)

Family Schilbeidae

Schilbe intermedius (Ruppell, 1832)

Family Channidae

Parachanna obscura (Gunther, 1861)

Table 4.18: Relative abundance of fish species in Ibuya River

Families	Species	No of fish	Relative Abundance (%)
Cichlidae	*Hemichromis fasciatus*	10	2.63
	Oreochromis niloticus	11	2.89
	Coptodon dageti	5	1.32
	C. guineensis	27	7.11
	C. zillii	33	8.68
Cyprinidae	*Labeo brachypoma*	16	4.21
	L. parvus	35	9.21
	Raiamas senegalensis	15	3.95
Clariidae	*Clarias gariepinus*	27	7.11
	Heterobranchus bidorsalis	12	3.16
	H. longifilis	7	1.84
Alestidae	*Brycinus nurse*	9	2.37
	Micralestes occidentalis	11	2.89
	M. elongatus	15	3.95
Mormyridae	*Marcusenius senegalensis*	17	4.47
	Mormyrus rume rume	18	4.74
Bagridae	*Bagrus docmac niger*	11	2.89
Claroteidae	*Chrysichthys aluuensis*	6	1.58
	C. nigrodigitatus	17	4.47
Hepsetidae	*Hepsetus akawo*	30	7.89
Mochokidae	*Synodontis budgetti*	9	2.37
	S. gambiensis	14	3.68
Schilbeidae	*Schilbe intermedius*	16	4.21
Channidae	*Parachanna obscura*	9	2.37

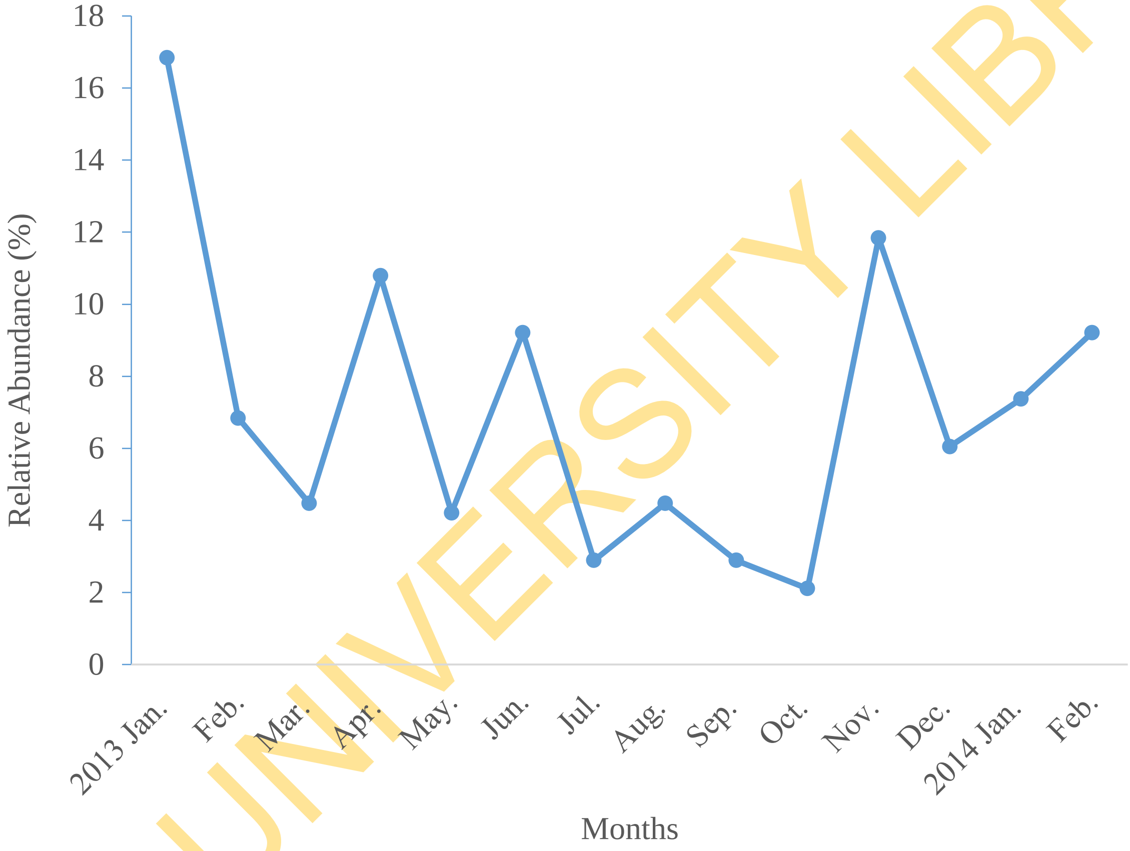
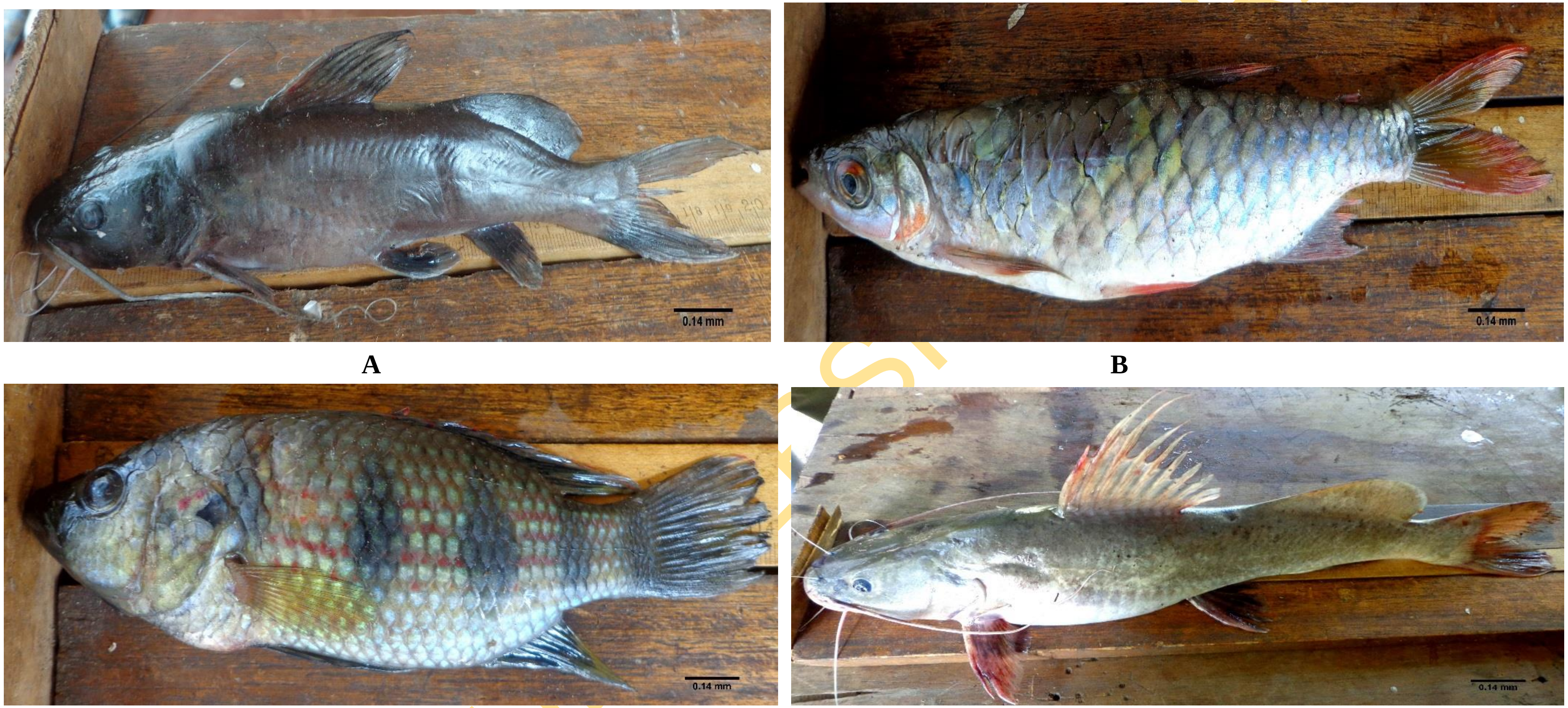


Fig. 4.31: Relative abundance of fish fauna in Ibuya River

Table 4.19: Diversity and evenness of fish species in Ibuya River.

Months	Diversity (H)	Evenness
2013 Jan.	2.82	0.96
Feb.	2.58	0.98
Mar.	2.45	0.96
Apr.	2.66	0.96
May	1.99	1.02
Jun.	2.48	0.94
Jul.	1.85	0.95
Aug.	1.88	0.96
Sep.	1.65	0.92
Oct	1.34	0.96
Nov.	2.54	0.96
Dec.	1.75	0.84
2014 Jan.	2.38	0.99
Feb.	2.16	0.87



A B

C D

Key: A. *Bagrus docmak niger* **C**. *Hemichromis fasciatus*
B. *Brycinus nurse* **D.** *Chrysichthys aluuensis*

Plate 4.9.1: Fish species encountered in Ibuya River

E

F

G H

Key: **E.** *Hepsetus akawo* **G**. *H. longifilis*
F. *Heterobranchus bidorsalis* **H**. *Labeo brachypoma*

Plate 4.9.2: Fish species encountered in Ibuya River

I

J

K

L

Key: I. *L. parvus* **J.** *Marcusenius senegalensis*
K. *Micralestes elongates* **L**. *M. occidentalis*

Plate 4.9.3: Fish species encountered in Ibuya River

M

N

O

P

Key: M. *Mormyrus rume rume* **O**. *Parachanna obscura*
N. *Oreochromis niloticus* **P**. *Schilbe intermedius*

Plate 4.9.4: Fish species encountered in Ibuya River

Q

R

S

T

Key: Q. *Raiamas senegalensis* **S.** *Coptodon guineensis*

R. *Synodontis gambiensis* **T.** *C. zillii*

Plate 4.9.5: Fish species encountered in Ibuya River

C. dageti

Plate 4.9.6: Fish species encountered in Ibuya River.

CHAPTER FIVE

DISCUSSION

5.1 Physicochemical parameters

5.1.1 Temperature

Temperature is a physical factor that alters the water characteristics and considered as an important factor in controlling the fluctuation and functioning of aquatic ecosystem (Dwivedi and Pandey, 2002; Singh and Mathur, 2005). In the present investigation, the slight increase in temperature in the dry season as compared to the wet season may be attributed to the low cloud cover and direct sun rays. However, lower temperatures recorded during December could be attributed to the cooling effects of harmattan wind during the period when the environment including waters were cold as suggested by Avoaja (2005). Water temperature ranged between 21.70 to 32.00 °C with no significant difference between stations. These variations fell within the permissible limit of < 40 °C recommended by WHO. This result is similar to the findings of Fafioye *et al.* (2005) who reported a range of 26.5 ℃ -31.5 ℃ in Omi water body, Ago iwoye, Ogun state, Nigeria.

5.1.2 pH

The mean pH (7.57 ± 0.04) of the river water tends towards alkalinity throughout both seasons. pH obtained in this study was within the acceptable level of 6.0 to 8.5 for culturing tropical fish species (Huet, 1977). These range may be conducive for fish since they usually live at pH levels between 6.0 and 9.0, although they may not tolerate a sudden change within this range (Adefemi *et al*., 2007). Similar trends (6.2 – 7.5 and 6.0 – 8.5) were reported in the Calabar River (Asuquo, 1999; Akpan, 2000), in the Niger Delta area of Nigeria. Idowu and Ugwumba (2005) recorded pH values ranging from 6.9 – 9.6, while Ayoade *et al.* (2006) reported a pH range of 6.2 – 8.5. The significant spatial variation in pH of Ibuya River is an indication that the various anthropogenic activities have significantly altered the pH along the river.

5.1.3 Dissolved oxygen (DO)

The dissolved oxygen for the river ranged from 2.68 mg/L to 8.89 mg/L, with a mean of 4.43 ± 0.15 mg/L. The DO values for the first few months were considerably low, this could be as a result of anthropogenic activities from surrounding towns into the water during the period of collection. The decrease in dissolved oxygen observed in July during wet season could be due to phytoplankton bloom and decomposition of allochthonous organic materials taking place at this time of the year. A similar report was recorded by Okayi (2003). The report stated that any observed depression in dissolved oxygen could be due to chemical and biological oxidation process in the water. Lewis (2000) regarded factors that work against oxygen retention in tropical waters as the poorer ability of water to hold oxygen at higher temperature than at lower temperature and to the higher rates of microbial metabolism at higher temperature.

5.1.4 Conductivity

The conductivity range (69.90 to 272.00 µS/cm) and mean value (140.83 ± 5.60 µS/cm) for the river during the study can be regarded as medium or moderate according to the classification by Adeleke (1982). Conductivity levels below 50 µmhos/cm are regarded as low; those between 50 – 600 µmhos/cm are medium while those above 600 µmhos/cm are high conductivity levels. Conductivity values showed marked seasonal variations. Significantly higher dry season conductivity value obtained could be attributed to concentration effect as a result of reduced water volume from their main tributary channels. Similarly, Oben (2000) in the limnological assessment of the impact of agricultural and domestic effluent on three man-made lakes in Ibadan, reported an increase in conductivity values during the dry season and attributed this to evaporation. He also suggested that decrease in conductivity values during the rainy season may be due to dilution by rain water. High conductivity values have been reported to be indicative of an increase in the amount of polluting particles (Oben, 2000).

5.1.5 TDS

TDS concentrations are used to evaluate the quality of freshwater systems (Manora-online, 2012). The maximum value of total dissolved solids was recorded in February, 2013 (188.00 mg/L) and minimum was recorded in September, 2012 (48.80 mg/L). A maximum value of 400 mg/L of total dissolved solids is permissible for diverse fish population (Chhatwal, 1998). Concentrations of total dissolved solids in the study area showed highly significant ($P<0.001$) variations between seasons with the lowest values recorded in the wet season and highest in the dry season. This variation could be explained by allochtonous input from agricultural land, anthropogenic activities such as clothes washing, cassava processing and sales of fuel, which are some common activities from nearby towns around the river. In addition, rock weathering and solid dissolution known to be very important determinants to dissolved solids concentration in water (McCutheon *et al.*, 1983) may play a key role.

5.1.6 Hardness

Hardness is indicative of the presence of alkaline earth metals such as magnesium. The most productive water however, are those with hardness <500 (Wetzel, 2001). Water hardness was higher during the dry season than the wet season. This could be as a result of low water levels and the concentration of ions, and the lower wet season value could be due to dilution as reported in Kolo and Oladimeji (2004) for Shiroro Lake. Higher hardness values are mainly due to weathering of Ca and Mg-rich rocks in the area (Zeitoun and Mehana, 2014). Kiran (2010) reported that water can be categorised according to the degree of hardness, as soft (0-75 mg/L) moderately (75-150 mg/L) hard, hard (150-300 mg/L) and above 300 mg/L as very hard. The trend in hardness values in this study showed that the river was soft, then moderately soft. For fish production in the tropics, moderately hard waters are preferred (Adakole *et al.*, 1998). Thus with respect to water hardness, the river is suitable for fish production.

5.1.7 Alkalinity

Alkalinity is a measure of the acid-neutralizing capacity of water. In most natural waters, it is due to the presence of carbonate (CO_3^-), bicarbonate (HCO_3^-), and hydroxyl (OH^-) anions. However, borates, phosphates, silicates, and other bases also contribute to alkalinity if present (Wilson, 2010). In the present study the alkalinity ranged between 4.50 mg/L $CaCO_3$ (August, 2013) and 27.00 mg/L $CaCO_3$ (October, 2012). It started decreasing progressively from March 2013 to February 2014. Seasonally, highest value was recorded during wet and lowest during the dry season. Increases in alkalinity during wet season could be due to input of water and dissolution of calcium carbonate ion in the water column (Padma and Periakali, 1999). The degradation of vegetative plants and other organism and organic waste might also be one of the reason for the increase in carbonate and bicarbonate thereby the alkalinity (Jain *et al.*, 1997; Chaurasia and Pandey, 2007). Alkalinity of 30 and 50 mg/L $CaCO_3$ are generally acceptable to fish and shrimp production (Lawson, 2011).

5.1.8 Transparency

Transparency is how easily light can pass through a substance. In other words, when the water is cloudy and contains a lot of particles, the light cannot penetrate as deeply into the water column which hence limits primary productivity. Transparency ranged between 5.50 cm (October, 2013) and 56.00 cm (January, 2014). The higher value of transparency recorded during dry season compared to that of the wet season could be due to absence of floodwater, surface run-offs and settling effect of suspended materials that followed the cessation of rainfall. Kemdirim (1990), reported similar observations. Low secchi-disc transparency recorded during wet season, agrees with the findings of Wade (1985), who observed that onset of rain decreased the secchi-disc visibility in two mine lakes around Jos, Nigeria. The trend in this study is that variations in transparency was low and consitent from the beginning, then at the later part of the study the values increased. The reduction in water transparency could be as a result of the human activities around the river source such as cassava processing, block moulding, bathing, clothes washing etc. and run offs from land erosion while the increase could be as a result of reduction in anthropogenic activites during the period of collection.

5.1.9 Turbidity

Water turbidity, which reflects transparency, is an important criterion for assessing the quality of water. The turbidity values ranges from 6.55 FTU to 36.20 FTU. The statistical analysis at 95 % confidence level showed no significant difference between sampling sites. The significantly higher turbidity recorded during the wet season compared to the dry season may be due to heavy rainfall leading to an increase in phytoplankton abundance and decay of organic matter in suspension in addition to surface runoff. Lewis (1978) opined that phytoplankton biomass influences water transparency, and therefore turbidity. Turbidity values obtained for the Ibuya River at all four sampling sites are higher than WHO standards which suggest 5 NTU (WHO, 2008). This indicates that the entire river generally contains pollutant and could pose problems to aquatic lives. This might be due to surface runoff and wastewater from different anthropogenic activities. Similar higher turbidity values were also recorded by many workers as compared to the limit set by WHO (Akan *et al.*, 2008; Mebrahtu and Zerabruk, 2011; Pal *et al.*, 2013). The adverse effects of turbidity on freshwaters include decreased penetration of light hence reduced primary and secondary production, adsorptions of nutrient elements to suspended materials making them unavailable for plankton production, oxygen deficiency, clogging of filter feeding apparatus and digestive organs of planktonic organisms and may greatly affect the hatching of larvae (Gupta and Gupta, 2006).

5.1.10 Heavy metals

Magnesium

Magnesium are among the most common constituents present in natural water and their salts are important contributors to the hardness of water. In the present study, the range of magnesium 0.199 to 6.95 mg/L recorded was higher than the tolerable range for natural freshwater in the tropics (Avoaja, 2005). At 95 % confidence level, significance differences in the concentrations of Mg was not observed among the four studied sites.

Manganese

Manganese compounds are used in fertilizers, varnish and fungicides and as livestock feeding supplements. Mangaese in water can be significantly bioconcentrated by aquatic biota e.g., phytoplankton, algae, mollusks and some fish (Abbasi *et al.*, 1998). In the present study, manganese content ranged from 0.00 mg/L to 0.69 mg/L with a mean of 0.21±0.02 mg/L. Manganese concentration was slightly higher in the wet season when compared to the dry season suggesting anthropogenic input and runoffs but the variation was not statistically significant ($p>0.05$). The mean manganese concentration recorded in the study was found to be above the maximum contaminant Levels of 0.05 mg/L. This finding is similar to the report of Dan'azumi and Bichi (2012) who recorded manganese concentration ranging from 0.249 to 1.681 mg/L for River Challawa in Kano Nigeria. A mean value of 3.85± 0.93 mg/L was reported for Lower River Niger drainage in North Central Nigeria (Olatunji and Osibanjo, 2012). The result from the study revealed threat from manganese poisoning especially in the wet season. Toxicity from manganese manifests with profound increase in the incidence of respiratory diseases. In chronic cases, there may be a neuro-psychiatric disorder characterized by irritability, difficulty in walking, speech disturbance, compultsive behaviour that may involve running, fighting and singing and may even result to Parkinson like syndrome (Omoregie *et al.*, 2002; Asonye *et al.*, 2007).

Copper

The minimum and maximum concentrations of copper obtained from the Ibuya river range from 0.00 mg/L to 0.49 mg/L. All the samples observed were below the maximum permissible limit set by WHO (2.0 mg/L). Copper is an essential nutrient, but at high doses it has been shown to cause stomach and intestinal distress, liver, kidney damage, and anemia (USEPA, 2002). On comparing with similar studies, Kakulu and Osibanjo (1992) reported high concentrations of Cu in water collected from Warri River, and Calabar River, than the value recorded in this study.

Iron

The Iron concentration in Ibuya river ranged between 0.03 and 8.32 mg/L. Interestingly, Iron concentration in all the water samples analyzed were excessively greater than the maximum contaminant levels of 0.30 mg/L USEPA (2010). Although, iron is one of the essential elements in human nutrition, however, their presence at elevated concentration in aquatic ecosystems, poses serious pollution and health problems. Toxicity of iron in humans has been found to bring about vomiting, cardiovascular collapse and diarrhea, while iron deficiency may lead to failure of blood clotting. The wet season value (3.16 mg/L) was higher than the dry season (1.25 mg/L) with significantly high variation between season ($p<0.001$). This excess concentration of iron may be attributed to rocks and soil containing iron, which dissolve into the water source during rain. Result agrees with previous works of Shalom, *et al.* (2011) and Akoto and Adiyiah (2007) where iron was reported to occur in high concentrations. Asonye *et al.* (2007) also observed a similar result for Kubanni Lake.

Cadmium

Cadmium is a natural, usually minor constituent of surface and groundwater, it enters aquatic systems through weathering and erosion of bedrocks and soils. Much of the cadmium entering fresh waters may be rapidly adsorbed by sediments which are significant sinks for cadmium emitted to the aquatic environment (WHO, 2011). The concentrations of Cd in the water samples fluctuate between 0.00 and 1.64 mg/L. The wet season values was higher than the dry season but the differences was not significant ($p>0.05$). No statistical significant spatial variation in cadmium levels was observed in the study ($p>0.05$). The high levels of Cd obtained might be due to runoff from agricultural lands where phosphate fertilizers are uesd. The levels of cadmium in the water samples from the four sampling point were above the standard values of 0.003 mg/L for the survival of aquatic organism (USEPA, 2010). Similarly, a higher concentration of cadmium ranging from 0 to 0.39 mg/L were reported for Warri River, Nigeria by Ayenimo *et al*., (2005).

Lead

The values of Pb obtained for the water ranged from 0.00 to 2.11 mg/L with no significant difference between seasons as well as all sampling stations ($p>0.05$). The mean level of Pb observed for all stations in this study were above the permissible limit (0.01 mg/L) set by WHO for water quality. Apeh and Ekenta (2012) reported mean Pb of 0.03 ± 0.02 mg/L for water obtained from River Benue (Opaluwa *et al*, 2012). Pb has been found to be responsible for chronic neurological disorders in foetuses and children especially when it is greater than 0.1 mg/L. Pb may impair renal function, red blood cell production, the nervous system and cause blindness (Asonye *et al.*, 2007).

Zinc

Zinc is an essential growth element for plants and animals but at elevated levels it is toxic to some species of aquatic life (WHO, 2004). Zn was found to be in relatively low concentrations in all the samples and ranged from 0.00 to 1.21 mg/L. These values are far below the maximum permissible limit of 3.0 mg/L set by WHO. The dry season value (0.22 mg/L) is higher compared to wet season value (0.07 mg/L) with significant difference at $p<0.01$. This could be associated with human activities such as the use of chemicals and zinc based fertilizers by farmers in the surrounding communities (Egila and Nimyel, 2002). Based on the result from the various sampling sites in this study, it can be implied that Zn do not pose any threat to aquatic organisms. On comparing with similar study of Abbasi and Ramasami (1999), it was seen that the concentrations of Zn in all the samples were below the regulatory desirable level.

5.1.11 Nutrients

Chloride

Chloride occurs in all natural waters in varying concentrations, though chloride anion is present in natural water, high chloride content may indicate pollution (Bertram and Balance, 1996). The values recorded for Ibuya River is in the range of 14.40 to 168.00 mg/L. The dry season value (83.40 mg/L) is higher than the wet season value (69.00 mg/L) but not significantly different ($p>0.05$). Higher chloride concentration in the dry season might be due to settling of anthropogenic discharges containing a large amount of chlorides (Addo *et al.*, 2013). The normal range according to Egereonu and Dike (2007) for river surface water is 45 – 155 mg/L. However, above a concentration of 250 mg/L chloride, the water may possibly pose threat to aquatic organisms (Hauser, 2001).

Phosphate

Phosphate is the key nutrient also causing eutrophication leading to extensive algal growth (Davies *et al.*, 2009). The results of present study showed that maximum phosphate concentration was 6.50 mg/L and minimum was 0.00 mg/L. It is evident from the data that seasonally phosphate concentration in the river was more in wet season and lower in the dry season. Highest seasonal values reported during wet season is in conformity with the findings of various workers (Kaur *et al.*, 1997; Hulyal and Kaliwal 2011; Verma *et al.*, 2012). The increase in the concentration of phosphate during the wet season is the result of incoming water from human settlements and the entry of domestic and agricultural run offs (Chaurasia and Adoni, 1985). The high PO_4^{3-} level in both dry and wet seasons indicated pollution since it was above NESREA standard limit of 3.50 mg/L in natural aquatic bodies. This could be as a result of flood water from farmland surrounding the river which brought in soil component associated with fertilizer, detergents and animal faeces which are washed into the river.

Sulphate

The sulphate values for all stations on Ibuya River range from 0.00 mg/L to 96.45 mg/L with a mean of 31.80±3.06 mg/L which is below the acceptable limit of 100 mg/L set by SON. The findings also showed significant differences between seasons ($p<0.001$) with the highest mean value of 45.20 mg/L recorded in the wet season as compared to the dry season value of 21.10 mg/L. These higher values can be attributted to the discharge of sulphate containing municipal waste from towns; and surface runoff that contain organic fertilizers from agricultural activities undertaking on the river side. The natural concentration of sulphates in most surface water is within the range of 2 to 80 mg/L (Manivasakam, 2005).

Nitrate

The concentration of nitrate is used as indication of the level of micronutrients in water bodies and has ability to support plant growth. High concentration of nitrate favored growth of phytoplankton (Anderson, *et al.*, 1998). Nitrate ranged between 0.00 mg/L and 97.60 mg/L with highest value recorded in November, 2013 while the least value recorded in February, 2013. The statistical analysis at 95% confidence level does not show any significance difference among the sampling stations. The dry season value

(36.10 mg/L) is higher than the wet season value of 26.80 mg/L with no significant difference between season $p>0.05$. Higher concentration of nitrate may be due to the influx of nitrogen rich flood water and bring about large amount of sewage (Anderson, *et al.*, 1998). Comin *et al.*, (1983), stated that high nitrate concentrations in lake is related to inputs from agricultural lands. The result obtained from all stations in the present study fall within the limit of WHO (2008) showing that the river is less polluted by nitrogenous materials.

5.1.12 Factor analysis of physico-chemical parameters

Factor analysis of physico-chemical parameters studied for Ibuya River shows differences in the most important factor for the two seasons. For the dry season, hardness, alkalinity and magnesium recorded high positive loading on the first component, which could therefore be regarded as carbonate-ionic factor. However, air temperature, water temperature and turbidity recorded positive loadings on the second component. This component can therefore be referred to as temperature-suspended matter factor or physical factor. Oduwole (1997) attributed significant differences in parameters between seasons as indicative of changes in water quality.

For the wet season, hardness, alkalinity and magnesium recorded high positive loading on the first component, which could therefore be regarded as carbonate-ionic factor. However, air temperature, water temperature, TDS, and Zn recorded high loadings on second component and therefore could be regarded as temperature-ionic factor or temperature-suspended matter factor.

For annual variability, conductivity, TDS, hardness and alkalinity recorded high loadings on the first component and could be regarded as suspended matter-carbonate factor or chemical factor. However, turbidity and iron recorded a high loading on the second component and could be regarded as carbonate-ionic factor. Air and water temperature recorded high positive loadings on the third component and could be regarded as temperature factor. Therefore, principal component analysis identified temperature, conductivity, turbidity, hardness, alkalinity, TDS and metals as the most important factors responsible for the variations observed in the physico-chemistry of Ibuya River.

5.2 Plankton

5.2.1. Phytoplankton

Cyanophyceae dominated with 56.13%, followed by Bacillariophyceae, Chlorophyceae, and Euglenophyceae with 38.82 %, 3.14 % and 1.91 % respectively of the relative abundance of Phytoplankton. However, the phytoplankton species composition was dominated by Bacillariophceae with 25 species, followed by Chlorophyceae with 9 species, Euglenophyceae with 8 species and Cyanophyceae with 3 species.

The dominance of Cyanophyceae in this river is similar to the findings by Sekadende *et al.* (2004), Dimowo (2013), and Shakila and Natarajan (2012). There has been report of dominance of blue-green algae in tropical freshwaters despite the greater number of taxa of the diatoms (Gonzalez *et al.*, 2004 and Atobatele *et al.*, 2007). Gonzalez *et al.* (2004) reported that blue-green algae in a tropical reservoir accounted for more than 75 % of the total plankton. The reservoir was regarded as hypereutrophic, which was as a result of high level of nutrients and biological production. *Merismopedia punctate* recorded the highest relative abundance (52.12 %) followed by *Oscillatoria sp*. (3.82 %) and *Microcystis sp*. (0.2 %). *Merismopedia* and *Microcystis* are colonial forms while *Oscillatoria* is a filamentous form of the blue-green algae. Station 1 and 2 had the highest percentage abundance of blue-green algae (65.40 % and 33.24 %) respectively while station 3 had the lowest value of (0.62 %). Cyanophyta showing more dominance in these stations, was a clear indication of deterioration of water quality. Cyanophyceae recorded no significant difference between seasons though the dry season value was higher compared with the wet season. Oduwole (1997) gave a similar report that among the phytoplankton of Ogunpa and Ona Rivers, the Cyanophyceae were dominant in the dry season. Oben (2000) and Atobatele *et al.* (2007) opined that the high relative abundance of blue-green algae and their presence either in colonial or filamentous form may be indicative of the influence of organic pollution of the water body.

Bacillariophyceae dominated the species composition of phytoplankton community with 25 species. The result of this study, however, varies considerably from some other studies in Nigeria. Yakubu *et al*. (2000) recorded 17, 20 and 34 species from Rivers

Nun, Orashi and Nkisa respectively while Erondu and Chindah (1991) reported 27 species from New Calabar River. The dominance of diatoms species in the study sites confirms the statement that diatoms are predominant in natural lotic water bodies in the tropics (Chindah and Braide, 2004; Ibiebele and Braide, 1984). *Aulacoseira granulata* dominated the diatoms with 14.35 % followed by *Fragilaria construens* and *F. oceanica* with 10.87 % and 7.56 % respectively in relative abundance. *Aulacoseira* is an R – strategist widespread diatom that can dominate in reservoirs under turbid conditions (Péréz *et al.*, 1999). *Aulacoseira* sp. has been attested to be a cosmopolitan species and is prevalent in prominent water bodies of Nigeria such as Eleiyele reservoir (Imevbore, 1967), River Osun (Egborge, 1973; 1974), Warri River (Opute, 1990), and in the coastal waters of Nigeria extending from Lagos to Cross River (Kadiri, 1999). The composition of diatoms varied across the different sampling stations in Ibuya River. Higher percentage abundance was recorded in station 1 while station 4 had lower percentage abundance. This could be attributed to organic waste, agricultural runoffs and anthropogenic inputs. The presence of these diatoms; *Navicula*, *Euglena*, *Nitzschia* and *Synedra* indicates organic pollution in Ibuya River. These species have been known to tolerate organic pollution (Nwankwo and Akinsoji, 1988; Nwankwo and Amuda, 1993; Passy *et al.*, 2004).

For Chlorophyceae, *Spirogyra dubra* dominated the green algae followed by *Scenedesmus protuberans*. The highest percentage abundance of green algae was recorded in station 1 while the lowest value was recorded in station 3. This suggest that the green algae are mostly freshwater forms that may not tolerate eutrophic or polluted condition. Chlorophyceae fluctuated between seasons and the fluctuations were not significantly different but recorded a higher value during the dry season. Oduwole (1997) reported that among the phytoplankton of Ogunpa and Ona rivers, the Chlorophyceae were dominant in the rainy season.

For Euglenophyceae, *Euglena spirogyra* dominated the euglenoids in Ibuya River followed by *E. ehrenbergii* and *Prorocentrum gracile.* The presence of species such as *Euglena, Phacus* and *Trachelomonas* is an indication that the water is tending towards pollution. Abubakar (2007) indicated that Euglenophyceae were common in environments rich in decaying organic matter, and large populations of *Euglena* were favored by the presence of high levels of dissolved organic compounds and high temperatures. Kim and Boo (2001) in their study on temporal changes of euglenoids and their relationships to environmental variables referred to green eugleniods as eutrophic species that are abundant in locations rich in organic and inorganic matter. Euglenoids such as *Phacus* have been reported in polluted waters; however, small species like *Trachelomonas* having high surface to volume ratio, are favoured in oligotrophic waters compared to large sized planktonic algae (Kim and Boo, 2001).

5.2.2. Zooplankton

Twenty-one species of zooplankton belonging to three groups were recorded for the river during the study period. Oke (1998) recorded four major groups of zooplankton compring 26 species for Owena reservoir and attributed the low number to taxonomic groups and species richness to non-availability of food. Zooplankton abundance and population dynamics have been reported to be influenced by repeated environmental fluctuations of which rainfall is a primary steering factor (Kizito and Nauwerck, 1995; Osore *et al.*, 1997 and Akin-Oriola, 2003). Zooplankton play an important role in the trophic structure of lake and rivers as consumers of phytoplankton and as a source of food for both fin-fish and shell fish. They could also serve as indicator organisms of water type, fish yield and/or total biological production (Ayodele and Adeniyi, 2006). Adesalu *et al.* (2010) and Nwankwo (2004) reported that high concentrations of nutrient such as phosphate and nitrate usually give rise to high abundance of some zooplankton species in aquatic environments.

The highest number of species (15 species) was recorded for Rotifera, followed by Crustacea (5 species) and Insecta (one species). Insecta was recorded in only few instances during the study period and contributed very little to the zooplankton of the river. Rotifera has been reported to dominate lacustrine ecosystems in terms of number of species (Starling, 2000), especially many Nigerian aquatic ecosystems (Ayodele and Adeniyi, 2006; Okogwu and Ugwumba, 2006; Jeje and Fernando, 1986; and Akin-Oriola, 2003). The abundance of the genera *Trichocerca, Brachionus, Platyias* and *Lecane* showed that the rotifer fauna was made up of a typical tropical assemblage (Jeje and Fernando, 1986).

Five species of Crustacea were recorded and was dominated by *Mesocyclops leuckarti* with 11.64 % of the total zooplankton species. *Mesocyclops leuckarti* showed fluctuation of high and low abundance throughout the study period. Temperature is an important factor in the aquatic environment. Temperature had a positive correlation with abundance of Crustacea suggesting that increased temperature favours increased abundance of Crustacea and therefore that of total zooplankton.

5.3 Macrozoobenthos

A total number of 8 species of macrobenthic invertebrate was reported in this study. The taxa richness of Ibuya River is similar to the report of Chukwu and Nwankwo (2003) who recorded 8 species in Port Novo Creek. High number of pollution indicator species like *Melanoides tuberculata* and *Chironomus sp.* were encountered in Stations 1 and 4 when compared with Stations 2 and 3. This could be attributed to organic pollution from domestic sewage, detergents, and agricultural effluents with fertilizers. The organic pollution tolerant species found in these stations are morphologically and physiologically adapted to survive conditions of low water quality. These adaptations for *Chironomus sp* include possession of pigment haemoglobin which gives affinity for oxygen even at very low concentration (Pertet *et al.*, 1999). Gregoric *et al.* (2007) stated that the principal reason for the success of *M. tuberculata* in water bodies is their toughness, strength and thickness of their shell. Most snail eating fish as well as many other predators are not able to crush their shell. One of the most remarkable features of the snails is their parthenogenetic reproduction (Williams, 1980).

Station 4 had the highest population density of Gastropods which could be attributed to the rocky nature of the environment while the least is recorded in station 3. Gastropods are known to be relatively tolerant to physical and chemical variations in the environment and are usually present in a broad range of habitats (Brown, 1994). It is therefore not surprising that they dominated the macrobenthos of the study area. This finding is similar to the report of Ajao and Fagade (2002), which recorded gastropods as the dominant benthic fauna in Lagos lagoon. Yakub (2010) reported decline in number of macroinvertebrate as well as presence of only organic pollution tolerant species at abattoir effluent discharge area in Lower Ogun River. Higher numbers of macrobenthic invertebrate belonging to the tolerant classes were encountered in the wet season compared to the dry season. This finding is similar to the report of Moreno and Callisto (2006), which attributed the variations to unstable bottom sediments caused by rain which lead to dislodgement of benthic animals.

5.4 Fish Fauna

24 species of 11 families of fish encountered in the present study have been reported to occur in Nigeria's water bodies. This result is similar to the findings of Sikoki *et al.* (1998), which recorded 25 fish species belonging to 15 families in Lower Nun River using gill nets. They noted that gill nets had the capacity to catch fish of all sizes, shapes and species in all water habitats. The 24 fish species identified in the Ibuya water body have also been observed by several fisheries‟ workers and researchers (Ita *et al.*, 1984; 1985; Akinyemi, 1987; Allison and Okadi, 2013; Oguntade *et al.*, 2014) including species in other families, and found to constitute the major fisheries of inland waters in Nigeria, due to their ability to adapt to the physico-chemical parameters of the water bodies.

The most abundant species during sampling was the Chichlids (22.63 %). This comprises predominantly *Coptodon zillii* (8.68 %) and *C. guineensis* (7.11%). The dominance of cichlids in this study is similar to the observations of Akinyemi (1987) on Eleiyele River and Olaniran (2003) on IITA water body; they both reported Cichlidae as the dominant family and suggested that this could be due to their ability to utilize a wide range of foods at the lower trophic level as herbivores, as well as their high fecundity and prolific nature. Food and high reproductive efficiency, as reported by Komolafe and Arawomo (2007), might be responsible for abundance of the cichlids. Moses (1974) suggested that the dominance of cichlids in Lower Nun River may be attributed to gear selectivity.

The observed seasonal variation in fish population size, being higher in the dry season than in the wet season could be attributed to low water level which increases catch. This concurs with the reports of Chinda and Osuamkpe (1994) in Lower Bony River, Niger Delta; Allison *et al*. (1997) in Lower Nun River; Sikoki *et al*. (1998) in Lower Nun River; Nweke (2000) in Elechi Creek and Ebere (2002) in Okrika Creek. They reported a higher population of fish in the dry season than in the rainy season, which was attributed to low volume and clarity of the water. Nevertheless, this report is contrary to the observations of Moses (1974) and Abowei (2010) in Lower Nun River of the Niger Delta. They noted that during floods, some fish species could move to another water body or migrate to a favourable habitat for food and breeding, causing the increase in population that they observed in the rainy season.

5.5 CONCLUSION AND RECOMMENDATIONS

This study provided baseline information on the ecological status of Ibuya River. The dominance of diatom species such as *Aulacoseira granulata*, and *Fragilaria construens*; blue-green algae *Oscillatoria sp.* and *Microcystis aeruginosa*; *Mesocyclops leuckarti* among the crustacean and the *Melanoides tuberculata* and *Indoplanorbis exustus* among the macrozoobenthos strongly showed that the river is eutropic. The composition and diversity of both plankton and macrozoobenthos could be potentially used as bio-indicators for assessing and monitoring Ibuya River. The present investigation shows that most of the studied physicochemical parameter concentrations of Ibuya River water were found to be above the recommended limit. In addition, the river appeared to be under pollution pressure due to high metals and nutrient concentration, and abundance of pollution tolerant species like *Oscillatoria sp., Merismopedia punctata, Aulacoseira granulata, Melanoides tuberculata* and *Indoplanorbis exustus*. It can be safely concluded that Ibuya River is undergoing gradual deterioration in water quality. Thus may result in waters being unable to support some types of aquatic life.

In other to ensure sustainable management and conservation of the aquatic environment and biodiversity, as well as the socio-economic status of Ibuya River, the following regulatory measures are hereby recommended:

Management efforts must be directed towards ensuring that waste disposal facilities should be provided for the surrounding communities.

Waste should be properly collected, processed and disposed. This can be achieved by building sewage and effluent treatment plants, phasing out open dump sites and raw sewage disposal into Ibuya River, to safeguard public health from water borne diseases.

Activities dicouraging by-products resulting in organic effluents into River should be discouraged.

Enforcement of environmental protection measures and legislations with severe penalties to discourage indiscriminate use of fertilizers, pesticides and other agricultural product.

Environmental intervention, enlighment and awareness programmes should be organized through public health workers for local resident on the environmental devastations that result from anthropogenic discharges into natural water bodies as well as the benefits of management.

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APPENDICES

Appendix 1: Monthly values of physico-chemical parameters of station 1 measured during the study period

	Air temp ^{0}C	Water temp ^{0}C	pH	DO mg/l	Cond µS/cm	TDS mg/l	Hard mg/l $CaCO_3$	Alk mg/l $CaCO_3$	Trans cm	Turb FTU	Mg mg/l	Mn mg/l	Cu mg/l	Fe mg/l	Cd mg/l	Pb mg/l	Zn mg/l	Cl^- mg/l	PO_4^- mg/l	SO_4^- mg/l	NO_3^- mg/l
12-Sep	24.8	23.8	7.36	3.28	69.9	48.8	55.5	22.5	10.5	19.38	3.8	0.11	0	2.36	0	0	0.066	90	0.02	12.6	0.18
12-Oct	27.1	25.6	7.42	3.29	133.2	90.1	81.4	24.35	12.75	14.17	2.09	0.12	0.046	2.89	0	0	0.023	21.6	0.042	9.34	0.217
12-Nov	28.5	25.3	7.46	3.47	100.1	65.7	68.6	12.5	13.75	20.35	2.48	0.11	0.013	3.13	0	2.113	0.018	106.5	0.032	17.2	6.09
12-Dec	26.4	24.2	8.39	3.64	245	168	59	13	11	19.26	4.7	0.18	0.09	2.82	0	0.04	0.06	162	0.04	1.73	7.12
13-Jan	20.7	19.8	7.45	3.25	250	178	69.4	10	20	19.38	6.07	0.46	0.05	0.77	0	0.06	0.08	116	0.026	0.57	5.34
13-Feb	26.5	25.83	7.45	3.73	272	188	53.2	12.5	10.67	13.57	5.63	0.57	0.028	0.85	0	0.63	0.26	35.5	0.27	0.1	0.1
13-Mar	27.6	26.4	6.93	3.55	135.9	93.2	27.4	9	19.5	22.86	0.199	0.06	0.055	1.22	0.049	0.438	0.102	96.35	0.039	32.1	16.93
13-Apr	28.8	27.7	6.88	3.2	116.2	79.7	36.6	8.5	6.5	21.38	0.269	0.13	0.092	0.64	0.096	0.14	0.328	98.21	0.008	33.8	62.32
13-May	27	26.6	7.42	4.73	130.4	89.6	33.4	7.2	10.2	15.21	1.066	0.04	0.105	1.63	0.065	1.838	0.203	78.23	29.67	28.6	38.76
13-Jun	26.4	25.8	7.33	3.41	178.4	121.4	24.6	11.5	7.3	23.36	4.03	0.41	0.079	1.53	0.008	0.264	0.089	35	15.36	13.7	17.36
13-Jul	25.5	24.7	7.24	2.95	93.3	63.7	36	7.35	10.5	27.18	0.586	0.03	0.214	6.41	0.076	0.843	0.058	61.28	33.85	59.3	78.36
13-Aug	24.9	23.9	7.56	4.5	103	71.6	30.6	4.5	8.5	31.2	1.066	0.48	0.483	4.6	1.066	0.93	0.055	81.2	42.6	72.6	21.6
13-Sep	25.5	25	7.47	8.89	113.2	78.7	26	6.17	7.75	32.8	1.445	0.17	0.311	5.26	0.056	0.59	0	92.3	44.7	75.3	34.2
13-Oct	24.8	24.7	7.53	6.11	102.8	71.4	30.66	8.35	8.25	25.3	1.204	0.113	0.065	1.08	0.016	1.772	0.04	78.6	56.3	54.6	15.7
13-Nov	26.3	25.3	7.36	4.1	116.9	80.7	36	5.835	15.25	23.8	1.186	.219	0.16	3.45	0.028	0.652	0.063	76.3	47.5	28.5	97.6
13-Dec	20.3	20.6	7.51	6.94	129.2	92.6	26	6	38	12.4	0.78	0.3	0.219	1.48	0.526	0.35	1.219	36	36	43.2	67.5
14-Jan	24.6	23.8	7.4	4.21	169.9	119	30	5.75	33.25	10.8	1.213	0.23	0.284	0.63	0.526	1.01	0.619	72	40.5	35.3	86.5
14-Feb	22.3	21.8	7.3	4	128	94.5	26	6.25	28.5	10.2	0.986	0.28	0.334	3.1	0.629	1.08	0.301	72	48.5	25	88.4

Key: Air temp = Air Temperature, Water temp = Water Temperature, Cond = Conductivity, Hard = Hardness, Alka = Alkalinity, Trans = Transparency, Turb = Turbidity

Appendix 2: Monthly values of physico-chemical parameters of station 2 measured during the study period

	Air temp ^0C	Water temp ^0C	pH	DO mg/l	Cond µS/cm	TDS mg/l	Hard mg/l $CaCO_3$	Alk mg/l $CaCO_3$	Trans cm	Turb FTU	Mg mg/l	Mn mg/l	Cu mg/l	Fe mg/l	Cd mg/l	Pb mg/l	Zn mg/l	Cl^{-} mg/l	PO_4^{-} mg/l	SO_4^{-} mg/l	NO_3^{-} mg/l
12-Sep	25.7	24.6	7.36	3.64	187	130.7	43.7	15.4	12.3	16.38	3.44	0.06	0	2.11	0	0	0.063	90	0.019	14.21	0.162
12-Oct	25.27	24.97	8.06	3.06	101.9	81	70.6	19.5	9.8	13.05	2.24	0.1	0.02	4.48	0	0	0.07	14.4	0.044	11.17	0.268
12-Nov	26.7	25.3	7.94	3.43	99.2	65.2	64.6	17.15	11	18.2	2.5	0.08	0.011	2.74	0	1.909	0.003	106.5	0.027	21.16	3.96
12-Dec	26.4	24.5	8.23	3.14	208	140	40	10	10.3	14.31	5.13	0.14	0.11	2.28	0	0.17	0.34	108	0.03	0.99	7.48
13-Jan	21.4	20.1	7.42	3.08	203	136.9	71.4	11.5	18	16.38	6.95	0.26	0.06	1.34	0	0.1	0.18	137	0.025	1.46	5.7
13-Feb	28.6	27	7.66	4.49	180.8	128.1	41.4	13.35	10.5	18.85	3.27	0	0.13	0.41	0	0.59	0.25	27.25	0	0	0
13-Mar	28.4	27.9	7.5	4.8	204	140	32.6	8	9	12.97	1.65	0.01	0.05	0.12	0.069	0.086	0.032	67.85	0.01	13.15	15.26
13-Apr	31.7	28.6	7.86	5.01	176.7	122	40	9.15	12.5	17.21	1.599	0.08	0.086	0.14	0.043	0.238	0.078	76.83	0.007	23.41	25.28
13-May	27.3	26.6	7.38	4.56	130.1	90.9	26.6	7.35	10	16.24	1.062	0.02	0.116	2.59	0.046	1.798	0.186	81.56	33.28	31.86	42.65
13-Jun	26.5	26	7.31	3.86	149.9	106.3	36.8	11	11	20.27	2.88	0.42	0.097	0.81	0.011	0.081	0.105	27	16.17	11.64	14.72
13-Jul	26.9	25	7.42	3.14	92.2	62	23.4	7.35	12	28.15	0.569	0.3	0.215	6.34	0.092	1.283	0.044	66.85	29.68	71.36	34.79
13-Aug	24.4	22.9	7.58	4.53	111.3	76.6	29	5.85	11	33.6	1.638	0.69	0.222	4.34	1.638	1.28	0.006	86.3	37.2	77.8	18.7
13-Sep	25.2	25	7.6	7.5	114	78.8	27.32	6.335	10.5	34.2	1.459	0.4	0.435	2.93	0.459	0.61	0	95.6	41.6	81.4	26.5
13-Oct	25.2	24.9	7.46	7.06	94.8	65.7	31.34	6.165	6.375	27.3	1.12	0.153	0.071	4.08	0.005	0.685	0.07	112.4	58.2	51.7	24.6
13-Nov	25.5	24.7	7.36	5.06	117.5	81.6	27.34	5.67	17	24.5	1.296	0.375	0.064	1.81	0.047	1.628	0.036	109.6	55.6	65.3	12.6
13-Dec	21.8	22.1	7.48	6.11	129.9	90.3	26	6	32	10.8	1.14	0.24	0.297	2.01	0.543	0.2	0.416	36	45	36.5	71.3
14-Jan	25	24.4	7.38	5.78	142.4	99.6	28	6.5	42.5	9.4	1.311	0.4	0.199	0.95	0.616	1.32	0.619	72	42.5	31.8	74.1
14-Feb	23.7	23.2	7.5	4.4	149.1	103.8	26	5.25	34.5	10.6	0.974	0.19	0.187	1.37	0.704	1.36	0.407	72	55.1	30.6	80.3

Key: Air temp = Air Temperature, Water temp = Water Temperature, Cond = Conductivity, Hard = Hardness, Alka = Alkalinity, Trans = Transparency, Turb = Turbidity

Appendix 3: Monthly values of physico-chemical parameters of station 3 measured during the study period

	Air temp ^{0}C	Water temp ^{0}C	pH	DO mg/l	Cond µS/cm	TDS mg/l	Hard mg/l $CaCO_3$	Alk mg/l $CaCO_3$	Trans cm	Turb FTU	Mg mg/l	Mn mg/l	Cu mg/l	Fe mg/l	Cd mg/l	Pb mg/l	Zn mg/l	Cl^- mg/l	PO_4^- mg/l	SO_4^- mg/l	NO_3^- mg/l
12-Sep	26.1	24.5	7.42	3.27	102.2	84.7	49.3	14.5	10.5	11.78	2.98	0.17	0	2.73	0	0	0.201	72	4.368	23.72	0.144
12-Oct	25.87	25.03	7.99	3.36	90	60.4	111.4	27	13	12.82	1.74	0.06	0.018	4.38	0	0	0.021	18	0.045	17.5	0.108
12-Nov	26.5	25.2	8.09	3.57	91.8	65.8	60	19.85	13.75	15.1	3.17	0.06	0.009	4.08	0	1.692	0.005	99.4	0.021	25.75	4.64
12-Dec	26.8	24.2	8.12	3.25	255	171	51	16.75	13	14.1	4.55	0.16	0.12	2.13	0	0.21	0.02	144	0.05	0.89	7.83
13-Jan	22.9	21.6	7.36	3.61	239	154	42.6	13.5	10	12.78	5.22	0.16	0.06	0.69	0	0.1	0.05	168	0.025	0.87	4.92
13-Feb	28.9	26.6	7.54	4.21	180.7	125.9	31.2	10.15	10.5	6.55	3.51	0	0.012	0.03	0	0.31	0.22	17.75	0.2	0	0.2
13-Mar	27.8	26.6	7.38	4.6	202	140	36	7.15	16.5	8.35	1.633	0.03	0.06	0.11	0.051	0.057	0.113	78.23	0.038	15.38	17.21
13-Apr	32	30.7	7.56	4.05	172.7	120.1	40.6	8.15	10.4	14.37	1.604	0.11	0.147	0.16	0.07	0.305	0.232	83.25	0.01	17.13	19.05
13-May	27.8	26.9	7.38	5	129	90.4	24	6.65	11.1	23.21	1.097	0.04	0.097	2.58	0.045	1.541	0.193	90.05	41.87	37.28	47.39
13-Jun	26.7	26.1	7.4	3.75	148.2	103.1	24	9.3	12.5	21.34	2.87	0.39	0.091	0.7	0.003	0.142	0.083	18.9	13.73	17.26	15.36
13-Jul	26.5	25.7	7.47	3.03	92	64	26.8	10.35	13.4	35.26	0.472	0.32	0.242	8.32	0.086	0.99	0.068	58.24	44.67	96.45	68.34
13-Aug	24.6	23.7	7.58	4.46	111.6	78.8	30	6.85	13	32.7	1.239	0.64	0.41	3.56	1.239	1.36	0.033	84.6	47.3	84.2	26.8
13-Sep	25.7	25.1	7.66	7.31	114.5	81.2	28	6.5	7	33.1	1.517	0.44	0.493	4.57	1.517	0.67	0.009	93.4	53.4	85.6	33.8
13-Oct	25.8	25.3	7.62	5.26	92.1	65	26.68	5	7.15	25.7	1.013	0.219	0.153	0.52	0.011	0.063	0.068	118.7	67.2	68.7	64.7
13-Nov	25.5	25.1	7.35	5.08	117.8	81.5	35.34	5.665	11	22.6	1.064	0.099	0.094	0.56	0.014	0.196	0.09	114.6	64.4	63.1	58.3
13-Dec	20.6	22.4	7.65	6.17	129.3	90.6	42	5.25	35	12	1.321	0.3	0.198	1.02	0.491	0.45	0.258	72	37.5	33.1	70.4
14-Jan	24.5	24.2	7.68	5.32	139.6	98.3	36	5.5	39.5	10	1.52	0.38	0.3	0.66	0.606	1.41	0.209	36	40.8	30.3	93.3
14-Feb	23.5	22	7.39	5.12	148.5	103.3	28	7	32	10	1.138	0.3	0.119	0.64	0.711	1.49	0.752	36	56.5	28.4	83.1

Key: Air temp = Air Temperature, Water temp = Water Temperature, Cond = Conductivity, Hard = Hardness, Alka = Alkalinity, Trans = Transparency, Turb = Turbidity

Appendix 4: Monthly values of physico-chemical parameters of station 4 measured during the study period

	Air temp ^0C	Water temp ^0C	pH	DO mg/l	Cond µS/cm	TDS mg/l	Hard mg/l $CaCO_3$	Alk mg/l $CaCO_3$	Trans cm	Turb FTU	Mg mg/l	Mn mg/l	Cu mg/l	Fe mg/l	Cd mg/l	Pb mg/l	Zn mg/l	Cl^- mg/l	PO_4^- mg/l	SO_4^- mg/l	NO_3^- mg/l
12-Sep	24.4	23	7.44	3.55	79	70.4	38.67	16.65	12.5	20.67	0.28	0.07	0	1.93	0	0	0.092	90	2.652	17.33	0.198
12-Oct	25.1	24.3	8.01	3.34	76.6	56.2	96	13.35	11	15.85	1.95	0.08	0.018	2.96	0	0	0.017	21.6	0.037	12.27	0.226
12-Nov	26	25.2	8.11	3.61	101.4	68.1	54.6	11.15	11.5	23.52	2.46	0.07	0.001	1.43	0	1.458	0	106.5	0.008	19.23	5.66
12-Dec	26.5	24.2	8.16	3.28	207	136	75	12.25	10	17.4	4.61	0.14	0.14	1.69	0	0.15	0.02	126	0.04	1.48	7.83
13-Jan	23.5	21.7	7.62	3.84	196.5	135.5	50.6	12.85	19.5	16.67	5.01	0.16	0.07	0.71	0	0.09	0.04	123	0.032	0.69	6.41
13-Feb	28	26.9	7.61	4.04	192.1	136	38	12.3	10.8	19.67	3.83	0.27	0.01	0.3	0	0.69	0.2	35.5	0.2	0.07	0.13
13-Mar	28	27.6	7.24	3.98	206	146	37.2	7	11	13.38	1.591	0.02	0.092	0.08	0.059	0.479	0.059	61.66	0.031	12.38	13.16
13-Apr	29.5	28.5	6.89	3.37	112.5	77.9	25.4	6.15	12.4	17.13	1.518	0.08	0.12	0.2	0.074	0.207	0.031	81.24	0.02	28.23	59.26
13-May	27.2	26.6	7.64	4.28	126.6	87.9	27.4	8.2	12	24.86	1.048	0.03	0.123	2.12	0.075	1.466	0.178	42.48	44.38	39.12	48.11
13-Jun	26.4	25.8	7.54	3.58	140	104	23	9.5	9.5	19.47	3.17	0.45	0.077	0.99	0.014	0.06	0.064	35	12.43	15.3	12.43
13-Jul	26.6	25.3	7.66	2.61	92.3	63.2	21.4	11.15	13.3	26.78	0.582	0.04	0.251	2.37	0.089	0.82	0.051	71.26	22.34	34.79	66.24
13-Aug	24.6	23	7.84	4.47	113.3	79.3	33.2	5.35	13.9	35.3	1.269	0.46	0.497	4.8	1.269	1.17	0.091	91.3	45.8	82.8	31.2
13-Sep	25.6	24.9	7.82	6.78	115.8	80.9	30	7	8.75	36.2	1.392	0.43	0.441	4.47	1.392	0.69	0.002	96.2	49.2	86.3	37.4
13-Oct	24.9	24.8	7.87	6.28	91	63.5	28.66	6.5	5.5	26.8	0.933	0.199	0.091	0.81	0.023	1.575	0.079	93.8	65.3	49.6	36.4
13-Nov	25.8	24.6	7.67	5.45	115.8	81.9	30	5.5	16	23.5	1.074	0.026	0.151	1.27	0.017	0.217	0.092	88.5	61.4	33.4	19.5
13-Dec	19.7	20.1	8.1	5.39	125.2	86.1	27	6	45	8.8	0.936	0.21	0.127	1.48	0.48	0.6	0.418	36	38.1	30.8	65.7
14-Jan	24.5	24.2	7.63	5.91	149	103.8	24	5.75	56	10	1.146	0.23	0.188	0.72	0.711	1.21	0.192	72	53.6	28.6	87.5
14-Feb	23.2	22.7	7.56	5.02	164.8	115	28	5	43	10.9	1.521	0.28	0.152	0.76	0.723	1.2	0.501	72	68.5	32.3	86.5

Key: Air temp = Air Temperature, Water temp = Water Temperature, Cond = Conductivity, Hard = Hardness, Alka = Alkalinity, Trans = Transparency, Turb = Turbidity

Appendix 5: Two-way ANOVA for Physico-chemical parameters measured at Ibuya River

(1) Air temperature

```
Source of variation      d.f.       s.s.       m.s.     v.r.  F pr.
station                     3      3.886      1.295     0.25  0.858
season                      1     48.858     48.858     9.59  0.003
station.season              3      1.176      0.392     0.08  0.972
Residual                   64    326.034      5.094
Total                      71    379.954
```

(2) Water temperature

```
Source of variation      d.f.       s.s.       m.s.     v.r.  F pr.
station                     3     3.369      1.123      0.31   0.817
season                      1     56.256     56.256    15.60   <.001
station.season              3      0.465      0.155     0.04  0.988
Residual                   64    230.783      3.606
Total                      71    290.874
```

(3) pH

```
Source of variation      d.f.       s.s.       m.s.     v.r.  F pr.
station                     3   0.70357    0.23452      2.89  0.042
season                      1    0.27608    0.27608     3.40  0.070
Sstation.season             3    0.05119    0.01706     0.21  0.889
Residual                   64    5.19124    0.08111
Total                      71    6.22209
```

(4) DO

```
Source of variation      d.f.       s.s.       m.s.     v.r.  F pr.
station                     3     0.892      0.297      0.17  0.919
season                      1      0.042      0.042     0.02  0.879
station.season              3      1.577      0.526     0.29  0.830
Residual                   64    114.628      1.791
Total                      71    117.139
```

(5) Conductivity

```
Source of variation      d.f.       s.s.       m.s.     v.r.  F pr.
station                    3      1297.       432.      0.21  0.886
season                      1     25925.     25925.    12.88   <.001
station.season              3      3411.      1137.     0.56  0.640
Residual                   64    128820.      2013.
Total                      71    159452.
```

(6) TDS

```
Source of variation      d.f.       s.s.       m.s.     v.r.  F pr.
station                    3      422.9      141.0      0.15  0.927
season                      1    10793.9    10793.9    11.76   0.001
station.season              3     2070.6      690.2     0.75  0.525
Residual                   64    58724.5      917.6
Total                      71    72012.0
```

(7) Alkalinity

```
Source of variation      d.f.       s.s.       m.s.     v.r.  F pr.
station                     3      18.43       6.14     0.24  0.866
season                      1       5.90       5.90     0.23  0.631
station.season              3      16.24       5.41     0.21  0.887
Residual                   64    1620.79      25.32
```

```
Total                    71     1661.36
```

(8) Hardness

```
Source of variation     d.f.        s.s.        m.s.     v.r.   F pr.
station                   3        157.3        52.4     0.15   0.932
season                    1        247.5       247.5     0.69   0.409
station.season            3         41.4        13.8     0.04   0.990
Residual                 64      22924.1       358.2
Total                    71      23370.3
```

(9) Transparency

```
Source of variation     d.f.        s.s.        m.s.     v.r.   F pr.
station                   3       84.32        28.11     0.32   0.809
season                    1     2580.72      2580.72    29.57   <.001
station.season            3       91.50        30.50     0.35   0.790
Residual                 64     5585.33        87.27
Total                    71     8341.87
```

(10) Turbidity

```
Source of variation     d.f.        s.s.        m.s.     v.r.   F pr.
station                   3       71.64        23.88     0.48   0.695
season                    1      952.09       952.09    19.29   <.001
station.season            3       18.74         6.25     0.13   0.944
Residual                 64     3158.13        49.35
Total                    71     4200.60
```

(11) Mg

```
Source of variation     d.f.        s.s.        m.s.     v.r.   F pr.
station                   3       1.056        0.352     0.15   0.927
season                    1      19.453       19.453     8.52   0.005
station.season            3       0.274        0.091     0.04   0.989
Residual                 64     146.043        2.282
Total                    71     166.827
```

(12) Mn

```
Source of variation     d.f.        s.s.        m.s.     v.r.   F pr.
station                   3     0.02042      0.00681     0.24   0.872
season                    1     0.00004      0.00004     0.00   0.971
station.season            3     0.05323      0.01774     0.61   0.609
Residual                 64     1.85350      0.02896
Total                    71     1.92718
```

(13) Cu

```
Source of variation     d.f.        s.s.        m.s.     v.r.   F pr.
station                   3     0.00242      0.00081     0.05   0.987
season                    1     0.02183      0.02183     1.25   0.269
station.season            3     0.01355      0.00452     0.26   0.856
Residual                 64     1.12221      0.01753
Total                    71     1.16002
```

(14) Fe

```
Source of variation     d.f.        s.s.        m.s.     v.r.   F pr.
station                   3       6.772        2.257     0.78   0.507
season                    1      25.011       25.011     8.69   0.004
station.season            3       0.823        0.274     0.10   0.962
Residual                 64     184.188        2.878
Total                    71     216.794
```

(15) Cd

```
Source of variation     d.f.       s.s.       m.s.     v.r.  F pr.
station                    3     0.1129     0.0376     0.21  0.892
season                     1     0.0086     0.0086     0.05  0.830
station.season             3     0.0389     0.0130     0.07  0.975
Residual                  64    11.7305     0.1833
Total                     71    11.8908
```

(16) Pb

```
Source of variation     d.f.       s.s.       m.s.     v.r.  F pr.
station                    3     0.1696     0.0565     0.14  0.937
season                     1     0.3697     0.3697     0.90  0.346
station.season             3     0.2674     0.0891     0.22  0.884
Residual                  64    26.3029     0.4110
Total                     71    27.1096
```

(17) Zn

```
Source of variation     d.f.       s.s.       m.s.     v.r.  F pr.
station                    3    0.06160    0.02053     0.55  0.649
season                     1    0.45384    0.45384    12.20  <.001
station.season             3    0.04901    0.01634     0.44  0.726
Residual                  64    2.38063    0.03720
Total                     71    2.94507
```

(18) Cl^-

```
Source of variation     d.f.       s.s.       m.s.     v.r.  F pr.
station                    3       144.        48.     0.04  0.990
season                     1      3400.      3400.     2.64  0.109
station.season             3        30.        10.     0.01  0.999
Residual                  64     82407.      1288.
Total                     71     85982.
```

(19) SO_4^-

```
Source of variation     d.f.       s.s.       m.s.     v.r.  F pr.
station                    3      471.0      157.0     0.25  0.863
season                     1     6761.6     6761.6    10.66  0.002
station.season             3      150.5       50.2     0.08  0.971
Residual                  64    40599.2      634.4
Total                     71    47982.2
```

(20) PO_4^-

```
Source of variation     d.f.       s.s.       m.s.     v.r.  F pr.
station                    3      233.2       77.7     0.12  0.947
season                     1        1.7        1.7     0.00  0.959
staion.season              3      258.7       86.2     0.14  0.939
Residual                  64    40829.1      638.0
Total                     71    41322.8
```

(21) NO_3^-

```
Source of variation     d.f.       s.s.       m.s.     v.r.  F pr.
station                    3     1118.2      372.7     0.38  0.765
season                     1     1697.6     1697.6     1.75  0.191
station.season             3      168.9       56.3     0.06  0.981
Residual                  64    62101.6      970.3
Total                     71    65086.3
```

Appendix 6: Raw values of phytoplankton Abundance encountered during the study period

Bacillariophyceae	Sep. 12	Oct. 12	Nov. 12	Dec. 12	Jan. 13	Feb. 13	Mar. 13	Apr. 13	May. 13	Jun. 13	Jul.13	Aug. 13	sep. 13	Oct. 13	Nov. 13	Dec. 13	Jan. 14	Feb. 14
Aulacoseira granulata	4914	1638	1365	3003	6279	1638	4095	1365	3822	8190	1254	1228	2,457	0	1638	1092	0	0
Cosinodiscus lineatus	0	0	234	0	0	52	104	208	52	91	104	0	143	0	0	247	0	0
Cybella sp.	0	65	0	0	0	0	0	0	52	0	52	0	0	91	0	78	0	0
Cyclotella stelligera	0	0	0	195	52	0	26	0	0	13	0	0	0	0	0	52	0	91
Diatoma elongatum	0	0	182	0	0	0	0	0	0	0	13	0	117	0	221	65	78	0
Ditylum brightwellii	78	0	0	0	0	39	0	39	0	0	26	26	0	0	65	0	52	0
Fragilaria construens	7904	1248	3328	3744	0	4212	0	0	6240	832	0	0	2496	0	2080	0	1248	0
F. oceanica	0	2808	0	3510	8424	0	0	702	702	2808	0	0	1404	0	2106	0	0	702
Frustulia rhomboides	0	0	0	52	26	0	26	0	13	39	13	0	78	0	0	0	195	0
F. weinholdii	0	0	65	0	0	26	65	0	0	91	78	0	0	117	0	65	78	0
Gomphonema dubravicense	0	0	0	221	195	0	0	0	13	39	0	91	0	0	0	0	182	0
Gyrosigma fasciola	0	39	169	26	13	0	52	13	13	0	91	26	0	0	65	0	0	0
Navicula mutica	65	0	0	0	65	13	195	0	13	39	0	0	26	0	91	0	0	0
Nitzscha sigmoidea	221	117	0	0	0	169	0	13	0	0	0	0	0	195	143	78	0	143
Nitzscha sp.	0	0	247	247	286	0	0	13	91	377	0	0	0	0	274	0	0	0
N. spiculum	533	169	91	429	0	0	78	0	0	0	91	13	156	208	227	0	0	0
Peridinum sp.	0	0	0	182	130	0	0	0	0	0	0	39	0	0	0	104	78	0
Pinnularia biceps	0	0	117	65	0	26	0	0	0	26	104	0	0	0	0	65	0	0

P. cardinalis	390	104	0	130	130	0	65	91	65	104	0	0	0	0	156	0	0	91
P. gibba	325	0	0	0	65	26	0	0	13	0	0	13	0	0	52	0	0	0
P. nobilis	0	0	0	0	0	0	0	78	0	78	26	39	91	0	0	0	52	0
Synedra acus	312	91	156	143	364	0	13	91	13	52	0	0	0	0	0	208	0	13
S. crystallina	182	0	0	0	0	65	0	0	0	0	156	104	0	196	91	0	0	0
S. ulna	208	39	0	26	364	533	104	26	104	117	13	0	0	0	78	0	0	0
Tabellaria fenestrata	0	78	0	52	130	52	195	26	117	208	0	0	0	0	195	91	0	0
Euglenophyceae																		
Euglena ehrenbergii	325	0	91	0	0	26	13	52	0	39	0	0	247	0	65	0	208	0
E. oxyuris	0	0	39	0	0	0	0	0	26	104	0	0	0	221	0	65	78	91
E. spirogyra	260	0	65	0	0	0	26	351	117	247	0	13	0	0	0	0	143	13
E. tripteris	156	0	104	0	0	0	0	13	0	13	0	91	0	0	0	130	0	26
Phacus longicauda	0	26	0	0	0	52	0	78	0	0	0	104	0	143	0	52	65	0
P. pleuronectes	0	0	0	0	91	0	104	39	26	52	0	39	143	0	104	0	0	0
Prorocentrum gracile	0	0	507	143	0	0	0	0	26	0	0	0	52	0	0	182	0	0
Trachelomonas planctonia	0	65	0	65	0	0	0	13	39	13	39	0	0	0	52	0	0	78
Chlorophyceae																		
Closterium acerosum	91	0	0	0	0	65	0	0	0	0	91	117	0	195	39	0	104	0
C. ehrenbergii	0	0	0	0	39	0	26	0	26	26	104	0	0	0	78	0	0	52
C. lineatum	0	0	0	26	0	39	39	26	0	0	0	0	78	91	65	65	0	39
Cosmarium granatum	0	0	78	13	0	0	0	0	0	39	52	0	0	65	0	26	91	26
Pandorina morum	0	156	0	0	0	0	26	39	0	0	13	0	0	52	0	0	0	0
Pediastrum	65	0	0	0	0	0	78	26	0	0	0	39	91	0	0	143	0	0

duplex																		
Scenedesmus opoliensis	0	0	0	143	0	0	0	182	0	0	143	26	0	0	0	0	117	0
S. protuberans	0	0	0	0	0	39	481	0	0	78	117	0	0	0	182	0	52	0
Spirogyra dubra	1521	0	0	0	819	0	468	624	156	624	0	0	0	0	273	0	0	936
Cyanophyceae																		
Microcystis aeruginosa	0	54	0	0	26	39	0	0	0	0	104	91	78	0	52	156	0	0
Merismopedia punctata	0	0	0	0	53248	0	0	0	0	0	53248	0	0	0	53248	0	0	0
Oscillatoria sp.	1170	0	3510	585	0	0	2340	585	1170	585	0	585	0	0	1170	0	0	0

Appendix 7: Two-way analysis of variance for the abundance of phytoplankton group measured at Ibuya River.

(a) Bacillariophyceae

```
Source of variation     d.f.       s.s.       m.s.    v.r.  F pr.
stations                   3   2080228.    693409.    0.31  0.819
season                     1   1110333.   1110333.    0.49  0.485
stations.season            3    648401.    216134.    0.10  0.962
Residual                  64 144038588.   2250603.
Total                     71 147877550.
```

(b) Chlorophyceae

```
Source of variation     d.f.       s.s.       m.s.    v.r.  F pr.
stations                   3     43221.     14407.    0.76  0.523
season                     1      2671.      2671.    0.14  0.710
stations.season            3     10138.      3379.    0.18  0.912
Residual                  64   1220915.     19077.
Total                     71   1276944.
```

(c) Cyanophyceae

```
Source of variation     d.f.       s.s.       m.s.    v.r.  F pr.
stations                   3  4.740E+08  1.580E+08    1.35  0.267
season                     1  2.113E+07  2.113E+07    0.18  0.673
stations.season            3  1.014E+08  3.381E+07    0.29  0.834
Residual                  64  7.509E+09  1.173E+08
Total                     71  8.106E+09
```

(d) Euglenophyceae

```
Source of variation     d.f.       s.s.       m.s.    v.r.  F pr.
stations                   3     30109.     10036.    1.82  0.153
season                     1        38.        38.    0.01  0.934
stations.season            3      3189.      1063.    0.19  0.901
Residual                  64    353377.      5522.
Total                     71    386714.
```

Appendix 8: Seasonal variation in Phytoplankton Abundance during the period of study

	Levene's Test for Equality of Variances		t-test for Equality of Means						
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
								Lower	Upper
Bacillariophyceae	1.595	.211	.728	70	.469	249.913	343.421	-435.019	934.844
Euglenophyceae	.035	.852	.083	70	.934	1.463	17.627	-33.694	36.619
Chlorophyceae	.063	.802	-.383	70	.703	-12.256	32.000	-76.077	51.565
Cyanophyceae	.612	.437	-.428	70	.670	-1090.319	2548.825	-6173.789	3993.152

Appendix 9: Raw values of zooplankton Abundance encountered during the study period in Ibuya River

Rotifera	Sep. 12	Oct.12	Nov.12	Dec.12	Jan.13	Feb.13	Mar.13	Apr.13	May.13	Jun.13	Jul.13	Aug.13	Sep.13	Oct.13	Nov.13	Dec.13	Jan.14	Feb.14
Anuraeopsis fissa	0	0	52	91	0	13	13	0	0	0	13	0	39	13	0	0	0	26
Brachionus angularis	0	52	0	13	39	26	0	0	0	0	65	0	0	26	0	78	0	0
B. falcatus	130	39	0	208	0	13	0	39	0	0	0	0	0	0	0	91	0	0
B. calyciflorus	0	0	0	39	0	0	13	0	91	0	39	104	26	0	0	0	26	0
Chromogaster ovalis	0	0	26	0	26	0	0	13	0	39	0	0	39	0	52	0	0	13
Filinia terminalis	0	26	0	0	0	39	0	0	13	0	91	104	0	39	0	26	0	0
F. opoliensis	0	0	13	26	26	0	13	52	0	0	0	0	0	91	0	13	0	0
Keratella quadrata	0	26	52	0	26	26	0	0	0	78	0	0	52	104	0	13	0	0
K. valga	0	0	0	0	0	26	0	13	26	0	0	0	13	0	52	0	0	39
Lecane bulla	247	0	0	0	0	39	0	0	0	0	26	39	65	0	78	0	52	0
L. luna	0	0	78	0	130	0	0	26	52	0	13	0	0	39	0	65	0	0
Platyias quadricornis	0	39	26	52	0	0	0	195	0	0	13	52	0	0	0	39	0	0
Polyarthra dolicoptera	0	0	13	0	0	26	13	0	0	221	52	0	0	91	0	0	0	26
P. vulgaris	0	26	0	0	52	0	0	0	91	0	0	104	39	78	52	0	0	0
Trichocerca elongate	91	0	0	13	0	78	260	117	0	52	0	0	0	26	13	26	0	0
Crustacea																		
Mesocyclops leuckarti	39	39	0	26	52	39	117	520	0	52	0	52	0	0	0	104	0	13
Harpacticoid sp.	0	0	65	0	0	0	234	130	0	39	0	52	0	13	0	0	0	91
Moina micrura	26	52	0	117	0	52	0	143	78	0	52	0	65	0	65	0	26	0
Arachnactis larva	52	26	39	0	0	13	13	0	39	0	39	0	26	0	0	52	0	0
Nauplius larva	0	0	0	26	39	0	13	91	0	39	0	0	65	13	0	13	0	26
Insecta																		
Chironomus sp.	39	0	26	52	0	26	0	26	26	39	0	52	0	52	13	0	0	52

Appendix 10: Two-way analysis of variance for the abundance of zooplankton group measured at Ibuya River.

(1) Rotifera

```
Source of variation     d.f.         s.s.        m.s.    v.r.  F pr.
season                     1        5577.       5577.    1.28  0.262
stations                   3       33518.      11173.    2.56  0.062
season.stations            3       14330.       4777.    1.10  0.357
Residual                  64      278791.       4356.
Total                     71      332216.
```

(2) Crustacea

```
Source of variation     d.f.         s.s.        m.s.    v.r.  F pr.
season                     1       12168.      12168.    3.84  0.054
stations                   3       21282.       7094.    2.24  0.092
season.stations            3        2834.        945.    0.30  0.827
Residual                  64      202792.       3169.
Total                     71      239076.
```

(3) Insecta

```
Source of variation     d.f.         s.s.        m.s.    v.r.  F pr.
season                     1        46.94       46.94    0.65  0.425
stations                   3       570.38      190.13    2.61  0.059
season.stations            3        76.05       25.35    0.35  0.790
Residual                  64      4655.95       72.75
Total                     71      5349.32
```

Appendix 11: Seasonal variation in Zooplankton Abundance during the period of study

	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
Crustacea	6.116	.016	-1.938	70	.057	-26.163	13.503	-53.094	.769
Insecta	.376	.542	.787	70	.434	1.625	2.064	-2.492	5.742
Rotifera	.945	.334	1.093	70	.278	17.713	16.201	-14.600	50.025

Appendix 12: Raw values of Macrozoobenthos sampled for the month of September, 2012

Species	**Station 1**			**Station 2**			**Station 3**			**Station 4**		
Replicate	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Gastropoda												
Lanistes libycus	3	0	0	0	0	2	0	2	0	2	1	1
Indoplanorbis exustus	2	1	3	0	3	0	2	0	0	2	4	2
Melanoides tuberculata	0	0	4	1	0	0	0	0	0	0	5	5
Potadoma moerchi	2	0	0	0	0	0	0	0	0	0	0	3
Gabbiella sp.	0	1	0	0	0	0	0	0	0	0	3	0
Insecta												
Chironomus species	1	1	0	0	0	0	0	0	0	1	0	0
Bivalva												
Donax vittatus	0	0	0	0	0	0	0	0	0	0	2	0
Crustacea												
Cardisoma sp.	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 13: Raw values of Macrozoobenthos sampled for the month of October, 2012

Species	**Station 1**			**Station 2**			**Station 3**			**Station 4**		
Replicate	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Gastropoda												
Lanistes libycus	0	0	0	0	0	0	0	0	0	0	0	0
Indoplanorbis exustus	0	4	0	0	0	1	0	1	0	0	0	5
Melanoides tuberculata	3	0	0	2	0	0	2	0	0	2	4	2
Potadoma moerchi	0	0	0	0	0	0	0	0	0	0	0	0
Gabbiella sp.	0	0	0	0	0	0	0	0	0	0	0	0
Insecta												
Chironomus species	0	0	3	0	1	0	1	0	0	0	2	0
Bivalva												
Donax vittatus	0	0	0	0	0	0	0	0	0	1	0	0
Crustacea												
Cardisoma sp.	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 14: Raw values of Macrozoobenthos sampled for the month of November, 2012

Species	**Station 1**			**Station 2**			**Station 3**			**Station 4**		
Replicate	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Gastropoda												
Lanistes libycus	3	0	0	2	0	0	1	0	0	0	0	6
Indoplanorbis exustus	0	4	4	0	0	4	0	0	1	0	3	4
Melanoides tuberculata	0	0	7	0	3	0	0	3	0	4	0	0
Potadoma moerchi	1	0	0	0	0	0	0	0	0	0	1	0
Gabbiella sp.	1	0	0	0	0	0	0	0	0	0	0	1
Insecta												
Chironomus species	0	2	2	0	0	1	2	0	0	2	0	0
Bivalva												
Donax vittatus	0	0	0	0	0	0	0	0	0	0	0	0
Crustacea												
Cardisoma sp.	0	0	0	0	0	0	0	0	0	0	2	0

Appendix 15: Raw values of Macrozoobenthos sampled for the month of December, 2012

Species	**Station 1**			**Station 2**			**Station 3**			**Station 4**		
Replicate	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Gastropoda												
Lanistes libycus	0	0	0	0	0	0	0	0	0	0	0	0
Indoplanorbis exustus	1	1	0	0	0	0	1	0	0	0	3	0
Melanoides tuberculata	0	0	2	1	0	0	1	0	0	0	2	1
Potadoma moerchi	0	0	0	0	0	0	0	0	0	0	0	0
Gabbiella sp.	0	0	0	0	0	0	0	0	0	0	0	0
Insecta												
Chironomus species	0	2	0	0	0	0	0	0	0	0	0	0
Bivalva												
Donax vittatus	0	0	0	0	0	0	0	0	0	0	0	0
Crustacea												
Cardisoma sp.	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 16: Raw values of Macrozoobenthos sampled for the month of January, 2013

Species	**Station 1**			**Station 2**			**Station 3**			**Station 4**		
Replicate	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Gastropoda												
Lanistes libycus	0	1	1	1	0	0	1	0	0	0	1	0
Indoplanorbis exustus	0	0	0	0	0	0	0	0	0	0	0	0
Melanoides tuberculata	0	0	2	0	0	1	0	0	1	1	1	1
Potadoma moerchi	0	0	0	0	0	0	0	0	0	0	0	0
Gabbiella sp.	0	0	0	0	0	0	0	0	0	0	0	0
Insecta												
Chironomus species	0	0	0	0	0	0	0	0	0	0	0	0
Bivalva												
Donax vittatus	0	0	0	0	0	0	0	0	0	0	0	0
Crustacea												
Cardisoma sp.	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 17: Raw values of Macrozoobenthos sampled for the month of February, 2013

Species	**Station 1**			**Station 2**			**Station 3**			**Station 4**		
Replicate	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Gastropoda												
Lanistes libycus	0	0	0	0	0	0	0	0	0	0	0	0
Indoplanorbis exustus	0	0	4	0	0	2	0	0	3	0	0	6
Melanoides tuberculata	4	0	0	0	2	0	0	0	1	0	4	0
Potadoma moerchi	0	0	0	2	0	0	1	0	0	2	0	0
Gabbiella sp.	0	0	0	0	0	0	0	0	0	0	0	0
Insecta												
Chironomus species	0	3	0	0	0	0	0	0	0	1	0	0
Bivalva												
Donax vittatus	0	0	2	0	0	0	0	1	0	0	3	0
Crustacea												
Cardisoma sp.	1	0	0	0	0	0	0	0	0	0	2	0

Appendix 18: Raw values of Macrozoobenthos sampled for the month of March, 2013

Species	**Station 1**			**Station 2**			**Station 3**			**Station 4**		
Replicate	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Gastropoda												
Lanistes libycus	0	0	0	0	0	0	0	0	0	0	0	0
Indoplanorbis exustus	0	0	0	0	0	0	0	0	0	0	2	0
Melanoides tuberculata	0	0	0	0	0	0	0	0	0	0	0	0
Potadoma moerchi	0	0	0	0	0	0	0	0	0	0	0	0
Gabbiella sp.	0	0	0	0	0	0	0	0	0	0	0	0
Insecta												
Chironomus species	0	0	0	0	0	0	0	0	0	0	0	0
Bivalva												
Donax vittatus	0	0	0	0	0	0	0	0	0	0	0	0
Crustacea												
Cardisoma sp.	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 19: Raw values of Macrozoobenthos sampled for the month of April, 2013

Species	**Station 1**			**Station 2**			**Station 3**			**Station 4**		
Replicate	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Gastropoda												
Lanistes libycus	0	0	2	1	0	0	1	0	0	0	1	0
Indoplanorbis exustus	1	0	0	1	0	0	0	1	0	0	1	0
Melanoides tuberculata	2	0	0	0	0	1	0	0	1	4	0	0
Potadoma moerchi	1	1	0	0	1	1	0	0	1	0	0	3
Gabbiella sp.	0	0	0	0	0	0	0	0	0	0	0	0
Insecta												
Chironomus species	0	0	5	0	0	0	0	0	0	2	0	0
Bivalva												
Donax vittatus	0	0	0	0	0	0	0	0	0	0	0	0
Crustacea												
Cardosoma sp.	0	1	0	0	0	0	0	0	1	0	0	1

Appendix 20: Raw values of Macrozoobenthos sampled for the month of May, 2013

Species	**Station 1**			**Station 2**			**Station 3**			**Station 4**		
Replicate	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Gastropoda												
Lanistes libycus	0	1	0	0	0	1	0	0	0	0	0	2
Indoplanorbis exustus	0	2	0	0	0	1	0	0	1	6	0	0
Melanoides tuberculata	2	0	0	1	0	0	0	1	0	0	1	0
Potadoma moerchi	0	1	0	0	1	0	1	0	0	1	0	0
Gabbiella sp.	0	0	0	0	0	0	0	0	0	0	0	0
Insecta												
Chironomus species	1	0	0	0	0	0	0	0	0	0	0	0
Bivalva												
Donax vittatus	0	0	0	0	0	0	0	0	0	0	2	0
Crustacea												
Cardisoma sp.	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 21: Raw values of Macrozoobenthos sampled for the month of June, 2013

Species	**Station 1**			**Station 2**			**Station 3**			**Station 4**		
Replicate	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Gastropoda												
Lanistes libycus	0	0	0	0	0	0	0	0	0	0	0	0
Indoplanorbis exustus	0	2	0	0	0	0	0	0	0	0	4	0
Melanoides tuberculata	1	0	0	0	0	0	0	0	0	5	0	0
Potadoma moerchi	0	0	0	0	0	0	0	0	0	0	0	0
Gabbiella sp.	0	0	0	0	0	0	0	0	0	0	0	0
Insecta												
Chironomus species	3	0	0	1	0	0	0	0	0	1	0	0
Bivalva												
Donax vittatus	0	0	0	0	0	0	0	0	0	0	0	0
Crustacea												
Cardisoma sp.	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 22: Raw values of Macrozoobenthos sampled for the month of July, 2013

Species	**Station 1**			**Station 2**			**Station 3**			**Station 4**		
Replicate	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Gastropoda												
Lanistes libycus	0	0	0	0	0	0	0	0	0	0	0	0
Indoplanorbis exustus	0	0	0	0	0	0	0	0	0	0	2	0
Melanoides tuberculata	0	0	0	0	0	0	0	0	0	0	2	0
Potadoma moerchi	0	0	0	0	0	0	0	0	0	0	0	0
Gabbiella sp.	0	0	0	0	0	0	0	0	0	0	0	0
Insecta												
Chironomus species	2	0	0	0	0	0	0	0	0	0	0	0
Bivalva												
Donax vittatus	0	0	0	0	0	0	0	0	0	0	0	0
Crustacea												
Cardisoma sp.	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 23: Raw values of Macrozoobenthos sampled for the month of August, 2013

Species	**Station 1**			**Station 2**			**Station 3**			**Station 4**		
Replicate	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Gastropoda												
Lanistes libycus	1	1	1	0	1	0	1	0	0	0	0	1
Indoplanorbis exustus	2	0	2	0	2	0	0	0	0	0	7	0
Melanoides tuberculata	0	0	2	0	0	1	0	0	1	0	3	3
Potadoma moerchi	0	1	0	1	0	0	1	0	0	1	0	0
Gabbiella sp.	0	0	0	0	0	0	0	0	0	1	0	0
Insecta												
Chironomus species	0	0	2	0	1	0	0	0	0	0	0	0
Bivalva												
Donax vittatus	0	0	0	0	0	0	0	0	0	0	0	0
Crustacea												
Cardisoma sp.	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 24: Raw values of Macrozoobenthos sampled for the month of September, 2013

Species	**Station 1**			**Station 2**			**Station 3**			**Station 4**		
Replicate	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Gastropoda												
Lanistes libycus	0	0	0	0	0	0	0	0	0	0	0	0
Indoplanorbis exustus	0	0	1	0	0	0	0	0	0	0	0	0
Melanoides tuberculata	0	0	0	0	0	0	0	0	0	2	0	0
Potadoma moerchi	0	0	0	0	0	0	0	0	0	0	0	0
Gabbiella sp.	0	0	0	0	0	0	0	0	0	0	0	0
Insecta												
Chironomus species	0	0	0	0	0	0	0	0	0	0	0	0
Bivalva												
Donax vittatus	0	0	0	0	0	0	0	0	0	0	0	0
Crustacea												
Cardisoma sp.	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 25: Raw values of Macrozoobenthos sampled for the month of October, 2013

Species	**Station 1**			**Station 2**			**Station 3**			**Station 4**		
Replicate	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Gastropoda												
Lanistes libycus	0	0	0	0	0	0	0	0	0	0	0	0
Indoplanorbis exustus	0	2	3	0	3	0	1	0	0	6	3	0
Melanoides tuberculata	1	1	0	0	1	1	0	1	0	5	0	0
Potadoma moerchi	4	0	0	0	0	3	0	1	0	0	0	3
Gabbiella sp.	2	0	0	0	1	0	0	0	1	0	0	1
Insecta												
Chironomus species	0	0	5	1	0	0	0	0	0	0	2	0
Bivalva												
Donax vittatus	0	1	0	2	0	0	0	0	0	0	2	0
Crustacea												
Cardisoma sp.	1	0	0	0	0	0	0	0	0	0	0	2

Appendix 26: Raw values of Macrozoobenthos sampled for the month of November, 2013

Species	**Station 1**			**Station 2**			**Station 3**			**Station 4**		
Replicate	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Gastropoda												
Lanistes libycus	0	0	3	0	0	2	2	0	0	0	4	0
Indoplanorbis exustus	5	0	0	0	0	3	0	0	2	0	6	2
Melanoides tuberculata	0	0	2	1	0	0	1	0	0	3	0	0
Potadoma moerchi	0	0	0	0	0	0	0	0	0	0	0	0
Gabbiella sp.	1	0	0	0	0	0	0	0	0	2	0	0
Insecta												
Chironomus species	0	3	0	0	0	0	0	0	0	1	0	0
Bivalva												
Donax vittatus	1	0	0	2	0	0	1	0	0	0	3	0
Crustacea												
Cardisoma sp.	0	1	0	0	0	0	0	0	0	0	2	0

Appendix 27: Raw values of Macrozoobenthos sampled for the month of December, 2013

Species	**Station 1**			**Station 2**			**Station 3**			**Station 4**		
Replicate	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Gastropoda												
Lanistes libycus	0	3	0	0	0	0	0	0	0	0	1	0
Indoplanorbis exustus	0	3	0	0	0	0	0	0	0	0	1	0
Melanoides tuberculata	0	1	1	0	0	0	1	0	0	0	0	3
Potadoma moerchi	0	0	2	0	0	0	0	0	1	3	0	0
Gabbiella sp.	0	0	0	0	0	0	0	0	0	2	0	0
Insecta												
Chironomus species	3	0	0	0	0	0	0	0	0	0	1	0
Bivalva												
Donax vittatus	0	0	1	0	0	1	1	0	0	0	0	2
Crustacea												
Cardisoma sp.	1	0	0	0	0	0	0	0	0	1	0	0

Appendix 28: Raw values of Macrozoobenthos sampled for the month of January, 2014

Species	**Station 1**			**Station 2**			**Station 3**			**Station 4**		
Rep;icate	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Gastropoda												
Lanistes libycus	0	2	0	1	0	0	1	0	0	0	2	2
Indoplanorbis exustus	1	1	0	0	0	2	1	0	0	3	0	0
Melanoides tuberculata	0	0	0	0	0	0	0	0	0	0	0	0
Potadoma moerchi	0	0	0	0	0	0	0	0	0	0	0	0
Gabbiella sp.	3	0	0	0	1	0	0	0	0	1	0	0
Insecta												
Chironomus species	0	0	1	0	1	0	0	1	0	2	0	0
Bivalva												
Donax vittatus	0	0	0	0	0	0	0	0	0	0	0	0
Crustacea												
Cardisoma sp.	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 29: Raw values of Macrozoobenthos sampled for the month of February, 2014

Species	**Station 1**			**Station 2**			**Station 3**			**Station 4**		
Replicate	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Gastropoda												
Lanistes libycus	0	0	1	0	1	0	0	0	0	2	0	0
Indoplanorbis exustus	0	0	5	0	0	3	2	0	0	8	0	0
Melanoides tuberculata	0	2	2	1	0	0	0	0	0	2	5	0
Potadoma moerchi	0	0	1	0	0	0	0	1	0	0	1	0
Gabbiella sp.	0	0	0	0	0	0	0	0	0	0	0	2
Insecta												
Chironomus species	1	0	0	0	0	0	1	0	0	1	0	0
Bivalva												
Donax vittatus	0	0	0	0	0	0	0	0	0	0	0	0
Crustacea												
Cardisoma sp.	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 30: Seasonal variation of Macrozoobenthos during the study period (T-test)

	Levene's Test for Equality of Variances		t-test for Equality of Means						
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
								Lower	Upper
Gastropoda	1.079	.302	-.166	70	.869	-.231	1.392	-3.008	2.545
Bivalvas	1.489	.226	-.742	70	.461	-.138	.185	-.507	.232
Insecta	.054	.817	-.149	70	.882	-.044	.293	-.628	.540
Crustacea	13.438	.000	-1.848	70	.069	-.231	.125	-.481	.018

Appendix 31: Raw values of Fish encountered during the study period in Ibuya River

Species/Month	Sep. 12	Oct. 12	Nov 12	Dec. 12	Jan. 13	Feb. 13	Mar. 13	Apr. 13	May 13	Jun. 13	Jul. 13	Aug 13	Sep. 13	Oct. 13	Nov 13	Dec. 13	Jan. 14	Feb. 14
Brycinus Macrolepidotus	0	0	0	0	3	0	0	1	0	3	0	0	0	0	0	0	2	0
B. nurse	0	0	0	0	1	0	2	2	0	0	0	0	0	3	0	0	3	0
Clarias gariepinus	0	0	0	0	6	2	0	4	0	3	2	2	0	0	3	0	2	3
Chrysichthys nigrodigitatus	0	0	0	0	4	2	0	1	2	0	0	3	0	0	1	0	4	0
C. aluuensis	0	0	0	0	0	1	0	2	0	0	0	1	0	0	2	0	0	0
Gnathonemus senegalensis	0	0	0	0	4	1	0	3	0	0	0	0	1	0	7	0	0	1
Heterobranchus bidorsalis	0	0	0	0	2	0	1	0	0	2	0	0	0	0	2	2	0	3
H. longifilis	0	0	0	0	0	0	1	0	0	0	3	0	1	0	0	0	2	0
Hepsetus odoe	0	0	0	0	6	4	1	3	2	0	0	3	0	2	4	2	3	0
Hemichromis fasciatus	0	0	0	0	3	0	0	2	0	2	1	0	0	0	0	0	0	2
Labeo brachypoma	0	0	0	0	3	0	0	2	0	2	0	0	0	0	2	2	0	5
L. parvus	0	0	0	0	6	3	1	2	2	2	0	2	0	0	0	10	3	4
Micralestes elongatus	0	0	0	0	3	2	1	0	0	4	0	0	2	0	3	0	0	0
Mormyrus rume	0	0	0	0	5	2	2	0	0	2	0	0	0	0	5	0	2	0
Oreochromis niloticus	0	0	0	0	3	1	0	4	0	0	1	0	0	0	0	0	0	2

Parachanna obscura	0	0	0	0	0	0	1	2	0	2	0	0	1	0	0	0	0	3
Raiamas senegalensis	0	0	0	0	2	1	1	4	0	0	0	2	0	0	3	0	2	0
Schilbe intermedius	0	0	0	0	2	0	0	0	3	2	0	0	4	0	3	2	0	0
Synodontis budgeti	0	0	0	0	0	0	2	0	3	1	0	0	0	1	0	2	0	0
S. gambiensis	0	0	0	0	3	2	1	0	0	2	2	0	0	0	2	0	2	0
Coptodon dageti	0	0	0	0	0	0	1	2	0	0	0	0	0	0	0	0	0	2
C. guineesis	0	0	0	0	4	1	2	3	2	5	1	0	0	0	3	1	0	5
C. zillii	0	0	0	0	6	2	0	4	2	0	1	4	0	2	5	2	3	2
Bagrus docmac niger	0	0	0	0	1	2	0	0	0	3	0	0	2	0	0	0	0	3