FOOD COMPOSITION AND SELECTIVITY INDICES OF *Labeobarbus altianalis* *(*BOULINGER, 1900) IN RIVER KUJA BASIN, KENYA.

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JULY, 2019

DECLARATION AND RECOMMENDATION

Declaration by the Candidate

I declare that this thesis is my original work and has not been presented in any university.

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DEDICATION

I dedicate this thesis to Hope Rotich who has been supportive and my parents Mr. Richard Sigei and Angela Sigei who always encouraged me when I felt I could not make it.

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ABSTRACT

Studies on food items occurrence, composition and selectivity in riverine cyprinid species in River Kuja basin have not been adequately addressed towards habitat quality assessment for Lake Victoria basin. In particular literature on food items selectivity and composition by weight for *Labeobarbus altianalis* is scanty. Therefore, a study was conducted on the distribution, abundance and the diversity of food items in the habitat, occurrence, composition and selectivity in the guts of *L.altianalis* in the Kuja-Migori River between November 2016 and August 2017. Five stations were chosen based on longitudinal occurrence (Kegati, Ogembo, Kanga, Gogo dam and Wath Onger) and sampled during the rainy season(November to March) and dry season (April to August). July and August experienced long rains. Stomach contents of 1032 specimens were collected by electrofisher and analysed. The major diet of fish <5 cm total length was found to be insects, zooplankton and algae, bigger fish fed on wide range of food items including plant matter and insects. Detritus, macrophytes and insects were found to be the dominant food items in all size classes, whereas the contributions of fish scales, zooplankton and phytoplankton were low. Ivlev`s of electivity (E) indicated that the most preferred food items in the upper section of the river during the dry season were Diptera (E = +0.64) and Ephemeroptera (E = +0.63), in the lower section the most preferred were Diptera (E = +0.72) and Decapoda (E = +0.60). Comparatively, during the wet season in the upper section of River Kuja basin the most preferred food items was Odonata (E = +0.72) while Pulmonata and Hirudinia were mostly avoided (E = -1). Based on the results it can be concluded that *Labeobarbus altianalis is* omnivorous in its feeding habits in River Kuja Basin.

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LIST OF ACRONYMS

IUCN - International Union for conservation of Nature

TL - Total length

SL - Standard Length

CM - Centimeters

TDS - Total suspended solids

GPS - Geographical positioning system

NTUs - Nepherometric Turbidity Units (NTUs) (Owen, 1975);
DOC - Dissolved oxygen concentration

Ml - milliliters

Mg - milligrams

APHA - American Public Health Association

Spp - Species

FAO - Food and Agriculture Organization

pH - Potential Hydrogen

SPSS - Statistical Package for social sciences

μScm^{-1} - Microsiemens per centimeter

μgL^{-1} - Microgram per Litre

DEFINITION OF TERMS

1. Ivlev's electivity indices - This is an index which ranges from negative 1 to +1, indicating then prevalence of a food item by a fish in the Aquatic environment.
2. Food Forage ratio - Is the logarithmic ratio of the proportion of a fish food item in the gut to that in the aquatic environment.
3. Linear food index - Is the preference of a fish food items on a scale ranging from -1 to +1 this being the difference between the proportion of fish food item in the gut and that in the aquatic the environment.
4. Percentage occurrence - is the number of times a food item occurs in a given number of sampling points in a fish habitats represented as a percentage.
5. Percent composition - Is the portion of a food item in the total amount of food consume by a fish express as a percentage.
6. Stomach fullness index - Is the extent to which the stomach/gut of a fish is filled with food items.
7. Stalking of prey - Identification/ visualization of a fish food organism in the water column by a fish.
8. Smothering of fish breeding habitats - The blanketing of the habitats in a river with fine silt brought from the catchment by rainfall.
9. Spatial variation - Random variation in a well defined space.

10. Temporal Variation - Variation in a well defined period or time

CHAPTER ONE

INTRODUCTION

1.1 Background information

This study focused on the food composition and selectivity indices of the cyprinid fish *Labeobarbus altianalis* in River Kuja that drains into Lake Victoria in South West Kenya. Selectivity indices are measures of the utilization of different food items by fish. They indicate the most preferred food items, the ones which are not preferred and the one that are randomly selected when the most preferred ones are not available. Therefore in a way they can assist in the formulation of fish feed if the species in question is to be cultured. The indices can be used to study the distribution of fish as the latter tend to be concentrated where their most preferred food items are available (Stergiou & Karpouzi, 2002).

Studies on the food and feeding habits of different fishes worldwide including that of cyprinid species has been conducted by many researchers since 1943, (Manon & Hossain, 2011). These studies have only concentrated on food occurrence and composition in the guts of fish but paid little attention to food selection and energy transfer at higher tropic levels (Wetherbee & Cortes, 2004). In particular feeding ecology of cyprinid fish species in South East Asia has to some extent paid attention to the use of the feeding biology of the fishes for use in selecting species for aquaculture (Manon & Hossain, 2011).

Fish diet composition play a major role for research on many important ecological issues among them - resource partitioning due to species competition, prey selection, predator-prey size relationships, ontogenic diet shifts, habitat selection and testing models on foraging on prey (Stergiou & Karpouzi, 2002).

Fish food provides the major source of energy that plays an important role in determining the population dynamics such as rate of growth and condition of fishes (Begum et al., 2008). The success on good fisheries management of fish species depends on the knowledge of their biological aspects in which information on food and feeding habits include a valuable and significant contribution (Sarkar & Deepak, 2009). Further, studies on the feeding ecology of fishes are important in fishery biology and management. Fish food organism provides the energy that fuels their internal and external body activities such as growth, metabolism and reproduction (Sandipan & Banerjee, 2013). *Labeobarbus altianalis (*Figure1) belongs to a group of fish known as cypriniformes (carps)-rayfinned fishes. In East Africa its common name is Ripon falls barbel. Among the local communities, it's known as *Odhadho* in the *Luo* community of Kenya, *Kasinja* in Tanzania, *Enzunguli in* Uganda and Ripon falls barb in Rwanda (Froese & Pauly., 2018).

Figure 1**: *Labeobarbus altianalis* from River Kuja, Kenya (Photo taken by me)**

Labeobarbus altianalis is a large freshwater cyprinid fish whose population has been and is still threatened by overfishing and climate change. It has also been reported that the decline of the species natural stocks have been attributed to ecological changes that have taken place in Lake Victoria basin in addition to intense fishing pressure and poor water quality associated with the release of untreated sewage into the lake (Ogutu - Ohwayo, 1990).

This study focuses on the feeding ecology of *L. altianalis*; in particular it concentrates on factors that affect the distribution of its food items, food composition and selection.

1.2 Statement of the problem

Labeobarbus altianalis is one of the threatened species and yet it has never received adequate attention by researchers and conservationist in the region. Under International Union of conservation of nature (IUCN), the species is listed as one of the least concern due to lack of reliable information (Ntakimazi, 2006). There is lack of information on feeding ecology of *L. altianalis* and conservation of riverine fish species. The agricultural activities practiced contribute majorly to degradation of rivers and extinction of fish species due to deposition of silt and enrichment of rivers with nutrients (eutrophication) as well as introduction of pollutants. Constructions of bridges across rivers destroy feeding and breeding habitats of fish and also hinder or inhibit fish migration. This research will thus provide information on fish food distribution, occurrence, composition and selectivity and also further information on the effects of selected water quality parameters on the distribution and abundance of fish food organisms as well as on the fish itself in the River Kuja Basin. The information that will accrue from this study will be useful in the formulation of conservation and fisheries management measures for *L. altianalis* in the River Kuja Basin.

1.3 Justification

There is need to know more on feeding ecology and food selection of a fish species as these determine its distribution in the aquatic environment. The distribution and abundance of food items further determine fish survival which in turns affects growth, recruitment, maturity and reproduction in riverine habitat however little is known on distribution, abundance of food items, food composition and selection by fish in the Kuja River Basin.

It’s therefore important to know ecological information for formulating management measures for the conservation of the species so as to avoid its extinction in the Lake

Victoria Basin. The fact that there is little information on the biology of these fish species in the Lake Victoria Basin makes its conservation difficult. Most fish food studies in the Lake Victoria Basin are only descriptive giving list on the occurrence and food composition of items on which fish feed on. Furthermore, there has been no attempt to conduct studies on food selectivity and foraging by fish.

For River Kuja, the situation is even worse because no study has ever been conducted on feeding ecology of *L. altianalis* and the effects of physical and chemical parameters on the distribution of fish food items.

This study therefore focused on the food item occurrence, abundance, composition and selectivity of the species. This will help generate information for policy makers concerning conservation of the species *L. altianalis* and its environment.

1.4 Objectives of the study

1.4.1 General objective

This study aimed at conducting investigations on the feeding ecology of *Labeobarbus altianalis* in River Kuja Basin.

1.4.2 Specific objectives

1. To determine the distribution patterns of food items of *L. altianalis* in River Kuja Basin.
2. To determine food item occurrence and composition in the guts of *L. altianalis* in River Kuja Basin.
3. To determine food item selectivity by *L. altianalis* in the River Kuja Basin.
4. To correlate the distribution of the food items of *L. altianalis* with selected physicochemical parameters of the River Kuja Basin.

1.5 Hypothesis

H_0: There is no significance difference in the number of food items of *L. altianalis* in the different sampling points in River Kuja Basin.

H_0: There is no significant difference in food items occurrence and composition in the guts of *L. altianalis*.

H_0: There is no significant difference in food items selectivity of *L. altianalis* in the River Kuja Basin.

H_0: There is no correlation between physicochemical parameters with the distribution of fish food items of *L. altianalis* in the River Kuja Basin.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Introduction

Fish in the wild (aquatic ecosystems) feed on a great diversity of food organism (items) for example algae, zooplankton (cladocera, copepod and rotifera) benthic and non-benthic macro and micro invertebrates, benthic deposits, other fishes and aquatic submerge and emergent macrophytes, (Chemoiwa, 2018). Understanding the knowledge on the types of natural foods a fish feeds on helps in the formulation of fish feed requirement for those species that are farmed in extensive and intensive aquaculture. This also helps to ascertain on whether the population structure of fish in the ecosystem is in proper relation or is well supported by food energy resources that are available to it (Begum et al., 2008).

In Lake Victoria, most of the fish food studies have concentrated mainly on food occurrence and composition in the guts of fishes such as the Nile perch, *Lates niloticus*, (Katunzi, Van Densen, Wanink & Witte, 2006) , the siluroid catfishes- *Synodontis victoriae* and *Synodontis afrofischeri* , *Bagrus docmac*, and the small bodied cyprinid, *Rastrineobola argentea* (Yongo, Manyala, Kito, Matsushita, Outa & Njiru, 2016), catfishes, *Clarias gariepinus* (Ogari, 1988). Other research conducted in Lake Victoria basin about *L.altianalis* only focused on biology of the species (Chemoiwa, Abila, Macdonald, Lamb, Njenga & Barasa, 2013; Chemoiwa, Abila, Njenga, & Barasa, 2017; Witte & De Winter, 1995). The food occurrence, composition and selection studies have only been conducted on only one species, the Nile tilapia (*Oreochromis niloticus) in* the Nyanza Gulf of Lake Victoria by Getabu (1994), Njiru, Okeyo-Owuor, Muchiri and

Cowx (2004) and Outa , Kitaka & Njiru (2014).

A recent study conducted along River Nyando by Chemoiwa (2018) on spatial variation in food selection, feeding habits and ontogenic diet shift of *Labeobarbus altianalis* indicated that the species are capable of changing their food items depending on the habitat and availability. The study further found out that rotifers and copepods were avoided by this species while insect remains and Diptera were the dominant food items. The two were thus selected as food due to their availability in the environment. Preliminary studies by earlier scientist such as Corbet (1961) and Balirwa (1979) showed that the cyprinid *L. altianalis* feeds on benthic invertebrates, macrophytes, algae and zooplantkton. They also found that the juvenile *L .altianalis* fed on detritus and plant matter while the mature ones were found to have consumed fish, annelids and even fruits like the guavas. This therefore demonstrate an ontogenic shift in diet where the young ones of *L. altianalis* transist from juvenile to adult stage.

Little information exists on food selectivity of *L. altianalis*; only work done is on gonadal recrudescence and induced spawning in *L. altianalis* by Rutaisire, Berta, Cassius and Constantine (2013). A study by Kembenya (2015), tested the food preference of both natural and artificial feeds of a similar cyprinid, *Labeo victorianus* and found out that there was no difference on growth performance of juveniles fed on artificial and natural diets in captivity (laboratory).

Outside the Lake Victoria basin, some studies have been done on food and feeding habits of *Labeobarbus intermedius* in Lake Koka in Ethiopia. Further, various authors have studied food and feeding habit of the same species, (Admassu & Dadebo,1997; Sibbing, 1998; De Graaf, 2003;Assaminew, 2005;Desta, Børgstrøm, Rosseland &

Zinabu, 2006; Mengesha, 2009; Deribe et al., 2011). Admassu and Dadebo (1997) studied the diet composition, length-weight relationship and condition factor of *L. intermedius* in Lake Hawassa in Ethiopia and found that the diet composition of the species comprised of phytoplankton, insects, detritus, macrophytes, gastropods and fish. Dadebo, Tesfahun, and Teklegiorgis (2013) studied food and feeding habits of the African big barb *Labeobarbus intermedius* in Lake Koka, Ethiopia and reported an ontogenic diet shift and omnivorous tropic level exhibited the species.

A study conducted within Iranian freshwater drainages by Motamedi, Madjdzadeh, Teimori, Esmaeili and Mohsenzadeh (2014) only concentrated on the morphological and molecular aspects on geographical differentiation of *Barbus* population. Their findings presented remarkable variation on their morphometric and meristic characteristics due to geographical differences brought by the varied environmental drainage systems.

A recent study conducted in River Kuja (Orina, Getabu, Omondi & Sigei 2018) showed that the river is inhabited by different fish species. A total of 12 families (Cyprinidae, Mastacembelidae, Cichlidae, Alestidae, Schilbeidae, Protopteridae, Poeciliidae, Mochokidae, Amphillidae, Claridae, Mormyridae and Latidae) comprising of 27 species were identified. The identified fish species had a diverse tropic levels namely carnivores, omnivores and detivores.

2.2 Biology of the species

Labeobarbus altianalis can be identified by the following features; it has 3 spines and 9 - 11 soft rays on the dorsal fins, 2 - 3 anal spines and 5 - 6 soft rays on the anal fin. The anterior barbel reaches the middle of the eye but in general its very short and does not reach the anterior part of the eye, while the posterior barbel always extend beyond the anterior part of the eye. It has well developed lips and occasional outgrowth is present on the snout (De Vos & Thys Van den Audenaerde 1990). The fish grows to a maximum size of 90cm total length (Boulinger 1900; quoted by Greenwood, 1966).

The fish is known to mature at different sizes in different aquatic habitats. In the Sondu-Miriu River in Kenya, *L. altianalis* was found to mature at (L_{m50}) of 7.0cm (Standard length); in the Lakes Edward and George in Uganda, males were found to mature at (L_{m50}) of 36.0cm (SL) while another study , females were found to mature at (L_{m50}) of 54.0cm (SL) , (De Vos & Thys Van den Audenaerde, 1990). *L. altianalis* is known to feed on gastropods, mollusc, insects, plants, fishes and crustacean (Corbet, 1961, Witte & Winter, 1995).

Information on the biology and ecology of *L. altianalis* in the River Kuja is scanty though its reported as an omnivorous species and the types of food item consumed depends on prey availability, season and habitat differences and size of the fish (Dadebo et al., 2013; Sibbing & Nagelkerke, 2001; Desta et al., 2006). Balirwa (1979) working on food of six cyprinid fishes in three areas of the Lake Victoria Basin indicated that, *L. altianalis* is an omnivorous fish whose diet is associated with detritus dominated by algae, plant material, molluscs, chironomids and caddisfly larvae.

2.3 Taxonomy of the species

The systematics of *Barbus altianalis* has been a subject of much more recent revision by fish taxonomists. The genus *Barbus* is restricted to a small number of species inhabiting the European ichthyographic region including Northeast Africa. Most of the African *Barbus* species currently included in the genus, taxonomically are not closely related to the *Barbus (*Seegers, De Vos & Okeyo, 2003).

The African *Barbus* are further divided into two major groups, namely the large-size hexaploid species and the small-size ones that are diploid (Berrebi, Kottelat, Skelton & Ráb, 1996). The former have since been placed in the genus *Labeobarbus,* (Skelton 2001, Berrebi & Tsigenopoulos, 2003). Banyankimbona, Vreven, Ntakimazi and Snoeks (2012) therefore transferred the large-size hexaploid '*Barbus*' *altianalis* to the genus *Labeobarbus.*

Previously three subspecies were recognised: *Barbus altianalis altianalis* in the Lake Victoria Basin; *B. altianalis eduardianus*; and *B. altianalis radcliffii*. Currently, those subspecies are considered invalid (De Vos & Thys van den Audenaerde 1990).

2.4 Ecology of the species

Worldwide, the species is known to be distributed in the marine - neritic and marine oceanic habitats, brackish water and freshwaters mainly in lakes, ponds and rivers (Witte & Winter, 1995). Its human uses mainly constitute of fisheries and sport fishing (Froese & Pauly 2018).

In lakes Edward and George, the fish inhabits shallow water (Greenwood, 1966) while in the Rusizi systems, it migrates to small upstream rivers to spawn (Marlier, 1953). The fish is oviparous (Breder & Rosen, 1966) and is a food fish for humans (Robbins, Bailey, Bond, Brooker, Lachner & Scott, 1991) but not of major commercial significance (Greenwood 1966, De vos & Thys Van den Audenaerde, 1990).

In the Lake Victoria basin, it is commonly found in inshore waters and its affluent rivers. The major ones consisting of River Nzoia, Yala, Nyando, Sondu-miriu, Kuja and Migori, (Greenwood, 1966 & Van Oijen., 1995). The juveniles of *L. altianalis* occur in shoals (Copley, 1958) in the riverine habitats while adults occur in both riverine and lacustrine habitats, the fish is potamodromous - it swims upstream to spawn probably in swift rocky upper reaches of rivers (Witte & Winter, 1995).

Labeobarbus altianalis is benthopelagic meaning it occurs in the benthic and pelagic zones in the aquatic environment. *L. altianalis* occurs naturally in many water bodies within the Lake Victoria basin and its affluent rivers (Greenwood, 1966). It is migratory and often exploits lacustrine - riverine interconnectivity to spawn and grow (De Stefano & De Graaf, 2003). The species is distributed mostly in the depth range of 0 - 50m in tropical fresh waters and is zoogeographically endemic in Ethiopia and is native to Lake Edward, Lake Tanganyika, Lake Victoria, Lake Kivu and the Rusizi Rivers. It also occurs in the middle Akagera which drains into lake Victoria, Lake kyoga drainages and northern part Lake Tanganyika (De Vos & Thys Van den Audenaerde,1990, Snoeks, Kaningini, Masilya, Nyinza-Wamwiza & Guillard, 2012) .

The species is relished as a food item among the fishing communities in the Lake Victoria basin and was once a significant component of the Lake Victoria fisheries before its populations drastically declined (Witte, Gouwdswaard, Katunzi, Mkumbo, Seehausen & Wanink*,* 1999).

Labeobarbus altianalis is a threatened species (Ntakimazi, 2006) and thus there is need to know about its ecology and in particular foods and feeding habits, to obtain information that can be use for it conservation and management. Conservation of the species in future will depend on thorough knowledge on feeding ecology, their distribution and factors which affect feeding of fish. The purpose of this study was therefore, to investigate food composition and selectivity index of *L. altianalis* and factors that affect the distribution of its food items in River Kuja.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Background

This chapter presents the geographical description of the study area, research design, data collection procedures (sample and sampling techniques), methods of data processing and analysis.

3.2 Geographical description of the study area

The River Kuja Migori Basin is a

vast expansive river basin that consists of two river system; Rivers Kuja and Migori Systems. These two rivers merge at a confluence in Sango area in Central Kadem Location in Nyatike district to become the wide River Kuja - Migori. The river thereafter flows and pours its water in Lake Victoria. River Kuja has its source in Nyamira County in the Kisii highlands while River Migori has its source in Mau forest Narok County. The total area of the catchment is 2196km^2. River Kuja is among the tributaries of the greater Kuja - Migori River whose total drainage area is 5180km^2 (Ojany & Ogendo, 1986). Considering the Kuja-Migori River system as a whole, the Kuja catchment constitutes approximately 42% of the total catchment area of the Kuja-Migori River system (Ojany & Ogendo, 1986). It lies between longitude 34º 37'00"and 35º01'00"East and latitude 00º 24' 00" and 00º 59' 00" South, while the altitude of the areas lies between 900m and 2000m above the mean sea level. It experiences two rainfall seasons within the year i.e. short rains that run from September to November and long rains that occur in February to June while temperatures range from 16ºC in wet to 27ºC dry.

The area is characterized by highlands and open plain suitable for cultivation of agricultural crops like tea, coffee, maize and sugarcane plantation. Most farming occurs along the River and eucalyptus trees are the major trees along the river. The River Basin is inhabited by variety of riverine species which include cyprinidae; *Labeo species*, characidae: *Prycinus jacksonii*, siluroid catfishes dominated by *Clarias* species, *Synodontis* species, schilbeid; *Schilbe intermedius.*

River Kuja Basin acts as an important source of water and several utilities to the communities living along the river. The river therefore attracts people for work and new settlement due to water availability for irrigation, trees for building purposes and sugar plantation is practiced in the lower part of the river. The factories release untreated sewage to the river posing a big threat to fish survival. Due to its several uses more of the riparian zones which could have been conserved have been encroach and put into several agricultural activities which pose a big treat to the rivers, rainfall patterns and the diversity of organisms in the river. Muyodi, Mwanuzi and Kapiyo (2011) in their study on environmental quality and fish communities in selected catchments of Lake Victoria, argued that changes in population size, consumption patterns and utilization of the natural resources will compromise with the environmental quality if management measures are not observed which similarly applies to River Kuja.

Part of Migori River also has a lot of gold mining taking place downstream, (Macalder gold mining in Nyatike District and in Nyokal bridge near Awendo). The sugar and tea plantation effluents contain fertilizers and pesticides which may cause pollution and contribute to biodiversity loss of fish and macroinvertebrate.

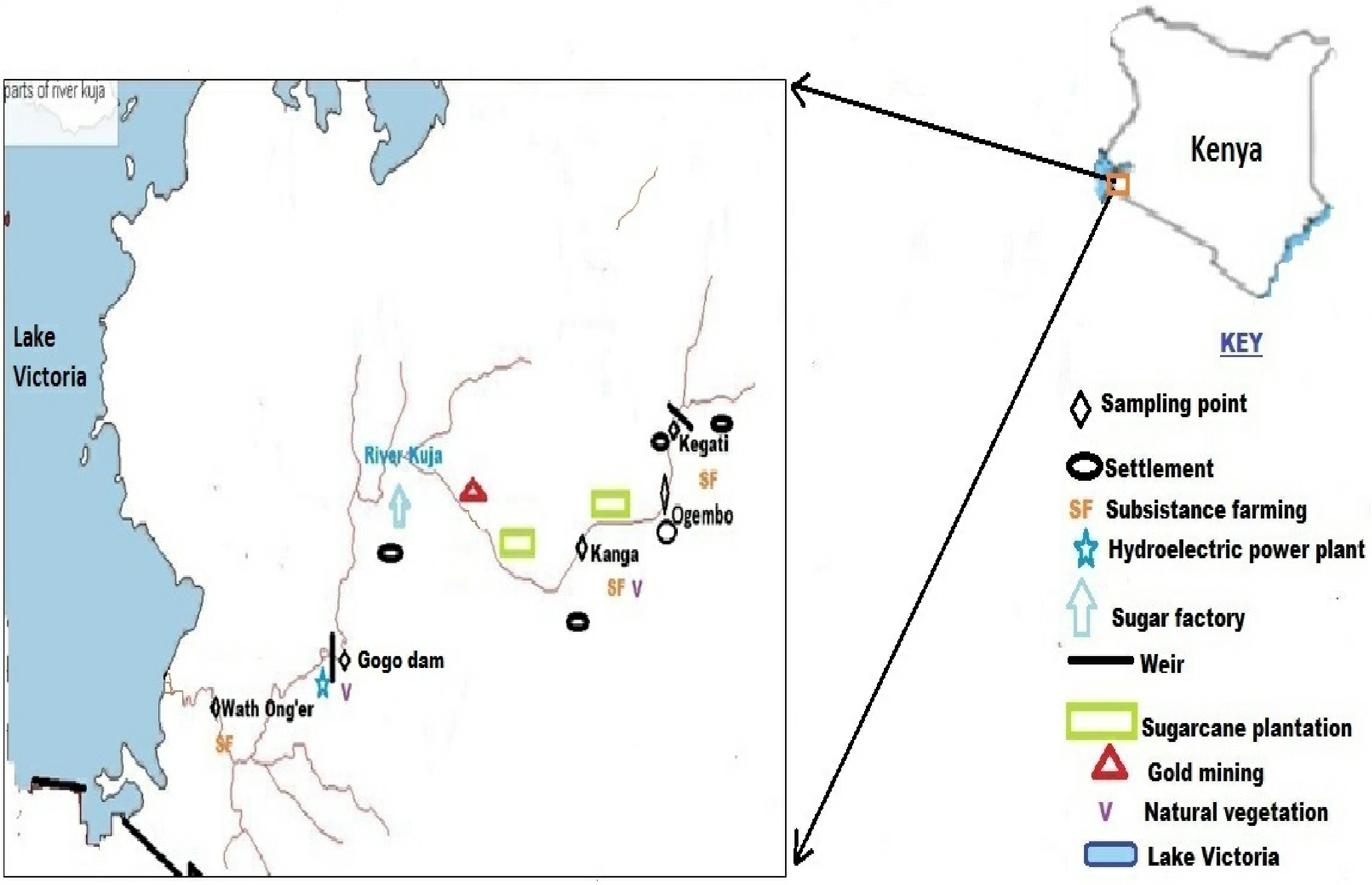


Figure **2: Map of Lake Victoria Basin with sampling points indicated along River Kuja systems. (Source: Adapted from Google maps)**

3.3 Research design

River Kuja Basin was divided into two sections, namely the upper and the lower Kuja. The upper River Kuja started from the source around Kiabonyoru Mountain in Nyamira county upto Ogembo town in Kisii County while the lower Kuja started from Ogembo town all the way up to the River mouth in Nyatike Sub-county of Migori County.

A total of five sampling stations were selected along the full length of the river. The geographical positions of all the sampling stations were marked using a GPS system, (GARMIN, GPSMAP 78s).

Station 1 (Kegati) was located in Nyamira county, it has a longitude of 34.821817˚E, latitude of 0.711408˚S and an altitude of 1760m above sea level. The upper site of the station has a lot of reeds growing in stagnant water; a water treatment plant is also constructed in the upper section of the station. It has a bridge constructed across the river and a lot of agricultural activities; tea plantation, maize farming and animal grazing next to the river.

Station 2 (Ogembo bridge) was located in Ogembo town at a longitude of 34.974980˚E and a latitude of 0.609960˚S. The area is characterized by agricultural activities, the riparian zones has a lot of eucalyptus trees and animal grazing along the river. The site was affected by dumping of waste from the trading centre and car wash activities.

Station 3 (Kanga) is situated at a longitude of 34.587100˚E and latitude of 0.833480˚S. The site has a lot of agricultural activities and human settlement. Sugar farming is one of the major agricultural activities in the area. It is characterized with abundance of fish and fish food items, rocky substratum and some section covered with mud.

Station 4 (Gogo) was located at a longitude of 34.349540˚E and latitude of 0.908027˚S. It is situated in the lower section of the River Kuja Basin. The site has a lot of reeds growing along the river; it has a hydroelectric power generation plant, human settlement and agricultural activities. The upper part of the station (Nyokal) has gold mining activities taking place next to the river.

Station 5 (Wath Onger) has a longitude of 34.210316˚E and a latitude of 0.951535˚S, located in the lower part of River Kuja Basin. The site has human settlement along the river, animal grazing and laundry activities next to the river. It was characterized by low abundance fish and fish food organisms. It has little vegetation along the riparian section as compared to upstream stations.

Sampling was conducted for a period of eight months in the selected stations and at each sampling replicated sample was obtained for further laboratory analysis.

3.4 Data collection procedures

The procedures covered under section involved those of physicochemical parameters namely dissolved oxygen concentration, temperature, pH, turbidity, Total suspended solids, conductivity and chlorophyll *a* concentration, sampling methods of benthic invertebrates, fish sampling and gut content analysis.

3.4.1 Measurements of physicochemical parameters

Replicate samples of physicochemical parameters, namely DO (mg L^{-1}), conductivity (µS cm^{-l}), turbidity (NTU), TDS (mg L^{-1}), temperature (˚C), chlorophyll *a* concentration(µg L^{-1}) and pH were measured *in-situ* at each sampling station for a period of eight months using YSI hydro lab model 650 MDS before fishing to avoid disturbance of the water quality. The equipment was calibrated with standards for each parameter before commencement of the measurements of the parameters. During the measurements, the YSI hydro lab model 650 MDS was lowered to the middle of the water column in the river (Halfway between the surface and bottom of the river) and left to stay still for 5 minutes before its retrieval. After retrieving, the recorded data was downloaded on a laptop and saved in a file folder which was later analyzed. Water transparency was measured using a 12.0 cm diameter black and white secchi disc which was lowered on a shaded part of the river to avoid interference of any surface scattering light which would otherwise affect the estimation of the level of water transparency.

3.4.2 Sampling methods of invertebrates

Replicates samples of invertebrates and other benthic materials were obtained monthly for a period of eight months using a kick sampler with the netting of 250 µm. A kick sampler was positioned in the river bed against the water current. The kick sampler was deployed in the river for a period of 30 minutes after which it contents were poured into white plastic trays. Following this, individual invertebrates were picked using forceps and placed in sampling bottles of 200 ml containing 5% formalin. Each sampling bottle was marked with the sample number and the name of the sampling station. Where possible the different types of invertebrates collected from the sample were identified using keys by Jung (2004) and counted. Records of the invertebrates collected were kept for further analysis. Other benthic material which included detritus, benthic algae, plant material and water column plankton obtained by the kick sampler were identified and recorded. It was not possible to sort out detritus, benthic algae and plant material because it was intermingled with zooplankton and consisted of a wide range of sizes as it also included some silt.

3.4.3 Fish sampling and gut content analysis

Fishing was done monthly at each sampling site to obtain replicate samples for a duration of 30 minutes using electrofisher (Electrafish model- SAMUS 1000) and electronic GX240 Honda 8.0 generator Ferguson power East Africa limited that produces a current of 400V and 16 A. Immediately after capture, fish were collected using plastic containers and sorted out according to species. Specimen of *L. altianalis* were separated and used for gut content analysis. These were preserved in 500 ml plastic sampling bottles containing 5% formalin. Alternatively, when fish samples were few, the total lengths of fish were measured using a measuring board to the nearest 0.1cm total length and weighed to the nearest 1.0 g using an electronic balance (Mettler Toledo, AG204).

Both in the laboratory and in the field the fish were dissected and their guts removed. Since *L. altianalis* is a stomachless fish the guts were removed up to the first bend of the intestine and then preserved in 500 ml plastic sample bottles containing 5% formalin.

In the laboratory, the guts were removed from the sample bottles, dissected and their contents poured to white enamel dishes. Visual examination was used to identify larger food items, but a dissecting microscope (LEICA X20) and a compound microscope (LEICA X200-1000) was used to identify microscopic food items.

The gut contents were analyzed using a modified point method according to Hynes (1950) as reviewed by Hyslop (1980). Each stomach was awarded an index of fullness from 0 to 20; empty stomach scored 0; a quarter full 5; half full 10; three quarter full 15 and full 20. Each category was assigned a number of points proportional to the estimated contribution. The importance of each food category was expressed as a percentage by dividing the total points awarded to all food types into number of points awarded to the food type in question. Stomach contents for each 5cm length class were assessed separately.

The larger macroinvertebrates found in the guts of *L. altianalis* were sorted out in the petri dish identified using keys by Jung (2004) and Lizeth (2001) respectively for the calculation of the Strauss Linear index and counted for use in estimating electivity indices.

3.4.4 Data analysis

All data analysis in this study were conducted using the excel spreadsheet and Statistical Package for Social Sciences Software (SPSS) programs.

The means of physical chemical parameters were calculated and their temporal and spatial patterns were plotted and presented graphically. Similarly the data on samples of food items collected in the environment were treated and presented in tables and figures. The percentage occurrences of food item in the environment were calculated using the formula:

Percentage occurrence = (number of occurrences of a food item at the sampling sites/ total number of sampling sites) × 100

(Equation 1)

The method only gives what the organisms fed on however it does not gives information on quantities of the food item consumed and those which could not be digested.

The percentage composition of a food item at each sampling site was calculated as:

Percentage composition = (Abundance in numbers of the food item/total abundance of all food items) × 100

(Equation 2)

The percentage occurrence of a food item in fish was computed by dividing the number of fish in which the food item appeared divided by the total number of fish analyzed multiplied by a hundred (100), while the percentage composition of the food item was calculated by dividing the abundance of food items in the guts of fish divided by the total abundance of all food items.

River Kuja was divided into two sections namely the upper and lower River Kuja sections respectively and the electivity indices were estimated separately for the two sections. The upper River Kuja sampling stations included; Kegati and Ogembo sampling points while the lower sampling points included Kanga, Gogo falls and Wath Onger, Figure 1(map). Since there was no *L. altianalis* got at the River Kuja mouth sampling point, no electivity indices were estimated for the same.

Two types of fish food electivity indices were estimated; the Ivlev’s index of electivity (E) and the linear food index (L). The Ivlev`s index of electivity ranges from -1, indicating strongest avoidance of a fish food items to +1 indicating the strongest preference of a food item by a fish. An Ivlev`s index of zero (0) indicates no preference or random selection of a food item, meaning that all food items with this value have a less equal chance of being selected as fish food item by fish. Similarly the linear food index has the same characteristic as Ivlev`s index of electivity but represents a more accurate estimation of fish food selectivity relative to the Ivlev`s index.

The Ivlev`s index was used to study food selectivity by *L. altianalis*, where by Ivlev`s index

$$E= (ri -pi)/ (ri+pi) \qquad \text{(Equation 3)}$$

Where ri equals concentration of food items in the stomach and pi concentration of food items in the environment.

The linear food index was computed using the formula as in Getabu (1994) and Strauss (1979).

$L = ri - pi$ (Equation 4)

Where:

ri is the proportion of prey taxon in the guts of *L. altianalis* and *pi* is the proportion of the same taxon in the environment. The means of *ri* and *pi* weighed by the number of prey in each sample were used to calculate *Li.*

The forage ratio is the logarithm of the proportion of a food item in the stomach or gut divided by the logarithm of the concentration of the food item in the aquatic environment. It ranges from 0 to positive infinity, Low values indicate poor foraging while high values indicate acceptance of a food item by fish. Forage ratio was computed as:

$\log pi / \log ri$ (Equation 5)

Changes of the food items consumed were related to changes in fish size to study ontogenic shift in diet. The respective fish class used in the study had an interval of 0 – 5 cm. A total of 1032 of *L. altianalis* were analyzed for stomach fullness index. The length and weight range of the fish specimens were 0.5 cm total length to 45.0 cm and 0.1 g to 752.8 g total weight.

Out of this 425 were analyzed during the dry season representing 41.18 %, while 607 were analyzed during the wet season representing 58.82%. The mean numbers of food items were computed for each sampling sites, the distribution of food items in the habitat were tested for significance using chi-square test.

The correlation between food distribution, occurrence, composition, and selectivity with physicochemical parameters was analyzed using the spearman rank correlation analysis. The correlation was used to estimate the relationship between number of food items and values of physicochemical measurements together with the *L. altianalis*. Stomach fullness was visually checked.

CHAPTER FOUR

4.0 RESULTS

4.1 Background

This chapter presents results on habitat characteristics of the sampling points which include: description on their physical and chemical characteristics, occurrence of food items of *L. altianalis*, percentage composition, food selectivity indices and forage ratios. A comparison is made between occurrence and percentage composition of food items based on the point method and on the direct counts of the food item that could be enumerated. The results include seasonal patterns for dry and wet season and correlation between abundance of fish food organism and physicochemical parameters.

4.2 THE PHYSICOCHEMICAL AND BIOLOGIAL CHARACTERISTIC OF THE RIVER KUJA ENVIRONMENT

4.2.1 Dissolved oxygen concentration

The overall dissolved oxygen concentration varied from 0.4 mg L^{-1} at Gogo falls in February 2017 to 7.36 mg L^{-1} at Ogembo and Kegati in June and August 2017 respectively. The monthly mean oxygen concentrations varied from 3.64 ± 1.39mg L^{-1} at Wath Onger in December 2016 to 6.67 ± 0.89 mg L^{-1} at Ogembo in August 2017 (Appendix 1 & 2). Dissolved oxygen concentration decreased downstream. The black vertical error bars represents standard deviations.

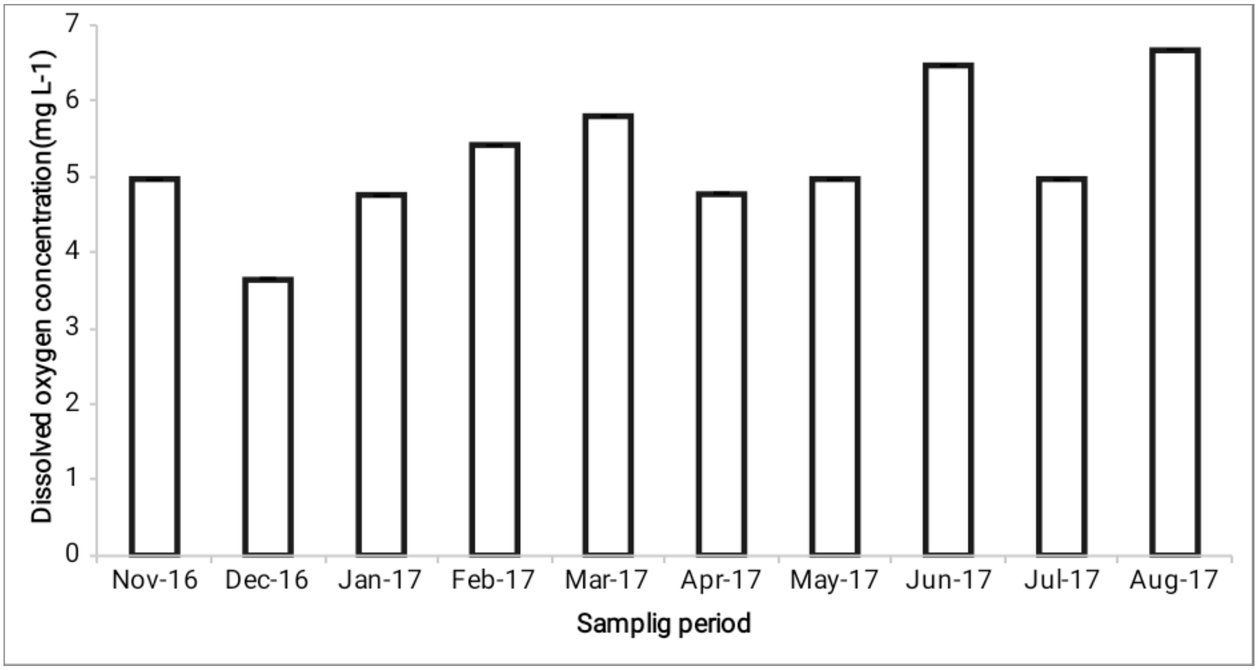


***Figure 3*: Temporal variations of dissolved oxygen concentration in River Kuja during the period November 2016 - August 2017.**

4.2.2 Temperature

Temperature showed a wide variation of 16.05 ^{0}C at Kegati station in July 2017 to 26.66 ^{0}C August 2017 at Wath Onger respectively (Appendix 3). Temperatures in the dry season (Nov 2016 - Dec 2017) were generally higher than those of wet season, (April – Aug 2017 Figure 4). The lowest mean temperature was 20.37 ^{0}C at Ogembo in May 2017 during the wet season while it was highest (24.26 ^{0}C) at Wath Onger in December 2016.

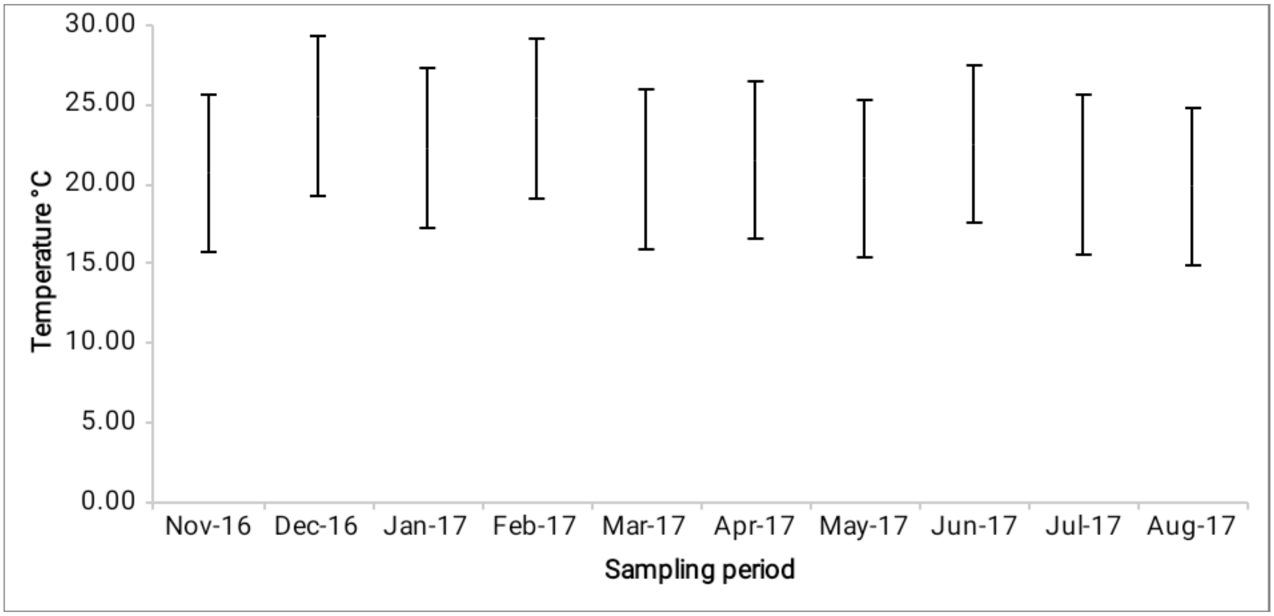


***Figure 4*: Temporal variations of temperature in River Kuja during the period November 2016 - August 2017.**

Temperature increased downstream from Kegati to Wath Onger during the sampling period (Appendix 3).

4.2.3 Turbidity

Turbidity in the River Kuja showed high variability ranging from 20.64 NTU at Kegati in

March 2017 during the dry season to 280.56 NTU at Wath Onger station in June and August 2017 during the wet season, (Appendix 5). The mean turbidity values also exhibited a wide variation ranging from 50.07 NTU in March 2017 to 138.38 NTU in June, (Figure 5).

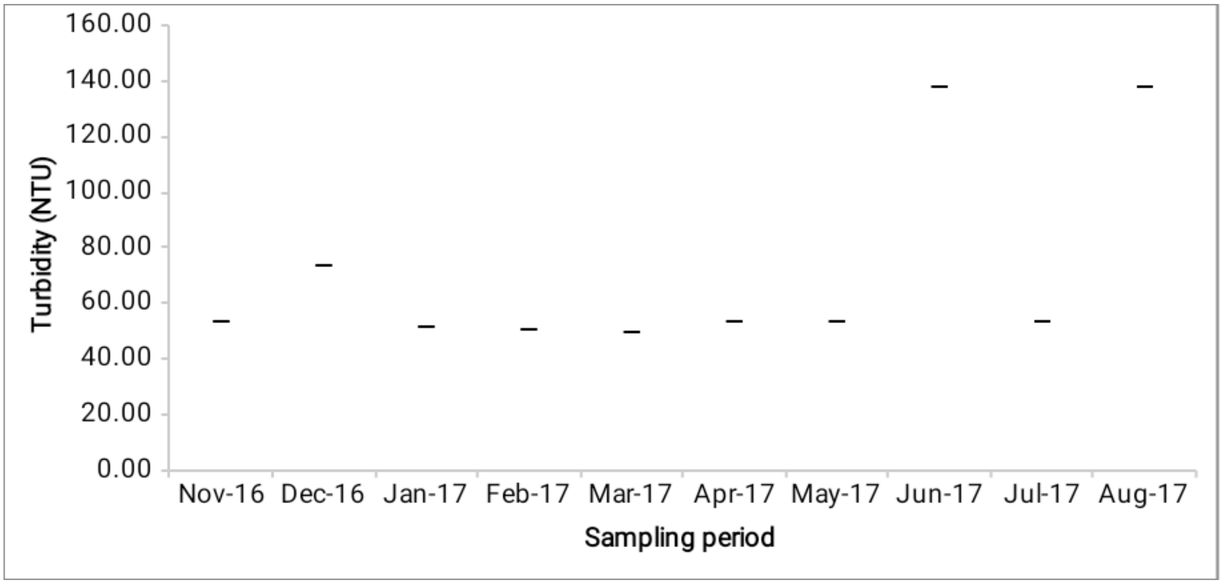


Figure 5**: Temporal variations of turbidity in River Kuja during the period November 2016-August 2017.**

In the wet season (April – Aug 2017) when the turbidity was high, water in the river was observed to be brown in colour. In the dry season the water in the river was reduced in volume and was clearer than in the wet season.

4.2.4 Chlorophyll *a* concentration

The chlorophyll *a* concentrations were generally low. They were higher during dry season compared to the wet season. They ranged from 0.40 μgl^{-1} at Kegati and Ogembo stations in May 2017 during the wet season to 16.0 μgl^{-l} at Wath Onger in December 2016. The temporal and spatial trend of chlorophyll *a* during the study period is presented in Figure 6 and Appendix 7.

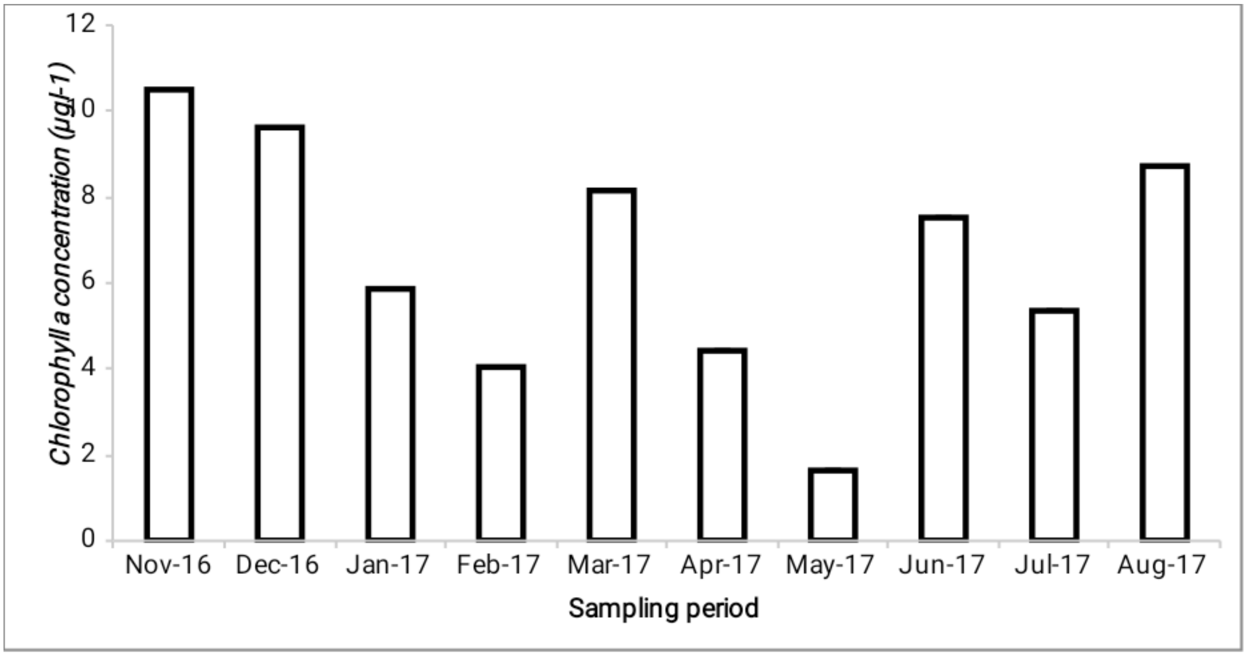


Figure 6: Temporal variations of chlorophyll a concentration (µgl^{-l}) in River Kuja during the period November 2016 - August 2017.

4.2.5 pH

The temporal and spatial variation of pH in the river is presented in Figure 7 and Appendix 9.

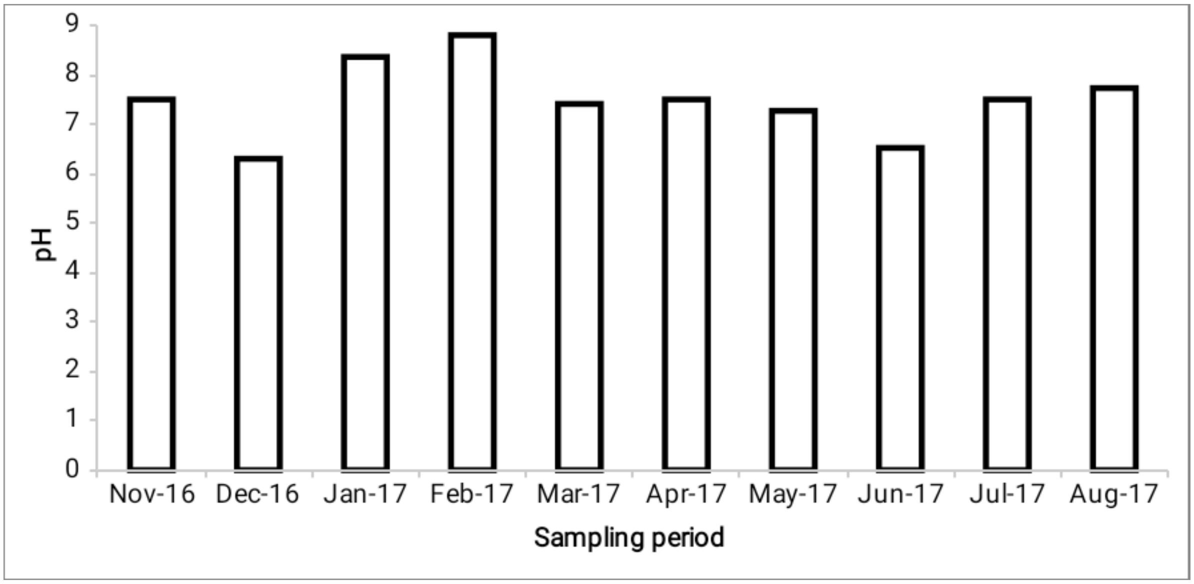


Figure 7: **Temporal variations of pH in River Kuja during the period November 2016 - August 2017.**

The pH was generally higher (8.8 ± 0.37) during dry season compared to the wet season (5.23 ± 0.34).

4.2.6 Total dissolved solids

The TDS in River Kuja exhibited mixed variability during the dry and wet season (Figure 8). The spatial variations showed an increasing trend from Kegati station to Wath Onger, (Appendix 1).

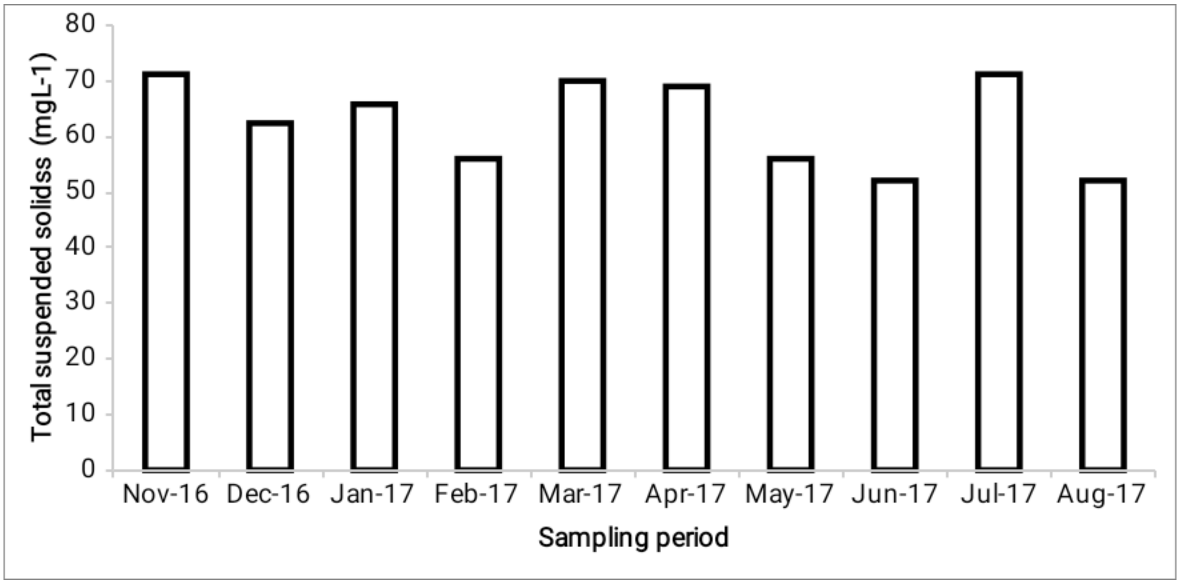


***Figure 8*: Temporal variations of TDS in River Kuja during the period November 2016 - August 2017.**

The mean TDS concentrations ranged from 56 ± 12 mg L^{-1} at Kegati to 65.8 ± 12.98 mg L^{-1} in February and January respectively. The mean TDS values were within the range varying from 52.08 ± 5.9 mg L^{-1} at Kanga to 71.0 ± 10.57mg L^{-1} at Wath Onger in June and July 2017 respectively. Gogo falls and Wath Onger stations had almost equal levels of TDS, (Appendix 1).

4.4 Food occurrence

4.4.1 Food occurrence in dry and wet season

The percentage occurrence of food items in River Kuja during the dry and wet season is presented in Table 1. Only one order had an occurrence of more than 20% (Hemiptera) while three orders namely Hirudinida, Haplotaxida and Hecapoda had an occurrence of less than 5%.

***Table 1*: Percentage occurrence of food items in River Kuja during the dry season**

Order	SUM (N)	% occurrence
Diptera	45	14.61
Ephemeroptera	35	11.36
Hemiptera	74	24.02
Hirudinida	8	2.59
Odonata	37	12.01
Pulmonata	31	10.06
Coleoptera	27	8.76
Decapoda	12	3.89
Unionida	31	10.06
Haplotaxida	8	2.59

4.4.2 Food occurrence in wet season

The percentage occurrence of food items in River Kuja during wet season is presented in Table 2.There were a total of 8 orders out of which only Diptera had a percentage occurrence above 20%. Only one order Decapoda had an occurrence of less than 5%.

***Table 2*: Percentage occurrence of food items in River Kuja during the wet season**

ORDER	SUM (N)	% occurrence
Diptera	43	25.90
Ephemeroptera	12	7.22
Hemiptera	18	10.84
Hirudinida	12	7.22
Odonata	31	18.67
Pulmonata	13	7.83
Coleoptera	29	17.47
Decapoda	8	4.82

Diptera was the most widely distributed, Decapoda being the least widely distributed during the wet season while haplotaxida and hirudinida were the least distributed in the dry season.

4.3 ABUNDANCE OF FOOD

4.3.1 Abundance of food items during dry months.

The abundance of food items at different sites of River Kuja during dry months showed that there were high numbers of food items at Kegati station (302) and Ogembo had the lowest amount of food items (154) as shown in Table 3.

***Table 3*: Abundance of food items in River Kuja at sampling stations during dry months.**

(SD = Standard Deviation, SE = Standard Error, N= Total number of food items at the sampling sites, CI=95% Confidence level).

	Kegati	Ogembo	Kanga	Gogo falls	Wath Onger
Mean	1.84	0.94	1.20	1.68	1.66
SE	0.27	0.14	0.32	0.38	0.31
SD	3.47	1.79	4.06	4.81	3.94
SUM(N)	302	154	197	275	272
CI(95%)	0.53	0.28	0.63	0.74	0.61

The abundance of food item of *L. altianalis* significantly differed (x^2 $_{0.05}$ df, 20=63.9>31.14) among the five different sampling stations.

4.3.2 Abundance of food items during wet months.

The abundance of food items at the different sites of River Kuja is depicted in Table 4. The food items occurred in low numbers and had low variation as indicated by small standard deviations. However, Wath Onger had highest number of food items (267) while Kanga had the lowest abundance (112).

***Table 4*: Abundance of food items in River Kuja at sampling stations during wet months**

(SD = Standard Deviation, SE =Standard Error, N=Total number of food items at the sampling sites, CI=95% Confidence level).

	Kegati	**Ogembo**	**Kanga**	**Gogo falls**	**Wath Onger**
Mean	0.98	0.78	0.59	0.61	1.41
SE	0.17	0.09	0.09	0.14	0.20
SD	2.32	1.26	1.20	1.90	2.72
SUM(N)	184	149	112	115	267
CI (95%)	0.33	0.18	0.17	0.27	0.39

The abundance of food item of *L. altianalis* significantly differed (x^2 $_{0.05}$ df, 20 =

98.81>31.14) among the five different sampling stations. The total number of food items for all the sampling sites was higher during the dry season (N = 1200) than in the wet season (N = 827), yet the sampling effort was kept constant.

4.5 COMPOSITION OF FOOD ITEMS IN THE ENVIRONMENT

4.5.1 Food items during dry season

The percentage composition of food items in River Kuja during the dry season is presented in Table 5. There were 10 orders represented by the food items , out of which two orders were above 20% (Diptera and Decapoda) while three orders had a percentage composition less than 5% (Odonata, Pulmonata and Haplotaxida).

***Table 5*: Percentage composition of food items in River Kuja during the dry season**

ORDER	Sum (N)	% COMPOSITION
Diptera	220	21.83
Ephemeroptera	96	9.52
Hemiptera	117	11.61
Hirudinida	65	6.45
Odonata	37	3.70
Pulmonata	32	3.2
Coleoptera	98	9.72
Decapoda	212	21.03

Unionida	92	9.13
Haplotaxida	39	3.87

Despite the fact that the order Hemiptera had the highest percentage occurrence, its percentage composition was lower than that of Diptera and Decapoda, meaning that the later two orders were more abundance than the former.

4.5.2 Food items during wet season.

The percentage composition of food items in River Kuja during the wet season is presented in Table 6. There were nine orders represented by the food items, out of which one food item (Diptera) had a percentage composition of above 20% while the order Hirudinida had a percentage composition of less than 5%.

***Table 6*: Percentage composition of food items in River Kuja during the wet season**

ORDER	Sum (N)	% COMPOSITION
Diptera	134	26.59
Ephemeroptera	59	11.7
Hemiptera	36	7.14
Hirudinida	16	3.17
Odonata	61	12.10
Oligochaeta	29	5.73

Pulmonata	29	5.73
Decapoda	68	13.49
Coleoptera	72	14.29

As observed above, the concentration of food items during the wet season was much lower than during the dry season, Tables 5 and 6. The most abundant orders were Diptera and Decapoda similar to the observation made on the abundance of organism during the dry season though at a lower concentration.

4.6 Stomach fullness index

A total of 31 guts were found to be empty during the dry season representing 7.29%. During the wet season, 56 guts representing 9.23% were also found to be empty. It was noted that, few *L. altianalis* (31) had their stomach empty during the dry season compared to the wet season where a total of 56 *L. altianalis* were found to have not fed during sampling.

4.6.1 Stomach fullness during the dry season.

The results of the analysis are presented in Figure 9. *Labeobarbus altianalis* with three quarter full guts had the highest representation (42.59%), half full guts (32.47%), full guts (24.47%), quarter full guts (16.71 %) and empty guts (7.29 %) respectively.

***Figure 9*: Stomach fullness index of *L. altianalis* in River Kuja during the dry season.**

It’s apparent that over 50% of fish had stomach fullness of half full to completely full.

4.6.2 Stomach fullness index of *Labeobarbus altianalis* in River Kuja during the wet season

A total of 607 *L. altianalis* were sampled for gut content analysis during the wet season. 75% had a percentage fullness of equal or greater than half full while fish with empty stomach constituted only 56 (9.23%). In the wet season the majority of the fish (89%) had already fed by the time sampling started, (Figure 10).

***Figure 10*: Stomach fullness index of *L. altianalis* in River Kuja during the wet season.**

The stomach fullness in the lower range of empty to half full followed the similar trend in both dry and wet season however the three quarter level fullness was higher during dry season (42.59%) compared to the wet season (17.63%).

4.7 Food items occurrence

4.7.1 Gut content analysis on the food of *L. altianalis* in River Kuja

In this section, gut content analysis was conducted for 1032 specimens, a total of 87 guts were empty and 945 guts had food content on them. The types of food items which were encountered included, detritus, algae, zooplanktons, plant matter , termites and invertebrates included in the orders of Diptera, Decapoda, Coleoptera, Ephemeroptera Unionida and Odonata. Due to a wide variety of food items, it was decided that the food items detritus, algae, zooplankton and plant matter be analyzed only for their percentage occurrence in the aquatic environment of River Kuja and in the guts of *L. altianalis*. These food items posed a great challenge on further analysis to produce food selectivity indices and forage ratios because they could not be easily quantified for example detritus and plant material. The mixing of detritus with zooplankton and algae in the guts of *L. altianalis* and the fact that there were numerous species to be considered in the study made it not possible to conduct detailed analysis for food electivity indices and forage ratio thus further analysis on these aspects focused on those food items which could easily be quantify such as Diptera, Coleoptera, Decapoda, Ephemeroptera, Hemiptera, Odonata, Haplotaxida, Hirudinida and Unionida. Hence the Ivlev`s index of electivity, linear food index and forage ratio is estimated relative to the abundance of the later food items.

4.7.2 Occurrence of food items in guts during the dry season

During the dry season, a total of 394 *L. altianalis* were analyzed for percentage occurrence of food items in their guts, the results of the analysis are presented in Table 7. The analysis revealed that despite the fact that most food items had wider occurrence in the river, their occurrences in the guts of *L. altianalis* were very low, Ephemeroptera (0.83%) and Decapoda (1.41%).

***Table 7*: Food percentage occurrence in guts of *L. altianalis* during the dry season**

Food item (order)	Occurrence (n)	Occurrence (%)
Diptera	74	20.44
Ephemeroptera	3	0.83
Decapoda	6	1.41
Zooplankton	23	6.35
Algae	72	19.89
Plant matter	28	7.73

The two food items with the highest occurrence were Diptera (20.44%) and algae (19.89%). The percentage occurrences were in general low for all the organisms with none having occurrences greater than 25%. This shows that the distribution of the food item in the river was not uniform. The result of $x^2{}_{0.05}$ df, 24 = 143.43>36.42 indicated that the occurrence of food items in the guts of *L. altianalis* during the dry season significantly differed from fish to fish at the different sampling stations.

4.7.3 Occurrence of food items in the guts of *Labeobarbus altianalis* in River Kuja during the wet season

During the wet season 551 specimens of *L. altianalis* in River Kuja were analyzed for percentage occurrence of food items in their guts. The results of the analysis are presented in table 8. Algae and Diptera had the highest percentage occurrence (24.11%) and (22.17%) respectively while Decapoda (0.3%), Coleoptera (0.7%), zooplankton (3.87%) and Ephemeroptera (2.23%) had the lowest percentage occurrence.

***Table 8*: Food percentage occurrence in guts of *L. altianalis* during the wet season**

Food item (order)	**Occurrence (n)**	**Occurrence (%)**
Diptera	149	22.17
Ephemeroptera	15	2.23
Decapoda	2	0.30
Zooplankton	26	3.87
Algae	162	24.11
Plant matter	108	16.07
Coleoptera	5	0.7

The occurrences of the food items as in the dry season were generally low.

From the two seasons it can be concluded that, algae had the highest percentage occurrence of 24.11% in the guts of *L. altianalis* during the dry season compared to the wet season (19.89%). The result of $x^2{}_{0.05}$ df, 28=447.0>41.34 indicated that the occurrence of food items in the guts of *L. altianalis* during the wet season significantly differed from fish to fish at the different sampling stations.

4.8 Percentage composition of food items in the guts

4.8.1 Percentage composition of the food items in guts of *L. altianalis* during the dry season

The computations of the percentage composition of food items in both the environment and the guts of *L. altianalis* faced a number of challenges. It was difficult to use the volumetric method because algae, fine detritus, silt, zooplankton and plant matter were intermingled to the extent that it was difficult to determine the actual volumes of each of this food items. Therefore the percentage composition was computed for those food items which could be completely isolated from the rest of the "debris" hence the percentage composition of insects and other invertebrate larvae were possible to compute because these food items could be easily identified and quantified. Figure 11 therefore presents the relative percentage composition of insects and other invertebrates food items in the guts of *L. altianalis* during dry season.

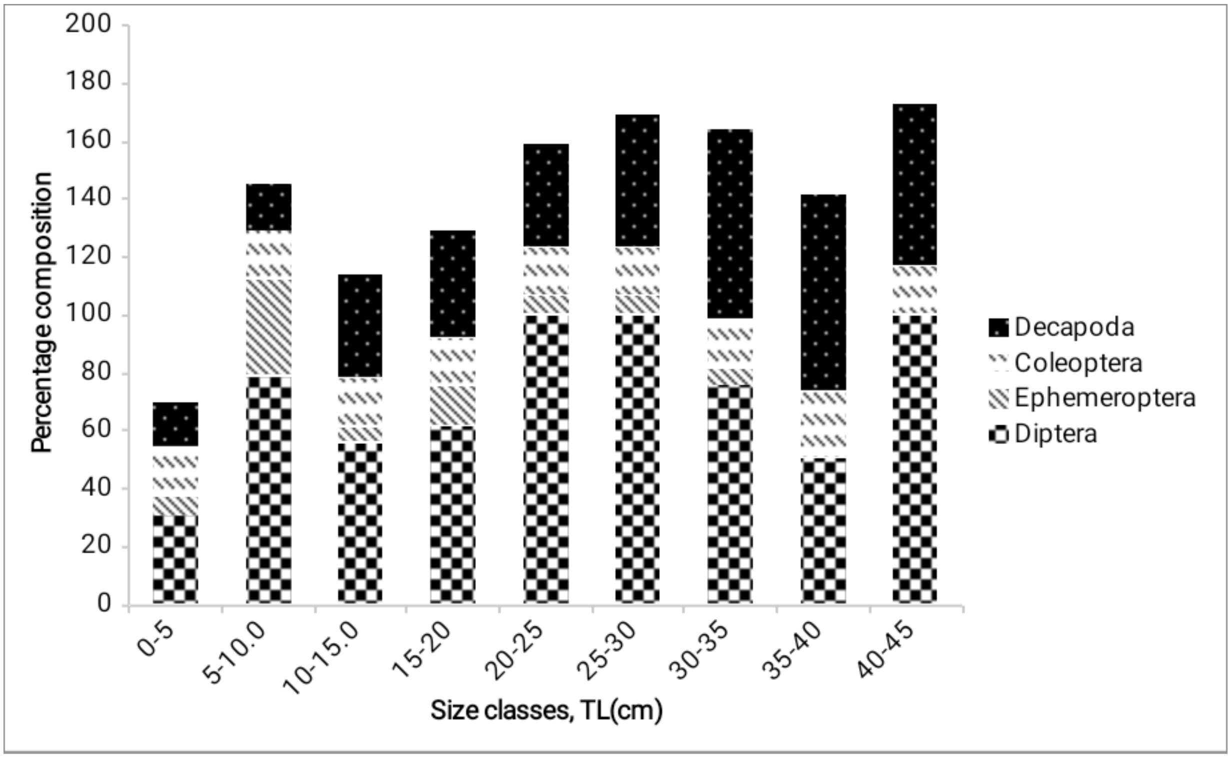


***Figure 11*: Relative percentage compositions of food items in the guts of *L. altianalis* in River Kuja during the dry season**

There were four major invertebrates' food items: the larvae of Diptera, Coleoptera, Ephemeroptera and decapods, shrimp *Caridina nilotica* in the guts of *L. altianalis* during the dry season. The smallest size range of fish of 0 – 5 cm TL consumed the lowest percentage of Diptera (30.83%) while the rest consumed Diptera of 50% or more. There was no clear pattern on the percentage composition of Coleopteran larvae consumed by *L. altianalis* in the river during the dry season as these range from 16.72% to 22.72%. The consumption of the decapods, shrimps (*Caridina nilotica*) indicated an increase in percentage in the guts of *L. altianalis* with increase in fish size. The smallest size range of 0 – 5 cm TL had the lowest percentage composition of 16.03% while these increased to 68.03% in the size range of 35 – 40 cm TL and slightly decreased to 56.03% TL in the size range of 40 - 45 cm TL. For the

Ephemeroptera larvae there was no clear pattern as percentages composition fluctuated with increase in fish size. From Figure 11 above, the food item which exhibited the highest percentage composition were Diptera and Decapoda.

4.8.2 Percentage composition of the food items in guts of *Labeobarbus altianalis* during the wet season

The percentage compositions of food items consumed by *L. altianalis* in River Kuja during the wet season are presented in Figure 12. As in the dry season, the major food items during the wet season constituted of the larvae of Diptera, Coleoptera, Ephemeroptera and the decapods fresh water shrimp, *Caridina nilotica.*

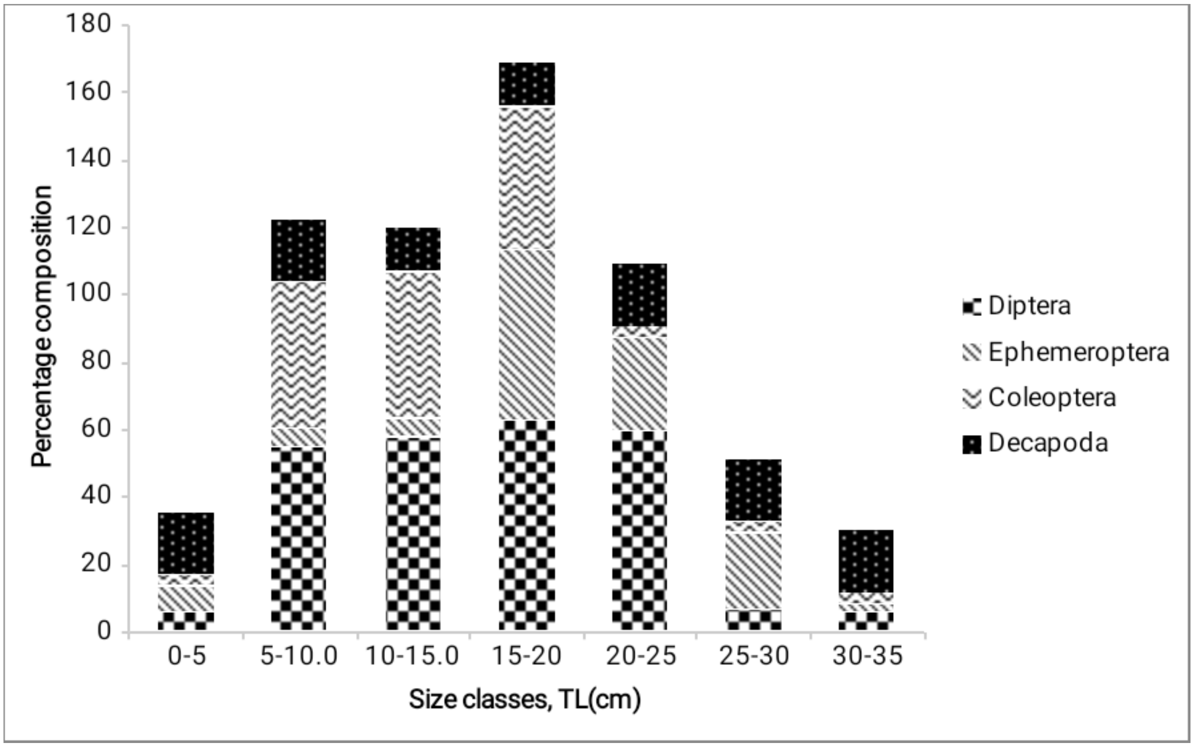


***Figure 12*: Food percentage composition in guts of *L. altianalis* during the wet season**

The larvae of Diptera exhibited relatively higher percentage composition compared to those of other food items. Decapoda generally had the lowest percentage composition of all food items during the dry season compared to those consumed during the wet season. The percentage of Coleoptera and Ephemeroptera were low during the dry season than the wet season.

4.8.3 Ontogenic dietary shift

The analysis of the percentage composition of fish food items for both season showed that different sizes of fish consumed different percentage composition of the different food items. This is the only ontogenic pattern that could be deduced for the fish food items during both seasons. Below, a comparison is made between the percentage composition of food items consumed based on the percentages derived from the point method and those obtained using direct counts of the fish food items in the guts. A slight difference is introduced due to the point scoring of phytoplankton, zooplankton, chironomids, insects remains, molluscs, crustaceans and plant matter whose enumeration was not possible due to the intermingling of this food items with detritus of all sizes, silt and other benthic material. However there is a clear pattern of ontogenic shift of the food items consumed by smaller fish compared with big fish during both season. The ontogenic dietary shift is presented in Figure 13.

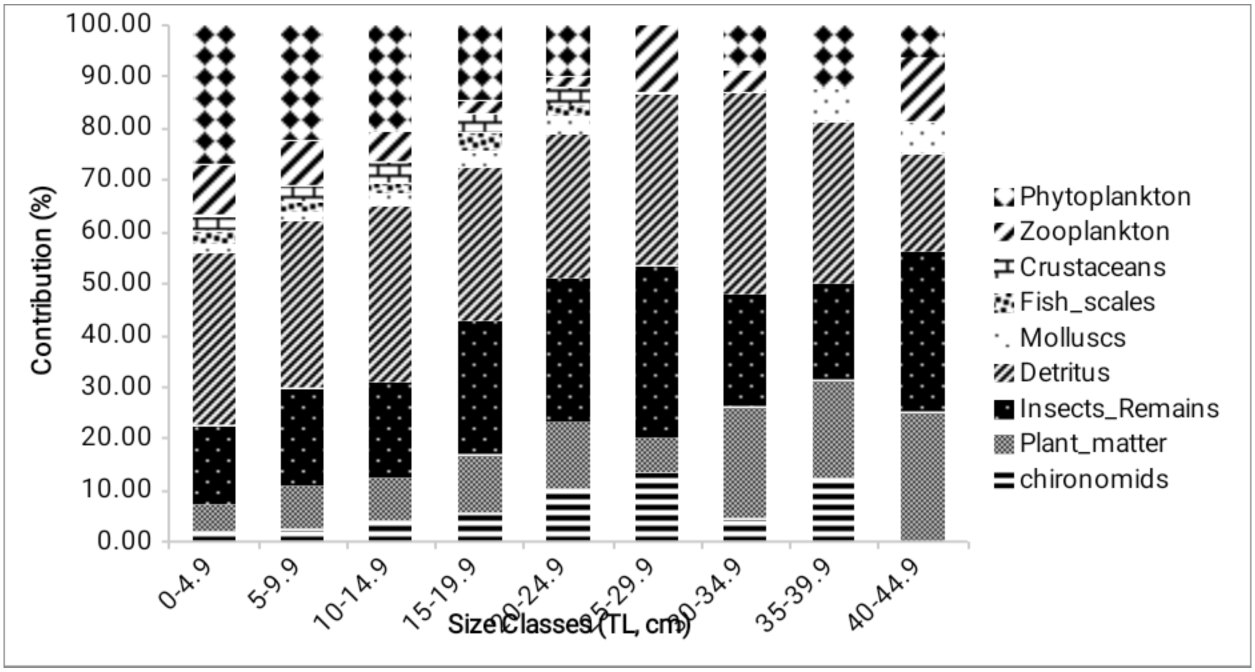


***Figure 13*: Ontogenic shift on the feeding of *L. altianalis* in River Kuja during the study period.**

Detritus, plant matter and insect remains were the most dominant food item for all the size ranges (Figure 13). The contribution of fish scales, molluscs and crustaceans were very low across all the size class ranges. Smaller *L. altianalis* consumed lower percentage compositions of chironomids, molluscs and crustaceans compared to big fish. In size class 5 - 9.9 cm TL specifically, the percentage contribution of chironomids, molluscs and crustaceans were 2.29%, 1.88%, and 2.92% respectively. Molluscs and crustaceans did not contributed fully to the size range 25 - 39.9cm TL and 40 - 44.9 cm TL.

Smaller fish consumed higher percentages of phytoplankton compared to big *L. altianalis*. Size class 0 - 4.9 cm, 5 - 9.9 cm, 10 - 14.9 cm and 15 - 19.9 cm the percentage contribution of phytoplankton were 27.11%, 22.50%, 20.70% and 14.81% respectively. This shows a decreasing trend as the fish moves from juvenile to adult fish, it reduces the consumption of phytoplankton.

Similarly the smaller fish fed on higher percentage of zooplankton than the bigger fish. Size class 0 - 4.9 cm TL, they consumed 9.9% of the zooplankton while size range of 35 - 39.9 cm TL, totally avoided zooplanktons in their environment

4.2.7 Composition of fish food items based on point method

The percentage composition of food items consumed by *L. altianalis* based on point method is presented in Table 9. The composition was also calculated based on fish size classes of approximately 5 cm TL.

***Table 9*: Composition of food items consumed by *L. altianalis* based on point method**

Size class length TL(cm)	Plant matter	Detritus	Insect remains	Molluscs	Zooplanktons	Phytoplankton
0-4.9	5.25	33.53	17.2	1.75	12.83	27.11
5-9.9	8.54	32.50	21.04	1.88	11.67	22.50
10-14.9	8.28	34.08	22.61	2.55	9.87	20.70
15-19.9	11.11	29.63	31.69	2.88	6.17	14.81
20-24.9	13.33	27.78	37.78	3.33	5.55	10.00
25-29.9	6.67	33.33	46.66	0.00	13.33	0.00
30-34.9	21.74	39.13	26.09	0.00	4.35	8.7

35-39.9	18.75	31.25	31.25	6.25	0.00	12.5
40-44.9	25.00	18.75	31.25	6.25	12.5	6.25

Food items which had the highest percentage composition were detritus, insect remains, plant matter and phytoplankton, while those with the least percentage composition were fish scales, chironomids and crustaceans. There is an apparent ontogenic shift in the different type of food items consumed by the species. For instance, the percentage composition of detritus ingested decreased with an increase in size of *L. altianalis* while that of insects remains increased with fish size. Similarly the percentage composition of phytoplankton decreased with increase in fish size while plant matter increase with increase in fish size. Small sizes of fish consumed crustaceans and molluscs; these food items were absent in big fish.

4.9 Fish food selection

4.9.0 Electivity indices

4.9.1 Ivlev's electivity indices during the dry and wet season

The Ivlev's electivity indices of food items consumed by *L. altianalis* during the dry and wet seasons are presented in Table 10 and 11, respectively.

Table 10: **Ivlev's electivity indices of food items of *L. altianalis* in the lower River Kuja section during the dry season.**

Key: DPT = Diptera, EPT = Ephemeroptera, CPT = Coleoptera, OGT = Oligochaeta, HPT = Hemiptera, DPD = Decapoda, ODT = Odonata, PLT = Pulmonata, HDT = Hirudinada

Fish size range TL(cm)	Class midpoint(cm)	Sample size	DPT	EPT	CPT	OGT	HPT	DPD
0-5	2.5	14	+0.22	-1	-1	-1	-1	-0.22
5-10	7.5	35	+0.64	-1	-1	-1	-1	-0.22
10-15	12.5	28	+0.65	-1	-1	-1	-1	-1
15-20	17.5	9	+0.56	-1	-1	-1	-1	-1
20-25	22.5	2	+0.72	-1	-1	-1	-1	-1
25-30	27.5	4	+0.72	-1	-1	-1	-1	+0.43
30-35	32.5	4	+0.63	-1	-1	-1	-1	+0.58
35-40	37.5	6	-1	-1	+0.11	-1	-1	+0.60
40-45	42.5	3	+0.72	-1	-1	-1	-1	+0.52

In the dry season, the food items with positive electivity indices included; Diptera

(+0.72, +0.63, +0.65, +0.64, + 0.22), Ephemeroptera (+0.6, +0.58, +0.52, +0.43), Coleoptera (+0.11). During the dry season some food items exhibited strongest avoidance by fish and had an Ivlev`s index of -1, these included Oligochaeta (-1), Hemiptera (-1). Some fish food items indicated size dependent selectivity. For example, *L. altianalis* of size range 0 - 35cm TL indicated positive selectivity for the food item Diptera and Decapoda represented by the fresh water shrimp, *Caridina nilotica* showed negative selectivity in the size range 0 - 25 cm TL and positive selectivity in the size range 25 – 45 cm TL for the decapodes ,*Caridina nilotica*. For the Coleoptera food item smaller fish sizes in the range 0 - 35cm TL exhibited negative selectivity while larger fish sizes in the size range 35 - 40 cm TL exhibited positive selectivity.

The Ivlev’s index of electivity of fish food items of *L. altianalis* in the upper River Kuja section during the dry season is presented in Table 13. Only Diptera exhibited positive electivity indices while Oligochaeta, Hemiptera exhibited strong negative electivity indices. Ephemeroptera exhibited mixed electivity (positive and negative electivity indices). For these food items fish in the size ranges 5 – 10 cm TL and 15 – 20 cm TL exhibited positive selectivity for the food item while the rest of the size ranges exhibited negative electivity.

Table 11: **Ivlev's electivity indices of food items of *L. altianalis* in the upper River Kuja section during the dry season**

Fish size range TL(cm)	Class midpoint(cm)	Sample size	DPT	EPT	CPT	OGT	HPT
0-5	2.5	9	+0.52	-1	-1	-1	-1
5-10	7.5	61	+0.53	+0.63	-1	-1	-1
10-15	12.5	44	+0.61	-1	-1	-1	-1
15-20	17.5	41	+0.42	+0.37	-1	-1	-1
20-25	22.5	10	+0.51	-1	-1	-1	-1
25-30	27.5	2	+0.64	-1	-1	-1	-1
30-35	32.5	6	+0.49	-1	-1	-1	-1

4.9.2 Ivlev's electivity indices of food items of *Labeobarbus altianalis* in the lower River Kuja section during the wet season

The electivity indices of food items of *L. altianalis* in the lower Kuja section during the wet season are presented in Table 12.

***Table 12*: Ivlev's electivity indices of food items of *L. altianalis* in the lower River Kuja section during the wet season**

Fish size range TL(cm)	Class midpoint(cm)	Sample size	DPT	EPT	CPT	OGT	HPT	PLT	ODT
0-5	2.5	3	-1	-1	-1	-1	-1	-1	-1
5-10	7.5	43	+0.23	-1	-1	-1	-1	-1	-1
10-15	12.5	39	0.30	-1	-1	-1	-1	-1	-1
15-20	17.5	23	0.52	-1	-1	-1	-1	-1	+0.89
20-25	22.5	10	+0.54	-1	-1	-1	-1	-1	-1

Labeobarbus altianalis in the size range 0 - 5 cm TL exhibited negative electivity for Diptera while the rest of the size range exhibited positive electivity for the food item. For Odonata, *L. altianalis* exhibited positive electivity in the size range 15 - 20 cm TL, while the rest of the size ranges exhibited negative electivity for the food item. All the other food items (Coleoptera, Oligochaeta, Hemiptera and Pulmonata) had negative electivity indices.

4.9.3 Ivlev's electivity indices of food items of *Labeobarbus altianalis* in the upper River Kuja section during the wet season

The Ivlev's electivity indices of *L. altianalis* for different food items in the upper Kuja River section during the wet season are presented in Table 13. As in the other periods *L. altianalis* exhibited mixed electivity indices for different food items in the river.

Table 13: **Ivlev's electivity indices of food items of *Labeobarbus altianalis* in the upper River Kuja section during the wet season**

Fish size range TL(cm)	Class midpoint(cm)	Sample size	EPT	DPT	CPT	ODT	PLT	HDD
0-5	2.5	0	-1	-1	-1	-1	-1	-1
5-10	7.5	25	+0.71	+0.47	+0.57	-1	-1	-1
10-15	12.5	35	+0.71	+0.43	+0.57	+0.72	-1	-1
15-20	17.5	52	+0.68	+0.47	+0.57	+0.72	-1	-1
20-25	22.5	18	+0.4	+0.44	-1	-1	-1	-1
25-30	27.5	1	-0.04	-1	-1	-1	-1	-1
30-35	32.5	1	-1	-1	-1	-1	-1	-1
35-40	37.5	0	-1	-1	-1	-1	-1	-1
40-45	42.5	0	-1	-1	-1	-1	-1	-1

Labeobarbus altianalis in the size range 0 - 5 exhibited negative electivity for diptera, while the middle size ranges (5 – 25 cm TL) exhibited positive electivity; older size ranges above 25 cm TL exhibited negative electivity for Diptera. Similarly, smaller *L. altianalis* in the size range 0 - 5 showed negative electivity for Ephemeroptera while the middle size ranges from 5 -30 cm TL showed positive electivity for Ephemeroptera. Bigger size range of 30 - 45 cm TL showed negative electivity for food item. For Coleoptera, smaller fish size ranges (5 - 20cm TL) showed positive electivity while bigger size ranges (20 - 45cm TL) showed negative electivity indices. These observations are different from what has been observed above and therefore indicating some seasonal dependence of food selection by *L. altianalis*. Food item electivity for Odonata indicated size dependence whereby smaller *L. altianalis* (0 - 10cm TL) indicated negative electivity while 10 - 20 cm TL indicated positive electivity and those above 10cm TL indicated negative electivity. The other food items (Pulmonata and Hirudinida) exhibited strong negative electivity indices. Thus in the upper River Kuja section during the wet season, there were size and seasonal dependence of food electivity by *L. altianalis*.

4.9.4 The linear food index

a) Linear food indices of fish food items of *Labeobarbus altianalis* in the lower River Kuja during the dry season

The linear food indices of different food items in the lower River Kuja during the dry season are presented in Table 14.

Table 14: **Linear food indices of fish food items of *Labeobarbus altianalis* in the lower River Kuja during the dry season**

Fish size range TL(cm)	Class midpoint(cm)	Sample size (n)	Diptera	Coleoptera	Decapoda
0-5	2.5	14	0.09	0.07	-0.05
5-10	7.5	35	0.57	0.07	-0.05
10-15	12.5	28	0.34	0.07	0.15
15-20	17.5	9	0.40	0.07	0.16
20-25	22.5	2	0.84	0.07	O.15
25-30	27.5	4	0.84	0.07	0.25

30-35	32.5	4	0.54	0.07	0.45
35-40	37.5	6	-0.16	0.13	0.47
40-45	42.5	3	0.84	0.07	0.35

There was no size dependence of the electivity of food item Diptera by *L. altianalis*, since almost all the size ranges except one of 35 – 40 cm TL had positive linear food indices. Similarly Coleoptera had all positive linear food indices in it full size range (0 – 45 cm TL). However of all the three food items indicated size dependence of food electivity by *L. altianalis*. Fish in the size range 0 - 10 indicated negative linear food indices for Decapoda while fish above this size indicated positive linear food indices.

b) Linear food indices of fish food items of *Labeobarbus altianalis* in the upper River Kuja during the dry season

The linear food indices of fish food items of *L. altianalis* in the upper River Kuja section during the dry season is presented in Table 15 below.

Table 15: **Linear food indices of fish food items of *Labeobarbus altianalis* in the upper River Kuja during the dry season**

Fish size range TL(cm)	Class midpoint(cm)	Sample size (n)	Diptera	Ephemeroptera

0-5	2.5	9	0.34	-0.16
5-10	7.5	61	0.52	0.24
10-15	12.5	44	0.50	-0.15
15-20	17.5	41	0.54	0.04
20-25	22.5	10	0.27	-0.16
25-30	27.5	2	0.39	-0.16
30-35	32.5	6	0.34	-0.15

The food item Diptera did not exhibit any size dependence on food items since all linear food indices were positive. However the food item Ephemeroptera indicated mixed selectivity for different sizes of *L. altianalis*.

c) Linear food indices of fish food items of *L. altianalis* in the lower River Kuja during the wet season

The Linear food indices of fish food items of *L. altianalis* in the lower River Kuja section during the wet season are presented (Table 16). Linear food indices of two food items namely, Diptera and Decapoda are indicated.

***Table 16*: Linear food indices of fish food items of *Labeobarbus altianalis* in the lower River Kuja during**

the wet season.

Fish size range TL(cm)	Class midpoint(cm)	Sample size (n)	Diptera	Decapoda
0-5	2.5	3	-0.21	-0.32
5-10	7.5	43	0.13	-0.32
10-15	12.5	39	0.18	-0.32
15-20	17.5	23	0.17	0.68
20-25	22.5	10	0.49	-0.32

The linear food indices of Diptera were generally positive, indicating little size dependence. The food item Decapoda indicated size dependence of the lower food indices with size range 0 - 15 cm TL showing negative linear food indices while fish of size range 15 - 20cm TL showing positive index.

d) **Linear food indices of fish food items of *L. altianalis* in the upper River Kuja during the wet season.**

The Linear food indices of fish food items of *L. altianalis* in the upper River Kuja section during the wet season are presented in Table 17. Linear food indices of four food items namely; Diptera, Ephemeroptera, Coleoptera and Decapoda are indicated.

***Table 17*: Linear food indices of fish food items of *Labeobarbus altianalis* in the upper River Kuja during the wet season.**

Fish size range TL(cm)	Class midpoint(cm)	Sample size (n)	Diptera	Ephemeroptera	Coleoptera	Decapoda
0-5	2.5	0	-0.21	-0.9	-0.11	-0.32
5-10	7.5	25	0.28	0.46	0.29	-0.32
10-15	12.5	35	0.31	0.45	0.29	-0.02
15-20	17.5	52	0.36	0.39	0.28	-0.02
20-25	22.5	18	0.33	0.16	-0.11	-0.32
25-30	27.5	1	-0.20	0.11	-0.11	-0.32
30-35	32.5	1	-0.21	-0.09	-0.11	-0.32

Diptera indicated size dependence on its linear food indices. Fish in the size range 0 - 5 cm TL had negative linear food indices, while those in the range 5 - 25 cm TL had positive linear food indices. Those above 25cm TL had negative linear food indices. The food item Ephemeroptera exhibited almost a similar trend to that of the food item Diptera. The size range 0 - 5 cm TL had negative linear food indices while size range 5

- 30 cm TL positive linear food indices and sizes above this had negative indices. Hence like in the other observations this is a case of mixed sized dependence of food selection by *L. altianalis*. Food item Coleoptera had more or less similar trend of linear food indices as that observed in Ephemeroptera (Table 19). Decapoda in the upper River Kuja section seems to present a case of seasonal dependence of food item selectivity by *L. altianalis*. Contrary to the other season all the linear food indices of Decapoda in the upper River Kuja section during the wet season were negative.

4.9.7 FORAGE RATIO

There were only three food items fed on in the lower River Kuja during the dry season, namely: Diptera, Decapoda and Coleoptera. Among the three, the most foraged on was the Diptera followed by Decapoda while there was limited foraging on the Coleoptera (Table 18).

***Table 18*: Forage ratio of food items fed on by *Labeobarbus altianalis* in the lower River Kuja section during the dry season.**

Fish size range TL(cm)	Class midpoint(cm)	Sample size	Diptera	Decapoda	Coleoptera
0-5	2.5	14	0.76	0	0
5-10	7.5	35	0.18	1.21	0
10-15	12.5	28	0.33	0	0
15-20	17.5	9	0.40	0	0
20-25	22.5	2	0	0	0
25-30	27.5	4	0	0.48	0
30-35	32.5	4	0.19	0.27	0
35-40	37.5	6	0	0.26	0.61
40-45	42.5	3	0	0.37	0

Most of the forage ratios were below +1, indicating poor foraging on the three food item. However, Diptera had higher foraging ratios compared to the two other food items. Foraging on Coleoptera was highly limited as only one size range, 35 - 40 cm TL was found to have fed on the food item.

a) Forage ratio of food items during the dry season.

The results on the forage ratio in the upper River Kuja section during the dry season are presented in Table 19. In the upper River Kuja section, only Diptera and Ephemeroptera were foraged on by *L. altianalis* during the dry season. Most of the forage ratios for the two food items were below 0.5.

Table 19: **The forage ratio of food items fed on by *Labeobarbus altianalis* in the upper River Kuja section during the dry season.**

Fish size range TL(cm)	Class midpoint(cm)	Sample size (n)	Diptera	Ephemeroptera
0-5	2.5	9	0.37	0
5-10	7.5	61	0.2	0.38
10-15	12.5	44	1.22	0
15-20	17.5	41	0.19	0.67
20-25	22.5	10	0.46	0
25-30	27.5	2	0.32	0
30-35	32.5	6	0.37	0

L. altianalis of size range 10 - 15 cm TL had the highest foraging ratio in the river of 1.22 and this was on the food item Diptera. This underlines the importance of Diptera as a major food item of *L. altianalis* in the river.

b) Forage ratio of fish food items fed on by *L.altianalis* in the lower River Kuja during the wet season

In the lower River Kuja section, the food items foraged on were Diptera and Decapoda during wet season (Table 20).

Table 20: **Forage ratio of fish food items fed on by *Labeobarbus altianalis* in the lower River Kuja during the wet season.**

Fish size range TL(cm)	Class midpoint(cm)	Sample size (n)	Diptera	Decapoda
0-5	2.5	3	0	0
5-10	7.5	43	0.69	0
10-15	12.5	39	0.59	0
15-20	17.5	23	0.60	0.6
20-25	22.5	10	0.22	0

The fish largely fed on Diptera and to a very limited extent on Decapoda.

c) Forage ratio during the wet season

The number of food items foraged on by *L. altianalis* in the upper River Kuja section during the wet season were four namely; Diptrea, Ephemeroptera, Coleoptera and Decapoda (Table 21).

Table 21: **Forage ratio of fish food items in the upper River Kuja during the wet season**

Fish size range TL(cm)	Class midpoint(cm)	Sample size (n)	Diptera	Ephemeroptera	Coleoptera	Decapoda
0-5	2.5	0	0	0	0	0
5-10	7.5	25	0.46	0.24	0.42	0
10-15	12.5	35	0.41	0.24	0.42	0.05
15-20	17.5	52	0.39	0.30	0.42	0.05
20-25	22.5	18	0.39	0.58	0	0.05

25-30	27.5	1	0	0.67	0	0

Size dependence on foraging by *L. altianalis* was exhibited in two food items: Diptera and Ephemeroptera. For Diptera, the forage ratio decreased with an increase in size of the fish while in Ephemeroptera the ratio increased with increasing size of fish. No feeding pattern was exhibited by the forage ratio in Decapoda and Coleoptera. The foraging ratios were generally low for all the food items that are close to zero.

4.9.8 CORRELATION BETWEEN ABUNDANCE OF FISH FOOD ORGANISM AND PHYSICOCHEMICAL PARAMETERS

4.9.8.1 Turbidity

In this study, there was correlation of food abundance and distribution with physicochemical characteristic in the River Kuja. The relationship between fish food abundance and turbidity showed an inverse relationship with a negative gradient (Figure 14).

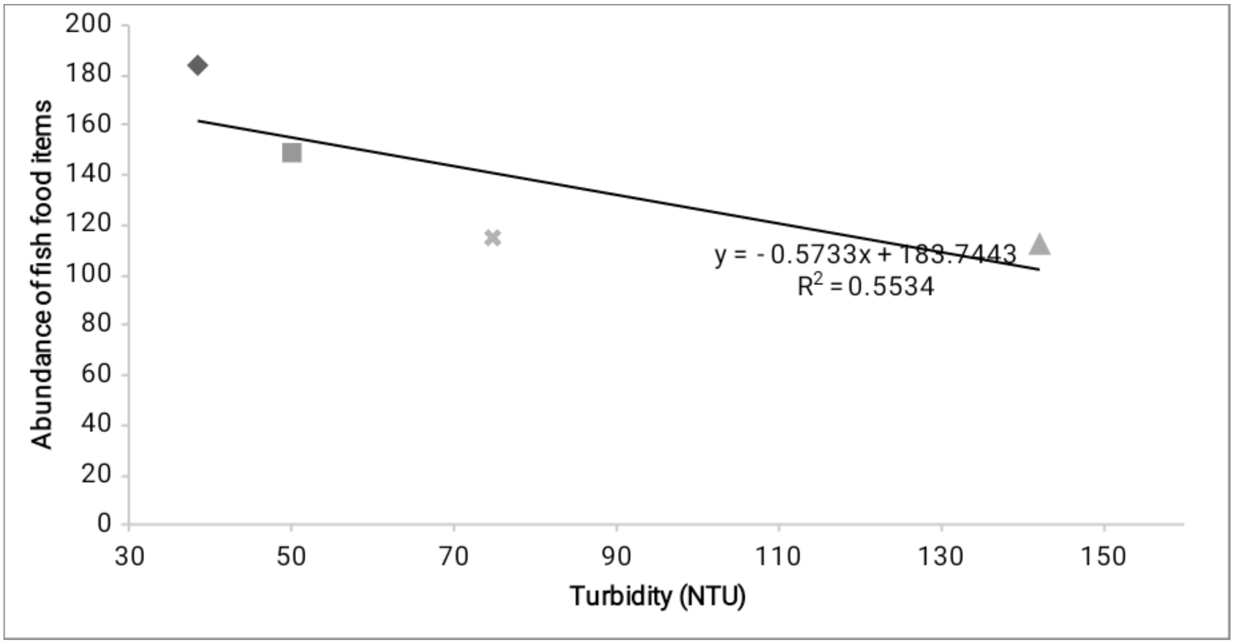


Figure 14: **The relationship between abundance of fish food organism and turbidity in the River Kuja during the wet season**

As turbidity increases, the number of fish food organism in the river decreased (R^2 = 0.62). During the dry season, the relationship was also inverse (R^2 = 0.96) which is much stronger and more significant than that of the wet season.

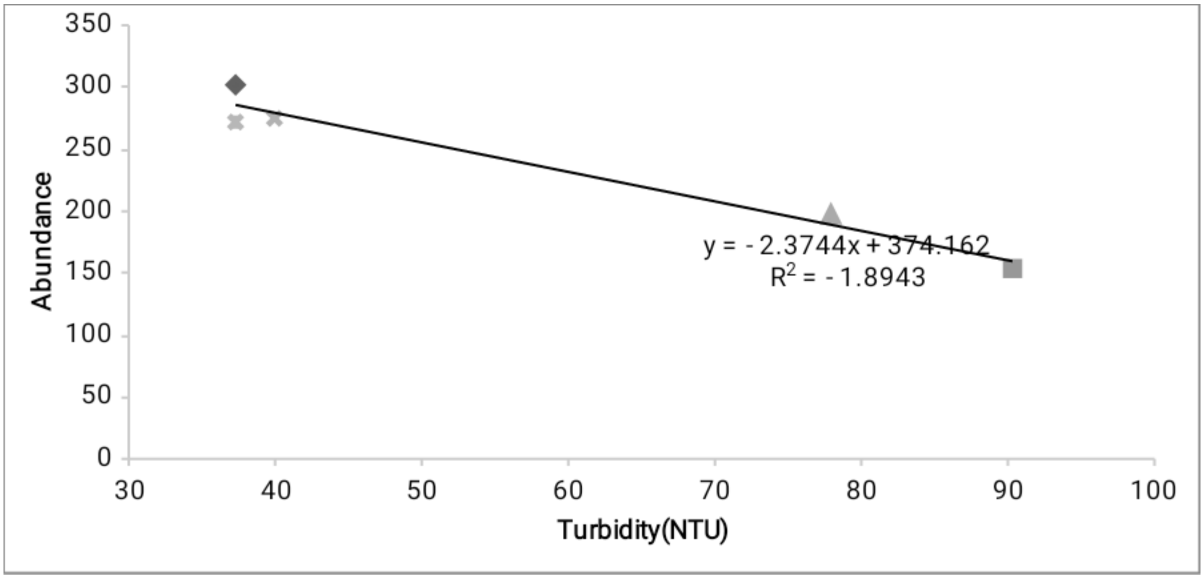


***Figure 15*: The relationship between abundance of fish food organism and turbidity in the River Kuja during the dry season**

4.9.8.2 Chlorophyll *a* concentration

The relationship between the concentration of chlorophyll *a* and the abundance of fish food organism in the water column during the wet season is depicted in Figure 16.

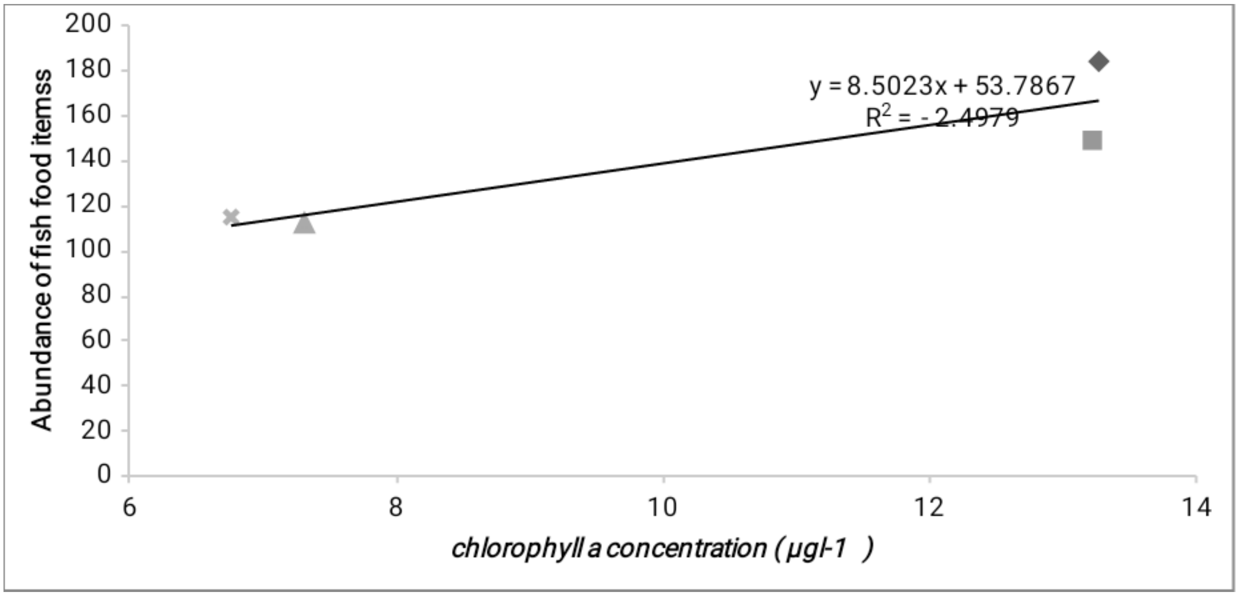


***Figure 16*: The relationship between chlorophyll *a* concentration and abundance of fish food organism in River Kuja during the wet season.**

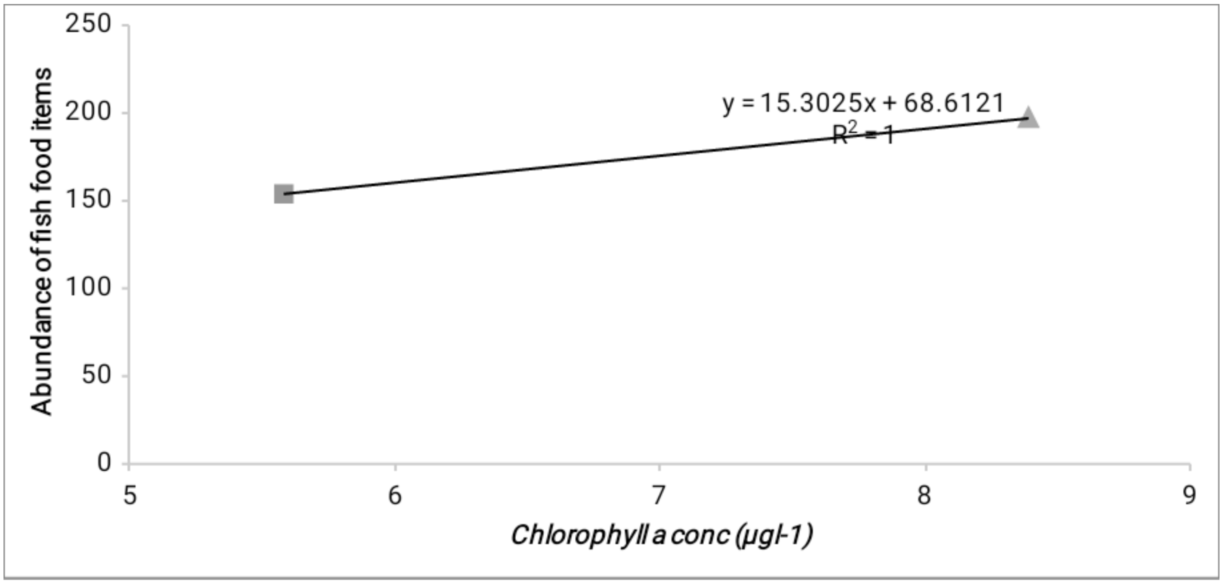


Figure 17: **The relationship between chlorophyll *a* concentration and abundance of fish food organism in River Kuja during the dry season.**

The relationship was a positive gradient of 23.89 and a correlation coefficient R^2 = 0.94 which was significant. For the wet season, the relationship between chlorophyll *a* concentration and fish food organism is similar with a positive gradient of 8.5 and R^2 = 0.81.

4.9.8.3 Temperature

The relationship between temperature and the abundance of fish food organism in River Kuja during the dry season is depicted in Figure 18.

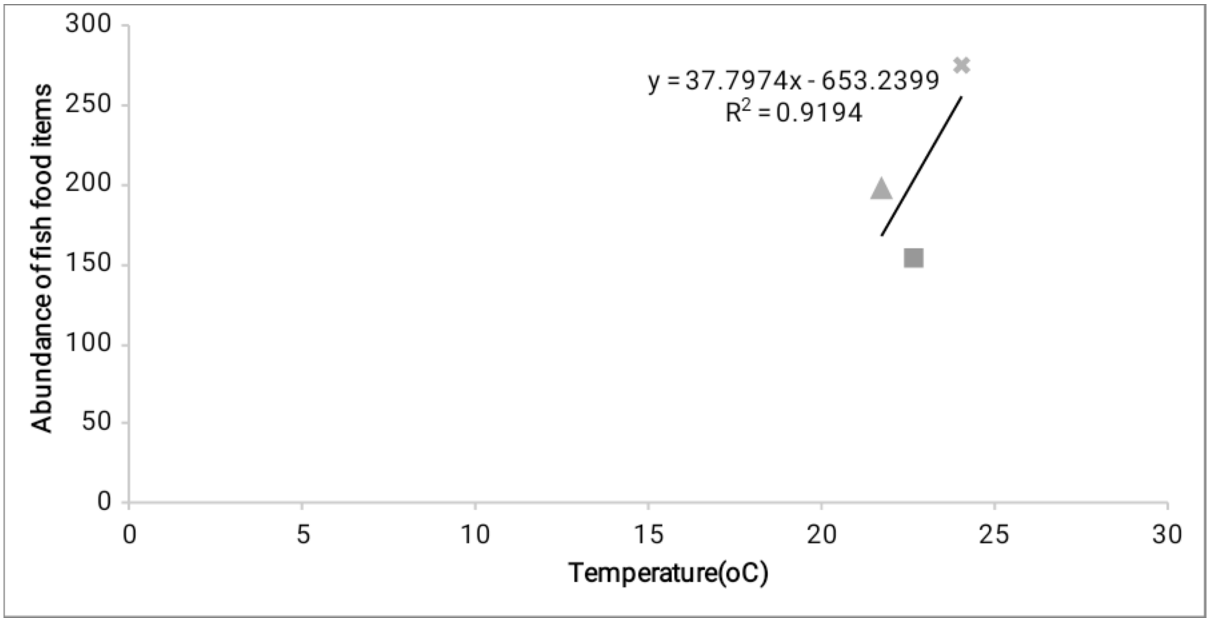


***Figure 18*: The relationship between temperature and abundance of fish food organisms in River Kuja during the dry season.**

As the temperature increased the abundance of fish food organism in the river also increased. The relationship during dry season had a positive gradient of 33.84 and R^2 = 0.65 which is significant. Similar observations between the two characteristic were made during the wet season; the relationship gave a positive gradient of 25.66 and R^2 = 0.35

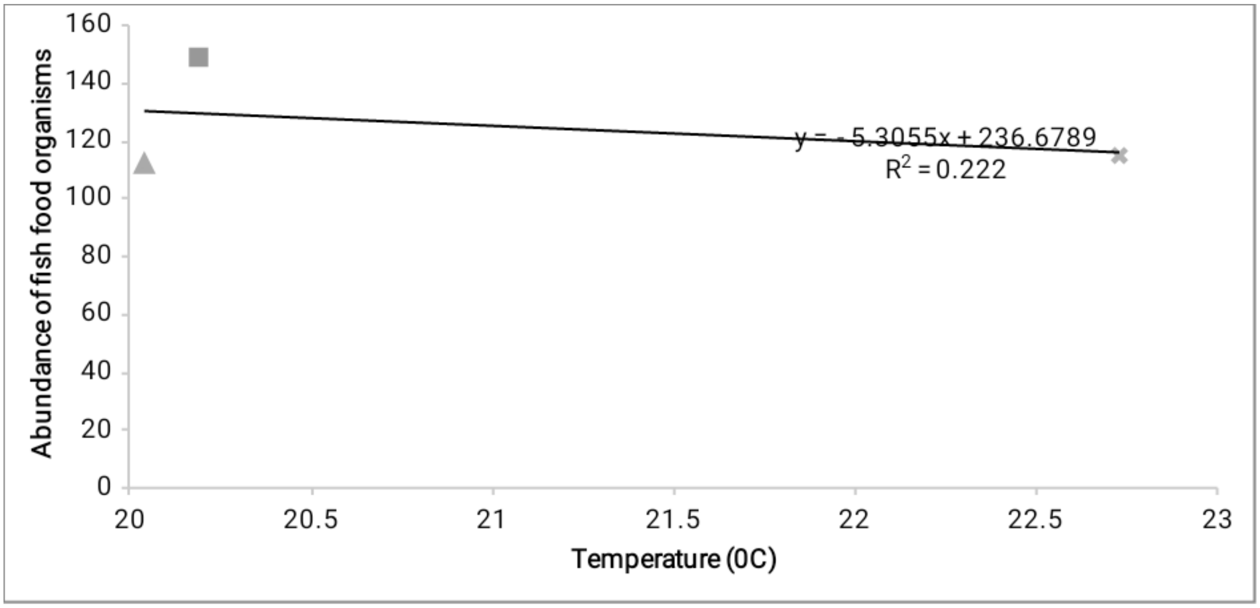


Figure 19: **The relationship between temperature and abundance of fish food organisms in River Kuja during the wet season.**

4.9.8.4 Conductivity

The relationship of conductivity and fish food organism during the dry season is depicted in Figure 20.

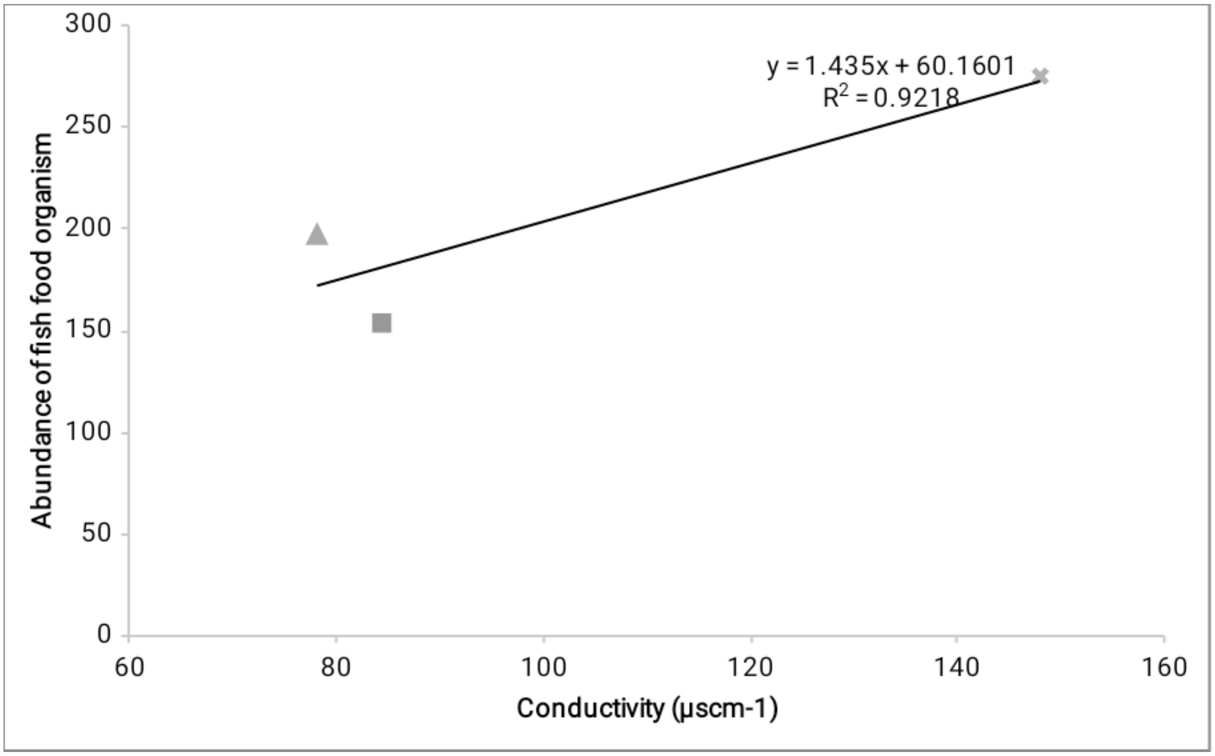


***Figure 20*: The relationship between conductivity and abundance of fish food organisms in River Kuja during the dry season.**

The relationship has positive gradient of 1.47 and R^2 = 0.87, indicating that as conductivity increases, the number of fish food organism also increases.

The relationship between conductivity and fish food organisms in River Kuja during the wet season is depicted in Figure 21.

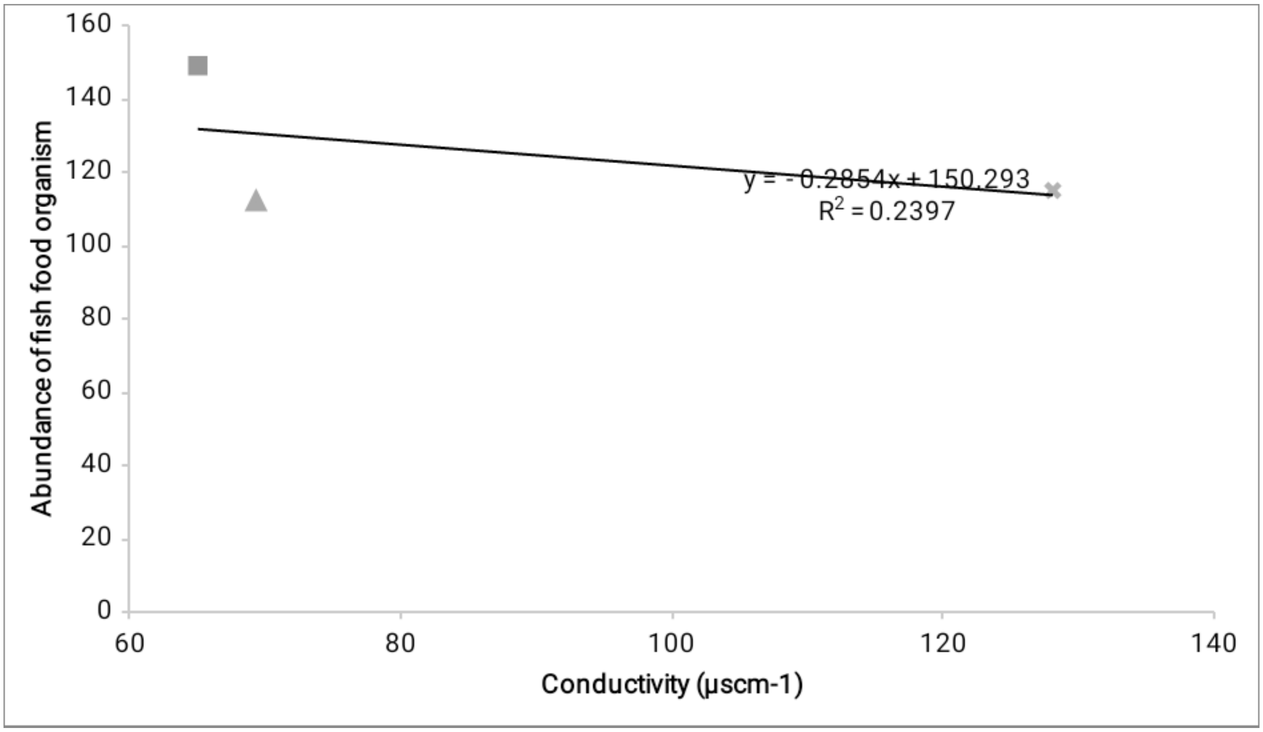


***Figure 21*: The relationship between conductivity and abundance of fish food organisms in River Kuja during the wet season.**

The relationship of conductivity with abundance of food during wet season also showed a positive gradient.

CHAPTER FIVE

5.0 DISCUSSION

5.1 Introduction

This chapter deals with the discussion on food item occurrence, composition, and selection by *L. altianalis*, the distribution of the fish and food items and its relationship to the variation of the selected physicochemical parameters: turbidity, dissolved oxygen concentration, chlorophyll *a* concentration, temperature, pH and conductivity in the River Kuja which drains to Lake Victoria.

The abundance and distribution of fish food organism in the aquatic environment depends on the nature of the physical and chemical characteristic and natural productivity. The availability of nutrients in the aquatic environment ensures its continuity in maintaining natural productivity. Thus the distribution of fish and their food organisms is directly affected by the physicochemical characteristic in their aquatic habitat. It is therefore important to maintain water quality within the recommended levels of World Health Organization (WHO, 2006).

5.2 Physicochemical parameters

In this study, the occurrence and abundance of fish food items in the aquatic environment was found to be related to the occurrence and abundance of fish as well as the physical and chemical characteristics. Studies on the distribution of (*L. altianali*s) in Ethiopian lakes were found to be related to the abundance of fish food items and their seasonal and spatial differences (Dadebo et al., 2013; Sibbing & Nagelkerke, 2001).

5.2.1 Dissolved oxygen

Results from this study indicated that the physicochemical characteristic from different sampling points varied spatially and temporarily. Dissolved oxygen concentration varied downstream and were found to be affected by pollutant inputs at Gogo falls sampling station, where a sugar factory effluent discharged into the river, reducing oxygen levels to below 1.0 mg L^{-1}. It was noted that mean dissolved oxygen concentrations were lower during the dry season (November 2016 - March 2017) than during the wet season (April - August 2017). Variations downstream in dissolved oxygen concentration reduced from station 1 - 5 were due to agricultural effluents which normally contain a lot of organic allochthonous material which consumes a lot of dissolved oxygen concentration during its decomposition process thus affecting the concentration of oxygen in the river.

The physical and chemical environment of a fish habitat is known to be determined by spatial and temporal differences which in turn affect the distribution of fish food items. Studies on the feeding habit of *Barbus* species in a Sri Lankan reservoir by Balcombe, Bunn, Davies and Smith (2004) indicated that the species consumed more detritus and fewer insects during high water level. This study further indicated that high water levels were regarded as resource rich compared to low water levels in fish tropic studies, and that availability of food items varies throughout the year with season and feeding habits of fish. Contrary to the latter observations, this study established that the abundance of food items decreased during the rainy season when water level in

River Kuja was high. These differences can be attributed to the fact that the former study in Sri Lanka was conducted in a reservoir while this study was conducted in a riverine environment.

Aquatic organisms require optimal conditions of dissolved oxygen concentration for their survival. The organisms also constitute the food of fish in the aquatic environment. They therefore determined the abundance of fish at different localities in the aquatic ecosystem. In this study, the abundance of *L. altianalis* was found to vary among the sampling stations. In River Kuja very low concentrations of fish food organisms were found to correlate with low abundance of *L. altianalis*. The low abundance of fish food organisms was associated with poor water quality resulting from discharge of agricultural and urban effluents into the river.

When dissolved oxygen concentration in the water column is not optimal, this can be stressful to the organisms or lead to the migration to areas where the dissolved oxygen concentration is optimal. Bonzemo, (2013) showed that dissolved oxygen is important in the survival of aquatic organisms which was also established during this study. Low levels of dissolved oxygen affect the distribution of fish in the localities or habitats where the dissolved oxygen concentration is not optimal. This may lead to a reduction in the concentrations of fish and fish food organisms in the area which is affected. In River Kuja, during the dry season January 2017, dissolved oxygen concentration was as low as 0.4 mg L^{-1}. Normally, the minimum oxygen concentration required for optimum growth of warm water fish species is 5 mg L^{-1} (Pillay and Kutty, 2005). In River Kuja, the number of fish food organism fed on by *L. altianalis* were very much reduced to between two and three in both the upper and lower sections during the dry season (Nov 2016 - March 2017). During the wet season (April - Aug 2017), oxygen concentration in both lower and upper sections of the river were higher (Appendix 2) and therefore optimal for survival of fish and other aquatic organisms.

5.1.2 Turbidity

The turbidity in River Kuja showed a wide variance from low values (20.64 NTU in March 2017) during the dry season to high values (280.56NTU in June and August 2017) during the wet season in both the upper and lower sections of the river (Appendix 6). Much fewer organisms, only two to three were selected by *L. altianalis* as food (Diptera, Coleoptera and Ephemeroptera) during the wet season. The turbidity of water can affect fish feeding when it's very high. Omondi, Yasindi and Magana (2011) in their findings on spatial and temporal variations of zooplankton in relation to environmental factors in Lake Baringo reported that, turbidity reduces visibility of the predators and feeding rhythms which is in agreements with the results of this study in River Kuja Basin.

Turbidity in water depends on amount of suspended and dissolved matter and when it is high, fish cannot detect their food organism. This is because on certain instances, fish depends on sight to identify and pick their prey. This therefore affects fish selection of an organism as food. Normally, high turbidities are mainly experienced during rainy seasons as these periods are characterized by high rates of soil erosion, (Palamuleni, Simic, Simonovic, Cvijan, Subakov & Gacic*,* 2001), which is in agreement with the findings of this research. During the wet season, the turbidity of the water was very high as a result of siltation loading from the catchment, the river was flooded as the large volume of water from heavy rainfall and the high rate of flow dislodged fish food organism from their habitats and smothered the breeding areas of fish with silt (Wetzel, 2001). Turbidity can also increase water temperature since sediments tend to observe more solar heat than pure water does (Wetzel, 2001). Under this condition selection of fish food organism in the water column by fish is greatly affected since it’s difficult for fish to stalk their prey. During the wet season, the water level also increased and this affected feeding habit of the species at various depth of the river. Dadebo et al. (2013), showed that the major factors that influence fish diet are fish size, maturity, condition, season (water level), bottom, depth, latitude, longitude and habitat types which is also true to the findings of this research.

The presence of silt in the water also affects the filtration of fish food organism from the water since it (silt) clogs the gills preventing them from filtering the fish food organisms from the water column. In the dry season water in the river was much clearer and under this condition the fish could easily detect their prey and therefore were able to select the most preferred food item, while avoiding those they don’t feed on. Kotrschal, Brandstätter, Gomahr, Junger, Palzenberger and Zaunreiter (1991) argued that, in the open pelagic zones where there is adequate light and under clear conditions, large and contrasting prey is vulnerable to prolonged, vision - guided pursuit.

5.1.3 Chlorophyll *a* concentration

Chlorophyll *a* is a measure of the quantity of algae in the water column. The higher it is, the higher the number of algal cells, colonies or filaments in the water. It indicates the level of primary productivity in a water column, higher concentration means higher primary productivity. In this study, chlorophyll *a* concentration exhibited a temporal distribution, whereby its concentration were higher during the dry season compared to the wet season (Appendix 8). The abundance of fish food organisms greatly depends on its natural productivity. Observations on the gut contents of *L. altianalis* indicated that it does feed on algae indicating that it's a filter feeder. However the measured levels of chlorophyll *a* concentrations in the water column during the wet season were too low meaning that the quantity of algae was lower than during the dry season. This is because of the increased siltation which normally suffocates benthic organisms and sediments algae from the water column thus reducing its density (EPA, 2012). In this way the density and the availability of algae as a fish food item is much reduced hence the temporal trend of chlorophyll *a* concentration observed. The algae also form the major foundation of the tropic levels above it (secondary and tertiary levels). *L. altianalis* was found to be omnivorous indicating that it feeds at primary, secondary and tertiary levels of the food webs. Thus any reduction in the abundance of algae can reduce the abundance of fish food organisms at higher tropic levels and that of the fish themselves.

5.1.4 pH

The pH in River Kuja exhibited variations; commonly alkaline during dry season at Wath Onger and mostly near neutral during the wet season at the upstream station (Kegati and Ogembo) (Appendix 9 and 10). Contrary to this, the optimum pH for fish survival should be approximately neutral. The variations can be related to the changes of physicochemical characteristics particularly turbidity, dissolved oxygen concentration and chlorophyll *a* concentration which were within the recommended levels for most fish (6.5 - 8.5) (WHO 2015). pH is also affected by agricultural, urban and industrial effluents from the catchment of the river or lake. These can be linked to distribution of certain fish food organism for example the concentration of algae as indicated by chlorophyll *a* concentration which was lower during the wet season than in the dry season. Algae support the survival of certain fish food organisms such as zooplankton and filter feeding invertebrates on which *L. altianalis* feed on in the river. Hence the temporal changes in pH act through the physical chemical structure of the aquatic environment which had direct effect on the distribution of fish food organism in water. In a study conducted by Mulanda (2008), it was found that the level of pH can have a direct effect on the physiology of the aquatic organisms, which is also the case for this study. Any slight change of pH in the riverine environment had direct negative effects on the aquatic organisms. pH is a stable parameter whereby it changes very little with small perturbations. Therefore it's not possible to relate the small changes in pH with any changes in the distribution and abundance of fish food items and fish themselves. However, during very large perturbations for example in Gogo falls in January 2017 when a large urban agricultural effluent was discharged into the river led to reduction in the abundance of fish and their prey. This is due to the shift of pH from 7.2 to 8.1, however, the levels of pH at the site were still within the recommended pH range (Chapman et al., 1996, WHO 2000) for clean drinking water (pH: 6.5 - 9.5).

5.1.5 Total dissolved solids

The total dissolved solids (TDS) represents the concentration of organic and inorganic ions from compounds dissolved in water. Its concentration is closely related to conductivity of a solution whereby the conversion factor of TDS to conductivity is by multiplying the former by 0.65 (Ali, Mo, & Kim, 2012). It's a function of dissolved organic matter as well as other dissolved chemical compounds in the water column. The presence of both affects visibility and when their concentrations are high fish can't be able to take their prey

In the wet season TDS was high (Appendix 11) especially at downstream stations (Gogo falls and Wath Onger) , the number and diversity of fish prey in the water column was much reduced thus fish fed on few preys which were available. This could affect the selection of fish prey as food due to the fact that there were few choices for the fish to select from.

5.1.6 Temperature

The distribution of fish food organisms in River Kuja appeared to favor areas with high temperature. Compared to Lake Victoria; the temperatures in River Kuja are lower than those of the surface waters of the Lake. The open water of Lake Victoria is much exposed to sunlight as opposed to that of River Kuja where some riparian zones of the river were covered with eucalyptus plantations especially at Kegati where low temperature was recorded (16.04^{o}C). Observations indicated that the temperatures increased from the upstream of River Kuja (Appendix 3) towards the Lake as the vegetation cover along the river decreased.

Temperature is an important physical parameter that determines the distribution of organisms in the aquatic environment. Different organisms have different optimal temperatures for their survival. A study by Collier and Smith (2000) found out that riparian vegetation plays a crucial role in influencing water temperature which in turns affects survival of macroinvertebrate communities.

Any fluctuations in water temperature will consequently affects behavior choices of aquatic organisms ; moving to warmer or cooler water after feeding, predator-prey responses and migration routes, species like sharks and sting rays will move to warmer waters when pregnant (Bennett & Di Santo, 2011). It's known that under low temperature fish feeding and mobility is adversely affected. Study by Lucas and Batley (1996) showed that after multiple winter floods, adult barbel (*Barbus barbus*) were found several kilometers downstream from their wintering habitats, where they had been largely physically inactive. This was simply because of the low temperatures experienced during winter which make fish inactive and cannot feed normally. This findings are in agreement with findings of this study where *L. altianalis* were found to be active during the dry season and had most of their guts full compared to the wet season (low temperatures).

Temperature has been found to also affect feeding rate of invertebrates and fish, with the feeding rate varying significantly at different temperatures (Kishi, Murakami, Nakano & Maekawa, 2005). Such low temperatures as 16.04^{o}C that at certain times were measured at Kegati in River Kuja were not conducive for fish feeding. It was also clear that fish food organism favors areas with optimal temperatures for their survival. It can be concluded that higher abundance of fish and fish food organism observed at the sampling sites were attributed to higher mean temperature at Kanga downstream closer to Lake Victoria (24.90 ± 1.13°C) and Gogo falls (25.60 ± 0.29°C) during the dry month of February. Temperature also affects the distribution of fish, in this case *L. altianalis* whereby it concentrates itself in areas in which the density of this food items is high whose its distribution there is determine by temperature. Water temperature greatly affects geographic distribution of a species (Dallas, 2008) and any variations in water temperature may lead to structural changes in the abundance, biomass, diversity and composition of aquatic communities like fish.

5.1.7 Conductivity

Conductivity is the measure of the electrical activity of dissolved positive and negative ions in a solution. It's a measure of the extent to which a solution can conduct electric current; it is measured in μScm^{-1}. Any sudden increase or decrease in conductivity in a water body indicates pollution, agricultural runoff or a sewage leakage will increase conductivity due to an additional of chloride, phosphates and nitrate ions (EPA, 2012). The results generally showed that as the conductivity increases the amount of fish food organism also increased. Although there seems to be a weak relationship between the level of conductivity and distribution of fish food organism, the later occurred in higher numbers where conductivity was higher. This is because high conductivity positively enhances primary productivity which forms the energy base of all other aquatic organism. Conductivity therefore affects both the distribution and abundance of fish and their food organism in the aquatic environment. This is why among other reasons *L. altianalis* was observed to concentrate in areas of high conductivity where most of it food item were distributed. Since total dissolved solids is directly related to conductivity the distribution of *L. altianalis* and its food organisms seem to follow same pattern as that exhibited by conductivity whereby higher numbers of fish food organism was found in places with high TDS, *L. altianalis* followed the same pattern.

5.2 Distribution of fish food items along River Kuja

It was observed that the total number of fish food items in most of the sampling sites differed significantly between the dry and the wet season (Table 3 and 4). The depth of water at different sampling stations is not the same and also the natural productivity. During the wet season most of the foods items are washed downstream by floods. The flow rate is higher during wet season and also the geochemistry of the sampling sites varies from place to place. Siltation sediment some of the fish food organisms such as algae making it inaccessible to fish. Further, the water flow regime downstream sampling sites is different from the upstream sampling sites. Habitat characteristics of the sampling sites varied from one site to another spatially and temporally hence these factors contributes to differences in the number of fish food items at sampling sites. It is also known that diet composition of fish varies depending on temporal and spatial conditions and environmental factors (Tesfahun & Temesgen, 2018).

Kegati and Gogo falls shared almost the same characteristic (reeds growing around it banks and very little disturbance from human activities) and thus both had highest number of food items.

Kegati had the highest food items since it's the first flow of water, it also has a stationary point with a lot of reeds, so water settled there for sometime before being discharged downstream. The reeds act as a habitat for most food items and also breeding areas for fish. The riparian zone for Kegati is highly vegetated and bushy thus reasons for high number of food items. Ogembo on the other hand had the lowest number of food items which can be attributed to pollution and dumping of waste from Ogembo town. The site was located just next to the Ogembo trading centre and a lot of water abstraction , dumping of waste, animal grazing, car washing, farming along the banks not leaving any riparian vegetation along the site. All these activities might have contributed to the low number of food items at the site. The pollution brought around by waste could drive away most aquatic organisms. The reason why Kanga had the lowest food items was observed to be the first flow of water and also similar observation was made at Gogo falls which had similar water flow conditions.

There were significant differences in the distribution of fish food items as well as the fish themselves at the different sampling stations in River Kuja. The abundance of *L. altianalis* during wet and dry season significantly differed among the five different sampling stations ($x^{2}_{0.05}$ df, $20=369.31>31.14$ and $x^{2}_{0.05}$ df, $20=139.17>31.14$) respectively following a similar trend of food items hence the null hypothesis that there were no significant differences in the abundance of *L. altianalis* at the different sampling stations is rejected and the alternate hypothesis accepted.

The differences in the numbers of fish food items during the dry and wet season explain the observed differences in the occurrence, composition and selectivity by *L.*

altianalis in River Kuja.

Few studies exist on the food composition occurrence and selection of *L. altianalis* in Lake Victoria and its basin. In this study the major food items of the species were Diptera, detritus, algae, plant matter and zooplankton while the minor ones were Ephemeroptera, Coleopteran, fish scales and Decapoda. The percentage compositions of fish scales in guts of fish were very low. This could be due to the fact that *L. altianalis* does not directly feed on fish scales, inferring that the scales were probably picked accidentally while the fish were feeding on the benthic material.

A study conducted by Chemoiwa (2018) along River Nyando within Lake Victoria basin, Kenya revealed that *L. altianalis* fed on ten different food items; herbaceous plant materials, algae, invertebrate classes mainly Ephemeroptera, Coleoptera, Diptera, insects, gastropods, and detritus. These findings revealed significant variations in the proportion of different food items at the different sampling sites which is in agreement with the findings of this study.

Other studies on the food composition and occurrence have been conducted in Ethiopian Lakes. Despite the fact that the food of *Labeobarbus* species is similar in different types of lakes and aquatic habitats of East Africa, there are some significant variations of the food composition and occurrence in different habitats exists. In addition, the number of food items fed on by the species varies from locality to locality. For instance studies in Lake Hawassa by Desta et al. (2006) on major difference in mercury concentrations of the African big barb, *Barbus intermedius* due to shifts in trophic position showed that the fish fed on molluscs, fish prey and aquatic insects. In

Lake Koka, Dadebo et al. (2013) found that the fish fed on macrophytes, detritus and aquatic insects, while in Lake Tana studies by Sibbings (1998) and De Graaf (2003) indicated that the fish fed on benthic prey specifically insects larvae and detritus. Witte and Winter (1995) reported that fish species fed on three categories of food items during predatory stage (Juvenile and adult) including; plants, zoobenthos and bony fish. The general picture that emerges from all these studies is that the species is omnivorous though the diet composition varies from habitat to habitat.

5.3 Ivlev`s electivity indices

Decapoda and Odonata was the most ubiquitous organism in River Kuja and they had the highest percentage composition of all the invertebrates. When their Ivlev’s indices of electivity are compared with those of other organism, it can be deduced that they are generally higher. Interestingly enough therefore they seem to be the most preferred food items by *L. altianalis* in the River.

Some food items such as Hemiptera were present in the River Kuja in significant percentage composition yet *L. altianalis* mostly avoided feeding on them as their Ivlev’s indices of electivity were mostly as much as -1. Studies need to be conducted to establish the reason why the fish avoided Hemiptera and other organisms in the river. Some food items were positively selected as a food item in one season or habitat while they were avoided in the other seasons or habitats. This could be due to the fact that there were no food items so that they could be selected in one season, while in some instances they were avoided, this could be due to presence of more preferred food items. Diptera had the widest distribution in the river during the dry season (Table 5) while Haplotaxida and Hirudinida were the least widely distributed order and had the least distribution during the wet season (Table 6). Diptera is a pollution tolerant taxa while Ephemeroptera is a pollution intolerant taxa, this helps to explain why Diptera was widely distributed during dry season while Ephemeroptera was absent especially in the downstream station, Wath Onger. Margolis, Raesly and Shumway (2001) claimed that changes in assemblages of benthic macroinvertebrate are brought about by differences in the ability of resident genera to tolerate the environment around it but not changes in the quality and availability of food item.

From the findings, there were differences in the mostly widely distributed organism in the river during wet and dry season. In the wet season (Table 6), Hemiptera were the most distributed while Diptera were the most widely distributed in the dry season. Some food items such as Pulmonata were strongly avoided with their Ivlev's electivity indices being mostly as high as -1 (Table 13, these do not constituted the food of *L. altianalis*. The negative values of electivity showed that they were mostly avoided because of the hard shell possessed by most of its members which is hard to handle and digest by fish. This implies that *L. altianialis* can be able to detect its prey in water and it's therefore a visual feeder.

There was an observed size dependence of food items by fish whereby the Ivlev's indices of electivity for example of Diptera increased with the increased size of *L. altianalis* (Table 10). This means that older fish had much more strong electivity relative to smaller fish. The reason could be that smaller *L. altianalis* are not efficient in handling the Diptera invertebrate as food compared to the bigger *L. altianalis*, this is because the smaller fish have a smaller mouth gape and therefore not capable of ingesting the larger size food items which much bigger and older fish were able to. It could be further due to the fact that smaller fishes do feed on other simpler food items such as algae which are easier to handle. Studies by (Dadebo et al., 2013) showed that there is size dependence on the type and quantity of food items consumed by fish. For example, fingerlings of *Labeobarbus* in Lake Koka, Ethiopia were found to feed mainly on detritus and insects while adults were found to feed on macrophytes, detritus and insects. However in some cases for other food organism there was no observed size dependence of electivity of food items (Table 14 and 15). This means that both smaller and bigger *L. altianalis* were able to feed on these food categories with no discrimination.

In a mixed electivity there could have been a wide variety of food item which made the *L. altianalis* to randomly pick any of them as food. In this case one can expect a mixed electivity of both acceptance and avoidance of food item to exist.

The presence of fish scales in the guts of *L. altianalis* is not a clear indication that it feeds on its smaller fish, the percentage contribution was too low as compared to other food items which formed the bulk of the diet. In the Ethiopian lakes, some studies showed that fish were some of the major food items of the species. For example in Lake Tana, Ethiopia, Negelkerke (1997) found out that five out of eight big barbs were found to be specialized on fish as the major food items. In this study, fish did not constitute a major food items in the guts of *L. altianalis*, the only item which seems to indicate that the fish had fed on fish was the presence of fish scales in the guts that were analyzed. It’s not clear that these scales came from fish that were fed on by the species. Alternatively, these scales could have been picked from bottom sediments or detritus. It could have also originated from dead fish that could have sank to the bottom of the river due to a number of reasons, for example, dead due to diseases, natural mortality or screeded scales by other fish such as *Clarias gariepinus*, Synodontis species and Nile perch that predominantly feed on fish. Feeding on fish (piscivory) by fish of similar genera has also been observed in Europe (Desta et al., 2006). Also in Africa piscivory has been observed among similar genera of cyprinidae (Dadebo et al., 2013).

CHAPTER SIX

6.0 CONCLUSION

Labeobarbus altianalis in River Kuja feeds on a wider variety of food item with age being an important factor on selectivity. The food items that were identified in the diet of *L. altianalis* included: algae, detritus, insects, zooplankton, phytoplankton, fish scales, benthic macroinvertebrates, and macrophytes. Insects and detritus were the most important food item identified in the guts during the study while algae, fish scales and plant remains were not majorly fed on and thus had lower contribution as food items.

During the dry season, numbers of food items were higher in the various stations compare to the wet season which had lower number of food items. Detritus and insects were mostly consumed by younger fish and as they grow older, they varied their diet to insects, detritus, phytoplankton, fish remains and bivalves.

Riparian vegetation highly played an important role in the life of a fish by acting as sources of food, nursery grounds and a hide out from predators. Physicochemical parameters play an important role in determining the availability of a food item in any water body.

Labeobarbus altianalis was therefore found to be an omnivorous fish feeding mostly on insects and macrophytes.

6.1 RECOMMENDATION

Due to varied agricultural activities taking place along River Kuja, farmers should be trained more on preservation of riparian sites which could lead to loss of fish breeding and nursery sites and proper waste disposal from factories. Stakeholders should come together and form laws and regulations which guides on fishing in rivers, this will greatly improve fish population in the river and subsequently in the Lake Victoria.

Community empowerment should be done by enhancing poverty alleviation programs such as micro-financing on aquaculture, formation of community based ecosystem management, provision of infrastructure and clean water which will ease and reduce fishing pressure and water abstraction in rivers and improve livelihoods of communities who depends mostly on fishing.

Labeobarbus altianalis is not categorized as an endangered species by IUCN but instead under species of least concern this is due to lack of adequate information, more research on distribution and ecology of the species should be conducted to generate more information which will guide on conservation.

Since the species lives in diverse habitats, awareness on its social and economic importance should be made by responsible authorities so as to avoid extinction by regulating erosion, deforestation and human settlement along rivers which they inhabit.

In future studies, more time should be allocated so as to deal with several aspects of feeding and check whether the food items ingested is really incorporated to the fish somatic growth.

There would be need to conduct 24 hours sampling on the food consumption of *L. altianalis* to estimate stomach or gut evacuation rates which are useful in estimating the food consumption per unit biomass of fish. This is important in estimating energy efficiency transfer between the different tropic levels in which the species is involved and ultimately in estimation of the impact of the fish on its prey population.

REFERENCES

Admassu, D., & Dadebo, E. (1997). Diet composition, length-weight relationship and condition factor of *Barbus species (Rüppell, 1836) (*Pisces: Cyprinidae) in Lake Awassa, Ethiopia. *Ethiopian Journal of Science 20*, pp 13-30.

Ali, N.S., Mo, K., & Kim, M. (2012). A case study on the relationship between conductivity and dissolved solids to evaluate the potential for reuse of reclaimed industrial wastewater KSCE, *Journal of Civil Engineering 16,* 708-713.

Assaminew, K. (2005). Distribution, abundance and feeding biology of fish species in Koka reservoir and the associated Awash River floodplain, Ethiopia. . Unpublished M.Sc Thesis. UNESCO-IHE Institute for Water Education, Delft.

Balcombe, S.R., Bunn, S.E., Davies, P.M., & Smith, F.J. (2004). Variability of fish diets between dry and flood periods in an arid zone floodplain river. *Journal of Fish Biol*ogy (55): 609-617.

Balirwa, J.S. (1979). A contribution to the study of the food of six cyprinid fishes in three areas of the: Lake Victoria basin, East Africa. *Hydrobiologia* (66), 65–72.

Banyankimbona, G., Vreven E., Ntakimazi G., & Snoeks J., (2012). The riverine fishes of Burundi (East Central Africa); An annotated checklist. *Ichthyological Exploration of Freshwaters, 23*(3), 273-288.

Begum, M., Alam, M.J., Islam, M.A. & Pal, H.K. (2008). Food and feeding habit of an estuarine catfish *Mystus gulio,* in the south-west coast of Bangladesh. *University Journal of Zoology, 27*, 91-94.

Bennett, W.A., & Di Santo, V. (2011). *Effect of rapid temperature change on resting routine metabolic rates of two benthic elasmobranchs.* Fish Physiol Biochem. Springer Science.

Berrebi, P., & Tsigenopoulos, C.S. (2003). Phylogeny and biogeography of the family Cyprinidae in the Middle East inferred from cytochrome b DNA-evolutionary significance of this region. *Molecular Phylogenetics and Evolution, 22* (1), 91-100.

Bonzemo, W.S. (2013). *Assessment of water quality status of River Kibisi, Kenya using the Ephemeroptera, Plecoptera and Trichoptera (ept) index*. Unpublished Msc. Thesis Kenyatta University, pp 73.

Breder, C.M., & Rosen D.E.(1966). *Modes of reproduction in fishes*. T.F.H. Publications, Neptune City, New Jersey.

Chapman, L. J., Schneider, K. R., Apodaca, C., & Chapman, C. A. (1996). Respiratory ecology of macro-invertebrates in a swamp river system of East Africa., *Biotropica*, *36* (4), 572-585.

Chemoiwa, E.J., ., Abila, R. E., Njenga , E., & Barasa J. E. (2017). Morphological characterization and relationship between morphometric parameters and standard length *Barbus altianalis.* Populations in Lake Victoria drainage basin, Kenya. *ARRB, 14*(5)*, 1-11.*

Chemoiwa, E.J., & Hilda J. (2018). Spatial Variation in Food selection, Feeding Habits, and Ontogenetic Diet Shift of Labeobarbus altianalis (Boulenger, 1900) along River Nyando, Kenya. *African Journal of Education, Science and Technology, 4*. (3).

Chemoiwa, E.J., Abila R., Macdonald A., Lamb J., Njenga E. & Barasa E. (2013). Genetic diversity and population structure of the endangered ripon barbel, *Barbus altianalis* (Boulenger, 1900) in Lake Victoria catchment, Kenya based on mitochondrial DNA sequences. *Journal of applied ichthyology*, *29* (6), 1225-1233.

Collier, K., & Smith, B. (2000). Interactions of adult stoneflies (Plecoptera) with riparian zones. Effects of air temperature and humidity on longevity. *Aquatic Insects, 22*, 275-284.

Copley, H. (1958). *Common freshwater fishes of East Africa*. H.F., & G. Witherby Ltd., London, 172p.

Corbet, P.S. (1961). The food of non-cichlid fishes in Lake Victoria basin, with remarks on their evolution and adaptation to lacustrine conditions. *Journal of Zoology*, *136* (1), 1-101.

Dadebo, E., Tesfahun A., & Teklegiorgis Y. (2013). Food and feeding habits of the

African big barbLabeobarbus intermedius (Rüppell, 1836) (Pisces: Cyprinidae) in Lake Koka, Ethiopia. *E3 Journal of Agricultural Research and Development, 3*(4), 049-058.

Dallas, H. (2008).Water temperature and riverine ecosystems: *An overview of knowledge and approaches for assessing biotic responses, with special reference to South Africa*, *34*(3) 0378-4738, (2008, July)

De Graaf, M. (2003). The piscivorous barbs of Lake Tana (Ethiopia):major questions on their evolution and exploitation. *Netherlands Journal of Zoology 50*(20), 215-223.

De Stefano, S., & De Graaf, R.M. (2003). Exploring the ecology of suburban wildlife. *Frontiers in Ecology and the Environment 1*, 95–101.

De Vos, L. & Thys Van den Audenaerde, D.F.E. (1990). *Description de Barbus Claudinae sp.n. (cyprinidae) avec synopsis des grandes especes de Barbus du Rwanda*. *Cybium 14*(1), 3-25.

Deribe, E., Børgstrøm, R., Rosseland. B.O., Salbu B., Norli, H.R., Elko, O.M., …Zinabu, G. M. (2011). Bioaccumulation of persistent organic pollutants (POPS) in fish species from Lake Koka, Ethiopia. *The influence of lipid content and tropic position. Science of the Total Environment,* 410-411.

Desta, Z., Børgstrøm, R., Rosseland, B.O. & Zinabu, G.M. (2006). Major difference in mercury concentrations of the African big barb, Barbus intermedius (R.) due to shifts in trophic position. *Ecology of Freshwater Fish 5*, 532–543.

EPA., (2012). 5.5 *Turbidity. In Water: Monitoring & Assessment*. Retrieved from http://water.epa.gov/type/rsl/monitoring/vms55.cfm. 1/6/2018.

EPA., (2012). 5.9 *Conductivity. In Water: Monitoring & Assessment*. Retrieved from http://water.epa.gov/type/rsl/monitoring/vms59.cfm.

Froese, R., & Pauly, D. (2018). *FishBase. World Wide Web electronic publications*. Retrieved from www.fishbase.org, version (02/2018). 28/5/2018

Getabu, A. (1994). *A comparative study on the feeding habits of Oreochromis niloticus in Nyanza Gulf, Lake Victoria and Sewage ponds. In: Proceedings of the Second EEC Regional Seminar on Recent Trends of Research on Lake Victoria Fisheries, Kisumu, Kenya*, pp; 25–27 September, Kenya, 1992 (Eds E. Okemwa, E. Wakwabi and A. Getabu). ICIPE Press, Nairobi, Kenya.

Greenwood, P.H.(1966). *The Fishes of Uganda*. The Uganda society, Kampala. 131p.

Grover, J.J. (1998). Feeding habits of pelagic summer flounder, Paralichthys dentatus, larvae in oceanic and estuarine habitats. *Fish Bull, 90* (2), 248-257.

Hynes, H.B. N. (1950). The food of the freshwater sticklebacks (Gastrosteus aculeatus) and Pygosteus pungitius) with a review of methods used in studies of the food of fishes. *Journal of Animal Ecol*ogy, *19*, 36-58.

Hyslop, E. J. (1980). Stomach contents analysis*: A review of methods and their application*. *Journal of Fish Biology*, *17*, 411-429.

Ivlev`s, V.S. (1961). *Experimental ecology of the feeding of fishes*. Yale University Press, New Haven, Conn.

Jung, F. (2004). A guide to Tropical Freshwater Zooplankton.Identification, ecology and impact on fisheries. *Aquatic Ecology, 38*, 1-432.

Katunzi, E.F.B, Van Densen, W.L.T., Wanink J.H. & Witte F. (2006). Spatial and seasonal patterns in the feeding habits of juvenile Lates niloticus (L.), in the Mwanza Gulf of Lake Victoria. *Hydrobiologia, 568*,(1) 121–133. https://doi.org/10.1007/s10750-006-0033-3

Kembenya, E.M. (2015). *Broodstock management, larval and fingerling rearing of the cyprinid fish (labeo victorianis ,Boulenger 1901) at Kegati, Kisii Kenya*. Msc. Thesis Kisii University, pp84.

Kishi, D., Murakami, M., Nakano, S., & Maekawa, K. (2005). Water temperature determines strength of top-down control in a stream food web. *Freshwater Biology, 50*, 1315-1322.

Kotrschal, K., Brandstätter, R., Gomahr, A., Junger, H., Palzenberger, M., & Zaunreiter, M. (1991). *Brain and sensory systems*. *In*: Winfield, I.J. and Nelson, J.S. (eds.), *Cyprinid Fishes: Systematics, Biology and Exploitation.* Chapman and Hall, London, pp. 284–331.

Lizeth, B. (2001). *Phytoplankton Identification.* Catalogue.GloBallast Monograph Series 2001: *7*, pp1-88.

Lucas, M.C., & Batley, E. (1996). Seasonal movements and behaviour of adult barbel Barbus barbus, a riverine cyprinid fish: Implications for river management. *Journal of Applied Ecology, 33*, 1345–1358.

Margolis, B.E., Raesly, R. L., & Shumway, D.L. (2001). The effect of Beaver-Created wetlands on the benthic macroinvertebrate assemblages two Appalachian Streams. In:, 554-563.

Marlier, G. (1953). Etude biogeographique du basin de la Ruzizi, basee sur la distribution des poisons, *Annalen de la societe Royale Zoologique de Belgique,* *84*(1), 175-224.

Manon, M.R., & Hossain, M.D., (2011). Food and feeding habits of *Cyprinus carpio var. specularis. Journal of Science Foundation, 9* (1 & 2): 163-181, June - December 2011.

Mengesha, M. (2009). *Heavy metal pollution in the rift valley Lakes of Awassa and Koka*. Unpublished M. Sc Thesis. University of Bremen, Germany.

Motamedi. M., Madjdzadeh S. M. , Teimori A., Esmaeili H. R., & Mohsenzadeh S. (2014) Morphological and Molecular Perspective on Geographical Differentiation of *Barbus* Populations (Actinopterygii; Cyprinidae) within Iranian Freshwater Drainages. *Turkish Journal of Fisheries and Aquatic Sciences 14, 339-351.* doi: 10.4194/1303-2712-v14_2_05

Mulanda, A., (2008). *Macroinvertebrate Index of Biotic Integrity for Assessing the Water Quality of Rivers Kipkaren and Sosiani, Nzoia River Basin, Kenya*. M.Sc, Moi University, pg 12.

Muyodi, F.J., Mwanuzi, F.L., & Kapiyo, R. (2011). Environmental quality and fish communities in selected catchments of Lake Victoria. *The open environmental engineering journal, 4,* 54-65.

Nagelkerke, L. (1997). *The barbs of Lake Tana, Ethiopia: morphological diversity and its implications for taxonomy, trophic resource partitioning, and fisheries*. Unpublished Ph. D Thesis,Wageningen Agricultural University, Wageningen, the Netherlands.

Njiru M., Okeyo-Owuor, J. B., Muchiri, M., & Cowx, I. G. (2004). Shifts in the food of Nile tilapia, *Oreochromis niloticus (L.)* in Lake Victoria, Kenya*. African Journal of*

Ecology, 42(10), 163–170.

Ntakimazi, G. (2006). *Barbus altianalis. The IUCN Red List of Threatened Species 2006:e.T61243A12452945.* Retrieved from *http://dx.doi.org/10.2305/IUCN.UK.2006.RLTS.T61243A12452945.en*. 19/6/2018.

Ogari. J. (1988). *Predator-prey relationship in Lake Victoria with special reference to Nileperch (Lates niloticus) (Linne). In D. Lewis (ed). Predator-prey relationship, populations dynamics and fisheries of large African lakes.* Committee for Inland Fisheries of Africa (CIFA), Occasional paper. 15, 53-58.

Ogutu-Ohwayo, R. (1990). The decline of native fishes of Lake Victoria and Kyoga (EastAfrica) and the impact of introduced species, especially the Nile Perch, *Lates niloticus* and Nile tilapia, *Oreochromis niloticus*. *Environmental biology of fishes* pp.81-96.

Ojany, F. F., & Ogendo, R. B., (1986): *A Study in Physical and Human Geography; Longman, Kenya.*

Omondi, R, Yasindi, A.W., & Magana, A.M. (2011). “Spatial and temporal variations of zooplankton in Relation to some environmental factors in lake Baringo, Kenya”. *Egerton Journal of Science and Technology, 11*, 29-50.

Orina, N. E., Getabu, A., Omondi, R., & Sigei, E**. (**2018). Ecosystem integrity of River Kuja based on habitat and fish biotic indices. *Journal of tropical hydrobiology and fisheries, 1*(1), 7-13.

Outa, N.O., Kitaka, N., & Njiru, J.M. (2014). Some aspects of the feeding ecology of Nile tilapia, *Oreochromis niloticus* in Lake Naivasha, Kenya. *International Journal of*

Fisheries and Aquatic Studies, *2* (2), 1-8.

Owen, O. (1975). *Some involved in the use of dissolved oxygen distribution in streams to determine productivity*. Memorial International Hydro-biology 18 Supplementary, pp 209-224.

Palamuleni, M., Simic, V., Simonovic, P., Cvijan, M. Subakov, G.,…Gacic, Z. (2001). *Biological Research Quality Elements in WFD implementation in Serbia – typology, reference conditions and ecological status class boundaries*. Technical Report Contracts No. 01-300-2007, 01-560-2007 and 01-1325-2007. Institute for Biological Research “SinisaStankovic.” Beograd 1-209.

Pillay, T.V., & Kutty, M.N. (2005). *Aquaculture principles and practices.* 2nd edn. Wiley-Blackwell. pp.67.

Robbins, C.R., Bailey R.M., Bond C.E, Brooker J.R., Lachner E.A.,…Scott, W.B. (1991). *World fishes important to North Americans*. Exclusive of species from the continental waters of the United states and Canada. American Fisheries Society Special Publication (21): 243p.

Rutaisire, J., Berta L., Cassius A., & Constantine C. O. (2013). *Gonadal recrudescence and induced spawning in Barbus altianalis*. *Aquaculture research*, 1-10. doi:10.1111/are.12213

Sandipan, G. & Banerjee, S. (2013). Food and feeding habit of *Amblypharyngodon mola,* In West Bengal, India. *International Journal of Scientific Research 2*(5), 67-71.

Sarkar, U.K. & Deepak, P.K. (2009). The diet of clown knife fish *Chitala chitala* an endangered Notopterid from different wild population (India). *Electronic Journal of Ichthyology, 1*, 11-20.

Seegers, L., De Vos, L., & Okeyo, D. (2003). Annotated Checklist of the Freshwater Fishes of Kenya (excluding the lacustrine haplochromines from Lake Victoria). *Journal of East African Natural History, 92*(1), 11-47.

Sibbing, F.A., & Nagelkerke L. (2001). *Resource partitioning by Lake Tana barbs predicted from fish morphometrics and prey characteristics. Reviews in Fish Biology and Fisheries 10*: 393-437.

Sibbing, F.A. (1998). Ecomorphology as a tool in fisheries: identification and ecotyping of Lake Tana barbs (Barbus intermedius Complex), Ethiopia. *Netherlands Journal of Agriculture and Science, 42*: pp.77-85.

Stergiou, K.I., & Karpouzi, V.S. (2002). Feeding habits and tropic levels of Mediterranean fish. *Reviews in Fish Biology and Fisheries 11*: 217–254.

Skelton, P.H., (2001). A complete guide to the freshwater fishes of Southern Africa. *African journal of Aquatic Science, 27*(2), 171-174.

Snoeks, J., Kaningini, B., Masilya, P., Nyinza- Wamwiza, L., & Guillard, J. (2012). Chapter 8. *Fishes in Lake Kivu: Diversity and Fisheries*. pp. 127-152.

Strauss, R.E. (1979). Reliability estimates for Ivlev`s electivity index, the forage ratios and a proposed linear index of food selection. *Trans America Fisheries Society .108*(4), 344-355.

Tesfahun, A. & Temesgen, M. (2018). Food and feeding habits of Nile tilapia *Oreochromis Niloticus* (L.) in Ethiopian water bodies. *International Journal of fisheries and aquatic studies, 6*(1), 43-47.

Van Oijen, M.J. (1995). Appendix 1.*Key to Lake Victoria fishes other than haplochromine cichlids*. Pp.209-300. In F.Witte and W.L.T. van Densen (eds.)

Fish stocks and fisheries of Lake Victoria. A handbook for field observations. Samara publishing Limited, Dyfed, Great Britain.

Wetzel, R.G. (2001). *Limnology*: Lake and River Ecosystems (3rd ed.). San Diedo, CA: Academic Press. pp.17.

WHO, (2000). *Guidelines for Drinking Water Quality*. World Health Publication. NY, USA.

WHO, (2006). *Surveillance of drinking-water quality*. Geneva, Monograph Series No. 63.

WHO, (2015). UN-Water Glaas Trach Fin Initiative: *Tracking financing to sanitation, hygiene and drinking-water at the national level.* Guidance document summary for decision-makers. Geneva Switzerland.

Wetherbee, M.B., & Cortes , E. (2004). Food consumption and feeding habits. March 2004, DOI: 10.1201/9780203491317.ch8.

Witte, F., & Winter W. de. (1995). Appendix 11. *Biology of the major fish species of Lake Victoria.* pp. 301-320. In F. Witte and W.L.T. Van Densen(eds.). *Fish stocks and fisheries of Lake Victoria.* A handbook for field observations. Samara Publishing Limited Dyfed, Great Britain.

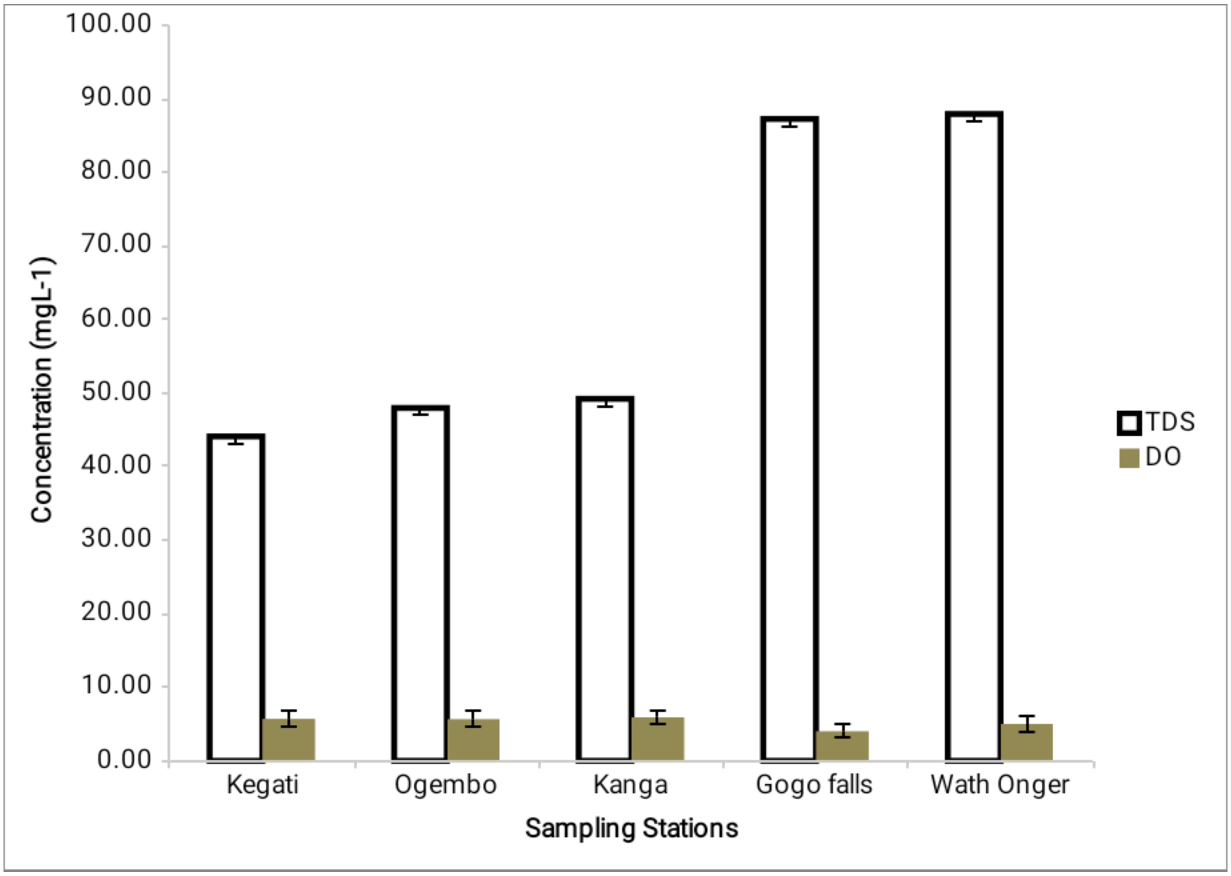
Witte, F., Gouwdswaard, T., Katunzi, E.F.B., Mkumbo, O.C.,Seehausen, O., & Wanink, J.H. (1999). *Lake Victoria'secological changes and their relationships with their riparian societies*. In: Ancient Lakes: Their Cultural and Biological Diversity (ed. by H. Kawanabe, G.W. Coulter & A.C. Roosevelt), pp. 189–202. Kenobi Productions, Belgium.

Yongo, E., Manyala, J.O., Kito, K., Matsushita,Y., Outa N.O., & Njiru, J.M. (2016). Diet of of silver cyprinid, *Rastrineobola argentea* in Lake Victoria, Kenya. *International Journal of Advanced Research, 4*(4), 144-149.

APPENDICES

Appendix 1: Spatial variations of dissolved oxygen concentration and total dissolved solids in River Kuja during the period November 2016-August 2017

The black vertical error bars represent standard deviations.

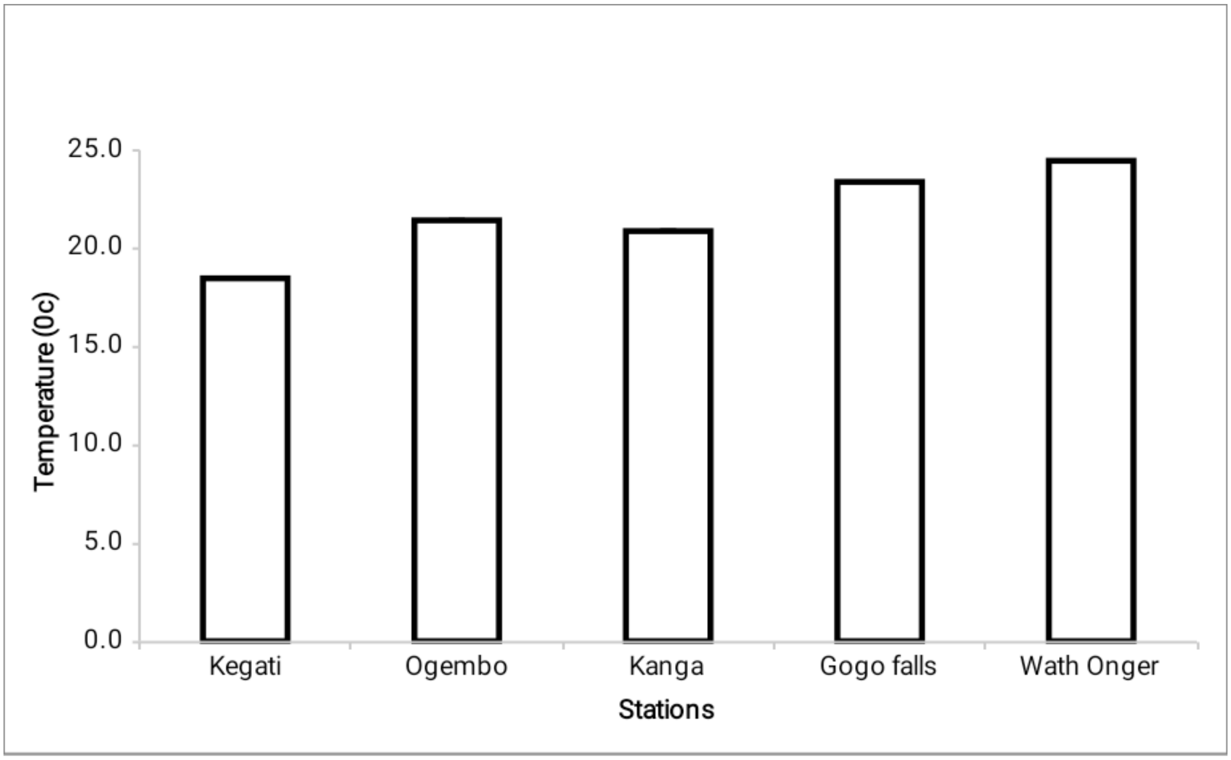


Appendix 2: Temporal variations of dissolved oxygen concentration and total dissolved solids in River Kuja during the period November 2016-August 2017

Month	RANGE	X	SD	SE	CI(95%)

November	3.46-6.22	4.97	1.12	0.50	1.39
December	2.00-5.3	3.64	1.39	0.62	1.39
January	2.00-5.30	3.64	1.39	0.62	1.73
February	4.5-6.00	5.42	0.60	0.27	0.74
March	4.46-6.75	5.80	0.86	0.38	1.06
April	3.46-6.22	4.77	0.91	0.41	1.13
May	3.46-6.22	4.97	1.12	0.50	1.39
June	5.23-7.36	6.47	0.84	0.38	1.05
July	3.46-6.22	4.97	1.12	0.5	1.39
August	5.23-7.36	6.67	0.89	0.4	1.11

Appendix 3: Spatial variations of temperature in River Kuja during the period November 2016-August 2017

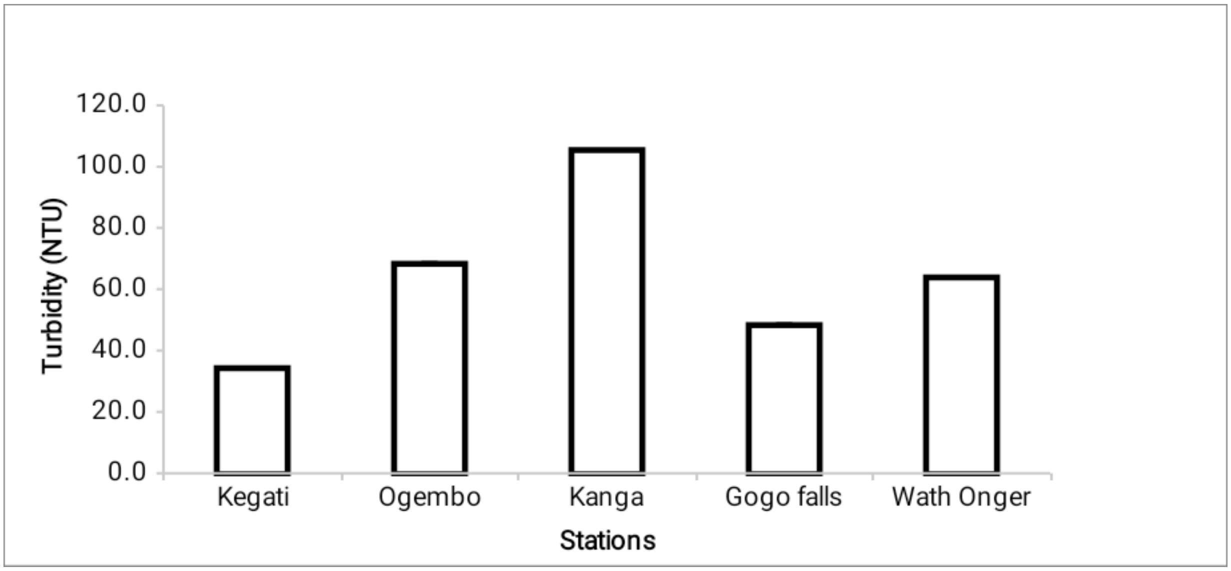

25.0
20.0
15.0
10.0
5.0
0.0
Temperature (0c)
Kegati
Ogembo
Kanga
Gogo falls
Wath Onger
Stations

Appendix 4: Temporal variations of temperature in River Kuja during the period November 2016-August 2017

Month	RANGE	X	SD	SE	CI(95%)
November	16.5-26.66	20.7	4.08	1.82	5.06
December	19.4-26.5	24.60	2.83	1.26	3.51
January	20.0-23.0	22.26	1.13	0.52	1.41
February	19.4-25.9	24.16	2.69	1.20	3.34
March	16.90-25.66	20.94	3.49	1.54	4.29
April	16.06-26.66	21.51	4.25	1.9	5.28
May	19.7-21.25	20.37	0.65	0.29	0.81
June	21.1-24.00	22.5	1.08	0.49	1.35
July	16.05-26.66	20.61	4.2	1.88	5.21
August	16.64-22.62	10.88	2.53	1.13	3.14

Appendix 5: Spatial variations of turbidity in River Kuja during the period November

2016-August 2017

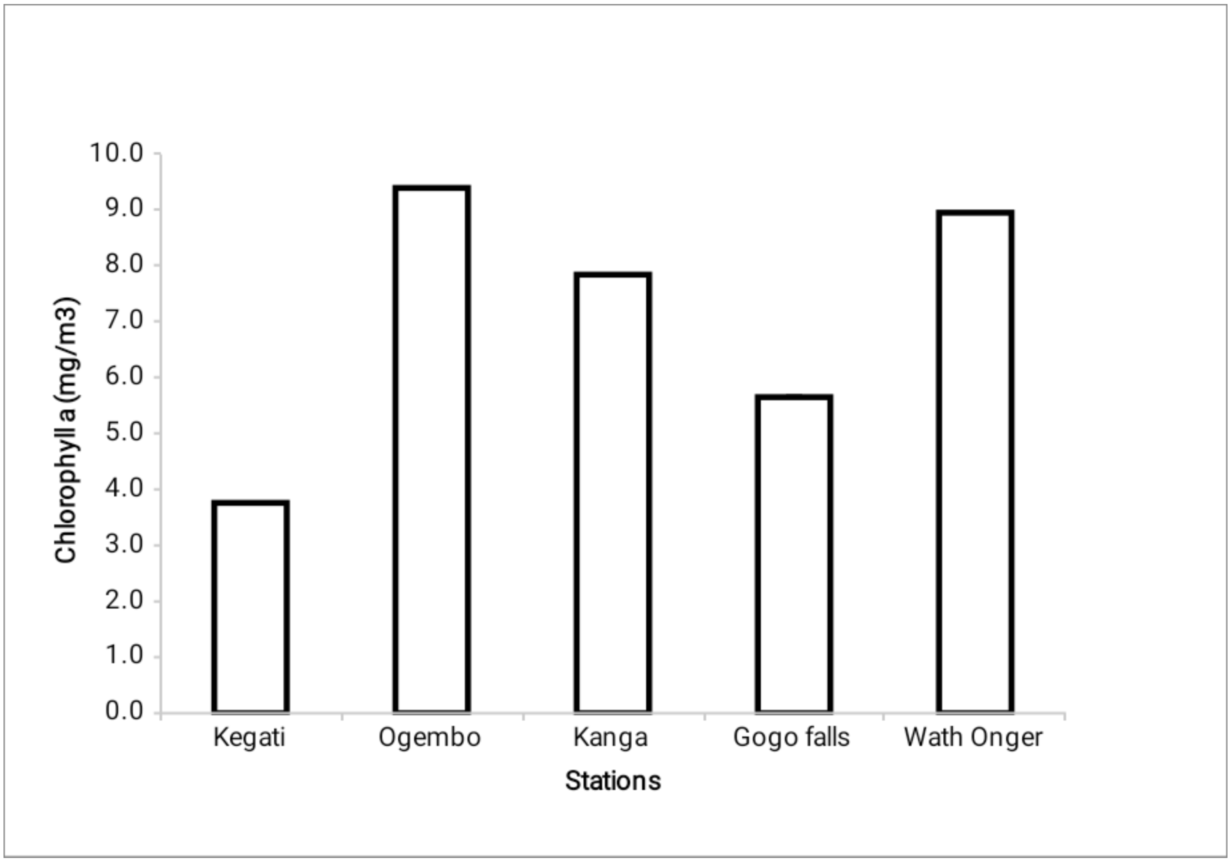


Appendix 6: Temporal variations of turbidity in River Kuja during the period November

2016-August 2017

Month	RANGE	X	SD	SE	CI(95%)
November	29-136.75	53.55	46.55	20.82	57.8
December	46.2-150.4	73.76	44.69	19.99	55.49
January	22.5-129.6	51.41	44.36	19.84	55.08
February	22.8-123.00	50.26	41.52	18.57	51.55
March	20.64-130.75	50.07	45.56	20.37	56.57
April	27.30-136.75	53.58	46.70	20.9	58.02
May	29.7-136.75	53.55	46.55	20.81	57.79
June	48.2-280.56	138.38	89.86	40.18	111.58
July	29.64-136.75	53.55	46.55	20.81	57.79
August	48.2-280.56	138.37	89.87	40.19	111.59

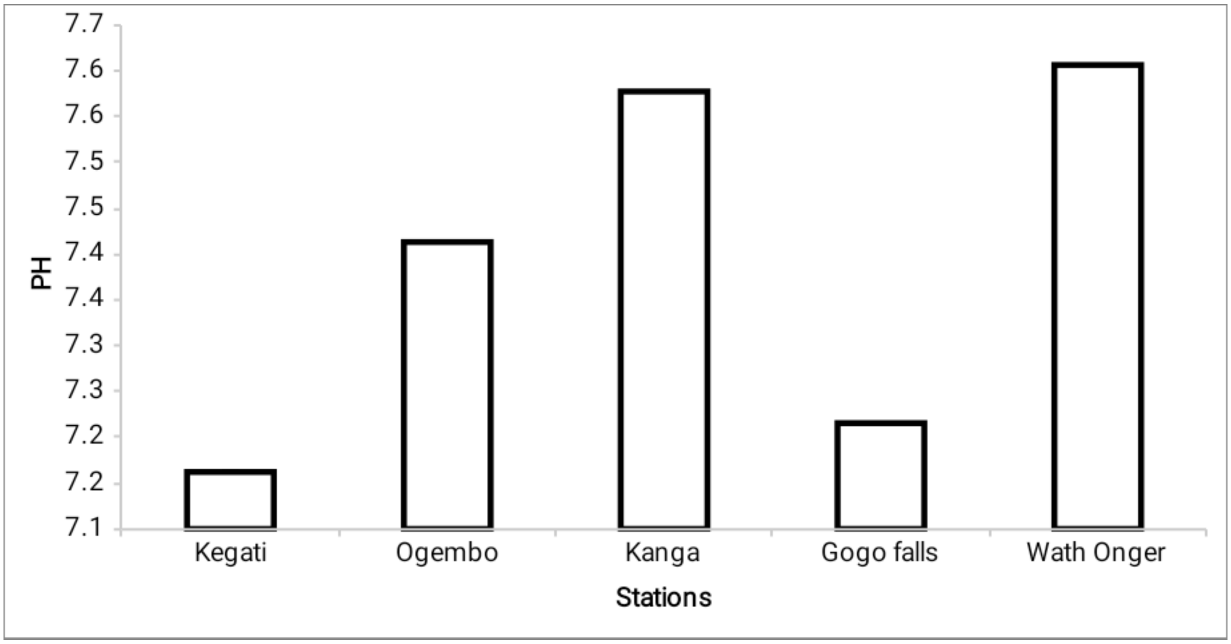
Appendix 7: Spatial chlorophyll a concentrations in River Kuja during the period November 2016-August 2017



Appendix 8: Temporal chlorophyll a concentrations in River Kuja during the period November 2016-August 2017

Month	RANGE	X	SD	SE	CI(95%)
November	6.9-16.8	10.5	3.45	1.54	4.28
December	3.6-18.00	9.60	6.28	2.81	7.8
January	4.0-20.0	5.86	1.32	0.59	1.64
February	2.00-6.00	4.04	1.82	0.82	2.26
March	5.18-12.6	8.15	3.05	1.36	3.79
April	2.18-7.25	4.42	2.06	0.92	2.56
May	0.4-6.00	1.63	2.44	1.09	3.04
June	4.0-10.78	7.52	2.82	1.26	3.5
July	5.18-5.18	5.35	1.03	1.5	1.27
August	4.6-13.79	8.72	3.49	1.5	4.33

Appendix 9: Spatial variations of PH in River Kuja during the period November 2016-August 2017



Appendix 10: Temporal variations of PH in River Kuja during the period November 2016-August 2017

Months	Range	X	SD	SE	CI(95%)
Nov-16	7.33-7.65	7.5	0.13	0.06	0.16
Dec-16	5.8-7.20	6.3	0.65	0.29	0.81
Jan-17	8.00-9.00	8.36	0.42	0.19	0.53
Feb-17	8.00-10.00	8.8	0.83	0.37	1.03
Mar-17	7.15-7.65	7.41	0.18	0.08	0.23
Apr-17	7.33-7.65	7.5	0.13	0.05	0.16
May-17	7-7.62	7.27	0.26	0.12	0.33
Jun-17	5.23-7.36	6.52	0.83	0.37	1.03
Jul-17	7.33--7.65	7.5	0.13	0.06	0.16
Aug-17	6.52-8.65	7.73	0.76	0.34	0.95

Appendix 11: Temporal variations of TDS in River Kuja during the period November 2016-August 2017

Month	RANGE	X	SD	SE	CI(95%)	
50-98	71.2	23.63	10.57	29.34		
November	December	43-95	62.4	26.6	11.75	32.61
January	43-100	65.8	29.03	12.98	36.04	
February	33-95	56	26.85	12	33.34	
March	49-97	70	23.77	10.63	29.52	
April	44-98	69	28.83	10.66	29.59	
May	50-96	56	22.3	9.97	27.69	
June	38.00-70.25	52.08	13.4	5.9	16.63	
July	50.0-98.0	71.2	23.63	10.57	29.34	
August	38.0-70.25	52.08	13.4	5.99	16.63	