SPATIAL VARIATION IN SOME ASPECTS OF BIOLOGY OF *Barbus altianalis*(Boulenger, 1900) ALONG RIVER NYANDO, KENYA

BY

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DECLARATION

Declaration by the Candidate

This thesis is my original work and has not been presented for a degree in any other University. No part of this thesis may be reproduced without the prior written permission of the author and/or University of Eldoret.

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Declaration by the Supervisor

This thesis has been submitted with my approval as University supervisor.

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DEDICATION

This work is dedicated to my Husband Mr Elias Maritim and My son Edsel Maritim.

ABSTRACT

This study aimed at determining the spatial variation in condition factor and growth patterns, fecundity, gonadal maturity stages and feeding habits of *B. altianalis* and further correlates its feeding aspects with selected water quality parameters along River Nyando. Three sites S1 at the upper region; S2 at the mid region and S3 at the lower region closer to the river mouth were sampled. Fish sampling was done using an electrofisher and the sampled fish identified in the field. The length and weight of *Barbus altianalis* were taken in the field to the nearest 0.1 g. The stomachs were gutted and then preserved in vials in 5% formalin for later examination of dietary components; Fresh ovaries were fixed in buffered 10% formalin for 12 hours and stored in 70% ethanol for determination of fecundity. Total weight varied significantly among sites in tandem with variation in TL and condition factor. The highest total weight was recorded at site S1, and the lowest at S2 this could be attributed to food availability where food were more at S1 and water quality which affected fish at S2 due to pollution. Fecundity was found to differ significantly among the sampling locations. Highest fecundity occurred in fish sampled from S1 this could be attributed to the high proportion of females at the station followed by fish sampled from S3 while the least fecundity occurred at site S2. Where there was low proportion of ripe/running females. At all the sampling sites females were significantly higher than males there could be a possibility of sex reversal where males reverse their sex in response to environment another factor could be male mortality due to greater reproductive investment. Ten dietary groups were identified from the guts among the sampling sites. At site S1, ephemeroptera, cladocera and detritus were the dominant food items this was because of its availability in the environment and presence of a higher proportion of mature fish, while S2 were dominated exclusively by insects and diptera and at S3, plant materials, insects and diptera were more dominant. Gastropods plant seeds and algae were consumed by the fish but at low numerical abundance at all the sampling sites due to lack of preference by fish. . There were strong negative electivity for rotifers and copepods by the fish. At site S1, coleoptera and insects were positively selected while at site S2, there was negative electivity for plant materials, and gastropods. At S3, very strong negative electivity was observed for algae, gastropod shells and cladocera with plant materials, coleopteran, plant seeds and detritus having positive selection. Conclusion fish size and condition factor varied between the stations along River Nyando. *B.altianalis* within the upper region was generally bigger in size compared to those around the river mouth. Based on the results of this study and conclusion above, the following are recommended a size frequency research should be done for this fish in River Nyando over a long period of time preferably two years to ascertain spatial variation of Barbus.

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LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
GPS	Global Positioning System
GSI	Gonado-Somatic Index
IUCN	International Union for Conservation of Nature
KMFRI	Kenya Marine Fisheries Research Institute
SL	Standard Length
TL	Total Length
TW	Total Weight

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CHAPTER ONE

INTRODUCTION

1.1 Background information

The Nyando River basin covers an area of 3517 km^2 of Western Kenya. The river basin drains into the Winam Gulf in Lake Victoria. River Nyando has its source originating from the Nandi and Tinderet Hills in Nandi County and Londiani and West Mau Forests in Kericho County and has a total length of about 170 km. The Nyando, which traverses the sugar belt region in Kenya, is apparently polluted by sugar factory effluent (Mugo and Tweddle, 1999).Species abundance and distribution in this river is strongly dependent on habitat type and prevailing conditions(Fayazi et al.,2006)

The ripon barbel (*Barbus altianalis*) is a ray-finned fish species from East Africa in the family Cyprinidae locally known by the Luos in Kenya as *Fuani*It has been found in Lake and its drainage basin and surrounding areas in the East Africa, including Lakes Kyoga, Edward, Kivu and George (Ntakimazi, 2006). It has also been reported in Rivers Ruzizi, and Kagera. It is an omnivore and often fished for sport and food while in Rwanda (Kagera River population) it is used for commercial purposes (De Graaf *et al.*, 2007).

*Barbusaltianalis*inhabits inshore waters and rivers and prefers sand and gravel substrate (Eccles, 1992). Juveniles stay in riverine habitats while adults inhabit diverse freshwater habitat which include both riverine and lacustrine habitats (Eccles, 1992). Gastropod molluscs are an important food item in the lake, while insect larvae are of equal importance in hard bottom areas. Plants, fishes, and crustaceans are also eaten. More plant material is consumed by juveniles (Witte and De Winter, 1995).

The fish is slow growing and therefore takes long to mature. Occurrence and abundance for such a large fish is attributed to its ecological tolerance and omnivorous habits. As a result of its widespread status, the Ripon barbel is not considered threatened by IUCN. However local stocks face a serious threat from siltation of aquatic habitats resulting into increased turbidity. According to De Graaf *et al*. (2007) erosion has seriously affected population of this species in Kagera River and must be addressed. Lack of reliable data could have informed IUCN position that does not consider this species threatened. However, recent developments on habitat destruction and fragmentations for example hydroelectric power projects in Sondu Miriu are real threats to this riverine species.

The maximum total length ever recorded in the world is 90cm (Froese and Pauly 2003). In many temperate and tropical fishes (frequently called multiple,partial, serial, or heterochronal spawners), annual fecundity is seasonally indeterminate and batch fecundity is the only useful measurement. In such fishes the standing stock of yolked eggs,regardless of maturity state, give no indication of annual fecundity because these fishes continuously mature new spawning batches throughout a typically protracted spawning season. In the active ovaries of fishes with indeterminate annual fecundity, the oocytes usually occur in nearly all maturity stages; they range in size continuously from small unyolked oocytes <0.1 mm diameter. to yolkedoocytes 0.4-0.7 mm diameter, and no large hiatus exists between maturity classes of oocytes except for one between hydrated oocytes and advanced yolked oocytes which is of a temporary nature. Such fishes usually spawn many times during a season. According to (Cadwalladr, 1965, Katunzi, 1985), when ripe female and males congregate on their way to spawn in the riverine environment it leads to recruitment overfishing. Apart from overfishing, most of these species are threatened by modification of riverine regimes by human activities such as farming, settlement and pollution from factories. The decline of the species natural stocks has also been attributed to ecological changes that have taken place in Lake Victoria.

As Witte and De Winter, (1995) noted, *Barbus spp* have not been given the deserved attention despite their socio-economic, socio-cultural and ecological importance therefore it is of importance to re-evaluate existing information on the biology of *B. altianalis*

1.2Statement of problem

Populations of *B.altianalis*inKenya have been reported in several rivers including Nyando, Yala, Sondu Miriu, Nzoia and Mara among others (Balirwa and Bugenyi, 1980; Manyala and Ochumba, 1992; Raburu (2003) Ojwang' *et al.*, 2007). Within all these rivers, there has been aspatial trend in the morphometric measurements of the fish. Within these rivers, it has been reported that *B. altianalis* at the river mouths are relatively smaller in size compared to those in the upper regions of the same system (Ojwang' *et al*., 2007). In an attempt to find a reason for this variation in size, several hypotheses have been advanced which include evolution of another sub species or difference in genetic make-up.

Chemoiwa *et al*. (2013) investigated the genetic diversity of the rippon barbell along rivers within Lake Victoria basin and did not find intra-system variation despite the varying size and inter-system variation. This result in part rules out the possibility of evolution of a different species from *B. altianalis*. The cause for the varying sizes has thus remained a puzzle. Other factors that have been found to influence fish growth and size are maturity stages (age), environmental quality, and feeding habits. Electrical conductivity has been found responsible for the stunted growth of Tilapia in Lake Baringo. Quality of feed and feed acceptability are major considerations in aquaculture since they influences growth rates of fish (WRC, 2010). Since these factors (maturity stage, water quality and food items) have not been investigated against the varying sizes of *B. altianalis* this study seeks to investigate the relationship between the three biological aspects and the size and welfare of the fish along River Nyando.

1.3Justification of the study

This study is a situational analysis aimed at establishing the spatial variation in, condition factor, Fecundity feeding habits and composition of gonad maturity stages of *B. altianalis* along River Nyando. The findings of this study will contribute in formulation of conservation strategies aimed at protecting the fish and to the scientific world would try add information on possible reasons for varying sizes along the river. Recommendations on management and sustainable use shall also help the fisher community and conservationists if implemented.

1.4Objectives

1.4.1 Main Objective

To determine spatial variation in some aspects of biology of *B. altianalis* along River Nyando.

1.4.2 Specific Objectives

1. To determine the spatial variation in the condition factor and growth patterns of *B. altianalis* along River Nyando
2. Determine the spatial variation in reproductive strategies (fecundity, gonadal maturation and size at different maturity stage) of *B. altianalis* along River Nyando
3. Determine the spatial variation in the feeding habits and food types of *B. altianalis* along River Nyando
4. To find out the influence of dissolved oxygen, Temperature, pH, Conductivity, TSS, TDS and Turbidity on feeding habits of *B. altianalis* along River Nyando

1.5 Hypothesis

1. There is no spatial variation in condition factor and growth pattern of *B. altianalis* along River Nyando
2. There is no spatial variation in the composition of sex and gonad maturity stages of *B. altianalis* along River Nyando
3. The dietary composition of *B.altianalis* along river Nyando is relatively uniform in type and proportion.

4. Dissolved oxygen, Temperature, pH, Conductivity, TSS, TDS and Turbidity on feeding habits of *B. altianalis* along River Nyando do not influence feeding habits of *B. altianalis* along River Nyando

CHAPTER TWO

LITERATURE REVIEW

2.1 Fish Condition Factor

Condition factor which is a measure of the wellbeing of a fish is derived from the length and weight data of a specific fish. The length-weight relationship (Condition factor and growth exponent) is very important for sustainable use, management and conservation of different populations of fish species (Morey *et al.,* 2003). Length-Weight relationship provides valuable information on the status in terms of quality and resource availability of the habitat where the fish lives (Froese, 2006). This measure can further be used to estimate the standing crop biomass of a given fish population and seasonal variations in fish growth (Pervin *et al*., 2008; Mansor *et al.,* 2010).

Previous studies have shown that length-weight parameters of the same species may be vary in due to differences in feeding habits, reproduction activities, water quality and human activities such as fishing among others. Therefore, data on functional length-weight relationship of fish species is important for fish stock assessment and parameters a and b can be used for length-weight conversion (Froese, 2006). In fisheries science, the condition factor is used in order to compare the "condition", "fatness" or wellbeing of fish. It is based on the hypothesis that heavier fish of a particular length are in a better physiological condition. Condition factor is also a useful index for monitoring feeding intensity, age, and growth rates in fish (Mansor *et al.,* 2010). It is strongly influenced by both biotic and abiotic environmental conditions and can be used as an index to assess the status of the aquatic ecosystem in which fish live (Anene, 2005).

The minimal documented information on this relationship of *B. altianalis* along River Nyando propelled the study. This study in part is aimed at bridging this gap and further attempt to relate it the varying fish sizes and other biological parameters along the river.

2.2Sex and Maturity stages

The study of life-history theory is of fundamental importance to the analysis of population performance and thus to both theoretical ecology and resource management. Life-history theory is based on the concept of trade-off constraints between alternative energy-consuming functions, and the resulting balance between life history traits tends to maximize fitness (Beverton 1963, Roff 1992, Stearns 1992, Charnov, 1993). When various life-history parameters such as growth, maturation and mortality are plotted against each other for a large number of fish species, clear patterns emerge (Pauly 1998, Froese and Pauly 1998). Thus, For instance, tropical fishes are smaller, attain their asymptotic sizes faster, have for any given asymptotic size higher natural mortality, and have higher trophic levels than their colder counterparts (Pauly 1998). Several empirical studies on fishes have shown that some of the emerging patterns are consistent with the trade-off concept such as negative correlations between current reproduction and some component of fitness, usually survival of offspring, mortality and growth (Wootton 1990, Jennings and Beverton, 1991, Stearns 1992, Roff 1992, Pauly 1998).

Parameters of fishes have proven critical in not only the understanding of fish species, but also for their proper management Life history parameters, such as maximum, size at maturity, fecundity, growth rate (adult or larval), stage-specific mortality/survival rate, and spawning seasonality are very important in trying to understand the biology of any fish species(; Parker 1980; Jensen *et al*., 1982; Saila *et al*., 1997; Lo *et al*., 2005; Newbold and Iovanna 2007). Sufficient research effort into these parameters has been generally limited to commercially important species in Europe that has led to success in their culture (http://www.dfg.ca.gov/marine/lifehistory).

The determinations of the sex ratio and of the sequence of changes in maturity stage during a period of time are of considerable importance in building a thorough knowledge of the general biology of an exploited stock (Achionye-Nzeh, 2010). For some species it may be necessary to maintain routine programmes of sex ratio and maturity stage analyses (Offem *et al*., 2011). The male and female fish of some species, such as Tilapia, Barbus and Sebastes, have different rates of growth and therefore expected to vary in sizes (Howard and Landa, 1958). Mortality rates also differ between sexes which explain dominance of one sex over the other. Moreover, where the catch of a species contains a mixture of stocks, maturity data may provide the best guide to the relative proportions of the stocks in the catches and to changes in these proportions.

The determinations of sex and sexual maturity stages provide basic knowledge of the reproductive biology of a species (Offem *et al*., 2011). The information derived from these analyses can be used in ascertaining the age and size at which fish attain sexual maturity, the time and place of spawning and the duration of the cycle from the beginning of the development of the ovary to the final release of eggs (Benegal and Tesch, 1978). Together with fecundity estimates this information can be used to calculate the size of a stock and its reproductive potential. The age and size at sexual maturity may be important in assessing the optimum age of first capture of a species and the time and place of spawning can be used to plan fishing tactics because many species of fish are easiest to catch when they congregate to spawn. Fecundity studies found that *B. altianalis* had low level of relative fecundity (6 eggs g^{-1}) as comparedwith other cyprinids such as *L. victorianus*with 299 eggs g^{-1} (Rutaisire & Booth 2005),*C. caprio* with 123 g^{-1} (Bishai, Ishak & Labib1975) and Labeo horie with 60–290 eggs g^{-1} of body weight (Dadebo, Ahlgren & Ahlgren 2003).The low fecundity could be attributed to the largesize of eggs and the histological finding that the oocytes develop in batches. This was further confirmedby the few eggs released upon stripping (1500–3000 eggs kg body weight).

2.3 Food and Feeding Habits

The study of the feeding habits of fish and other animals based upon analysis of stomach content has become a standard practice (Hyslop 1980). Stomach content analysis provides important insight into fish feeding patterns and quantitative assessment of food habits is an important aspect of fisheries management. Lagler, (1949) pointed out that the gut contents only indicate what the fish would feed on. Accurate description of fish diets and feeding habits also provides the basis for understanding trophic interactions in aquatic food webs. Diets of fishes represent an integration of many important ecological components that include behavior, condition, habitat use, energy intake and inter/intra specific interactions.

A food habit study might be conducted to determine the most frequently consumed prey or to determine the relative importance of different food types to fish nutrition and to quantify the consumption rate of individual prey types. Each of these questions requires information on fish diets and necessitates different approaches on how one collects and analyzes data. In an attempt to characterize the feeding habits and feed types of fishes within Lake Victoria Basin, researchers have worked on stomach contents which have been found very reliable and accurate (Ochumba and Manyala, 1992). It is assumed that when a fish is caught before digestion, all that is ingested will be found in the stomach. The information on feeding habits and feed types is very important since it determines the growth rates and wellbeing of the fish. A fish feeding on high protein feed do not grow at similar rates to those feeding on high carbohydrate feeds. On the other hand, starving fish is likely to have a stunted growth or die due to lack of energy.

On *B. altianalis*, research has shown that it is an omnivorous fish whose diet consists of algae dominated detritus, plant material, mollusks, chironomids and cardis fly larvae (Balirwa, 1979; Cambray and Jackson 1984; De Stefano and De Graaf, 2003). The studies on feeding habits done in Kenya have not considered spatial aspects within species and have generalized the data. This condition creates lack of information on food items and feeding habits at specific stations the Kenyan population. This study thus seeks to provide a step towards addressing this problem by determining the feeding habits among the populations of *B. altianalis* along River Nyando.

2.4 Influence of Water Quality on Fish Size

Growth of fish is a relatively very complex process that is affected by many behavioural, physiological, nutritional, and environmental factors. Some of the well documented environmental factors that affect fish growth and size include dissolved oxygen, temperature, pH, conductivity, TSS, TDS and turbidity (Chatterjee *et al*., 2004; Larsson and Berglund, 2005). Temperature for example affects general growth, food intake, and food conversion of fish (Martinez *et al*., 1996). Conductivity on the other hand leads to stunted growth in tilapia fish. In the natural aquatic systems, fish moves into deeper water when surface water temperature decreases or increases beyond their preferred range (Brett*et al.*, 1979). The effects of water quality parameters on growth and development of fish have been well documented for many species (El-Sayed *et al*., 1996; Van Ham *et al*., 2003;Anelli *et al*., 2004; Campinho *et al*., 2004; Chatterjee *et al*.,2004; Larsson and Berglund, 2005). Most of these studies have been done to fish in captivity and they have revealed significant influences.

Even though most riverine fisheries researches in Kenya have factored in water quality parameters, information on the relationship between these parameters and fish sizes is scanty. This work thus aims at determining the relationship between these parameters and selected aspects of biology of *B. altianalis* which has been reported to vary in size along rivers.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study Area

The study was conducted along River Nyando within Lake Victoria basin, Kenya. River Nyando has its source originating from the Nandi and Tinderet Hills in Nandi County and Londiani and West Mau Forests in Kericho County and has a total length of about 170 km and drains a catchment of high agricultural potential dominated with several agro-based industries such as coffee and sugar factories. The River Nyando is one of the rivers flowing into the Lake Victoria in Kenya and is polluted in some stretches by sugar factory effluent. The choice for research along this river is easily accessibility by road.

3.2 Sampling Stations

Three stations were marked along the river to represent up-stream, mid-stream and downstream habitats (Figure 3.1). Station 1 denoted as S1 was at Fort Tenan Bridge at latitude -0.21208 and longitude 35.30047. This station was picked to represent the upstream habitat of the river. Thesecond station (S2) which was the mid-streamwas at Chemelil-Awasi bridge (latitude -0.1466, longitude 35.12586) while the downstream habitat was represented by S3 (latitude -0.17222, longitude 34.9208) located at Ahero Bridge.

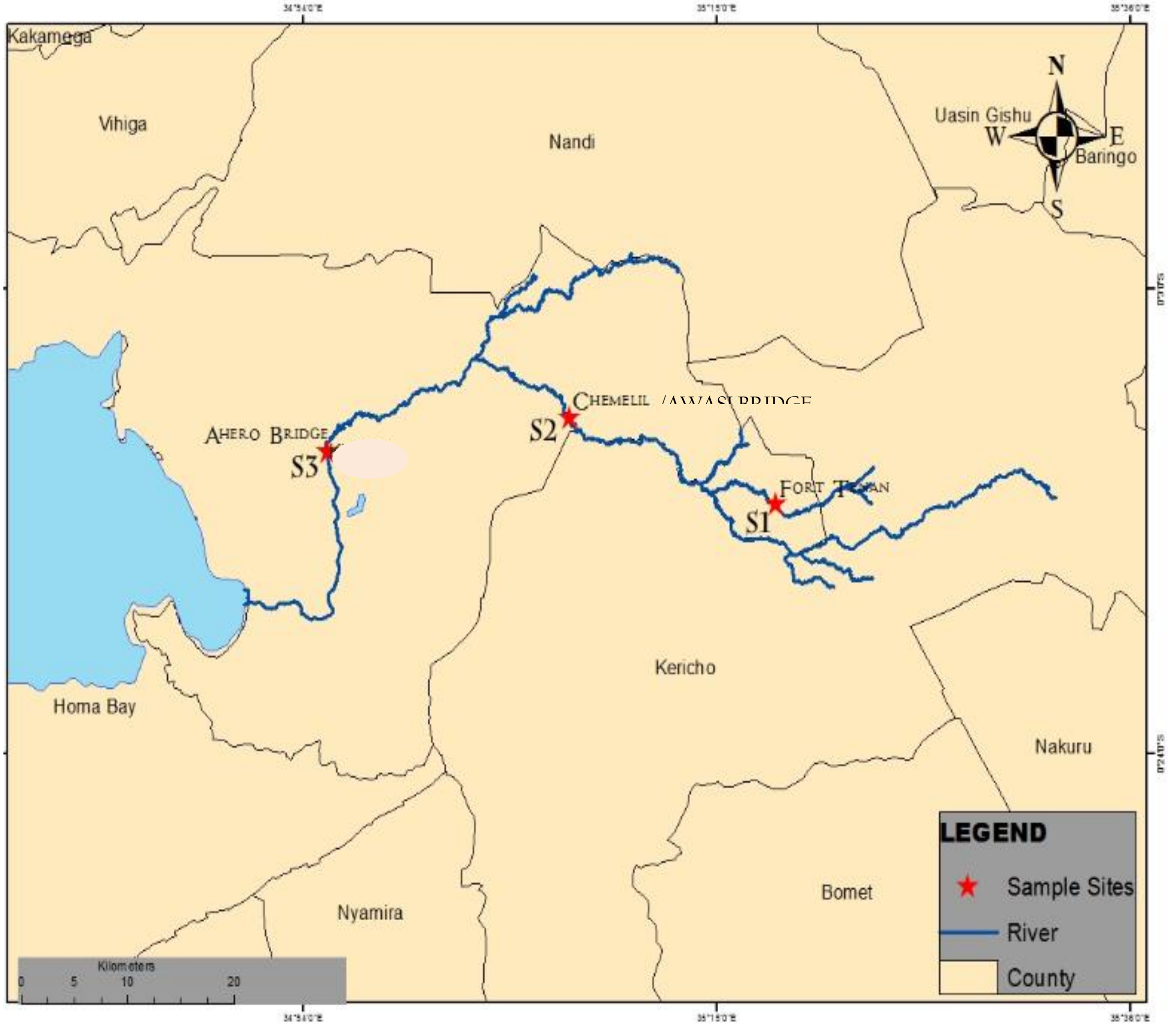


Figure 3.1: Map showing River Nyando and the sampling stations (Source:Author 2015)

3.3 Sampling (Data Collection)

Sampling was done monthly for six months from Dec 2014 to May 2015.170fish samples were obtained using a GPP electro-fisher ranging in power from 2.5 to 9kW, Smith-Root which quickly immobilized fishes and caused minimal habitat disturbance (appendix III). The generator was a Honda GX 240 8 HP that produced a current at 400 V and 10 A. The electro-fishing exercise was carried out for a timed period, usually between 15 and 20 min per site, depending on water depth, terrain and catches. This allowed enough time for a 50 M span of operation upstream and downstream of the generator. At each site location data (GPS readings) and physical characteristics were noted. As soon as the fish were landed, they were counted and identified using morphological characteristics stated in the manuals of Greenwood (1966; 1981) (appendix II). The non target species were returned into the river where as the *B. altianalis* were weighed to the nearest 0.1g using a potable weighing balance(appendix IV), The Total Length (TL) of the fish was measured from the tip of the anterior part of the mouth to the caudal fin and standard length(SL) was measured from the rostral tip of the upper jaw to the origin of the caudal fin. The TL and SL were measured using a meter rule calibrated in centimeters.

3.4 Reproductive Biology

3.4.1 Reproductive Seasonality

Individuals were sexed macroscopically; Gonads were removed from each sample of *B.altianalis*, and preserved in 10% buffered formalin. Each gonad sample were then dehydrated in an ascending series of ethanol and cleared in toluene. After dehydration, samples were embedded in paraffin, and histological sections cut at 5 µm using a rotary microtome. Sections were mounted on glass slides and stained with Harris hematoxylin followed by eosin counter stain. The slides were evaluated to determine the stage of the spermatogenic cycle in males and the ovarian cycle in females. Female stages were categorized according to with Goldberg (1981).The stages of gonadal development is presented in appendix 1.Stage 1 is the non spawning condition consisting mainly of primary oocytes; Stage 2 consists of slightly enlarged vacuolated oocytes; Stage 3 was characterized by yolk deposition in progress. In Stage 4 (spawning) mature/ripe oocytes predominate and some postovulatory follicles were present. This was done to determine variation of the different stages at the three stations. Cyclic gonadal recrudescence was described by a periodic regression of observed gonosomatic index (GSI) on the sine and cosine of the angular transformation of the independent variable.

3.4.2 Sexual Maturity

Sex of each individual was determined from gonad inspection following anatomical dissection and/or external characters. Gonad state was assessed using a seven-point scale modified after Hopson (1972). this result was useful in determining their variation between the stations.

3.4.3 Fecundity and Egg Size

For the determination of fecundity and egg size, only fish in the “ripe- and- running” stages were considered since research has shown that only fish at maturity stages have yolked eggs (Cambray and Jackson, 1982).Appendix (vi) Fresh ovaries were fixed in buffered 10% formalin for 12 hours and stored in 70% ethanol. Ovary mass was then recorded and all the eggs from the left ovary emptied into a beaker of Gilson fluid and shaken gently to cause uniform mixing. A volumetric sub sample of 1-2 ml was pipette from the mixture and transferred to a Petri dish where all ova were counted using a tally counter. Fecundity was then calculated as

$$F = n \times (V/v) \times (W/w)$$

Where **n** is the number of ova in the sub sample,

V is the volume of ova and water,

v is the volume of sub sample,

W the weight of both ovaries

w the weight of the ovary whose eggs were counted.

A second sample of ova was obtained from the ovary that was not used for fecundity studies, and their diameter measured along their median axis with a calibrated eyepiece micrometer fitted on a dissecting microscope at ×20 magnifications.

Absolute fecundity and egg size was plotted against eviscerated mass and fork lengths and the least-squares regression parameters estimated from the base-10 logarithm transformed data. Elevations and slopes of the regression of the three populations was compared by analysis of interactions in the multiple regression models.

3.5Stomach Contents

Sample representatives of *B.altianalis* were gutted and each stomach content put in a separate vial with labels specimen label, the site collected and collection date. The stomachs contents were fixed in 5% formalin. Stomach samples were then taken to the Kenya Marine Fisheries Research Institute (KMFRI) laboratory in Kisumu for analysis. In the laboratory, the peritoneum was removed from the stomachs and examined under a binocular 16 dissecting microscope. Empty or highly digested stomachs were excluded. The relative percentage for each food item in each stomach was recorded. The stomach contents were separated into ten broad categories: sand and/or pebbles (pebbles), terrestrial vegetation or seeds (plant material), Ephemeroptera, Tricoptera, Diptera and Odonata larvae (insect larvae) Isoptera, Odonata and Hymenoptera adults(adult insects),bird feathers (birds), earthworms (annelid), fish, crabs, silt and detritus. Analysis of stomach contents was based on percentage occurrence of dominant food items where more than 50% was considered to be most abundant, 20-50% abundant and less than 20% rare (Ogari and Dadzie, 1988; Okach & Dadzie, 1988).

Water quality

At every sampling point physic-chemical parameters were taken *in-situ* in triplicates using calibrated portable water quality meters prior to fish sampling. These included pH and temperature (ºC) with microprocessor pH meter, Conductivity (µScm^{-1}) with a WTW microprocessor conductivity meter LF6 which consist of conductance cells having electrodes of platinum used to measure the ability of aqueous medium to carry on electric current and results were measured at 25°c given that temperature is a dependent factor. Dissolved Oxygen (DO) (mgL^{-1}) was measured with a WTW Microprocessor Oximeter Oxi 320and turbidity using WQC-24 water quality meter designed by TOA-DKK.For Total suspended solids (TSS) and Total dissolved solids (TDS), water samples were collected and taken to the laboratory at Kenya Marine and Fisheries Research Institute, Kisumu for determination. In the lab total suspended solids was measured using the following procedure:

Measurement of total dissolved solids:

Procedure

1. Filter paper was washed
2. It was then dried in an evaporating dish & weigh
3. Sample was stired
4. 50 ml was Pipetted while stirring
5. It was then filtered and washed three times

6. Filtrate was transfered to evaporating dish & dry

7. It was Cooled & weighed

8. Then it was calculated in mg/ L

The following formula was used in calculating Total Dissolved Solids concentration:

$$\text{mg Dissolved Solids/L} = \frac{(A-B)\times 1000}{\text{ml sample}}$$

Where:

A = weight of dried residue + dish, mg

B = weight of dish, mg.

Measurement of Total suspended solids

1. Filter paper was washed and cooled

2. Filter paper was cooled & weighed

3. Filtration apparatus was assembled

4. Filter paper was wet with distilled water

5. Sample was stirred

6. 50ml was pipetted while stirring

7. Sample was filtered and washed three times

8. The filter was transferred to evaporating dish & dry

9. It was then cooled& weighed

10. It was then calculated in mg/ L

11. Steps were repeated 1 to 10 using 10 ml aliquot

Total suspended solids concentration was calculated using the formula

$$\text{Mg suspended solids/L} = \frac{(A-B)\ \text{x}1000}{\text{Ml sample}}$$

Where:

A = weight of filter + dried residue, mg

B = weight of filter, mg

Food in the environment

At each sampling station, three replicate macro-invertebrate samples were collected from different channel units using a scoop net (1 m2, 500 µm mesh size). The macroinvertebrates were washed through a 300 µm mesh size sieve, hand sorted in the field and preserved in 70% alcohol. In the laboratory, the preserved macroinvertebrates were identified to genus level according to Stehr, (1991); Merritt and Cummins, (1996) and Quigley (1977) and then counted.

I collected phytoplankton using Phytoplankton nets fine meshed (10 □m) and after collecting them I counted them while fresh and recorded.

3.6 Data Analysis

All the data generated from the sampling was entered into excel spreadsheet for the purpose of management and storage Analysis was done using Minitab version 15 software for windows. All the fish sampled were put in categories depending on sizes. The proportions of food items were averaged for every species and size category per sampling station. The proportions of each food item was represented in bar charts and compared between stations.

The data on length and weight was log-transformed and used to determine the length-weight relationship and the condition factor at each station using regression analysis. This result was then represented in regression graphs. Parameters such as condition factor (Kn), growth exponent, and maximum possible size were then determined. Relative condition factor was then calculated using the following formulae;

$$Kn = TW/aTL^b$$

Kn is condition factor,

TW is total weight

TL is total length.

a and b are constants representing initial growth coefficient or y-intercept and growth coefficient respectively. The spatial variation in condition factor and fecundity were tested using One-way Analysis of variance ($p < 0.05$).

The proportions of each gonadal maturity stage for *Barbus altianalis* was determined and represented in bar charts for each station. The stations were then compared for each gonadal maturity stage and spatial variation determined using chi-square statistics ($P< 0.05$).Variation in fecundity with total length was determined at each station using regression analysis.

Numerical abundance (%N) was used in quantitative description of the diet as described by Bowen (1984). Numerical abundance was the number of each food item determined from the fish examined and was calculated as: Numerical abundance (%N) =

(Ni/∑Ni)*100. Where Ni is the number of food items counted in the stomach, ∑Ni is the total number of items counted in all stomachs.

Selectivity of food items by *B.altianalis* was estimated using the Ivlev's index of electivity (E) (Strauss, 1979).

$$E = \frac{r_i - p_i}{r_i + p_i}$$

Where r_i= proportion of a food item in fish stomach.

P_i = proportion of the food item in the water sample

Electivity values determined using the index have a possible range of –1 to +1. Values closer to +1 indicate preference whereas values closer to –1 indicate avoidance of prey. Zero electivity indicates that the prey is being eaten in the same proportion to their availability in the environment. Differences in diets per sampling site, and among different size classes were analyzed using Chi-square test.

Water quality parameters were summarized in a table as mean ± SE for each sampling station and spatial variation tested using one-way ANOVA at 95% confidence level. A correlation analysis was further performed to test the relationship between water quality parameters and condition factor and fish size.

CHAPTER FOUR

RESULTS

4.1 Length Weight Relationships and Condition Factors of *Barbus altianalis*

The spatial variation in Total Length (TL) Standard Length (SL) and Total Weight (W) of *B. altianalis* is shown in table 4.1. There were significant differences in the TL among the sampling locations (One-Way ANOVA; F = 6.1212, df = 2, P = 0.034). Fish sampled from site S1 had the highest SL followed by those in S3 while mean TL at S2 was the lowest. Again the trends in variation of SL was similar to that of the TL with significant differences being noted among the sampling sites (One-Way ANOVA; F = 8.564, df = 2, P = 0.017). Total weight varied significantly (One-Way ANOVA; F = 3.001, df = 2, P = 0.044) among sites in tandem with variation in TL and TW. The highest total weight was recorded at site S1, and the lowest at S2.

Table 4.1: Mean (± SD) of the Total length (TL), Standard Length (SL) and Total Weight (W) of *Barbus altianalis* sampled from three stations along River Nyando

	Sampling station		
Parameter	S1	S2	S3
Number (N)	69	48	53
Total Length (TL)	16.97 ± 3.82^c	14.21 ± 3.12^a	15.15 ± 3.76^b
Standard length (SL)	12.64 ± 2.12^c	10.12 ± 2.87^a	10.21 ± 2.94^b
Total Weight (W)	49.13 ± 5.44^c	36.14 ± 4.21^a	39.4 ± 3.12^b

Values with different letters differ significantly ($P < 0.05$)

Information on the length-weight relationships of fish at the three sites are shown in Figure 4.1. Fish at site S1 exhibited isometric growth ($b \approx 3$) while in the other two sites, there was negative allometric growth (b < 3.0) with site S2 being the place with the least fish growth performance.

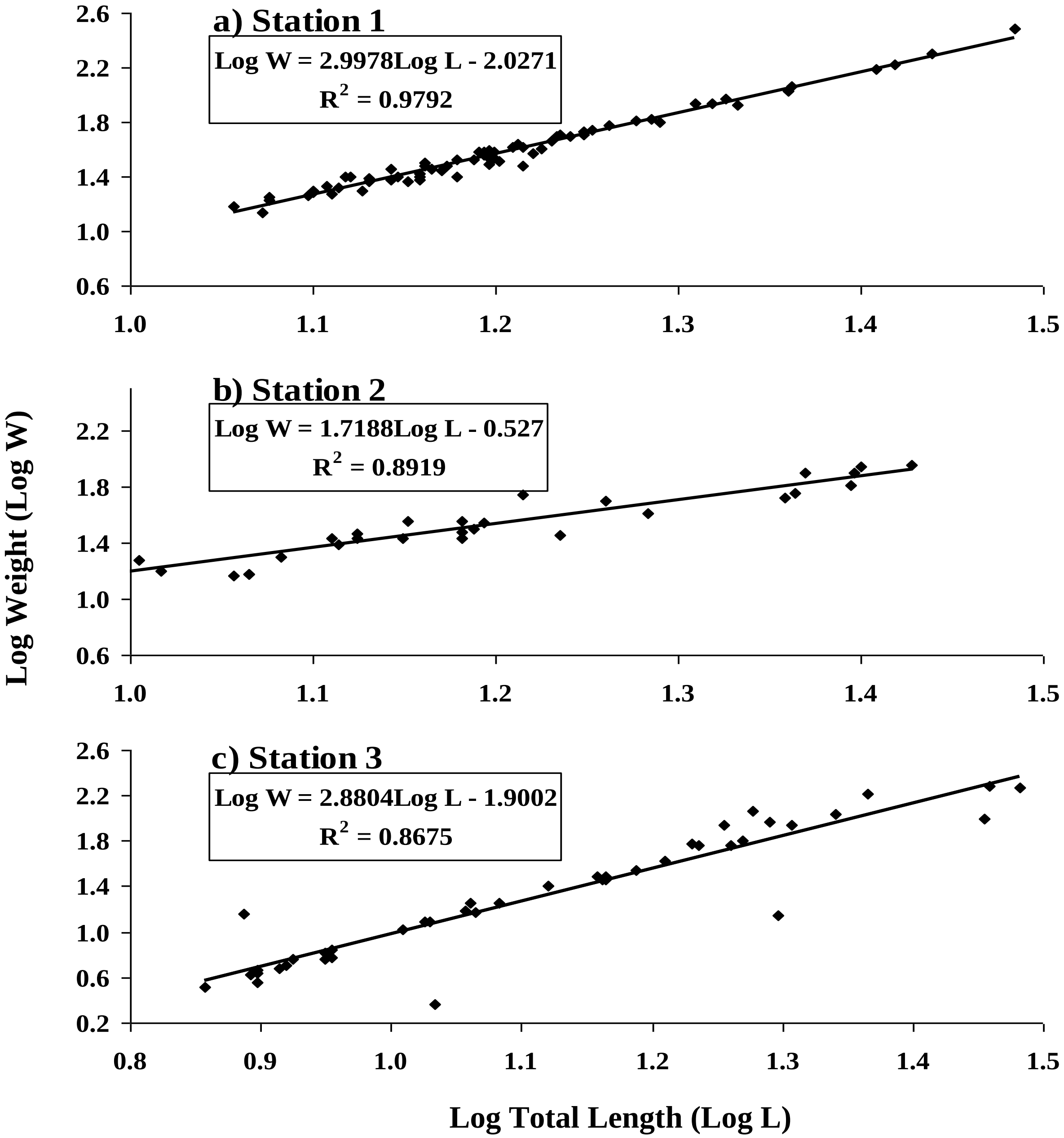


Figure 4.1: Length-weight relationships in *Barbus altianalis* at three sites along River Nyando

The fish condition factors (Kn) are provided in Figure 4.2. There were differences in condition factor among stations. Fish at site S1 had the highest Kn (1.38 ± 0.25) followed by Kn at S3 (1.06 ± 0.12) and the least Kn was reported at site S2 (0.85 ± 0.11).

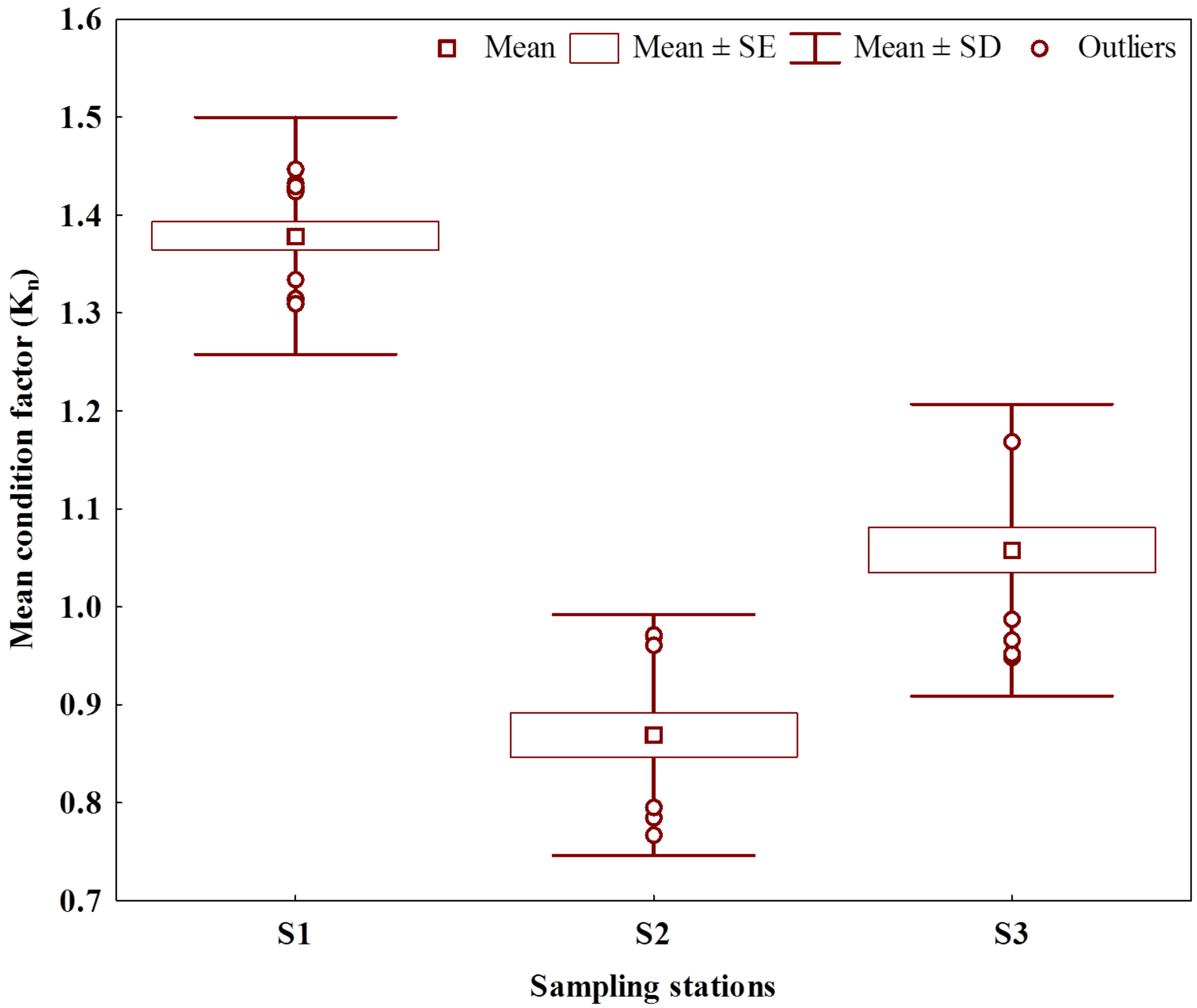


Figure 4.2: Mean condition factor of *Barbus altianalis* at three sampling sites along River Nyando

4.2 Reproductive biology (fecundity, size at sexual maturity and gonadal maturity stages) of *Barbus altianalis*

4.2.1 Sex Ratios

The sex ratios of fish sampled from the three sites along River Nyando is provided in Table 4.2. At all the sampling sites the number of females was significantly higher than males (Chi-square test; $P < 0.05$). At site S1 two fifth of the population were female and significantly higher than males ($\chi^2 = 5.432$, df = 1, $P = 0.0043$). At site S2 upto 58.3% of the sample was dominated by females that were significantly higher than males ($\chi^2 = 5.242$, df = 1, $P = 0.0063$). Similarly, site S3 had 66% being female and 34% being males were found to be significantly different ($\chi^2 = 7.432$, df = 1, $P = 0.0012$).

Table 4.2: Number of male and female fish sampled at three sampling stations of River Nyando [% are in parenthesis]

	Sampling sites		
	S1	S2	S3
Male	27 (39.1)	20 (41.7)	18 (33.9)
Female	42 (60.9)	28 (58.3)	35 (66.1)
Total	69	48	53

4.2.2 Gonado-somatic Index and Gonadal Maturity Stages

The mean gonad somatic index of *Barbus altianalis* sampled at three sites along River Nyando is provided in Figure 4.3. There was a higher Gonad somatic index recorded by females more than males in all the stations with the highest in S1 and lowest in S2. For males, the Gonad somatic index was high at S1 and lowest at S2

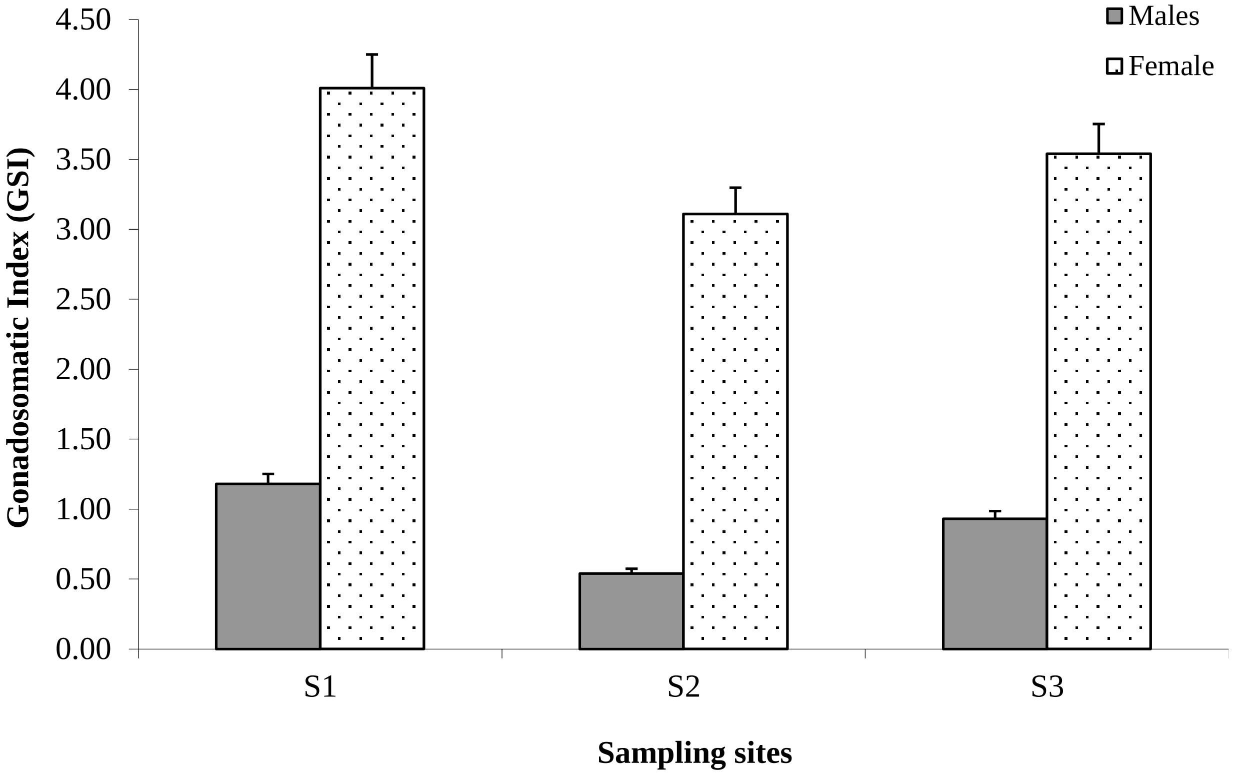


Figure 4.3: The mean gonad somatic index of *Barbus altianalis* sampled at three sites along River Nyando

4.2.3 Fecundity

The average numbers of eggs per litre at the three sampling sites are shown in Figure 4.4. Fecundity was found to differ significantly among the sampling locations (One-Way ANOVA; F = 20.5423, df = 2, P = 0.0043). Highest fecundity occurred in fish sampled from S1 49,440 ± 11,432 eggs/L) followed by fish sampled from S3 (37,453 ± 7895 eggs/L) while the least fecundity occurred at site S2 (32450 ± 4235 eggs/L).

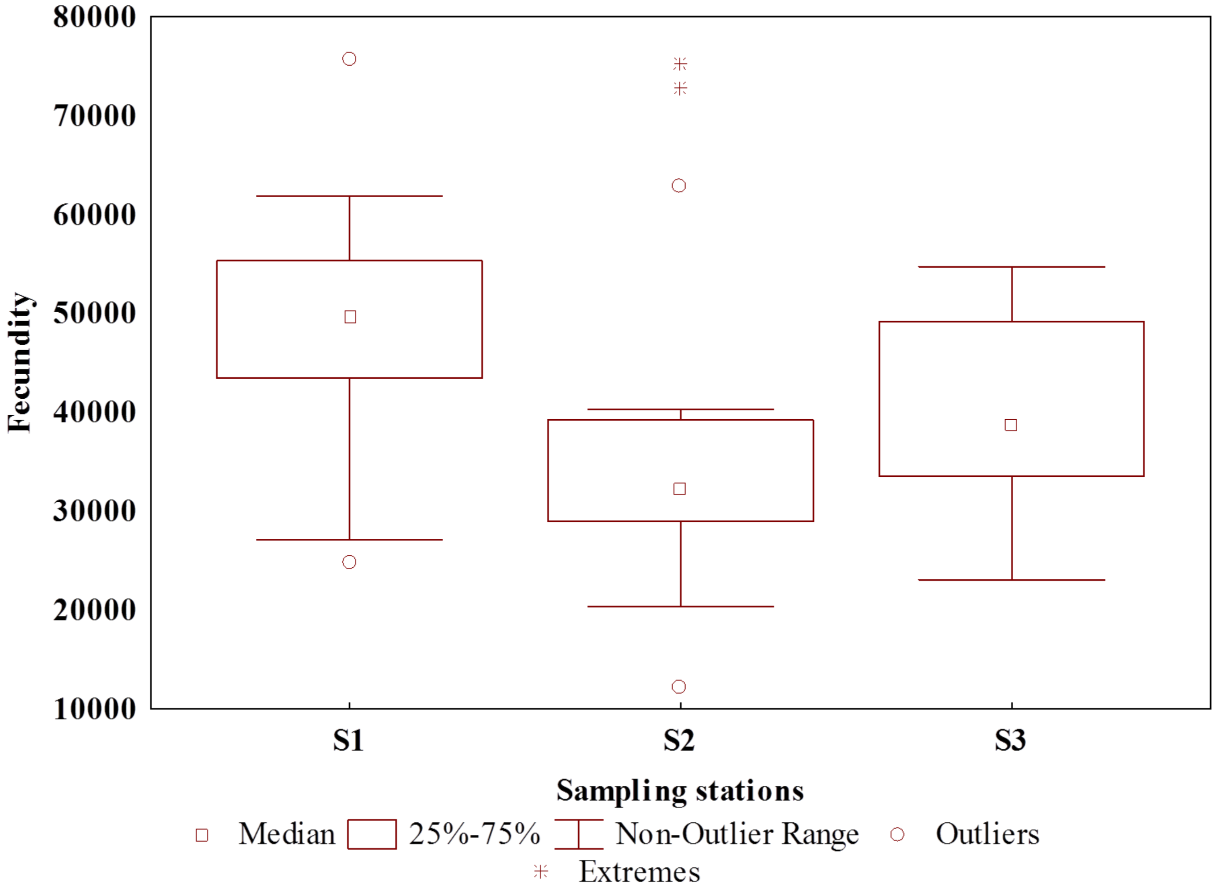
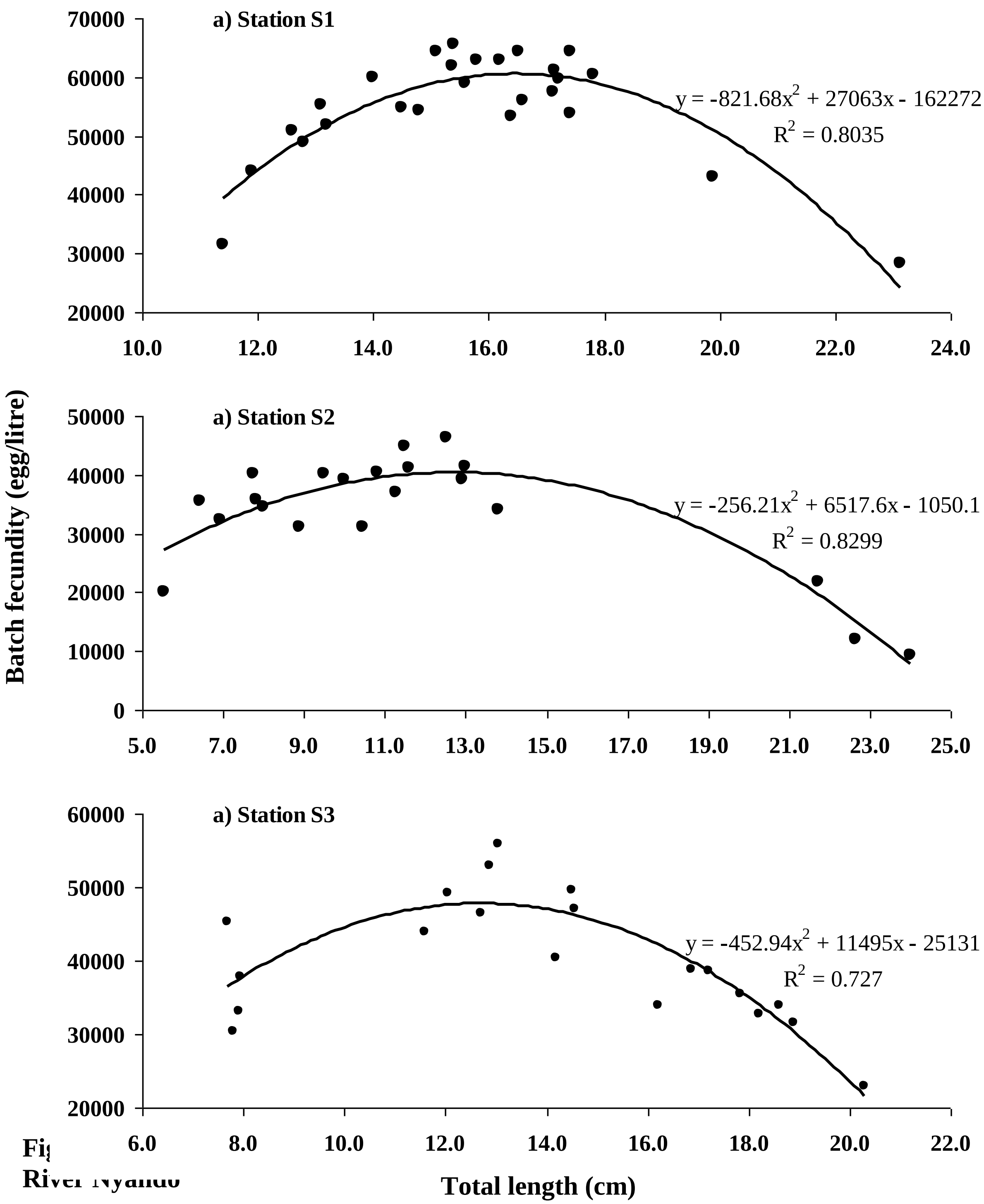


Figure 4.4: Average number of eggs/L at the three sampling sites along River Nyando

The modeled relationships between fecundity and length found that it was exhibited a binomial response (following quadratic response) increasing with length from about 14 cm to a maximum of about 54,000 eggs/L at length 15 to 16 cm before declining (Figure 4.5)



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4.2.4 Maturation Stages and Cyclicity

Variation in maturation stages of the male and male female fish sampled along three sites of River Nyando is shown in Figure 4.6. There were significant variations in proportion of fish at different maturation stages in males (Chi-square; χ^2 = 32.123, df = 10, P =

0.002) as well as among the female fish (Chi-square; $\chi^2 = 44.125$, df = 12, P = 0.001) sampled along the River Nyando. As for the male fish (a), site S1 was dominated by mature/ripe fish while site S2 was dominated by spent and maturing/resting fish while S3 appeared to have more of the maturing and mature/ripe fish dominating the samples. Females (b) at site S1 was dominated by early maturing and ripe fish, S2 by late maturing while site S3 was dominated by early maturing followed by late maturing.

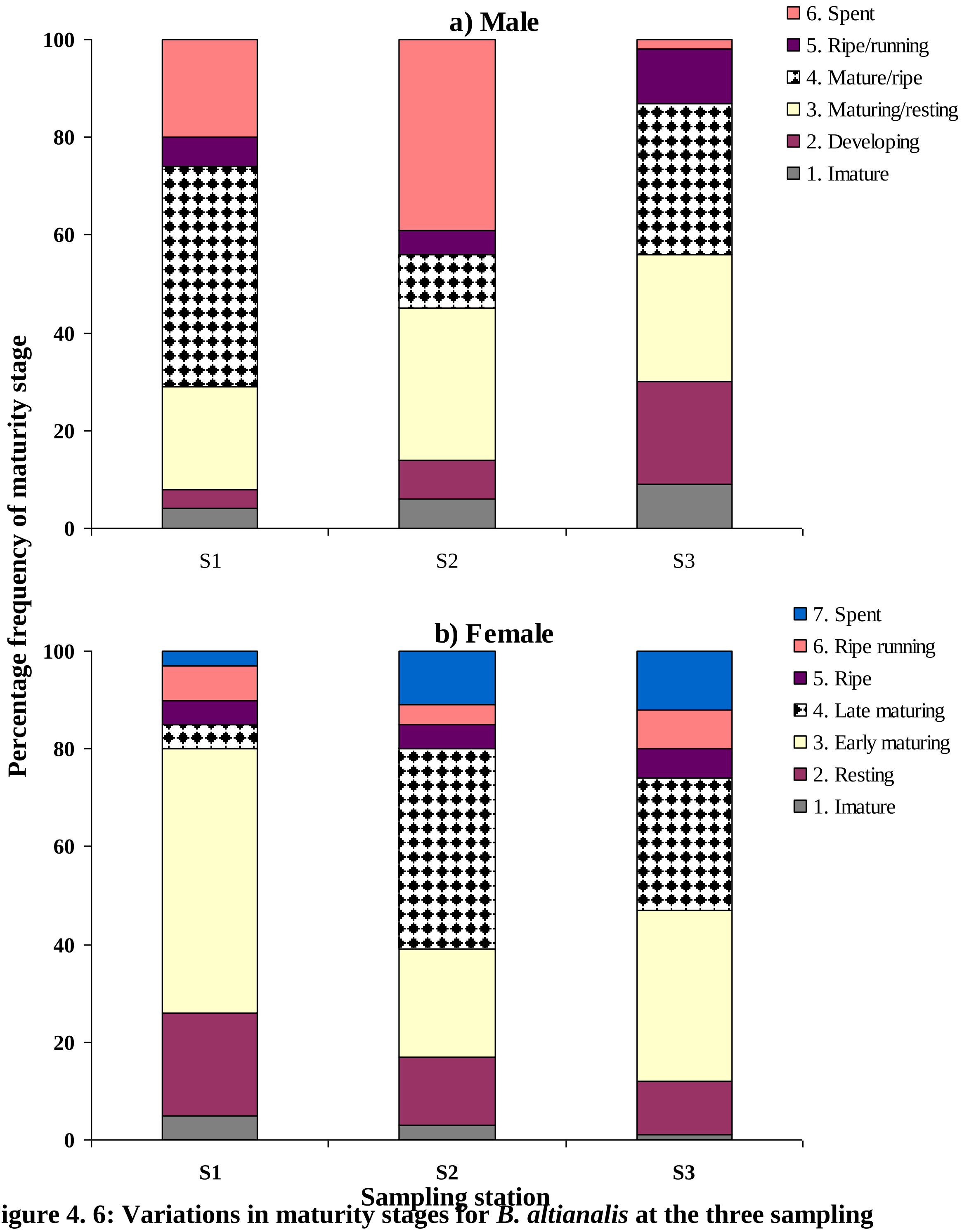

Figure 4. 6: Variations in maturity stages for *B. altianalis* at the three sampling stations along River Nyando

4.2.5 Size at Various Maturation Stages of *Barbus altianalis*

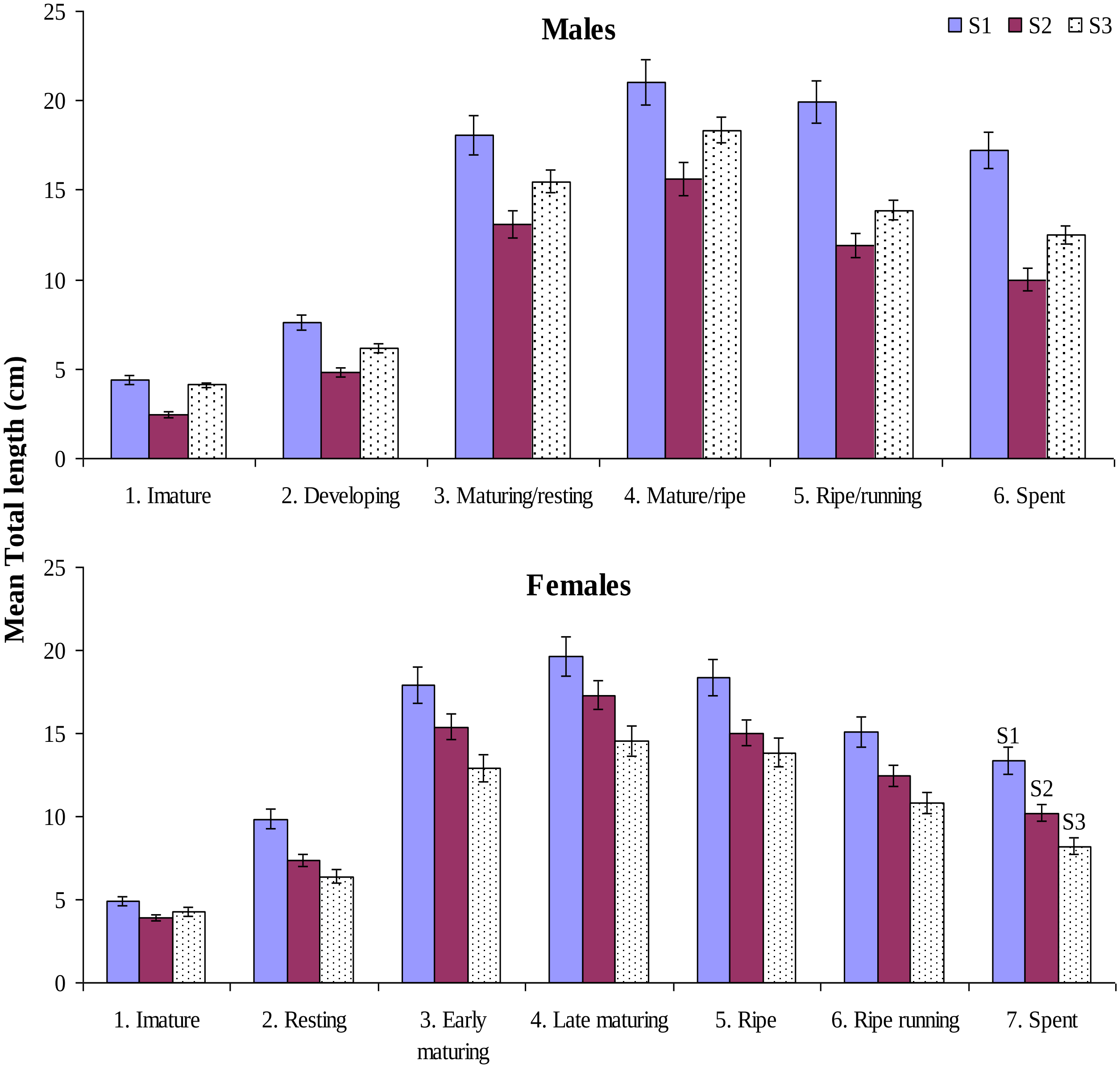

Figure 4.7: Variation in mean TL at each maturity stages of *Barbus altianalis* along River Nyando

4.3 Food and Feeding Habits

4.3.1 Food of *Barbus altianalis*

Diet analyzed in 170 *B. altianalis* stomachs from each sampling station is shown in Table 4.2. All stomachs were full. A total of ten different dietary groups were recognized. These were: herbaceous plant materials, algae, invertebrate classes mainly ephemeroptera, coleopteran, diptera and insects, gastropods, and detritus. There were significant variations in the proportion of the food materials among the three sampling sites (Chi-square; $\chi^2 = 129.12$, df = 20, P = 0.0000). At site S1, ephemeroptera, cladocera and detritus were the dominant food items, while at S2 the food materials were dominated exclusively by insects and diptera and at S3, plant materials, insects and diptera were more dominant. Gastropods plant seeds and algae were consumed by the fish but at low numerical abundance at all the sampling sites.

Table 4.3: Diet composition expressed as percentage contribution by number (%N) in the guts of *Barbus altianalis* at the three sampling locations along River Nyando

	Numerical abundance (%N)		
Food items	S1	S2	S3
Plant materials	15.6	6.6	30.4
Algae	4.2	3.1	0.0
Ephemeroptera	17.1	0.0	2.1
Coleoptera	7.4	0.0	4.4
Cladocera	10.7	0.0	1.6
Insects	5.8	41.3	15.9
Diptera	5.2	43.1	32.7
Gastropod shells	1.7	1.3	1.6
Detritus	31.1	3.1	7.6
Unidentified materials	1.2	1.5	3.7
Total	100	100	100

4.3.2 Food Selectivity in *Barbus altianalis*

Table 4.4: Generalized food items in the environment of *Barbus altianalis* at the three sites along River Nyando

	Numerical abundance (%N)		
Food items	S1	S2	S3
Plant materials	21.1	8.2	16.3
Algae	7.2	3.2	2.5
Ephemeroptera	13.2	2.2	2.3
Coleoptera	1.8	1.3	3.2
Cladocera	7.8	3.2	2.5
Insects	2.2	35.3	19.6
Diptera	5.1	36.7	39.7
Gastropod shells	2.1	4.5	3.2
Detritus	24.8	3.9	6.2
Rotifers	11.2	0.0	2.4
Copepods	3.5	1.5	2.1
Total	100	100	100

The Ivlev’s electivity index for pooled data in the three sampling locations shows large variations. At sampling sites there were strong negative electivity for rotifers and copepods. At site S1, coleoptera and insects were positively selected while at site S2, there was negative electivity for plant materials, invertebrate taxa (EPT) and gastropods. At S3, very strong negative electivity was observed for algae, gastropod shells and cladocera with plant materials, coleopteran, plant seeds and detritus having positive selection.

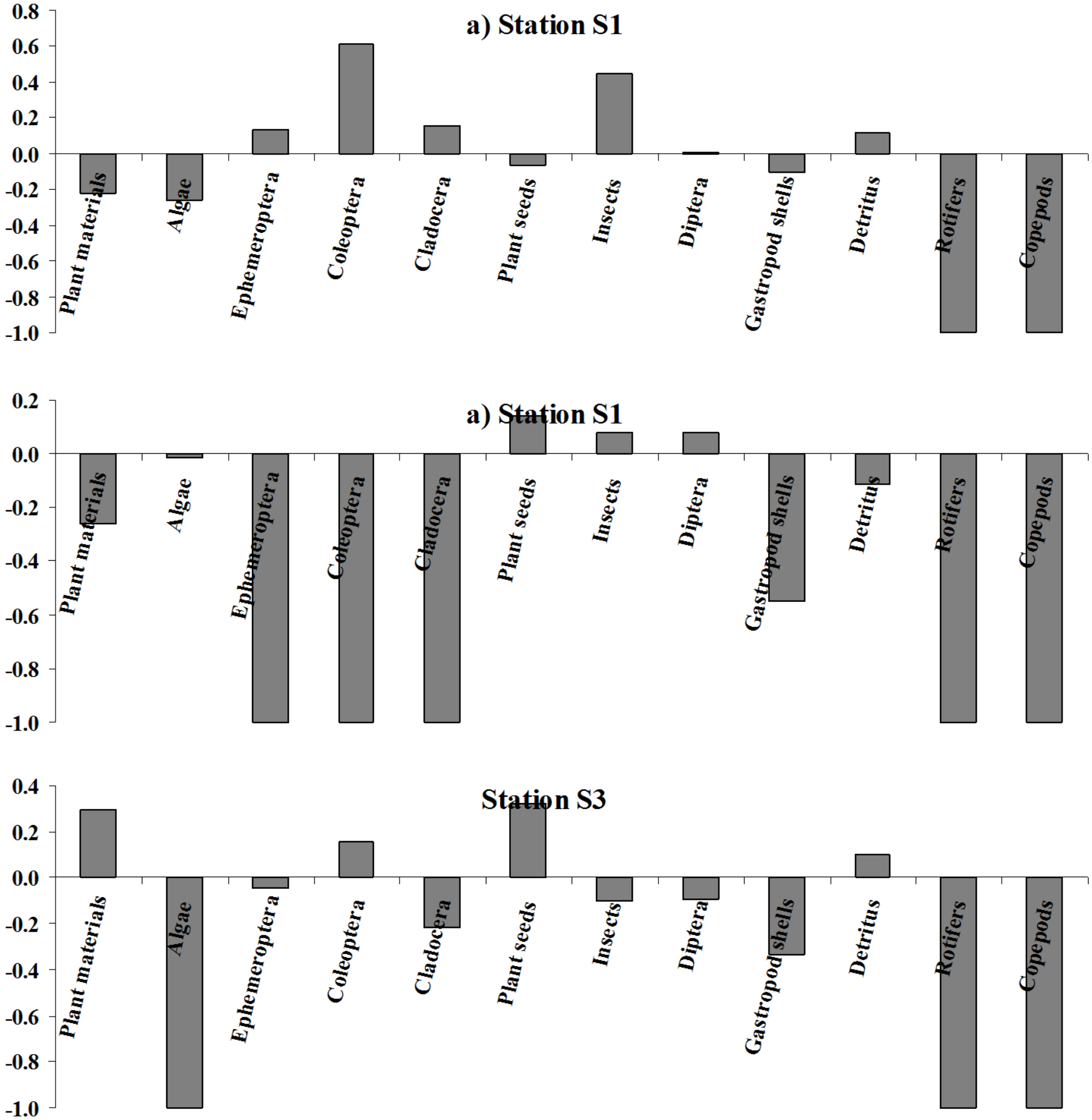

Figure 4.8: Ivelevs Electivity Index for *Barbus altianalis* at the three sampling sites in River Nyando

4.3.3. Ontogenetic Shift in Food for *Barbus altianalis*

The diet of the *B. altianalis* showed significant ($p < 0.05$) variation according to the classes and among the sampling locations (Figure 4.14; Chi-square; $\chi^2 = 89.121$, df = 18, P = 0.0000). At site S1, plant materials, crustaceans and molluscs increased in proportion with respect to size class while algae and insects showed opposing trends. It is also noted that cannibalism increased with size class, being highest at >80.1 mm.

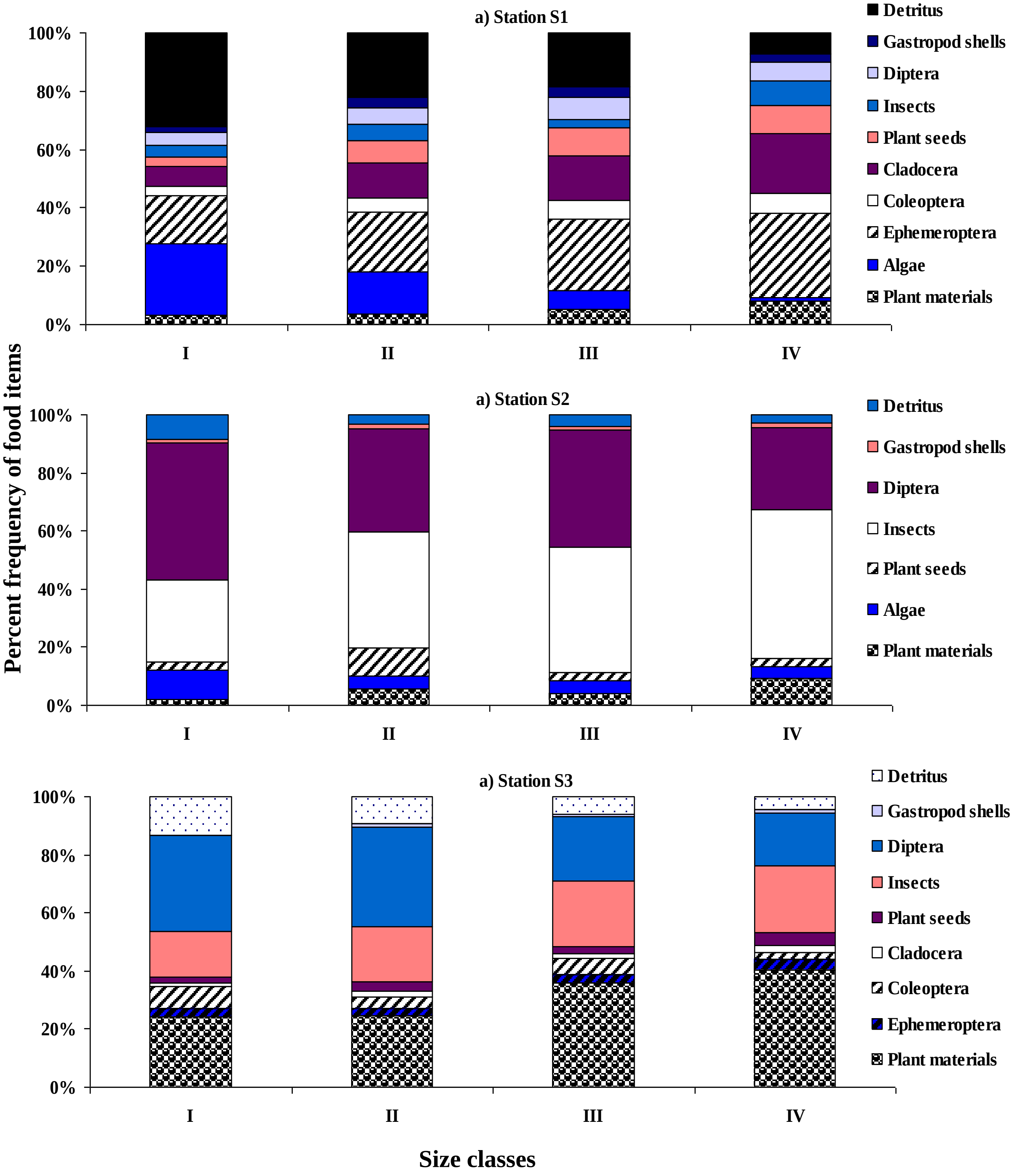

Figure 4.9: Ontogenetic shift in the diet of *Barbus altianalis* at the three sites in River Nyando

4.4 Influence of Physico-chemical Parameters on Size and Gut Contents

4.4.1 Physico-chemical Parameters

Physico-chemical parameter values are shown in table 4.5 below. Dissolved oxygen did not vary significantly between the stations though post hoc test separated station S3, which recorded the lowest value (5.91 ± 0.39 mgl^{-1}) from the other two stations. Temperature was lowest at station S1 and highest at S3 with ANOVA revealing significant variation at 95% confidence level (F = 64.78; p = 0.003). Duncan's multiple range test singled out station S1 as the only different station from the rest thus the probable cause of the significant variation.

Conductivity and pH did not vary significantly between stations with post hoc test further showing them as homogeneous. Total suspended solids (TSS) was lowest at S1 (124 ± 36 mgl^{-1}) and was different from the other stations but the variation was not significant between site S2 and S3. Total dissolved solids (TDS) values were similar among stations where as turbidity was highest at S3 followed by S2 and lowest at S1.

Table 4.5: Physico-chemical parameter values (Mean ± SE) within sampling stations along River Nyando (Different superscript values show significant variation)

Parameters	S1	S2	S3	F	P
Dissolved Oxygen (mgl^{-1})	6.13 ± 1.32	6.24 ± 0.01	5.91 ± 0.39	0.04	0.957
Temperature (^{O}C)	19.9 ± 0.01^{a}	25.0 ± 0.70^{b}	26.15 ± 0.15^{c}	64.78	0.003
pH	8.23 ± 0.06	7.92 ± 0.14	7.79 ± 0.08	5.18	0.106
Conductivity (μScm^{-1})	290.5 ± 15.4	265.1 ± 3.9	239.0 ± 44.0	0.91	0.492
TSS (mgl^{-1})	124.0 ± 36^{a}	391.0 ± 263^{b}	360.0 ± $102b^{b}$	7.79	0.000
TDS (mgl^{-1})	317.0 ± 49	322.0 ± 54	320.0 ± 20	0.0001	0.997
Turbidity (NTU)	170.0 ± 39^{a}	231.5 ± 85^{b}	462.0 ± 155^{c}	6.63	0.002

4.4.2 Correlation dissolved oxygen and PH with total length, total weight and condition factor

Dissolved Oxygen, conductivity and pH showed a strong significant positive correlation with total length, total weight and condition factor (Table 4.6). Temperature, and turbidity all recorded significant negative correlation with TL, TW and K. The relationship between TSS and TDS with TL, TW and K were not significant.

Table 4.6: Correlation between water quality parameters and fish size (values in bracket represent p values whereas * depicts significant relationships)

Parameters	DO (mgl^{-1})	Temp (°C)	pH	Conductivity (μScm^{-1})	TSS (mgl^{-1})	TDS (mgl^{-1})	Turbidity (NTU)
Total length (cm)	0.834(0.000)*	-0.816(0.001)*	0.875(0.001)*	0.965(0.000)*	-0.133 (0.916)	-0.357 (0.767)	-0.929(0.000)*
Total Weight (g)	0.690(0.004)*	-0.925(0.000)*	0.961(0.000)*	0.923(0.025)*	-0.350(0.772)	-0.557(0.084)	-0.962(0.000)*
Condition Factor (K)	0.625(0.007)*	-0.954(0.000)*	0.981(0.000)*	0.911(0.000)*	-0.429(0.718)	-0.626 (0.062)	-0.936(0.000)*

CHAPTER FIVE

DISCUSSION

5.1 Condition Factor and Growth Pattern

Condition factor is an indication of the wellbeing of a fish species research was done by Abowei, ,J.FN.(2010) on*Ilisha Africana.* A higher value as of condition factor in Station1 indicates better wellbeing in comparison to those with a smaller value (Begenal, 1978). According to Barnham and Baxter (1998) who worked on Salmonids argue that a K value above 1.2 shows good to excellent health while values between 1.2 and 1.6 indicates fair wellbeing. Those with values below 1 indicate poor condition. Gayanilo and Pauly (1997) reported that certain factors often affect the well – being of a fish. These include: data pooling, sorting into classes, sex, stages of maturity and state of the stomach. The condition factor (K) reflects, through its variations, information on the physiological state of the fish in relation to its welfare. From a nutritional point of view, there is the accumulation of fat and gonad development (LeCren, 1951). From a reproductive point of view, the highest K values are reached in some species. From this study, it can thus be concluded that *B.altianalis* from S1 had a better wellbeing because of its high condition factor which could be attributed to abundance of fish that are not ripe therefore less energy is spent on reproduction also presence of food . Braga (1986), through other authors, showed that values of the condition factor vary according to seasons and are influenced by environmental conditions. The same may be occurring in the environment under study.

Lower condition factor value in S2 can be attributed to several factors as observed within the station. Vazzoler (1996) confirmed lowest K during more developed gonad stages might mean resource transfer to the gonads during the reproductive period. In this study S2 having the lowest condition factor is also because of abundance of fish that were ripe and running the high GSI because fish is diverting energy from muscles to gonads in preparation for breeding in the environment as the sampling period was the breeding period of fish of between March-August and October-December.

Barbus altianalis from station S1 exhibited an isometric growth pattern (b ≈ 3) which implies that the rate of change in length is equal to that of weight. Stations 2 and Station3 exhibited negative allometric growth with S2 recording the least fish growth performance. The growth exponent (b) has been found to range between 1.7 and 2.9 and fish in good welfare is expected to be 3 or near 3 which depicts isometric growth (Carlander, 1977; Froese, 2006; Ahmed *et al.*, (2012). S1 and S3 met this criteria of isometry where as S3 was slightly below 3. Just like condition factor, the exponent was again lowest in S2 pointing at a possible problem within this mid station which could be the low food proportion present, deteriorating water quality due to pollution from factories around like Chemelil sugar factory and also erosion from farms where the is a lot of farming at the river bank also velocity of water which is low and the depth.

5.2 Reproductive Biology (Sex ratio,fecundity, Size at Sexual Maturity and Gonadal maturity stages) of *Barbus altianalis*

5.2.1 Sex Ratios

According to the sex ratio model of Fisher (1930), animals should produce offspring of a balanced sex ratio. Therefore, a population with unbalanced sex ratio will be exposed to frequency-dependent selection for the minor sex. In general, a population with an imbalanced sex ratio due to unusual environmental conditions can be considered to be disturbed or maladapted for the given conditions. As shown by Conover Van Voorhees (1990) in the Atlantic silverside, Menidiamenidia, an unbalanced sex ratio induced by high temperature may become balanced under warm, but stable environmental conditions within a few generations in artificial systems. In thermal springs, the environmental conditions are generally warmer and more stable than in surrounding habitats and effluent rivers. Therefore, Fisher's principle should apply in a Similar manner as in the experiments of Conover and Van Voorhees (1990). If the sex ratio of an migrating fish species were biased at first by the environmental conditions, it would be expected to rebalance in time. From this study females dominated in the three stations. The significant difference in sex ratio could be attributed to a number of factors including a possibility of sex reversal whereby males reverse their sex in response to changes in environmental parameters. There is a possibility that there is high male mortality probably due to greater reproductive investment, food supply could be a determining factor where females predominate when food is abundant, while male predominate in oligotrophic environments (Nikolsky, 1963). A more detailed study could unravel the bias of population towards females

5.2.2 Fecundity, Gonado-somatic Index and Gonadal Maturity Stages

The fecundity of *B.altianalis* in the three sites was also investigated since it is known to vary among populations, and at times, between strains of fish species (Bromage *et al.*, 1990; Jonsson and Jonsson, 1999). The determination of actual numbers of eggs produced would be more useful for analysis of stock dynamics (Mason, 1985).Fecundity differed significantly among the three sampling sites as S1 had the highest fecundity this could be due to the habit of fish migrating upstream to breed. S3 followed and the site with the lowest fecundity was S2 as the proportion of ripe and running females was lowest at this site. Such variations could also be attributed to the differential abundance of food (Coward and Bromage, 2000) and the effects of age and genetic factors (Wootton, 1979). The observed differences of these *B. a altianalis* could be a result of the complex interaction of age, food abundance and stations.

Fecundity increased with length as expected. Gonad somatic indices remained clearly high mostly above 2 for females in all the three stations being higher in Station 1 this implied *B.altianalis* females are characterized by high (GSI value >2), the high fecundity also coincided with high levels of dissolved oxygen and low temperature at the station which is suitable for spawning gonad activity throughout the three stations However, even if breeding takes place throughout the three stations, peak spawning activities occur in station 1 this could be because fish migrate upstream to spawn. It was of interest to note that fish with running ovaries (stage V) were found in samples almost in all the stations.

Fish maturity stage largely depends on the age of fish and thus affects the sizes. It is expected that the stage 1 fish of the same species are smaller than the other stages though this may vary due to fluctuating environmental conditions. Information on sex and gonad maturity stages is thus very crucial in trying to explain the cause of spatial variation in sizes of same fish species within a system. Since this is lacking for *B. altianalis* in Nyando River, this study targets not only to explain the cause of varying sizes but to bridge the information gap.

5.2.3 Percentage of Maturity Stages

At S1 males that were mature dominated, this could be because they were migrating upstream to spawn and the ones with the lowest proportion were those at stage 2 developing .At S2 males with spent was at a higher proportion followed by stage 3 maturing/resting and then those at stage 4 mature/ripe the least was those at stage 5ripe/running.

5.3 Food and feeding habits of *Barbus altanalis*

From this study ten different dietary groups were recognized. These were: plant materials, algae, invertebrate classes mainly ephemeroptera, coleopteran, diptera and insects, gastropods, and detritus. There were significant variations in the proportion of the plant materials among the three sampling sites. On *B. altianalis*, research has shown that it is an omnivorous fish whose diet consists of algae dominated detritus, plant material, mollusks, chironomids and cardisfly larvae (Balirwa 1979; Cambray and Jackson 1984; De Stefano and De Graaf 2003). In River Nzoia, almost the same results on gut contents of this species showing predomince by algae and higher plant material . Insects formed the third most common food component.

From this study the change from one food type in one site to a different type in another is especially necessary for the survival of this species which migrates up affluent rivers for breeding purposes. Algae and higher plants are likely to be more abundant in riverine than in lacustrine habitats and this was observed by their presence in S3. It is therefore unlikely that algae and higher plants can be limiting.In riverine conditions, rather, animal life might be more restricted.

Barbus altianalis indicates that the species are versatile feeders, utilizing foods when they are available and changing to others when occasion demands at site1 the predominance of ephemeroptera, cladocera and detritus could be attributed to its availability and abundance in the environment so that fish could not utilize a lot of energy searching for it and this contributed to the high condition factor recorded in fish at this site. The two food items that dominated at station 2 were insect remains and diptera this is due to its availability in the environment this could have contributed to the lowest condition factor and negative allometric growth exponent of fish in the station. Imam *et al*. (2010) and Mahomoud *et al*. (2011) in their respective studies of length-weight relationship blamed absence of enough quality food in the environment for poor condition factor and growth patterns this could be attributed to the effects of pollution by the factories around like Chemelil and also erosion as there is a lot of farming along the river banks.

As per electivity index, Coleoptera and insect at S1 were positively selected this could be attributed to domination of Mature/ripe and Maturing fish which are able to feed on the food and they preferred it. In S2 Plant materials, Invertebrate taxa and gastropods were negatively selected this could be because the fish did not prefer the food so could not feed on them and at S3 very strong negative electivity was observed for algae gastropod shells and cladocera with plant seeds and detritus having positive selection as immature fish were more here.

5.4 Influence of Water Quality Parameters on Size and Condition Factor

5.4.1 Water Quality Parameters

Variations in physico-chemical parameters between the three stations along River Nyando can be attributed to both anthropogenic and natural influences. Dissolved oxygen though did not show any significant spatial variation was least at S3. The reducing DO between stations can be explained by water significant drop in altitude and water velocity between the stations (Busulwa and Bailey, 2004). Stations S1 and S2 had relatively faster water compared to S3 at the river mouth.

The Water temperature varied significantly between the stations. This variation can probably be attributed to vegetation cover and altitude change. Station 1 which recorded lowest temperature had a relatively good riparian vegetation cover and was in the high altitude area as opposed to S2 and S3.Areas with low vegetation cover often experience high solar radiation, resulting into high temperatures. Conductivity, TSS, TDS and Turbidity did not show any significant variation. Turbidity however increased as downstream with the highest value at S3. The increasing turbidity can be attributed to additional suspended solids carried in from tributaries that join the main river and run off from the riparian zone.

5.4.2 Correlation

Water quality parameters determine the structure and composition of any aquatic life within a system. Dissolved Oxygen and pH for instance showed a strong positive correlation with total length, total weight and condition factor. Even though none of these relationships were significant, it can be concluded that the two parameters in a way influences fish size. The small sized fish at S3 can partly be due to low DO levels of 5.91 among other factors. Low dissolved Oxygen has been reported to cause stress to fish both in the wild and under captivity.

Conductivity also exhibited a significant positive correlation with total weight and condition factor. This result is in contrast to that of Omondi *et al*. (2013) who found a negative correlation between conductivity and Tilapia size in Lake Baringo. Turbidity recorded a significant negative correlation with TL, TW and K. Being that *B. altianalis* is an omnivorous, it depends on clear vision to get its prey. High turbidity therefore hinders this vision and probably could have led to lack of enough protein in the diet which eventually affects fish growth and weight gain.

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

- Fish size and condition factor varied between the stations along River Nyando. *B. altianalis* within the upper region were generally bigger in size compared to those around the river mouth. Females dominated in the three stations.
- Fecundity of *B. altianalis* along River Nyando was high at the upper region followed by the lower station; the mid region recorded the lowest fecundity and it increased with length.
- Males had a higher length at maturity of 23 cm more than the females at 20 cm males at S1 matured faster followed by S3 and the lowest length at maturity was recorded at S2. For females S1 recorded the highest length at maturity of 20 cm followed by S2 the lowest length was recorded at S2.
- The varying fish sizes along the river is thus as a result of sex and gonad maturity composition; food items consumed; and influence of dissolved oxygen, pH and Turbidity.

6.2 Recommendation

Based on the results of this study and conclusion above, the following are recommended;

- A size frequency research should be done for this fish in River Nyando over a long period of time preferably two years to ascertain the site preferences of each sex and gonadal maturity stages.

- Fecundity should be studied over a long period of time
- Better farming practices and sustainable use of the river water should be embraced to reduce water quality deterioration which eventually affects the wellbeing not only for *B. altianalis* but for all aquatic life.
- Similar studies covering the other main rivers drawing into Lake Victoria should be conducted in order to compare with this of River Nyando
- Since this work has been done for a relatively short period of time, influence of these parameters on the sizes of *Barbus altianalis* should be verified over a long duration.

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APPENDICES

Appendix I: Female and male gonad maturity stage classifications of B. altenialis, as modified from Hopson (1972). Stage VI spent males were not included in Hopson's classification

Gonad stages	**Male**	**Gonad stages**	**Female**
Stage I: Immature	Testes were a pair of thin transparent filaments running longitudinally, along the dorsal wall of the body cavity. Sex was indistinguishable.	**Stage I:** Immature	Ovary paired, thin, transparent running longitudinally dorsal to body wall. Sex indistinguishable.
Stage II: Developing (M1)	Testes semi-transparent greyish-white, flat with longitudinal fat attached by the mesentery to its vertical surface. The testes were small in transverse section. Testes were well vascularised, with no milt.	**Stage II:** Resting(F1)	Ovaries greyish-white, transparent, smooth cylindrical and lightly vascularised. They did not span over the entire length of the peritoneal cavity.
Stage III: Mature/Resting	Testes opaque, white-pinkish, soft and triangular in section, well vascularised and flattened along the edge. The fat was smaller than the testes but still prominent. Milt exuded from the lumen of cut testes.	**Stage III:** Early maturing	The ovaries were reddish-pink, semi-transparent, pear shaped in transverse section and well vascularised.
Stage IV: Mature/Ripe	Testes opaque, ivory-white or pinkish, triangular in cross section, edges rounded with the fat strand reduced, lying in the	**Stage IV:** Late maturing	Ovaries were pinkish with clearly visible small, opaque, pear-shaped yolky oocytes. Small blood vessels were present.

	longitudinal groove on the ventral surface of the testes. Large volumes of milt.		
Stage V: Ripe/running	Testes appearance similar to those in stage VI. A large volume of milt was released through the cloaca on applying gentle pressure on the abdomen. Testes turgid.	**Stage V:** Ripe	Ovaries were opaque with large, yellow, yolky oocytes discernible through a superficial membrane. Large blood vessels were prominent on the surface of the ovaries.
Stage VI: Spent	Testes were flabby, reddish-pink and smaller than in stage V.	**Stage VI:** Running	Oocytes were yellow-brownish in colour. Slight pressure resulted in eggs exuding from the vent.
		Stage VII: Spent	Ovaries were flabby and loose with a few scattered residual Stage V oocytes.

Plate II: The photo of the researcher Sampling *Barbus antianalis*
(Source: Author, 2015)

Plate III: Photo of a technician connecting the Electrofisher
(Source: Author, 2015)

Plate IV: Photo of the researcher weighing the *Barbus altianalis*
(Source: Author, 2015)

PlateV: Measuring the TL and SL of the *Barbus altianalis*
(Source: Author, 2015)

Plate VI: Photo of the researcher collecting stomach content and gonads

(Source: Author, 2015)