DIET AND SOME BIOLOGICAL ASPECTS OF SILVER CYPRINID, *Rastrineobola argentea* (Pellegrin, 1904) IN LAKE VICTORIA, KENYA.

BY

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DECLARATION

This thesis contains my original work which has not been submitted for the award of an academic degree in any university and should not be copied, reproduced in any format without written authority from the author or University of Eldoret.

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This work is dedicated to my beloved family

ABSTRACT

Studies on the diet and some biological aspects of *Rastrineobola argentea* were conducted between August 2014 and March 2015 in the Kenyan waters of Lake Victoria. Stomach contents of 1154 specimens collected from commercial fishers and experimental seining were quantitatively analysed. Juveniles of *R. argentea* under 30 mm SL fed almost exclusively on zooplanktons, while adult fish larger than 40 mm SL preferred insects. Changes in diet require morphological and physiological changes which are not yet well developed in young fish, thus, they can easily digest zooplankton that also satisfy their demand for protein. Diel feeding regime suggested that *R. argentea* is a visual feeder. There was spatial variation in the diet with rotifers, copepods and insects dominating the diet of *R. argentea* at Dunga, Ngegu and Wichlum stations. The change in diet among stations could be attributed to environmental changes shaping the zooplankton community in Lake Victoria. Results for length-weight relationship revealed that *R. argentea* experienced positive allometric growth pattern ($b>3$). The regression slope b was significantly different between the sexes (ANCOVA: F=18.13, p=0.001) and within the stations (ANCOVA: F=10.23, p=0.032). The highest value of b was recorded in male fish from Dunga (3.40) and the lowest in female fish from Ngegu (2.92). The fish population was dominated by females with an overall male to female ratio of 1.00:1.38. The highest length at 50% maturity (L_{M50}) was recorded in male fish from Honge (39.8 mm SL) and the lowest in female fish from Ngegu (35.7 mm SL). The mean (±SE) condition values recorded were 1.096±0.01 in males and 1.097±0.01 in females with range values of 0.78-1.59 and 0.77-1.57 respectively. The condition factor did not differ significantly between males and females (Kruskal Wallis test; H = 0.03, p=0.86). The mean (±SE) Gonadal Somatic Index (GSI) recorded were 1.08±0.04 (males) and 6.02±0.14 (females) with range values of 0.02-3.38 and 0.34-17.39 in males and females respectively. *Rastrineobola argentea* showed peak condition and GSI in September/February and October/March for open waters and Nyanza gulf respectively. The following recommendations were outlined from this study: sampling for diet study during the day when the fish feeds, further study on change in diet with season, not assume isometric growth for this fish and to revise the mesh-size for the fishery due to the small size at maturity.

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ACKNOWLEDGMENTS

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LIST OF ABBREVIATION AND ACRONYMS

ANCOVA : Analysis of Covariance

ANOVA : Analysis of Variance

GSI : Gonadal Somatic Index

K : Fulton's Condition Factor

KMFRI : Kenya Marine and Fisheries Research Institute

K_n : Le Cren's/Relative Condition Factor

LVFO : Lake Victoria Fisheries Organization

RGI : Relative Gonadal Index

SC : Stomach Content

SE : Standard Error

SL : Standard Length

TL : Total Length

VPA : Virtual Population Analysis

CHAPTER ONE

INTRODUCTION

1.1 Background Information

The Silver Cyprinid, *Rastrineobola argentea* (Pellegrin, 1904) is locally known as Omena in Kenya, Dagaa in Tanzania and Mukene in Uganda. It is one of the surviving endemic fish species in Lake Victoria (Manyala and Ojuok, 2007). The fish is also found in Lakes Kyoga, Bulera and Ruhondo. The diel behaviour of *R. argentea* is associated with feeding on insects near the surface at night and aggregating in the lower water column around the oxycline during the day where they feed on zooplankton (Getabu *et al*., 2003). High densities of *R. argentea* are mostly found off shore in deep waters (LVFO, 2011) while it prefer shallow littoral habitats as breeding where they use as nursery grounds (Manyala and Ojuok, 2007).

Rastrineobola argentea is currently one of the major commercial fisheries of Lake Victoria comprising 60% of the total catch, out of which 20% goes for human consumption while 80% is processed for animal feed (LVFO, 2012). The fishing of *R. argentea* in Lake Victoria is largely based on the attraction of fish by an artificial light at night and by using seine nets. The minimum net mesh-size of 10 mm on Lake Victoria is allowed by law in Kenya, Tanzania and Uganda for fishing *R. argentea* (LVFO, 2012), though fishers use 5 mm mesh-size net to increase on their catch.

There are seasonal variations in catches of *R. argentea* linked to the lunar cycle. During full moon, the catches are very low due to the reduced power of light attraction and catches are highest during the darkest nights with little or no moon (Ojwang *et al*., 2014). A closed season for *R. argentea* is enforced in the Kenyan part of the lake from 1st April to 31st August which appears to be its peak breeding season (Njiru *et al*., 2005, 2014). This has never been implemented adequately since some illegal fishing still occur in some parts of the lake even during the closed season.

There are distinct variations in size at maturity of *R. argentea* from various studies (Okedi, 1973; Wanink, 1988; Manyala *et al*., 1992; Wandera, 1993). Manyala *et al*. (1992) found significantly more females than males with an overall sex ratio of 1.00:2.56 (males: females) in Lake Victoria. The fish has been reported to breed throughout the year with peaks between March and June, and December and January (Ojwang *et al*., 2014). Studies by Manyala and Ojuok (2007) showed that fecundity of *R. argentea* weighing up to 2.8 g body weight is 1,800 – 3,500 eggs. There is an indication that fecundity of *R. argentea* is higher in the Nyanza Gulf compared to Mwanza Gulf for larger specimens above 57 mm TL (Manyala *et al*., 1992).

1.2 Statement of the problem

The *R. argentea* stocks in Lake Victoria are facing the effects of intensive fishing, predation, environmental changes and pollution. The increased fishing pressure is attributed to the increase in the number of small seine nets targeting *R. argentea* from 3079 in the year 2012 to 4,137 in 2014. Fishers have also reduced their seine nets below the recommended 10 mm mesh-size thus, adding more pressure to the fishery. Environmental changes have really caused disturbances in the littoral zones used by the fish for spawning. Deterioration in water quality resulting from lake pollution has indeed altered the composition and abundance of zooplankton that form the major item food for *R. argentea* in Lake Victoria. Increased predation from Nile perch, *Latest niloticus* has been reported to cause a reduction in size at maturity and maximum size attained by *R. argentea* in the lake. Infection by the Cestode *Ligula intestinalis* has also been reported to impair reproduction and reduce fecundity of *R. argentea*.

1.3 Justification

Rastrineobola argentea is used as a major input for fishmeal processing based on its relatively higher protein content than other fishes (>50% crude protein). Its low price, easy divisibility into smaller and cheaper units and its longer shelf life in the dried form increases its demand for human consumption. The fish also plays a crucial role within the ecosystem of Lake Victoria being one of the main prey species of Nile perch, *Latest niloticus* thus supporting its survival in the lake. However, despite its commercial and ecological importance, there is no up-to-date information on biology and ecology of this fish thus, the present study linked this knowledge gap. Such information are useful for the fisheries management. For instance, information on length at maturity will guide the fisheries managers in setting the mesh size that can target adult fish while conserving the juvenile fish.

1.4 Objectives

1.4.1 General Objective

To investigate diet and some biological aspects of Silver Cyprinid, *Rastrineobola argentea* in Lake Victoria, Kenya.

1.4.2 Specific objectives

i. To determine the diet of *R. argentea* in Lake Victoria, Kenya
ii. To analyze the length-weight relationship of *R. argentea* in Lake Victoria,
iii. To determine the length at 50% maturity (L_{M50}) and Sex ratio of *R. argentea*,
iv. To determine the condition factor of *R. argentea* in Lake Victoria, Kenya
v. To determine the Gonadal Somatic Index of *R. argentea* in Lake Victoria.

1.5 Hypotheses

i. Diet of *R. argentea* do not significantly vary spatially in Lake Victoria
ii. Length-weight relationship of *R. argentea* do not vary significantly with sex and stations
iii. Numbers of male and female *R. argentea* in Lake Victoria are not significantly different
iv. Condition factor of *R. argentea* in Lake Victoria is not significantly different with sex
v. There are no changes in the Gonadal Somatic Index of *R. argentea* in Lake Victoria

CHAPTER TWO

LITERATURE REVIEW

2.1 Classification of *R. argentea*

Rastrineobola argentea is a species of ray-finned fishes with the following scientific classification (Pellegrin 1904):

Kingdom: Animalia

Phylum: Chordata

Class: Actinopterygii

Order: Cypriniformes

Family: Cyprinidae

Genus: Rastrineobola

Species: *R. argentea*

2.2 Distribution and feeding habits of *R. argentea*

The distribution of *R. argentea* in Lake Victoria depends on several environmental variables such as temperature, turbidity and dissolved oxygen (Manyala and Ojuok, 2007). Areas with high turbidity usually have low densities of *R. argentea* as compared to offshore clear deep waters (Ojwang *et al.*, 2014). With Increased turbidity the sediments clog the fish gills, reduce vision by the fish. *Rastrineobola argentea* is more or less an obligate zooplanktivore and as such has a crucial role in the ecosystem of the lake as a link between the zooplankton and the top predator (*L. niloticus*) (Manyala and Ojuok, 2007). The diet of *R. argentea* predominantly consists of copepods, with relatively little contribution from cladocerans and rotifers (Wanink, 1998). However, studies are lacking to ascertain its feeding habit in Lake Victoria, Kenya.

2.3 Length-weight relationship in fish

Length-weight relationships provide information on the condition of fish and to determine whether somatic growth is isometric or allometric. Positive allometric growth implies that the fish becomes relatively stouter or deeper-bodied as it increases in length. Negative allometric implies that the fish becomes more slender as it increases in length while isometric is associated with no change of body shape as the fish grows (Riedel *et al*., 2007). The length–weight relationships are important because they allow the conversion of growth in-length equations to growth in-weight, which is useful in stock assessment models and allow the estimation of biomass from length observations (Morey *et al*., 2002). According to Arslan *et al.* (2004), the value of the regression coefficient *b* (slope) in the length-weight relationship of fish can be used as an indicator of food intake and growth pattern, and may differ according to biotic and abiotic factors, food availability and habitat type.

2.4 Condition factor

Condition factor refers to the well-being or health status of fish (Blackwell *et al*., 2000). It is an important concept in fisheries management and can be used to assess the health and potential of the fishery to support the fishing pressure. In fish biological studies, the condition of the fish is estimated from length-weight relationship thus can be used for life history and morphological comparisons between different fish population or the same fish from different habitats to determine habitat suitability (Moutopoulos and Stergiou, 2002). The condition factor of fish can be affected by a number of factors such as stress, sex, season, availability of feeds and other water quality parameters (Khallaf *et al*., 2003).

Fulton's condition factor, K is calculated from the equation: $K = (W\times100)/TL^3$, where, W is the body weight (g) and TL is the total length (cm); the factor 100 is used to bring K close to a value of one. Fulton's condition factor assumes isometric growth (Cooney and Kwak, 2010). If a fish stock does not exhibit isometric growth, which is not often the case, then K tends to differ depending on the length of the fish. Furthermore, comparing K between species is problematic because both species would need to exhibit isometric growth for the comparison to be valid. Because of these limitations, Fulton's condition factor should be avoided.

To facilitate comparisons, Le Cren (1951) introduced the relative condition factor, which compensates for changes in form or condition with increase in length, and thus measures the deviation of an individual from the average weight for length in the respective sample: $K_n = W/ aTL^b$, where, W is the observed weight of fish and aTL^b is the mean weight predicted from length-weight relationship. Le Cren (1951) pointed out that the interpretation of the condition factor is difficult and prone to error. For example, a difference in mean condition between two populations can be caused by: (i) slight differences in body shape between these populations; (ii) different mean lengths in the respective samples if *b* is far less than or more than 3; and (iii) differences in season or development of gonads between the two samples.

2.5 Length at 50% maturity and sex ratio

Length at 50% maturity (L_{M50}) is the length at which 50% of the fish are mature. It guides the fisheries managers in setting mesh-sizes that will target mature fish which have contributed to the next generation and giving juvenile fish time to grow and mature (Karna *et al*., 2012). The length at 50% maturity of *R. argentea* at Pilkington Bay in the Ugandan waters of Lake Victoria has been determined to be 40–41 mm SL for males and 43–44 mm SL for females (Wandera, 1993). Manyala *et al* (1992) found significantly more females than males with an overall sex ratio of 1.00:2.56 (males : females), and estimated the length at 50% maturity at 34 mm SL for males and 36 mm SL for females in the Kenyan section of Lake Victoria. Okedi (1973) reported a sex ratio of 1.00: 1.56 (male to female).

2.6 Gonadal Somatic Index (GSI)

The Gonadal Somatic Index (GSI), expressed as gonad mass as a percentage of total body or somatic mass, is widely used as a simple measure of the extent of reproductive investment or gonadal development (Cubillos and Claramunt, 2009). Despite its popularity, the validity of GSI has often been questioned (Erickson *et al.,* 1985; West, 1990). This is because both gonad and somatic mass are highly variable in relation to individual condition, the maturational status of the gonads and environmental factors (Lambert *et al.*, 2003). Moreover, somatic mass often varies independently of ovary mass for individuals. Somatic energy reserves become progressively depleted over the spawning season when an individual continues to spawn repeatedly (Cubillos and Claramunt, 2009).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study Area

Lake Victoria with an area of 68,800 km^2 is the second largest freshwater lake in the world. The Lake is shared by Kenya, Uganda and Tanzania in the ratios 6%, 45% and 49% of the surface area (Johnson *et al.*, 2000). It stretches 412 km from North to South between 0°30'N and 3°12'S and 355 km from West to East between 31°37' and 34°53'E, and lies across the equator at an altitude of 1135 m above sea level (Johnson *et al.*, 2000).

The lake is relatively shallow, with a recorded maximum depth of about 80 m and an average depth of 40 m. It has about 3,500 km indented shoreline, enclosing innumerable small, shallow bays and inlets. It contains numerous islands. The main rivers flowing into the lake are the Kagera which, together with Nzoia, Yala, Sondu and Awach-Kabuon, contribute about 50% of the flow. Nyanza gulf is a large inlet from Lake Victoria that extends into Kenya, and it is comparatively shallow, with maximum and average depth of 68 m and 6 m respectively.

The present study was conducted in the Kenyan waters of Lake Victoria (Fig. 1). The lake was divided into two regions namely, Nyanza Gulf with sampling stations at Dunga (0˚08'40.7"S, 34˚44'12.4"E); Ngegu (0˚29'25.0"S, 34˚30'03.8"E), and open waters with sampling stations at Honge (0˚02'37"S, 34˚00'48.6"E); Wichlum (0˚14'21.4"S, 34˚12'34.3"E). The fishery at Dunga is shallow (3-4 m) covering the inner Nyanza gulf waters while Ngegu is deep (8-14 m) and covers the mid gulf waters. The fishery at Wichlum is shallow (5-7 m) covering the open waters while Honge is deep (16-25 m) and covers the open waters.

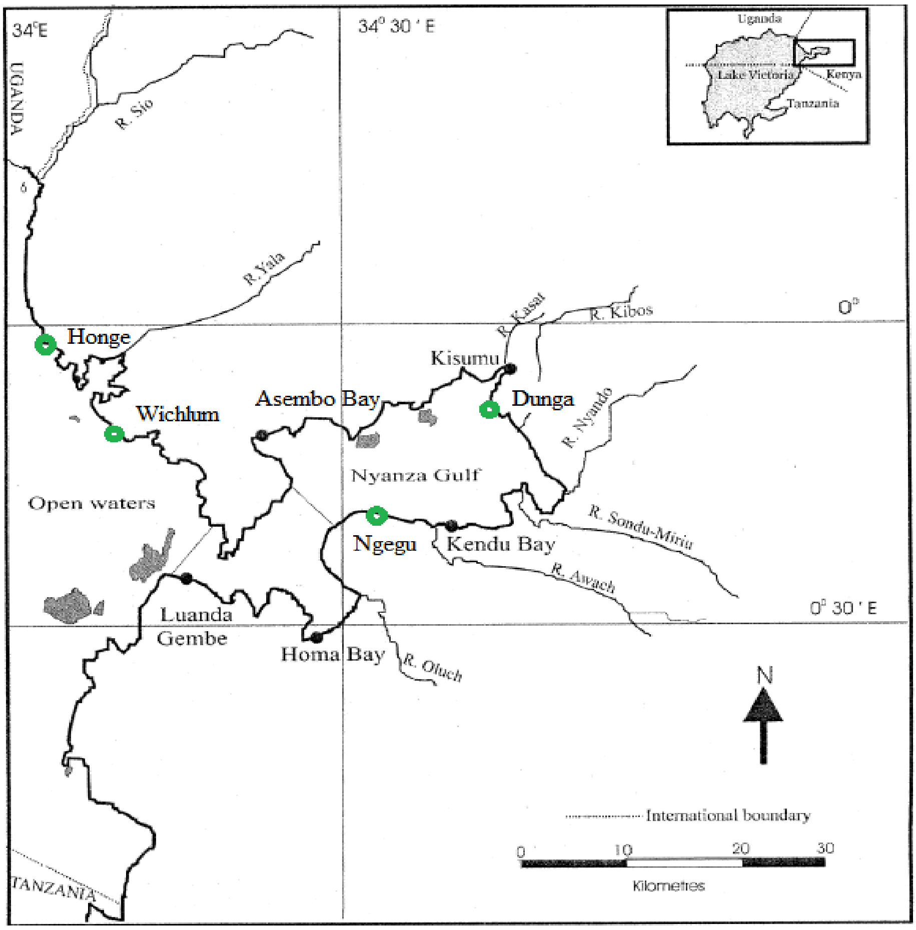

Figure 1: Map of Lake Victoria showing the sampled stations

(Source: Njiru *et al.*, 2004)

3.2 Sampling procedures

For biological studies 80 fresh fish were collected monthly from landed commercial catches at four stations between August 2014 and March 2015 (total sample = 2240 fish). Individual fish were measured (SL; TL cm) and weighed (0.01g) in the field using an electronic balance (KERN, EMB 200-2). Sub-samples of 840 fish were preserved in 5% formalin for gonad analysis. In the laboratory each fish was dissected ventrally using scalpel and sexed, then the gonads weighed (0.01 mg) using a sensitive electronic balance (Mettler Toledo, AG204).

The fresh fish samples (1154 fish) for diet studies were collected by seining at three stations, namely: Ngegu, Dunga and Wichlum. Honge was excluded for diet studies since Wichlum samples were considered representative enough. A 24-h sampling study was done by seining at 3-h interval using small seine net of mesh-size 5-8 mm, length 60-100 m and width 4-8 m. The fish samples were preserved in 5% formalin. While fishing, composite vertical samples of zooplankton were collected from the water column from 4-30 m depth using 50µm plankton net of diameter 30 cm and preserved in 500 ml vials with 5% formalin (Fig. 2).

Figure 2: Collection of fish and zooplankton samples

(Source: Author, 2016)

In the laboratory, the zooplankton samples were allowed to settle overnight, and the overlying water siphoned using a pipette to give concentrated samples of 20 ml, which were then shaken to mix. A sub-sample of 1 ml was drawn using a teat pipette into a Sedgwick Rafter chamber for counting and identification of the zooplankton under an inverted microscope (Motic®AE31 series). Zooplankton was identified to genus level using keys by Jung (2004). The counting chamber was divided into four strips and organisms in twenty cells counted per strip. Four counts were carried out per sample and an average calculated. The fish were preserved for not more than two days before the stomach analysis was done. The stomach contents (SC) were weighed to the nearest (0.1 mg) using an electronic balance. The contents were then put into a petri dish and the zooplanktons sorted and identified under a microscope.

3.2.1 Food selection

Strauss Linear index (Strauss, 1979) was used to calculate food selection:

$$L_i = r_i - p_i$$

Where, r_i is the proportion of prey taxon i in the guts and p_i is the proportion of the same taxon in the environment. The means of r_i and p_i weighed by the number of prey in each sample was used to calculate L_i.

3.2.2 Length-weight relationship of *R. argentea*

The length-weight relationship was determined using the allometric equation of Ricker (1973):

$$W = a \times TL^b$$

Where, W is the weight of the fish (g), TL is the total length (cm), *a* is the intercept and *b* is the regression coefficient.

3.2.3 Relative Condition Factor

Relative Condition Factor (K_n), was calculated according to Le Cren (1951):

$$K_n = \frac{W}{a \times TL^b}$$

Where, W is the observed weight, a, TL and b are the intercept, total length and regression coefficient, whereas n is the number of observations.

3.2.4 Gonadal Somatic Index (GSI)

Gonadal Somatic Index was calculated according to Zeyl *et al*. (2013):

$$GSI = \frac{Gonad\ weight\ \times 100}{Gonad\ free\ body\ weight}$$

3.2.5 Length at 50% maturity and sex ratio

The length at 50% maturity (L_{M50}) was estimated from logistic curve equations:

$$Ln\left(\left(\frac{1}{P_L}\right) - 1\right) = S_1 - S_2 * L$$

$$L_{M50} = \frac{S1}{S2}$$

Where, P_L is the probability of maturity at length L, S_1 is the intercept and S_2 is the slope.

Sex and maturity were determined according to Manyala *et al* (1992) as described below (Table 1). Fish in maturity stages I and II were considered immature, while those in stages III-V were considered mature for the purpose of calculating the length at first maturity (L_{M50}).

3.3 Statistical Analysis

Kruskal-Wallis test was used to test variations in condition factor. Chi-square test was used to test the sex ratio and spatial variation in diet composition. Analysis of Covariance (ANCOVA) was used to test for the slopes of the length weight relationships in relation to sex and stations.

Table 1: Coding maturity of *Rastrineobola argentea* (Manyala *et al*., 1992).

Maturity	**Male**	**Female**
Stage I: Undetermined	Gonads are not yet well formed to identify sex	Gonads are not yet well formed to identify sex
Stage II: Immature	Testis appears as a thin-threadlike structure covered with fat and anterior tip extends to gill region.	The ovary is more flattened, covered with fat and ends into a blunt tip
Stage III: Maturing	Testes have increased in size and are even rounded	Ovaries show eggs and when pieced eggs are held together by the interstitial tissue with transparent egg structures
Stage IV: Mature almost ready to spawn or spawning	Testis large and tend towards flattening with some showing folds. Spawning individual have part of testis empty with milt concentrated at the pore	Ovaries are enlarged with large eggs of almost size. When the ovary is punctured eggs separate easily
Stage V: Resting	Testes do not completely loose milt but grow smaller and appear as in stage III	Eggs have been shed and the few remaining are reabsorbed ending in a flat firm structure similar to the immature stage.

CHAPTER FOUR

RESULTS

4.1 Diet of *R. argentea*

4.1.1 Diet composition

During the period August 2014 to March 2015 the gut contents of 1154 specimens of *R. argentea* were analysed. They consisted mostly of copepods, cladocerans, rotifers and insects (Fig. 3). Copepods contributed the highest (34.6%) while insects contributed the least (18.7%). The insects together composed of chaoborus and chironomids and larvae/pupae.

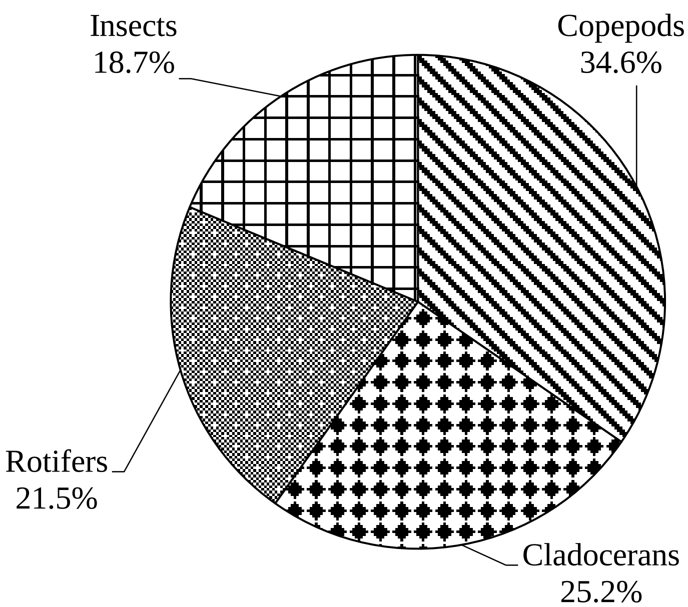

Figure 3: Contribution of different food items in the diet of *R. argentea* in Lake Victoria, Kenya during the study period.

4.1.2 Spatial variation in diet composition

There was spatial variation in the composition of the food items consumed by *R. argentea* from the three sampled stations in Lake Victoria (Table 2). The dominant food items in the diet of *R. argentea* in terms of weight were rotifers (36.8%), copepods (54.2%) and insects (32.0%) at Dunga, Ngegu and Wichlum. The other important food item in the lake was cladocerans. Chi-square test revealed significant difference between the ingested copepods (χ^2=16.96, df=2, p=0.00), rotifers (χ^2=17.51, df=2, p=0.0001) and insect (χ^2=21.63, df=2, p=0.0001) in the three stations. No significant spatial variation was detected with cladocerans (χ^2=5.72, df=2, p=0.06).

Table 2: Contribution of various food items in the guts of *R. argentea* from various stations in Lake Victoria, Kenya. Parentheses indicate percentages (%) and numbers outside indicate weights (mg).

Food items	Dunga (n=253)	Ngegu (n=320)	Wichlum (n=581)
Copepods	38(27.1)	70(54.2)	36(22.5)
Cladocerans	22(15.6)	41(31.7)	45(28.3)
Rotifers	52(36.8)	14(10.4)	28(17.2)
Insects	29(20.5)	5(3.7)	51(32.0)

4.1.3 Food ingested in relation to fish size

The fish examined ranged from 27 to 59 mm SL. A change in the diet with increasing size was apparent, with all size classes consuming all the important food items (Fig. 4). Copepods were the major food of *R. argentea* under 30 mm SL, and was of little importance to fish larger than 40 mm SL. Insects were also of little importance to the diet of small *R. argentea* (<30 mm), but were major food items of larger fish. Cladocerans and rotifers were consistently important to all size groups.

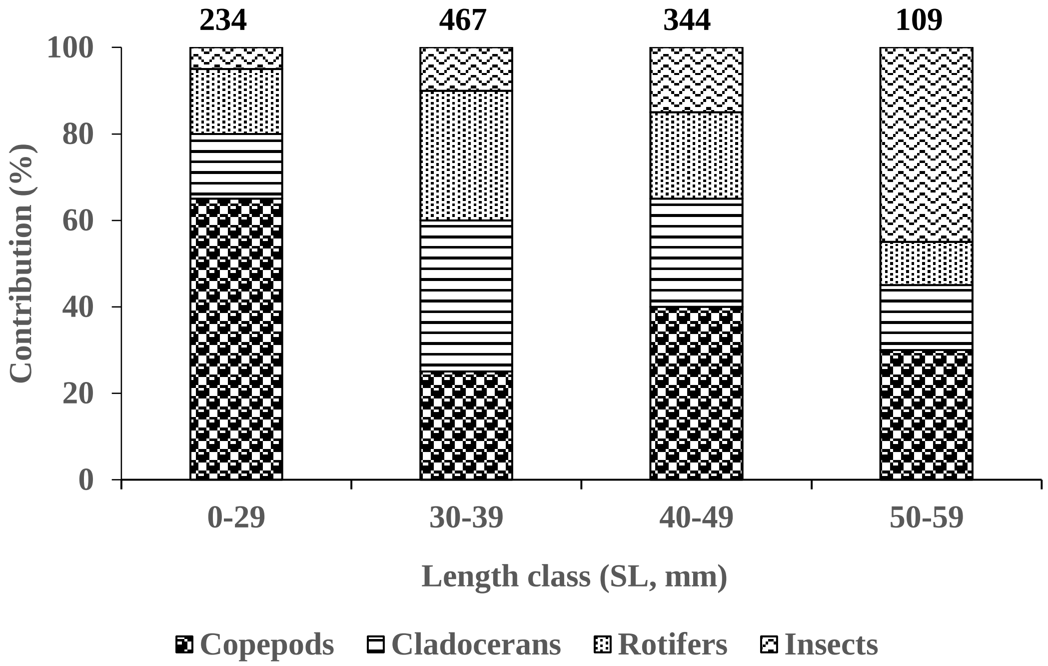

Figure 4: Food of *R. argentea* of different length classes from Lake Victoria, Kenya during the study period. Numbers above columns indicate sample size (n).

4.1.4 Food selection

A total of 20 zooplankton species were identified in Lake Victoria (Annex 1), out of which only 6 families were found in the gut of *R. argentea.* Strauss Linear Index of food selection showed that *R. argentea* preferred Cyclopoida at Ngegu, Daphnia at Wichlum and Brachionus at Dunga (positive values). However, Calanoida, Bosmina and Keratella were avoided in most stations (negative values) (Fig. 5).

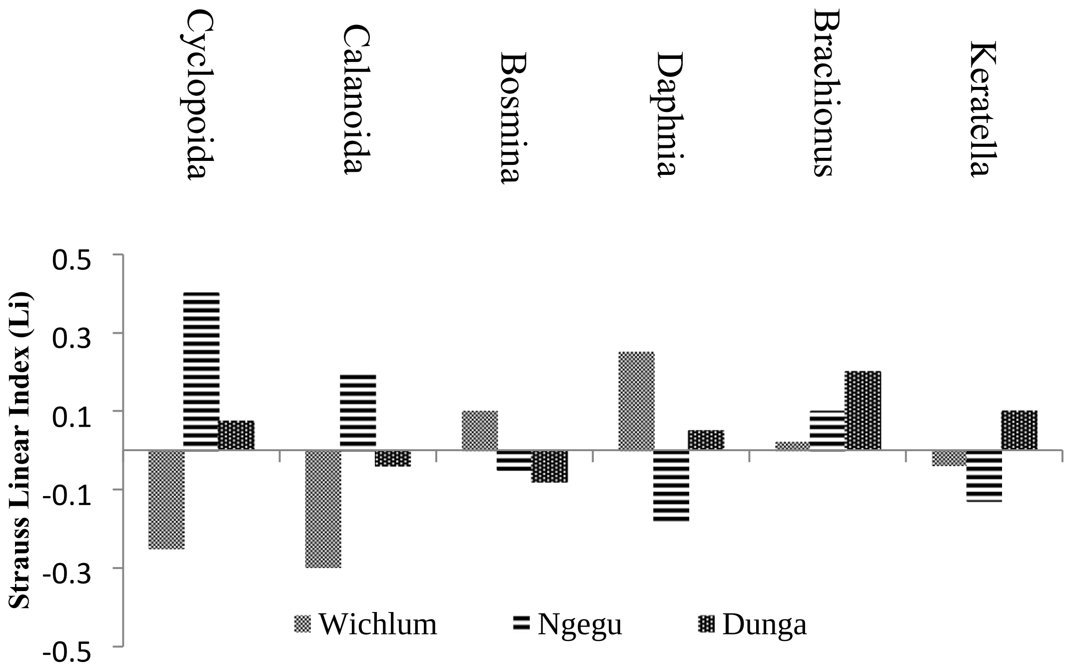

Figure 5: Selectivity of zooplankton species by *R. argentea* in Lake Victoria, Kenya.

4.1.5 Diel feeding rhythm

A 24-h feeding study showed that *R. argentea* fed mostly during the day, and ingests very little food at night. The feeding regime in the Nyanza Gulf showed two peaks around 6pm and 6am, whereas in the open waters the peaks were around 6pm and 9am (Fig. 6). The stomach content reduces reaching the lowest levels at midnight in the Nyanza Gulf and 3am in the open waters. An increase in the stomach contents was recorded from around 3 am and 6 am in the Nyanza Gulf and open waters respectively.

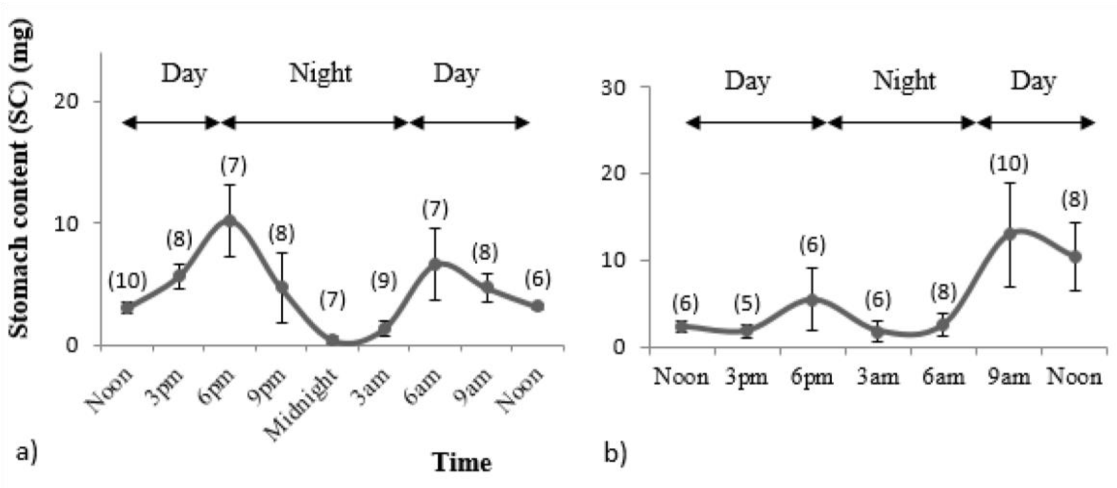

Figure 6: Diel feeding regime of *R. argentea* in Lake Victoria, Kenya. a) Nyanza Gulf, b) open waters. Vertical lines indicate the mean ± SE. Parentheses indicate sample size.

4.2 Biological aspects

4.2.1 Length-weight relationship

Results for length-weight relationship showed that *R. argentea* experienced positive allometric growth pattern (*b*>3) in most stations (Fig. 7). The highest value of the regression slope *b* was recorded in male fish from Dunga (3.40) and the lowest in female fish from Ngegu (2.92). The regression slope *b* was significantly different between the sexes (ANCOVA: F=18.13, df=1, p=0.001) and within the stations (ANCOVA: F=10.23, df=3, p=0.032). The highest mean (±SE) standard length (46.50±0.20) and lowest (44.10±0.20) were recorded at Honge and Ngegu respectively.

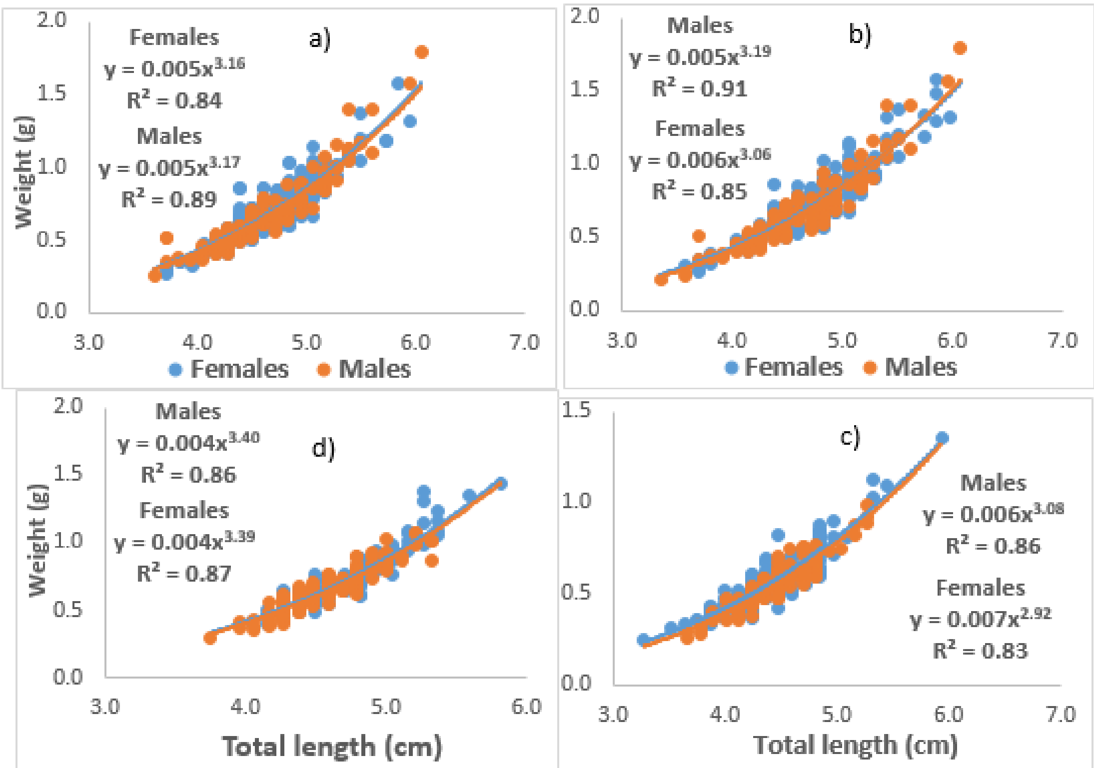

Figure 7: Length- weight relationship of *R. argentea* in Lake Victoria, Kenya. a) Honge, b) Wichlum, c) Ngegu and d) Dunga.

4.2.2 Length at 50% maturity

Lengths at 50% maturity (L_{M50}) for either sex are presented for each station (Table 3). In male fish, Honge (39.8 mm SL) and Ngegu (36.4 mm SL) recorded the highest and lowest L_{M50} respectively, whereas in females Dunga (39.1 mm SL) recorded the highest and Ngegu (35.7 mm SL) the lowest.

Table 3: Length at 50% maturity of *R. argentea* from Lake Victoria, Kenya.

Sex	Ngegu	Honge	Wichlum	Dunga
L_{M50} Male (mm SL)	36.38	39.83	38.71	38.33
L_{M50} Female (mm SL)	35.65	38.66	38.78	42.39

4.2.3 Sex ratio

Numbers and sex ratios for each station and the whole lake are summarized in Table 4. The female fish were significantly dominant than male in nearly all stations, except at Dunga where male fish were dominant. The fish population was dominated by females with an overall male to female ratio of 1.00:1.38. Sex ratio showed that females were significantly more than males and deviated from 1:1 ratio (χ^2=37.12, df=1, p=0.0001).

Table 4: Numbers and sex ratio of *R. argentea* from Lake Victoria, Kenya.

Site	Ngegu	Dunga	Wichlum	Honge	Whole lake
Males	117	198	143	151	609
Females	197	154	232	258	841
Sex ratio (M: F)	1:1.68	1:0.78	1:1.62	1:1.71	1:1.38

4.2.4 Temporal variation in GSI and Relative condition factor

The mean (±SE) condition values recorded were 1.096±0.01 in males and 1.097±0.01 in females with range values of 0.78-1.59 and 0.77-1.57 respectively. The condition factor did not differ significantly between males and females (Kruskal Wallis test; H = 0.03, p=0.86). The mean (±SE) Gonadal Somatic Index (GSI) recorded were 1.08±0.04 (males) and 6.02±0.14 (females) with range values of 0.02-3.38 and 0.34-17.39 in males and females respectively. Both condition factor and GSI did not differ significantly with the stations and data from the stations were pooled to represent Nyanza Gulf and open water stations. *Rastrineobola argentea* showed peak condition and GSI in September and February, and October and March for open waters and Nyanza Gulf respectively (Fig. 8). There was no *R. argentea* fishing in the Nyanza Gulf during August and November due to bad weather.

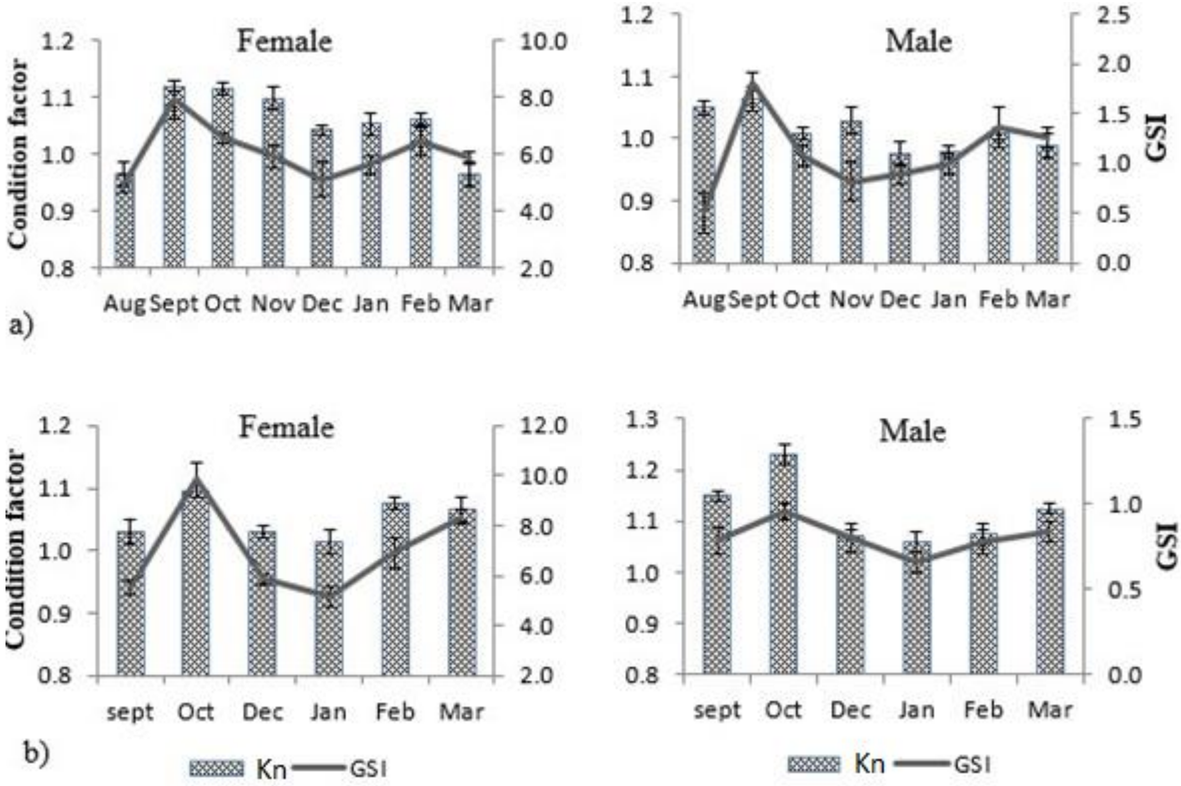

Figure 8: Monthly variation in condition factor and Gonadal Somatic Index (GSI) of male and female *R. argentea* from a) open waters b) Nyanza Gulf Lake Victoria, Kenya during the study period. Vertical lines (mean ± SE).

CHAPTER FIVE

DISCUSSION

5.1 Diet and feeding habit

5.1.1 Diet composition

The study identified four food items of *R. argentea* to be copepods, cladocerans, rotifers and insects, of which copepods contributed the highest proportion of the diet. The dominance of copepods in the diet of *R. argentea* could be attributed to their higher abundance than other zooplankton in the lake. Copepods could also be ingested because of their relatively bigger size. *Rastrineobola argentea* in Lake Victoria could therefore be regarded as a zooplanktivore from the nature of food items ingested consisting more of zooplankton.

These results concur with Wandera (1992) who found copepods forming the major diet of *R. argentea* with little contribution from insect larvae and pupae in the Napoleon Gulf and Pilkington Bay in the Ugandan waters of Lake Victoria. The results are also comparable with Budeba and Cowx (2007) who identified six food items of *R. argentea* to be *Caridina nilotica*, cladoceran, copepod, chaoborus, insects and chironomids in the Tanzanian part of Lake Victoria. However, Isumbisho *et al* (2011) reported dominance of plant remnant in the diet of *R. argentea* in Lake Bulera and cladoceran (*Daphnia* sp) in Lake Ruhondo in Rwanda. The reliance on plant remnants in Lake Bulera was likely due to poor food resources.

5.1.2 Spatial variation in diet composition

Insects were more important in the diet of *R. argentea* at Wichlum compared to other stations. This could be as a result of the mode of fishing since light was used to concentrate the fish at night, thus attracting more insects as well. However, rotifers and copepods were more important in the diet of *R. argentea* at Dunga and Ngegu respectively. These results differ from Owili (1999) who reported the dominance of cladocerans in the diet of *R. argentea* in the Nyanza Gulf of Lake Victoria. Because of increased deterioration of water quality, the zooplankton community in the lake is currently dominated by small sized cyclopoids contrasting the past situation where large sized cladocerans and calanoids dominated (Ngupula *et al*., 2010).

Ngupula (2013) linked the highest success of zooplankton (mostly cyclopoids and rotifers) in the nearshore waters to their high adaptability to poor environmental conditions as nearshore are the most polluted (highly turbid), whereas, calanoids and cladocerans of the Lake Victoria are somehow successful in the offshore waters. According to Wanink *et al*. (2002), the zooplanktivore fish (including *R. argentea*, haplochromines and juveniles of Nile perch) do not have any significant preferences towards big sized calanoids and cladocerans. However based on the present study *R. argentea* tended to prefer big sized cyclopoids and calanoids.

5.1.3 Food in relation to fish size

Juveniles of *R. argentea* under 30 mm SL fed almost exclusively on zooplankton, while adult fish larger than 40 mm SL preferred insects. The dominance of zooplankton in the diet of juvenile *R. argentea* was probably because of their smaller mouth gape (Wandera, 1992). Changes in diet require morphological and physiological changes (including enzyme production) that are not yet well developed in young fish, thus, they can easily digest zooplankton that lack cell wall (Govoni *et al*., 1986). Similarly Njiru *et al* (2004) reported zooplankton as the major food of *Oreochromis niloticus* under 5 cm TL in Lake Victoria.

5.1.4 Diel feeding rhythm

Rastrineobola argentea fed mostly during the day, and ingested very little food at night. This suggests that *R. argentea* is a visual feeder and may depend on sight for food selection. In fish the photoreceptors retinal cells (rods and cones) are actively depolarized in the dark and hyperpolarized in the light (Emran *et al*., 2010). According to Wanink (1988), adult *R. argentea* stay near the bottom during the day and moves to the surface during the night. In tendem with diel vertical migration of zooplankton. This avails the fish with a zooplankton diet during the day, while at night the fish appears to favour the larger insect larvae attracted by light from pressure lamps even in the presence of zooplankton in the water column.

The low stomach contents recorded at night was mainly due to the completion of digestion of the food consumed during the day, while the rise in stomach contents from dusk could be due to feeding by the fish to satisfy the demand after the digestion at night. These results concur with that of Wandera (1992) who found that feeding peaks of *R. argentea* in Lake Victoria occur during daylight hours while least feeding occur at night, and digestion is usually completed after midnight. Outa *et al.* (2014) reported almost similar diurnal feeding regime with *Oreochromis niloticus* in Lake Naivasha, Kenya.

5.2 Biological aspects

5.2.1 Length-weight relationship

The fish showed a positive allometric growth pattern (b>3). This implies that it becomes relatively stouter or deeper-bodied as it increases in length (Riedel *et al*., 2007). However, Limuwa *et al*. (2014) found a negative isometric growth in *Opsaridium microlepis* from Linthipe River in Central Malawi. The *R. argentea* caught from the open waters of Lake Victoria had a slightly higher mean length than from the Gulf. This could be because fishers in the open waters mainly fish in the deeper waters where they catch adult fish, unlike in the gulf where fishing is done in the near shore areas that are known nursery and breeding areas.

5.2.2 Length at 50% maturity

The study showed a reduction in length at 50% maturity for both male and female fish especially at Ngegu. The great reduction in length at maturity of *R. argentea* at Ngegu station is linked to the rampant use of illegal seines less than 10 mm mesh-size in this fishing ground. According to Manyala and Ojuok (2007), *R. argentea* in Lake Victoria has reduced its size at maturity as well as its maximum size in response to increased predation and fishing. Length at maturity in some fish species, such as tilapias, may decline in response to adverse environmental conditions (Welcomme, 2001). The intensive fishing in this case could be justified by the frame survey results in which the total number of small seine nets targeting *R. argentea* in Lake Victoria increased from 3,079 in the year 2012 to 4,137 in 2014 (Frame Survey, 2014).

5.2.3 Sex ratio

The results indicated that females were significantly more than males. The dominance of female over male *R. argentea* revealed in this study agrees with that of Manyala *et al*. (1992) in the Kenyan waters of Lake Victoria. The results are also in agreement with those of Okedi (1973) who reported a sex ratio of 1.00: 1.56 (male to female) in the Ugandan waters of Lake Victoria. The dominance of females together with high fecundity could help the fishery withstand intensive fishing in Lake Victoria. However, Usman *et al* (2013) reported a sex ratio of 1.00: 1.25 (male to female) in *Sardinella sindensis* from Karachi coast in Pakistan, but was not significantly different from the expected theoretically 1:1 ratio.

5.2.4 GSI and Relative Condition Factor

Populations of *R. argentea* showed peak condition and GSI during the months of September/February and October/March for open waters and Nyanza Gulf respectively. The fish showed mean condition with values above 1, which means that it had attained a better condition. This could be due to abundance of food within the lake as this has been shown to improve the condition of fish (Khallaf *et al*., 2003). These results are in agreement with Ojwang *et al*. (2014), but differ from Wandera (1999), who reported the fish showing peak condition in the drier months of August and December-January, and minimal breeding in the rainy months of April-May and October-November. Usman *et al* (2013) found the highest Gonadal Somatic Index value in male and female *Sardinella sindensis* during June-August.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

i. *Rastrineobola argentea* was found to feed during the day and prefers copepods
ii. The fish exhibited positive allometric growth pattern
iii. The fish has reduced in length at 50% maturity
iv. Females were significantly more than males
v. The condition factor was greater than one but not different with sex
vi. The Gonadal Somatic Index varied during the study period

6.2 Recommendations

i. Sampling for diet analysis should be done during the day when the fish feeds
ii. I recommend further study on temporal change in diet with season
iii. Researchers should not assume isometric growth for the study of this fish
iv. The fisheries managers should revise the mesh-size for the fishery

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APPENDICES

Annex 1: Zooplankton recorded from Lake Victoria, Kenya during the study period.

Stations	**Dunga**	**Wichlum**	**Ngegu**
Taxa			
Cladocera			
Diaphanosoma excisum Sars 1885	+	+	+
Moina micrura Kurz,1874	+	+	+
Ceriodaphnia cornuta Sars, 1885	+		+
Bosmina longirostris Muller, 1885	+	+	+
Daphnia barbata Weltner, 1898	+	+	
Daphnia lumholtzi Sars, 1885	+	+	+
Calanoida			
Calanoid copepodite	+	+	+
Thermodiaptomus galeboides Sars, 1901	+	+	+
Cyclopoida			
Cyclopoid copepodite	+	+	+
Eucyclops sp	+	+	+
Mesocylops sp	+	+	+
Thermocylops decipiens	+	+	+
Tropocylops confinis	+	+	+
Rotifers			
Brachionus calyciflorus	+	+	
Brachionus angularis	+	+	+
Brachionus patulus	+		
Brachionus quadridentatus	+	+	+
Keratella tropica	+		+
Keratella quadrata	+		+
Polyarthra sp.			+
Filinia sp.	+	+	
Lecane sp.			+