LENGTH-WEIGHT AND DIET COMPOSITION OF SELECTED TELEOST FISHES FROM KILIFI COUNTY, KENYA.

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DECLARATION

I, OBUYA JULIA AKINYI, declare that this dissertation is my original work and has not been presented anywhere else for academic award.

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Declaration by university supervisors

This dissertation has been submitted for examination with our approval as the university supervisors:

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DEDICATION

This dissertation is dedicated to the entire Obuya's family whose continued support and push for perseverance has enabled me to finish this project.

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ABBREVIATION AND ACRONYMS

BW	-	Body Weight
BMU	-	Beach Management Units
CN	-	Numerical Composition
EEZ	-	Exclusive Economic Zone
GoK	-	Government of Kenya
K	-	Condition Factor
Kn	-	Relative Condition Factor
WIO	-	Western Indian Ocean
LWR	-	Length-Weight Relationship
KCDP	-	Kenya Coastal Development Program
SDF	-	State Department of Fisheries
SL	-	Standard Length
TL	-	Total Length
UNEP	-	United Nations Environmental Programme

ABSTRACT

Sustainable exploitation of fishery resources requires knowledge of the population dynamics of the target resource. Studies have shown consistence and considerable decline in the densities and species richness of most coral reef fishes along the Kenya coast. Concerns over the sustainability of current fishing pressure on target fish species has led to recommendations on conducting population dynamics on those species. Fish were obtained from catches of artisanal fishers at three landing sites (Mtwapa, Kanamai and Kuruwitu) in Kilifi County between February and April 2017 in order to determine their length-weight relationship, condition factors and diet composition in two species. The fishers used spearguns, gill nets, basket traps, beach seines, monofilament nets using motor boats and dugout canoes. A total of 454 fishes were sampled, belonging to seven families, eight genera and nine species. Length-Weight relationship and relative condition studies were conducted on seven demersal species; *Calotomus carolinus* (Valenciennes, 1835), *Decapterus macrosoma* (Bleeker, 1851), *Lethrinus nebulosus* (Forsskal, 1775), *Lethrinus harak* (Forsskal, 1775), *Lutjanus fulviflamma* (Forsskal, 1775), *Sargocenton caudimaculatus* (Ruppel, 1838) and *Siganus sutor* (Valenciennes, 1835) and two pelagic species; *Rastrelliger kanagurta* (Cuvier, 1816) and *Scomberoides tol* (Cuvier 1832).There was a significant ($p < 0.05$) positive relationship between total length and body weight in all the fish sampled ($r = 0.909 – 0.962$) suggesting that the growth of fish length and weight is proportionate. The t-test calculated on b revealed no significant deviations ($p > 0.05$) from the expected cube value of 3 indicating no existence of cubic relationship between length and weight for the species. These fish species had relative condition factors above one, ranging between 1.0037 ± 0.053 to 1.0210 ± 0.089076 revealing that the nutritional requirements were available in the ecosystem for fish growth. The diet composition was determined for *S. sutor* and *L. harak* because they had a relatively high market demand compared to the other fish species. The diet was established using frequency of occurrence and numerical method. Diet composition of *S. sutor* revealed that important food items consisted mainly of algae (*Hypnea spp*) and seagrass (*Thalassodendron ciliatum*) while in *L. harak*, crustaceans (crabs) and worms were abundant. The length-weight relationship of two species, *C. carolinus* and *S. caudimaculatus* are described for the first time in Kenya. The present length-weight relationship for the nine species could be used as a baseline tool for enhanced fisheries management in Kilifi. The assessed diets of *S. sutor* and *L. harak* could be used to attempt culture possibilities of the two fish species. However, more extensive research needs to be undertaken which would involve the standardization of sampling seasons and measurement of environmental physico-chemical parameters before additional inference could be made.

CHAPTER ONE

1.0. Introduction

The Kenya coast is approximately 640 km long and borders Somalia to the north and Tanzania to the south. This forms part of the Western Indian Ocean (WIO) marine eco-region. It is distinguished by the presence of a fringing coral reef running along the coast with discontinuities where rivers enter the ocean (Ochumba, 1983). The Kenyan Exclusive Economic Zone (EEZ) is approximately 235,000 km^2 and includes a narrow continental shelf about 4km wide (Aloo *et al*, 2014). Weather and climate systems are influenced by extensive pressure systems creating two distinct seasons, the North East Monsoon (NEM) from October to March and the South East Monsoon (SEM) from April to September (McClanahan, 1988). The marine habitats include mangrove forests, sea grass beds and coral reefs supporting a wide variety of species which are mostly exploited by the small scale artisanal fishers (UNEP, 1998).

Marine fisheries resources comprise of a number of species which are mainly demersal, harvested by small-scale artisanal fishers from inshore fishing grounds. The marine fisheries resources along the Kenya coast commonly land demersal fishes including: Rabbitfishes, (*Siganus sutor*) variegated emperor (*Lethrinus variegates*), parrotfishes, (*Calotomus carolinus*), yellow goatfishes, (*Parupeneus barberinus*), thumbprint emperor, (*Lethrinus harak*), red snappers, (*Lutjanus argentimaculatus*), (Fondo, 2004). Majority of fishers target finfish while others fish for crabs, lobsters and octopus (Hoorweg & Muthiga, 2009). Le Manach *et al.*, (1984) assessed the status of fish catches and yields of reef fishes and reported declining trends in fish abundance. Analyses of long-term trends in the status of demersal reef fish landings shows that Kenyan reef yields approximately 3 - 4 tonnes km^{-2} yr^{-1} (Kaunda-Arara *et al.*, 2003). Although the long-term temporal trends are inconsistent, existing evidence shows decline in size and biomass of landings in Kenya (Kaundra-Arara *et al*., 2003).

Catch assessment of reef fishes has revealed that *Lutjanidae, Carangidae, Siganidae, Scaridae, Caesinidae, Scombridae, Plectorhynchidae and Sphyraenidae* are the major fish groups harvested in Kiliifi Creek (Nzioka, 1990). Reef fisheries are highly multi-species character with catch rates including over 160 species along the coast of Kenya (McClanahan and Mangi, 2004). Assessment of the reef fish populations along the coast of Kenya (McClanahan and Abunge, 2014) has shown a consistent and considerable decline in the population density and species richness of most fish species. The densities of fishers on the reefs are between 7 - 13 fishers/km^2 (McClanahan and Kaunda- Arara, 1996). The annual catches of marine landings of the selected families have fluctuated between 2, 736 and 3081 MT (Table 1) (GoK, 2016). These species contribute approximately 70% of the annual catches of marine and coastal landings.

Table 1: Kenyan marine and coastal fish landings by families and Weight from 2011 – 2016 of 7 demersal and 2 pelagic families (Government of Kenya)

	2011	**2012**	**2013**	**2014**	**2015**	**2016**
Demersal fish Families	**M. tons**	**M. tons**	**M. tons**	**M. tons**	**M. tons**	**M.tons**
Rabbitfishes (Siganidae)	791	645	794	722	702	718
Scavengers (Lethrinidae)	683	602	685	686	689	637
Snapper (Lujanidae)	346	432	347	319	402	351
Parrotfishes (Scaridae)	538	416	540	508	486	498
Squarel fishes (holocentridae)	94	71	52	24	47	87
TOTAL	**2,452**	**2,166**	**2,418**	**2,259**	**2,326**	**2,291**
Pelagic fish						
Cavalla jacks	283	241	274	234	302	324
(Carangidae) Mackerels	339	329	328	347	321	296
(scombridae) **TOTAL**	**629**	**570**	**602**	**581**	**623**	**620**
Grand Total	**3,081**	**2,736**	**3,020**	**2,840**	**2,949**	**2,911**

Fish length and weight data are commonly used parameters for length-weight relationship (LWR) analyses and diet composition (Mendes *et al*., 2004). The length and weight data can be used for a range of studies, including the estimation of fish growth rates and the overall health of fish stocks (Kohler *et al.,*1996). Length-weight data can give significant signals about the climate and environmental changes to fisheries and also change in methods of anthropogenic utilization (Sale *et al.*, 2014). Diet of fishes is useful in ecological studies and investigations of ecosystem dynamics (Engdaw, 2014). Considering the LWR and diet composition of reef associated fishes all over the world, several studies have been carried out. In New Caledonia, Letourneur *et al*. (1998) studied the length-weight relationship of fishes from lagoons and coral reefs. Length- weight relationship and feeding ecology have been investigated in *Siganus canaliculatus* from the Gulf of Mannar (Jayasankar, 1990; Anand & Reddy, 2012) while Vasantharajan et al., (2013) reported on *Lethrinus nebulosus* and *Lethrinus lentjan* from Thoothukudi coast, India.

Studies are available for length-weight relationship and diet composition of some reef associated fishes in Kenya. Mbaru *et al*. (2010) reported the length-weight relationship of 39 selected reef fishes. At the south coast, Kimani *et al.* (2008) studied the morphometric and condition factors of *Siganus stellatus, Siganus canaliculatus* and *Siganus sutor*. In North-coast of Kenya, the length- weight relationship of *Dentex maroccanus* has also been studied in Malindi- Ungwana bay (Aura *et al.*, 2011). Nyunja *et al*. (2002) studied the feeding ecology of *Sardinella gibbosa* and *Atherinomorous lacunosus* at Mwapa and Wasini and reported that copepods were the most abundant prey for the two species. De Troch *et al.* (1998) also studied the trophic organization and community structure of abundant fishes in Gazi Bay and reported that the diets of juvenile fish comprise mainly of plankton and benthic organisms.

On the northern Kenyan coast only 15% of the species contribute to 90% of the catch with *S. sutor*, *L. harak* and *L. letjan* being the three most commonly caught species (Samoilys *et al*., 2015). The catch rates over the years have fluctuated and are artificially maintained by the shifting proportions of species in catches with *S. sutor*, *L. fulviflamma*, *R. kangurta* and *L. nebulosus* increasingly contributing to the catch (Samoilys *et al*., 2015). Resource extraction rates are estimated at approximately 1.3 tonnes/km^2/yr^{-1} with the fishers preferring certain families of fish such as Siganidae, Lethrinidae, Lutjanidae and Serranidae (McClanahan *et al.*, 2010). McClanahan *et al.,* (2007) reported a stable and significant decline in the population densities and species richness of five fish families; Scaridae, Balistidae, Acanthuridae, Chaetodontidae and Pomacanthidae. A shift in the species composition of the landings where predatory snappers and groupers once dominated, opportunistic and lower trophic level species such as rabbitfish and parrotfishes have been observed (McClanahan and Omukoto, 2011).

1.1. Problem statement

Artisanal fishery has been the main cause of decline of populations of reef fishes due to high levels of fishing effort coupled with the use of destructive fishing gears (Mangi & Roberts, 2006) resulting into a shift in species composition. Studies have shown consistence and considerable decline in the densities and species richness of most of the target species (McClanahan *et al.,* 2007). Local fishers have also noted significant decrease in the catches of the selected fish species. At the moment, only a few estimates of species-specific LWR parameters are available for coastal fishes from Kilifi.

1.2. Justification

Small scale and artisanal fisheries account for more than 40% of the global marine fisheries taken for human consumption (Jennings *et al.*, 2010). Kenya's artisanal fisheries contributes valuable fish landings and support the livelihood of some 13, 000 fishers on the coast (GoK, 2012). Kilifi County is home to traditional fishing communities and is an important location for artisanal fishermen on the north coast of Kenya. The selected fishes are key fisher target species which has been suggested as a driver for the persistent use of illegal gears resulting into some species becoming commercially extinct (McClanahan *et al.*, 2010). The diet composition of two species, *S. stuor* and *L. harak* were investigated to assess their nutritional standing in the context of the fish community in this region. These two species are key target species in women's small-scale fish trade because of their high market value and flavor. Because of this, the demand of these two species has been reported to be relatively high. The present study therefore establishes the LWR of nine teleost fishes contributing to the available data for the main commercially exploited coral reef fishes in Kenya and also assessing the diet composition of two of the selected two species to describe their diets for culture possibility that would increase their yield for the coastal population.

1.3. General objective

To evaluate the length-weight relationships, condition factor and diet composition of commercially important teleost fish species in Kilifi County.

1.4. Specific Objectives

II. To evaluate the length and weight relationship of nine selected teleost fishes at Kilifi County.

III. To determine the condition factors of the selected nine teleost fishes in Kilifi County.

IV. To determine the diet composition of *Siganus sutor* and *Lethrinus harak* in Kilifi County.

1.5. Research hypothesis

Fish growth pattern is not isometric

CHAPTER TWO

2.0. Exploitation strategy of Marine resources in Kenya

Artisanal fishery along the Kenyan fishery is a multi-species, multi-gear and multi-vessel with variable and unpredictable catch and effort all year round (Mcclanahan, 1998; Gomes *et al.*, 2014). Various fishing gears and vessels are used by fishermen along the Kenyan coast (Samoilys *et al.,* 2011). Gears include basket traps, gill nets (mesh size <63>250 mm), prawn nets, spearguns/ harpoons, troll-lines, ring nets, long-lines, beach seines, mono and multi filament nets, seine nets (Mbuga, 1984; GoK, 2006). Vessels such as dugout canoes and motorized boats are operated. Overfishing and environmentally unfriendly fishing gears have led to a reduction in marine fisheries along the Kenyan coast (Fondo *et al.*, 2010) and in some cases degradation of habitats especially in the coral reefs. Reports on fishing methods and destructive gears (Cros and McClanahan, 2003; McClanahan and Mangi 2004; Crabble and McClahanan, 2006) are available. Mangi *et al.*, (2006) reported that increase in number of fishers and use of destructive fishing gears augments overfishing. Local fishers have cited significant decrease in catch. Samoilys *et al.* (2011) reported that mesh size selection of nets affects the size of fish caught resulting in different growth patterns. Spearguns and use of monofilament nets are illegal (GoK, 1991). Spear fishing is destructive as fishers may break the corals when target is missed (Hoorweg *et al.*, 2009).

2.1. Biological studies on Kenyan marine fishes

Several biological studies have been conducted for approximately 45 species of marine fishes along the Kenya coast (Fondo *et al.*, 2010). These include, aspects of the biology and feeding ecology of the reef fish *Scolopsis bimaculatus,* estimates of growth and mortality rates of rabbitfish *Siganus sutor* (Maina *et al.,* 2013); morphometric and condition factors of *Siganus* *stellatus* Forsskal, 1775, *Siganus canaliculatus,* and *Siganus sutor* (Kimani *et al.*, 2008) and population dynamics of the genus *Epinephelus* off the south coast (Agembe *et al.,* 2010).

Reproductive biology of some fishes including *Lethrinus harak* (Kulmiye *et al.*, 2002), and *Lutjanus fulviflamma* (Kaunda-arara and Ntiba, 1997) have been studied. They have a prolonged spawning season which in *L. harak* extends from October to April while in *L. fulviflamma* it extends from December to May. The spawning aggregations of reef fishes have also been investigated (Nzioka, 1979; Ntiba and Jaccarini, 1990). Most reef fishes spawn during the NEM season when the water temperature is high and the sea calm (Robinson *et al.*, 2008) while some spawn in both seasons (Nzioka, 1979; Ntiba and Jaccarani, 1990). However, the spawning aggregations information is inadequate and has not been monitored exhaustively (Robinson *et al.,* 2008).

In *Siganus sutor,* Ntiba and Jaccarini, (1988) reported length at maturity of 36.2cm and condition factor of 0.87 which is useful for stock assessment of the species. The growth and survival rates of coral reef fishes have been reported for *Lethrinus mahsena* and *Siganus sutor* (Fondo *et al*., 2014). Survival rates of these two fish species were quite low within parks and natural mortality and environmental variables are the main cause of low annual survival rates (Kaunda-arara and Rose, 2006). These studies have been significant in estimating the biomass energetics of coral reef fishes which are target of fishing activities (Aura *et al*., 2011). Catch assessment conducted in Kilifi Creek revealed that major fish groups harvested include; *Lutjanidae, Carangidae, Siganidae, Scaridae, Caesinidae, Scombridae, Plectorhynchidae and Sphyraenidae* (Nzioka, 1990). A study of the fish fauna in the creek gives biodiversity of 63 finfish species with a high number of the species from the order Perciformes (Sigana *et al.,* 2009).

2.2. Length-Weight Relationship and Relative Condition Factor

Length Weight Relationship is significant in fish biology by providing information on fishes within a geographical region (Morato *et al.*, 2001; Aura *et al.,* 2011). Mbaru *et al.* (2011) reported that 72% of the studied reef fishes had b value conforming to the classical range of 2.5 to 3.5. Length-weight relationships and condition factor have been conducted for *Dentex maroccanus* in Malindi-Ungwana bay (Aura *et al.*, 2011). Allometric coefficients of individual sex and combined sex are within the values of b = 2.5 - 3.5 and compare favorably with other sparids (Aura *et al.*, 2011).

Studies on length-weight relationships on nine deep sea species off the Kenyan coast revealed that all the species had a positive allometric growth except *Squalis asper* (spurdog) with a negative allometric growth (Aura *et al.*, 2011). These species were in healthy condition shown by relative condition factor greater than one. The regression coefficient of the nine species in the study compared favorably to other fish species but not to similar deep sea species counterparts from other localities like western coast of India and Atlantic Ocean (Aura *et al.*, 2011).

Population dynamics of the genus *Epinephelus* off south coast has been investigated (Ogongo *et al.*, 2015). Thirty species of *Epinephelus* were assessed and the results showed generally low population abundance with skewed distribution patterns (Ogongo *et al.,* 2015). Length-weight relationship conducted on twenty five species revealed a negative growth pattern with only two species *E. fuscoguttatus* and *E. miliaris* having isometric growth pattern ($b \approx 3$) (Ogongo *et al*, 2015). Morphometric and condition factors of *Siganus stellatus, Siganus canaliculatus* and *Siganus sutor* in WIO waters of south coast of Kenya have been studied by Kimani *et al.*, (2008). They observed that LWR and Standard Length-Total Length for most of the siganid species from south coast of Kenya revealed that they are still young with a negative allometric growth pattern.

Fulton's condition factor of K>1 indicated that these siganid populations were in healthy conditions although there were slight variations within species. Length-weight relationship of fish populations may be influenced by diet, stomach fullness and gonad development but seasonal or annual data is required to confirm this hypothesis (Aura *et al*, 2011).

2.3. Diet composition in fishes

Diet compositions contribute to the understanding of ecosystem structure and population energetics (Ahlbeck *et al.*, 2012). Diet of fishes is useful in ecological studies and investigations of ecosystem dynamics (Endaw, 2014). Food is the main factor in growth regulation, abundance and migration pattern in fishes (Nyunja *et al.*, 2002). Mavuti *et al*. (2004) investigated diet composition in eight common juvenile fishes in Mtwapa Creek and reported an overlap in the feeding niches of the species suggesting elasticity in their diets. Nyunja *et al*. (2002) studied the feeding ecology of *Sardinella gibbosa* and *Atherinomorous lacunosus* at Mwapa and Wasini and reported that copepods were the most abundant prey for the two species. Prey abundance was found to be high during North East Monsoon due to abundant food resources compared to South East Monsoon. De Troch *et al.* (1998) reported that the diets of juvenile fish comprise mainly of plankton and benthic organisms.

Variation in food types available for fish can impact on their individual size. Fishes feed on a diversity of food items including zooplankton, phytoplankton, invertebrates, benthic deposits, other fishes and aquatic macrophytes (Engdaw, 2014). Trophic organization of fish fauna investigated in Gazi bay revealed four guilds, zooplanktivores, piscivores, omnivores and benthic carnivores (Wakwabi, 1999). However, De Troch *et al.* (1998) initially reported that the trophic categories were in fact only three guilds; benthivores, planktivores and piscivores with benthivores being abundant. Such studies are useful in understanding the relationship between age structure and food resource availability in fisheries (Mazlan *et al.*, 2007). Investigations of fish diets are useful in determining the possibility of sustaining the locally reproducing populations in order to restock the adjacent areas (Kaunda-Arara and Rose, 2004). The feeding habits are significant in fishery biology and for species culture (Manoharan *et al.*, 2012).

CHAPTER THREE

3.0. Materials and methods

3.1. Study Area

The study area is located between Mombasa and Malindi towns. The area experiences bimodal rainfall consisting of the long rains between April and July and short rains between October and December, generally controlled by the Inter- Tropical Convergence Zone (ITCZ) (McClahanan, 1988). The county is generally warm throughout the year with temperatures ranging between 21 ^{0} C during the coldest months (June and July) and 32 ^{0} C during the hottest months (January and February). Agriculture, tourism and fishing are the major economic activities in Kilifi. Fishing is widely practiced because of the high demand of fish in Kilifi's hotel industry. Fishing goes on continuously throughout the year within this area. Fish was collected in three main fishing grounds, Mtwapa, Kanamai and Kuruwitu straddling at 3°57′S, 39°45′E, 3°55′S, 39°47′E and 3°47′S, 39°50′E north of Mombasa. These three fishing grounds were selected to represent the ideal fishing grounds across Kilifi area with a high concentration of artisanal fishers. These fishing grounds serve as useful case study of ecological systems subject to social, economic and ecological drivers of change. The three fishing grounds have fairly uniform reef lagoon comprising a mixture of sand, seagrass, corals and the outer reef edge that drops into a sand plain at a depth of approximately 10 to 15m (McClahanan & Abunge, 2014). The lagoon and the immediate reef edge are ecologically similar with regards to habitat and fish compositions but differ in terms of fish abundance and types of fishing gears employed (McClahanan *et al.,* 2008).

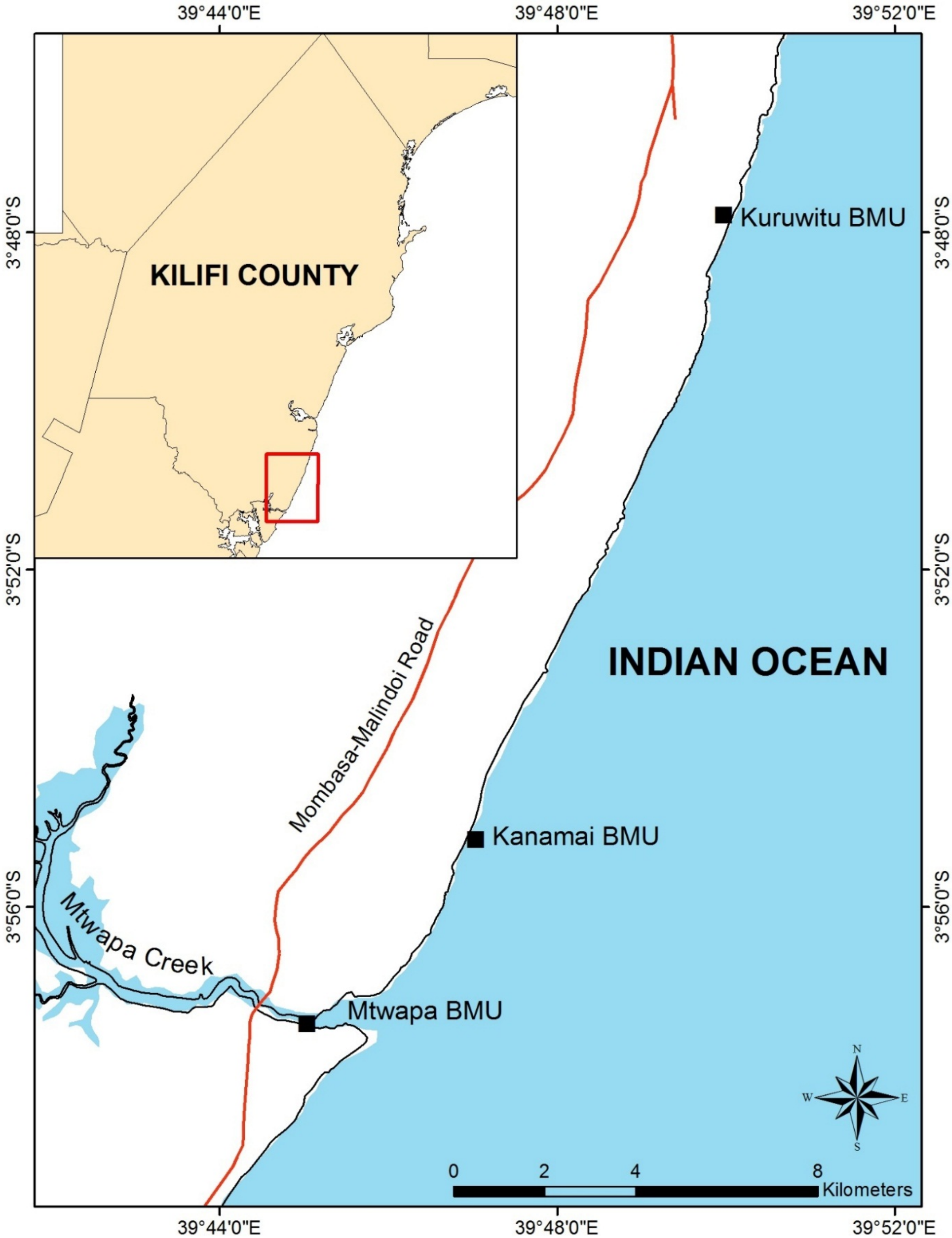

Figure 1: The sampling stations, Mtwapa, Kanamai and Kuruwitu (KMFRI GIS Coastal Resources Database)

3.2. Fish sampling and Identification

Fish collection was carried out at each fishing ground during the day from preidentified fishermen. The fishermen were identified by the chairmen of the various BMUs. The preidentified fishermen landed a considerably high catches of various species. The collection took three days a week per landing station from February to April 2017. Once the fish were landed, the species of interest were identified and sorted from the mixed species catch. The sample size varied between 30 and 100 individuals depending on the species average size. Identification was done up to species level with the help of identification guide according to Anam and Mostarda, (2012). The gear types and vessels used by the fishers were recorded.

3.3. Estimation of Length-Weight Relationship

The total length (TL), from tip of snout to tip of caudal fin was measured to the nearest 0.1cm precision using a tape measure while wet body weight (BW) was measured using a portable electronic weighing scale (WeiHeng 40/10, Japan) to the nearest 0.01g precision (Figure 2).

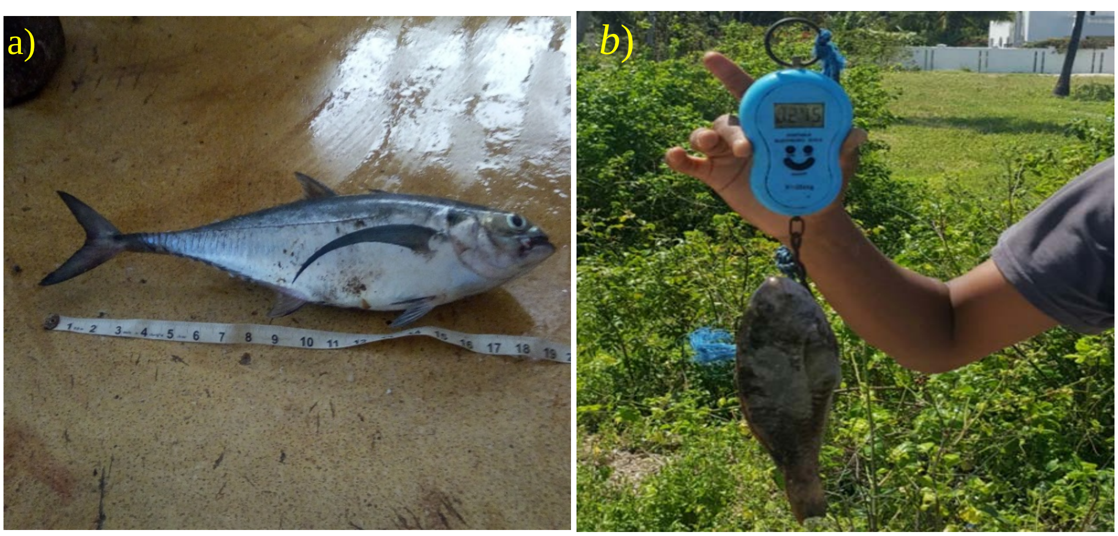

Figure 2: Total length (a) and Body weight measurement (b) of fish sampled during the study period

3.4. Identification of Stomach Content

The species *Siganus sutor* and *Lethrinus harak* were collected for stomach content analysis from the artisanal fishermen in Kuruwitu. Each fish regardless of sex was dissected and the stomach removed then classified according to fullness index. Point-based method was employed and the stomach contents classified as full – 4 points; ¾ full – 3points; ½ full – 2 points; ¼ full – 1 point and empty stomach – 0 points (Hyslop, 1980). In point-based method, each food category is awarded points proportional to its estimated contribution to stomach volume. The technique considers differences in stomach fullness. The stomach contents were then transferred to the container and preserved in 5% formaldehyde solution. These were transported to Kenya marine and Fisheries Research Institute laboratory for further sorting and identification of food items (Figure 3). In the laboratory, the stomach contents from the specimen containers were emptied into petri dish and each food item counted under the dissecting microscope (Lavenhuk 3ST Stereo, 110V) (Figure 4). Identification of major food items was done to the lowest taxonomic groups following guidelines by Bolton *et al.*, (2007) and Richmond, (2002).

Figure 3: Sorting food items from stomach content of *S. sutor*.

Figure 4: Sample of *S.sutor* stomach content on the stereomicroscope

The stomach content was analyzed for frequency of occurrence and numerical method (Hynes, 1950) whereby the number of stomachs in which each item occurred was recorded and expressed as a percentage of the total number of stomachs examined. In numerical method, the number of individuals of each food item in the stomach was counted and expressed as a percentage of the total number of food items in the sample studied. These were then converted to percentages in order to obtain the total percentage of food types contributing to the diet of the sampled fish.

3.5. Statistical analysis

Data was recorded on excel spreadsheet (2013) and analyzed using SPSS statistical software. The statistical relationship between the length and weight of fishes was established as per the parabolic equation TW = aTLb (Froese, 2006). Where TW = Total Weight of fish in grams; TL = Total Length of fish in centimeters; a = Y intercept and b = slope of the regression line, respectively. The length-weight relationship was obtained by logarithmic transformation of

(TW = aTLb) to provide linear association between the variables. The least square method of linearregression model was used for the expression: log W = log (a) + b log (L) (Le Cren, 1951). A plot of log (L) against log (W) for the species was used to estimate the intercept and slope variables, a and b respectively, of the equation (Hayes *et al.,* 1995). The exponent b of the LWR for the species was tested for significant deviation from the isometric value of b = 3 following (Froese, 2006). Relative condition factor (Kn) was calculated following Le Cren's (1951) formula, Kn = W/^W. W is the observed weight and ^W is the weight calculated from the length-weight relationship ^W = $aL^{3-b.}$ Pooled totals of length-weight data for individual species obtained during the study was used. The stomach content was interpreted in terms of points, numerical (%N) and frequency (%F). Chi-square test of independence was used to assess for the effect of fishing gears in the observed stomach fullness. All statistical tests were conducted at a significance level of 95% ($\alpha = 0.05$).

CHAPTER FOUR

4.0. Fishing gears and vessels used by fishers at various landing sites

The fisheries resource in Kilifi is small scale with a great number of artisanal fishers fishing near shore coastal reefs. Majority of the fishermen were using passive gears such as basket traps (malema), gill nets, spearguns, handlines and drift nets (Figure 5). Most of the fishers in Mtwapa landing station used motorized boats to access the offshore waters. There was a great co-operation of fishers from this area. Gears used by fishers were mainly basket traps and gillnets. Fishermen from Kanamai landing station were mainly footfishers mostly using spearguns but also employ a wide variety of other fishing gears such as hooked sticks and pointed sticks. These fishers, however, lack an organized system of beach management. Fishing expeditions were more individualistic. Most of the fishermen were disempowered and unable to access the waters further away from the reef. The method of fish exploitation in Kuruwitu was mainly through basket traps, spearguns and gill nets. They also employ the use of dugout canoes to access the offshore waters.

Spearguns were operated by individual fishers who swam on the sub surface to target fish. The use of spearguns is harmful to the coral reef ecosystem as it breaks the corals when the targeted fish is missed. The fishers also trampled on the corals which might lead to long term degradation of the reef corals. Multifilament nets were also operated in the open water offshore beyond the fringing reef mainly targeting family *Scomberoides*. There were no reported impacts of these nets on fish populations and fishing grounds and thus considered legal.

Figure 5: Fishing gears used by artisanal fishers in Kilifi County (a) Speargun, (b) monofilament net (c) gill net (d) Dugout canoe and (e) Footfisher

4.1. Length-Weight Relationship and Relative Condition Factor

4.2. Length-weight Relationship of the selected species

A total of 454 fishes from 7 families, 8 genera and 9 species were collected for length-weight analysis (Figure 6). The species were selected because they dominated the catch landings. The length weight Relationship of individual fish species are shown in Figure 7 - 24. The results of the student ‘t’ test revealed significant deviation of b value from the hypothetical value of 3.0 in the nine species studied. In this current study, the highest value of b was obtained for *Ratrelliger kanagurta* (3.249±0.187) and the lowest for *Calotomus carolinus* (2.214±0.078). The b values of the species fell within the classical range of 2.5 < b > 3.5 (Table 2). Table (3) gives the mean total lengths and mean wet weights of individual fish species.

Table 2: Summary of LWR in the selected species, intercept (log a), slope (b), standard error of b (sb) and t-test on 'b' and paired t-test results (p<0.05).

Family	Species	Log a	b	Sb (p<0.05)	t^b	R	t-reg (p<0.05)
Carangidae	*Scomberoides tol*	-1.276	2.482	0.1013	5.115	0.9622	24.491
Carangidae	*Decapterus macrosoma*	-1.144	2.543	0.1585	2.881	0.9181	16.043
Holocentridae	*Sargocentron caudimaculatus*	1.455	2.680	0.1506	2.127	0.9319	17.792
Lethrinidae	*Lethrinus nebulosus*	-1.525	2.957	0.1258	0.340	0.9592	23.511
Lethrinidae	*Lethrinus harak*	-1.503	2.687	0.1222	2.563	0.9538	21.982
Lutjanidae	*Lutjanus fulviflamma*	-0.936	2.347	0.1453	4.498	0.9190	24.491
Scaridae	*Calotomus Carolinus*	-0.613	2.214	0.0811	9.684	0.9692	27.293
Scombridae	*Rastrelliger Kanagurta*	-2.091	3.249	0.1885	1.321	0.9279	17.238
Siganidae	*Siganus sutor*	-1.619	2.820	0.1877	0.961	0.9080	15.019

Figure 6: Selected demersal fishes from Kilifi landing stations (a) *C. carolinus* (b) *D. macrosoma* (c) *L. nebulosus* (d) *L. harak* (e) *L. fulviflamma* (f) *R. kanagurta* (g) *S. caudimaculatus* (h) *S. tol* and (i) *S. sutor* (Source-Julia).

Table 3: Mean total length (cm) and Mean wet weight (g) of the fish species with Standard error.

Family	Species	Mean±SE	
		TL (cm)	**BW(g)**
Carangidae	*Decapterus macrosoma* (59)	32.5±0.8	535.2±29.8
Carangidae	*Scomberoides tol* (41)	36.4±0.6	409.1±18.3
Holocentridae	*Sargocentron caudimaculatus* (32)	20.8±0.3	124.5±5.9
Lethrinidae	*Lethrinus nebulosus* (50)	22.7±0.5	332.7±21.7
Lethrinidae	*Lethrinus harak* (53)	30.5±0.5	317.0±13.8
Lutjanidae	*Lutjanus fulviflamma* (50)	29.7±0.7	349.2±20.4
Scaridae	*Calotomus carolinus* (55)	24.4±0.7	303.6±17.5
Scombridae	*Rastrelliger kanagurta* (70)	25.1±0.3	296.8±11.9
Siganidae	*Siganus sutor* (44)	30.0±0.6	381.6±25.9

4.2.1. *Calotomus carolinus*

Total length ranged from 14.9cm to 35.5cm. The highest mean length was recorded in February (26.3 ± 1.26) and the lowest in March (23.04 ± 1.04) (Figure 7). One-way ANOVA revealed no significant differences in the observed mean lengths (df = 54, F = 3.0; P > 0.05). Weight ranged from 101.63g to 558.92g with mean weight of 303.57 ± 17.45. The length-weight relationship for *Calotomus carolinus* was $Log_{10}BW=2.2143Log_{10}TL-0.6127$ (Figure 8). The b value of 2.214 obtained was significantly lower than 3.0 for isometric growth thus indicating a likelihood towards negative allometric growth. This means that there is a reduction if relative body weight as the fish grows. The classical range of 2.5 < b > 3.5 has thus not been confirmed with regards to the observed b value. Length and weight relationship was positively correlated (r = 0.909). The regression model accounted for 86.3% of the variation in length and weight ($r^2 = 0.868$). The t-test calculated for the regression line ($t = 27.29$; df: 1, $p < 0.05$) suggests that the length of *C carolinus* is significantly linearly related to its weight. The 't' test on b showed significant average deviations from the expected value of 3 ($t = 9.684$; df: 53, $p < 0.05$) suggesting that there is no cubic relationship between length and weight for the species.

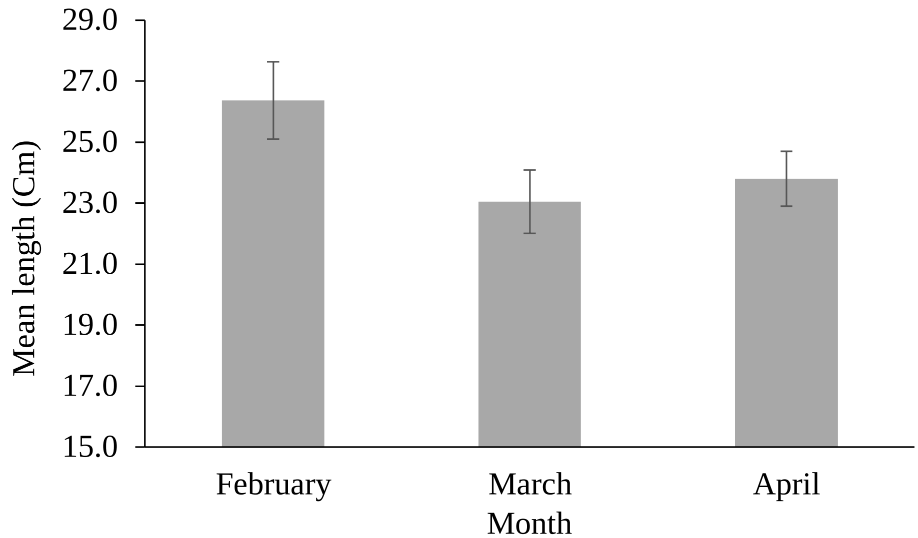

Figure 7: Monthly mean±SE length of *C. carolinus* sampled during the study period.

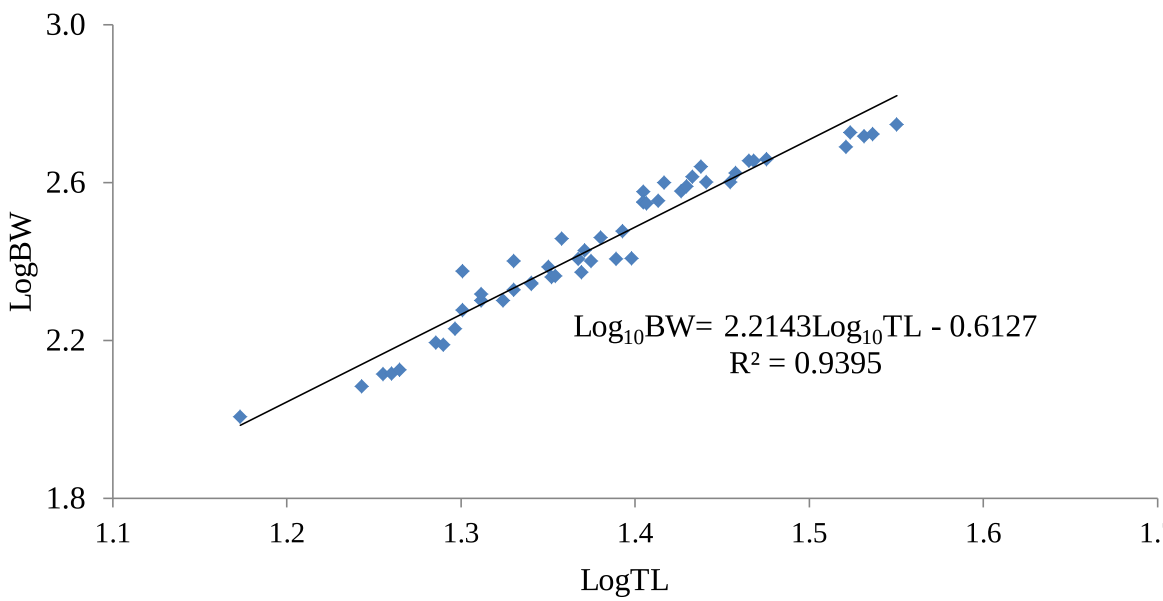

Figure 8: The Length-Weight relationship of *C. carolinus* sampled during the study period.

4.2.2. ***Decapterus macrosoma***

Total length ranged from 20.5cm to 40.9cm. The highest mean length was recorded in April (33.8 ± 1.19) and the lowest in March (30.7 ± 1.37) (Figure 9). One-way ANOVA revealed no significant differences between months (df = 58, F = 1.763; P > 0.05). Weight ranged from 179.36g to 789.63g with mean weight of 535.2 ± 29.84. The equation $\log_{10}BW = 2.5433\text{Log}_{10}TL-1.144$ (Figure 10) described the LWR for the species. The value of 2.5433 obtained for 'b' is significantly smaller than the 3.0 for isometric growth thus indicating a tendency towards a negative allometric growth of the species. The b value was within the classical range of 2.5 < b > 3.5 for species. The fish reduces in body weight with increase in length. The LWR for the species was positively correlated (r = 0.9181). The t- test calculated on the regression line (t = 16.04; df: 1, p < 0.05) revealed that the relationship between the length and weight of *D. macrosoma* is linear. The coefficient of determination 'r^2'= 0.8428 was found to be highly significant with reference to the fitted regression line. There was a significant deviation of b from the expected cube value of 3 (t = 2.881; df: 58, p < 0.05) indicating allometric growth.

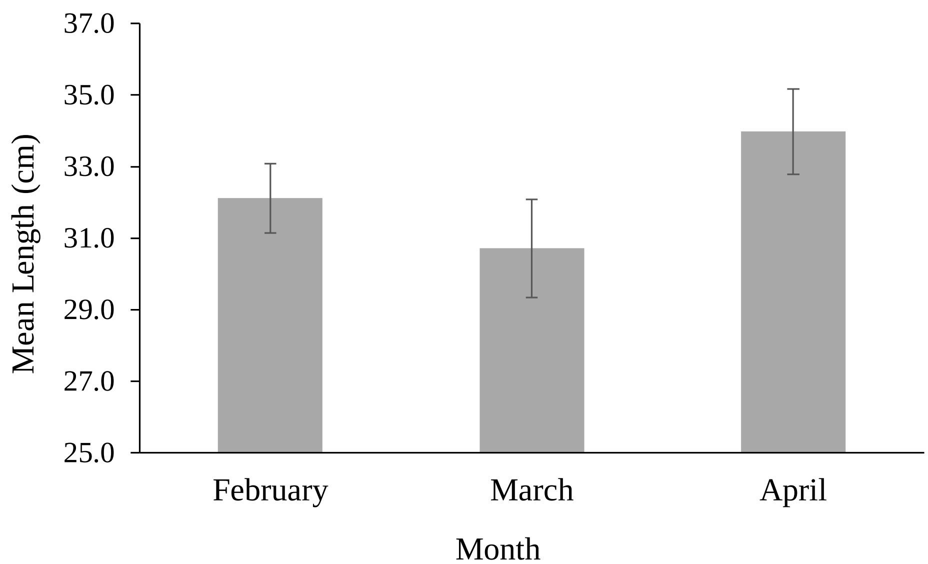

Figure 9: Monthly mean±SE length of *D. macrosoma* sampled during the study period.

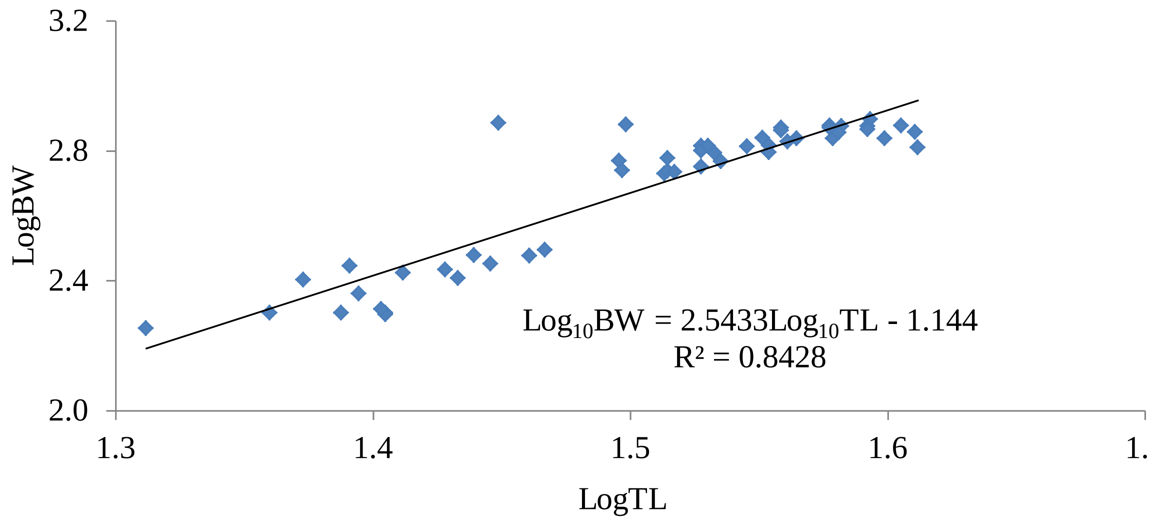

Figure 10: Length-Weight relationship of *D. macrosoma* sampled during the study period.

4.2.3. *Lethrinus nebulosus*

Total length ranged from 12.9cm to 30.5cm. The highest mean length was recorded in March (24.9 ± 0.99) and the lowest in April (18.7 ± 0.47) (Figure 11). One-way ANOVA revealed no significant differences between months (df = 49, F = 1.99; P > 0.05). Weight ranged from 89.9g to 601.35g with mean weight of 332.71 ± 21.72. The length-weight relationship for *L. nebulosus* was $\log_{10}BW=2.9572Log_{10}TL-1.5252$ (Figure 12). The value of 2.957 obtained for 'b' was so close to 3 suggesting an isometric growth of the species. This value also fell within the expected range of $2.5 < b > 3.5$. There was a positively correlation between the length and weight relationship for the species (r = 0.959). The t-test calculated for the regression line (t = 23.51; df:1, $p < 0.05$) suggested that linear relationship exist between the length and weight for the species. The goodness of fit of the regression model was high (r^2 = 0.920) reveaveling a good relationship of the fitted model. The t-test calculated for b revealed no significant deviation from the cube value of 3 (t= 0.340; df: 49, $p > 0.05$) suggesting cubic relationship between length and weight of the species.

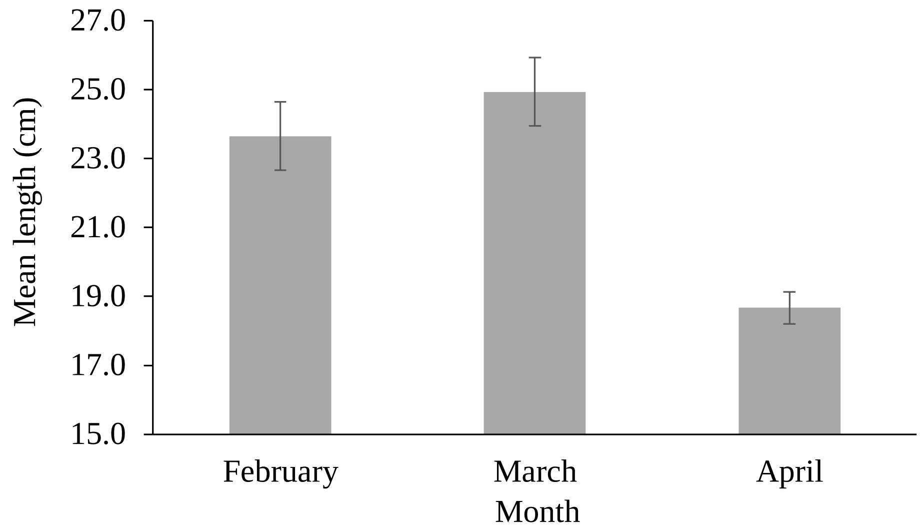

Figure 11: Monthly mean±SE length of *L. nebulosus* sampled during the study period.

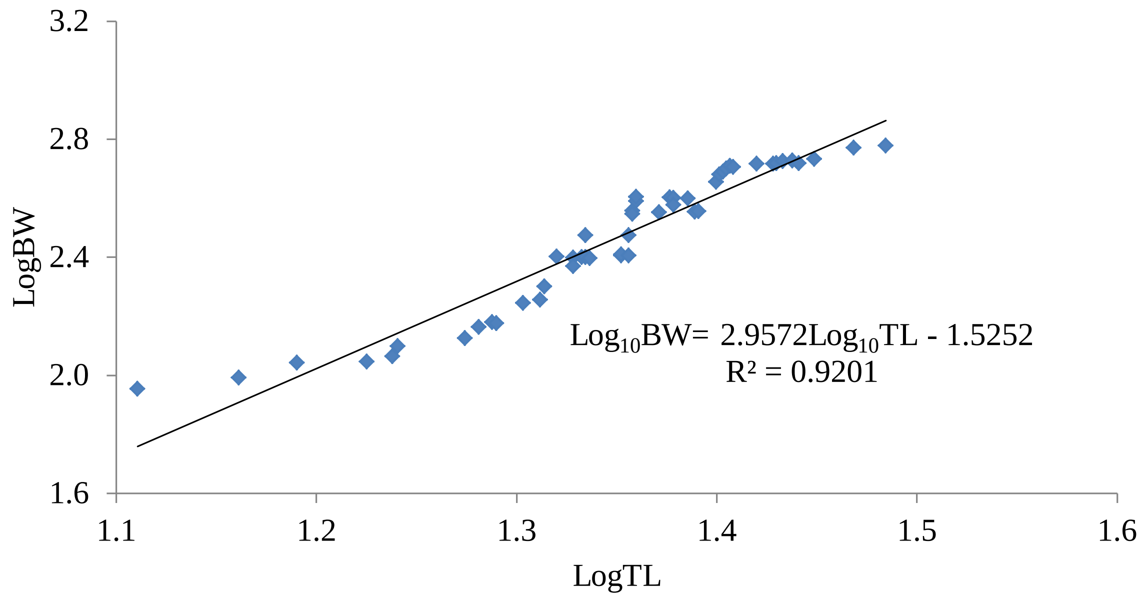

Figure 12: Length-Weight relationship of *L. nebulosus* sampled during the study period.

4.2.4. *Lethrinus harak*

Total length ranged from 22 cm to 35.8cm. The highest mean length was recorded in March (33.1 ± 1.04) and the lowest in February (28.6 ± 0.83) (Figure 13). One-way ANOVA revealed no significant differences in the observed mean lengths (df = 52, F= 6.618; $P > 0.05$). Weight ranged from 110.23g to 472.45g with mean weight of 317.21 ± 13.76. The length-weight relationship for *L. harak* was $\log_{10}BW=2.6868\log_{10}TL-1.5034$ (Figure 14). The 'b' value of 2.687 was slightly smaller than 3.0 for isometric growth consequently indicating a negative allometric growth and was in the classical range for most species $2.5 < b > 3.5$. Negative allometric growth illustrates a reduction in relative body weight of the fish with an increase in length. The observed length and weight relationship was positively correlated (r= 0.954). The t-test calculated for the slope (t = 21.98; df: 1, $p < 0.05$) suggested linear relation between the length and weight for the species. The goodness of fit for the regression model revealved good fit ($r^2 = 0.91$). The 't' test on b showed significant departure from the cube value of 3 (t =2.563; df: 52, $p < 0.05$).

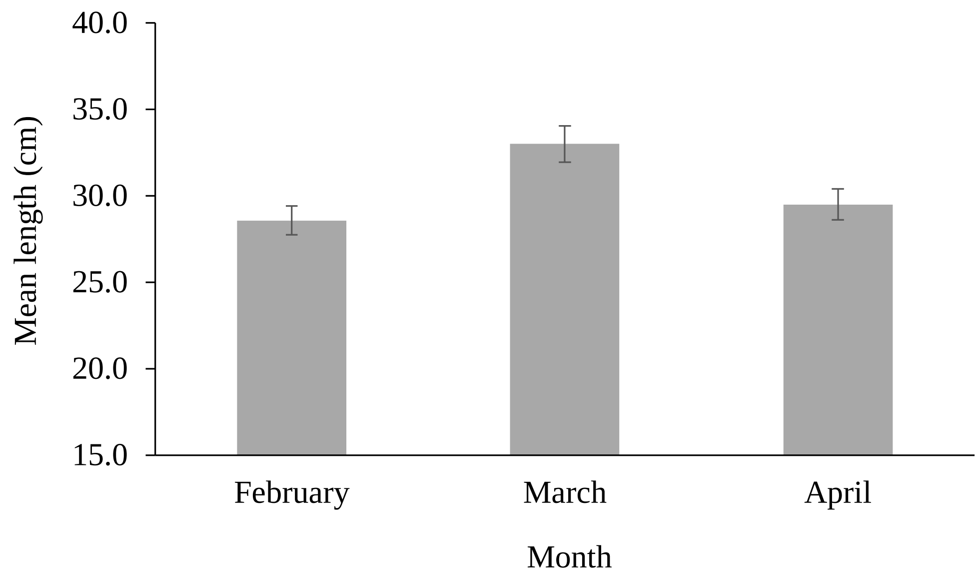

Figure 13: Monthly mean±SE length for *L. harak* sampled during the study period.

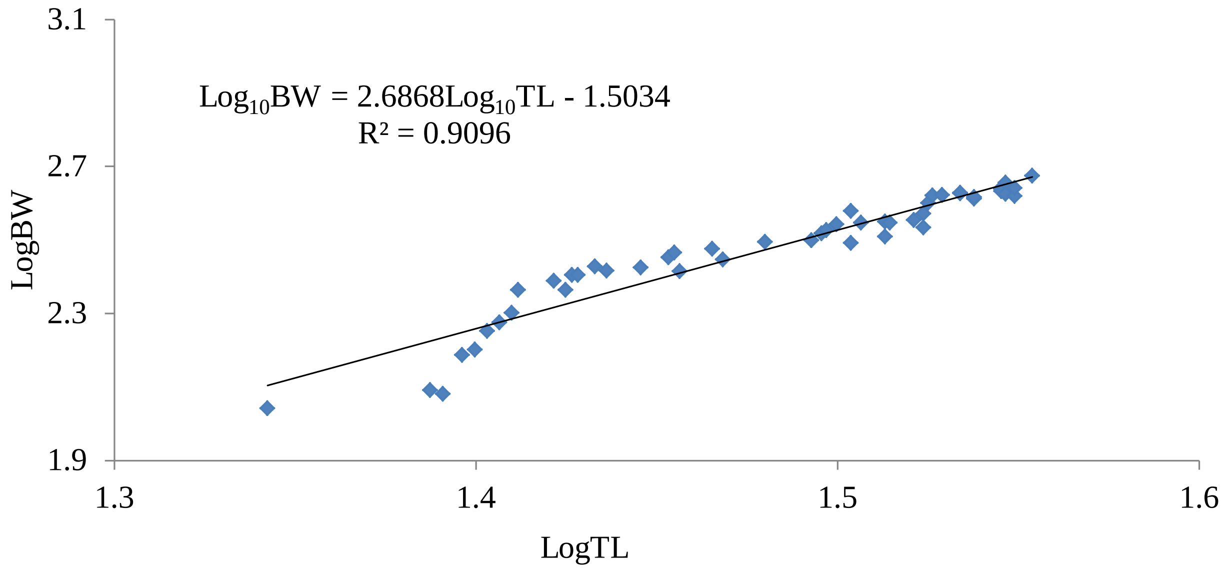

Figure 14: Length-Weight relationship of *L. harak* sampled during the study period.

4.2.5. *Lutjanus fulviflamma*

Total length ranged from 19.2cm to 38.4cm throughout the sampling period. The highest mean length was recorded in April (33.3 ± 1.02) and the lowest in March (27.8 ± 0.90) (Figure 15). One-way ANOVA revealed no significant differences in the observed mean lengths (df = 51, F= 6.831; P > 0.05). Weight ranged from 132.76g to 650.32g with mean weight of 349.21 ± 20.39. The length-weight relationship for *L. fulviflamma* was $log_{10}BW=2.3465Log_{10}TL-0.9359$ (Figure 16). The b value 2.3465 was significantly lower than 3.0 for ideal growth thus indicating a tendency towards negative allometric growth. The expected range 2.5<b>3.5 has not been confirmed for the species in relation to the calculated b value. The relationship between length and weight was positively correlated (r = 0.919). The t-test calculated for the slope (t = 24.49; df:1, p < 0.05) suggests that the length for the species is significantly linearly related to its weight. Linear regression indicated that 84% of the variation in weight was accounted for by the linear relationship between length and weight (r^2= 0.845) suggesting good fit of the fitted regression model. The ‘t’ test on b calculated for the species (t = 4.498; df: 48, p < 0.05) showed significant deviations from the cube value of 3.

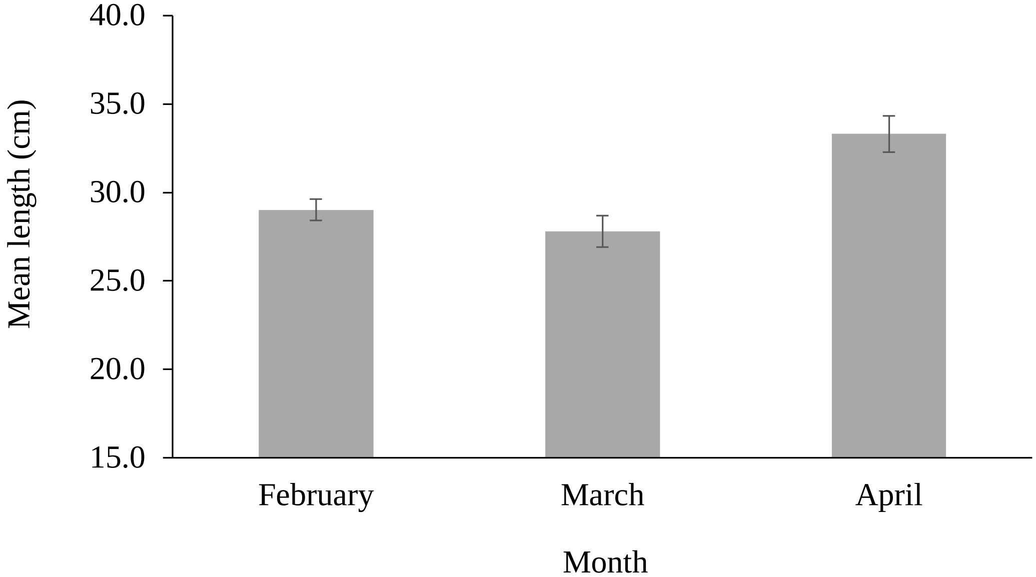

Figure 15: Monthly mean±SE length of *L. fulviflamma* sampled during the study period.

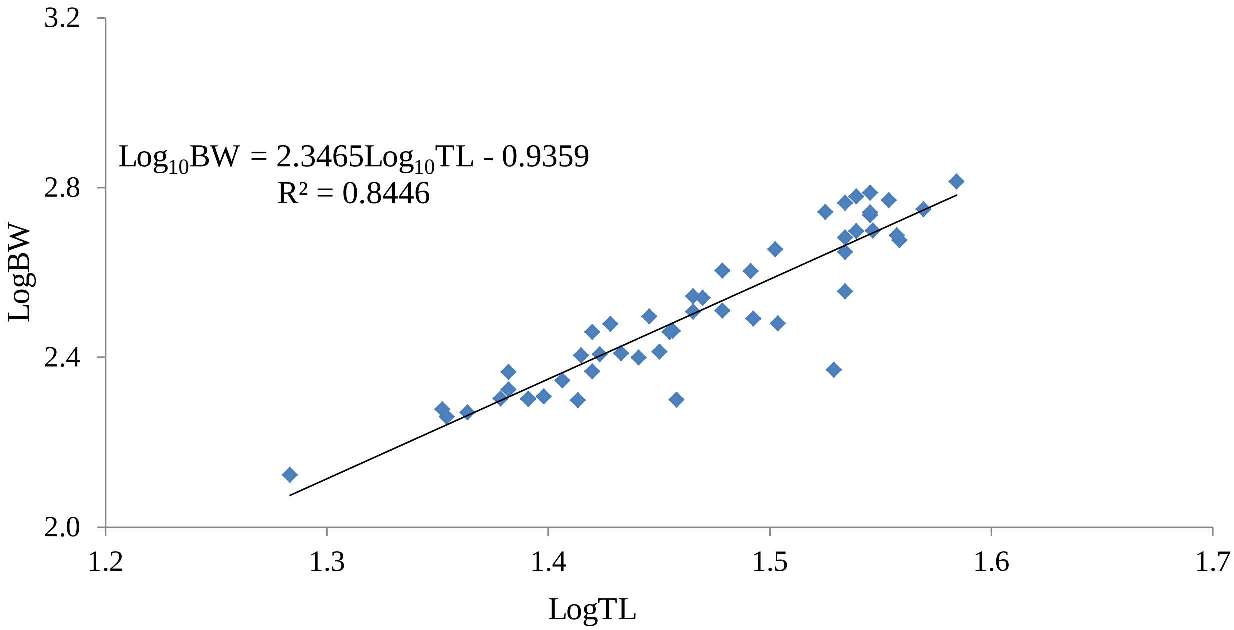

Figure 16: Length-Weight relationship of *L. fulviflamma* sampled during the study period.

4.2.6. *Rastrelliger kanagurta*

Total length ranged from 18.2cm to 28.6cm. The highest mean length was recorded in March (26.3 ± 0.28) and the lowest in April (24.1 ± 0.19) (Figure 17). One-way ANOVA revealed no significant differences between months (df = 69, F = 2.826; P > 0.05). Weight ranged from 111.01g to 451.23g with mean weight of 296.83 ± 11.95. The length-weight relationship for *R. kanagurta* was $log_{10}BW= 3.249Log_{10}TL-2.0914$ (Figure 18). The 'b' value of 3.249 is significantly larger than 3.0 for isometric growth thus suggesting strong positive allometric growth. The expected range of 2.5 < b > 3.5 for species has therefore been affirmed. Length and weight relationship was positively correlated for the species (r = 0.928). The t-test for the regression line (t = 17.24; df:1, p < 0.05) suggests that the length and weight for the species is significantly linearly related. The correlation coefficient showed that 86% of the difference in body weight is explained by the linear relationship between length and weight ($r^2 = 0.8609$). No significant deviation of b from the cube value of 3 was observed for the species (t = 1.321; df: 69, p > 0.05).

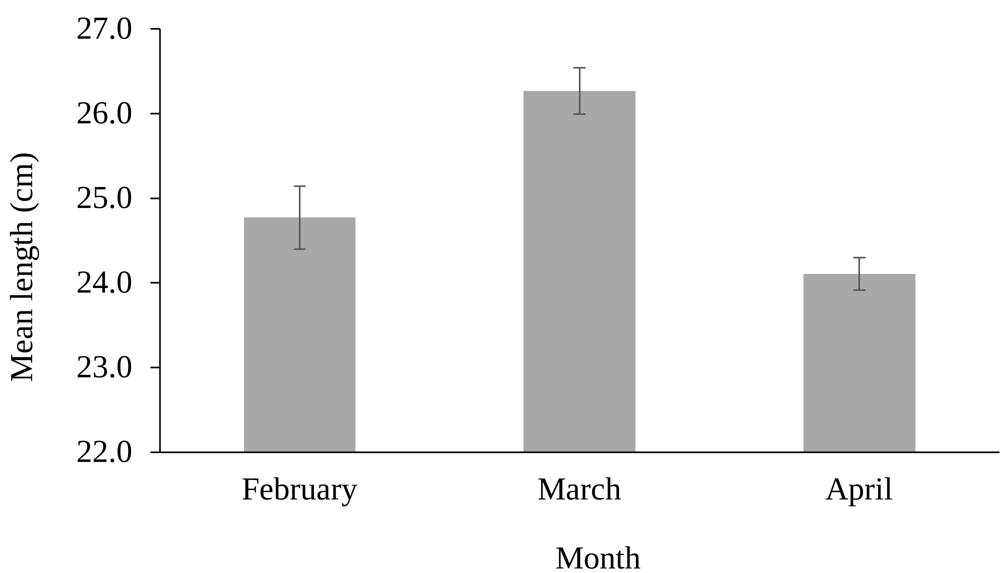

Figure 17: Monthly mean±SE length of *R. kanagurta* sampled during the study period.

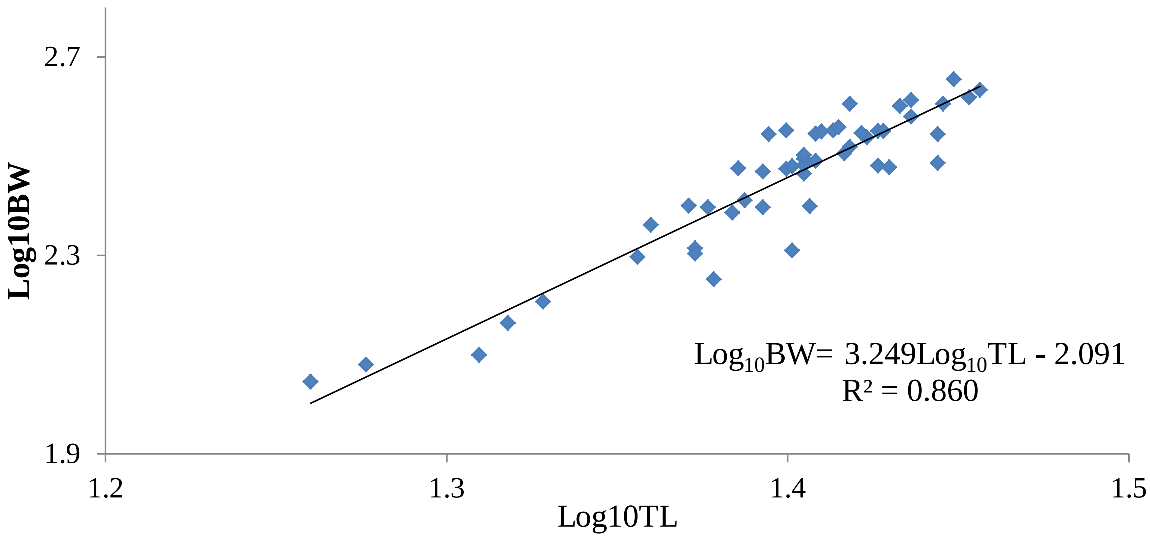

Figure 18: Length-Weight relationship of *R. kanagurta* sampled during the study period.

4.2.7. *Sargocentron caudimaculatus*

Total length ranged from 16.7cm to 25.9cm. The highest mean length was recorded in March (21.4 ± 0.76) and the lowest in February (20.8 ± 0.57) (Figure 19). One-way ANOVA revealed no significant differences between months (df =31, F = 1.519; P > 0.05). Weight ranged from 68.93g to 221.32g with mean weight of 124.45 ± 5.95. Figure 20 gives the length-weight relationship for *S. caudimaculatus* $\log_{10}BW= 2.6797Log_{10}TL-1.4549$. The value of 2.6797 obtained for 'b' is significantly smaller than 3.0 for isometric growth thus showing a deviation towards negative allometric growth. However it lies within the classical range of 2.5 < b > 3.5. The length-weight relationship has also shown positive correlation (r= 0.932).). The t-test calculated for the slope (t = 17.79; df:1, p < 0.05) suggest a linear relationship between the length and weight for the species. The linear regression model accounts for 86% of the variations in length and weight (r^2=0.868). The 't' test indicated a significant deviation of b from the expected cube value of 3 (t=2.127; df: 31, p < 0.05).

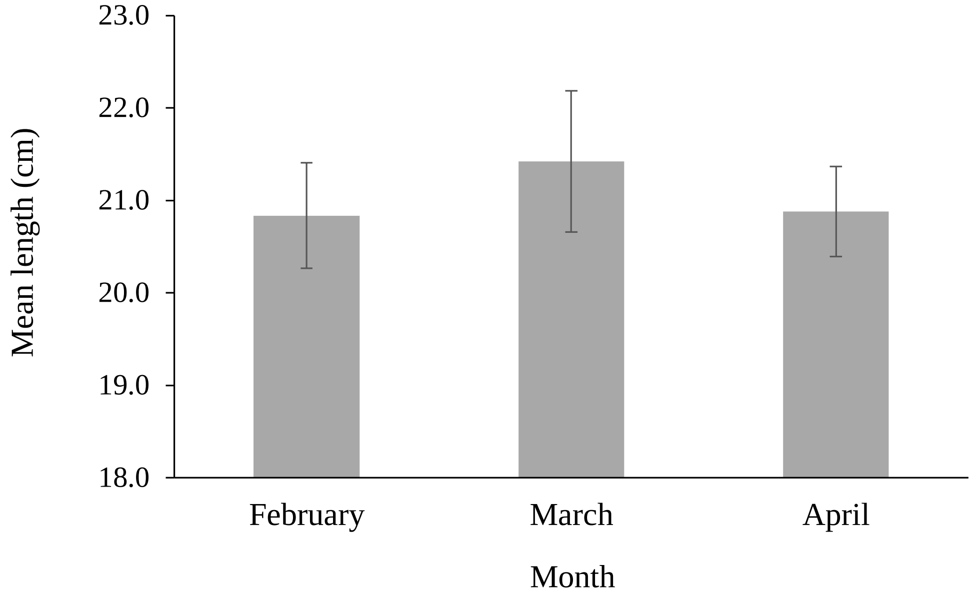

Figure 19: Monthly mean±SE length of *S. caudimaculatus* sampled during the study period.

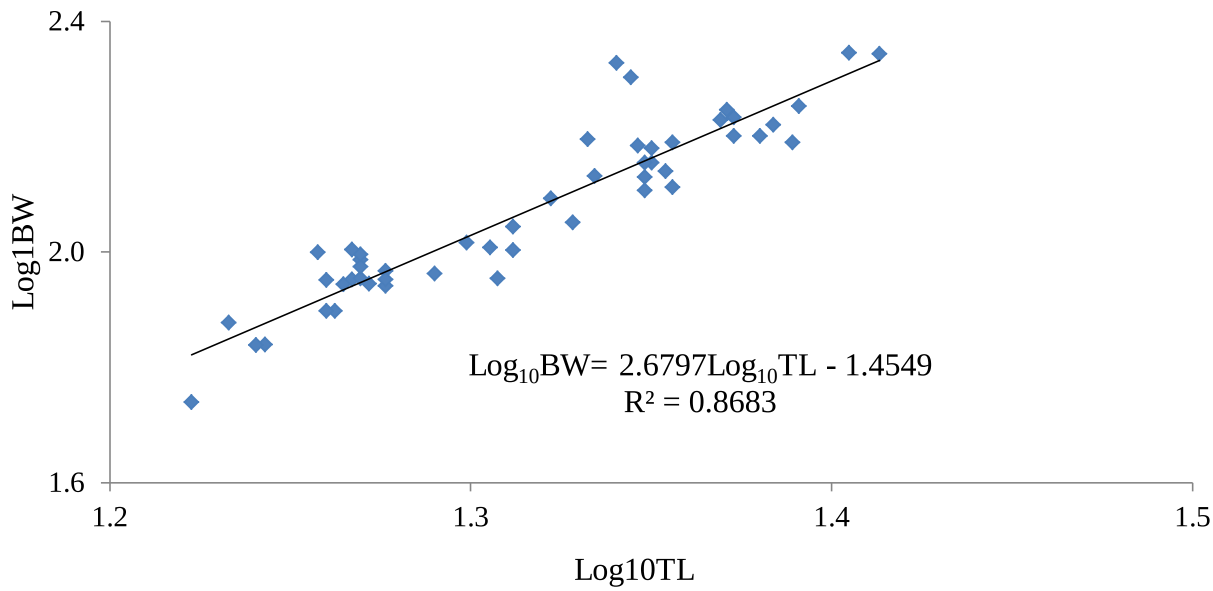

Figure 20: Length-Weight relationship of *S. caudimaculatus* sampled during the study period

4.2.8. *Scomberoides tol*

Total length ranged from 24.6cm to 48.3cm throughout the sampling period. The highest mean length was recorded in February (38.3 ± 1.39) and the lowest in April (34.7 ± 0.77) (Figure 21). One-way ANOVA revealed no significant differences in the observed mean lengths (df: 40, F= 2.308; P > 0.05). Weight ranged from 152.89g to 694.79g with mean weight of 409.14 ± 18.3. The LWR for *S. tol* was illustrated by the equation $\log_{10}BW = 2.4817\text{Log}_{10}TL-1.276$ (Figure 22). The value of 2.4817 obtained for 'b' was significantly lower than 3.0 for isometric growth suggesting that the fish had a negative allometric growth pattern. The expected b range 2.5 < b > 3.5 has however been confirmed. Length-weight relationship has also shown a positive correlation (r = 0.9259). Length-weight relationship has also shown a positive correlation (r = 0.9259). The t-test for the regression line (t = 24.49; df:1, p < 0.05) suggest a linear relationship between the length and weight for the species. The fitted regression line accounts for 92% of the variations in the observed length and weight (r^2= 0.9259). The student 't' test on b (t =5.115; df: 40, p < 0.05) indicated significant deviation from the cube value of 3.

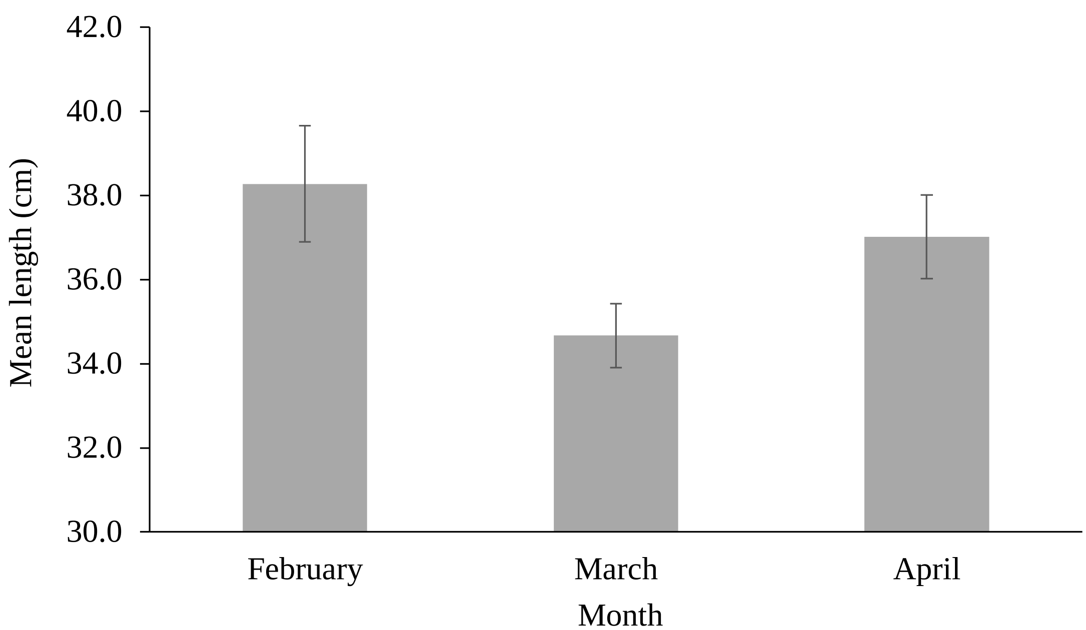

Figure 21: Monthly mean±SE length of *S. tol* sampled during the study period.

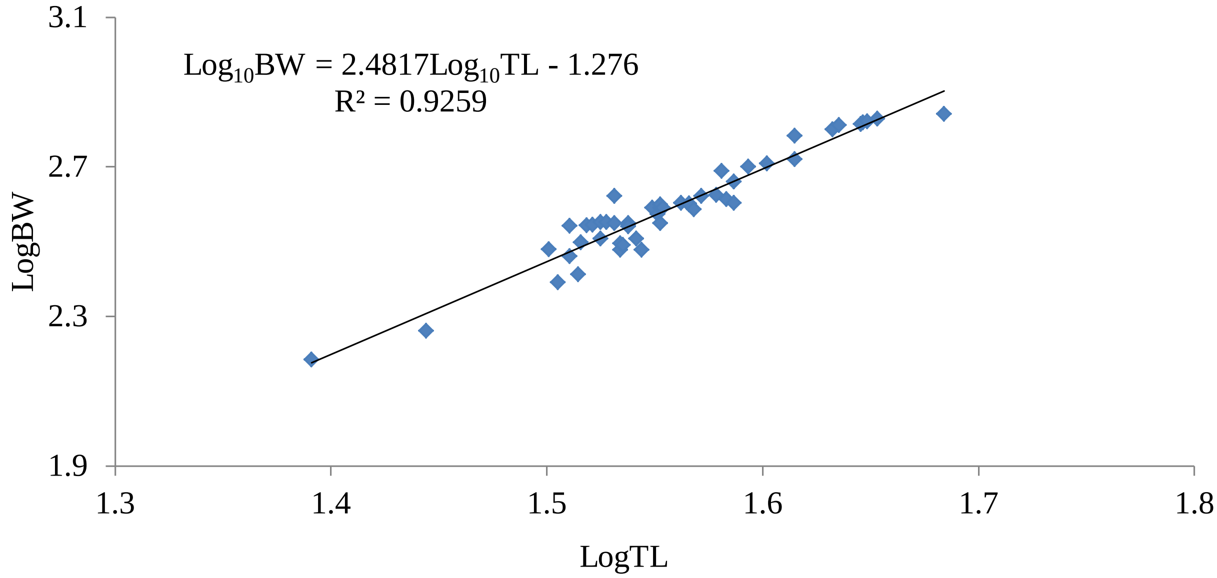

Figure 22: Length-Weight relationship of *S. tol* sampled during the study period.

4.2.9. *Siganus sutor*

The length ranged from 22.1cm to 38.5cm throughout the sampling period. The highest mean length was recorded in February (30.6 ± 0.45) and the lowest in April (29.4 ± 0.85) (Figure 23). Although there were observable monthly differences in length, one-way ANOVA revealed no significant differences in the observed mean lengths (df: 42, F= 0.19; P > 0.05). Weight ranged from 183.96g to 627.76g with mean weight of 381.58 ± 25.97. The length-weight relationship for *S. sutor* was $\log_{10}BW = 2.8195\log_{10}TL - 1.6189$ (Figure 24). The 'b' value of 2.8195 was smaller than 3.0 for isometric growth thus indicating that the fish had a negative allometric growth . The expected range 2.5<b>3.5 has been confirmed for the species. The length-weight relationship has indicated a positive correlation (r = 0.908). The t-test for the slope (t = 15.02; df:1, p < 0.05) indicate significant linear relationship between the length and weight for the species. The linear regression model shows that the fitted line was significant in approximating the length and weight data ($r^2 = 0.825$). Results of t-test on b (t = 0.961; df: 42, $p > 0.05$) revealed no significant deviations from the cube value of 3.

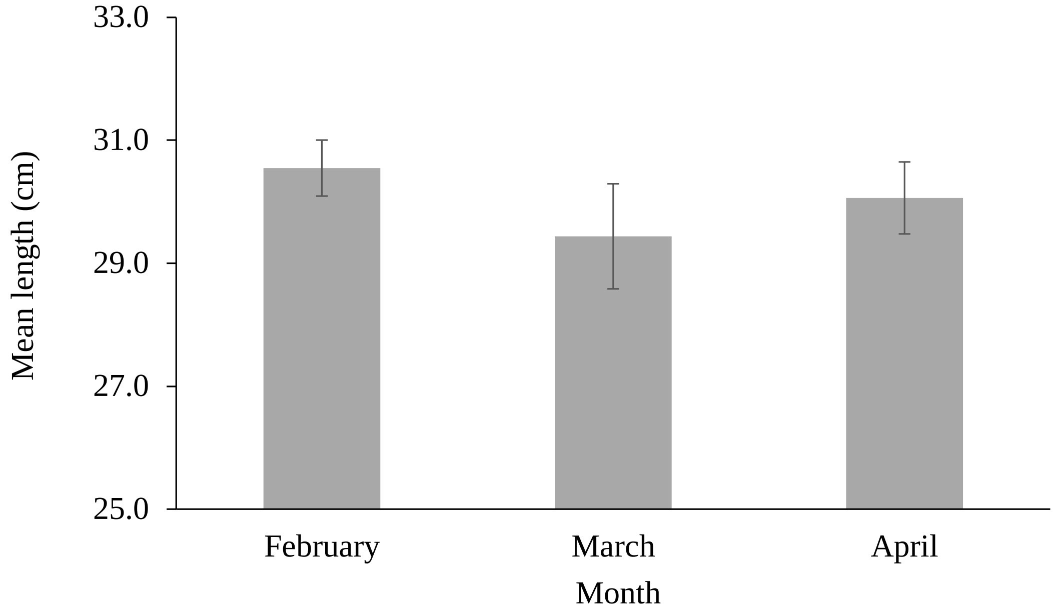

Figure 23: Monthly mean±SE length of *S. sutor* sampled during the study period.

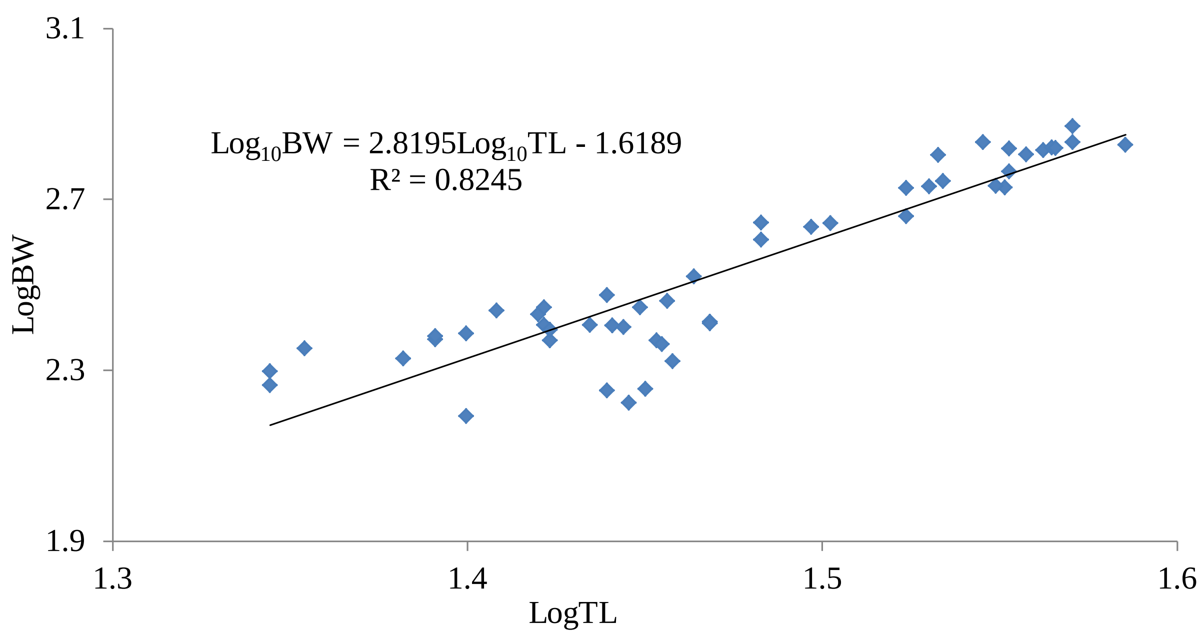

Figure 24: Length-Weight relationship of *S. sutor* sampled during the study period.

4.3. Relative Condition Factor (Kn) in selected species.

The overall relative condition factor for the nine teleost fishes sampled is represented in (Table 3). Kn value is correlated to LWR thus the b value is important in determining the general well-being of fishes. All fish species sampled for the present study had relative condition factors greater than one.

Table 4: Mean±SE relative condition factor (Kn) for the selected species.

Family	Species	Mean relative condition factor (Mean±SE)
Carangidae	*Scomberoides tol*	1.004±0.086
Carangidae	*Decapterus macrosoma*	1.021±0.089
Holocentridae	*Sargocentron caudimaculatus*	1.008±0.009
Lethrinidae	*Lethrinus nebulosus*	1.012±0.043
Lethrinidae	*Lethrinus harak*	1.006 ±0.032
Lutjanidae	*Lutjanus fulviflamma*	1.013±0.076
Scaridae	*Calotomus carolinus*	1.006±0.053
Scombridae	*Rastrelliger kanagurta*	1.008±0.053
Siganidae	*Siganus sutor*	1.019±0.071

4.3.1. *Calotomus carolinus*

The mean monthly relative condition factor was high in February and April than in March. February and April recorded relative condition values of 1.031 ± 0.003 and 1.0297 ± 0.009 respectively (Figure 25). The overall mean Kn was 1.006 ± 0.053 (Table 3) suggesting that the species was in healthy condition during the sampling period. One-way ANOVA revealed no significant deviations of the mean body conditions between the months (df=54, F= 1.14; $P > 0.05$).

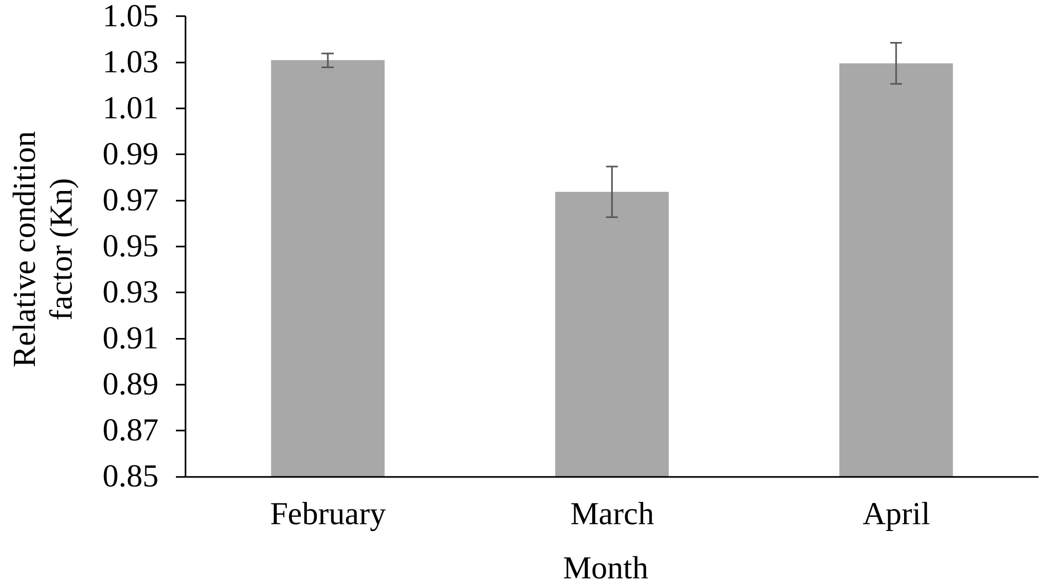

Figure 25: Mean±SE relative condition factor of *C. carolinus* sampled during the study period.

4.3.2. *Decapterus macrosoma*

The mean monthly relative condition factor showed a general slight increase from the month of February to March and a decrease in April. The highest Kn was recorded in March (1.064 ± 0.011) and the lowest in April (0.976 ± 0.031) (Figure 26). The overall mean Kn was (1.021 ± 0.089) (Table 3). One-way ANOVA revealed no significant deviations of the mean relative conditions between the months (df =58, F= 0.851; $P > 0.05$).

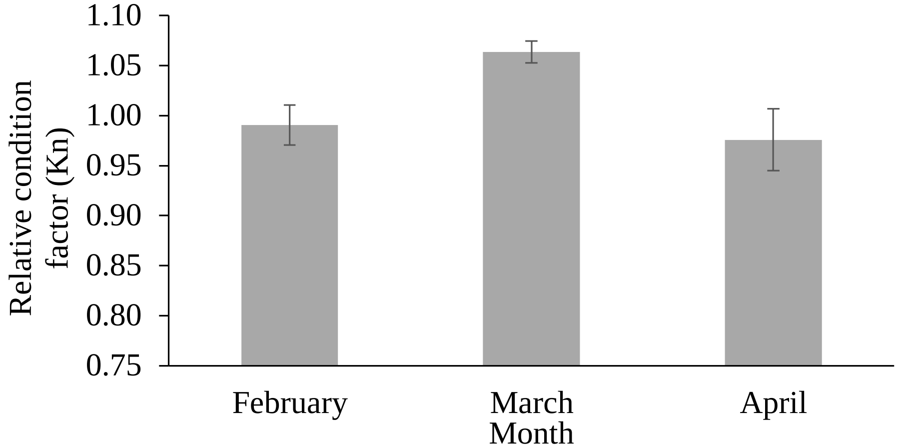

Figure 26: Mean±SE relative condition factor of *D. macrosoma* sampled during the study period.

4.3.3. *Lethrinus nebulosus*

The highest Kn was recorded in April (1.042 ± 0.029) and the lowest in February 0.947 ± 0.065 (Figure 27). There was a slight increase from February to March with a moderately uniform Kn through to April. The overall mean Kn was 1.012 ± 0.043 (Table 3) and one-way ANOVA revealed no significant deviations of the mean body conditions between the months (df = 49, F= 1.844; P > 0.05).

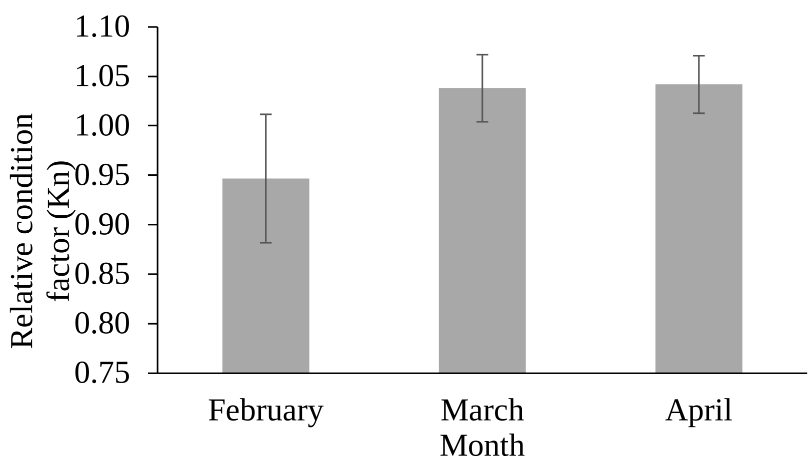

Figure 27: Mean±SE relative condition factor of *L. nebulosus* sampled during the study period.

4.3.4. *Lethrinus harak*

The highest relative condition was recorded in March (1.075 ± 0.049) and the lowest in April (0.971 ± 0.031) (Figure 28). The overall mean Kn was 1.006 ± 0.032. One-way ANOVA revealed significant deviations of mean body conditions between the months (df= 52, F= 7.299; P < 0.05). Bonferroni post-hoc test showed that March and April differed significantly (t = 0.0456; p < 0.05). No significant difference (p > 0.05) was observed between February and the other two months.

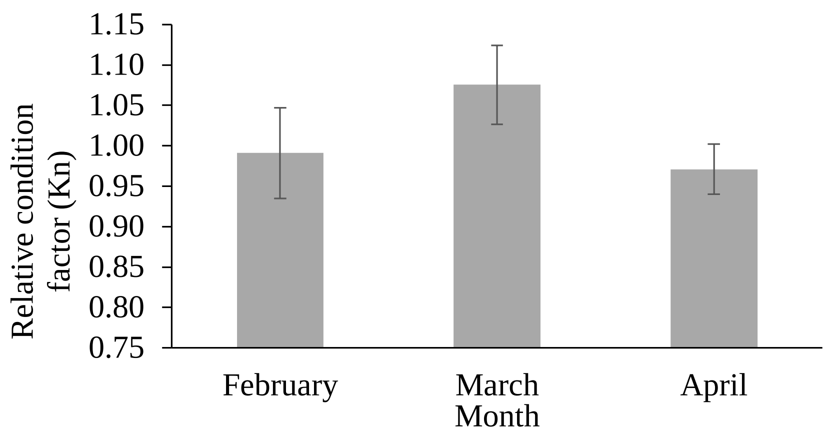

Figure 28: Mean±SE relative condition factor of *L. harak* sampled during the study period

4.3.5. *Lutjanus fulviflamma*

The mean monthly relative condition factor showed a general decrease from the month of February to March and slight increase in April. The highest Kn was recorded in February at (1.076 ± 0.065) and the lowest in March at (0.951 ± 0.03) (Figure 29). The overall mean Kn was (1.013 ± 0.076) (Table 3). One-way ANOVA revealed significant deviations of the mean monthly relative conditions (df=49, F= 3.70; P < 0.05). Bonferroni post-hoc test showed that relative condition factor in February and March differed significantly (t = 0.032; p < 0.05. April was not significantly different from the other two months.

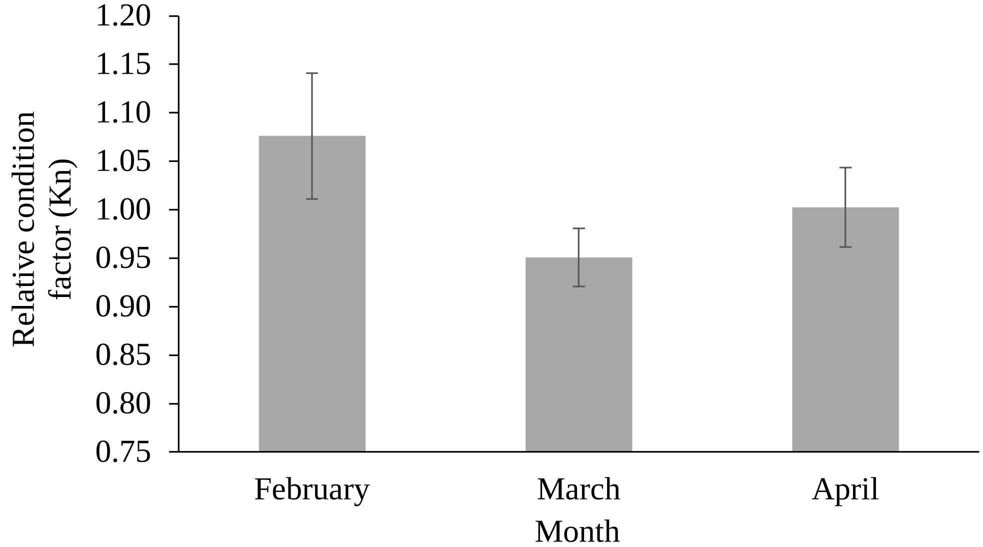

Figure 29: Mean±SE relative condition factor of *L. fulviflamma* sampled during the study period

4.3.6. *Rastrelliger kanagurta*

The highest Kn was recorded in March at 1.029 ± 0.006 and the lowest in February 0.982 ± 0.003 (Figure 30). The overall mean Kn was 1.008 ± 0.053 (Table 3) but one-way ANOVA revealed no significant deviations of the mean body conditions between the months (df=69, F= 0.961, $P > 0.05$).

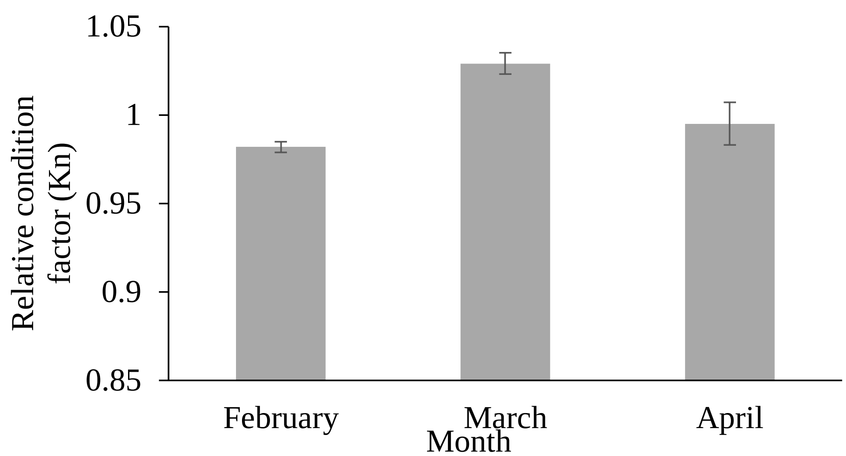

Figure 30: Mean±SE relative condition factor of *R. kanagurta* sampled during the study period.

4.3.7. ***Sagocentron caudimaculatus***

The mean monthly relative condition factor showed a general increase from the month of February to March and a decrease in April. The highest Kn was recorded in March at 1.019 ± 0.043 and the lowest in February 0.943 ± 0.001 (Figure 31). The overall mean Kn was 1.007 ± 0.009 (Table 3) and one-way ANOVA revealed significant deviations of the mean body conditions between the months (df=3, F= 3.388; $P < 0.05$). Bonferroni post-hoc test revealed significant deviations ($p < 0.05$) between the months of February and March. No significant deviations ($p > 0.05$) were observed between April and the other months.

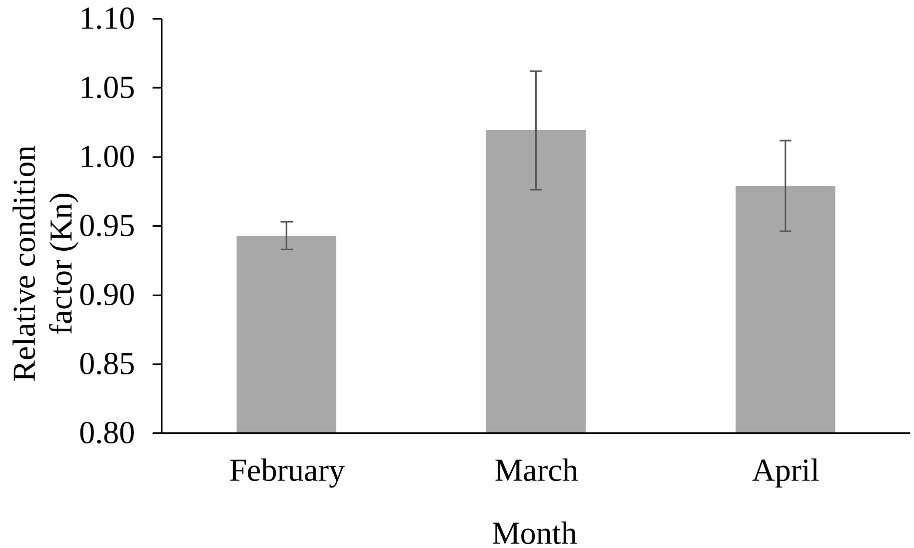

Figure 31: Mean±SE relative condition factor of *S. caudimaculatus* sampled during the study period.

4.3.8. ***Scomberoides tol***

The mean monthly relative condition factor showed a general decrease from the month of February to March and a slight increase in April. The highest Kn was recorded in February at 1.044 ± 0.008 and the lowest in March at 0.976 ± 0.022 (Figure 32). The overall mean Kn was 1.004 ± 0.086 (Table 3) and one-way ANOVA revealed no significant deviations of the mean relative conditions (df =40, F = 2.679; $P > 0.05$).

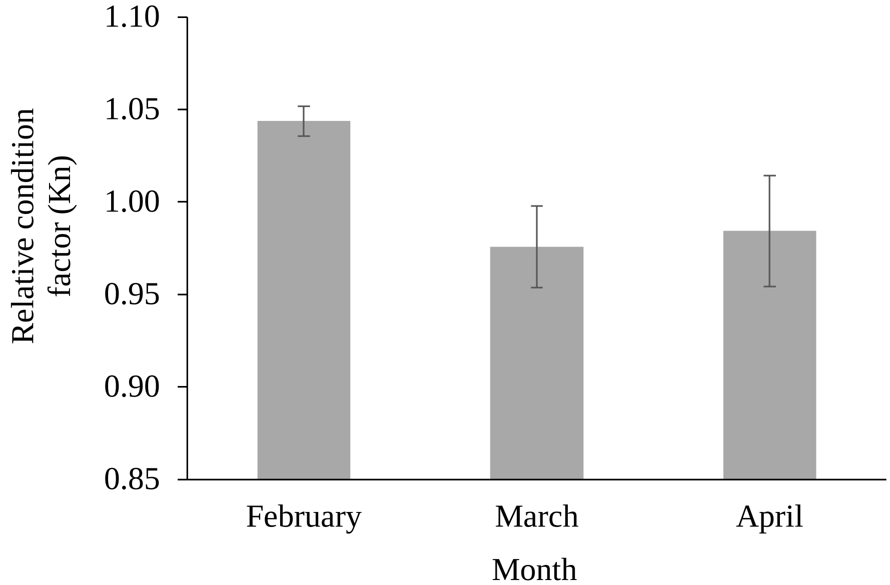

Figure 32: Mean±SE relative condition factor of *S. tol* sampled during the study period.

4.3.9. *Siganus sutor*

The monthly relative condition factor showed a general decrease from the month of February to March and slight increase in April. The highest Kn was recorded in February at 1.068 ± 0.009 and the lowest in March at 0.952 ± 0.019 (Figure 33). The overall mean Kn was 1.019 ± 0.071 (Table 3) and one-way ANOVA revealed no significant deviations of the mean monthly body conditions (df = 42, F= 1.37; $P > 0.05$).

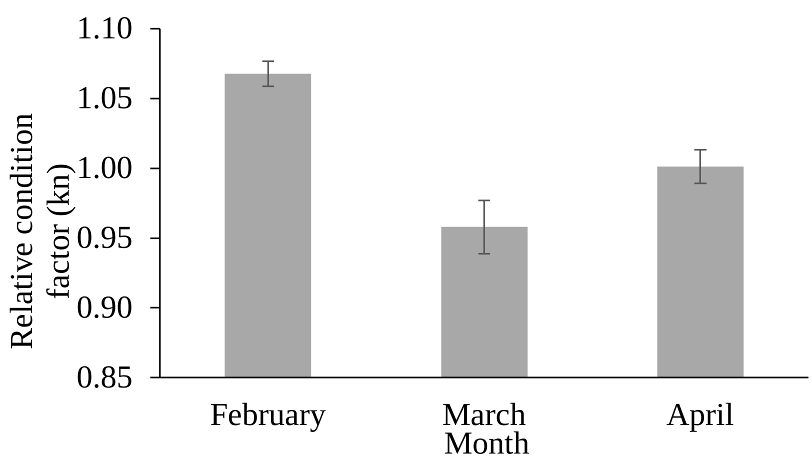

Figure 33: Mean±SE relative condition factor of *S. sutor* sampled during the study period.

4.4. Diet composition of the selected fish species

The two species selected for stomach content analysis were *S. sutor* and *L. harak*. These two fish species had a relatively high market value compared to the other 7 species sampled during the study. Local fishers also noted a significant decrease in the catch of these species.

4.4.1. Stomach fullness of *Siganus sutor*

Samples were composed of both sub-adults and adult individuals. Based on the point method of stomach content analysis of the species, it was observed that out of the 20 specimen of *Siganus sutor* used for the study, one had empty stomach accounting for 5%; three specimen had a full stomach (15%); five specimen had three quarter full stomach content (25%); six specimen had half-full stomach (30%); while five specimen had quarter-full stomach accounting for (25%) (Table 5).

Table 5: Point method of stomach content analysis for *Siganus sutor*

No.	Total length (cm)	Stomach fullness index	Points
1	18.3	¼	1
2	18.6	¾	3
3	19.4	½	2
4	20.2	¾	3
5	23.1	½	2
6	24.8	½	2
7	25.2	¾	3
8	25.4	½	2
9	27.1	¼	1
10	27.1	1	4
11	27.5	¼	1
12	27.6	¾	3
13	27.6	1	4
14	27.8	¼	1
15	28.2	½	2
16	28.4	0	0
17	30.4	¾	3
18	30.7	¼	1
19	35.6	1	4
20	35.7	½	2

4.4.2. Stomach content of *S. sutor*

Analysis of the stomach content of *S. sutor* was done with respect to the importance of prey consumed using frequency of occurrence and numerical method. The stomach content of *Siganus sutor* consisted mainly of pieces of marine algae particularly Chlorophyta, Phaeophyta and Rhodophyta. Numerically, the algae Rhodophyta comprised the dominant food item identified for *Siganus sutor* (44.83% of the total ingested prey) while Chlorophyta and Phaeophyta accounted for 18.19% and 17.67% respectively. Items such as grains of sand and detritus also contributed 4.62%. The most important food item was *Hypnea spp* contributing 15.19% of the entire diet, followed by *Thalassodendron ciliatum* (seagrass) with 14.69% (Table 6). Other food items included *Chaetomorpha spp*, *Ulva spp*, *Bacchelotia spp*, *Sargassum spp*, *Gracillaria spp*, *Jania spp*, *Laurencia spp* and *Spyridia spp* which recorded low food content in the diet.

Table 6: Percentage numerical composition and Percentage frequency of occurrence of food item in the diet of *Siganus sutor*

Taxa	Food item	Percentage Numerical	Percentage Frequency
Cymodoceaceae	Thalassodendron *spp*	14.69	14.13
Chlorophyta	*Chaetomorpha spp*	6.24	6.52
	Ulva spp	11.95	13.04
	Sub-Total	**18.19**	**19.56**
Rhodophyta	*Gracillaria spp*	10.23	10.87
	Hypnea spp	15.19	15.22
	Jania spp	2.10	2.17
	Laurencia spp	3.60	3.26
	Spyridia spp	13.71	8.7
	Sub-Total	**44.83**	**40.22**
Phaeophyta	*Bachelotia spp*	4.48	5.43
	Sargassum spp	13.19	11.96
	Sub-Total	**17.67**	**17.39**
Others	(Sand grains and detritus)	4.62	8.7
	Total	**100.00**	**100.00**

Chi-square test of independence revealed a significant difference (Chi = 13.467, $p < 0.05$) on the gear type with regards to the fullness of the stomach. Fish caught using speargun recorded a high number of full stomachs than those caught using gill nets (Table 7). The fullness index for *Siganus sutor* ranged from 1.545 (35.6cm) to 1.14 (18.3cm). The diet was diverse with H'= 2.163. A total of 10 food items belonging to four phyla of algae were identified.

Table 7: Stomach fullness of *S. sutor* by fishing gear type

	Full	$^3/_4$ full	$^1/_2$full	$^1/_4$full	Empty	Chi^2	P
Speargun	3	5	1	1	0	13.467	0.009
Gill net	0	0	5	4	1		

4.4.3. Stomach fullness of *Lethrinus harak*

Of the 20 specimens collected for *Lethrinus harak*, two had full stomachs accounting for (10%), four had three-quarter full stomach content (20%), four had half-full gut content accounting for (20%), five had quarter full gut contented (25%) while five had empty gut accounting for (25%) (Table 8).

4.4.4. Stomach content analysis of *L. harak*

Two major food items (Table 9) were identified in the gut of *Lethrinus harak*. The diet composition showed that the major food items identified were benthic crustaceans (Crabs and shrimps). Crabs and shrimps accounted for 29.58% by numerical method and 40.63% by frequency of occurrence method. Other important food organisms include worms generally from the family Phascolosomatidae (Sipuncula worms) and Pectinariidae (Trumpet worms) which had a mean contribution of 12.68% by number. Sand grains and plant detritus were also found in the stomach of the fish contributing 33.8% by number.

Table 8: Point method of stomach analysis for *L. harak*

No.	Total length (cm)	Stomach fullness index	Points
1	18.5	½	2
2	18.9	0	0
3	19.1	0	0
4	20.6	¾	3
5	20.7	1	4
6	21.3	0	0
7	21.6	¼	1
8	21.9	¼	1
9	22.2	¼	1
10	22.6	½	2
11	22.8	0	0
12	23.4	¾	3
13	23.8	¾	3
14	24.9	½	2
15	26.6	¼	1
16	28.2	0	0
17	29.4	¾	3
18	30.6	1	4
19	31.3	½	2
20	31.6	¼	1

Table 9: Percentage numerical composition (CN) and Percentage frequency of occurrence of food item in the diet of *Lethrinus harak*.

Food item	Percentage Numerical	Percentage Frequency
Crustaceans		
Crabs and shrimps	29.58	40.63
Worms	12.68	25
Sand grains and detritus	33.8	21.88
Grand Total	**100**	**100**

Chi-square test revealed that there were no significant deviations (Chi = 7.6, $p > 0.05$) in the stomach fullness of *L. harak* with regards to method of fish capture (Table 10). This suggests that the stomach fullness was independent on the gear used. The fullness index ranged from 0.52

(30.6 cm) to 0.13(21.6 cm). The diet was less diverse (H'=0.41) with only three items forming part of the diet.

Table 10: Stomach fullness of *Lethrinus harak* by fishing gear type

Gear type	Full	$^{3}/_{4}$full	$^{1}/_{2}$full	$^{1}/_{4}$full	Empty	Chi^2	P
Speargun	2	3	3	1	1	7.6	0.107
Gill net	0	1	1	4	4		

CHAPTER FIVE

5.0. Discussion

5.1. Length-Weight Relationship and Relative Condition Factor

Various authors have studied the length-weight relationships of different species in different regions worldwide. Varying values of b for various fishes have been reported. The exponent b is a shape parameter for the body form of the fish species (Ricker, 1773). Allen (1938) indicated that b calculated from the LWR of fishes is normally 3.0. Beverton and Holt (1957) also pointed out that the cube law for length and weight relationship prevailed and proposed that the b value is close to 3.0. Ricker (1968) reported that a great number of fish species also advanced towards this ideal value of 3. Later, Carlander (1982) and Froese (2006) mentioned that the value of b is usually close to 3.0 but could range between 2.5 and 3.5. The latter report has been supported by the current study conducted on the nine teleost fishes. Most of the estimates of b value *Decapterus macrosoma* (2.543), *Sargocentron* caudimaculatus (2.680), *Lethrinus nebulosus* (2.957), *Lethrinus harak* (2.687), *Rastrelliger kanagurta* (3.249) and *Siganus sutor* (2.820) fell within this expected range $2.5 < b > 3.5$ for fishes. However, the observed b values could not be compared for constancy since the investigated fishes belonged to different species having differing rates of metabolism.

The length-weight relationships of most fish species in this current study are available. The current estimated values conform to previous results on LWR of five species studied in Kenya. The b values revealed by Mbaru *et al*. (2010) for *Siganus sutor* (3.290), *Lethrinus nebulosus* (3.024), *Decapterus macrosoma* (3.930), *Lethrinus harak* (3.082) and *Lutjanus fulviflamma* (3.987) are slightly higher compared to the present findings *S. sutor* (2.820), *L. harak* (2.687), *L. nebulosus* (2.957), *L. fulviflamma* (2.347) and *D. macrosoma* (2.543). Kimani *et al*. (2008) and

Vasantharajan *et al*. (2014) however, reported almost similar b values for *S. sutor* (2.716) and *L. nebulosus* (2.964) in south coast of Kenya and Coast of India respectively. Variation in LWR variables may represent difference over time (Sparre *et al*., 1989). This might be attributed to the impact of the quality of water quality or availability of food on the growth of fish (Mommsen, 1998). Nevertheless, the observed deviations in this current comparison could be due to a smaller sample sizes (n < 100) collated to many specimens (n > 100) on which the LWRs of the earlier studies were derived. The deviations could also be due to the disparities in sampling methods, period of the collection of samples and also the size range of catches in this specific area during the sampling period (Kimmerer *et al.,* 2005; Froese, 2006). Other factors such as fishing seasons and fishing gears could have also resulted into the observed differences.

Length-weight relationships are not constant for fishes from various geographical regions and the b values may be influenced by environmental factors such as salinity, availability of food and water temperature (Kimmerer *et al.,* 2005). In India, Abdurahiman *et al.* (2004) and Caspian sea, Daliri *et al*. (2012) reported b value *S. tol* (2.937) and *L. nebulosus* (2.683) respectively. These results differ from the present findings of b value 2.482 and 2.957 for *S. tol* and *L. nebulosus* respectively. Ongkers *et al.* (2017) reported that in Ambon, Indonesia b values ranged from 2.976 to 4.108 in *Decapterus macrosoma* but this study reports lower value of 2.543. The variations observed in this current study could be ascribed to the ecological variations of the geographical localities, availability of food and differing habitat conditions (Froese, 2006).

Biological factors such as sex, health, and morphological differences can also result into the observed differences (Ricker, 1973; Froese, 2006). Letourneur et al*.*, (1998) reported the b values for *Scomberoides lysan* a species related genus to *S. tol* at 2.896 and 2.685 in New Caledonia and

South Africa respectively. These values are higher than the calculated b value for *S. tol* in the current study. Siganid populations in other parts of the world have also indicated variations in the observed b values. Al-marzouqi *et al.* (2009) reported the b values of male and female *Siganus canaliculatus* which belong to related species of S. sutor in Arabian Sea coast of Oman at 2.674 and 2.805, respectively which is closely similar to the present findings because they are all within the Western Indian Ocean.

The b values reported by Mehanna (2001), Torres (1991), Abdussamad *et al.,* (2006) Amin *et al.*, (2015), Jayabalan *et al*., (2014) for *Rastreliger kanagurta* in Red sea, South Africa, India, Pakistan and Sohar coast of Oman, respectively concur with the b value recorded for the same species of 3.249. This indicates that the species is stable in a range of environmental conditions. However, comparisons of the results of this study shows that two species *Calotomus carolinus* and *Sargocentron caudimaculatus* lack existing statistical records on length-weight relationship in FishBase or any earlier information on their LWR in Kenya.

Variables (*a* and *b*) of length-weight relationship are used to understand the allometric changes related to fish ontogenesis (Sani *et al.,* 2010). Length-weight relationships has been employed to investigate whether the growth in fishes is isometric or allometric (Le Cren, 1951; Ricker, 1973). Based on the observed b values, seven species *C. carolinus, D. macrosoma*, *L. harak*, *L. fulfiflamma*, *S. caudimaculatus*, *S. tol* and *S. sutor* had negative allometric growth. *R. kanagurta* had positive allometric and *L. nebulosus* had isometric growth pattern. The differences in growth types could be ascribed to one or a combination of factors such as differences in number of specimen examined, observed length ranges of the species caught, fishing methods, fishing seasons, sex, habitat, diet, gonad maturation, general fish condition and health status of fish

(Bagenal and Tesch, 1978; Froese, 2006; Alam *et al.*, 2013). Nevertheless, these factors were outside the scope of the current study.

The linkages between length-weight relationships and fish conditions is important for improving the knowledge about the implications for growth and reproductive success of fishes (Mbaru *et al.*, 2010). Relative condition factor (Kn) in fishes reflects the physiological condition of fishes in correlation to their welfare (Lambert and Dutil, 1997). Slight deviations were noticed in the monthly relative conditions of the species. These deviations could be due to nutritional requirements of the fish species which were not examined in this current study. The relative condition factors (Kn) of the nine species revealed that all fish species were healthy indicated by Kn greater than 1 *C. carolinus* (1.005±0.042), *D. macrosomma* (1.021±0.089), *L. nebulosus* (1.012±0.043), *L. harak* (1.006±0.032), *L. fulviflamma* (1.012±0.076), *R. kanagurta* (1.008±0.053), *S. caudimaculatus* (1.007±0.009), *S. tol* (1.004±0.086) and *S. sutor* (1.019±0.071). This present study conforms to previous studies conducted on similar species in various regions of the Kenya coast. Kimani *et al*. (2008) reported a condition factor of [Kn=1] for siganid populations of south coast Kenya. Aura *et al*. (2011) and Mbaru *et al*. (2011) on selected reef species along the Kenyan coast also corroborate the present findings.

Several authors have asserted that the significant deviations in body condition of fishes could be due to food supply. Populations of fish in relatively warm and eutrophic locations are in better conditions where favorable feeding and physiological conditions prevail (Jakob *et al*., 1996; Lambert and Dutil, 1999). Kenya marine climate regime is divided into two distinct monsoon seasons; North East Monsoon (NEM) and South East Monsoon (SEM) (McClanahan, 1988). Fish were sampled during the warm NEM which is usually a period of warm and calm waters. The NEM winds causes upwelling in the upper reaches of the north coast banks of Kenya. This current counteracts with the Equatorial Counter Current (ECC) creating a turbulence which enhances primary production subsequently creating a fertile fishing ground (McClanahan, 1988). This could in part explain why the conditions of the fish species studied are relatively high in Kilifi County. The specimens in this study were found to conform to these previous findings with all the fish species having condition factors equal to or greater than 1. This suggests that the coastal water of Kilifi County was suitable for growth and survival of most fish species.

The Kn value is strongly related to Length-Weight relationship and thus the b is critical in determining the well-being of fish (Froese, 2006). Relative condition factor studies have been employed in fisheries to assess and compare changes in conditions of fish in relation to its environment hence presenting the health status of fish (Nash *et al.*, 2006). Condition factor could also be influenced by almost the same factors as for length-weight relationship (Aryani *et al*, 2015). However, lack of comparative literature studies on condition factor of most coral reef fishes from other populations in Western Indian Ocean (WIO) waters made it difficult to gauge the overall health of fish populations of the present study.

These relative conditions of selected fish species denote that the coastal waters of Kilifi County could provide a favorable environmental conditions and suitable habitat for the growth of fishes. According to Thorsen *et al*. (2006), differences in relative condition factor could be attributed to the food organism available at specific times and also due to the differences of gonad development. However, the current findings could not elucidate which factors among those illustrated could have led to the observed results. These observed differences in LWR and condition factor of the species in this current study could be ascribed to the factors earlier listed or a combination of those factors that need additional research. This research has thus provided additional knowledge of the fishery resources in this area.

5.2. Stomach content composition

Fishes feed on diverse food types such as zooplankton, phytoplankton, invertebrates, benthic detritus, other fishes and aquatic macrophytes (Engdaw, 2014). The diets of most juvenile and sub-adult groups of fish in Kenya comprise mainly plankton and benthos (De Troch, 1998; Wakwabi, 1996; Nyunja and Mavuti, 2001). Wakwabi, (1999) reported on the trophic ecology of fish fauna in Gazi Bay and revealed that there were four trophic guilds: benthic carnivores, omnivores, piscivores and zooplantivores. Based on the numerical composition of the diet, stomach fullness index and the diet diversity in the present study, the fishes distinguished are herbivores and carnivores. *Siganus sutor* is a herbivore which mainly feed on marine plants especially algae and seagrasses including detritus while *Lethrinus harak* is a carnivore mainly feeding on benthic crustaceans (Woodland 1990).

The diet of siganid populations of Mediterranean coast of Israel (Lundberg *et al*., 1995), suggest that the species is a herbivore feeding on algae though different fish species prefer different classes of algae. The algae Rhodophyta in this current study was the dominant food item identified for *Siganus sutor* suggesting that the prey could be abundant in the ecosystem and have a high nutritional value compared to other algal groups (Wakwabi, 1999). The contribution of semi digested matter in *S. sutor* was high. The presence of considerable quantities of semi digested matter might be due to the rapid digestion that takes place in the tropical waters due to a high metabolic rate (Binod and Jayabalan, 2000). The species was characterized by a high fullness index and a high diversity of the algal food item.

Kulbicki *et al.* (2005) reported on the diet composition of carnivorous fishes from coral lagoons of New Caledonia and suggested that Lethrinids prefer prey that are less mobile such as molluscs. Lethrinids are schooling species which feed on aggregated prey such as bivalves, sand grains, urchins and benthic crustaceans particularly crabs. The diet of *L. harak* mainly consisted of macro-crustacean especially crabs and shrimps which concur with earlier studies. No other food items were identified in the diet of *L.harak* in the present study indicating that carnivorous fish select their food items and do not necessarily feed on unwanted food even if it is abundant in the ecosystem. This statement has been affirmed by Jones (2005) who showed that the feeding rates of two Lethrinid species, *L. nebulosus* and *L. atkinsoni* was not linked to the prey abundance. The low number of different food items in *Lethrinus harak* suggests that the species is more selective in its diet and specializes on particular food items. Worms formed part of the diet of the species though it did not represent a high percentage number probably because this prey type was not available for the fish.

Stomach content identification for fishes is usually not easy because the food items are normally completely digested or unidentifiable. Moreover, most of the fish samples have empty stomachs (Kulbicki et al., 2005). In this study only 15% of sampled stomachs in *S. sutor* and 10% in *L. harak* had full stomachs which contributed to a relatively low identifiable food items. The method of fish exploitation could have an impact on the stomach fullness index (Mbuga, 1984). Samoilys *et al.* (2011) studied the gears used along the Kenya coast and reported that most fish caught using spearguns have full stomachs as compared to other gears such as basket traps and nets. This could be due to the fact that spearguns kill the fish instantly thereby reducing the rate of digestion. The present study has confirmed this statement as shown by a high number of full stomachs in the two species that were caught using spearguns. Diet studies are useful in understanding the relationship between age structure and food resource availability in fisheries (Mazlan *et al.*, 2007). Studies on fish diets are useful in determining the sustainability of local reproducing populations which restock the adjacent reef areas (Kaunda-arara and Rose, 2004).

CHAPTER SIX

6.0. Conclusion and Recommendations

This study has provided additional information on the length-weight relationship (LWR) of nine commercially important teleost fishes in Kilifi County. Seven species *C. carolinus*, *D. macrosoma*, *L. harak*, *L. fulviflamma*, *S. sargocentron*, *S. tol* and *S. sutor* had a negative allometric growth; one species, *R. kanagurta* had a positive allometric growth and one species, *L. nebulosus* had isometric growth. These results suggest that cubic relationship does not exist between the length and weight of most fish species. All the selected species exhibited a high condition factor as indicated by relative condition factor of greater than 1. These conditions denote that the coastal waters of Kilifi could provide a suitable habitat for growth of those fishes. *Siganus sutor* is an herbivore which mainly feed on marine plants especially algae and seagrass while *Lethrinus harak* is a carnivore feeding on inverterbrates such as crustaceans. The parameters as shown in this study could be employed to study the growth and population dynamics of these selected fish species exploited in this region. Therefore, this study recommends the following,

i. Further research needs to be done which would involve the standardization of the sampling seasons, environmental physico-chemical parameters and sampling sizes as well as understanding the fish biology before additional inferences could be made.
ii. There is also need for enforcement of specific fishing gears used by the artisanal fishermen during different seasons to minimize the threats imposed by such gears.

iii. The present study confirms that *Siganus sutor* is an herbivore feeding on marine algae and sea grasses available in the ecosystem hence culture possibility could be attempted for the species to increase the yields.

iv. This study has revealed the importance of algae and crustaceans as food for fish in this region, thus conservation should ensure sustainability of these resources.

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