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Length-weight relationship of selected teleost fishes from Kilifi County, Kenya

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Abstract

Sustainable exploitation of fishery resources requires knowledge of the population dynamics of the target resources. Length-weight relationship and relative condition parameters were determined for nine teleost fish species, *Calotomus carolinus* (Valenciennes, 1835), *Decapterus macrosoma* (Bleeker, 1851), *Lethrinus nebulosus* (Forsskal, 1775), *Lethrinus harak* (Forsskal, 1775), *Lutjanus fulviflamma* (Forsskal, 1775), *Rastrelliger kanagurta* (Cuvier, 1816), *Sargocenton caudimaculatus* (Ruppel, 1838), *Scomberoides tol* (Cuvier 1832) and *Siganus sutor* (Valenciennes, 1835). The fish were randomly collected from artisanal fishers who operated gears such as gill nets, speargun and basket traps at three landing sites in Kilifi County between February and April 2017. The linear regression revealed a positive relationship between total length and body weight in all the fish sampled. The t-test calculated on b for most species revealed no significant deviations from the expected cube value of three, except for *L. nebulosus* ($t=0.340$, $p<0.05$), *R. kanagurta* ($t=1.321$, $p<0.05$) and *S. sutor* ($t=0.961$, $p<0.05$). These fish populations are healthy as shown by a relative condition factor above 1 in all species, suggesting that the nutritional requirements are available in the ecosystem, and that the Kilifi coral reefs have thus not been degraded.

Keywords: Length, weight, teleost, Kilifi, condition factor

Introduction

In Kenya, marine fishes are mainly harvested by small scale artisanal fishers operating between the shoreline and the reef (Kimani *et al.,* 2008). The 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 and Roberts, 2006). Teleost fishes are the target of a valuable fishery on the Kenyan coast, harvested both for subsistence and commercial purposes. Local fishers have noted a significant decrease in the catch of these fishes. 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 fishes. A shift in the species composition of the landings has occurred, where predatory snappers and groupers once dominated, with opportunistic and lower trophic level species such as rabbitfish becoming more prevalent in the catches (McClanahan and Omukoto, 2011). Fundamental information on the population dynamics of the target species is thus important in the management of the small-scale coastal fishery.

Fish length and weight data are commonly used for analyses in fisheries biology (Mendes *et al.*, 2004). The length-weight relationship (LWR) equation has been extensively used in the study of fish population dynamics for estimating the unknown weights from known lengths in fish stock assessments (Froese and Pauly, 1996). The length and weight data can be used in the estimation of fish growth rates and the overall health of fish stocks (Kohler *et al.,*1996). The relationship between length and weight has also been useful in fishery management by helping in the prediction of potential yields and in determination of size at capture, and for obtaining MSY (maximum sustainable yield), as these management parameters are directly related to the weight of fish (Froese and Pauly, 1996). Considering the LWR of reef associated fishes all over the world,

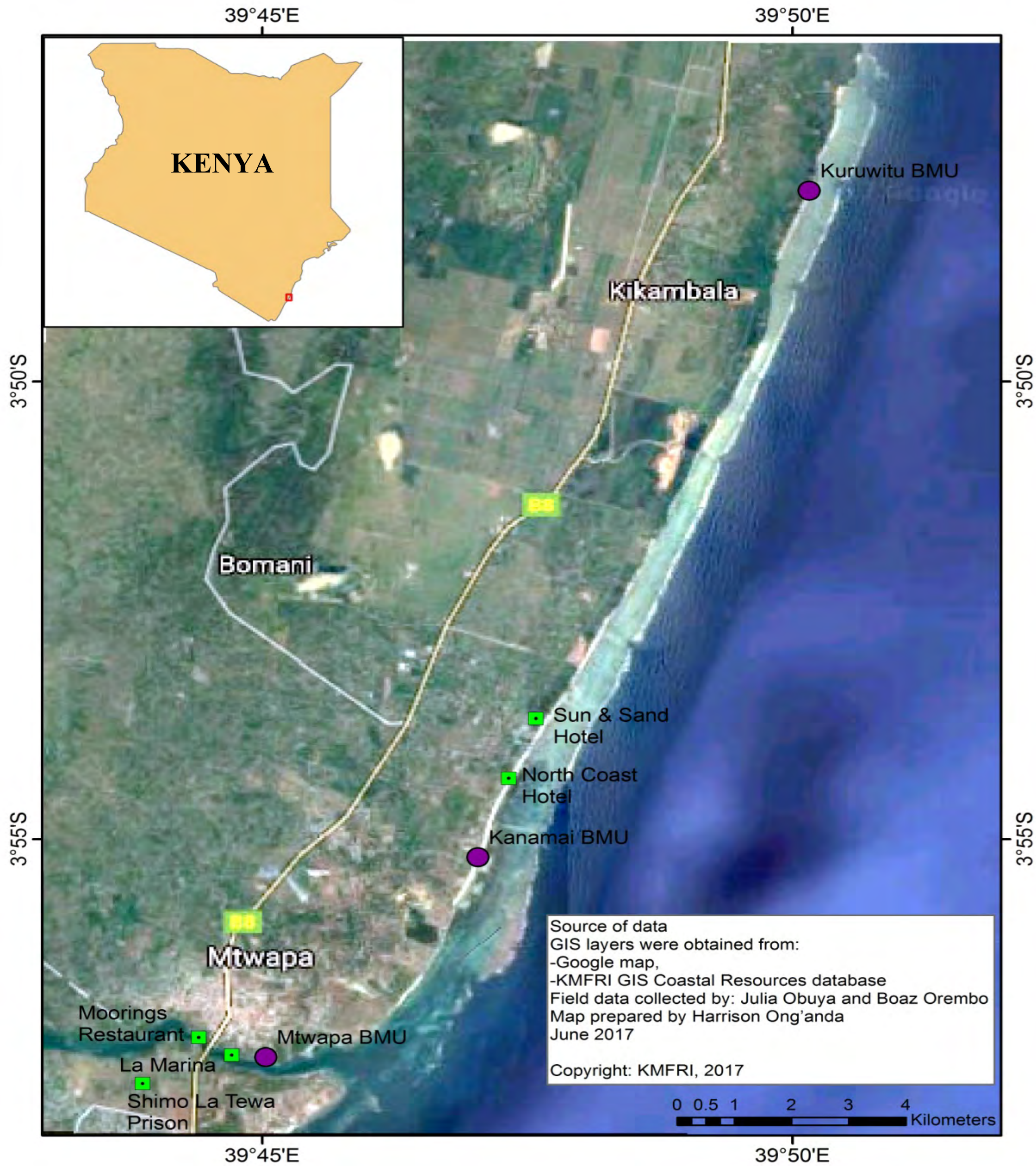

Figure 1. Map of Kilifi County in Kenya indicating the sampling sites.

several studies have been carried out. Letourneur *et al.* (1998) reported on the LWR of fishes from lagoons and coral reefs of New Caledonia. In India, LWR and feeding ecology have been investigated in *Siganus canaliculatus* (Park, 1797) from the Gulf of Mannar (Anand and Reddy, 2012; Jayasankar, 1990), and *Lethrinus nebulosus* and *Lethrinus lentjan* (Lacepede, 1802) on the Thoothukudi coast (Vasantharajan *et al.*, 2013).

Studies on the LWR of most reef associated fishes are available in Kenya. Mbaru *et al.* (2010) reported on the LWR of 39 selected reef fishes in Kenyan coastal waters. Kimani *et al.* (2008) studied the morphometric and condition factors of *Siganus stellatus* (Forsskal, 1775), *Siganus canaliculatus* (Park, 1797) and *Siganus sutor* (Valenciennes, 1835). Agembe *et al.* (2010) also studied the catch composition, abundance and LWR of groupers from inshore waters of Kenya. However, most of these studies have been reported from the south coast of Kenya. Kilifi County is home to traditional fishing communities and is an important location for artisanal fishermen on the north coast of Kenya. Only a few estimates of species-specific LWR parameters are available for coastal fishes from this area. The LWR of *Dentex maroccanus* (Valenciennes, 1830) has been the only reported study in Malindi-Ungwana Bay on the north coast of Kenya (Aura *et al.,* 2011). The present study therefore establishes the LWR of nine teleost fishes in Kilifi County, providing additional contribution to the available LWR for the main commercially exploited coral reef fishes in Kenya.

Materials and Methods

Study Area

Kilifi County is located some 60 km north of the city of Mombasa. 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) (McClanahan, 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). Kilifi town is set on Kilifi Creek between Mombasa and Malindi, which is located 52 km to the north. 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. Three sampling sites were selected, Mtwapa, Kanamai and Kuruwitu (Fig. 1). Mtwapa is located within Mtwapa creek, approximately 25 km (3° 57′ S, 39° 45′ E) north of Mombasa. There is a dense mangrove forest of *Rhizophora mucronata* on the extensive mudbanks of the creek. Fresh water input into the creek is from seasonal runoff (Owuor *et al.,* 2017). The creek has also been reported to be eutrophic as a result of direct release of raw sewage from Shimo la Tewa prison (Rodwell *et al.,* 2003). Kanamai is located approximately 10 km (3 °55′ S, 39° 47′ E) north of Mtwapa creek. The area has an extensive sandy beach on the shore. There are however little industrial activities around the area except for few operational hotels. Fishing expeditions are mostly carried out by individuals rather than groups. Kuruwitu sampling site lies approximately 30 km (3° 47′ S, 39° 50′ E) north of Kanamai. The area is dominated by sandy shores with an extensive lagoon. There are, however, few operational hotels along the area. Fishermen in this area are organized within Beach Management Units (BMUs).

Selection of Study sites

The selected study sites occur within the richest fishing grounds in the county, with a high concentration of artisanal fishermen. These study sites had the most operational BMUs under the State Department of Fisheries. The sites have fairly uniform reef lagoon comprising a mixture of sand, seagrass, corals and an outer reef edge that drops into a sand plain at a depth of approximately 10 to 15 m (McClanahan and Abunge, 2014). The lagoon and the immediate reef edge are ecologically similar between sites with regards to habitat and fish compositions, but differ in terms of fish abundance and types of fishing gears employed (McClanahan, 1988).

Fish sampling and Identification

Fish samples were randomly selected from the mixed composition of the landing. The sample size of individual fish species depended on the available mixed catch during the sampling period. Once the fish were landed, the fish families were identified and sorted from the mixed species catch. Taxonomic identification of the fish in the sample was then done up to

Table 1. Summary of LWR in the selected species, sample size (n), total length (TL), total weight (TW) with (±SE), intercept (log a), regression coefficient 'b', results of t-test on 'b', and coefficient of determination 'r^2'.

Family	Species	n	TL	TW	Log a	b	t^b	r^2
Carangidae	*D. macrosoma*	52	32.5±0.8	535.2±29.8	-1.144	2.543	2.874	0.843
Carangidae	*S. tol*	49	36.4±0.6	409.1±18.3	-1.246	2.482	5.129	0.926
Holocentridae	*S. caumadiculatus*	48	20.8±0.3	124.5±5.9	1.455	2.680	2.119	0.868
Lethrinidae	*L. nebulosus*	50	22.7±0.5	332.71±21.7	-1.525	2.957	0.341	0.920
Lethrinidae	*L. harak*	53	30.5±0.5	317.3±13.8	-1.503	2.687	2.566	0.910
Lutjanidae	*L. fulviflamma*	50	29.7±0.7	349.2±20.4	-0.936	2.347	4.503	0.845
Scaridae	*C. carolinus*	51	24.4±0.7	303.6±17.5	-0.613	2.214	9.704	0.940
Scombridae	*R. kanagurta*	55	25.1±0.3	296.8±11.9	-2.091	3.248	1.318	0.860
Siganidae	*S. sutor*	49	30.0±0.6	381.6±25.9	-1.619	2.820	0.957	0.825

species level with the help of a standard reference book (Anam and Mostarda, 2012).

Length-Weight Relationship

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

Data analysis

Data was analyzed using SPSS statistical software. The data generated from the measured parameters were expressed using descriptive statistics. The statistical relationship between the length and weight of fishes was established as per the parabolic equation $TW = aTL^b$ (Froese, 2006). Where: TW = Total Wet body weight of fish in grams; TL = Total length of fish in centimeters; a = Y intercept; and b = slope of the line, respectively. The length-weight relationship was obtained by logarithmic transformation of ($TW = aTL^b$) to provide a linear association between the variables. The least squares method on a linear regression model was used for 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 (k_n) factor was calculated following Le Cren's (1951) formula, $K_n = W/\hat{W}$. W is the observed weight and $\hat{W}$ is the weight calculated from the length-weight relationship $\hat{W} = aL^{3-b}$. Pooled totals of length-weight data for individual species obtained during the study was used. All statistical tests were conducted at a significance level of 95% ($\alpha = 0.05$).

Results

Length-Weight Relationship

A total of 457 fishes from seven families, eight genera and nine species were collected for length-weight analysis (Table 1). These species (Fig. 2) were selected because they dominated the landings. The LWR of the fish species are shown in Figs. 3-11. The sample sizes ranged from 48 individuals for *S. caudimaculatus*,

Figure 2. Selected teleost fishes from Kilifi sampling sites (Photo credits: Julia, 2017).

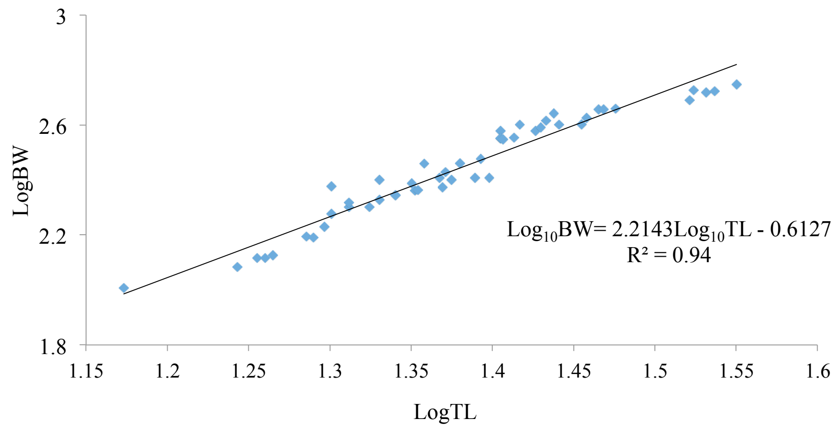

Figure 3. The Length-Weight relationship in *C. carolinus*.

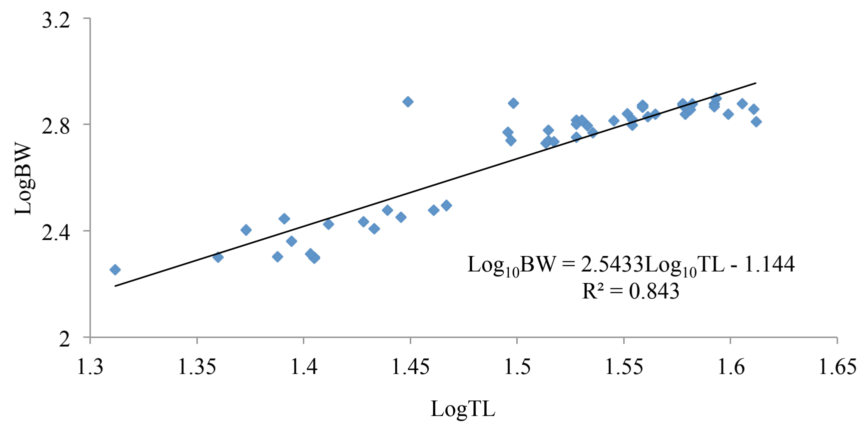

Figure 4. Length-Weight relationship in *D. macrosoma*.

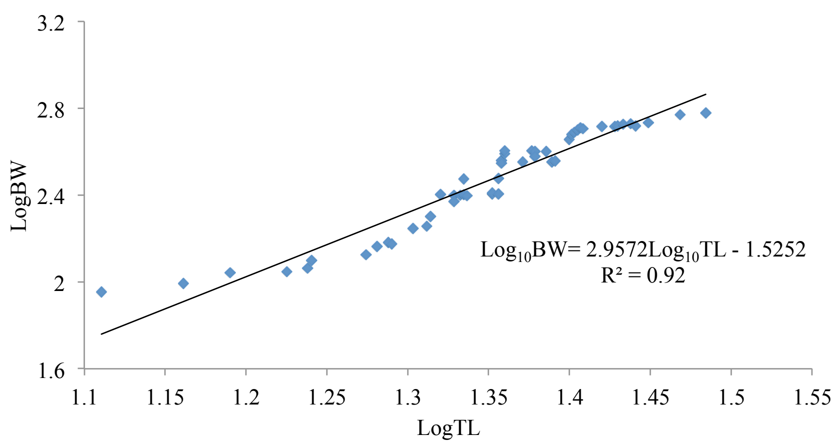

Figure 5. Length-Weight relationship in *L. nebulosus*.

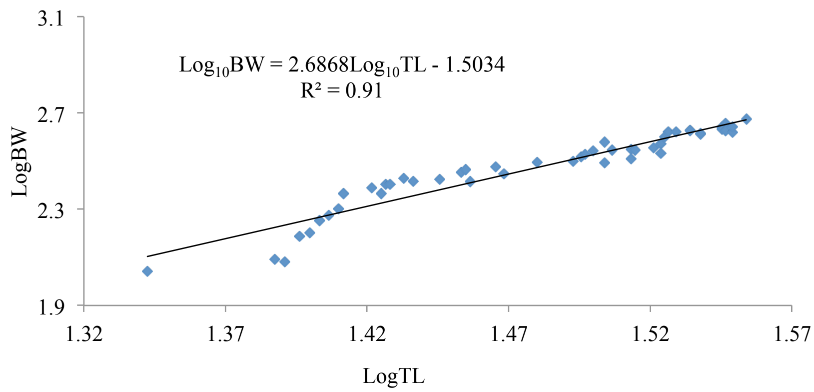

Figure 6. Length-Weight relationship in *L. harak*.

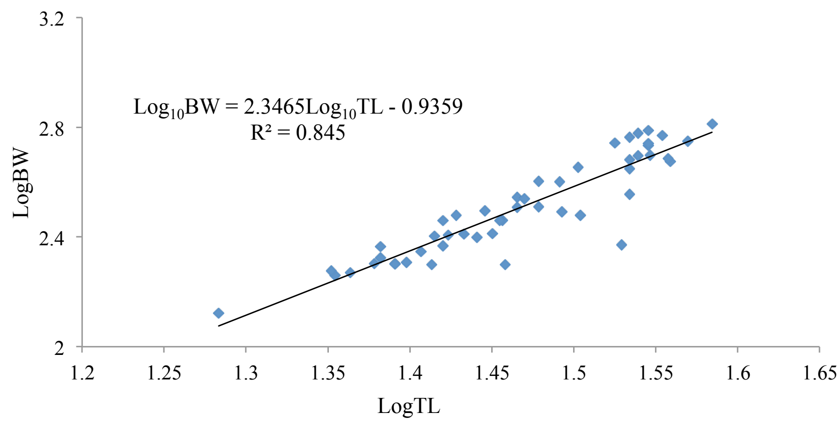

Figure 7. Length-Weight relationship in *L. fulviflamma*.

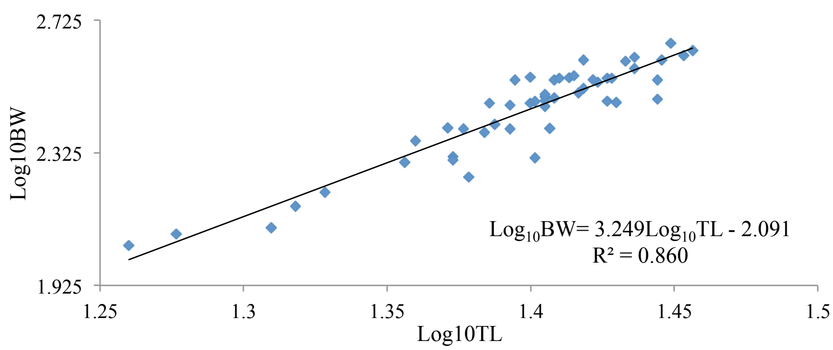

Figure 8. Length-Weight relationship in *R. kanagurta*.

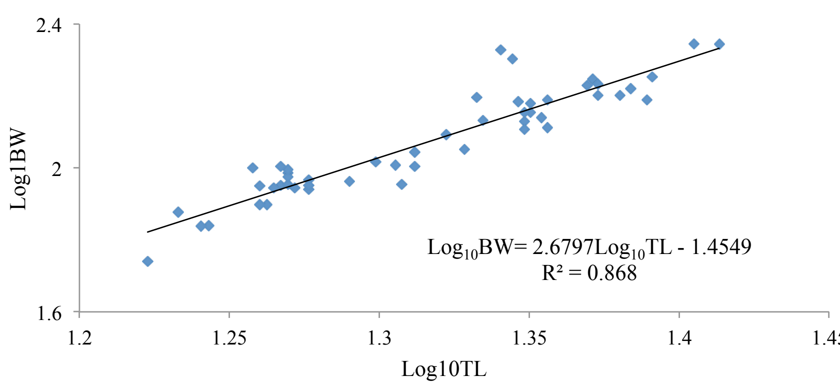

Figure 9. Length-Weight relationship in *S. caudimaculatus*.

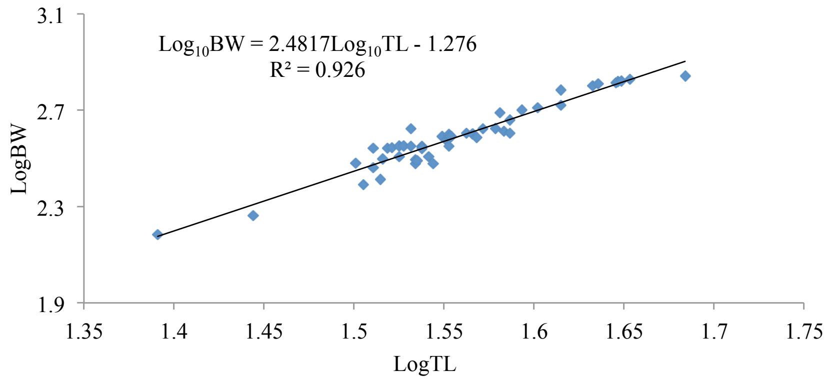

Figure 10. Length-Weight relationship in *S. tol*.

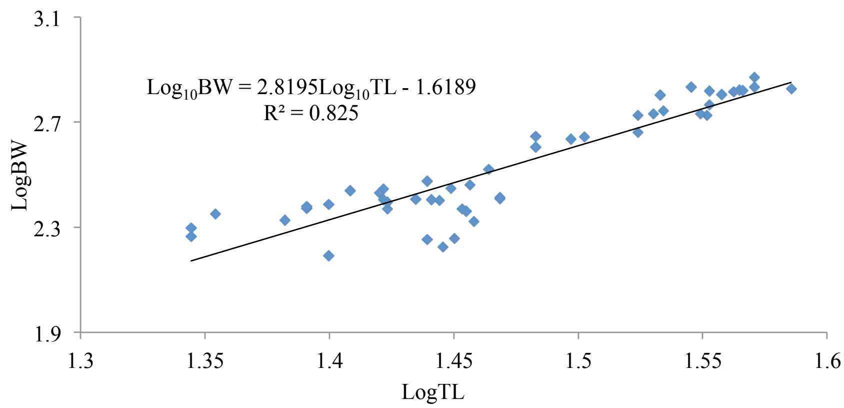

Figure 11. Length-Weight relationship in *S. sutor*.

to 55 for *R. kanagurta*. The coefficient of determination (r^2) values ranged from 0.825 for *S. sutor* to 0.940 for *C. carolinus*. The exponent 'b' value ranged from 2.214 for *C. carolinus* to 3.249 for *R. kanagurta*. T-tests revealed no significant deviation from the expected cube value of 3 for most species (Table 1). Significant differences were noted for *L.nebulosus*, *R. kanagurta* and *S. sutor*.

Condition Factor

The overall relative condition factor (K_n) for the nine species sampled is presented in Table 2.

Table 2. Mean relative condition factor (K_n) for the selected species.

Species	Overall relative condition factor (Mean±SE)
Calotomus carolinus	1.006±0.053
Decapterus Macrosoma	1.021±0.089
Lethrinus harak	1.006 ±0.032
Lethrinus nebulosus	1.012±0.043
Lutjanus Fulviflamma	1.013±0.076
Rastrelliger kanagurta	1.008±0.053
Sargocentron caudimaculatus	1.008±0.009
Scomberoides tol	1.004±0.086
Siganus sutor	1.019±0.071

Discussion

Length-Weight Relationship

Various authors have studied the LWR of most fish and fishery resources in different regions worldwide. Varying values of b for various fishes have been reported. Allen (1938) indicated that for an ideal fish exhibiting isometric growth, the b value should be 3. 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. The cube law suggests constancy of density and form in an ideal fish. However, as fish grow in length, they change in form and shape which causes a deviation from the cube law proposed for the ideal fish. Le Cren (1951) suggested that these deviations could be ascribed to the physiological condition of the fish, environmental parameters, sex, taxonomic differences or reproductive activities. Ricker (1973) reported that the b value of a reasonable fish species is close to this ideal value of 3 although the cube law does not usually hold true for most fishes. The b value may change due to changes in body proportions during the life of a fish, maturity and geographical localities (Ricker, 1973). Carlander (1982) and Froese (2006) later mentioned that the value of b is usually close to 3.0 but could range between 2.5 and 3.5 due to the variations listed earlier.

The present study on LWR conducted on the nine demersal fishes showed that the estimates of b value for the species fell within the expected range 2.5 < b > 3.5 for fishes as suggested by Carlander (1982) and Froese (2006). The b values for most of the species were significantly lower than 3.0 suggesting that these fishes are lighter in relation to their individual lengths. There were no significant differences in the LWR of these species indicating homogeneity in their growth pattern. Significant deviation of b from the cube value was noticed for *L. nebulosus*, *R. kanagurta* and *S. sutor*. *L. nebulous* had a b value which was very close to 3.0 indicating isometric growth, while *R. kanagurta* had a b value significantly higher than 3.0 for isometric growth, indicating a tendency towards slightly positive allometric growth. The observed b values for *L. nebulosus*, *R. kanagurta* and *S. sutor* were close to 3 suggesting that these fishes are neither heavier nor lighter in relation to their individual lengths. However, the observed b values could not be compared for consistency since the investigated fishes belonged to different species having differing rates of metabolism.

In the LWR of fish, the exponent b shows a normal distribution on both sides of the cubic value with little variation (Froese, 2006). These variations might be attributed to the impact of water quality or availability of food on the growth of fish (Mommsen, 1998). The b values revealed by Mbaru *et al*. (2010) for *D. macrosoma* (3.930), *L. nebulosus* (3.024), *L. harak* (3.082), *L. fulviflamma* (3.987) and *S. sutor* (3.290) are slightly higher compared to the present findings of LWR of similar species in Kenya. Vasantharajan *et al*. (2014) and Kimani *et al*. (2008) however, reported almost similar b values for *L. nebulosus* (2.964) and *S. sutor* (2.716) in India and the south coast of Kenya, respectively. Variation in LWR variables may represent differences over time (Sparre *et al*., 1989). Nevertheless, the observed deviations in this current comparison could be due to a smaller sample size (n < 100) compared to the many specimens (n > 100) from which the LWRs of the earlier studies were derived. The deviations could also be due to the disparities in sampling period and 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 in the observed differences.

LWR is 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 the Caspian Sea, Daliri *et al*. (2012), and India, Abdurahiman *et al.* (2004) reported b value for *L. nebulosus* (2.683) and *S. tol* (2.937), respectively. These results differ from the present findings of b values for the two species. Ongkers *et al.* (2017) reported b values for *D. macrosoma* ranging from 2.976 to 4.108 in Ambon, Indonesia, but this study reports a lower value of 2.543 for the species. The variations observed in the current study could be ascribed to the ecological variations of the geographical localities and differing habitat conditions (Froese, 2006).

Biological factors such as sex, health, and morphological differences can also result in the observed differences (Ricker, 1973; Froese, 2006). Letourneur *et al*. (1998) reported the b values for *Scomberoides lysan* (Forsskal, 1775), a species of the same genus as *S. tol*, to be 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* (Park, 1797), which belongs to the same genus as *S. sutor* on the Arabian Sea coast of Oman, as

2.674 and 2.805, respectively, which is similar to the present findings of b value for the species. These similarities could be due to the fact that the two localities fall within the Western Indian Ocean eco-region.

The b values reported by Amal *et al.* (2015), Jayabalan *et al*. (2014), Abdussamad *et al.* (2006), Mehanna (2001), and Torres (1991) for *R. kanagurta* in Pakistan, the Sohar coast of Oman, India, the Red sea, and South Africa, respectively, concur with the b value recorded for the same species. This indicates that the species is stable in a range of environmental conditions. However, comparison of the results of this study show that two species, *C. carolinus* and *S. caudimaculatus*, lack existing statistical records on LWR in FishBase or any other source for Kenya, thus this study is the first to document this parameter.

Condition factor

Le Cren (1951) suggested the calculation of relative condition factor (Kn) based on LWR in order to eliminate the variation caused by length and other factors such as maturity, age, sex, sampling methods and feeding intensity of fish. Kn in fishes reflects the physiological state of a fish in relation to its welfare (Lambert and Dutil, 1997). Kn also gives information when comparing two populations living in certain feeding density, climate, and other conditions (Lambert and Dutil, 1997). Slight deviations were noticed in the monthly relative conditions of the species. These deviations could be due to the changing physical conditions and nutritional requirements of the fish species which were not considered in the present study. Kimani *et al*. (2008) reported a condition factor of 1 for siganid populations on the south coast Kenya. Aura *et al*. (2011) and Mbaru *et al*. (2010) investigated the Kn of selected reef species along the Kenyan coast reporting a Kn of close to 1. The overall Kn of the nine species in the current study conforms to the earlier studies indicating a Kn of greater than 1 and suggesting that the fish species were healthy.

Fish populations in relatively warm and eutrophic locations are in better conditions due to the prevailing favorable feeding and physiological conditions (Jakob *et al*., 1996; Lambert and Dutil, 1999). The Kenyan coastal climate regime is divided into two distinct monsoon seasons; the warm north east monsoon and cool south east monsoon (McClanahan, 1988). Fish were sampled during the dry north east monsoon which is usually a period of warm and calm waters. The north east monsoon winds bring with it the Somalian stream current that causes upwelling in the upper reaches of the north coast banks of Kenya. This current counteracts with the Equatorial Counter Current 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, suggesting that the coastal water of Kilifi County is suitable for most fish species.

Conclusion

This study has provided additional information on the LWR of nine commercially important teleost fishes in Kilifi County that will also allow for future comparisons between populations of the same species. Data generated will form a baseline tool for enhanced fisheries management and utilization of species that are of commercial importance to improve sources of livelihood to the local communities. However, more extensive research needs to be undertaken which would involve the standardization of the sampling seasons and sample sizes, measurement of environmental physico-chemical parameters, as well as obtaining a better understanding of the biology of the species involved, before additional inferences can be made.

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