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Abundance, Length-Weight Relationship and Condition Factor in Selected Reef Fishes of the Kenyan Marine Artisanal Fishery

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Abstract: This study describes the results of length frequency distribution, catch per unit effort, Length-Weight Relationship and condition factor (Fulton's K) analysis of 4 major fish species along the Kenyan coast. Highest CPUE value (1.8±0.7 kg) was observed among *E. andersoni* in 2001, however all species recorded high CPUE values in 2005. Over 70% of the fish landed measured between 10-35 cm (total length) with a decrease in K values beyond the 50 cm length among the 4 species. From 5 cm size classes, parameters *a* and *b* of the length-weight relationship of the form $W = a \cdot L^b$ were estimated. All regressions were highly significant, with coefficient of determination (r^2) going up to 0.99 *(L. fulviflamma*, $p<0.05$). The Student's t-test revealed most size classes had b values ranging from 2.38 (25-29 cm) to 3.99 (70-74 cm) (*L. fulviflamma)* significantly different from 3 ($p<0.01$, $p<0.05$). This implies that the "cube law" cannot be applied to all size classes. The estimated parameters should be applied to the species within the specific length ranges analyzed. Knowledge of these species is important for adequate management and maintenance of the biological equilibrium of the ecosystem.

Key words: Condition factor, CPUE, kenyan coast, length frequency

INTRODUCTION

Inshore waters of most parts of the Kenyan coast are rich in fish resources in quantities that can support commercial exploitation on a sustainable basis (McClanahan and Mangi, 2004). However, the same authors in their later developments in fisheries studies pointed to the lack of adequate biological information of most of these reef fishes. In this analysis, we include the most common and representative coastal species of both soft and hard substrata and also most of the species targeted by local artisanal fisheries: *Epinephelus andersoni*, *Lethrinus lentjan*, *Lutjanus fulviflamma*, *Siganus sutor*. Although the Kenyan marine fishery is predominantly small scale and artisanal (UNEP, 1998), about 8,000 artisanal fishermen operating off the Kenyan coast intensely fish from nearshore reefs and the majority (80%) of those catches consists of these species (DoF, 2008, Table 1-4). These species also represent about 40% of the total fish catch from all artisanal fisheries (DoF, 2006), most of which is consumed to local markets. Furthermore, recent socio-economic surveys suggest that at least 90,000 people along the Kenyan coast depend on fish catches dominated by these 4 species (DoF, 2009). Despite the ecological and economical importance of these species, most lack basic biological data, and specifically relative abundance, condition factor and length-weight relationships (LWRs; Petrakis and Stergiou, 1995; Goncalves *et al*., 1997; Froese and Pauly, 2004). Knowledge of Condition Factor (CF), Length-Weight Relationship (LWR) and Catch per Unit Effort (CPUE) of these reef fishes are an important tool for fisheries biology studies (Smith *et al*., 1983). The LWR is useful in fishery assessments for predicting weights from the more easily measured lengths. Such a relationship is needed in yield assessment (Motos and Sarasua, 1998) and in the calculation of biomass (Vazzoler and Vazzoler, 1965). In addition, morphometric comparisons can be made between species and populations (King, 1996; Goncalves *et al*., 1997), as well as calculating relative condition factors of individuals in a population (Maguire and Mace, 1993). Catch per Unit Effort (CPUE) is also a useful index in the assessment of abundance of fish species (Marshall and Frank, 1999). It is essential in the determination of Maximum Sustainable Yield (MSY) and potential yield. This study is thus important for understanding the life cycle of fishes and contributes to adequate management of these fisheries and, therefore, to the maintenance of equilibrium in the ecosystem. This research also follows a series of investigations to understand the structure of the main foraging fish stocks of the Kenyan marine fishery towards assessing the biological aspects of the major fish stocks.

MATERIALS AND METHODS

The present work is based on a nine year (2001-2009) fisheries data collected in the framework of Catch

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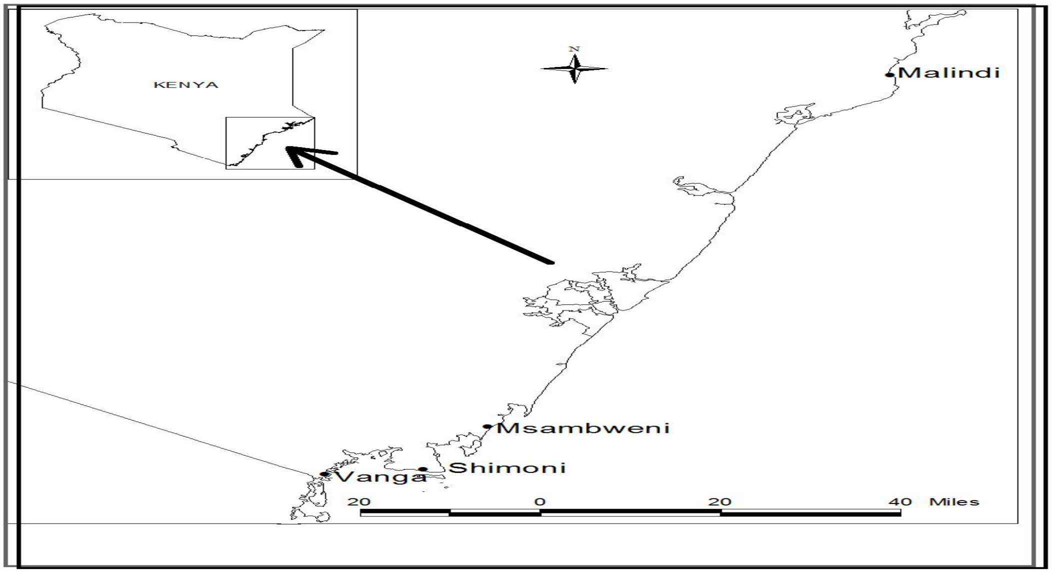

Fig. 1: Positions of the major landing beaches along the Kenyan coast

Assessment Survey (CAS) executed by Kenya Marine and Fisheries Research Institute (KMFRI). Fishes were collected by multiplicity of fishing fleets and gears with different mesh sizes. Data on total length (TL) in (cm) and total weight (TW) in (g) were recorded for each fish. The parameters a and b of the LWR were estimated using the logarithmic transformation of the equation: $W = a \cdot L^b$ (Ricker, 1975). In order to verify if calculated b was significantly different from 3, the Student's t-test was employed both at ($p = 0.01$) and ($p = 0.05$) (Sumbuloglu and Sumbuloglu, 2000). The value of b from the length-weight relation described in (Table 1- 4), were employed in calculating the Fulton's K, Condition Factor (CF). Individual values of the CF were obtained through the formula $K = 100$ ($TW/TL^{b)}$. The data used in the present analysis have been restricted to the major four species. This restriction contributed to the selection of stocks considered. There are more than the 4 analyzed species, but the disregarded ones were found to be hardly definable as major contributors to the overall landings from the local Artisanal Fishery (AF), or the necessary data were not available (length and body weight data) or substantial amount of datasets were not available due to their little dominance. However, the so-called big fish stocks found in all the landing beaches are included in our investigations representing a good coverage (Fig. 1). Separation by sex was not possible and the grouped form was used. The species data from a bibliographical survey were also employed. They dealt with aspects on reproduction, feeding, and population structure in other environments. Such data were a help in understanding species behavior.

Fish sampling and CPUE analysis: Fish specimens were procured from artisanal fishers and middlemen at their landing sites (Fig. 1). Sampling of landed catches was done on daily basis except during weekends and public holidays. Fishers used a wide range of fishing gear such as traps (10780), hook and line (6339), gill nets (2153), long line (4196), cast nets (302), and a combination of other gears (445). From the catches, fish specimens were randomly and identified using keys and descriptions by Holden and Reed (1972), Pitcher *et al.* (1998) and Watson *et al*. (2001). Relative abundance was estimated from the weight (g) of the total catch of each station for each species and compared for difference using Analysis of variance (ANOVA) to test for difference between the stations. Catch per Unit Effort (CPUE) was calculated by dividing the total yearly catch by the effort (number of fishers per boat) and finally dividing by the number of hours of fishing: CPUE = Total catch/No. of fishers/fishing hours CPUE = Kg/man/h (King, 1996). The Total Length (TL) of the fish was measured from the tip of the anterior or part of the month to the caudal fin using meter rule calibrated in centimeters. The mean lengths and weights of the classes were used for data analysis, the format accepted by FISAT (Gayanilo and Pauly, 1997).

RESULTS

Catch per unit effort: The CPUE for the four fish species in each year and landing stations is presented (Fig. 2 and 3). Fishers used a wide range of fishing gear such as traps (34%), hook and line (18%), gill nets (16%),

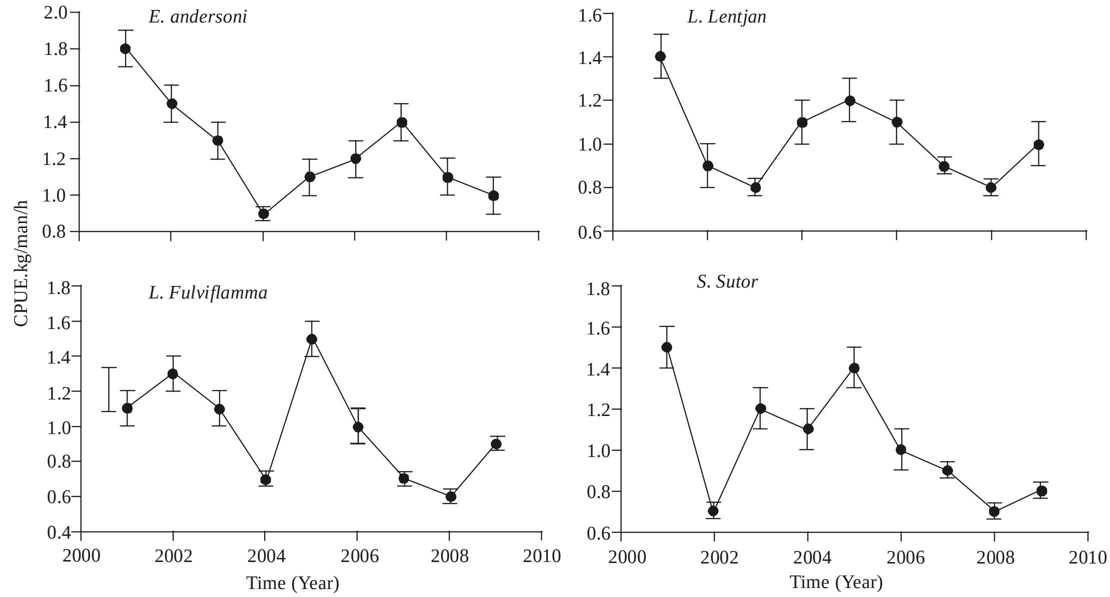

Fig. 2: Inter-annual CPUE for the four species (2001-2009)

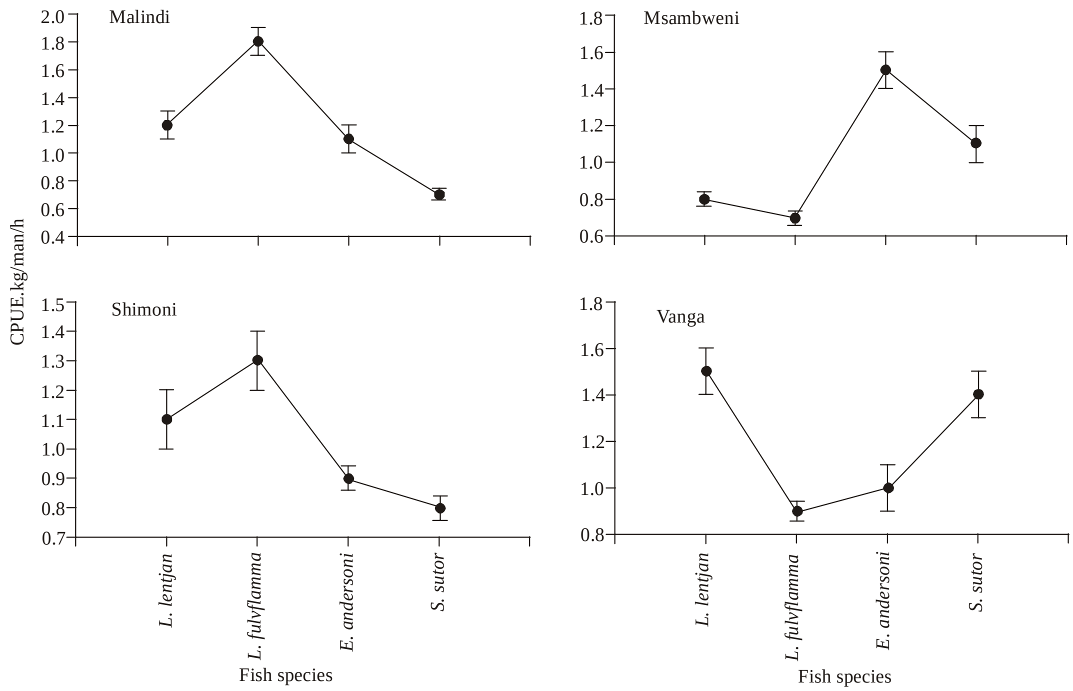

Fig. 3: CPUE at the 4 major landing stations

long line (14%), cast nets (8%), and a combination of other gears (10%).Inter annual analysis revealed an increase in CPUE in 2005 for all species with *L. fulviflamma* going upto 1.5±0.4 kg (Fig. 2). The highest CPUE value (1.8±0.7 kg) for *L. fulviflamma* was observed in the northern part of the Kenyan coast (Malindi) while Msambweni had the lowest CPUE value (0.7±0.2 kg) for the same species (Fig. 3).

Length frequency: Percentage length frequencies were plotted against the mid points of the 5 cm intervals. Records contained species of fish with length as low as

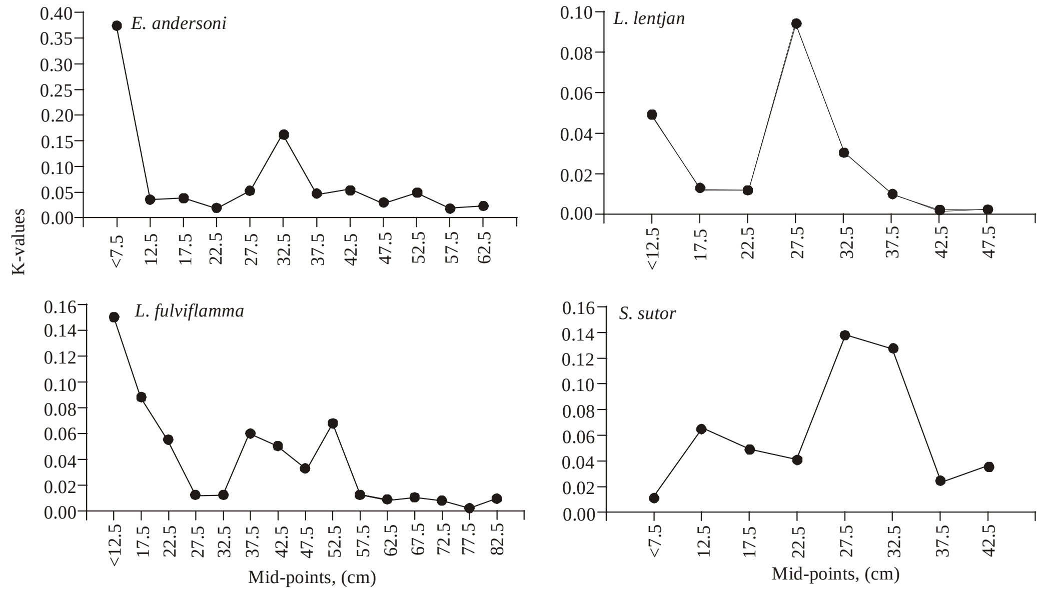

Fig. 4: Condition factor (Fulton's K) values for the four selected species

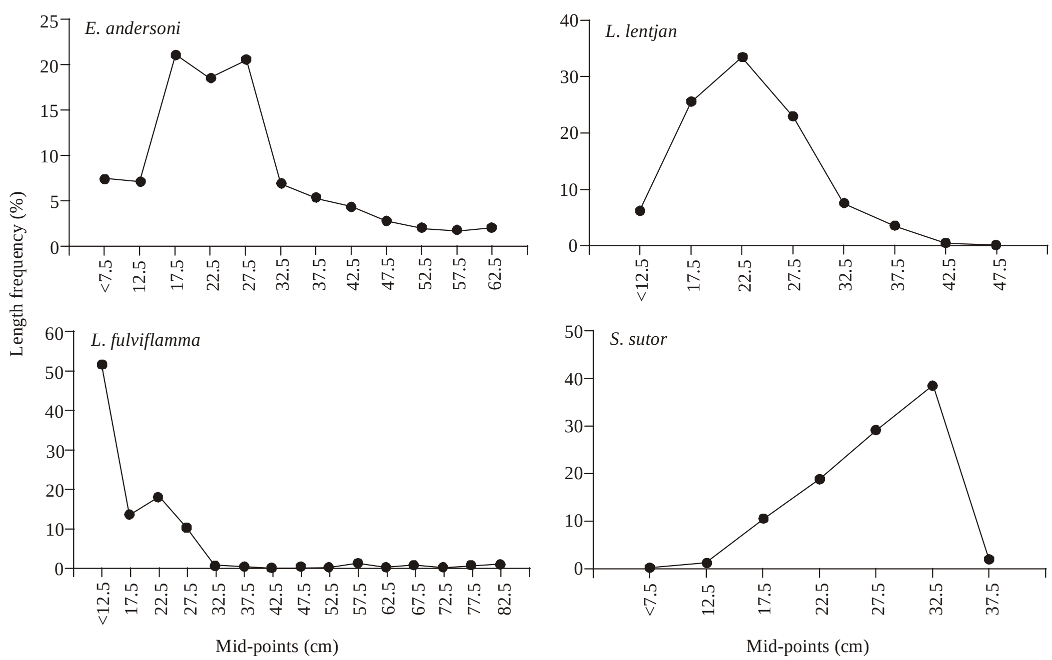

Fig. 5: Percentage length frequency for the four selected species

below 5 cm (*S. sutor* and *E. andersoni*) although these were fitted in the category of <7.5 cm (mid-point), size class (5-9 cm). Results indicated lengths of majority of stocks 15 to 30 cm (Fig. 5).

Length-weight relationship and Fulton's K, condition factor: Size classes analyzed had b values ranging from 2.38 (25-29 cm) to 3.99 (70-74 cm) (*L. fulviflamma*) with most of the regressions highly significant (Table 1-4). The coefficient of determination (r^2) went up to 0.99 (*L. fulviflamma*, $p<0.05$). Box-whiskers plots of the exponent b of the Length - Weight Relationship indicated percentiles of 70.0% of the b values (3.08-3.75) for *L. lentijan*, 18.7% (3.2-3.92) for *L. fulviflamma*, 49.7% (3.1-3.57) for *E. andersoni and* 70.8% (3.27-3.62) for *S. sutor* (Fig. 6). The overall values of condition factor K

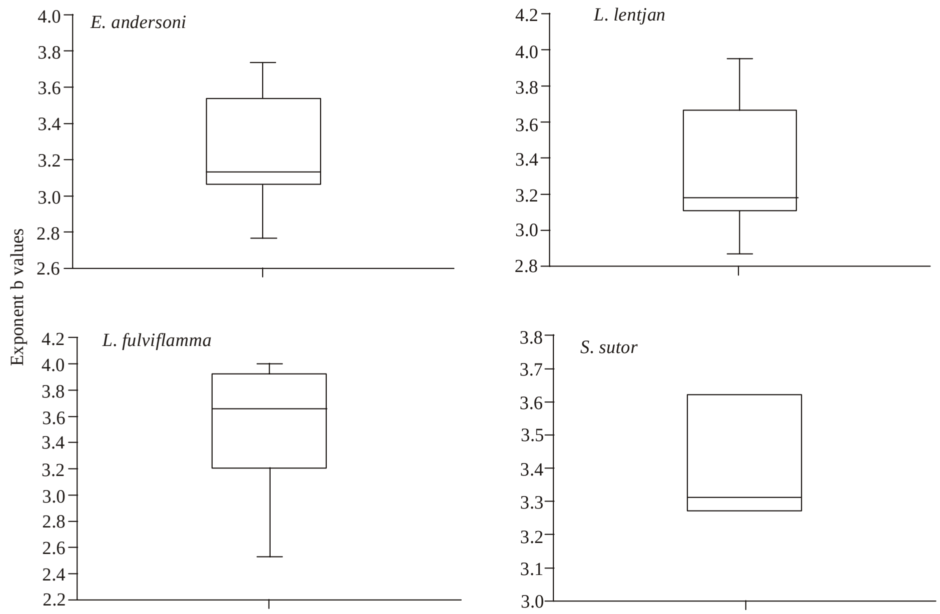

Fig. 6: Box-whiskers plots of the exponent b of the Length - Weight Relationship

Table 1: *Lethrinus lentjan* (TL/TW relationship)

Size classes	*n*	*a*	*b*	r^2
<14	1527	-8.53	3.51**	0.92
15-19	6396	-4.07	3.18**	0.90
20-24	8406	-1.54	3.08*	0.90
25-29	5760	-1.22	3.95**	0.91
30-34	1872	-4.16	2.87**	0.93
35-39	894	-2.29	3.13**	0.90
40-44	150	-22.01	3.75**	0.97
45-49	36	-34.06	3.58**	0.93
>45	432	-12.24	3.18**	0.96

Table 2: *Lutjanus fulviflamma* (TL/TW relationship)

Size classes	*n*	*a*	*b*	r^2
<14	7688	-15.68	3.99**	0.95
15-19	2028	-10.47	3.87**	0.91
20-24	2672	-4.69	3.09*	0.90
25-29	1516	-3.59	2.63**	0.91
30-34	88	-13.26	3.60**	0.92
35-39	64	-92.76	2.37**	0.98
40-44	16	-25.45	3.60**	0.93
45-49	56	-1.21	3.93**	0.90
50-54	36	-189.70	3.65**	0.94
55-59	192	-79.30	3.83**	0.99
60-64	48	-71.77	3.92**	0.91
65-69	120	-139.90	3.20**	0.94
70-74	64	-90.83	3.99**	0.94
75-79	132	-62.05	3.32**	0.93
80-84	176	-26.08	3.74**	0.95

of the various species were listed (Fig. 4). *L. fluviflamma* and *L. lentjan* exhibited reduced K values at higher size (length) classes while *E. andersoni* and *S. sutor* portrayed mixed trends (Fig. 4). Box-whiskers plots of the exponent b of the length-weight relationship for different size classes were presented (Fig. 6).

Table 3: *Epinephelus andersoni* (TL/TW relationship)

Size classes	*n*	*a*	*b*	r^2
<9	1421	-5.76	3.60**	0.93
10-14	1372	-34.73	3.13**	0.90
15-19	4018	-7.14	3.11**	0.91
20-24	3528	-0.05	3.048	0.91
25-29	3920	-13.89	2.72**	0.93
30-34	1323	-0.74	3.57**	0.90
35-39	1029	-3.37	3.43**	0.90
40-44	833	-47.27	3.13**	0.93
45-49	539	-22.80	3.26**	0.94
50-54	392	-65.43	3.79**	0.97
55-59	343	-16.17	2.86**	0.91
60-64	392	-38.84	3.10*	0.98

Table 4: *Siganus sutor* (TL/TW relationship)

Size classes	*n*	*a*	*b*	r^2
<9	22	-4.27	3.12**	0.99
10-14	132	-18.20	3.27**	0.98
15-19	1136	-21.69	3.62**	0.94
20-24	2058	-10.49	3.59**	0.90
25-29	3172	-3.35	3.68**	0.90
30-34	4186	-5.50	3.29**	0.91
35-39	230	-1.56	3.31**	0.92

*: b significantly different from 3 ($p = 0.01$); **: b significantly different from 3 ($p = 0.05$)

DISCUSSION

The linkage between the abundance, length-weight relationship, fish condition and fish stock management underlines the importance to improve the knowledge about the complex of variation in these factors as a reaction to environmental and biological effects as well as implications for growth and reproductive success. For instance, the factor of condition (K) in fish reflects, through its variations, information on the physiological state of the fish in relation to its welfare (Lambert and Dutil, 1997a). Results show these species in poor physiological state at 22.5 and 57.5 cm for *E. andersoni*, 7.5 and 42.5 cm for *L. lentjan*, 27.5 and 77.5 cm for *L. fulviflamma,* 7.5 and 37.5 cm for *S. sutor* (Fig. 4). From a nutritional point of view, increase in K values (Fig. 4) indicates the accumulation of fat and sometimes gonadal development (Maguire and Mace, 1993). From a reproductive point of view, the highest K values (0.38- *E. andersoni*, 0.09- *L. lentjan*, 0.15- *L. fulviflamma* and 0.14- *S. sutor*, Fig. 4) are reached in species if the fish is fully mature and having higher reproductive potentiality (Angelescu *et al*., 1958). Other research done by Ratz *et al*. (1999) in body condition, gonadal maturation, growth and recruitment showed a relationship between length and K as described by Fig. 4 and 5 with other key biological reference points e.g., growth, weight at age, spawning biomass, reproductive potential, fecundity and recruitment. Figueiredo-Garuti and Garuti (1991) observed that some species may exhibit two to three reproductive periods: this might explain the mixed trend in terms of condition among the 4 species hence their dominance (Fig. 4). They also stated that the lowest K value occurs in the beginning of the reproductive period and the highest at its end. In this case both *E. andersoni* and *L. lentjan* are believed to exhibit two reproductive peak regimes while *L. fulviflamma* and *S. sutor* exhibit three (Fig. 4). K also gives information when comparing two populations living in certain feeding, density, climate, and other conditions; when determining the period of gonadal maturation; and when following up the degree of feeding activity of a species to verify whether it is making good use of its feeding source (Weatherley, 1972). Fishes with a low condition index (*L. lentjan*) are presumably believed to have experienced adverse physical environment or insufficient nutrition (Grecay and Targett 1996; Perry *et al*., 1996). Condition indices of fish stocks are also known to follow their length variations (Lambert and Dutil 1997a, b; Marshall *et al*., 1999; Lloret and Ratz 2000; Yaragina and Marshall, 2000), where higher K values of (0.38, 0.09, 0.15 and 0.14) were observed (Fig. 4) for *E. andersoni*, *L. lentjan*, *L. fulviflamma* and *S. sutor* at approximated length of 10, 30, 15 and 30 cm, respectively.

Perspectives of variations in condition factor: We have shown in this paper (Fig. 4) that the 4 species display different levels of condition as derived from the catch data, which are partly associated with the length frequencies, temporal and spatial distribution. Similar to what was observed in Fig. 4, spatial heterogeneity of the fish condition has been also found in other fish species, e.g., pink salmon (Perry *et al*., 1996) and weak fish (Grecay and Targett, 1996). However these variations were not consistent with spatial differences in food availability and environmental conditions experienced since the estimated parameters (Fig. 4) were considered composites across the whole year rather than representing a particular season because data was collected throughout the year. Authors assert that differences in fish condition could also be attributed to water temperature and food supply, individuals being in better condition at relatively warm and eutrophic locations where optimal physiological and feeding conditions prevail (Love, 1974; Kjesbu *et al*., 1992; Marshall *et al*., 1999; Lambert and Dutil, 1999). That might explain in part why condition of the stocks is relatively better among the large sized fish of *E. andersoni* and *S. sutor*, although we do not exclude other environmental effects such as differences in the physical nature of the ground where the fish were caught as they exhibit major variations from the bathymetric surveys previously done (Love, 1958; Wilkins, 1967; Krivobok and Tokareva, 1972; Dutil and Lambert, 2000). Among the 4 species, condition value increases with increase in length (growth) and oscillates around 0.15. Similar oscillations were observed around 0.05, which may signify the trends of their reproductive periods as well. However, for *E. andersoni,* the highest K value occurred midway as presented above (Fig. 4), possibly explaining why only a few individuals were captured during the survey. Results may be confirmed from other research indicating that the serranidae family is comprised of relatively large species e.g., the *E. andersoni* (Rodrigues *et al*., 1995). Results (Fig. 4) are not so clear on this point when compared with those of Rodrigues *et al.* (1995), which may be explained if one considers that the population in this species is essentially composed fish stocks which are not migratory. The results also show that individuals have varied values of K in all length classes during the survey period, suggesting continuous recruitment in the area under survey analysis. In the case of the condition factor per length class (Fig. 4), the present authors affirm that, as a general rule, most of the highest values of the condition factor occur in the lowest lengths, or rather, in the juvenile classes as increase in length is considered as growth. Vazzoler and De (1996) confirmed that lowest K-values during the more developed gonadal stages may mean resource transfer to the gonads during the reproductive period. We observed significant variations of the length-weight relationships parameters, particularly *a*, between size (length) class, unlike the parameter *b*, which did not vary significantly throughout size (length) classes (Table 1-4). This was in agreement to other research done by Bagenal and Tesch (1978), who in his similar findings observed that parameters of length-weight relationships, particularly *a*, may vary daily, seasonally, and/or between size (length) class, unlike the parameter *b*, which does not vary significantly throughout size (length) classes. As suggested by Petrakis and Stergiou (1995) the use of these length-weight relationships (Table 1-4) should be strictly limited to the observed length ranges used in the estimation of the linear regression.

CONCLUSION

The highest CPUE value among the species was observed for *L. fulviflamma* from Malindi landing station located in the northern part of the Kenyan coast while Msambweni located south of the Kenyan coast had the lowest CPUE value almost half of what was observed in Malindi. This clearly identifies the North Kenya Bank as providing catches per unit effort two or three times higher than the rest of the coast. Majority of the fish landed measured between 10-35 cm (total length) with a decrease in condition and welfare of the fish beyond the 50 cm length among the 4 species. We observed parameters of length - weight relationships, particularly *a*, significantly varied between size (length) class, unlike the parameter *b*, which did not vary significantly throughout size (length) classes. We are also aware that the quality of the calculated Fulton's condition factor K and the coefficients (a), (r^2) and (b) differ between the species considered due to the variations in the length classes and numbers of measurements available. Therefore, the present study should be updated and extended as the data improve with time and more stocks become available.

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