



Ecologia

ISSN 1996-4021



Academic
Journals Inc.

www.academicjournals.com

Population Structure, Condition and Length-Weight Relationships of Ten Vulnerable *Epinephelus* Genus Groupers off Kenyan South Coast Indian Ocean Marine Waters

^{1,3}B.O. Ogongo, ²E.C. Mwachiro and ³B.M. Fulanda

¹Department of Natural Products and Post-Harvest Technology, Coastal and Marine Fisheries Programme, Kenya Marine and Fisheries Research Institute, P.O. Box 81651-80100, Mombasa, Kenya

²Department of Environmental Studies, School of Pure and Applied Sciences, Pwani University, P.O. Box 195-80108, Kilifi, Kenya

³Department of Biological Sciences, School of Pure and Applied Sciences, Pwani University, P.O. Box 195-80108, Kilifi, Kenya

*Corresponding Author: B.O. Ogongo, Department of Natural Products and Post-Harvest Technology, Coastal and Marine Fisheries Programme, Kenya Marine and Fisheries Research Institute, P.O. Box 81651-80100, Mombasa, Kenya
Tel: +254733852287/+254208021560/1 Fax: +254202353226*

ABSTRACT

Groupers are apex predatory fishes playing important local economic roles and ecosystem functions worldwide. The Kenyan coast Indian Ocean waters have been a good landing centre for 30 *Epinephelus* genus species groupers. However, of late, their natural populations have greatly decreased with most being caught when still either juveniles or sub adults. Their individuals mean length and weights also showing drastic reductions. Thus, to avert this alarming population decline, length and weight reductions, information data is needed for use in the initiation of conservation measures for these prized premium fishes. This study therefore elucidates the population structure, conditions and length-weight relationships of 10 highly sought vulnerable *Epinephelus* genus grouper fishes off Kenyan inshore marine waters. The study results indicate declining population abundances, varying significant conditions ($p < 0.001$) and negative allometric Length-Weight Relationship (LWR) growth regression coefficients (r^2) appearing stronger ($r^2 > 0.7048$) for 9 of the species. Analysis of covariance (ANCOVA) between the regression line intercept (a) and slopes (b) among the species however revealed equal regression line slopes ($p > 0.05$) demonstrating that all came from populations with equal slopes. The consistent non isometric patterns shown by the r^2 analyses in the plotted power curved data also suggests that unless stringent management measures are implemented to restrict further over-exploitation of these International Union for Conservation of Nature (IUCN) vulnerable listed fishes; it is likely that the species already categorized as 'Near Threatened' in the IUCN red list would soon become 'Endangered' while those 'Endangered' extinct. This can greatly result into the alteration of the ecosystems' ecological health as the fishes constitute important apex predators in the demersal food web and their stock depletions would be disastrous to the ecosystems.

Key words: Threatened, predatory *Epinephelus* groupers, IUCN red list fishes, conservation, Kenyan Indian Ocean waters

INTRODUCTION

Marine biodiversity loss threats are increasing worldwide due to overfishing, climate change and habitat destructions. This vulnerability threat has been more apparent to fishes because of the

changing fishing patterns; excessive unwanted by-catch fishing's, illegal fishing's, excessive fishing of the fishes before attainment of first maturity lengths; use of harmful fishing techniques both to the environment and fish stocks among other factors. As a result, conservation of vulnerable and threatened fishes has thus gained great global ecological importance over recent years. However, effective implementation of sound conservation management strategies requires that the fish's life-history characteristic knowledge is well known (Agembe *et al.*, 2010; Hossain *et al.*, 2009a; Ogongo *et al.*, 2015).

The Kenyan Indian Ocean marine waters used to be home for slightly over 30 *Epinephelus* genus grouper species fishes apposite for human utilization in sufficient populations (Anam and Mostarda, 2012; Heemstra and Randall, 1993; Ogongo *et al.*, 2015). These Epinephelidae subfamily fishes within the Serranidae family (Heemstra and Randall, 1993) which are most widely distributed in Hawaii waters, Indo-West Pacific, Red Sea, Philippines, Southern Japan and in Eastern Africa are long lived, slow growers with lower fecundities. In addition, they also form spawning aggregations which are heavily exploited by both small and large-scale fishers (Hossain *et al.*, 2009b; Kaunda-Arara *et al.*, 2003; McClanahan and Graham, 2005; Sani *et al.*, 2010).

These grouper fishes in general constitute important components of the demersal fishery resources that are main targets of commercial fishers in both tropical and sub-tropical waters worldwide. As a result, the fishes are important components of the inshore small-scale fisheries along the Eastern coast of Africa where they are locally known as "Tewa" or Rock cods. However, a recent (UNEP and WIOMSA., 2015) United Nations Environmental Programme (UNEP)-Nairobi Convention in conjunction with the Western Indian Ocean Marine Science Association (WIOMSA), reported that an estimated 1,900 bony fish species including some *Epinephelus* genus groupers are threatened within the region (Esseen and Richmond, 2011). Despite this threatened status, they are still target species of the rural fisher folks within the Western Indian Ocean (WIO) region for income, fish protein and micronutrients. This, in addition to various ecological and environmental degradation changes of the natural habitats within the region, has resulted in serious population declines with some almost being driven to the verge of extinction (Esseen and Richmond, 2011).

The current global rate of grouper exploitation and mortality is also arguably the highest under current management regimes that unless a renewed initiative is undertaken, some species will become effectively extinct (Hossain *et al.*, 2009a) and create shifts in the biological communities with resultant systemic biodiversity losses (Jennings and Kaiser, 1998). Thus, given the vulnerability of the fishes even to modest fishing efforts due to their slow growth rates, late maturity, low fecundity and long life spans; potential recovery of their populations to overharvesting can take decades and human decisions regarding them is a crucial element of marine-related social science (Myers *et al.*, 2007).

A fish's Length-Weight Relationship (LWR) is an important fishery management tool in fisheries biology and stock assessments in all water bodies as it enables the determination of fish age, structure and health by providing various facts about its seasonal cycles and influential aspects of the biotic and abiotic factors (Ayoade and Ikulala, 2007). This is because an average fish weight of a given length group can easily be estimated by establishing a mathematical relation between length and weight parameters (Beyer, 1987). They also show an indication of the fish's gonad development and are useful for regional comparisons and specific species histories (Sarkar *et al.*, 2013). In addition, the data also provide important clues on climate, environmental

and human subsistence changes (Bolarinwa and Popoola, 2013; Sarkar *et al.*, 2013) that help in predicting the best suited time and length for harvesting of particular fish species (Muchlisin *et al.*, 2010; Sarkar *et al.*, 2009).

Therefore, since no information currently exist on the *Epinephelus* genus groupers' population structure, condition and length-weight relationships off the entire Kenyan Indian Ocean Marine Waters, the study presents the first study on population structure, condition and length-weight relationships of these vulnerable fish species in Kenya using a one year collected morphometric length and weight data.

MATERIALS AND METHODS

The study was conducted within the inshore small-scale marine fishing areas of Msambweni (04°30'31.26" S, 039°28'12.97" E) lying about 70 km South of Kenyan Mombasa city, Shimoni (04°38'52.67" S, 039°22'50.55" E) of which part of its traditional fishing grounds has been hived off and gazetted as a marine protected area under the Kisite-Mpunguti Marine National Park and Reserve and Vanga (04°40'16.11" S, 039°13'36.96" E) which its fishing grounds and village is situated on the Southern tip of Kenya-Tanzanian border in the Kenyan South coast (Fig. 1). The study sites were selected based on the existence of previous grouper studies undertaken from there; their high grouper fishers and fisheries activity coefficient within south coast of Kenyan and lastly, for being the most pristine and sheltered reefs on the Kenyan coast making them key grouper fishing areas.

Field sampling and laboratory work was conducted from December, 2013 to November, 2014. The *Epinephelus* genus grouper specimens were purchased from the small-scale artisanal fishery catches landed at the sites. Purchased freshly landed catches were immediately chilled in ice on site and transported to Kenya Marine and Fisheries Research Institute (KMFRI) Mombasa Laboratory for analyses. At the laboratory, the specimens were sorted and identified to species level

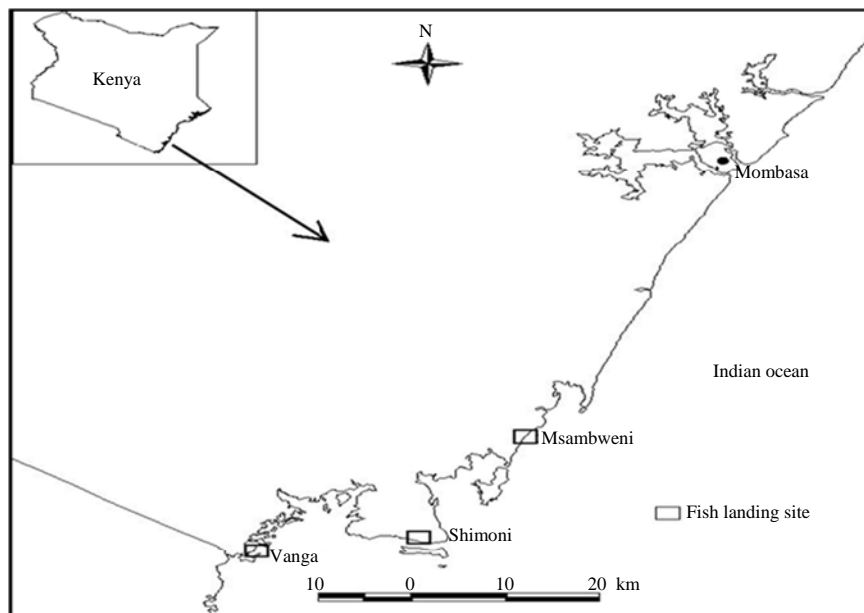


Fig. 1: Study landing sites map of Vanga, Shimoni and Msambweni

using keys and guides from Anam and Mostarda (2012) and Heemstra and Randall (1993). The already identified specimens total length and weights were then individually measured and recorded. Total Length (TL) was measured to the nearest 0.01 cm using digital slide calipers (Mitutoyo, CD-15PS) and total body Weight (W) was measured using an electronic balance (Shimadzu, EB-430 DW) with 0.01 g accuracy. All morphometric measurements were conducted according to Froese and Pauly (2011).

Length and sex-ratio distributions were also constructed separately for the species and only those with more than one individual landing were used for sex-ratio determinations. Each species lengths were categorized from the smallest to the largest to determine the existing ranges. The isometric ($b = 3$) or allometric growth relationship between Total Length (TL, cm) and total body Weight (W, g) was described for these fishes growing with their bodies becoming heavier using a plotted power function; $W = a \times TL^b$ in which a is the power function coefficient (the regression intercept) and b the exponent (the regression slope). The relationships were estimated by linear regression analyses based on natural logarithms:

$$\ln(W) = \ln(a) + b \ln(TL)$$

Prior to the analyses, ln-ln plots of length and weight values were performed for visual inspection of outliers in accordance to Froese (2006). Growths' were considered positively allometric if the estimate of b was approximately equal or greater than 3 and negative if less than 3. Fulton's condition factor (KF) (Cone, 1989) was calculated using the equation:

$$KF = 100 \times (W \times L^{-3})$$

Where:

W = Total body weight (W, g)

L = Total length (TL, cm)

The scaling factor of 100 was used to bring the KF close to unit.

The non parametric Chi-square goodness-of-fit test was used to test for significant deviations from the expected 1:1 male to female ratio and also to compare the species numbers within the study sites using MINITAB release 14 software. In addition, the plotted LWRs were power tested using the coefficient of determination (r^2) to determine significant differences from the isometric value of $b = 3$ using Microsoft® Excel-add-in-Daniel's XL Toolbox spreadsheet computer package. The a and b parameters of the species LWRs were also compared by covariance (ANCOVA) analysis to determine if all had equal regression line slopes and statistical significance tests determined at $\alpha = 0.05$.

RESULTS

The ten studied *Epinephelus* genus groupers lengths, weights and sexes were as tabulated in Table 1. Similarly, their population abundances were significantly ($p < 0.05$) generally lower with skewed distribution patterns within the study sites (Table 2). As a result, some species were not landed in certain sites and where landed, were less than 5 individuals. The observed minimum total length among the 268 sampled specimens ranged from 10-43.9 cm with majority being

Table 1: Landed genus species numbers, lengths, weights and sex data sampled at the study sites during the entire period of study

Landed species	Number	Length (cm)				Weight (g)		Sex	
		TL		SL		Min	Max	Female	Male
		Min	Max	Min	Max				
Msambweni data sheet									
<i>Epinephelus chlorostigma</i>	3	14.0	17.6	12.1	14.9	265	295	2	1
<i>Epinephelus coeruleopunctatus</i>	5	14.0	36.5	9.0	29.6	260	682	4	1
<i>Epinephelus fasciatus</i>	10	18.5	20.8	14.2	16.3	302	395	8	2
<i>Epinephelus longispinis</i>	6	10.0	12.4	7.9	10.1	199	262	4	2
<i>Epinephelus malabaricus</i>	4	35.8	70.6	29.5	65.0	480	985	3	1
<i>Epinephelus merra</i>	1	-	36.6	-	31.2	-	612	1	0
<i>Epinephelus multinotatus</i>	5	18.0	29.0	14.9	24.6	386	760	3	2
<i>Epinephelus tauvina</i>	4	22.5	25.2	16.9	20.4	299	304	3	1
Total	38	-	-	-	-	-	-	28	10
Shimoni data sheet									
<i>Epinephelus areolatus</i>	20	11.5	28.1	9.4	23.2	240	369	16	4
<i>Epinephelus chlorostigma</i>	10	14.0	17.6	12.1	14.9	265	295	8	2
<i>Epinephelus coeruleopunctatus</i>	18	15.9	36.5	12.7	29.6	285	682	14	4
<i>Epinephelus coioides</i>	12	18.0	22.8	15.0	18.2	298	502	8	4
<i>Epinephelus fasciatus</i>	26	12.8	22.4	10.2	18.4	288	489	16	10
<i>Epinephelus longispinis</i>	13	10.0	18.4	8.0	10.1	199	362	10	3
<i>Epinephelus malabaricus</i>	20	20.0	43.9	16.9	35.4	325	1110	16	4
<i>Epinephelus merra</i>	10	13.0	18.3	10.9	15.1	200	398	6	4
<i>Epinephelus multinotatus</i>	17	17.4	22.9	13.9	16.9	445	508	15	2
<i>Epinephelus tauvina</i>	10	12.0	17.5	9.9	14.5	235	299	8	2
Total	156	-	-	-	-	-	-	117	39
Vanga data sheet									
<i>Epinephelus areolatus</i>	6	17.5	41.4	14.5	34.1	412	996	4	2
<i>Epinephelus chlorostigma</i>	8	14.0	17.6	12.1	14.9	265	295	6	2
<i>Epinephelus coeruleopunctatus</i>	8	26.8	30.2	23.6	27.4	308	525	6	2
<i>Epinephelus coioides</i>	3	20.1	24.6	17.9	21.4	306	598	3	0
<i>Epinephelus fasciatus</i>	18	15.6	18.0	13.1	15.0	318	405	16	2
<i>Epinephelus longispinis</i>	9	10.0	18.4	8.0	10.1	199	362	8	1
<i>Epinephelus malabaricus</i>	12	30.0	43.9	27.9	35.4	600	1150	10	2
<i>Epinephelus merra</i>	6	13.0	36.6	10.0	31.2	200	612	4	2
<i>Epinephelus multinotatus</i>	2	18.0	21.0	14.9	17.0	386	458	2	0
<i>Epinephelus tauvina</i>	2	24.8	26.5	20.9	22.8	301	430	1	1
Total	74	-	-	-	-	-	-	61	13

Min: Minimum, Max: Maximum, F: Female, M: Male, TL: Total length

slightly above 22 cm. Their minimum and maximum length size ranges were; *E. areolatus* (11.5-41.4 cm), *E. coeruleopunctatus* (14-36.5 cm), *E. chlorostigma* (14-17.6 cm), *E. coioides* (18-24.5 cm), *E. fasciatus* (12.8-22.4 cm), *E. longispinis* (10-18.4 cm), *E. malabaricus* (20-70.6 cm), *E. merra* (13-36.5 cm), *E. multinotatus* (17.4-29 cm) and *E. tauvina* (12-26.5 cm). They also exhibited varied modal size classes as contained herein (*E. areolatus* (39.7 cm), *E. coeruleopunctatus* (30.2 cm), *E. chlorostigma* (14 and 15.8 cm), *E. coioides* (24 cm), *E. fasciatus* (13.5 and 14 cm), *E. longispinis* (13.9 cm), *E. malabaricus* (45 cm), *E. merra* (31 cm), *E. multinotatus* (21 cm) and *E. tauvina* (25 cm)). However, due to lack of the Kenyan genus primary maturity study data, secondary maturity data obtained from published literature was used to determine if the landings comprised of immature fishes as the present study's data could not allow for estimation of first maturity sizes.

The plotted and power tested length and weight growth data for the ten species using their regression coefficients (r^2) to determine if the relationships were isometric ($b = 3$) or allometric ($b < \text{or} > 3$), revealed that all had negative allometric growth relationships where $b < 3$ (Table 3). The

Table 2: Landed species abundance and distribution patterns at Msambweni, Shimoni and Vanga during the study period

Species	Msambweni	Shimoni	Vanga	p-values	Overall p-value
<i>E. areolatus</i>	0	20	6		
χ^2 contributions	0.11958	2.26162	4.08242	3.69504E-31	
<i>E. chlorostigma</i>	3	10	8		
χ^2 contributions	4.02342	2.66868	0.15773	7.96535E-90	
<i>E. coeruleopunctatus</i>	5	18	8		
χ^2 contributions	1.69075	0.47947	1.56432	6.6215E-147	
<i>E. coioides</i>	0	12	3		
χ^2 contributions	7.872	3.06129	4.16177	3.56935E-08	
<i>E. fasciatus</i>	10	26	18		
χ^2 contributions	4.73296	0.71675	3.1773	1.1111E-210	
<i>E. longispinis</i>	6	13	9		
χ^2 contributions	0.67573	0.47225	0.33291	5.3398E-131	
<i>E. malabaricus</i>	4	20	12		
χ^2 contributions	0.93769	3.21312	4.00225	2.05817E-25	
<i>E. merra</i>	1	10	6		
χ^2 contributions	0.35542	1.65042	4.5049	2.92334E-10	
<i>E. multinotatus</i>	5	17	2		
χ^2 contributions	0.85122	2.01875	2.20119	2.90675E-29	
<i>E. tauvina</i>	4	10	2		
χ^2 contributions	0.79718	4.0899	8.41446	1.9473E-06	
Pooled species total	38	156	74		
χ^2 contributions	3.44492	2.52536	0.588124	0.000	p < 0.001

N: No. landed, p-value: probability of significance at $\alpha = 0.05$

Table 3: General length-weight relationship and condition estimates for the landed genus species

Species	N	Weight-Length equation	r ²	Relationship	Fulton's condition factor (KF)
<i>E. areolatus</i>	26	$W = (2.93 \times 10^1) L^{0.8918}$	0.8521	Negative allometric	1.4036
<i>E. chlorostigma</i>	21	$W = (8.22 \times 10^1) L^{0.4428}$	0.9388	Negative allometric	5.4111
<i>E. coeruleopunctatus</i>	31	$W = (1.56 \times 10^1) L^{1.0453}$	0.9845	Negative allometric	1.4025
<i>E. coioides</i>	15	$W = (0.02 \times 10^1) L^{2.4721}$	0.7574	Negative allometric	4.0663
<i>E. fasciatus</i>	54	$W = (4.62 \times 10^1) L^{0.696}$	0.7048	Negative allometric	4.3508
<i>E. longispinis</i>	28	$W = (2.40 \times 10^1) L^{0.961}$	0.8426	Negative allometric	5.8111
<i>E. malabaricus</i>	36	$W = (0.93 \times 10^1) L^{1.1826}$	0.8910	Negative allometric	0.3268
<i>E. merra</i>	17	$W = (1.74 \times 10^1) L^{0.0103}$	0.9439	Negative allometric	1.2586
<i>E. multinotatus</i>	24	$W = (1.09 \times 10^1) L^{1.2377}$	0.8299	Negative allometric	3.1162
<i>E. tauvina</i>	16	$W = (1.08 \times 10^2) L^{0.3352}$	0.4947	Negative allometric	2.3106

N: No. of the landed individual species from the Kenyan South coast commercial fishery, r²: Regression coefficient of determination

species calculated Fulton's condition (KF) factor values also showed significant variations (p<0.01) with the best and worst performers being *E. longispinis* (5.8111) and *E. malabaricus* (0.3268), respectively (Table 3).

DISCUSSION

The Kenyan IUCN red list threatened fishes biometric information has been quite insufficient despite a number of studies having been conducted within the Asian countries (Hossain *et al.*, 2012; Gupta *et al.*, 2011; Muchlisin *et al.*, 2010; Naeem *et al.*, 2010, 2011; Patiyal *et al.*, 2010; Sani *et al.*, 2010; Sarkar *et al.*, 2009; Yousaf *et al.*, 2009). In this study, the 10 species size structures demonstrated some marked length size class range differences (Table 1). The differences may be particularly attributed to environmental water temperature and food availability variations (Hossain and Ohtomi, 2010) signalling the need for urgent extensive studies on the entire genus fishes to provide more management and conservation information.

The species catch abundance declines are greatly suspected to have resulted from increases in fishing effects and effort due to increased demand for food. Groupers are of great economic

importance in tropical and temperate fisheries (Marino *et al.*, 2001). However, biological characteristics such as slow growth, late age of maturity, protogynous hermaphroditism and aggregating behaviour make them vulnerable to overfishing. Therefore, as a result of this unique life history pattern, conventional management methods are unsuitable to protect the species. Results emerging from the present study suggest that the grouper catch in the Western Indian Ocean showed a decreasing trend with some species having become rare in the fishery as exhibited by lower catches. It could have been also a reflection of different species settlement histories as evidenced by their modal size class structure differences that were mostly below the reported first maturity sizes for most groupers (Mangi, 2006; McClanahan *et al.*, 2008). Conversely, the observed species dominance and distribution may have been also due to their ability differences to deal with extreme physical site conditions. This was evidenced by their respective significant distributions among the species (χ^2 contribution = 6.55840, 9 df, p-value < 0.001) (Table 2).

Nearly all fish species LWR is expressed by the equation: $W = a \times L^b$ and the change in weight can be described by the relationship. Thus, in cases where the relationship regression slope $b < 3$ or $b > 3$, growth is said to be allometric and the fish becomes less rotund when $b < 3$ or more rotund when $b > 3$ with increasing length. However, when $b = 3$, growth is said to be isometric and the fish grows with unchanged specific gravity and body proportions. It is however also possible for shape to change when $b = 3$ as a result of changes in the regression intercept “a” (Anderson and Gutreuter, 1989; Cone, 1989) making the estimated LWR parameters also to differ among seasons and years due to physicochemical characteristics of the environment, sex and maturity stages of a given fish species. This isometric relationship departure may however be minor for some early life history aspects but may become more important in the calculation of metabolic processes as was stated by Cone (1989) and Laurence (1979). As a result, fish condition studies assume that heavier fishes are often of better conditions and condition indices have been frequently used by fish culturists as indicators of the general population ‘well-being or fitness’.

This study’s results therefore provide the much needed information required for future comparisons and urgent detection of any long-term declines in the conditions that may have occurred as a result of environmental degradation, key physiological components of the fish’s life history and growth.

CONCLUSION

This study provides important baseline information for the Kenyan *Epinephelus* genus groupers LWR and conditions needed by fishery biologists, managers and conservationists’ for initiating early management strategies and future studies for the remaining stocks of these endangered fishes within Kenyan Marine ecosystems. Moreover, the LWR and condition information for these genus species in Kenya are clearly lacking from literature and data bases including those of FishBase. The results therefore, provide invaluable information for the online FishBase database.

ACKNOWLEDGMENTS

We express our gratitude to World Bank sponsored Kenya Coastal Development Project (KCDP) for funding the study through Kenya Marine and Fisheries Research Institute (KMFRI) Programmes, KMFRI Director for providing personnel and Institute facilities for the study’s undertaking, fellow workmates (Boaz Orembo, Joseph Kilonzo, Chanzera Kombe and Sammy Kadhengi) for assisting with species identification, sampling and analysis; Beach Management Unit (BMU) officials, fishery managers and local artisanal fishermen in Msambweni, Shimoni and Vanga for their excellent logistical work, connections and assistance during data collection. Thanks to all.

REFERENCES

- Agembe, S., C.M. Mlewa and B. Kaunda-Arara, 2010. Catch composition, abundance and length-weight relationships of groupers (Pisces: *Serranidae*) from inshore waters of Kenya. *Western Indian Ocean J. Marine Sci.*, 9: 91-102.
- Anam, R. and E. Mostarda, 2012. Field identification guide to the living marine resources of Kenya. *FAO Species Identification Guide for Fishery Purposes*, FAO, Rome.
- Anderson, R.O. and S.J. Gutreuter, 1989. Length Weight and Associated Structural Indices. In: *Fisheries Techniques*, Nielsen, L.A. and D.L. Johnson (Eds.). American Fisheries Society, Maryland, USA., pp: 283-300.
- Ayoade, A.A. and A.O.O. Ikulala, 2007. Length weight relationship, condition factor and stomach contents of *Hemichromis bimaculatus*, *Sarotherodon melanotheron* and *Chromidotilapia guentheri* (Perciformes: Cichlidae) in Eleiyele Lake, Southwestern Nigeria. *Rev. Biol. Trop.*, 55: 969-977.
- Beyer, J.E., 1987. On length-weight relationships: Part I: Computing the mean weight of the fish in a given length class. *ICLARM Fishbyte*, 5: 11-13.
- Bolarinwa, J.B. and Q. Popoola, 2013. Length-weight relationships of some economic fishes of Ibeshe Waterside, Lagos Lagoon, Nigeria. *J. Aquac Res. Dev.*, Vol. 5.
- Cone, R.S., 1989. The need to reconsider the use of condition indices in fishery science. *Trans. Am. Fish.*, 118: 510-514.
- Esseen, M. and M.D. Richmond, 2011. Superclass Pisces-Fish. In: *A Field Guide to the Seashores of Eastern Africa and the Western Indian Ocean Islands*, Richmond, M.D. (Ed.). 3rd Edn., WIOMSA, Sida, pp: 340-379.
- Froese, R., 2006. Cube law, condition factor and weight-length relationships: History, meta-analysis and recommendations. *J. Applied Ichthyol.*, 22: 241-253.
- Froese, R. and D. Pauly, 2011. *FishBase 2011*. World Wide Web Electronic Publication. <http://www.fishbase.org>.
- Gupta, B.K., U.K. Sarkar, S.K. Bhardwaj and A. Pal, 2011. Condition factor, length-weight and length-length relationships of an endangered fish *Ompok pabda* (Hamilton 1822) (Siluriformes: Siluridae) from the River Gomti, a tributary of the River Ganga, India. *J. Applied Ichthyol.*, 27: 962-964.
- Heemstra, P.C. and J.E. Randall, 1993. Vol. 16 groupers of the world (family Serranidae, Subfamily Epinephelinae). An annotated and illustrated catalogue of the groupers, rock cod, hind, coral grouper and lyre tail species known to date. *FAO Fisheries Synopsis No. 125*, Vol. 16, FAO, Rome, pp: 382.
- Hossain, M.Y., J. Ohtomi and Z.F. Ahmed, 2009a. Morphometric, meristic characteristics and conservation of the threatened fish, *Puntius sarana* (Hamilton, 1822) (Cyprinidae) in the Ganges River, northwestern Bangladesh. *Turk. J. Fish. Aquat. Sci.*, 9: 223-225.
- Hossain, M.Y., M.M. Rahman and M.F.A. Mollah, 2009b. Threatened fishes of the world: *Pangasius pangasius* Hamilton-buchanan, 1822 (Pangasiidae). *Environ. Biol. Fishes*, 84: 315-316.
- Hossain, M.Y. and J. Ohtomi, 2010. Growth of the southern rough shrimp *Trachysalambria curvirostris* (Penaeidae) in Kagoshima Bay, southern Japan. *J. Crustacean Biol.*, 30: 75-82.
- Hossain, M.Y., M.M. Rahman, B. Fulanda, M.A.S. Jewel, F. Ahamed and J. Ohtomi, 2012. Length-weight and length-length relationships of five threatened fish species from the Jamuna (Brahmaputra River tributary) River, Northern Bangladesh. *J. Appl. Ichthyol.*, 28: 275-277.

- Jennings, S. and M.J. Kaiser, 1998. The Effects of fishing on marine ecosystems. *Adv. Mar. Biol.*, 34: 201-212, 212e, 213-352.
- Kaunda-Arara, B., G.A. Rose, M.S. Muchiri and R. Kaka, 2003. Long-term trends in coral reef fish yields and exploitation rates of commercial species from coastal Kenya. *Western India Ocean J. Marine Sci.*, 2: 105-116.
- Laurence, G.C., 1979. Larval length-weight relations for seven species of northwest Atlantic fishes reared in the laboratory. *Fishery Bull.*, 76: 890-895.
- Mangi, S., 2006. Gear based management and Kenya coastal fishery. Ph.D. Thesis, University of York, England, UK.
- Marino, G., E. Azzurro, A. Massari, M.G. Finoia and A. Mandich, 2001. Reproduction in the dusky grouper from the Southern Mediterranean. *J. Fish Biol.*, 58: 909-927.
- McClanahan, T.R. and N.A.J. Graham, 2005. Recovery trajectories of coral reef fish assemblages within Kenyan marine protected areas. *Marine Ecol. Progr. Ser.*, 294: 241-248.
- McClanahan, T.R., C.C. Hicks and E.S. Darling, 2008. Malthusian overfishing and efforts to overcome it on Kenyan coral reefs. *Ecol. Applic.*, 18: 1516-1529.
- Muchlisin, Z.A., M. Musman and M.N.S. Azizah, 2010. Length weight relationships and condition factors of two threatened fishes, *Rasbora tawarensis* and *Poropuntius tawarensis*, endemic to Lake Laut Tawar, Aceh Province, Indonesia. *J. Applied Ichthyol.*, 26: 949-953.
- Myers, R.A., J.K. Baum, T.D. Shepherd, S.P. Powers and C.H. Peterson, 2007. Cascading effects of the loss of apex predatory sharks from a coastal ocean. *Science*, 315: 1846-1850.
- Naeem, M., A. Salam, Q. Gillani and A. Ishtiaq, 2010. Length weight relationships of *Notopterus notopterus* and introduced *Oreochromis niloticus* from the Indus River, southern Punjab, Pakistan. *J. Applied Ichthyol.*, 26: 620-620.
- Naeem, M., A. Salam and A. Ishtiaq, 2011. Length-weight relationships of wild and farmed *Tor putitora* from Pakistan. *J. Applied Ichthyol.*, 27: 1133-1134.
- Ogongo, O.B., M.E. Chenje and F.B. Mulwa, 2015. Distribution and reproductive patterns of the *Epinephelus* genus groupers off Kenyan South coast marine waters. *J. Fish. Aquatic Sci.*, 10: 159-170.
- Patiyal, R.S., R.C. Sharma, P. Punia, M. Goswami and W.S. Lakra, 2010. Length-weight relationship of *Tor putitora* (Hamilton, 1822) from the Ladhiya River, Uttarakhand, India. *J. Applied Ichthyol.*, 26: 472-473.
- Sani, R., B.K. Gupta, U.K. Sarkar, A. Pandey, V.K. Dubey and W.S. Lakra, 2010. Length-weight relationships of 14 Indian freshwater fish species from the Betwa (Yamuna River tributary) and Gomti (Ganga River tributary) rivers. *J. Applied Ichthyol.*, 26: 456-459.
- Sarkar, U.K., P.K. Deepak and R.S. Negi, 2009. Length-weight relationship of clown knifefish *Chitala chitala* (Hamilton 1822) from the River Ganga basin, India. *J. Applied Ichthyol.*, 25: 232-233.
- Sarkar, U.K., G.E. Khan, A. Dabas, A.K. Pathak and J.I. Mir *et al.*, 2013. Length weight relationship and condition factor of selected freshwater fish species found in river Ganga, Gomti and Rapti, India. *J. Environ. Biol.* 34: 951-956.
- UNEP and WIOMSA., 2015. The regional state of the coast report: Western Indian Ocean. United Nations Environmental Programme (UNEP), The Western Indian Ocean Marine Science Association (WIOMSA), Nairobi, Kenya, pp: 546.
- Yousaf, M., A. Salam and M. Naeem, 2009. Length-weight relationships of *Wallago attu* and *Sperata sarwari* from the Indus River, Southern Punjab, Pakistan. *J. Applied Ichthyol.*, 25: 614-615.