

Catch Composition, Abundance and Length-Weight Relationships of Groupers (Pisces: Serranidae) from Inshore Waters of Kenya

Simon Agembe^{1,3}, Chrisestom M. Mlewa² and Boaz Kaunda-Arara³

¹Kenya Marine & Fisheries Research Institute, P.O. Box 81651, Mombasa, Kenya;

²School of Pure and Applied Sciences, Pwani University College, P.O. Box 195, Kilifi, Kenya; ³Department of Fisheries and Aquatic Sciences, Moi

University, P.O. Box 1125, Eldoret, Kenya.

Keywords: Groupers, Serranidae, catch composition, abundance, length-weight relationship.

Abstract—Groupers (family Serranidae) support important artisanal fisheries in most of the Western Indian Ocean (WIO) region. However, despite their economic and ecological importance, they are poorly studied in the region. This study describes, for the first time, the species composition, abundance and length-weight relationship of groupers from Kenya's inshore artisanal fisheries. Data were obtained from landings by artisanal fishers on the south coast of Kenya from February to July 2007. A total of 37 species belonging to six genera, viz. *Anyperodon*, *Cephalopholis*, *Dermatolepis*, *Epinephelus*, *Plectropomus* and *Variola*, were landed by fishers. The genus *Epinephelus* was the most speciose in the landings, with 20 species. Significantly higher numbers of groupers were landed during the southeast monsoon (n = 616) compared to the northeast monsoon (n = 184) season ($\chi^2 = 125.812$, df = 1, p < 0.001). Of the three sites studied, more species were recorded at Shimoni (n = 36) compared to the Msambweni and Vanga sites (14 and 8 species, respectively). Length-weight relationships derived for 15 species indicated that most groupers exhibited isometric growth. This work provides baseline data on the composition, distribution and abundance of grouper species in Kenya useful for comparison with the rest of the WIO region.

INTRODUCTION

The family Serranidae contains about 500 species in more than 60 genera, including sea basses and groupers of the subfamily Epinephelinae (Smith, 1965; Heemstra & Randall, 1993). Groupers are the target of valuable fisheries in the Western Indian Ocean (WIO) region (Nzioka, 1979; Kaunda-Arara, 1997; Jiddawi & Stanley, 1999). In addition to their importance to local economies, groupers are apex predators thought to play important roles in ecosystem function (Huntsman *et al.*, 1999; Dulvy *et al.*, 2004; Campbell & Perdede, 2006). Loss or reduction of these species from coral reefs can therefore adversely affect local biodiversity and ecosystem stability (Dulvy *et al.*, 2004). Despite their ecological and economic importance, there is concern that many groupers are already being overfished (Sadovy, 1994; Luckhurst, 1996) and some grouper species are listed as threatened or endangered by IUCN (<http://www.redlist.org>). Many grouper species are long-lived, slow to mature, sedentary (Sadovy, 1996), and form spawning aggregations that are predictable in time and space (Domeier & Colin, 1997). These factors make them highly vulnerable to overfishing. In Kenya, grouper catches have declined by about 80% in the last decades (Kaunda-Arara *et al.*, 2003). The extent to which these declines are attributable to species-specific fishing vulnerability and/or environmental factors remains unknown.

Management of groupers must be based on scientific information if populations are to be maintained at commercially viable levels (Rhodes & Sadovy, 2002). However, bio-ecological data on these important fishes is scarce in the WIO region. In Kenya, data on exploited groupers are restricted to descriptive information on a few species (Nzioka, 1979), movement studies on the greasy grouper, *Epinephelus tauvina* (Kaunda-Arara & Rose, 2004), and preliminary investigations on their spawning aggregations (Samoilys *et al.*, 2006). Data on species composition and abundance are important in evaluating spatial effects of fishing effort (Jennings & Polunin, 1996), determining recruitment variability (Caley *et al.*, 1996) and for trend analysis, while length-weight parameters are useful inputs in length-structured models for stock assessment (Pauly, 1984). The objective of this study was therefore to build on the limited grouper database by providing information on species composition, abundance and length-weight relationships of groupers from Kenya's artisanal fisheries.

MATERIAL AND METHODS

Study sites

The study was undertaken at three fisheries landing beaches (Msambweni, Shimoni and Vanga) on the southern coast of Kenya (Fig. 1). These landing beaches were chosen because they

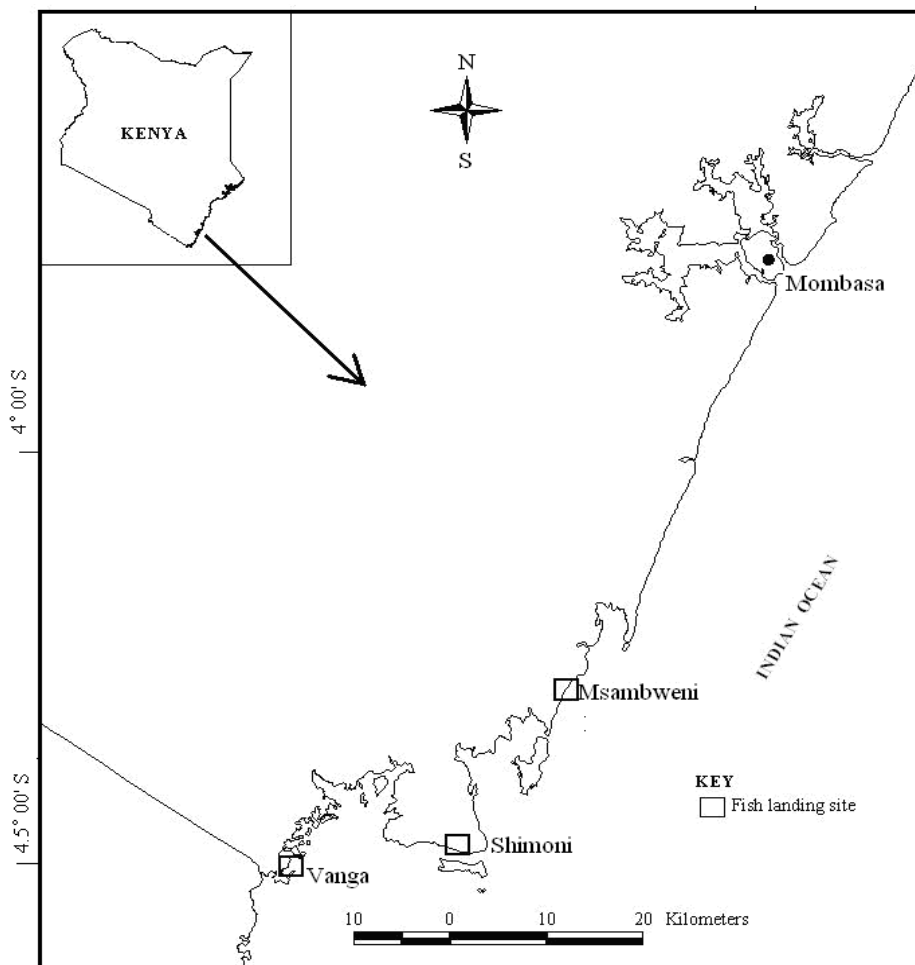


Figure 1: Map of south coast of Kenya showing the fish landing sites (Msambweni, Shimoni and Vanga) monitored in the study.

are some of the most active, with high artisanal fisheries landings for the Kenyan coast. Landings from the study sites were therefore considered more representative and likely to capture the variability in grouper composition on the Kenyan coast. Fishing activities off these landing beaches are concentrated within nearshore reef lagoons as fishermen infrequently venture beyond the outer reef because of the low power of their fishing craft.

Data collection

Fisher catches were sampled at the three beaches for ~10 days/beach/month during the northeast monsoon (February, March, April) and the southeast monsoon (May, June, July) months in 2007. Groupers were separated from the catches and identified to species level using keys from Heemstra & Randall 1993 and Smith & Heemstra, 1986. Total length (to the nearest 0.1 cm) and weight (to the nearest gram) were

measured for each fish, using a top-loading Salter digital balance for small fish (<2.0 kg) or on a hanging Salter scale (100 kg in 100 g increments) for bigger individuals.

Data analysis

Percentage abundance was used to determine the numerical dominance of species at each of the sites. The non-parametric Chi-square test was used to test for differences in numerical abundance of species between the northeast monsoon (NEM) and southeast (SEM) seasons. Length-weight relationships were determined using the equation: $\text{Log}_{10} W = \text{log}_{10} a + b \text{log}_{10} \text{TL}$, where W is body weight, TL is total length, a is the intercept, and b is the slope of the regression line (Wootton, 1990). This relationship was estimated for fifteen species for which there were data for 15 or more specimens. The slope of the length-weight relationship for each species was tested for significant difference from the isometric growth value of 3.0 (Ricker, 1975) using a one tailed t-test. Seasonal abundance of groupers was analysed for Shimoni, which had highest and most diverse landings of groupers. All statistical tests followed Zar (1996).

RESULTS

Species catch composition

Thirty seven species of groupers were landed at the three beaches. Shimoni landings were the most diverse with 36 species, while Msambweni

and Vanga sites yielded 14 and 8 species, respectively. At Shimoni, grouper species landed belonged to 6 genera; *Anyperodon*, *Cephalopholis*, *Dermatolepis*, *Epinephelus*, *Plectropomus* and *Variola* (Table 1). The genus *Epinephelus* was the most speciose in the samples, with 20 species, while the genera *Cephalopholis*, *Plectropomus*, *Dermatolepis* and *Variola* were represented by 7, 4, 2 and 2 species, respectively, and *Anyperodon* by only one species (Table 1). The number of individuals landed at sites varied considerably in some species, for example, it ranged from 1 to 124 in *Epinephelus caeruleopunctatus*. Only three species, *Cephalopholis boenak*, *E. caeruleopunctatus* and *E. fasciatus*, had more than 100 individuals landed at all the sites (Table 1).

In Shimoni, the white-spotted grouper, *Epinephelus caeruleopunctatus*, was numerically the most abundant (15.6%) in the catch followed by *Cephalopholis boenak* (13%) and *E. fasciatus* (12.9%) (Fig. 2a). Some species, such as *E. areolatus*, *E. spilotoceps*, *Plectropomus punctatus*, *P. laevis*, *E. hexagonatus*, *P. maculatus*, *E. tukula*, *Dermatolepis striolata*, *D. dermatolepis*, *E. melanostigma*, and *C. taeniops* comprised <1% of the catches.

In Vanga, the commonly landed species were the white-spotted grouper, *Epinephelus caeruleopunctatus*, the malabar grouper, *E. malabaricus*, and the chocolate hind, *C. boenak*, each of which comprised over 20% of the grouper landings (Fig. 2b). Four

Table 1: A comparison of numerical abundance of grouper species landed during the northeast (NEM) and southeast (SEM) monsoon seasons at Shimoni site. N = numbers landed, χ^2 is chi-square statistic, p is probability of significance of the difference at $\alpha = 0.05$.

Species	SEM	NEM	N	χ^2	p-value
<i>Anyperodon leucogrammicus</i>	5	3	8	0.254	0.614
<i>Cephalopholis argus</i>	13	15	28	0.072	0.789
<i>Cephalopholis boenak</i>	100	4	104	56.30	0.000
<i>Cephalopholis leopardus</i>	3	3	6	0.000	1.000
<i>Cephalopholis miniata</i>	10	5	15	0.883	0.347
<i>Cephalopholis sonnerati</i>	18	0	18	12.00	0.001
<i>Cephalopholis taeniops</i>	1	2	3	0.194	0.659
<i>Cephalopholis urodeta</i>	59	0	59	39.44	0.000
<i>Dermatolepis dermatolepis</i>	1	0	1	0.750	-
<i>Dermatolepis striolata</i>	2	1	3	0.194	0.659
<i>Epinephelus acanthistus</i>	0	1	1	0.750	-
<i>Epinephelus areolatus</i>	7	0	7	4.773	0.029
<i>Epinephelus bentoides</i>	2	0	2	1.333	-
<i>Epinephelus caeruleopunctatus</i>	95	29	124	18.90	0.000
<i>Epinephelus coioides</i>	55	19	74	9.307	0.002
<i>Epinephelus fasciatus</i>	92	12	102	36.11	0.000
<i>Epinephelus flavocaeruleus</i>	1	0	1	0.750	-
<i>Epinephelus fuscoguttatus</i>	23	1	24	12.77	0.000
<i>Epinephelus hexagonatus</i>	0	3	3	2.100	-
<i>Epinephelus lanceolatus</i>	1	0	1	0.750	-
<i>Epinephelus longispinis</i>	2	0	2	1.333	-
<i>Epinephelus macrospilus</i>	2	4	6	0.343	0.558
<i>Epinephelus malabaricus</i>	45	22	67	4.096	0.043
<i>Epinephelus melanostigma</i>	1	0	1	0.750	-
<i>Epinephelus merra</i>	14	10	24	0.336	0.562
<i>Epinephelus multinotatus</i>	25	18	43	0.567	0.451
<i>Epinephelus poecilonatus</i>	0	1	1	0.750	-
<i>Epinephelus socialis</i>	1	0	1	0.750	-
<i>Epinephelus spilotoceps</i>	6	0	6	4.000	0.046
<i>Epinephelus tauvina</i>	3	16	19	5.132	0.023
<i>Epinephelus tukula</i>	4	11	15	1.777	0.183
<i>Plectropomus laevis</i>	3	1	4	0.533	0.465
<i>Plectropomus maculatus</i>	2	0	2	1.333	-
<i>Plectropomus pessuliferus</i>	1	0	1	0.750	-
<i>Plectropomus punctatus</i>	3	1	4	0.533	0.465
<i>Variola albimarginata</i>	1	0	1	0.750	-
<i>Variola louti</i>	17	2	19	7.127	0.008
Total	616	184	800		

species, *E. multinotatus*, *E. tauvina*, *E. tukula* and *E. fasciatus*, were low in relative abundance (1-5%).

In Msambweni, only two species (*Epinephelus fasciatus* and *Cephalopholis urodeta*) had relative

Table 2: Length-weight relationships for fifteen species of groupers (Serranidae) landed on the south coast of Kenya. N = sample size; a = constant; b = length exponent.

Species	TL (cm)			L-W parameters		t-test statistics			
	N	min	Max	a	b	t [^]	tab	r ²	P
<i>Cephalopholis argus</i>	28	19.0	37.5	-1.90	3.08 I	-0.07	2.05	97.3	<0.001
<i>Cephalopholis boenak</i>	103	10.0	22.1	-1.67	2.89 I	0.36	1.98	85.9	<0.001
<i>Cephalopholis miniata</i>	15	19.0	30.8	-2.12	3.22 I	-0.18	2.18	96.8	<0.001
<i>Cephalopholis sonnerati</i>	18	16.4	54.3	-1.75	2.98 I	0.01	2.12	98.5	<0.001
<i>Cephalopholis urodeta</i>	59	13.5	25.0	-1.74	2.94 I	0.16	2.00	95.6	<0.001
<i>Epinephelus caeruleopunctatus</i>	124	16.5	52.0	-1.75	2.92 I	0.12	1.98	95.1	<0.001
<i>Epinephelus coioides</i>	72	20.5	104.5	-1.93	3.04 I	-0.02	1.99	99.3	<0.001
<i>Epinephelus fasciatus</i>	102	12.0	28.1	-1.77	2.93 I	0.24	1.98	93.0	<0.001
<i>Epinephelus fuscoguttatus</i>	24	24.1	90.1	-1.93	3.09 I	-0.02	2.07	97.9	<0.001
<i>Epinephelus malabaricus</i>	67	23.5	108.0	-1.71	2.90 I	0.04	1.99	97.7	<0.001
<i>Epinephelus merra</i>	24	16.0	34.5	-1.84	2.99 I	0.01	2.07	97.6	<0.001
<i>Epinephelus multinotatus</i>	43	14.8	65.0	-1.75	2.93 I	0.04	2.02	89.8	<0.001
<i>Epinephelus tauvina</i>	19	23.0	50.7	-1.95	3.05 I	-0.03	2.11	97.8	<0.001
<i>Epinephelus tukula</i>	15	27.5	77.5	-2.08	3.17 I	-0.04	2.16	98.4	<0.001
<i>Variola louti</i>	19	19.0	37.5	-1.64	2.77 I	0.06	2.11	97.1	<0.001

abundances >16% (Fig. 2c). Five species were landed in relatively abundance (2-5%) and seven at an abundance of 1% (Fig. 2c). The black-tip grouper, *E. fasciatus*, was the most commonly (19%) landed species at Msambweni, followed by *C. urodeta* which comprised 17% of the landings.

Catch composition by weight

Three species (*Epinephelus coioides*, *E. malabaricus* and *E. fuscoguttatus*) formed the bulk of the biomass of groupers landed at the three landing beaches. The white-spotted grouper, *E. caeruleopunctatus*, although dominant in numerical abundance, ranked only fourth in terms of the total weight landed. Seven species totalled ≥ 20 kg in landed weight, while 27 species weighed in at ≤ 15 kg (Fig. 3).

Seasonal variations in catches

The total number of groupers landed at the sites differed seasonally (Table 2). At Shimoni, higher numbers were caught during the SEM (n = 616) compared to the NEM (n = 184) season ($\chi^2 = 125.812$, df = 1, p <0.001) (Table1). The dominant species caught during the NEM season was the white spotted grouper, *Epinephelus caeruleopunctatus*, whereas the chocolate hind, *Cephalopholis boenak*, was dominant during the SEM season (Table 1). At Vanga, significantly higher numbers of groupers were landed during the SEM (n = 75) compared to the NEM (n = 22) ($\chi^2 = 13.033$, df = 1, p <0.05). Similarly, significantly higher number of groupers were landed at Msambweni during the SEM (n = 42)

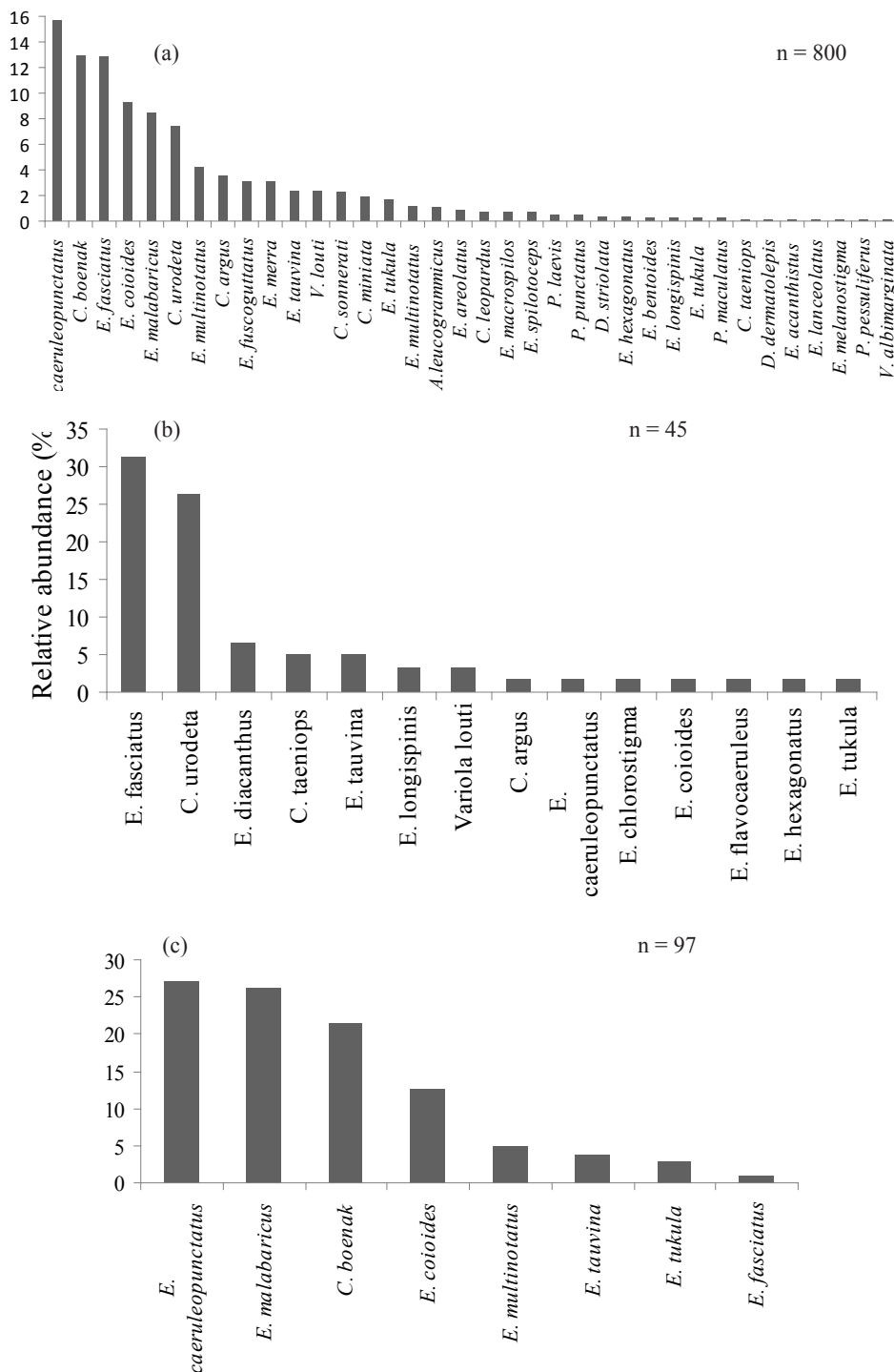


Figure 2: Percentage abundance of grouper species landed at (a) Shimoni, (b) Msambweni, and (c) Vanga landing sites on the south coast of Kenya from February to July 2007.

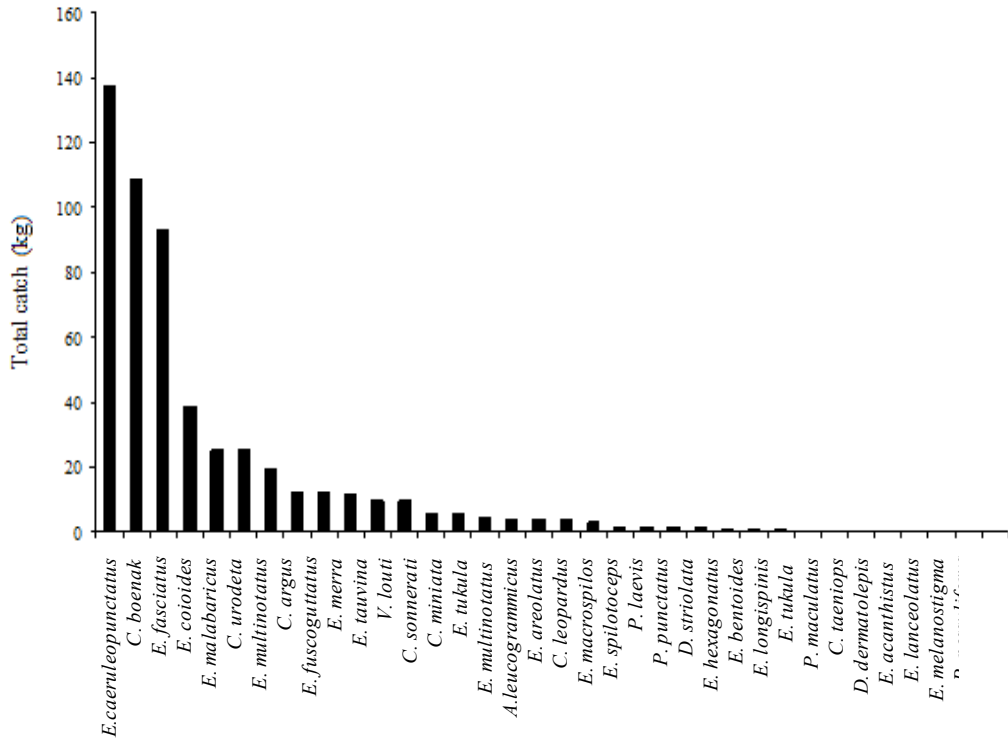


Figure 3: Total landings (kg) of grouper species from Shimoni, Vanga and Msambweni on the south coast of Kenya (n = 942) from February to July 2007.

compared to the NEM (n = 3) ($\chi^2 = 18.861$, df = 1, $p < 0.05$).

Length-weight relationships

The length-weight regressions for 15 grouper species were highly significant ($p < 0.001$) with r^2 values ranging from 85.9-99.3% (Table 2). A one tailed t-test result showed that the length exponents (b values) were not significantly different from 3 and were indicative of isometric growth (Table 2).

DISCUSSION

A total of 37 grouper species were landed by fishers at the three south Kenyan coast fish landing beaches,

with Shimoni having the highest diversity of grouper landings (36 species) compared to Vanga and Msambweni where 8 and 14 species were landed, respectively. Higher relative abundances of *Epinephelus caeruleopunctatus*, *Cephalopholis boenak* and *E. fasciatus* were recorded at Shimoni, while at Vanga, *E. caeruleopunctatus*, *E. malabaricus*, and *C. boenak* were the most abundant. *E. fasciatus*, *C. urodeta*, *E. diacanthus* were the dominant catch at Msambweni. This variation at the sites is probably due to spatial differences in fishing pressure, habitat characteristics or variability in recruitment. Groupers are sedentary fishes with high site-

fidelity, often around coral heads (Kaunda-Arara & Rose 2004a), a trait making their distribution dependent on habitat complexity. Additionally, site fidelity and spawning of some species in aggregations make them vulnerable to fishing mortality due to predictability in their abundance and distribution (Domeier & Colin, 1997). Recruitment data on Serranidae are lacking for the WIO region; however, recruitment variability is known to influence the spatial structure of fish populations in Kenya (Kaunda-Arara *et al.*, 2009) and elsewhere (Caley *et al.*, 1996), and could contribute to the spatial variations observed in species diversity and sample sizes between the three sites. The higher diversity at Shimoni could, among other factors, be related to the influence of the nearby Kisite-Mpunguti Marine Park, probably through larval re-seeding and spill-over effects of the park on the adjacent fisheries (Kaunda-Arara & Rose, 2004a, b; Bostford *et al.*, 2007).

The results indicate that *Cephalopholis boenak*, *C. urodeta*, *Epinephelus caeruleopunctatus*, *E. coioides* and *E. fasciatus* were numerically higher in catches during the southeast monsoon season, while the potato grouper, *E. tukula*, and the greasy grouper, *E. tauvina*, were more abundant during the northeast monsoon. More species were caught during the rougher SEM conditions compared to the calmer NEM season. These seasonal differences may be a reflection of seasonal variations in fishing effort as

fishers are known to concentrate their efforts on the inner reef during the SEM due to the rough sea conditions (McClanahan, 1988). While the higher effort probably contributes to enhanced catches in this season, the factors responsible for the higher diversity and numerical landings of groupers during the rougher SEM season are not clear. However, it may be that they take refuge in the calmer inshore waters during the SEM season, thereby increasing their vulnerability to fishing, and become more widely dispersed during the NEM, resulting in lower fishing mortality.

Five species, *Epinephelus caeruleopunctatus*, *E. coioides*, *E. tauvina*, *E. tukula*, and *E. fasciatus*, were common to all the landing sites. This may be attributed to the overall similarity in the geospatial distribution of the fringing reef from Vanga to Msambweni, providing a uniformity in macro-habitat that favours the common species. However, *E. diacanthus* and *E. chlorostigma* were only landed in Msambweni. This restricted distribution is perhaps attributable to recruitment variability, differences in micro-habitat preference and differential effects of fishing amongst other factors (Hixon & Beets, 1993, Kaunda-Arara & Rose, 2004). Although the Vanga and Shimoni sites share a similar reef structure (Samoilys, 1988), the low species diversity at Vanga may be attributable to dynamiting by fishers from Pemba Island (Tanzania) which destroyed the reefs at this site (Samoilys, 1988).

All the length exponents in the length-weight relationships for the fifteen grouper species were between 2.77 and 3.22 and were indicative of isometric growth (Bagenal & Tesch, 1978). Length-weight relationships are important in fisheries science (Ricker, 1975) and for modelling stocks (Pitcher, 1995); the data generated in this study will be therefore be useful in future stock assessment and modelling studies on these species in the WIO region.

This study has documented a higher diversity of groupers on the Kenyan south coast at Shimoni (37 species) than Msambweni (14 species) and Vanga (8 species). Spatial differences in diversity and catch between the sites may be attributable to differences in fishing effort, habitat structure and recruitment variability. Fishers land more groupers during the rough SEM season compared to the calm NEM season. The study has provided isometric length-weight relationships for 13 species useful for modelling the grouper stocks. The species checklist generated in this work will form useful future reference material for studies on the distribution and ecology of individual grouper species in Kenya and the WIO in general. It is recommended that the Kenyan government maintains landing statistics at the species level for purposes of monitoring changes in abundance and diversity of the fish stocks over time.

Acknowledgments: We wish to thank the director of Kenya Marine and Fisheries Research Institute for financial support. We are grateful to the technical staff, Messrs. B. Orembo, D. Odongo, J. Gonda, R. Anam, P. Nyalele, D. Ocharo, K. Omondi and J. Omweri, for assisting with data collection. We thank the anonymous reviewers for constructive criticisms and useful suggestions.

REFERENCES

- Bagenal, T.B., Tesch, F.W. (1978) Age and Growth. *In:* T. B. Bagenal (ed.). *Methods for Assessment of Fish Production in Fresh Waters*. Blackwell Scientific, Oxford. pp101-136.
- Bostford, L.W., Micheli, F. & Parma, A. M. (2007) Biological and Ecological Considerations in the Design, Implementation and Success of MPAs. *In:* Report and Documentation of the Expert Workshop on Marine Protected Areas and Fisheries Management: A Review of Issues and Considerations. Rome, 12-14 June 2006. *FAO Fish. Tech. Rep.* No.825. Rome, FAO. 332 pp.
- Caley, M.J., Carr, M.H. Hixon, M.A., Hughes, T.P. Jones, G.P. Menge B.A. (1996) Recruitment and the Local Dynamics of Open of Marine Populations. *Annual Reviews of Ecology and Systematics* **27**: 477-500.
- Campbell, S.J. & Perdede, S.T. (2006) Reef Fish Structure and Cascading Effects in Response to Artisanal Effects in Response to Artisanal Fishing Pressure. *Fish Res.* **79**: 75-83.
- Domeier, M.L. & Colin, P.L. (1997) Tropical Reef Fish Spawning Aggregations Defined and Reviewed. *Bull. Mar. Sci.* **60**: 698-726.

- Dulvy, N.K., Freckleton, R.P. & Polunin, N.V.C. (2004) Coral Reef Cascades and the Indirect Effects of Predator Removal by Exploitation. *Ecology Letters* **7**: 410-416.
- Heemstra, P.L. & Randall, J.E. (1993) FAO Species Catalogue. Vol.19. Groupers of the World. Family Serranidae, Subfamily Epinephelinae. An Annotated and Illustrated Catalogue of the Groupers and Lyretail Species Known to Date. *FAO Fish. Syn.*, vol. 125, no.16, FAO, Rome. 382pp.
- Hixon, M.A & Beets, J.P. (1993) Predation, Prey Refuges, and the Structure of Coral Reef Fish Assemblages. *Ecol. Monogr.* **63**: 77-101.
- Huntsman, G.R., Potts, J., Mays, R.W., Vaughan, D. (1999) Groupers (Serranidae, Epinephelinae): Endangered Apex Predators of Reef Communities. *Am. Fish. Soc. Symp.* **23**: 217-231.
- Jennings, S. & Polunin, N.V.C. (1996) Impacts of Fishing on Tropical Ecosystems. *Ambio* **25**: 44-49.
- Jiddawi, N.S. & Stanley R.D. (1999) Fisheries Stock Assessment in the Traditional Fisheries Sector: The Information Needs. In: N.S. Jiddawi & R.D. Stanley (eds). Proceedings of the National Workshop on the Artisanal Fisheries Sector, Zanzibar, September 22–24, 1997. 50-70 pp.
- Kaunda-Arara, B., Mwaluma, J.M., Gamoe, A.L. Oresland, V. & Osore, M.K. (2009) Temporal Variability in Fish Larval Supply to Malindi Marine Park, coastal Kenya. *Aquatic Conservation: Marine and Freshwater Ecosystems* **19**: S10-S18.
- Kaunda-Arara, B. & Rose, G.A. (2004) Homing and Site Fidelity in Greasy Grouper *Epinephelus tauvina* (Serranidae) within a Marine Protected Area in coastal Kenya. *Mar. Ecol. Prog. Ser.* **277**: 245-251.
- Kaunda-Arara, B. & Rose, G.A. (2004a) Effects of Marine Reef National Parks on Fishery CPUE in coastal Kenya. *Biol. Cons.* **118**: 1-13
- Kaunda-Arara, B. & Rose, G.A. (2004b) Outmigration of Tagged Fishes from Marine Reef National Parks to Fisheries in coastal Kenya. *Environ. Biol. Fish.* **70**: 363-372
- Kaunda-Arara, B., Rose, G.A., Muchiri, M.S. & Kaka, R. (2003) Long-term Trends in coral Reef Fish Yields and Exploitation Rates of Commercial Species from coastal Kenya. *Western India Ocean J. Mar. Sci.* **2**: 105-116.
- Kaunda-Arara, B. (1997) Analysis of Catch Data from 1985 to 1994 in the Kenyan Inshore Marine Waters. *Afr. J. Trop. Hydrobiol.* **7**: 1-6.
- Luckhurst, B.E. (1996) Trends in Commercial Fishery Landings of Groupers and Snappers in Bermuda from 1975 to 1992 and Associated Fishery Management Issues. In: Pauly D (ed.) *Biology, Fisheries and Culture of Tropical Groupers and Snappers. ICLARM Conf. Proc.* **48**: 277-288
- McClanahan, T.R. (1988) Seasonality in East Africa's Coastal Waters. *Mar. Ecol. Prog. Ser.* **44**: 191-199.
- Nzioka, R.M. (1979) Observation on the Spawning Seasons of East African Reef Fishes. *J. Fish Biol.* **14**: 329-342.
- Pauly, D. (1984) Length-converted Catch Curves: A Powerful Tool for Fisheries Research in the Tropics. Part II. *ICLARM Fishbyte* **1**: 17-19.
- Pitcher, T.J. (1995) Thinking the Unthinkable: a Candidate Model for Predicting Sustainable Yields of Introduced Fish Species in African Lakes. In: Pitcher, T.J. and Hart P.J.B. (eds.) *Impact of Species Changes in the African Lakes*. Chapman and Hall, London. pp 495-526.

- Rhodes, K.L. & Sadovy, Y. (2002) Temporal and Spatial Trends in Spawning Aggregations of Camouflage Grouper, *Epinephelus polyphkaidon*, in Pohnpei, Micronesia. *Env. Biol. Fish.* **63**: 27-39.
- Ricker, W.E. (1975) Computation and Interpretation of Biological Statistics of Fish Populations. *Bull. Fish. Res. Board Canada* **191**: 1-32.
- Sadovy, Y.J. (1996) Reproduction of Reef Fishery Species. In: Polunin, N.V.C. & Roberts, C.M. (eds.) *Reef fisheries*. Chapman & Hall, London. pp 15-59.
- Sadovy, Y.J. (1994) Grouper Stocks of the Western Central Atlantic: The need for Management and Management needs. *Proc. Gulf Carib. Fish. Inst.* **43**: 43-65.
- Samoilys, M.A. (1988) Abundance and Species Richness of Coral Reef Fish on the Kenyan Coast: The effects of Protective Management and Fishing. *Proc. Int. Coral Reef Symp.* **2**: 261-266.
- Samoilys, M.A., Church, J., Kaunda-Arara, B., Kamukuru, A. & Jiddawi, N. (2006) Preliminary Findings on Spawning Aggregations of Reef Fishes in East Africa. *Proc. 10th Int. Coral Reef Symp.* Okinawa, July 2004: 1335-1346.
- Smith, M.M. & Heemstra, P.C. (1986) *Smith's Sea Fishes*. Macmillan South Africa, Johannesburg. 1047 pp.
- Smith, C.L. (1965) The Patterns of Sexuality and the Classification of Serranid Fishes. *Am. Mus. Novitates*, **2207**: 1-20.
- Wootton, R.J. (1990) *Ecology of Teleost Fishes*. Fish and Fisheries Series. Chapman and Hall, New York. 404 pp.
- Zar, J.H. (1996) *Biostatistics Analysis*. Prentice Hall, New Jersey. 662 pp.