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## Distribution and Reproductive Patterns of the *Epinephelus* Genus Groupers off Kenyan South Coast Marine Waters

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### ABSTRACT

The *Epinephelus* genus grouper fishers (family: Serranidae) are among the most important sources of food and revenue to the local artisanal grouper fishers in Kenya. However, the fishery seems to be operating below maximum sustainable yield levels and their thorough distribution and reproductive patterns knowledge is required for development of management interventions to protect this important fishery. Their distribution and reproductive patterns was therefore investigated for a period of 8 months from December, 2013 to July, 2014 in the Kenyan south coast inshore marine waters of Vanga, Shimoni and Msambweni. Data was collected from these fishing grounds artisanal fishery landings and the species distribution and reproductive patterns validated through experimental underwater visual surveys, species abundance landings, diversity and maturity stages. A total of 30 species dominated by *Epinephelus fasciatus* landings were recorded with most showing narrow distribution patterns. Only *E. fasciatus*, *E. malabaricus*, *E. longispinis*, *E. chlorostigma*, *E. coeruleopunctatus*, *E. multinotatus*, *E. merra*, *E. melanostigma*, *E. tukula*, *E. fuscoguttatus* and *E. tauvina* had wider distributions. Eighteen had increased reproductive activity from April-July during southeast monsoon season suggesting the need for restricted fishing seasons. Further species habitat preference studies are also required to provide conservation and ecosystem protection information data.

**Key words:** *Epinephelus*, groupers, species, distribution, reproductive patterns

### INTRODUCTION

The *Epinephelus* genus groupers are teleost fishes belonging to the family Serranidae in the order perciformes. This family of fishes locally known as “Tewa” or Rock cods along the Eastern coast of Africa contains more than 400 species which are widely distributed in the tropical and sub-tropical areas all over the world (Heemstra and Randall, 1993). Nonetheless, the word “groupers” on its own is usually taken to mean fishes in the serranid subfamily Epinephelinae comprising of about 159 species in 15 genera (Heemstra and Randall, 1993). On the other hand, the

genus *Epinephelus* comprises 98 species from which slightly over 30 species are known to exist in the Kenyan waters (Anam and Mostarda, 2012).

Most are highly sedentary K-strategist slow growers with delayed reproduction, reduced spawning, long life-spans and large sizes (>100 cm total length) that make them vulnerable to over-exploitation. Many also form spawning aggregations that are predictable in space and time making them easy targets to even small scale spear fishers (Floeter *et al.*, 2006; Gillett and Moy, 2006; Chan *et al.*, 2008). These small scale multi-gear species fishes play important economic roles within the tropical and sub-tropical coral reef fisheries and heavy fishing pressure affects their population dynamics globally (Pears *et al.*, 2006; Dulvy *et al.*, 2004; Sadovy and Domeier, 2005; Sadovy, 2005; Robinson *et al.*, 2008). Consequently, their sustainable management can only be achieved by availing and using their basic life history parameters, various population dynamics and stock assessment aspects research information (Sale, 2002; Munday *et al.*, 2006).

These *Epinephelus* genus groupers are among the most common serranid fishes in Kenya important to the local artisanal grouper fishers as food and revenue sources. However, the fishery currently seems to be operating at levels not capable of generating maximum sustainable yields. This has resulted in driving huge fishing pressure on these valuable food fishes (Pauly *et al.*, 2002, 2005) and there can be no doubt that their natural supply is rapidly declining world wide (Bini *et al.*, 2005). As thorough distribution and reproductive patterns knowledge of these key lagoon reef fishes is therefore needed for the development of their protection management interventions in this natural world increasingly transformed by human activities to counter the already evident rapid natural supply decline.

In Kenya, the distribution and reproductive patterns of these key lagoon reef fishes remains largely unknown despite being exploited by over 8000 Kenyan artisanal fishermen (McClanahan and Graham, 2005). Therefore, taking into consideration that some 18 reef fish species including *Epinephelus fuscoguttatus* Forsskål, 1775 have been suspected of forming spawning aggregations along the Kenyan continental shelf (Robinson *et al.*, 2008; Church *et al.*, 2005), the study aimed at determining the *Epinephelus* genus grouper species distribution and reproductive patterns of Kenyan south coast marine waters for future management, restoration and conservation implications.

## **MATERIALS AND METHODS**

**Study sites:** The study was conducted within the inshore small-scale marine fishing areas of Msambweni (S 03°65'8", E 038°48'8"), Shimoni (S 04°44'54.2", E 039°21'58.8"), which is the part of its fishing grounds from the fishing villages of Mpunguti and Mipwa on the mainland, Mwamba Mkuu in the adjacent Wasini Island has been hived and gazetted as a marine protected area (Kisite-Mpunguti Marine National Park and Reserve) and Vanga (S 05°14'4", E 039°38'1") in south coast of Kenya (Fig. 1). The sites were selected due to the existence of previous grouper studies undertaken from there; high grouper fishers and fisheries activity coefficient within Kenyan south coast and lastly for being the most pristine and sheltered reefs on the Kenyan coast making them key grouper fishing areas (McClanahan *et al.*, 2007).

**Data collection:** Monthly field sampling and laboratory work involving inspection of the landed and visually observed *Epinephelus* genus groupers was conducted from December, 2013 to July, 2014. Data was obtained from both the small-scale fisheries landings and underwater visual

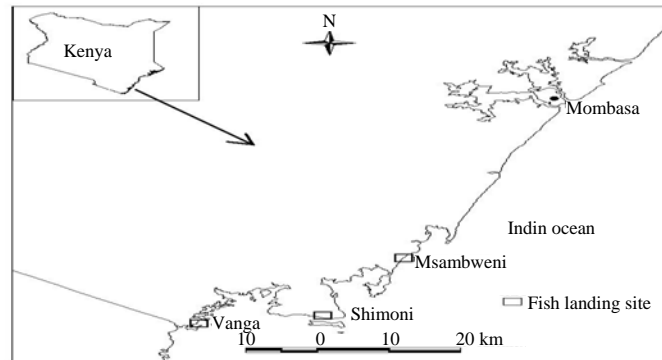


Fig. 1: A map of the Kenyan south coast showing the study sites of Vanga, Shimoni and Msambweni (Agembe, 2009)

surveys from the site's inshore waters where longitudinal swim surveys were carried out for three consecutive days in each sampling site for the collection of visual survey data. A long-swim transects method protocol adopted from Pears (2009) was employed for the longitudinal swim surveys in which timed, unidirectional 100 m transect belt underwater visual survey transect swims in depths of 2-15 m of water was undertaken at each study site. Multiple transects surveyed within the same study site were separated by tens of metres and the *Epinephelus* genus grouper counts undertaken by a diving swimming observer at the species-level of resolution for abundance analysis. The transect lengths and swim-speed of 30 m min<sup>-1</sup> were regularly checked and re-checked at the start of each sampling using GPS readings. The protocol involved detailed searches of buoy marked transect length substrata with slow timed swims of 45 min duration and fixed average search speed of 30 m min<sup>-1</sup>. An estimated 5 m transect width band was searched for cryptic and roving *Epinephelus* genus groupers due to their flighty nature. Observations of the larger sized mobile *Epinephelus* genus groupers were made over a 10 m estimated width band on either side of the central swim line. Each transect portion was viewed only once for each target species and all encountered species individuals of 6 cm Total Length (TL) or greater, estimated using wooden fish models from a distance of 2 m earlier compared with measured lengths; identified to species-level by the same observer, counted and data recorded onto a prepared water proof data slate to ensure consistency.

Landed *Epinephelus* genus groupers were also purchased from the small-scale grouper fishery operators at the landing sites for abundance, length, weight and gonad maturity staging analysis. The landings were sorted and identified to species level using keys and guides from Smith and Heemstra (1986), Heemstra and Randall (1993) and Anam and Mostarda (2012). Each groupers' total length was measured to the nearest 0.1 cm using a vernier calliper and also weighed to the nearest 0.01 g on a top loading Salter digital balance model 2010 for small fishes (<2.0 kg), or on a hanging Salter balance model 235 (100 kg by 100 g) for bigger individuals. Each specimen was then dissected, sexed and assigned a gonadal maturity stage based on macroscopic examination of the gonad following the scheme for *Epinephelus polyphekaidon* Bleeker, 1849 grouper described by Rhodes and Sadovy (2002). Additional features used in staging as key indicators of prior spawning as illustrated by Ramadan and El-Halfawy (2007) included gonad vascularisation and

Table 1: Macroscopic criteria used in the determination of maturity stages of the grouper species Scheme adapted from Ferreira (1995) and Adams (2003)

Maturity stages	Macroscopic features
<b>Ovaries</b>	
I: Immature	Ovary small, strand-like, compact, pink or cream, oocytes (eggs) not clearly distinct, not obviously different from immature or inactive males
II: Maturing	Ovary relatively small but rounded, less strand-like in appearance, grayish with thickened gonad wall, eggs not clearly distinct and small, Not clearly different from mature males prior to the development of yolk within the eggs
III: Mature, active	Ovary large and grayish with transparent gonad wall, large yolky eggs becoming clearly visible and tightly packed
IV-V: Mature, ripe	Ovary relatively large, clear, watery (hydrated) eggs visible through wall, typical of individuals just prior to spawning; egg release possible with application of light abdominal pressure
VI: Post-spawn (spent)	Ovary flaccid with obvious capillaries (small blood vessels), few eggs still visible
<b>Testes</b>	
I: Immature/inactive	Testes not obviously different from immature females (see the description of immature females)
II: Maturing	Early male II individuals are indistinguishable from female II. Single blood vessel on ventral side. No sperm extricable when pressed lightly
III: Mature, active	Testes expanding and becoming rounded and large, grayish in appearance, early maturing individuals are not clearly different from maturing females until milt (sperm) becomes evident in the sperm sinus along the gonad wall
IV-V: Mature, ripe	Testes large and white with sperm visible in sinuses along the gonad wall; milt release with light abdominal pressure
VI: Post-spawn (spent)	Testes flaccid and bloody, sperm release still possible on application of abdominal pressure

gonad walls' relative thickness. The ovaries and testes were then classified into developmental stages with adaptations from Ferreira (1995) and Adams (2003) and the obtained reproductive information matched with fishing season.

**Gonad processing and analysis:** Each individual's gonads were removed and preserved in 10% phosphate buffered formalin or immediately frozen whole for processing back in the laboratory. At the laboratory, each gonad pair was thawed, dried of excess fixative and their weights measured to the nearest 0.01 g. Where only one gonad lobe was available due to damage during processing, the gonad weight was estimated by multiplying the mass of the single complete lobe by two considering that the lobes are always equal in size for groupers as observed and recorded by Adams (2003). They were then classified into developmental stages with adaptations from Ferreira (1995) and Adams (2003) (Table 1).

**Statistical data analyses:** The non parametric Chi-square test (goodness-of-fit test) was used to test for significant deviations from the expected male to female ratio of 1:1 and also to compare numbers within the study sites. Comparison of the landed and visually observed *Epinephelus* genus groupers proportions was also undertaken using of proportions test using MINITAB release 14 software. The species Gonadosomatic Index (GSI) percentage contributions were also done using the computer MS-Excel spreadsheet package. Dominance, diversity, evenness, spatial and temporal distribution pattern variations of the visually observed *Epinephelus* genus groupers off the Kenyan south coast marine water inshore fisheries were determined through Ward's linkage and Squared Pearson Distance cluster method using PAST (Paleontological Statistics version 2.17 programme) software. All statistical tests of significance were determined at  $\alpha = 0.05$ .

## RESULTS

**Species composition, dominance, proportions, diversity and distribution patterns:** During the study, thirty species comprising of *E. areolatus*, *E. bentoides*, *E. chlorostigma*,

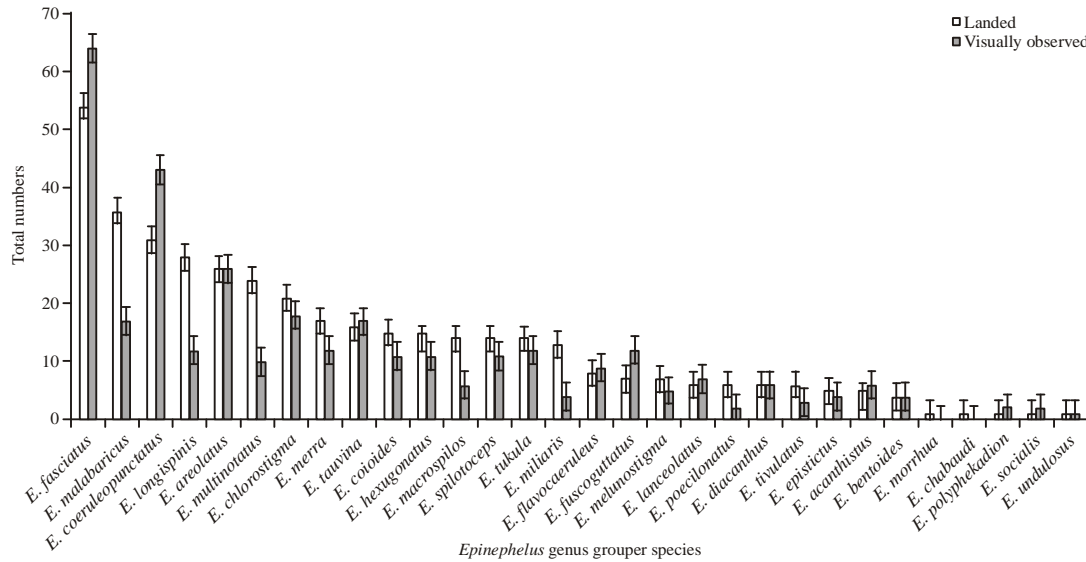


Fig. 2: Landed and visually observed species composition and dominance (Numbers±SE) off the Kenyan south coast inshore waters. Vertical bars represent standard error bars

Table 2: Landed and visually observed *Epinephelus* genus groupers proportions (N=numbers) at the study sites; p-value (probability of significance at  $\alpha = 0.05$ )

Sites/locations	Landed	Visually observed	N	$\chi^2$	p-value
Msambweni	77	55	132	0.913	0.339
Shimoni	223	224	447	3.331	0.067
Vanga	101	60	161	4.734	0.030
Total	401	339	740	8.978	0.011

*E. coeruleopunctatus*, *E. coioides*, *E. diacanthus*, *E. fasciatus*, *E. fuscoguttatus*, *E. hexagonatus*, *E. lanceolatus*, *E. longispinis*, *E. macrospilos*, *E. malabaricus*, *E. melanostigma*, *E. merra*, *E. miliaris*, *E. multinotatus*, *E. poecilonatus*, *E. polyphkadion*, *E. rivulatus*, *E. spilotoceps*, *E. tauvina*, *E. tukula*, *E. chabaudi*, *E. epistictus*, *E. flavocaeruleus*, *E. morrhua*, *E. socialis*, *E. undulosus* and *E. acanthistus* were landed, whereas (28) comprising *E. areolatus*, *E. bentoides*, *E. chlorostigma*, *E. coeruleopunctatus*, *E. coioides*, *E. diacanthus*, *E. fasciatus*, *E. fuscoguttatus*, *E. hexagonatus*, *E. lanceolatus*, *E. longispinis*, *E. macrospilos*, *E. malabaricus*, *E. melanostigma*, *E. merra*, *E. miliaris*, *E. multinotatus*, *E. poecilonatus*, *E. polyphkadion*, *E. rivulatus*, *E. spilotoceps*, *E. tauvina*, *E. tukula*, *E. epistictus*, *E. flavocaeruleus*, *E. socialis*, *E. undulosus* and *E. acanthistus* were visually observed off the Kenyan south coast marine waters. Only two species, *Epinephelus chabaudi* and *Epinephelus morrhua* were not visually observed during the surveys (Fig. 2).

*Epinephelus fasciatus* dominated the landings with 54 individuals followed by *E. malabaricus* (36) and *E. coeruleopunctatus* (31). In the visual surveys, only two species *Epinephelus fasciatus* (64) and *E. coeruleopunctatus* (43) registered counts above (31) individuals. *Epinephelus fasciatus* was still the most dominant species amongst the visual observations (Fig. 2). The two groups proportion using  $\chi^2$  test of proportions (Table 2) was found generally not differing ( $p > 0.05$ ) in Msambweni ( $p = 0.339$ ) and Shimoni ( $p = 0.067$ ). Vanga however had a slight difference ( $p = 0.030$ ) similar to that observed, when total landings and total visual observations were compared ( $p = 0.011$ ). In terms of species diversity using Shannon-Wiener diversity index analysis (Table 3),

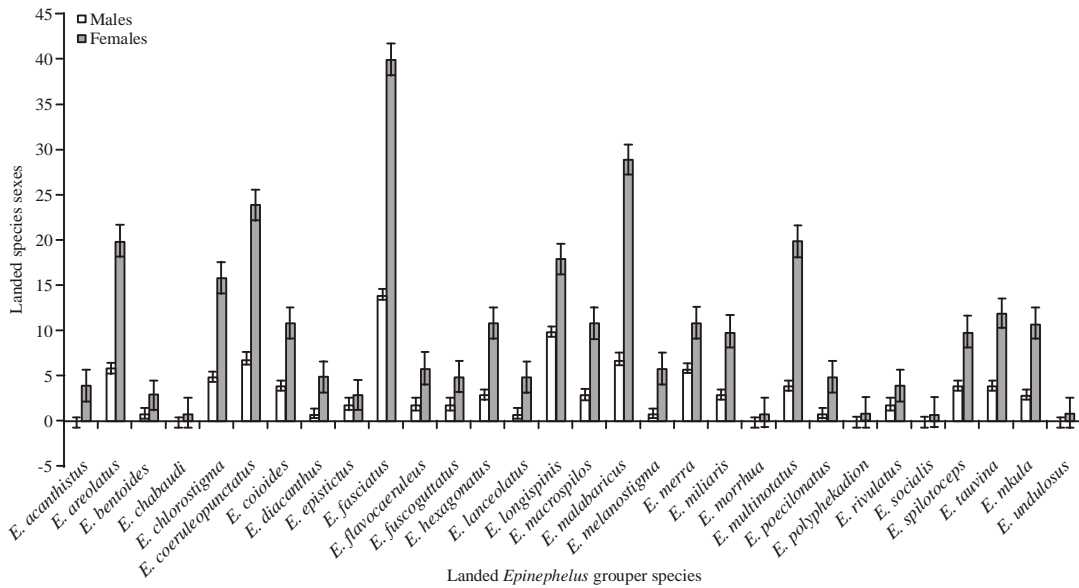


Fig. 3: Landed (Numbers±SE) Kenyan south coast artisanal *Epinephelus* genus fish sex ratios. Vertical bars represent standard error bars

Table 3: *Epinephelus* genus groupers diversity off Kenya’s south coast marine waters

Landed <i>Epinephelus</i> genus species groupers	Msambweni	Shimoni	Vanga
Different species landings	20	23	18
Total no. of landed individuals	77	223	101
Species dominance contributions	0.07303	0.06308	0.08832
Shannon-wiener H'	2.769	2.916	2.627
Evenness-e <sup>^</sup> H/S	0.7969	0.8031	0.7686

Shimoni had the highest diversity index at 2.916 in respect to its 223 landings involving the landed 23 species. Vanga with 101 landings involving 18 species was second with a diversity contribution of 2.627 whereas Msambweni was last with a diversity index of 2.769 for the 77 landings involving 20 species. The species abundances were generally lower and had varying distribution patterns. Eleven were coastally distributed, (5) restricted mainly to Msambweni whereas Shimoni and Vanga had restriction distribution of one species each. This made some species not to be landed in certain areas or where landed, were less than five individuals. This made the distribution approximation using the  $\chi^2$  p-value invalid and the samples had to be pooled into two categories to attain the  $\chi^2$  p-value distribution approximation threshold (Table 4). The first consisted of small and medium sized species growing to 31-76 cm adult growth lengths whereas the second consisted of the larger bodied and mobile ones growing to 80-234 cm. The analysis thereafter revealed no significant distribution pattern differences between the categories (p-value>0.05) within the study sites. The small and medium sized species (p-value = 0.416) and the larger sized and mobile ones (p-value = 0.085). A slight significant difference (p-value = 0.030) however existed on the distribution of the total landed species within the sites.

**Species sex ratios and reproductive patterns:** A total of 401 individuals were examined during the study. The North East Monsoon (NEM) season data had 115 individuals whereas the South East Monsoon (SEM) had 286. The individuals ranged from 13-77.9 cm in sizes with their female dominated sex ratio data depicted in Fig. 3. The encountered monthly gonadal

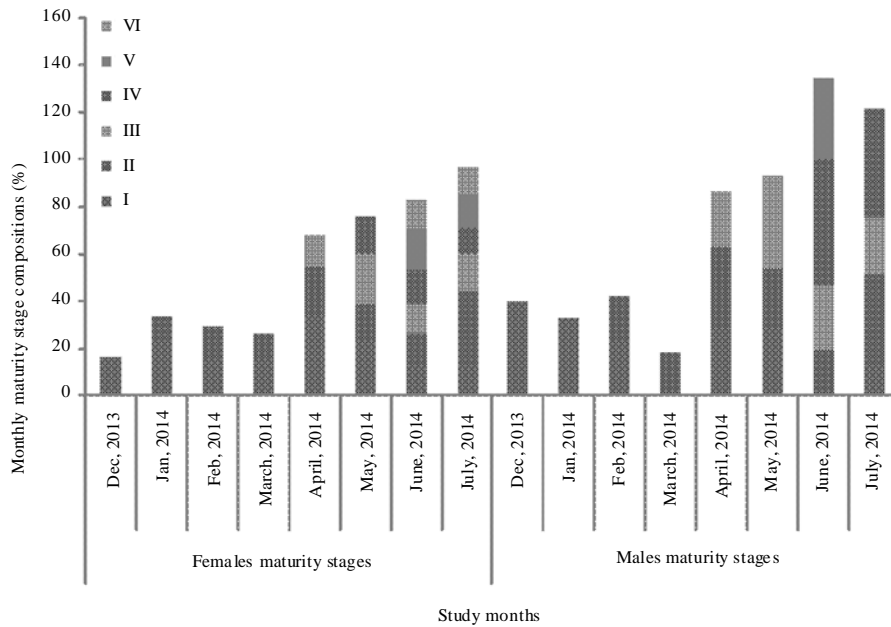


Fig. 4: Monthly gonadal maturity stage contributions of the landed *Epinephelus* genus groupers during the study period

Table 4: Pooled species distribution patterns during the study, N = landed numbers, p-value (probability of significance at  $\alpha = 0.05$ )

Pooled species landings	Msambweni	Shimoni	Vanga	N	$\chi^2$	p-value
Small and medium sized	45	162	76	283	2.055	0.416
Large sized and mobile	32	61	25	118	4.926	0.085
Total	77	223	101	401	6.981	0.030

maturity stage contributions for the landed *Epinephelus* genus groupers off the Kenyan south coast inshore marine water fisheries were also as depicted in Fig. 4.

The overall monthly reproductive patterns depicted by fish maturity stages for the encountered *Epinephelus* genus grouper species varied throughout the entire study period (Fig. 4). Inactive fishes (stages I-II) dominated in the first 6 months of study (December, 2013; January, February, March, April and May, 2014). Active, ripe and spent fishes (stages III, IV, V and VI) were mostly encountered as from April to July, 2014 (SEM season). The inactive fishes with 248 individual landings contributed approximately 61.85% of the total landings during the entire study period. Active fishes with 79 individual landings 19.70%, ripe fishes with 67 individuals 16.71% and spent fishes of 7 individuals 1.75%. Therefore, taken from the analyzed 401 samples, the gradual increase in the active and ripe stage fishes indicate that the period of highest reproductive activity is from April-July that falls within the SEM season. Active (stage III) and ripe fishes (stages IV-V) were not encountered from December, 2013-March, 2014 during the NEM study period. Inactive stage fishes (I-II) were however, encountered in all the four months of NEM study period [December, 2013-March, 2014]. The highest occurrence frequency of these inactive stage I-II fishes was encountered from December, 2013-March, 2014 during NEM season. This was followed by gradual occurrence of other stages maturity contributions and by June-July, 2014 all the six fish maturity stages were observed. During the SEM study period [April-July, 2014] (Fig. 4), ripe (stages IV-V) and spent (stage VI) fishes were not encountered in April whereas only ripe and spent (stages V-VI)



fishes were not encountered in May. All maturity stage (stages I-II, III, IV-V and VI) fishes were encountered in June and July with only spent fishes (stage VI) not being encountered amongst males.

Although, some grouper species are known to spawn over 6-8 months, most spawn over 1-5 months and many spawn primarily during 1-2 months (Shapiro, 1987). Consistent with these observations, the study of changes in gonad development and seasonal variation in mean GSI indicated a gonadal activity from April to July with peak spawning activities in June and July (Fig. 4) falling within the SEM season. The rough oceanographic conditions and colder temperatures in SEM (McClanahan, 1988), contrast with the calm oceanographic and warmer temperatures in NEM season. So, the marked fluctuations in sea surface temperatures between SEM and NEM could have been the cause of the observed heightened spawning of the *Epinephelus* genus groupers in SEM. But generalization of the observation becomes tricky since according to Shapiro (1987) no factor or combination of factors including water temperature, changes in water temperature, day length, plankton abundance or latitude clearly explains the variability in time of the year at which groupers spawn. More work is therefore still required on the aspect.

## DISCUSSION

Globally, the abundance and sizes of natural grouper fish populations continues to rapidly decline due to enhanced fishing pressure (MEA., 2005; Bini *et al.*, 2005; WWF., 2006; Rhodes and Tupper, 2007) demonstrating the fish's vulnerability even to relatively low fishing pressures (Kaunda-Arara *et al.*, 2003; Bostford *et al.*, 2007). This decline was clearly portrayed by the varying abundances and diversity of the landed and visually observed *Epinephelus* genus groupers found existing within the Kenyan south coast inshore marine waters (Fig. 2). However, lack of previous distribution and diversity data on these fishes made it difficult to compare their current status. The observations were therefore, assumed to have probably resulted from differences in fishing pressure, habitat characteristics, food availability or recruitment variability of the involved species and larval re-seeding effect by the restricted Kisite-Mpunguti Marine Park which is close to Shimoni fishing village. Regardless of the reason, the species modal size classes were also mostly below the reported sizes at first maturity for most groupers (Mangi, 2006) suggesting that the Kenyan grouper fisheries may be experiencing growth overfishing (Thomson and Munro, 1983), which occurs, when large fishes are increasingly being harvested as a result of excessive effort. It could have been also due to the subsistence nature of the inshore fisheries along the Kenyan coast, where deepening poverty has led most residents to turn to fishing (McClanahan *et al.*, 2008).

The distribution pattern analysis (Table 2), showed no clear distribution difference evidence between the two categories using  $\chi^2$  approximation test with the small and medium sized category having ( $\chi^2$  contribution = 2.055, 1 df, p-value = 0.416) and the larger sized and mobile ones having ( $\chi^2$  contribution = 4.926, 1 df, p-value = 0.085) even with different numbers being landed at the sites. There was however higher species dominance landings during (SEM) season compared to (NEM) season. These seasonal species dominance differences may be explained by the increased reproductive activity during SEM, where the rough oceanographic conditions favoured heightening of their reproductive activity (McClanahan, 1988) in accordance to their sedentary K-strategist life histories. The landing of eleven species in all the three study sites may also be attributed to the similar geo-spatial distribution of the fringing reef from Msambweni to Vanga providing suitable macro-habitat uniformity required by the nearly all grouper species. However, the existing minor microhabitat differences influenced by topographic complexity including protection measures and

fishing effects amongst others (Sale, 2004; Kaunda-Arara and Rose, 2004) excluded some species from certain sites. Thus, *E. flavocaeruleus*, *E. chabaudi*, *E. socialis*, *E. undulosus* and *E. morrhua* were restricted only in Msambweni, while *Epinephelus polyphekadion* in Shimoni and *Epinephelus acanthistus* in Vanga. Secondly, the distributions may have resulted from the species movement patterns (Chapman and Kramer, 2000; Marnane, 2000; Stewart and Jones, 2001; Bolden, 2000; Eristhee and Oxenford, 2001; Patterson III *et al.*, 2001). The extent to which these movements structure the populations still remains unclear and more multi-scale spatial and temporal movement studies are needed to determine the scales at which they vary and structure the populations.

In nature, the groupers male: Female sex ratio proportions in a population is expected to be 1:1 and any deviation may only happen due to differential sex behaviours, environmental conditions and fishing pressure amongst other reasons. During the study, (24) landed species had significantly skewed sex-ratios in favour of females (Fig. 3). This type of skewed female grouper sex-ratios had been previously reported to arise from their biological and distribution characteristics; differences in spatial distribution; and schooling behaviour between sexes (Jones *et al.*, 2005; Rhodes and Tupper, 2007). The overall male: Female sex-ratios during the study, ranged from 1:1.5-1:6 with active females being observed during April-July coinciding with the SEM season indicating higher spawning aggregations of the sexes at the spawning sites.

## CONCLUSION

A total of thirty *Epinephelus* genus grouper species with varying site restricted distribution patterns were found existing within Kenya's south coast marine waters. The species were dominated by the small bodied *Epinephelus fasciatus* landings at 13.5%. The species showed narrow distribution patterns with *E. rivulatus*, *E. poecilonatus*, *E. bentoides* and *E. polyphekadion* being recorded only in Shimoni; *E. flavocaeruleus*, *E. chabaudi*, *E. socialis*, *E. undulosus* and *E. morrhua* in Msambweni. The *E. acanthistus* was only in Vanga. Others including *E. diacanthus*, *E. spilotoceps*, *E. hexagonatus*, *E. epistictus*, *E. miliaris*, *E. areolatus*, *E. macropilos*, *E. coioides* and *E. lanceolatus* existed in at least two of the sites. The rest (*E. fasciatus*, *E. malabaricus*, *E. longispinis*, *E. chlorostigma*, *E. coeruleopunctatus*, *E. multinotatus*, *E. merra*, *E. melanostigma*, *E. tukula*, *E. fuscoguttatus* and *E. tauvina*) were in all sites. Eighteen (18) species also exhibited increased reproductive activity from April-July coinciding with the southeast monsoon (SEM) season suggesting the need for restricted fishing seasons. Further studies to ascertain the species preferred habitat spatio-temporal distributions are however required to provide conservation and ecosystem protection information data.

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