

Confirmed Sighting of a Spawning Aggregation of the Brown-marbled Grouper, *Epinephelus fuscoguttatus*, in Kenya

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Abstract — The occurrence of spawning aggregations at fixed sites and times is well documented for several species of reef fish. These aggregations are known to attract fishers and such species may therefore be vulnerable to overfishing. This is particularly true in the case of groupers which have intrinsically vulnerable life history traits. The brown-marbled grouper, *Epinephelus fuscoguttatus*, distributed throughout the Indo-Pacific region and classified by IUCN as Near Threatened, is reported to form spawning aggregations but little is known about its spawning behaviour; in the Western Indian Ocean this has only been reported for the Seychelles. This study confirmed spawning aggregation behaviour in *E. fuscoguttatus* in Kenya based on underwater observations and fishers' knowledge of the phenomenon. We showed that *E. fuscoguttatus* forms short aggregations for ~5 days linked to the new moon for a 3-4 month period during the northeast monsoon (austral summer). The numbers of aggregating fish appear to be low, however, and the species is currently not managed in Kenya. Considering the fact that only small areas of the Kenyan coastline are under total protection (8.6% of the country's coral reefs), these factors suggest that there is an urgent need for additional management of *E. fuscoguttatus* if it is to survive in Kenya.

INTRODUCTION

The brown-marbled grouper, *Epinephelus fuscoguttatus* (Epinephelidae) (Forsskål 1775), is widely distributed throughout the Indo-Pacific region (Heemstra & Randall, 1993) and is known to form spawning aggregations (Johannes *et al.*, 1999; Pet *et al.*, 2005; Robinson *et al.*, 2008a; Rhodes *et al.*, 2012). In the western Indian Ocean, *E. fuscoguttatus*

has been reported by fishers to form spawning aggregations in Kenya (Samoily *et al.*, 2006; Robinson *et al.*, 2013) but little is known about their spatio-temporal formation. The reproductive biology of this species remains unstudied in eastern Africa, with the exception of reports of spawning in the northeast monsoon (October to March) period (Nzioka, 1979).

Epinephelus fuscoguttatus is not considered an abundant grouper (Pears *et al.*, 2006) and, in Kenya, it is rare in artisanal catches, with only 24 individuals recorded in southern Kenya over a six-month period in 2007 (Agembe *et al.*, 2010). Due to its large size, it comprises a relatively important proportion of the biomass of reef fishes captured. In Kenya, it is targeted by speargun and handline, however catches are so small that they are not reported separately (WIOFish database (www.wiofish.org); McClanahan & Mangi, 2004).

Global concern over the status of *E. fuscoguttatus* populations led to its Near Threatened Redlist classification by the IUCN Groupers and Wrasses Specialist Group in 2007 (IUCN, 2015). Concerns over the status of the species in Kenya have arisen due to our awareness of two spawning aggregations within the Diani-Chale Reserve on the south coast of Kenya, an area not under active management and which does not include no-take zones (Robinson *et al.*, 2008a). There are anecdotal reports of targeted fishing of these aggregations for the local tourism market and catches of *E. fuscoguttatus* have been observed with running ripe gonads (MS pers. obs), suggesting aggregation fishing.

Epinephelus fuscoguttatus inhabits depths of up to 60 m (Heemstra & Randall, 1993) and may therefore be partially protected within a natural depth refuge (Tyler *et al.*, 2009; Mangubhai *et al.*, 2011; Rhodes *et al.*, 2012) since fishers in Kenya have less access to the seaward reef slopes where these fish occur. Boats are still largely not mechanised (Samoilyls *et al.*, 2011), preventing easy access to these sites, and the winds of the south-eastern monsoon (4-5 months) are prohibitively strong. However, with technological developments, notably the growing use of outboard engines, increasing effort by new fishers within an open access fishery (Samoilyls *et al.*, in review), and the intrinsic vulnerability of *E. fuscoguttatus* due to its life history characteristics (Robinson & Samoilyls, 2013a), this species is probably highly vulnerable to overexploitation in Kenya.

Fisher interviews were undertaken regarding *E. fuscoguttatus* spawning aggregations on the south coast of Kenya as part of a larger fisher knowledge survey of spawning aggregations in key fishery species (Samoilyls *et al.* 2006; Maina *et al.*, 2013; Samoilyls *et al.* 2013). Key informants and experienced fishers known

to target *E. fuscoguttatus* were questioned on their knowledge of spawning aggregation sites, behaviour and timing, based on established indicators defined by Colin *et al.* (2003). Fishers' descriptions considered reliable were assessed against established indicators, such as increased fish abundances (at least four-fold), courtship, territoriality, reproductive colouration, gravid females and gamete release. They reported that aggregations formed between January and April but were less knowledgeable concerning spawning behaviour or lunar timing (Samoilyls *et al.* 2013).

There is strong evidence that targeted spawning aggregation fishing is rarely sustainable (Sadovy & Domeier, 2005). This fact, combined with the life history characteristics of *E. fuscoguttatus*, viz. slow growth, late maturity and long life (Pears *et al.*, 2007), highlight the need to identify the management requirements of this species both at and apart from spawning sites vulnerable to fishing. This study was designed to verify a previously reported aggregation site in the Diani-Chale Reserve on the south coast of Kenya, describe the spawning behaviour of the species and determine the seasonal and lunar periodicity of aggregation formation. Aspects of the work presented in this paper were published (Samoilyls *et al.*, 2013) in an integrated and multi-disciplinary study of groupers in Kenya, Seychelles and Zanzibar (Robinson & Samoilyls, 2013b). The purpose of the present publication is to report the behaviour of *E. fuscoguttatus* in spawning aggregations to a wider audience and highlight the continuing lack of fisheries management of this species in East Africa, despite its vulnerable status.

METHODS

Study site

The study area was approximately 25 km south of Mombasa, and extended from Tiwi (4°12'36"S; 39°37.06"E) in the north to Chale Island off Gazi Bay (04°27'807"S; 39°32.158E) in the south, in the region of Diani that encompasses the Diani Chale Marine Reserve (Fig. 1). A linear fringing reef characterises this coastline, broken by the Tiwi River in the north and Gazi Bay to the south. The fringing reef has a spur and groove structure accentuated in places to form

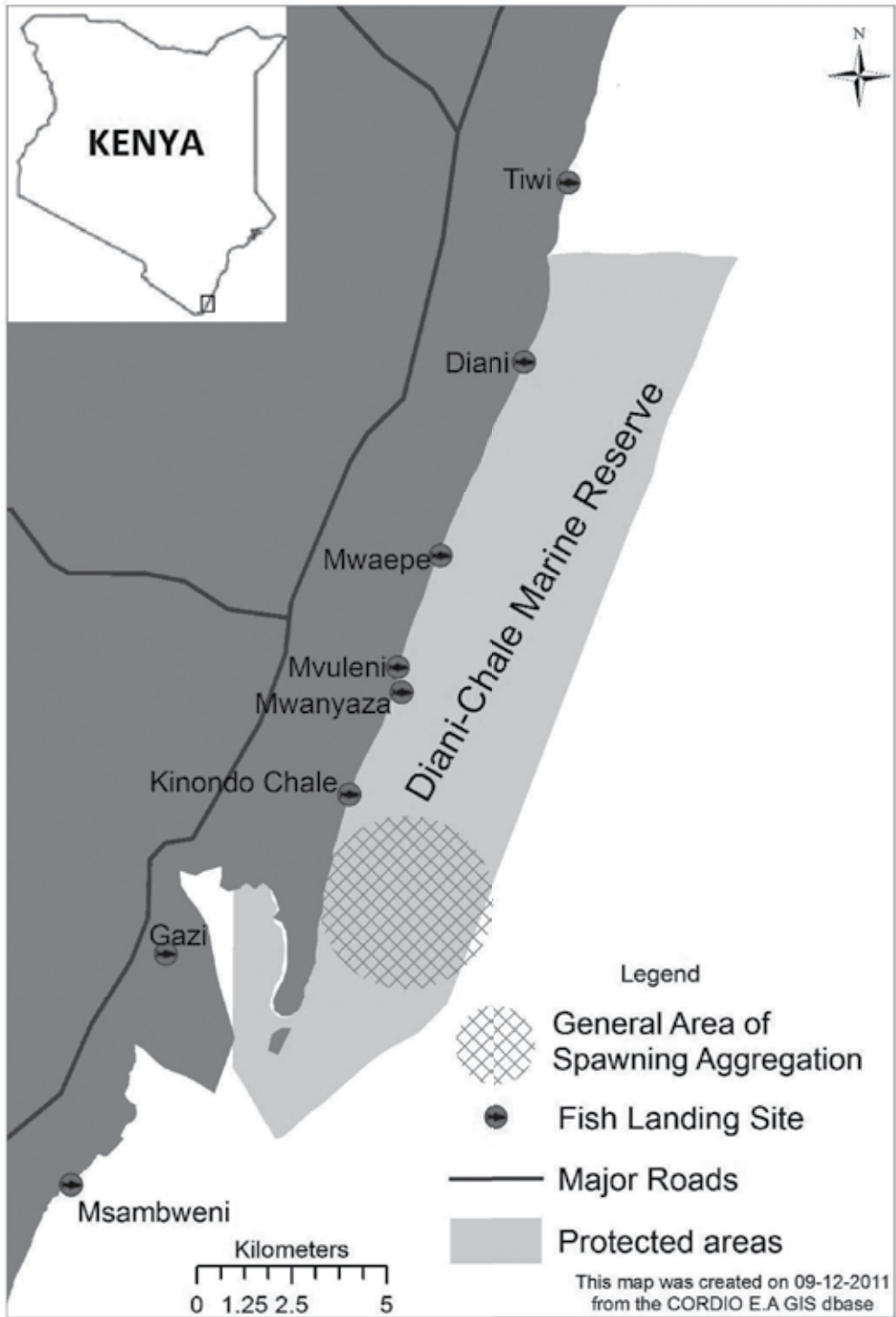


Figure 1. Study area and approximate location of the spawning aggregation site of *Epinephelus fuscoguttatus* in the Diani-Chale Marine Reserve.

promontories, and is broken by reef passages, all known and named by fishers.

Our study focused on a single *Epinephelus fuscoguttatus* spawning aggregation site reported by fishermen on the outer reef slope in the Diani area. It was subsequently identified as a potential spawning site during SCUBA observations and through further discussions with fishers. The site coordinates are not provided on the map for reasons of confidentiality.

Once numbers of *E. fuscoguttatus* were found at the aggregation site, the extent of the aggregation area, as defined by the presence of the groupers, was mapped by divers, including its depth and habitat features. The map was incorporated in the underwater datasheet for recording of fish numbers and their behaviour (Fig. 2). Co-ordinates delineating the perimeter of the aggregation site were obtained using GPS while swimming at the surface.

Underwater visual census surveys

Initial underwater visual census (UVC) counts of *E. fuscoguttatus* at the site were made during the new moon period (lunar days, LD, 25-3) of 11-18 November 2009. The new moon was selected for this, based on previous fishers' reports of lunar periodicity in the spawning of this species in Kenya and Seychelles (Samoilyš *et al.*, 2006; Robinson *et al.*, 2008b). UVC counts and behavioural observations of *E. fuscoguttatus* were repeated each month to February 2010, the period reported as the spawning season by fishers. UVC counts were also recorded during the purported non-spawning season in July-August 2010. In both seasons, censuses were always undertaken during a seven-day period over the new moon (LD 27-3, where 1=new moon). One full moon period (LD 17-18) was also surveyed (31 Jan-1 Feb 2010). We calculated the non-spawning density of *E. fuscoguttatus* from surveys conducted in July and August (winter), based on the fact that fishers reported that spawning aggregations occur only in summer months and studies of this species in the Pacific have revealed strong seasonality in its reproductive pattern, with a peak aggregation abundance over 3-4

months (Hamilton *et al.*, 2012; Rhodes *et al.*, 2012). We used criteria provided by Colin *et al.*, (2003) and Domeier (2012) to confirm the presence of spawning aggregations, considered to be fish abundances at least four times that of non-reproductive periods.

Abundances were estimated from counts made by a single diver along a set path around the site during a 30-min swim on SCUBA. Counts started along the deeper ledges (maximum depth 25 m) and finished in shallower areas closer to the reef crest (minimum depth 10 m). Swims consistently covered the same route and area, and were undertaken by one of two trained observers (MS, DM) to minimise observer bias. Although fish were sometimes mobile and visibility was often poor (around 10 m), biases caused by double counting were assumed to be consistent between counts. Fish location and size (in 5 cm size classes) were recorded on the datasheet map.

The presence of *E. fuscoguttatus* and spawning-related behaviour were recorded during all surveys, based on established criteria: a distinct reproductive colouration in males, courtship, swollen abdomens in females, male-to-male aggression and fish suspended unusually high in the water column (Samoilyš, 1997; Johannes *et al.*, 1999; Colin *et al.*, 2003; Robinson *et al.*, 2008b), bearing in mind that sexing this species underwater is uncertain. Following abundance counts, fish behaviour was recorded over a 10 min period to estimate the frequency of occurrence of the above events. Visual estimates of the size of fish engaging in spawning-related behaviour were also recorded. Still digital photographs of behaviour were recorded using a Nikon Coolpix camera (Nikon Inc., Melville, NY).

RESULTS

Spawning aggregation site

Spawning aggregations of *Epinephelus fuscoguttatus* were verified at the site, based on a combination of their increase in abundance above non-reproductive levels and observations of spawning-related behaviour. The area of the site was estimated to be 2744 m². It was

characterised by abundant soft corals on the upper slope (ca 10 m depth), which shelved gently (ca 25°) to the reef edge at 15-16 m depth (Fig. 2), where it dropped steeply to >30 m. The reef slope was high in relief with ledges, caves and overhangs. The site was bounded by a reef

passage to the north and a continuous reef slope to the south. *E. fuscoguttatus* were observed aggregating along the upper reef edge near the overhangs and caves, and also on the upper, more open reef slope at depths of 12-18 m.

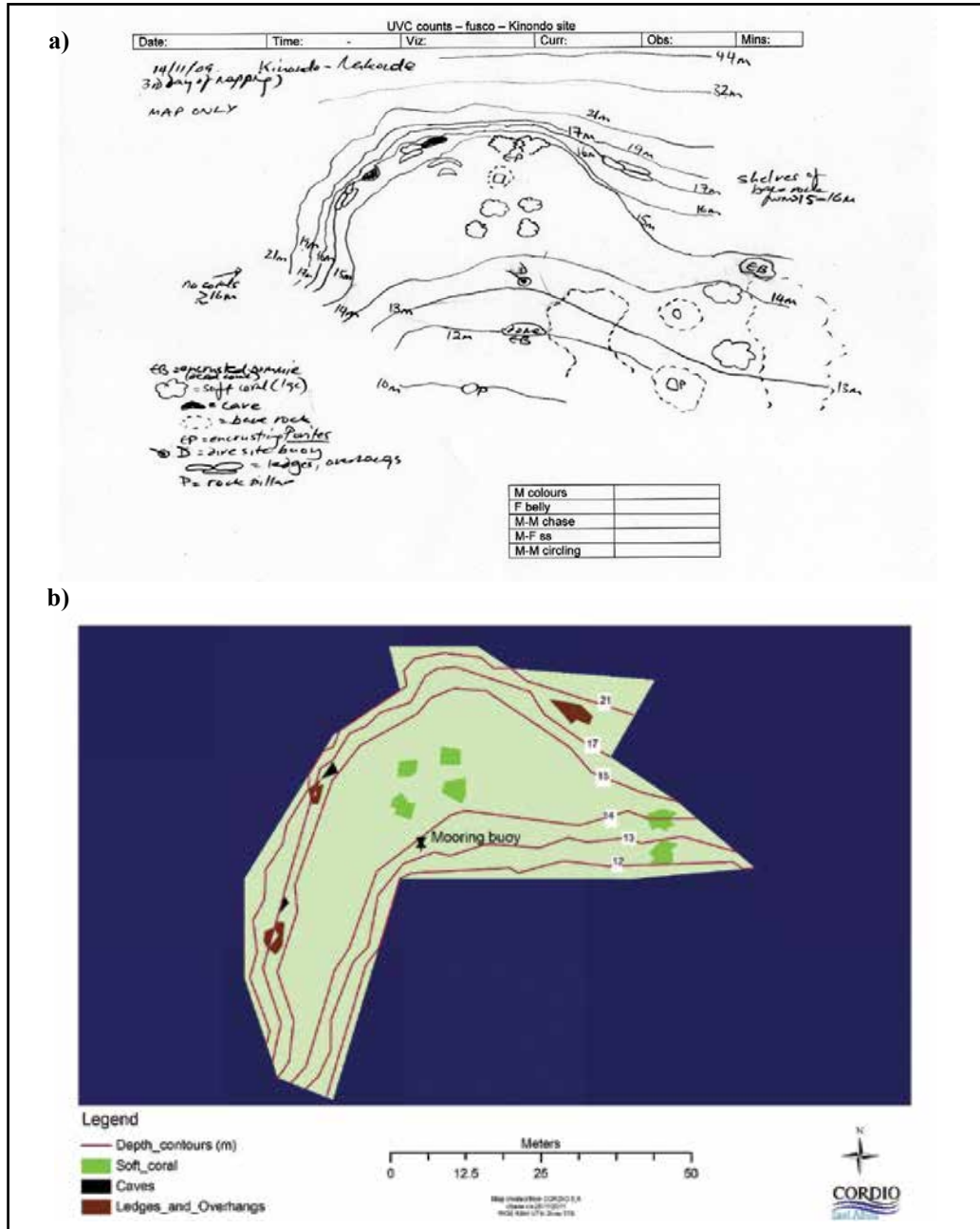


Figure 2. *Epinephelus fuscoguttatus* spawning aggregation site: a) diagrammatic map used as datasheet to record numbers and behaviour of fish and b) GIS map from GPS co-ordinates of the site perimeter, contours and features.

Size and periodicity of spawning aggregations

Relatively high numbers of *E. fuscoguttatus* were observed at the site from November 2009 to February 2010 with maximum monthly estimates ranging from 16 to 32 (Fig. 3). Numbers of *E. fuscoguttatus* in July and August, the putative non-spawning winter months, were lower, particularly in August when only three fish were observed. In contrast, a maximum of 13 fish were recorded in July (Fig. 3). We calculated the mean non-spawning density to be 6.0 fish (± 2.5 SE) during these winter months, though the sample size was limited ($n=4$ counts). Based on the published criteria of an at least four-fold increase in numbers (Domeier, 2012), 24 fish would therefore constitute a spawning aggregation of *E. fuscoguttatus*. Counts from November to February (LD 28-2) ranged from 10 to 32 ($n=9$), with a mean of 21.3 (± 2.6 SE), indicating that only some aggregations in December-February could be defined as spawning aggregations, while some densities were no different from those in July (Fig. 3).

Daily counts relative to lunar period indicated that the *E. fuscoguttatus* aggregations formed around the new moon (Fig. 4). A gradual increase in the numbers at the site was observed just prior to the new moon (LD 29) with peak numbers observed on LD 1. Exploratory surveys beyond the southern boundary of the site at new moon in

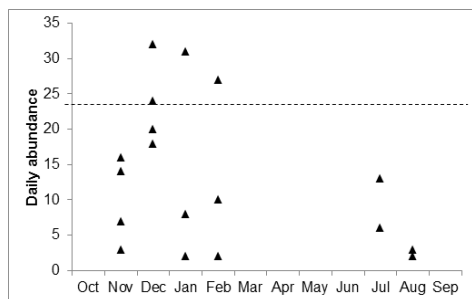


Figure 3. Seasonal pattern in abundance of *Epinephelus fuscoguttatus* at the spawning aggregation site (ca 2 744 m²). Data are total counts from daily UVC surveys. The dashed line represents the minimum abundance (24 fish) that constitutes an aggregation based on the criterion of at least a four-fold increase in fish density.

February 2010 yielded three *E. fuscoguttatus* (two males and one female). Aggregation numbers decreased abruptly on LD 2 and 3, suggesting fish had departed from the site. Unfortunately it was not possible to conduct surveys throughout a lunar cycle, but lower numbers of fish were observed during the full moon period (Fig. 4). Diel changes in aggregation abundance during LD 28-2 in December-February were not apparent. Diurnally, aggregation numbers were high (>25) by 0900 hr and throughout the day, though data were few.

Verification of spawning behaviour

Fish behaviour indicative of spawning was observed providing strong evidence for reproductive aggregations of *E. fuscoguttatus*. All five behavioural indicators were observed repeatedly during the new moon periods of December, January and February. These are described in Table 1 and their frequency presented in Table 2. However, spawning rushes and gamete release were never observed.

Males did not appear to defend territories but rather moved within small areas that seemed to be close to or overlapping that of other males. For example, in December 2009 (LD 1) we observed two males and two females together in a small area, approximately 5x5 m. Male-male aggression appeared in two forms (behaviour 4, Table 1), though chasing was more frequent (Table 2).

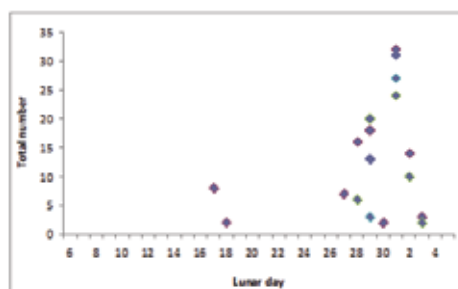


Figure 4. Lunar periodicity in numbers of *Epinephelus fuscoguttatus* at the spawning aggregation site during the reported spawning season (November-February).

Table 1. Spawning-related behaviour observed amongst *Epinephelus fuscoguttatus* at the aggregation site during the new moon period based on known criteria (Colin *et al.*, 2003). The timing and frequency of these behaviours are provided in Table 2. The normal colour of *Epinephelus fuscoguttatus* is shown for comparison (behaviour 1).







Behaviour and appearance	Description
<p>1. Normal colour</p> 	<p>Normal colour of male and female <i>Epinephelus fuscoguttatus</i> – black splotches on pale brown background.</p>
<p>2. Male colouration</p> 	<p>The usual brown-and-black marbled colour pattern (see 1) disappears completely; fish display white ventrally, on the opercula and the dorsal, caudal and anal fins. Fin edges darken to black, and dorsal half of body darken. When in this colour pattern, males swim slowly around and above the coral. Also court in this colour pattern (see 5). Assumed to be dominant males displaying to females within their territory. Possibly not all males display this colouration.</p>
<p>3. Female swollen with eggs</p> 	<p>Female with clearly swollen abdomen, probably due to hydrating eggs expanding the gonad; normal colouration.</p>
<p>4. Male aggression</p> 	<p>Fish assumed to be males based on behaviour but not in male colouration. Two behaviours were observed:</p> <ol style="list-style-type: none"> An individual chases another away from its area, swimming rapidly and following opponent for up to <i>ca</i> 10 m. Assumed to be males contesting territories. Two individuals circling tightly head to tail, moving very slowly; as one moves away (possibly a submissive response), the other uses its lips to audibly hit opponent on the caudal peduncle area. Some individuals were scarred with superficial wounds, while others were more severely injured. For example, one fish had a badly torn upper lip. These injuries were assumed to be from male-male aggression.
<p>5. Courtship</p> 	<p>Male in spawning colours (see 2) swims slowly, close to a female (see 3) and turns sideways towards her, then shakes his body while swimming slowly past her. This display lasts <2 min and was sometimes repeated to the same female within 10 to 15 minutes of the first encounter.</p>
<p>6. Suspended in the water column</p> 	<p>Fish stationary, or moving slowly, at least 1 m above the substratum. Individuals hovered over the same area where other fish were aggregating. This behaviour continued for 5-10 minutes. The fish were assumed to be males, but were not displaying male courtship colours (behaviour 2). This was assumed to be pre-spawning behaviour.</p>

Table 2. Frequency of *Epinephelus fuscoguttatus* spawning-related behaviour at the spawning site in spawning (December-February) and non-spawning months (July-August). Data comprise the number of individuals observed exhibiting a behaviour within the census period (30 min counts followed by 10 min observations). Numbers in parentheses refer to behaviour described in Table 1; an asterisk denotes pairs of fish. NM=new moon; FM=full moon.

Month & lunar stage	Colour change (2)	Gravid female (3)	Male-male chase (4a)*	Male-male, head to tail (4b)*	Courting (5)*	Suspended in water column (6)
Dec NM	31	11	7	1	3	5
Jan NM	7	5	2	0	5	0
Feb NM	7	6	2	0	3	0
Jan-Feb FM	2	2	0	0	1	0
Jul-Aug	0	0	0	0	0	0

Courtship behaviour was performed by the male with the female stationary on the reef bed (behaviour 5, Table 1). Observed courtship acts involved a male swimming slowly past a female, turning sideways to her and quivering his body. Males either engaged in multiple courtship acts with the same female, or with several females. Courtship behaviour ceased if divers approached too close. Females were observed hidden within the reef topography or lying close to the substratum; in one instance, a male was observed courting a female that was hidden within the reef.

Fish size and sex ratios in spawning aggregations

Twelve pairs of *E. fuscoguttatus* were observed courting and, in all but one case, the male was larger than the female. The modal size class of courting fish was 81-85 cm TL for males and 71-75 cm TL for females. Since it is possible to determine the sex of males when they are in courtship colouration or showing male-male aggression (Table 1), the approximate proportion of males in an aggregation could be calculated. This ranged from 7 to 64%, the mean being 35% ($\pm 7.3\%$ SE). Consistently higher proportions of males in aggregations (mean = 46%) were observed during the December new moon when most spawning-related behaviour was recorded (Table 2). Size frequency plots of the aggregations revealed that the minimum size of aggregating fish was 56-60 cm TL (December) and the maximum size was 96-

100 cm TL (November; Fig. 5). Monthly size frequencies showed that the largest fish were present only during the months of November, December and January.

DISCUSSION

Observations of spawning-related behaviour at the aggregations site, increased densities of fish and fishers' knowledge all combined to provide strong evidence for the occurrence of *Epinephelus fuscoguttatus* spawning aggregations at a site on the south coast of Kenya. A likely second spawning aggregation site approximately 23 km north of the study site has also been reported (Samoilyls *et al.*, 2013), providing some indication of the geographic scale at which these aggregations might occur.

The spawning behaviour of *E. fuscoguttatus* observed in Kenya is typical of many groupers that spawn in pairs within aggregations (Samoilyls & Squire, 1994; Samoilyls, 1997; Johannes *et al.*, 1999; Robinson *et al.*, 2008b). The distinct colour changes and swimming high in the water column by males have been previously described in *E. fuscoguttatus* spawning aggregations in Palau and the Seychelles (Johannes *et al.*, 1999; Robinson *et al.*, 2008b). Strong territorial behaviour by males at aggregation sites, such as that observed in the smaller, more mobile grouper, *Plectropomus leopardus* (Samoilyls, 1997), was not apparent. Although aggressive encounters between males occurred, the demarcation of territories was not apparent. A lack of male aggression

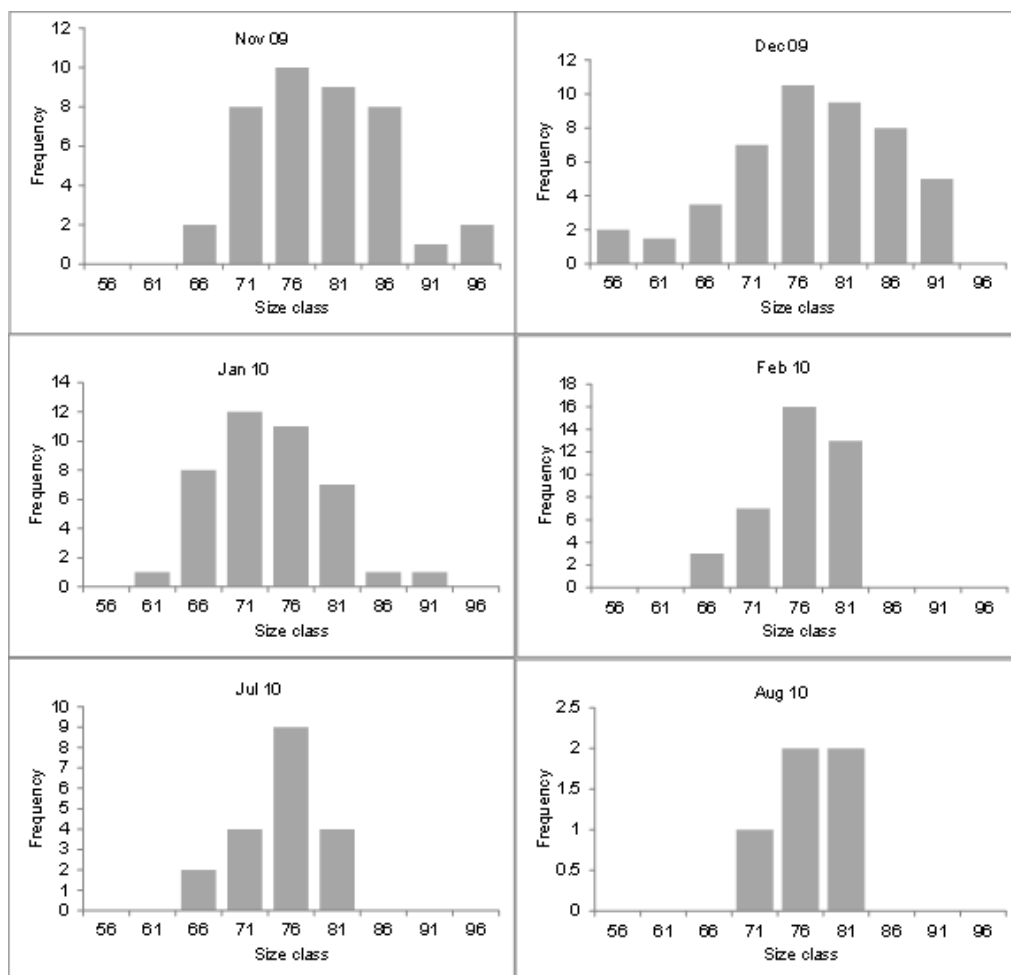


Figure 5. Size structure of the *Epinephelus fuscoguttatus* population at the spawning aggregation site during the spawning (November-February) and non-spawning months (July-August), based on underwater estimates of fish sizes to 5 cm. Samples comprise pooled data for each month (total numbers of fish are shown in Fig. 3).

in this species during the development of a spawning aggregation has been documented in the Seychelles, where the level of aggression increased with aggregation density (Robinson *et al.*, 2008b). Clear demarcation of territories occurred in the high density aggregations at Farquhar Atoll, with males regularly chasing other males (Robinson *et al.*, 2008b). The lack of territorial behaviour in males at the Kenyan site may reflect the low densities that characterised these aggregations.

Spawning rushes and the release of gametes, direct evidence that aggregations have formed for the purpose of spawning,

were not observed. This may be due to the SCUBA observations being limited to between 0900 and 1700 for safety reasons, since the sites were seaward of the fringing reef. However, courtship behaviour was observed as late as 1650, suggesting that spawning occurred after that, as appeared to be the case in the Seychelles (Robinson *et al.*, 2008b). Other grouper species are known to spawn during a narrow window before, during and after sunset (Colin *et al.*, 1987; Samoilys, 1997; Domeier & Colin, 1997; Heyman *et al.*, 2005; Rhodes & Sadovy, 2002). The proportion of males in aggregations, 45%

during December, is high for a protogynous grouper in which the sex ratios are normally female-biased (Pears *et al.*, 2007). This may be due to females remaining hidden in the reef and, therefore, undetectable during the UVC surveys. An observation of a male courting a female hidden deep within the reef supports this. Alternatively, sex ratios in aggregations may not mirror the overall population sex ratio, especially if females do not attend every aggregation (Rhodes *et al.*, 2012).

Our UVC surveys did not provide conclusive evidence of reproductive seasonality because counts were not continued throughout the year or the lunar month. However, the survey estimates of a three-month season (December-February) partially overlap fisher reports of a four month period (January-April, Samoilyls *et al.*, 2006). Monitoring of acoustically tagged *E. fuscoguttatus* in the Seychelles identified a 2-3 month aggregation period, with a reduced fish abundance in the final month. There, the spawning period started as early as November and finished as late as March (Bijoux *et al.*, 2013). Pears *et al.* (2007) found that *E. fuscoguttatus* spawns for three months (November-January) on the Great Barrier Reef, while Hamilton *et al.* (2012) reported that it spawned over 4-5 months (between December and March) in the Solomon Islands. The winter density at the Diani spawning site was relatively high in July, suggesting that reproduction may also occur in winter, a fact unknown by local fishers. However, this is not supported by studies in the Indo-pacific region in which *E. fuscoguttatus* was found to have a 3-5 month spawning season during the Austral summer.

In Kenya we found spawning aggregations occurred around the new moon (LD 28-2), which was also reported for the Seychelles (Robinson *et al.*, 2008b), Palau (Johannes *et al.*, 1999), Komodo in Indonesia (Pet *et al.*, 2005; Mangubhai *et al.*, 2011), the Solomon Islands (Hamilton *et al.*, 2012) and in captivity (Rimmer *et al.*, 2013). In contrast, the species appears to spawn just after full moon in Pohnpei, Micronesia (Rhodes *et al.*, 2012). *Epinephelus fuscoguttatus* aggregations usually develop gradually, 1-3 weeks in advance of

actual spawning. During these periods, females arrive later and stay for shorter periods than the males (Robinson *et al.*, 2008b, Nemeth, 2012; Rhodes *et al.*, 2012).

The mean number of *E. fuscoguttatus* at the aggregation site was 21.3 fish, corresponding to a density of 7.6 fish.1000 m⁻². When compared with the non-spawning count of 6.0 fish, equivalent to a density of 2.2 fish.1000 m⁻², the Kenyan aggregations of *E. fuscoguttatus* represent a 3.5-fold increase above the normal fish density. This does not strictly satisfy the Domeier (2012) definition of a four-fold increase in fishes in a spawning aggregation, and only some aggregations in December-February would comply with this requirement. Although our sample size was small, our estimate of the non-spawning density (2.2 fish.1000 m⁻²) was comparable to those of UVC surveys conducted elsewhere in the East African region where densities ranged from 0.8 (Mozambique) to a maximum of 3.2 (Tanzania) fish.1000 m⁻²; the mean density at three surveys sites was 1.8 (± 0.73 SE) fish.1000 m⁻² and zero sightings were recorded at a further 69 sites (Samoilyls, unpubl. data). *E. fuscoguttatus* aggregation sizes in Kenya thus appear small and most closely resemble those at Komodo in Indonesia, where high aggregation fishing pressure is reported (Pet *et al.*, 2005; Mangubhai *et al.*, 2011). Densities at the Kenyan site were four- to ten-fold less than those at the Solomon Islands, Palau, Micronesia and the Seychelles (Johannes *et al.*, 1999; Robinson *et al.*, 2008b; Hamilton *et al.*, 2012; Rhodes *et al.*, 2012). Fishing pressure has possibly been sufficiently intense to deplete numbers at this site. However, it is not strictly valid to assess the status of an aggregation through comparison with different sites, as aggregation size may vary substantially within the same reef system and may be inversely related or correlated to fishing pressure (Johannes *et al.*, 1999; Robinson *et al.*, 2008b; Mangubhai *et al.*, 2011). For example, at the Farquhar Atoll in the Seychelles, *E. fuscoguttatus* forms aggregations ranging in size from tens to hundreds of individuals at different sites, with the larger aggregations (68 fish.1000 m⁻²) the most heavily exploited (Robinson *et al.*, 2008b; Bijoux *et al.*, 2013).

Recent studies of groupers have demonstrated complex dynamics at aggregation sites, with the actual spawning or core site being small and nested within a larger courtship area, which is further nested within a staging area (Nemeth, 2012). This has been reported for *E. polyphekadion* and *E. fuscoguttatus* in the Seychelles (Robinson *et al.*, 2008b). Our surveys in Kenya did not determine these zones but it is likely that the aggregation site area of 2744 m² included the core area and most of the courtship area. Aggregation densities may thus vary, depending on whether the core area alone is surveyed or the fish catchment area is included. Kenya may be characterised by small aggregations of this species, but larger aggregations of *E. fuscoguttatus* may form elsewhere in southern Kenya, particularly if located on deeper fringing or submerged reefs where fishing effort is reduced (Samoilys *et al.*, 2011). Nevertheless, the relatively low numbers encountered in the study's aggregation raises cause for concern for this Near Threatened species in Kenya.

The sizes of *E. fuscoguttatus* individuals aggregating in the study aggregation conform to those of reproductively active *E. fuscoguttatus* on the Great Barrier Reef (GBR), Australia (Pears *et al.* (2006). These authors reported that this species is a long-lived protogynous hermaphrodite, with males ranging in size from 68.3 to 92.5 cm TL and mature females from 32.0 to 85.5 cm TL. No fish smaller than 56–60 cm TL were observed in the Kenyan aggregations. The change in size frequency distribution at the aggregation sites between the summer spawning and winter non-spawning periods, with fish greater than 90 cm TL being observed only during November–January, suggests that the largest males migrate to the aggregation site to spawn. These may be the males that dominate access to females, as seen in other groupers (Samoilys & Squire, 1994; Samoilys, 1997; Robinson *et al.*, 2008b).

Management implications

The long life of *E. fuscoguttatus* (≥ 40 years), the late onset of sexual maturity in females (nine years) and increasing female fecundity with age

over a ≥ 30 year reproductive lifespan (Pears *et al.*, 2006) does not confer it resilience to fishing. In fact, such life history traits are closely correlated with vulnerability to extinction (Mace & Hudson, 1999; Reynolds *et al.*, 2003; Dulvy *et al.*, 2003). These demographic factors, coupled with heavy fishing pressure and the many unmanaged fisheries for this grouper, led to it being classified by the IUCN Groupers and Wrasses Specialist Group in 2007 as Near Threatened on the Red List (IUCN, 2015). The fact that *E. fuscoguttatus* also forms spawning aggregations that appear to be spatio-temporally predictable increases its vulnerability (Sadovy de Mitcheson *et al.*, 2008). This is particularly so in Kenya where coastal fishing is not regulated by size class (both minimum and maximum size class fishery restrictions would be beneficial for this species). Additionally, the fully-protected marine areas (nationally gazetted Marine Parks) are small, protecting only 8.6% of the country's coral reef area (Spalding, 2001; Wells, 2006) in contrast with global recommendations in the order of 30% (Fernandes *et al.*, 2005). Recent reports of reproductive movements by *E. fuscoguttatus* and estimates of its catchment area suggest that large-scale marine parks are needed to protect populations of this species (Rhodes *et al.*, 2012).

A vulnerability analysis of spawning aggregations of this species revealed that they have relatively high intrinsic vulnerability (Robinson & Samoilys, 2013a). Local artisanal catches of *E. fuscoguttatus* have dwindled in recent years (Samoilys *et al.*, in review), reflected by our inability to collect adequate gonads for reproductive assessment, or to assess population abundance through catch rate analysis. Population abundance surveys on eastern African reefs using SCUBA to 30 m have also shown that this species is now rare (Samoilys, unpubl. data), possibly because of targeted fishing of aggregations of this species.

Considering the reproductive life history and small size of the *E. fuscoguttatus* aggregation we encountered, together with the small area of the Kenyan coastline under protection, there is clearly a need

for additional management measures for the conservation of this species if it is to survive along the southern Kenyan coast. The aggregation site documented here was neither managed nor protected, despite occurring within the nationally gazetted Diani-Chale Reserve. Compliance in this Reserve is not enforced due to strong local opposition by fishers. Furthermore, we know from studies in Australia (Pears *et al.*, 2006, 2007) that *E. fuscoguttatus* females need to breed for ≥ 30 years to reach their full reproductive potential and studies on spawning in this species suggest that aggregation sites are important for reproduction. We therefore recommend that management of this spawning aggregation site be discussed as a matter of urgency with all stakeholders, including local fishing communities, the hotel and dive tourism industry, and the Kenya Wildlife Service (KWS) which has authority over the Diani-Chale Reserve. Conflict between different users in this area has been ongoing for many years; however, a neighbouring fishing community in Msambweni has recently established a no-take zone to protect a spawning aggregation of the rabbitfish, *Siganus sutor* (CORDIO, unpubl. data), which provides a useful precedent. Now is the time to discuss management options, including permanent no-take zones, to protect the valuable and threatened brown-marbled grouper.

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