

Reef Fish Spawning Aggregations in the Western Indian Ocean: Current Knowledge and Implications for Management

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ABSTRACT

Studies of reef fish spawning aggregations are new to the Western Indian Ocean compared to other regions. This paper reviews the current state of knowledge of spawning aggregations in the region and assesses their implications for fisheries management and conservation. Fisher knowledge has identified more than 30 species of reef fish that aggregate to spawn, mainly belonging to the families Lutjanidae, Serranidae, Lethrinidae and Siganidae. Verification has been achieved for 25 spawning aggregations from 7 species, including five and six aggregations of *Epinephelus fuscoguttatus* and *Siganus sutor*, respectively. Reef fishes commonly spawn within the northeast (November-April) and inter-tropical monsoon periods. Serranid aggregation sites include reef passes, channels, reef slopes and pinnacles, while *Siganus sutor* spawns on patch reefs and granitic reefs. The status of spawning aggregations is poorly known and evidence of aggregation collapses are currently

confined to Seychelles. Few spawning aggregations are protected in the region and their applicability to new approaches of managing for resilience will not be realised without considerable efforts in research and advocacy. The management of spawning aggregations through marine protected areas does not constitute a solution for fisheries management and must be viewed as complementary to tools such as catch and effort controls.

INTRODUCTION

In the Western Indian Ocean (WIO) scientific information on artisanal fisheries is insufficient and management regimes require substantial improvement (van der Elst *et al.*, 2005). In areas of East Africa, overfishing may constitute the most important local threat to coral reefs (McClanahan *et al.*, 2000). Combined with the impacts of coral bleaching, coastal pollution, development and other direct and indirect causes (Samoilys & Church, 2004; Obura, 2005;

Obura, D.O., Tاملander, J., & Linden, O. (Eds) (2008). *Ten years after bleaching - facing the consequences of climate change in the Indian Ocean. CORDIO Status Report 2008. Coastal Oceans Research and Development in the Indian Ocean/Sida-SAREC. Mombasa.* <http://www.cordioea.org>

Payet, 2005), problems in the region often appear intractable. Marine protected areas (MPAs) or reserves are increasingly viewed as a solution to a global fish crisis (Gell & Roberts, 2003; Halpern 2003). While the functioning of MPAs for conservation objectives is not in doubt, improving their use for fisheries management requires filling significant scientific gaps in their application and design (Sale *et al.*, 2005).

In the context of coral reef degradation, concepts of managing for system resilience highlight the need for networks of MPAs (Obura, 2005, Schubert *et al.*, 2006). The protection of reef fish spawning sites as sources of seed is central to marine reserve network models (Sala *et al.*, 2002). However, this approach has progressed little as an applied conservation or reef fisheries management tool, even where scientific knowledge of aggregation sites is extensive. With few spawning aggregations effectively managed in no-take reserves (Sadovy & Domeier, 2005), let alone as part of networks, this element of managing for resilience lags far behind that of biodiversity and coral conservation (e.g. TNC, 2004, Grimsditch & Salm, 2006). Reef fishes are highly diverse in terms of their reproductive strategies and patterns (Sadovy, 1996) but spawning in aggregations at specific times and locations is common to several families of reef fishes (Domeier & Colin, 1997).

Dedicated initiatives to locate and study spawning aggregations in the WIO began in 2003 with a three-year programme in Seychelles to locate and verify sites reported by fishers (Robinson *et al.*, 2004; Robinson *et al.*, 2007). This was followed by an IUCN-led initiative to document local ecological knowledge of aggregations in Kenya, Mozambique and Tanzania and, later, to verify sites in Kenya (Samoilys *et al.*, 2006; Samoilys *et al.*, in prep). A more localised and fishery specific research project which also studied spawning aggregations was recently completed in southern Kenya (Kimani, in prep.). Fisher knowledge on fish spawning behaviour is often detailed (Johannes, 1981; Samoilys & Squire, 1994). Locating aggregations from fisher knowledge often remains a difficult task depending on the availability and quality of fisher information and other data on periodicity

and sites. Due to the fact that reef fish may aggregate for purposes other than reproduction, it is necessary to verify spawning and aggregation formation using spawning indicators, such as behavioural observations of spawning and surveys that demonstrate increase in abundance coupled with hydrated ovaries. Methodological approaches for this field have emerged in the last decade (Colin *et al.*, 2003; Pet *et al.*, 2006) and have formed the basis for much of the work in the WIO to date.

This paper reviews the current state of knowledge on reef fish spawning aggregations in the WIO region. The information presented largely draws on the three aforementioned projects in Seychelles, Kenya and Tanzania, but also draws on information from other countries and constitutes the first synthesis of its kind for the region.

FISHER KNOWLEDGE OF SPAWNING AGGREGATIONS

The documentation of fisher knowledge on reproductive behaviour is widely recommended as a first step to locating spawning aggregations (Johannes, 1981; Samoilys & Squire, 1994; Colin *et al.*, 2003). However, fishers' knowledge is also difficult information to analyse in order to distinguish reliable data on spawning aggregations (Daw, 2004). In summarising fishers' information from the WIO (Table 1), some or all of the following criteria were met (Robinson *et al.*, 2004, Samoilys *et al.*, 2006):

- i. descriptive information on spawning aggregation behaviour of species conforms to typical spawning behaviour such as courtship, territorial displays of males, release of gametes;
- ii. fish were seen with fully ripe gonads (hydrated ovaries);
- iii. information on species reported by >1 fisher;
- iv. information on location reported by >1 fisher.

Slightly more species have been reported to form spawning aggregations in Kenya compared to Seychelles, while the lack of reports from Tanzania is probably due to less research on this topic. The

Table 1. Species reported by fishers to form spawning aggregations in three countries of the WIO region (Robinson, *et al.*, 2004; Samoily, *et al.*, 2006; Kimani, in prep.; Samoily, *et al.*, in prep.).

Family	Species	Kenya	Seychelles	Tanzania
Acanthuridae	<i>Acanthurus mata</i>	√		
	<i>Naso brevirostris</i>	√		
Carangidae	<i>Carangoides gymnostethus</i>		√	
	<i>C. fulvoguttatus</i>		√	
	<i>Selar crumenophthalmus</i>		√	
Haemulidae	<i>Plectorhinchus flavomaculatus</i>	√		
	<i>P. gaterinus</i>	√		
	<i>P. schotaf</i>	√		
Lethrinidae	<i>Lethrinus crocineus</i>		√	
	<i>L. harak</i>	√		
	<i>L. nebulosus</i>		√	
	<i>L. obsoletus</i>	√		
Lutjanidae	<i>L. xanthochilus</i>	√		
	<i>Aprion virescens</i>		√	
	<i>Lutjanus argentimaculatus</i>	√		
	<i>L. bohar</i>	√	√	
	<i>L. ehrenbergi</i>	√		
	<i>L. fulviflamma</i> ¹	√		
	<i>L. gibbus</i>	√		
	<i>L. quinquelineatus</i>	√		
	<i>L. rivulatus</i>	√		
	<i>L. sanguineus</i>	√	√	
Serranidae	<i>L. sebae</i>	√	√	√
	<i>Cephalopholis miniata</i>	√		
	<i>Epinephelus fuscoguttatus</i>	√	√	
	<i>E. lanceolatus</i> ²			√
	<i>E. multinotatus</i> ³		√	
	<i>E. polyphkadion</i>	√	√	
Scaridae	<i>Plectropomus laevis</i>		√	
	<i>P. punctatus</i>	√	√	
	<i>Scarus rubroviolaceus</i>		√	
Siganidae	<i>Leptoscarus vaigiensis</i>	√		
	<i>S. argenteus</i>		√	
Sphyraenidae	<i>S. sutor</i>	√	√	√
	<i>Sphyraena jello</i>		√	
Mullidae	<i>Mulloidichthys vanicolensis</i>	√		

¹: Note: *L. fulviflamma* incorrectly reported as *L. kasmira* in Samoily *et al.*, 2006.

²: Information on *E. lanceolatus* provided by N. Jiddawi, Institute of Marine Sciences, Zanzibar.

³: The same Creole name is often used for *Epinephelus multinotatus* and *E. flavocaeruleus*, leading to uncertainty in fisher reports (Robinson *et al.*, 2007).

rabbitfish *Siganus sutor*, a regional endemic and an important target species of reef fisheries, is well known as an aggregating species in all three countries. At the family level, the most species reported to form

aggregations belong to the family Lutjanidae, followed by the Serranidae, the Lethrinidae and the Siganidae. Fisher observations of Carangidae spawning aggregations have largely been confined to Seychelles,

where these species are important components of the artisanal catch.

Spawning in large aggregations is common to serranids (Domeier & Colin, 1997; Sadovy, 1996). Knowledge of reproductive behaviour is widespread in Seychelles, where at least five serranids and several key spawning sites have been consistently identified by fishers (Robinson *et al.*, 2004). In contrast, knowledge in Kenya and Tanzania appears more fragmentary (Samoilys *et al.*, 2006). Unlike the Seychelles where serranids are a target species of the artisanal fishery (Grandcourt, 2005), observations of fish catches and long-term data from catch monitoring systems suggest that serranids are unimportant to the Kenyan (see Waweru *et al.*, this report; McClanahan *et al.*, 1999; Kaunda-Arara *et al.*, 2003) and Tanzanian (Anderson, 2004; Wells *et al.*, 2007; Samoilys *et al.*, in press) reef fisheries (but see below). It is therefore not surprising that fishers' information on their spawning aggregations is scant in East Africa. *E. polyphkadion* aggregations were known to fishers in northern Kenya and northern Tanzania (Samoilys *et al.*, 2006), however verification has only been obtained for *E. fuscoguttatus* spawning sites from southern Kenya, where large catches of this species with hydrated ovaries have also been observed (M.S. pers. obs.). Key informants and patriarchal fishers have proved invaluable in efforts to locate aggregations in the region.

VERIFIED SPAWNING AGGREGATIONS

A total of 25 spawning aggregations have been verified from seven species (Table 2). In Seychelles, 12 aggregations at 7 sites belonging to 4 species have been verified. *E. polyphkadion* and *E. fuscoguttatus* aggregations overlap spatially and temporally at three of the sites and are joined by *P. punctatus* at two sites. Multispecies sites are common amongst serranids, with *E. polyphkadion*, *E. fuscoguttatus* and *Plectropomus areolatus* commonly sharing sites in the Pacific (Sadovy, 2005). *P. punctatus*, being endemic to the

WIO, replaces *P. areolatus* in this region. Since numerous families have been observed to spawn in close association with these serranids, their spawning sites may be considered key sites in reef systems (Johannes *et al.*, 1999; Russell, 2001) and their protection may therefore be justified on grounds of biodiversity conservation in addition to fisheries management.

Aggregations of *E. fuscoguttatus* have been verified at two sites in Kenya through observations of behaviour and colour changes consistent with spawning in this species (Johannes *et al.*, 1999; Rhodes & Sadovy, 2002; Robinson *et al.*, 2007), and an increase in densities of fish at the two sites. These sites are also examples of multispecies sites, where spawning behaviour has been verified for several other species, using indirect behavioural signs (Table 2). Possible evidence that fishers have targeted *E. fuscoguttatus* aggregations was found at Msambweni, southern Kenya; fish with hydrated ovaries were observed in large catches of this species (M.S. pers. obs). Fishers also reported spawning behaviour at the sites of capture (P.K. pers. obs.). Note that this information was not obtained through the structured fisher interviews in the area (Kimani, in prep.), highlighting the importance of including macroscopic staging of gonads during catch monitoring. Hydrated gonads are easily identified as the eggs spill out from the abdomen in a characteristic manner, from which the term "running ripe" was derived.

Peak aggregation abundances vary greatly within and between species and sites. For example, *E. fuscoguttatus* abundances vary from less than 100 (in sites in Kenya and Seychelles) to more than 1000 fish (at sites in Seychelles). For the serranids, *E. polyphkadion* formed the largest aggregations, with numbers at one site peaking at over 2000 fish (Robinson *et al.*, in prep). No aggregations have been properly monitored in Kenya and therefore comparable data are not available. Aggregations of *Mulloidichthys vanicolensis* typically consisted of between 10 and 15 pairs (Samoilys *et al.*, in prep; Robinson *et al.*, 2007). The largest reef fish spawning aggregations verified in the WIO to date belong to *S.*

Table 2. Spawning aggregations verified in Seychelles and Kenya through a) direct or indirect observations of aggregative spawning and/or b) increases in abundance (Robinson *et al.*, 2007; Samoilyts *et al.*, in prep.; Kimani, in prep.).

Country	Site	Species	Spawning ¹		Abundance ²
			Direct	Indirect	
Seychelles	S1	<i>Epinephelus polyphkadion</i>	Yes	Yes	Yes
	S1	<i>Epinephelus fuscoguttatus</i>	Yes	Yes	Yes
	S1	<i>Plectropomus punctatus</i>	Yes	No	Yes
	S2	<i>Epinephelus polyphkadion</i>	Yes	Yes	No
	S2	<i>Epinephelus fuscoguttatus</i>	No	Yes	No
	S2	<i>Plectropomus punctatus</i>	Yes	No	No
	S3	<i>Epinephelus polyphkadion</i>	No	Yes	Yes
	S3	<i>Epinephelus fuscoguttatus</i>	No	Yes	Yes
	S4	<i>Plectropomus punctatus</i>	Yes	Yes	No
	S5	<i>Epinephelus polyphkadion</i>	No	Yes	Yes
	S6	<i>Siganus sutor</i>	Yes	Yes	Yes
S7	<i>Siganus sutor</i>	Yes	No	No	
Kenya	K1	<i>Epinephelus fuscoguttatus</i>	No	Yes	Yes
	K1	<i>Mulloidichthys vanicolensis</i>	No	Yes	No
	K1	<i>Acanthurus mata</i>	No	Yes	No
	K1	<i>Naso brevirostris</i>	No	Yes	No
	K2	<i>Epinephelus fuscoguttatus</i>	No	Yes	Yes
	K2	<i>Mulloidichthys vanicolensis</i>	No	Yes	No
	K3	<i>Mulloidichthys vanicolensis</i>	No	Yes	No
	K4	<i>Naso brevirostris</i>	No	Yes	No
	K5	<i>Epinephelus fuscoguttatus</i>	No	Yes	No
	K6	<i>Siganus sutor</i>	Yes	Yes	No
	K7	<i>Siganus sutor</i>	Yes	Yes	No
	K8	<i>Siganus sutor</i>	Yes	Yes	No
	K9	<i>Siganus sutor</i>	Yes	Yes	No

¹: Direct signs of spawning include observations of gamete release or hydrated ovaries. Indirect signs include patterns in gonado-somatic index, colour changes and territorial/courtship behaviour associated with spawning, and observations of gravid females.

²: Text in bold indicates where increase in abundances has been determined quantitatively in both aggregating and non-aggregating periods. Otherwise, estimates are qualitative and/or lacking non-aggregation observations.

sutor, with more than 5000 fish aggregating at each of the two verified sites in Seychelles (Robinson *et al.*, 2007).

The serranid aggregations verified in Seychelles

conformed to the transient type often associated with these species (Domeier & Colin, 1997). Transient aggregations, which are common to the Serranidae, are usually short lived, are often large, comprising

hundreds to tens of thousands (Smith, 1972; Samoily & Squire, 1994) of individuals, and participating fish may migrate considerable distances to and from the site (Bolden, 2000). Resident aggregations typically do not involve large distance migrations, form more regularly and occur close to or within the areas of residence for participating fish. Resident aggregations are common to the surgeonfishes (Acanthuridae) and some parrotfishes (Scaridae) (Domeier & Colin, 1997; Cornish, 2005). However, not all species conform to these two types, as seen in *Plectropomus leopardus* (Samoily, 1997).

Aggregations formed by siganids, namely *S. canaliculatus*, have been characterised as belonging to the transient type (Domeier & Colin, 1997). *S. sutor* aggregations appear to conform to this definition. Four *S. sutor* aggregations have been verified in the Msambweni area in Kenya, and there are indications that another seven sites identified by fishers could also be spawning sites. Fishers have described *S. sutor* migrations to the sites within a spawning period that often lasts from 7 to 12 days (Kimani, in prep); a similar duration was observed in Seychelles (Robinson *et al.*, 2007).

Few spawning aggregations have been verified in the WIO region compared to the western Pacific and tropical western Atlantic/Caribbean regions (Cornish, 2005). At the time of writing, a search of the online database of the Society for Conservation of Reef Fish Aggregations (www.scrfa.org) revealed that only two WIO aggregations (*E. fuscoguttatus* and *E. polyphkadion*, from Seychelles) have been reported. An *E. polyphkadion* aggregation from the Chagos archipelago and a *Plectropomus areolatus* aggregation from Maldives are also reported. The region remains inadequately represented compared to others where reports number in the hundreds. This situation most likely reflects a lack of research in the WIO rather than a rarity of occurrence (Cornish, 2005) since many species known to aggregate are common to the region and the reproductive strategy appears stable within species. The number of spawning aggregations that have been verified in the region during the past

few years through the studies reviewed here suggests that more are likely to be documented if targeted research can be maintained.

AGGREGATION SITE GEOMORPHOLOGY AND HABITATS

Spawning aggregations often form in reef passes and channels, on reef promontories, shelves and drop-offs, and on patch and pinnacle reefs (Sadovy, 1996; Samoily, 1997; Johannes *et al.*, 1999; Russell 2001), though this information still remains largely anecdotal (Colin *et al.*, 2003). The significance of site selection is still not fully understood (see Claydon, 2004). Reef passes or reef slopes close to major channels are common spawning sites for serranids in Seychelles, which are shallow (< 20 m) and defined by strong tidal currents. The serranid sites verified in Kenya are similar, being spurs on outer reef slopes. *S. sutor* aggregation sites may be more varied in terms of geomorphology and habitat. In Msambweni, Kenya, patch reefs inside the fringing reef lagoon are common spawning habitats for the verified spawning aggregations of *S. sutor*. These sites are characterised by generally high coral cover interspersed with coral rubble. Both *S. sutor* sites verified in Seychelles are granitic reefs on shallow bank habitats beyond the base of (carbonate) fringing reef slopes. Fishers in Seychelles also report that *S. sutor* and *S. argenteus* spawn on carbonate reefs, although this has not been verified. The degree of association with coral habitat appears stronger amongst serranids than siganids (Robinson *et al.*, 2007).

Habitat degradation caused by destructive fishing practices, pollution and coastal development are considered threats to spawning aggregations (Sadovy & Domeier, 2005). Although the relationship between habitat variables such as rugosity and aggregation abundances is not well defined, habitat appears important for certain species (Beets & Friedlander, 1998). For example, *E. polyphkadion*, *E. fuscoguttatus*, *P. leopardus* and *P. areolatus* aggregate at coral dominated sites where territories are defended

by males and refugia are occupied by large numbers of females (Samoilys & Squire, 1994; Johannes *et al.*, 1999), which may indicate a degree of reliance on habitat complexity for spawning success. The impact of coral bleaching on spawning aggregations remains unstudied but may become more significant in a changing climate. In terms of acute stresses, habitat destruction resulting from coastal development may be important on local scales. For example, land reclamation has led to the disappearance of *Epinephelus ongus* aggregations and the collapse of their fishery in Seychelles (Robinson *et al.*, 2007).

PERIODICITY OF SPAWNING AND AGGREGATION FORMATION

Many reef fishes exhibit peaks of spawning activity nested within protracted spawning seasons (Munro *et al.*, 1973; Sadovy, 1996). This pattern may be pronounced in the WIO due to the monsoon system (Nzioka, 1979; Kulmiye *et al.*, 2002). Detailed information is available for very few species (Table 3). *S. sutor* spawning appears to peak within two periods in Kenya and Seychelles. While Ntiba & Jaccarini (1990) did not recognise a protracted season, recent studies indicate that spawning probably occurs across much of the northeast (NE) monsoon (Table 3). Spawning periodicity has not been described for many serranids in the WIO but appears to be concentrated in the NE monsoon. Species that form transient aggregations often spawn within a narrow season (Sadovy, 1996; Claydon, 2004), which appears to be the case for *E. fuscoguttatus* and *E. polyphkadion* in Seychelles where the seasons are typically 2-3 months long (Robinson *et al.*, 2007). In Kenya, observations of *E. fuscoguttatus* aggregations vary from February to May, but more research is needed to determine the exact timing. The majority of other reef fish for which data exist also appear to spawn in the NE monsoon, including acanthurids and mullids (Table 3). Exceptions to this pattern include some siganids and lutjanids which spawn in the southeast monsoon (Robinson *et al.*, 2004; Robinson *et al.*, 2007; Samoilys *et al.*, in prep).

AGGREGATION STATUS AND FISHERIES

Owing to their predictability in time and space, transient spawning aggregations are highly vulnerable to overexploitation (Johannes *et al.*, 1999; Sala *et al.*, 2001). Moreover, much of the annual reproductive output of participating fish may occur in a single aggregation (Shapiro *et al.*, 1993; Samoilys, 1997), rendering populations of these species highly vulnerable to targeted aggregation fishing (Sadovy & Eklund, 1999; Sadovy & Domeier, 2005). The status of spawning aggregations, transient and resident, is poorly known in the WIO region. Fisheries-independent monitoring programmes are being developed for sites in Seychelles but are too recent to assess status. In the absence of scientific information, local knowledge indicates that several serranid aggregations have been depleted or have collapsed (Robinson *et al.*, 2004), both in areas close to centres of population (*Epinephelus ongus*) and on the outer banks of the Mahé Plateau (e.g. *Epinephelus multinotatus* and/or *Epinephelus flavocaeruleus*) (Robinson *et al.*, 2007). Fisher knowledge of spawning aggregations in Kenya indicates that while the phenomenon has been widely observed, few have understood its significance as an important source of seed and fisheries recruitment, and no assessment of the status of spawning aggregations has been done.

Reef fisheries are generally considered overexploited in the WIO (McClanahan *et al.*, 1999; Kaunda-Arara *et al.*, 2003; FAO, 2006). For families characterised by the formation of transient aggregations in particular, aggregation fishing may be contributing to this situation. Where landings data exist and are disaggregated by family, it is apparent that fisheries targeting serranids are significant (Fig. 1). Given the large reported catches of serranids in Mauritius and Tanzania, aggregations may have been targeted, especially where species such as *E. polyphkadion* and *E. fuscoguttatus* are important constituents of the catch. It should be noted, however, that the relatively large serranid catches reported to FAO by Tanzania does not concur with the findings

Table 3. Comparison of spawning and aggregation periodicity for species known to form spawning aggregations. Information on some species is separated for different sites within the country. Spawning season information is from a) fishers' knowledge, b) reproductive biology studies. Aggregation periods and lunar information are from research involving direct observation or gonad analyses. Lunar periods: NM = new moon, FM = full moon, Qtr = Quarter. Seasons in the WIO: NE monsoon (light trade winds) = Nov-Apr; SE Trades (strong trade winds) = Jun-Aug; inter-monsoon = May, Sep/Oct.

Species	Country	Spawning season: fishers	Spawning season: research	Aggregation: research	Lunar period: research	Reference(s)
<i>S. sutor</i>	Kenya		Jan-Feb, May-Jun			Ntiba & Jacarini (1990)
	Seychelles	Oct-May	Sep-May	Oct, Nov	FM	Robinson et al. (2004; 2007)
	Kenya	Apr-Sep				Samoilys et al. (in prep.)
	Kenya	Nov-Apr, Jun-Aug		Nov-Mar	FM	Kimani, P. (in prep)
<i>E. fuscoguttatus</i>	Kenya, Tanzania		Nov-Jan			Nzioka (1979)
	Seychelles	Nov-Jan	Dec-Feb	Dec-Feb	NM	Robinson et al. (2004; 2007)
	Seychelles	Nov-Dec		Feb	NM	Robinson et al. (2004; 2007)
	Kenya			Feb		Kimani, P. (in prep)
<i>E. polyphkadion</i>	Kenya			Apr, May	3rd Qtr, NM	Samoilys et al. (in prep)
	Seychelles	Nov-Jan	Dec-Feb	Dec-Feb	NM	Robinson et al. (2007)
	Seychelles			Mar, Apr		Robinson et al. (2007)
<i>P. punctatus</i>	Seychelles			Dec, Jan	NM	Robinson et al. (2007)
	Seychelles			Feb	1st Qtr	Robinson et al. (2007)
<i>M. vanicolensis</i>	Kenya			Apr	FM	Samoilys et al. (in prep)
<i>A. mata</i>	Kenya			May	3rd Qtr	Samoilys et al. (in prep)
<i>N. brevirostris</i>	Kenya			Apr	1st Qtr - FM	Samoilys et al. (in prep)

of localised studies on artisanal fisheries, which indicate that this group are not particularly important constituents of the catch (McClanahan *et al.*, 1999; Samoilys *et al.*, in press a). This finding suggests that commercial rather than artisanal fisheries predominantly target serranids. In heavily exploited

reef areas, sparse fisher knowledge relating to these phenomena may be because of low abundances or collapse of aggregations (Samoilys *et al.*, 2006).

Siganids are key target species of trap, line and net fisheries in the region (Anderson, 2004; Samoilys *et al.*, in press a) and aggregations are clearly known to

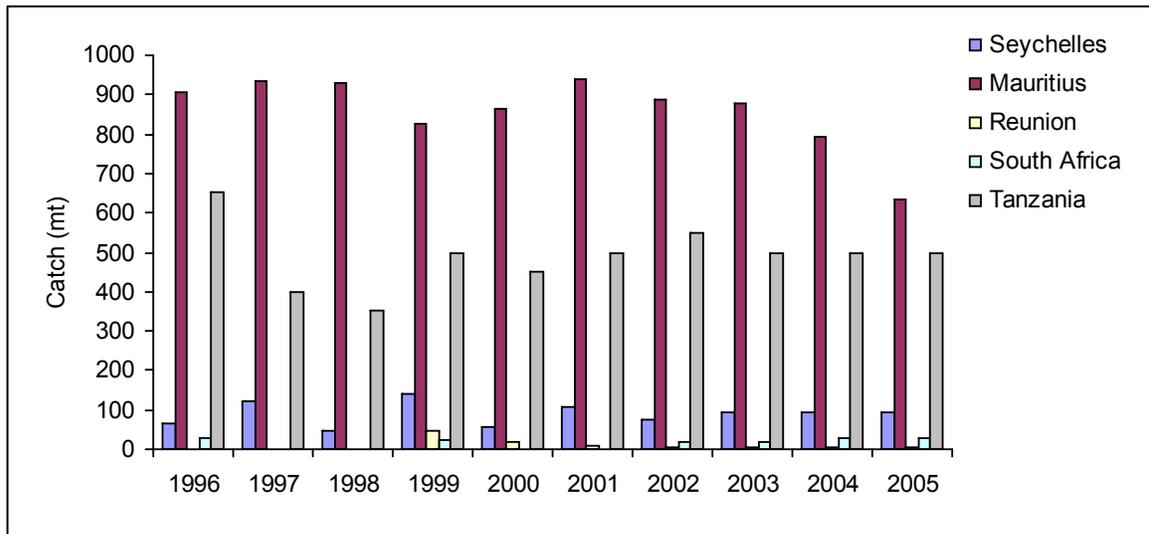


Figure 1. Reported catches of groupers (Serranidae) in the Western Indian Ocean (Source: FAO FISHSTAT Plus).

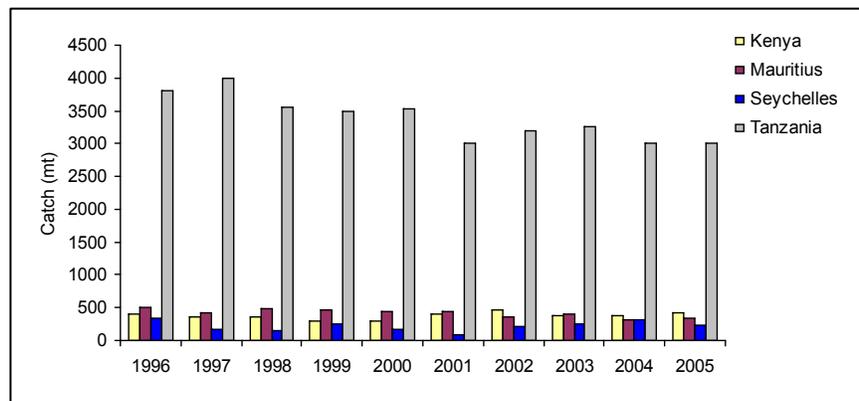


Figure 2. Reported catches of rabbitfish (Siganidae) in the western Indian Ocean (Source: FAO FISHSTAT Plus).

fishers and exploited (Kimani, in prep; Robinson *et al.*, 2004; Robinson *et al.*, 2007; Samoily *et al.*, 2006). Since Tanzanian fishers are aware that *S. sutor* spawns in transient aggregations, it is possible that aggregation fishing contributes to the large catches reported for this family in Tanzania (Fig. 2). Independent long-term monitoring since 1998 in Tanga, Tanzania, has shown a 5-6 fold decline in herbivore densities since 2003 which is attributed to the trap fishery that targets siganids (Samoily *et al.*, in press a, b).

In the Msambweni area of Kenya, four well known *S. sutor* spawning sites have been targeted by local fishers for generations, with anecdotal evidence indicating that the present day patriarch fishers began fishing the aggregations in the 1960s. Large catches of *S. sutor*, often close to 1 tonne, have been landed by ring-net fishers during a single fishing event (Fig. 3). While these catch data were recorded at the neighbouring landing site of Gazi, fishers ostensibly fished in Msambweni waters and are known to target the four prominent spawning sites located there

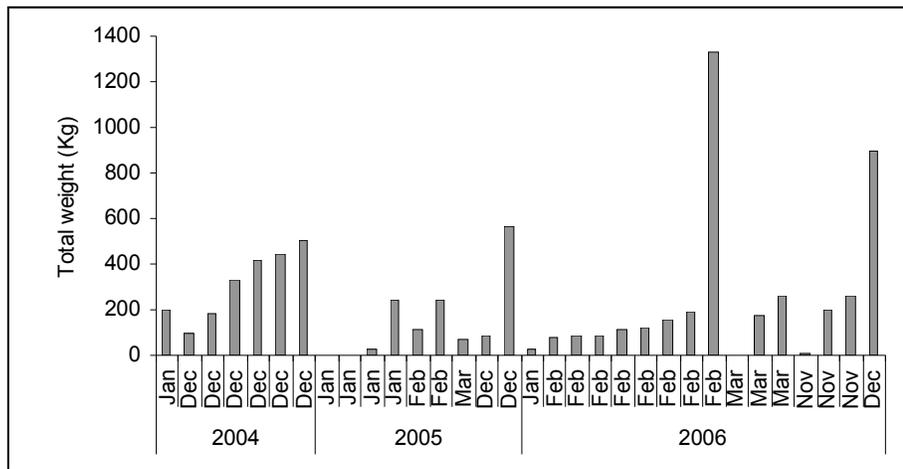


Figure 3. An extract of catch records of *Siganus sutor* from the Gazi fish landing site, Southern Kenya, showing magnitude of total daily catches by ring-net gear. Often, only between one and two ring-net boats operate in the area (Source: CORDIO East Africa).

(Kimani, in prep). A three month catch monitoring system at the Mkunguni landing site of Msambweni indicated that light artisanal gears like basket traps and fishing lines averaged up to 8 kg/fisher/day when fishing a *S. sutor* aggregation. Effort in the trap fishery is high (average 10 traps/fisher) and catches of up to 500 kg have been landed over a single lunar spawning period. In spite of the high levels of catch and effort, reports on the status of the fishery are contradictory, with many fishers reporting stable aggregation catches and others reporting a decline. By comparison, *S. sutor* has been heavily exploited, including its aggregations, for close to 100 years in Seychelles (Hornell, 1927), yet stocks have not collapsed, possibly due to the fact that only nearshore populations are targeted

MANAGEMENT IMPLICATIONS

Fisheries management in the region is largely focused on industrial fisheries. Few artisanal fisheries have clearly defined harvesting strategies or management plans including controls on inputs and outputs. Overexploited coastal fisheries and ecosystem impacts of fishing are widespread (De Young, 2006).

Consequently, the arguments for MPAs are well supported on both conservation and fisheries management grounds. For MPAs to complement fisheries management objectives, however, a greater emphasis on the protection of vulnerable life history stages is urgently required. MPAs are rarely designed to incorporate spawning aggregation sites and nursery habitats although some may have inadvertently received protection (e.g. in Seychelles). In Kenya, spawning aggregations were not considered in the design of MPAs. The early studies reported here have made some progress towards identifying spawning sites but much work remains in terms of verifying and studying the dynamics of aggregations.

A wide range of management tools for spawning aggregations could be considered depending on local circumstances. Appropriate responses to aggregation fisheries will likely differ between species, site, fishery and country. In Maldives, serranids form the basis of an economically important export-driven live reef food fishery (LRFF) (Sattar & Adam, 2005). This fishery is now considered heavily overexploited (Adam, 2006) and trade measures such as export restrictions or bans may be appropriate to limit effort. Seychelles recently prohibited the LRFF, in part to protect spawning

aggregations (Aumeeruddy & Robinson, 2006). In many countries, the reliance on species that aggregate to spawn for food security may dominate management objectives, as exemplified by the siganids. In this case, gear restrictions, temporary area or seasonal closures and rights-based management approaches may be more appropriate than the formation of MPAs, and certainly more acceptable from political and socio-economic perspectives. However, these measures may only work if traditional and local compliance systems are in place. From a fisheries management perspective, the choice of tool to manage spawning aggregations should be part of a suite of measures to manage the overall fishery, which is relevant to both governmental and community-based regimes. A much greater emphasis on, and support for, research will be required in the region if spawning aggregation protection is to be part of regional fisheries management and conservation toolboxes.

Plans for a wider regional research and management programme on spawning aggregations are at an advanced stage. Studies will focus on further verification of reported aggregation sites. This will be followed by efforts to define the spatial and temporal dynamics of aggregations at key sites in order to provide information for management. In addition to research, components of the programme will focus on closed area design and application, reserve networking and awareness raising activities within fisheries and conservation management domains.

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