Coastal Oceans Research and Development in the Indian Ocean.
Status Report 2008

The Coastal Oceans Research and Development in the Indian Ocean (CORDIO) programme was initiated in 1999 as a direct response to the El-Nño caused mass bleaching and mortality of corals in the Indian Ocean in 1998, focusing initially on Eastern Africa, Western Indian Ocean Islands and South Asia. Since the Indian Ocean tsunami in 2004 the programme also covers the Andaman Sea. The objectives of CORDIO are to sustain research on coastal and ocean ecosystems relevant to conserving and sustaining ecosystem function, goods and services; to strengthen social and economic assessment and research for integrated coastal management processes; to improve the livelihoods and well-being of coastal populations; to improve policies and the use of scientific and technical information in local to national and regional policy; to foster networking and integration of science, management and policy; and, finally, to build necessary capacity for meet these objectives.

This is the fifth in the series of CORDIO Status Reports, following ones published in 1999, 2000, 2002 and 2005. This publication reflects the evolution of the CORDIO programme in response to progressing threats from climate change as well as human activities. In all, the report includes 48 articles in sections covering overviews and regional summaries; reports on status, tsunami impact, biological research, fish spawning aggregations, artisanal fisheries, socioeconomics and livelihoods, and education and awareness.

We hope the publication will give the reader a sense of the immense scope of change that ecosystems and people are facing, and the urgent need to respond from local to global levels to assist positive responses and take steps to constrain and minimize the rate of climate change.

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Status Report 2008

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COASTAL OCEANS RESEARCH AND DEVELOPMENT IN THE INDIAN OCEAN
Status Report 2008

Coastal Oceans Research and Development in the Indian Ocean

Status Report 2008

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Foreword

Coral reefs and tropical Small Island States are among the most vulnerable of the planet's ecosystems and societies to climate change. Since the coral bleaching event in 1998 the Indian Ocean has had repeated reminders of the specter of climate change and other planetary-scale events – cyclones and floods in Mozambique and South Asia, repeated droughts in East Africa, the tsunami of 2004 affecting Asian and island states. Further, human population growth and its impact places further stress on these fragile ecosystems. With this uncertain future facing us, it is essential to build up local and regional initiatives to understand and respond to change.

The CORDIO programme which started in 1999 as a pragmatic response to the impacts of global warming on coral reefs has over the years improved our knowledge and management of coral reefs in the region. For example data collection in the Curieuse Marine Park in Seychelles, was instrumental in guiding government policy over the management of marine protected areas, especially those that have resilient coral ecosystems. Without such important and vital information politicians, parliamentarians, local governments and MPA managers will not be able to take decisions which take into consideration coral reef recovery and conservation issues. In fact this particular report has sought to bring together research and monitoring on environmental and socio-economic aspects and their relevance to management and policy approaches to education and community-based activities.

The Seychelles is acutely aware of the vulnerability of its coastline, marine and terrestrial habitats and population to climate change. With limited land area and high dependence on coastal resources we are indeed at the forefront of efforts to combat the complex and interacting problems of overexploitation, pollution, environmental degradation and climate change. In meeting this challenge we must continue to research and harness all the resources so that we can improve coastal management, reduce human pressures and adapt to climate change.

In September 2007, I launched the Sea Level Rise Foundation, a global platform of excellence on adaptation in small island states. With the continued bleaching of coral reefs, the role of reefs in coastal stability has been significantly weakened and I am confident that with the continuation of CORDIO in its work on coral reefs and as a partner of the Sea Level Rise Foundation we will be able to bring about further attention to the issues faced by small islands and low-lying coastal areas of east Africa and the world.

President James Alix Michel
Republic of Seychelles

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

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keywords: spawning aggregations; local ecological knowledge; verification; periodicity; habitat, management implications

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;

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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; Samoilys, *et al*., 2006; Kimani, in prep.; Samoilys, *et al*., in prep.).

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

[1]: *Note:* L. fulviflamma *incorrectly reported as* L. kasmira *in Samoilys 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 a) reef fisheries (but see below). It is therefore not surprising that fishers' information on their spawning aggregations is scant in East Africa. *E. polyphekadion* 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. polyphekadion* 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. polyphekadion, 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. polyphekadion* 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; Samoilys *et al*., in prep.; Kimani, in prep.).

Country	Site	Species	Spawning[1]		Abundance[2]
			Direct	Indirect	
Seychelles	S1	*Epinephelus polyphekadion*	Yes	Yes	**Yes**
	S1	*Epinephelus fuscoguttatus*	Yes	Yes	**Yes**
	S1	*Plectropomus punctatus*	Yes	No	Yes
	S2	*Epinephelus polyphekadion*	Yes	Yes	No
	S2	*Epinephelus fuscoguttatus*	No	Yes	No
	S2	*Plectropomus punctatus*	Yes	No	No
	S3	*Epinephelus polyphekadion*	No	Yes	**Yes**
	S3	*Epinephelus fuscoguttatus*	No	Yes	**Yes**
	S4	*Plectropomus punctatus*	Yes	Yes	No
	S5	*Epinephelus polyphekadion*	No	Yes	**Yes**
	S6	*Siganus sutor*	Yes	Yes	Yes
	S7	*Siganus sutor*	Yes	No	No
Kenya	K1	*Epinephelus fuscoguttatus*	No	Yes	Yes
	K1	*Mulloidichthys vanicolensis*	No	Yes	No
	K1	*Acanthurus mata*	No	Yes	No
	K1	*Naso brevirostris*	No	Yes	No
	K2	*Epinephelus fuscoguttatus*	No	Yes	Yes
	K2	*Mulloidichthys vanicolensis*	No	Yes	No
	K3	*Mulloidichthys vanicolensis*	No	Yes	No
	K4	*Naso brevirostris*	No	Yes	No
	K5	*Epinephelus fuscoguttatus*	No	Yes	No
	K6	*Siganus sutor*	Yes	Yes	No
	K7	*Siganus sutor*	Yes	Yes	No
	K8	*Siganus sutor*	Yes	Yes	No
	K9	*Siganus sutor*	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; Samoilys & 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* (Samoilys, 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. polyphekadion*, from Seychelles) have been reported. An *E. polyphekadion* 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; Samoilys, 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. polyphekadion, 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 lead 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. polyphekadion* 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. polyphekadion* 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)
S. sutor	Kenya		Jan-Feb, May-Jun			Ntiba & Jaccarini (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)
E. fuscoguttatus	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)
	Kenya			Apr, May	3rd Qtr, NM	Samoilys et al. (in prep)
E. polyphekadion	Seychelles	Nov-Jan	Dec-Feb	Dec-Feb	NM	Robinson et al. (2007)
	Seychelles			Mar, Apr		Robinson et al. (2007)
P. punctatus	Seychelles			Dec, Jan	NM	Robinson et al. (2007)
	Seychelles			Feb	1st Qtr	Robinson et al. (2007)
M. vanicolensis	Kenya			Apr	FM	Samoilys et al. (in prep)
A. mata	Kenya			May	3rd Qtr	Samoilys et al. (in prep)
N. brevirostris	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

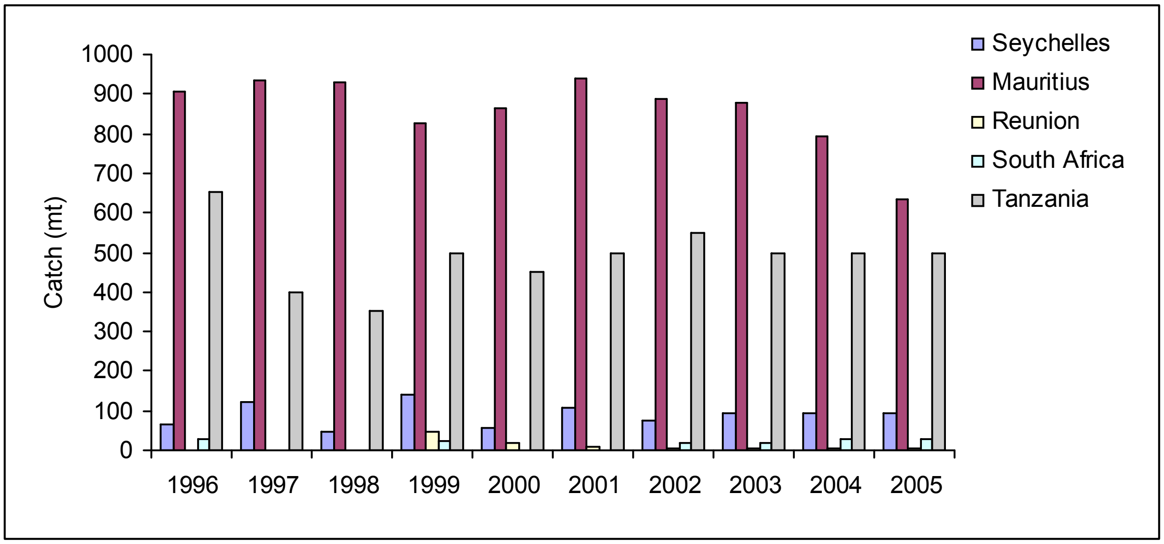

Figure 1. Reported catches of groupers (Serranidae) in the Western Indian Ocean (Source: FAO FISHSTAT Plus).

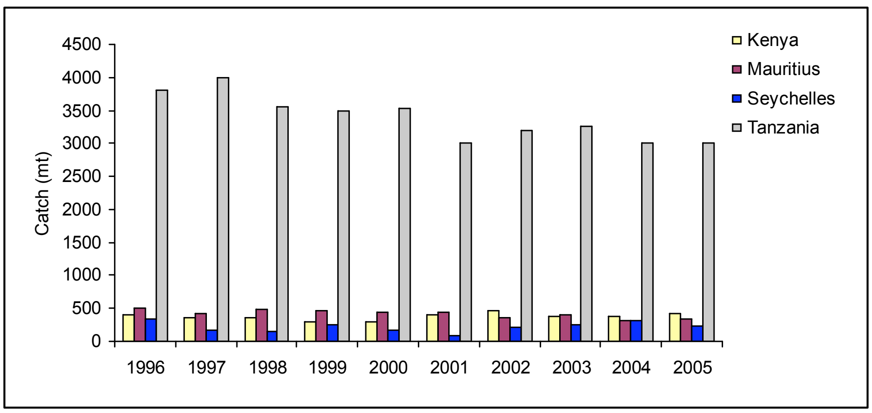

Figure 2. Reported catches of rabbitfish (Siganidae) in the western Indian Ocean (Source: FAO FISHSTAT Plus).

fishers and exploited (Kimani, in prep; Robinson *et al.*, 2004; Robinson *et al.*, 2007; Samoilys *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 (Samoilys *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

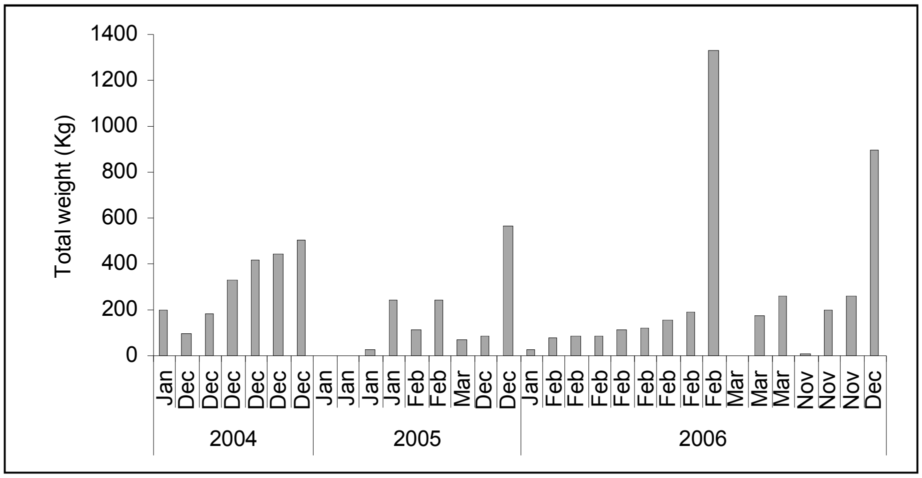

Figure 3. An extract of catch records of *Siganus sutor* from the Gazi fish landing site, Southern Kenya, showing magnitude of total daily catches by ring-net gear. Often, only between one and two ring-net boats operate in the area (Source: CORDIO East Africa).

(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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Reef Fish Spawning Aggregations in South Asia and the Andaman Sea: Preliminary Findings from Local Knowledge

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INTRODUCTION

Reef Fish Spawning Aggregations (FSA) are a phenomenon where reef fish species gather in large numbers at a specific time and site to spawn (for definitions see Domeier and Colin 1997). For coral reef fishes these sites are consistent over years. Spawning aggregations can be critical in the life cycle of the fishes that use this reproductive strategy. In particular, for those species that travel relatively large distances to aggregation sites and gather for a short period to spawn each year (termed "transient" spawning aggregations, Domeier and Colin 1997), such aggregations can represent 100 percent of the species' reproductive output.

Fish may migrate over very large distances (10s of km) to an aggregation site, as exemplified by the Nassau grouper in the Caribbean (Bolden 2000). In addition, the pelagic fertilised eggs and larvae from such aggregations may travel far before settling out of the plankton to mature. Thus a single spawning aggregation may have an impact on fish populations over an area spanning several hundred kilometres. If these aggregations break down, for example through persistent fishing of the aggregations, the species' population can decline dramatically to critically unsustainable levels (Sadovy 1999). Since many species from several families of reef fish spawn in aggregations careful management of this phenomenon is critical if the health of fish populations and hence

Obura, D.O., Tamelander, 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

the entire coral reef ecosystem is to be maintained (Sadovy and Domeier 2005). Accordingly, reef fish spawning aggregations are a central component to the coral reef resilience concept, as synthesised in *The Nature Conservancy's Reef Resilience (R2) Toolkit* (Domeier et al 2002, R2 2004). This Toolkit addresses methods for minimising stress to coral reefs in order to maximise their ability to resist or recover from coral bleaching caused by climate change (e.g. Obura 2005).

The character of spawning aggregations leaves them highly vulnerable to over exploitation, and there are many examples where fishing has drastically reduced spawning aggregations (e.g. Sala et al 2001, Aguilar-Perera 2006). In view of this, the 3rd IUCN World Conservation Congress adopted Recommendation 3.100 on "Reef-fish spawning aggregations" (IUCN 2004). The recommendation expresses the concern of IUCN's 1,072 member institutions about the increasing exploitation of reef-fish spawning aggregations in various parts of the world, and about the dramatic ecological and socio-economic effects that such exploitation can lead to. It further urges governments to establish sustainable management programmes for sustaining and protecting reef fish and their spawning aggregations, and also requests a number of organisations to take action to promote and facilitate the conservation and management of fish spawning aggregations, by raising awareness of the long term ecological, economic and societal values of spawning aggregations. The importance of this recommendation was further emphasised by the International Coral Reef Initiative (ICRI 2006).

Reef fish spawning aggregations have been described and/or documented in many locations, including the Caribbean (Sadovy 1999, Bolden 2000), South Pacific (Sadovy 2004), Micronesia (Johannes et al 1999), Australia (Samoilys 1997), the Seychelles (Robinson et al 2004), and East Africa (Samoilys et al 2006, Robinson et al, 2007). Studies have indicated some similarities between spawning aggregations. For example, aggregating fish tend to be of large species from the Serranidae, Lutjanidae, Siganidae, Labridae, Scaridae. The timing and behaviour of aggregations and the physical characteristics of the sites vary (Claydon 2004) and there is still much that we do not know or understand about this critical phenomenon (Domeier et al 2002).

Guidelines on the study of reef fish spawning aggregations have been prepared by Colin et al. (2003). However, it appears very little research has been focused on spawning aggregations in South Asia and the Andaman Sea, and while spawning aggregations are known to occur there seems to be little but anecdotal evidence available beyond some detailed work in Lamu atoll in the Maldives (Sluka 2001a,b,c). There is also little information available on the implications of reef fish reproductive biology for overall reef health as well as reef resource dependent human societies. Consequently, spawning aggregations have frequently not been considered in most aspects of coral reef and fisheries management in South Asia and the Andaman Sea.

Interview Survey in South Asia and the Andaman Sea

A project has been initiated by IUCN and CORDIO in collaboration with national and local institutions, aimed at gathering some of the first data on spawning aggregations in the South Asia and Andaman Sea region, with a view to providing information that can support further research on reef fish population dynamics and reef resilience, as well as strengthen management of coral reefs and reef resources.

The objectives of the study are to a) determine which reef fish species form spawning aggregations; b) determine the specific sites of aggregation formation; c) determine the seasonal patterns in spawning aggregations by species; d) determine the level of awareness of spawning aggregations and status of stocks of those species among fishers; e) sensitise fishers and marine resource personnel in south asia on reef fish spawning aggregations and their implications to conservation and sustainable fisheries; and f) provide recommendations for the protection and management of sites of spawning aggregations.

The study is being carried out through interview surveys with fishers, who often are aware of and are fishing spawning aggregations (Johannes 1981), following the guidelines by Colin et al (2003). The survey covers most of the key coral reef areas in the region, including Lakshadweep, Gulf of Mannar and Andaman and Nicobar Islands in India, the Thailand Andaman Sea coast, reef areas in the West and South of Sri Lanka, Aceh in Indonesia, and the Maldives. The interview surveys were initiated around the region between March and August 2007, and are still ongoing (September 2007).

Preliminary Findings

Based on discussions with fishers on the northern Sumatra islands of *Weh and Aceh, Indonesia,* as well as ecological assessments in the area, three potential spawning habitats for Giant Trevally (*Caranx ignobilis*) have been identified. A detailed survey of fishers knowledge gained from household and field surveys is currently in progress to identify biological and resource use characteristics of these areas and further potential spawning aggregation sites in the region.

In the *Maldives* surveys have been carried out at Vaavu and Baa Atolls. Fishermen on Vaavu are aware of reef fish spawning aggregations and have identified sites and times for groupers (*Epinephelus fuscoguttatus, Plectropomus areolatus and P. pessuliferus*). One island in the atoll has an established grouper fishery that targets spawning aggregations on a regular basis. However, reportedly the fishing pressure on these sites has decreased over the years. Preliminary results from islands in Baa atoll indicate most fishermen either do not know about spawning aggregations or are hesitant to provide information. However, this does not include results from some of the islands with a local reef fishery. Field verification and characterisation of some of the sites has been planned.

Interviews in the Union Territory of *Lakshadweep, India*, conducted in some depth on Minicoy and Agatti islands and opportunistically at Kavaratti and Kadmath islands, indicate limited knowledge of reef fish spawning aggregations. The phenomenon of spawning aggregations is known and has been observed in some tuna baitfish (a number of species are used for tuna bait, including *Spratelloides gracilis, S. delicatulus*, and *Encrasicholina heteroloba*, as well as some Caesionidae, Apogonidae, Pomacentridae etc.), but fishers in the area had never heard of or seen reef fish spawning aggregations in larger fish such as groupers and snappers. However, many seemed to know the spawning seasons of pelagic species. This is reflective of the relatively low commercial importance of reef fish in the islands, where the hook and line tuna fishery is the main export earner. The reefs in the archipelago do exhibit many of the characteristics associated with reef fish spawning aggregations elsewhere, and further field surveys as well as more intense interview surveys are underway. In view of the concerns with respect to a growing export fishery targeting high value reef fish, knowledge and management of potential reef fish spawning aggregations is viewed as a high priority.

In the North Andaman region of the *Andaman and Nicobar Islands, India,* a first preliminary survey provided indications of spawning aggregations including several grouper spawning aggregations (largely *Plectropomus* spp.) in South Andaman. These aggregations are apparently fished for the lucrative export trade to South East Asia.

Surveys of nine villages in the *Gulf of Mannar, India* have reported no spawning aggregations in the shallow (0.5-3m) reef areas around the near shore islands. However, four possible fish spawning aggregations have been identified in areas further off shore, 5-10 miles out and at depths between 10 and 20m, with opinions of species, timings, including lunar phase shared among several fishers from different villages. Species reported included primarily the Lethrinidae, but also Siganidae, Lutjanidae, and Scaridae. The area is heavily fished with gillnets and hook and line, and higher catches are reported at the times of aggregation.

Interviews with 190 small-scale fishers in the southern part of *Phuket Island* and *Bulon Island,* *Thailand* provided some evidence of fish aggregations, although none of the respondents specifically mentioned spawning as a reason for fish aggregating, with some considering feeding the primary reason and others unable to provide an explanation. Sites were characterised as isolated underwater rock-outcrops or rock pinnacles on sandy bottom, and some located in channels between islands. Species observed aggregating included trevally (Carangidae) as well as certain serranids (*Epinephelus coioides* and *E. lanceolatus*), lethrinids (*Lethrinus lentjan*), and scombrids (*Rastralliger brachysoma* and *R. kanagurta*).

DISCUSSION

While several potential reef fish spawning aggregation sites have been identified through this study, the results are preliminary and unverified, and thus indicative only. It is clear that although many fishers are not immediately aware of spawning aggregations, others possess at least some knowledge of spawning areas, species and times. Further, as has been found in many other parts of the world, it appears that many aggregations are targeted by fishers in the area. The results are encouraging in the sense that they indicate functional spawning aggregations can still be found in the region.

In view of the intense fishing pressure in many parts of the region, particularly over the past two decades, it is expected that some aggregations have been diminished. As this trend is likely to continue, accurate and reliable information as well increased awareness among managers and policy makers of reef fish spawning aggregations, their ecological significance and vulnerability, are needed in order to design and implement suitable management responses.

Detailed and final results from the surveys will be published in national reports as well as a regional synthesis intended for presentation at the 11th International Coral Reef Symposium in 2008. Information on exact locations and timings of fish spawning aggregations will not be published in the public domain, but will be reported to the Society for the Conservation of Reef Fish Aggregations (SCRFA) database.

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