Western Indian Ocean J. Mar. Sci. Vol. 3, No. 1, pp. 63–69, 2004

Spatial and Temporal Distribution of Reef Fish Spawning Aggregations in the Seychelles – An Interview-based Survey of Artisanal Fishers

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Key words: reef fish, spawning aggregations, Seychelles

Abstract—Many coral reef fish species aggregate at specific times and locations for the purpose of spawning. This study examined the spatial and temporal distribution of spawning aggregations in the Seychelles. An interview-based survey of the principal stakeholders, mainly artisanal fishers, yielded 89 reports of aggregation fishing for 26 demersal and semi-pelagic fish species. Grouper aggregations were largely concentrated in the outer coralline islands of the exclusive economic zone, whilst those of snappers and rabbitfishes were mainly reported from locations on the Seychelles Bank. The spatial patterns among fish families were attributed to a combination of differences in species abundance and distribution as well as variation in fishing effort. Spawning periodicity reported by fishers indicated that for snappers and rabbitfishes, the most activity occurred across a protracted period of October to April/May, with peaks in activity at either end of that period. Grouper spawning activity was concentrated in the northeast monsoon months of November to January. The findings of this study suggest that several spawning aggregations are targeted by fishers on a regular basis, a practice that constitutes a primary issue for artisanal fisheries research and management in the Seychelles.

INTRODUCTION

In recent decades there has been growing interest amongst scientists and resource managers in the importance of spawning aggregations to the management of coral reef fisheries (Beets & Friedlander, 1992; Bannerot et al., 1987; Sadovy, 1994). The over-fishing of grouper (Serranidae: Epinephelinae) spawning aggregations has contributed to the collapse of important commercial fish stocks, such as the Nassau grouper, *Epinephelus striatus*, in parts of the Caribbean (Sadovy & Eklund, 1999), and populations targeted by the live reef fish food trade (LRFFT) in South East Asia are increasingly threatened by the practice of aggregation fishing (Johannes, 1997; Sadovy & Vincent, 2002). However, in many parts of the world, especially the western Indian Ocean (WIO), information on the biology of spawning aggregations is lacking.

Numerous coral reef fish species form aggregations at specific times and locations for the purpose of reproduction (Domeier & Colin, 1997). The characteristics of spawning aggregations vary widely amongst coral reef fishes but a few general patterns have been defined. In some species of grouper, the formation of aggregations is restricted to narrow reproductive seasons and involves long-distance migrations ('transient aggregations') (Domeier & Colin, 1997). Other coral reef fishes, of the family Acanthuridae for example, form aggregations more frequently over protracted spawning periods, close to or within the areas of residence of participating fish ('resident

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aggregations') (Domeier & Colin, 1997). Spawning aggregations vary dramatically in size, ranging from small groups of individuals in some wrasses (Labridae), parrotfishes (Scaridae) and surgeonfishes (Acanthuridae), to the tens of thousands of individuals that can be present in transient aggregations of some groupers (Sadovy, 1996). For the purposes of evaluation and monitoring, it has been suggested that a three-fold increase in the density of spawning fish is the minimum threshold level that constitutes a spawning aggregation (Domeier & Colin, 1997; Samoilys, 1997).

The predictability of spawning aggregations in time and space renders them highly vulnerable to over-exploitation (Olsen & LaPlace, 1979; Sadovy et al., 1994). It is primarily the coral reef fishes that form transient aggregations that are prioritised for conservation (Colin et al., 2003; Domeier et al., 2002), mainly due to the fact that they may comprise a major proportion of the total spawning stock biomass and constitute the entire annual reproductive output for participating fish (Samoilys & Squire, 1994; Shapiro et al., 1993). Many large grouper species are especially vulnerable in this respect (Johannes et al., 1999).

The republic of Seychelles is an archipelago with a large exclusive economic zone (EEZ) of 1.37 M km^2. Within this area, fishing is carried out across a wide range of shallow (< 150 m) marine habitats, including the granite-based reefs and islands of the Seychelles Bank, the coralline platform reefs of the Amirantes Plateau, and atolls such as Cosmoledo and Farquhar (Fig. 1). Spawning aggregations have been reported to be an important resource and are targeted periodically. However, the extent to which this practice has impacted aggregations and the populations that form them is poorly understood. For example, around 3.5 metric tonnes of the brown marbled grouper, *Epinephelus fuscoguttatus*, were removed from a single aggregation site in less than a week during 2002 (Seychelles Fishing Authority, unpublished data). Reports indicate that 'spawning congregations' of the white-blotched grouper, *E. multinotatus*, were periodically fished as far back as 1947

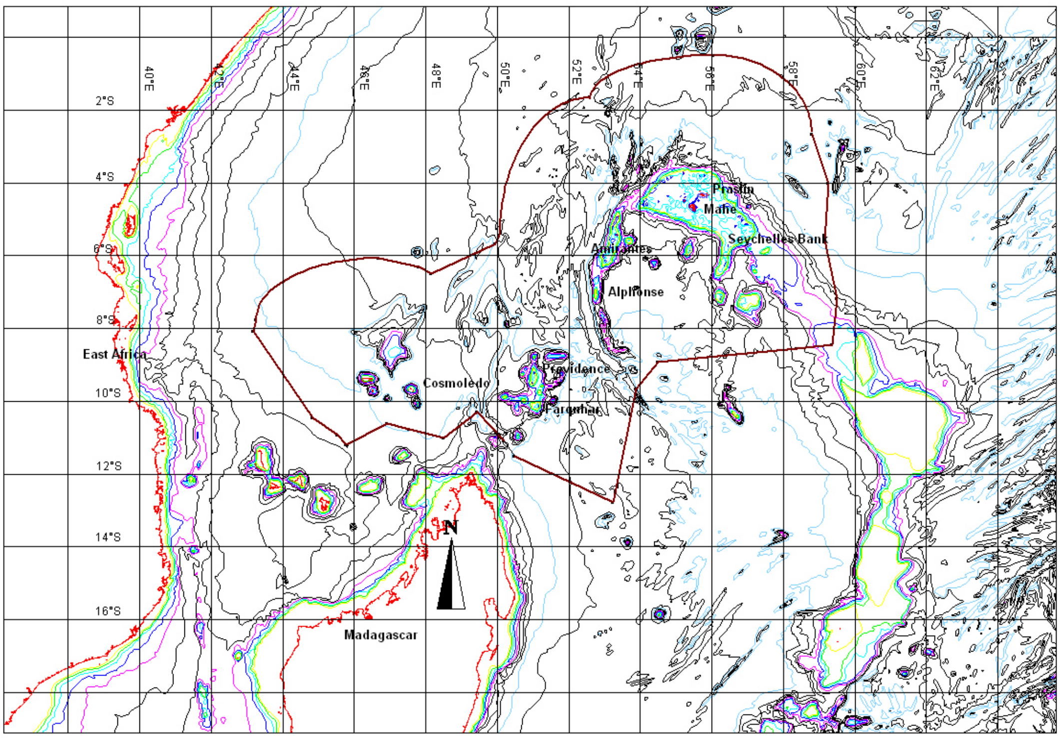

Fig. 1. Bathymetric chart of the Republic of Seychelles, showing the principal banks, islands and the extent of the exclusive economic zone (EEZ)

(Wheeler & Ommanney, 1953). Concentration of effort in the trap fishery within reproductive seasons and spawning areas of the shoemaker spinefoot, *Siganus sutor*, is a practice that has continued for nearly a century (Hornell, 1927).

Concerns over the status of spawning aggregations in the Seychelles have increased over recent years, mainly as a response to reports of heavy exploitation at several sites. Live Reef Fish Food Trade trials at a number of atolls in 1998/1999 (Bentley & Aumeeruddy, 1999) possibly targeted grouper spawning aggregations. The aim of the study reported here was to assimilate local knowledge of coral reef fish spawning aggregations and behaviour through interview-based surveys of the primary stakeholder groups, notably artisanal fishers.

METHODS

Surveys were based on anonymous, semi-structured interviews. A total of 44 interviews were conducted with stakeholders, primarily fishers, over the 10-month period from April 2002 to February 2003. To serve as a structural base for the interviews, which lasted approximately 15 minutes each, a questionnaire was developed with eight questions relating to key characteristics of spawning aggregations, including location, habitat, period of observation, lunar cycle, size and trends in catch, and fishing effort. Fishers were requested to mark locations on Admiralty charts, but were sometimes unwilling to comply or were vague in their responses. Since the accuracy of locations given varied considerably, independent observations for the same area were assessed at a scale of island region (for large islands), island or bank, with the more accurate reports nested within those wider scales; independent observations may not refer to the same aggregation if locations given were poorly described. The majority of interviews were conducted on the granitic islands of Mahé, Praslin and La Digue, centred on the Seychelles Bank (Fig. 1). Interviews were spread across fishers from the main artisanal fisheries (small boats with outboards, whaler and schooner vessels) that employ hook-and-line, drop-lines and traps to target demersal species (MRAG, 1996a). In addition to fishers, other stakeholders in the marine sector (e.g. dive operators) were also approached for interviews using modified questionnaires. A survey database was created to yield two descriptions of the data; number of independent observations of spawning aggregations by location and by spawning period.

For this report, descriptions of the data by location and spawning period are restricted to four commercially important fish groups, namely the groupers, emperors (Lethrinidae), snappers (Lutjanidae) and rabbitfishes (Siganidae), which accounted for the majority of observations. The locations of aggregations are not reported here, with codes being employed instead; these will remain confidential until spawning aggregation management measures are operational.

RESULTS

Most fishers interviewed for this survey were aware that certain coral reef fish species aggregate at specific times and locations to reproduce. The majority of fishers stated that they had personally fished spawning aggregations, which was generally evidenced by the fact that the catches on these occasions were reported to be comparatively large and dominated by numerous individuals of certain species in running ripe condition.

A total of 26 species were reported to form spawning aggregations, of which 14 comprised commercially important species of emperor, snapper, grouper and rabbitfish. A total of 89 aggregations were reported, spread across 22 locations (Table 1). Family level regional patterns were detected; reported observations of grouper spawning aggregations were concentrated to the outer coralline islands, whilst those of emperors, snappers and rabbitfishes were largely confined to the Seychelles Bank. Spawning aggregations of *Siganus sutor* were frequently identified, with eight independent observations for the central granitic islands of the Seychelles Bank.

The species characterised by the greatest number of observations (15) was *Epinephelus fuscoguttatus*; a spawning aggregation at an outer island atoll (OU06) was particularly well known. This species was followed closely by *S. sutor* and the emperor red snapper, *Lutjanus sebae*, both with 14 independent observations from the Seychelles

Table 1. Stakeholder observations of spawning aggregations by location for the key species groups. Sites are coded to safeguard the locations of aggregation sites. IN = locations on the Seychelles Bank; OU = locations on other banks and atolls in the EEZ

	IN														OU								
	01	02	03	04	05	06	07	08	09	10	11	12	13	14	01	02	03	04	05	06	07	08	Tot
Epinephelus fuscoguttatus								2							2	1	1	1	2	6			15
E. chlorostigma														1									1
E. multinotatus			1											2								1	4
E. tukula																1							1
Plectropomus laevis																				2		1	3
Siganus sutor		5	8	1																			14
S. argenteus	1	1	1			1	2						1								1		8
Aprion virescens		2					1	1	1					1	1					1	1		9
Lutjanus bohar										1										1			2
Lu. sanguineus	1	2				2			2					1									8
Lu. sebae		5	1		1	1	1	2		1				2									14
Lethrinus crocineus							1	1															2
Le. mahsena							1																1
Le. nebulosus								1						1	1	1				2	1		7
	2	15	11	1	1	4	6	7	3	2	0	0	1	8	4	3	1	1	2	12	3	2	89

Table 2. Stakeholder observations of spawning aggegations by month or period for the key species groups. Light grey columns = NE monsoon; dark grey column = SE Trades; unshaded columns = inter-tropical monsoon period

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Oct–Nov	Nov–Dec	Dec–Jan	Jan–Feb	Feb–Mar	Mar–Apr	Apr–May	Oct–May
Epinephelus fuscoguttatus											1	2		4	2					
E. chlorostigma												1								
E. multinotatus		1												1						1
E. tukula											1									
Plectropomus laevis												1						1		
Siganus sutor														4						9
S. argenteus													1					1	1	2
Aprion virescens		2		2			1						1	1				1		
Lutjanus bohar				1								1							1	
Lu. sanguineus			1	1									1					3		
Lu. sebae		1	1	2			1				1		1					2	1	1
Lethrinus crocineus				1															1	
Le. mahsena				1																
Le. nebulosus		1									1			1				1		

Bank. Nearly all the Seychelles Bank locations were reported to host aggregations for more than one species.

There were 69 positive responses from stakeholders in terms of the timing of spawning aggregations (Table 2). Ninety-seven percent (97%) of the reported aggregations of emperors, snappers, groupers and rabbitfishes fell between October and May, a period encompassing the NE monsoon and inter-tropical monsoon months (all periods stated are inclusive). In the SE Trades period of June to September there were only two reports of spawning aggregations, for the snappers *Aprion virescens* and *Lu. sebae*. With the exception of *E. multinotatus* and *Plectropomus laevis*, reports of grouper spawning activity were largely concentrated in a narrow period between

November and January. By comparison, observations for snappers were spread more widely across months and periods, with peaks tending towards the inter-monsoon periods of March to May and October to November. For rabbitfishes, the data imply a protracted spawning period between October and May, with a possible peak in November–December for *S. sutor*. There were only 10 observations for three species of emperor.

DISCUSSION

Interviewing fishers is a reliable method for locating spawning aggregations unknown to scientists (Johannes, 1981; Rhodes & Sadovy, 2002). Around one-third of the species reported by fishers in Seychelles are known to form spawning aggregations elsewhere in the Indo-Pacific (for a recent list of known aggregating species, see Russell, 2001), suggesting that many of the reports may be reliable. As expected, 'patriarchal' fishers were the most knowledgeable and were, in general, more willing to divulge detailed information to the interviewers. For example, a fisher called 'Mazarin', who has over 50 years experience fishing in the outer island groups, had a thorough understanding of six spawning aggregations from three different atolls or islands.

The broad-scale distribution of spawning aggregations across the archipelago appears to differ between species groups. Most grouper and *Le. nebulosus* aggregations were reported to occur in the outer, coralline island groups. For snappers and rabbitfishes, aggregations were generally located close to the inner granitic islands and elsewhere on the Seychelles Bank. This pattern probably reflects species distribution and abundance, and is also seen in fishing patterns. Both the trap fishery that targets rabbitfishes and the line fishery that targets *Lu. sebae* (and several other red snappers) are centred on the Seychelles Bank (Lablache et al., 1988; MRAG, 1996a). Groupers and *Le. nebulosus* often dominate catches from the outer island groups (MRAG, 1996a): *Le. nebulosus* is also known to form spawning aggregations in Japanese waters (Ebisawa, 1990). *Epinephelus fuscoguttatus* and *E. polyphekadion*, both known aggregating species, are common in atoll reef habitats (Johannes et al., 1999; Rhodes & Sadovy, 2002), and are rarely caught by vessels operating on the Seychelles Bank.

In Seychelles, snappers are known to exhibit a protracted spawning period between October and May, with peaks in activity at either end, corresponding to the inter-monsoon months (MRAG, 1996a; Wheeler & Ommanney, 1953), a pattern largely supported by the reports from fishers. In East Africa (Kenya and Tanzania), October was identified as a key spawning period for the snappers *Lu. sanguineus*, *Lu. bohar* and *Lu. sebae*, with a smaller peak also occurring in January and February (Nzioka, 1979). This pattern differs slightly from that in Seychelles, where spawning for these species peaks in March and April. The time lag between peaks may be explained by differences in sea surface temperature; although not fully understood, temperature may be a primary cue in annual reproductive cycles (Sadovy, 1996).

The targeting of rabbitfish 'breeding grounds' around the granitic islands was reported as far back as the 1920s (Hornell, 1927), and many modern fishers reported that these fishes exhibit a protracted spawning period between October and May, with October to December identified as a peak in activity. *Siganus argenteus* is known to form transient aggregations in Palau from March to May (Johannes, 1981), but little published information exists for *S. sutor*, which is restricted to the WIO region. A prolonged spawning periodicity with peaks of activity within shorter timeframes has been noted by other authors (Munro et al., 1973; Sadovy, 1996), and is especially known from areas subject to extreme seasonal upheavals, such as the eastern African region (Kulmiye et al., 2002; Nzioka, 1979).

Together with the closely related species *E. polyphekadion*, with which it often shares aggregation sites, *E. fuscoguttatus* typically spawns over two or three consecutive months (Johannes, 1981; Johannes et al., 1999; Rhodes & Sadovy, 2002), a pattern supported by the fisher data from the Seychelles where a large number of independent observations suggests a narrow periodicity of November to January. On the East African coast, Nzioka (1979) found ripe individuals of *E. fuscoguttatus* during the same months. The wide spawning period reported for *Plectropomus laevis* from the outer islands of the Seychelles, encompassing December to April, is similar to that reported for this species on the northern Great Barrier Reef (Johannes & Squire, 1988). In the case of *E. chlorostigma*, for which there were too few reports to adequately assess trends, empirical information reveals a protracted spawning period from November to April with peaks coinciding with the inter-monsoon months (Sanders et al., 1988). Fishers did not identify spawning activity for *E. multinotatus* during the months of August and September, although this period has been identified in the literature (Wheeler & Ommanney, 1953), and it is possible that this species has a wider periodicity than *E. fuscoguttatus*.

There have been several reports of a large grouper aggregation (*E. caeruleopunctatus* or *E. ongus*) that formed on the reef surrounding the lighthouse in Victoria Harbour on the main granitic island of Mahé (as noted in MRAG, 1996b). Throughout the mid-1900s, over a short period in the month of April, fishers from Victoria reportedly landed large catches dominated by this species; it was even known by the Creole name '*vyey avril*' due to the fact that it was so abundant in the markets during that month (Lindsey Chong-Seng, pers. comm.). Given the close proximity to the first settlements and the fact that aggregations can persist for decades or longer (Colin, 1996), it is conceivable that this may have been one of the first aggregation sites known to Seychellois fishers. Anecdotal reports suggest that this aggregation collapsed due to over-fishing some decades ago.

Through a three-year multidisciplinary research and management programme, efforts are now underway to prevent the collapse of other aggregations in Seychelles, particularly grouper aggregations, which are especially vulnerable to over-fishing.

Acknowledgements—The authors would like to thank the SFA Technicians, Danny Julie, Roland Azemia, Maria Cedras and Cynthia Baker, and all the SFA Fisheries Fieldworkers. David Boulle, Yvonne Sadovy, Rachel T. Graham, Kevin Rhodes, Howard Choat and Martin Russell provided valuable input to the development of this study. We are also grateful for the support of all the fishers who have shared their knowledge concerning spawning aggregations. This study forms part of a larger programme of research funded by the Marine Science for Management (MASMA) programme of the Western Indian Ocean Marine Science Association (WIOMSA).

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