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SHORT COMMUNICATION**OBSERVATIONS AT A MULTISPECIES PARROTFISH (SCARIDAE) SPAWNING AGGREGATION SITE AT BERMUDA WITH NOTES ON THE PREDATION BEHAVIOR OF BLACK GROUPEL (*MYCTEROPERCA BONACI*)**

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Introduction

Domeier and Colin (1997) defined a reef fish spawning aggregation as “a group of conspecific fish gathered for the purposes of spawning, with fish densities or numbers significantly higher than those found in the area of aggregation during the non-reproductive periods.” They also distinguished between resident and transient spawning aggregations. The principal characteristics of resident aggregations are: 1) fish are drawn from a relatively small, local area and the spawning site can be reached through a short migration. The site often lies within the home range of the participating individuals; 2) they occur at a specific time of day over numerous days and usually last only a few hours; and 3) they take place daily during an often lengthy reproductive period of the year. Parrotfishes (Scaridae), surgeonfishes (Acanthuridae) and wrasses (Labridae) form resident spawning aggregations (Domeier and Colin 1997). In comparison, transient spawning aggregations have the following characteristics: 1) fish are typically drawn from a relatively large area and must often travel days or weeks to reach the aggregation site; 2) they occur during a very specific portion of the year, usually 2–3 months and are entrained to the lunar cycle; 3) they persist for a period of days or at most a few weeks (Domeier and Colin 1997). Groupers (Serranidae), snappers (Lutjanidae) and rabbitfishes (Siganidae) are classified as forming transient spawning aggregations. As these families include many of the most important commercial species in tropical fisheries, the majority of research on spawning aggregations has been conducted on transient aggregation spawners (Whaylen et al. 2004, Matos-Caraballo et al. 2006, Heyman and Kjerfve 2008). Sadovy and Domeier (2005) discuss some of the challenges of evaluating and managing reef fish spawning aggregations and associated fisheries. In contrast to transient spawning aggregations, relatively little research has been conducted on resident spawning aggregations as these species are not generally

harvested in commercial fisheries, an exception being the landings of scarids and acanthurids in the trap fisheries of the wider Caribbean (Munro 1983). Scarids play an important role as grazers in the economy of coral reefs and thus understanding the spawning aggregations of these species is important for resource management (Hawkins and Roberts 2003). In the tropical western Atlantic, there are only two species of parrotfish (*Sparisoma rubripinne*, *Scarus iserti*) and two species of surgeonfish (*Acanthurus coeruleus*, *A. bahianus*) which have been adequately documented to form resident spawning aggregations (Sadovy et al. 2008).

However, the first study of any reef fish spawning aggregation was conducted on a resident aggregation of red-fin parrotfish (*S. rubripinne*) on a fringing reef in St. John, U.S. Virgin Islands (Randall and Randall 1963). Other studies on resident spawning aggregations of scarids in the Caribbean include those of Colin (1978) in Jamaica and Colin and Clavijo (1988) in Puerto Rico. Scarids have complex socio-sexual systems and exhibit both group and pair spawning (Thresher 1984). The most common relationship between sex and color pattern in scarids is exhibited by the presence of two distinctive color patterns; terminal-phase (TP) males and initial-phase (IP) males and females (Thresher 1984). TP males usually have brightly-colored patterns while IP fish are generally drab in appearance (Bohkle and Chaplin 1968). Robertson and Warner (1978) describe sex change, coloration, and mating behavior of 10 species of Caribbean parrotfishes from the San Blas islands of Panama, including all of the species discussed in this study.

The objective of the present study was to describe the spawning behavior of three different species of parrotfishes at the same spawning aggregation site with detailed timing sequences. In addition, observations of other species known to form resident spawning aggregations (i.e., surgeonfishes) and the predatory behavior of black grouper

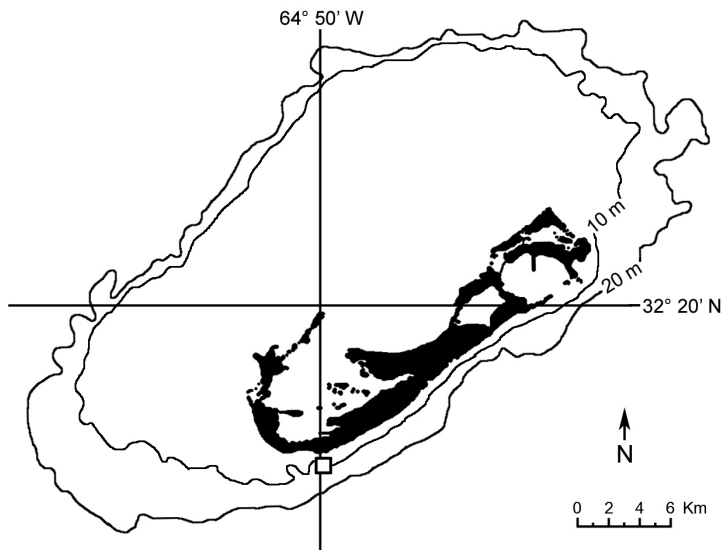


Figure 1. Map showing location of multispecies scarid spawning aggregation site (northeastern quadrant of square) off the southwest coast of Bermuda just outside the 10 m bathymetric curve. The 20 m bathymetric curve is also indicated.

(*Mycteroperca bonaci*) at this aggregation site are included.

Site Description

The spawning aggregation site was located just outside the breaking reef line along the southwest coast of Bermuda about 500 m from the shoreline (Figure 1). The site was a patch reef surrounded by sand in 10–12 m water depth. The top of the reef was relatively flat with low cover (< 20%) of live coral. Another larger reef 5–6 m to seaward had greater vertical relief and more crevices than the spawning site reef. The aggregation site was within the protected area (300 m radius) of the Marie Celeste dive site (J. Pitt, pers. comm., Marine Resources Division, Bermuda) which is a permanent no-take MPA (Marine Protected Area). Water temperature at 10 m depth was 24°C on both 9 June and 27 June 2003; it was 25°C on 7 July 2003.

Materials and Methods

Observations (see below) were made in the afternoon on 9 June and in the morning on 27 June and 7 July 2003 (Table 1). Two divers using SCUBA made stationary point counts while suspended in the water column, estimating the number of each scarid and acanthurid species present at the site. Counts and notes were recorded on waterproof paper on slates. Observations concentrated on those species believed to form resident spawning aggregations. Divers also noted behaviors of spawning fishes, color changes and times of occurrence of spawning events. The number and sizes of black grouper at the site were estimated and predation behavior was noted. At the end of each observation period, divers compared notes to arrive at a consensus about counts and observations.

Two types of spawning behavior were observed: group-spawning and pair-spawning. Definitions of the terms used in this paper follow Domeier and Colin (1997): **Spawning Rush** – a rapid burst of swimming, usually vertical or steeply inclined, that culminates in the release of gametes at its apex and the rapid return of the fish to the substrate or aggregation; **Group-Spawning** – spawning rush consisting of more than two fish, often many individuals. The group usually consists of a single female and multiple males; spawning may occur in the absence of elaborate courtship; **Pair-Spawning** – courtship and spawning by a single male and single female. Pair-spawning may occur within, or in the absence of a spawning aggregation; **Subgroup** – a portion of a larger spawning aggregation that interacts as a unit, often leading to spawning by the subgroup; and **Gamete Cloud** – gamete concentration left suspended in the water column by spawning fishes. Since eggs are nearly transparent, the visible cloud is primarily the result of sperm; may remain visible from a few seconds to a few minutes depending upon the currents and the amount of sperm.

Results

The location where spawning was actually observed was confined to an area of 30–40 m² on the eastern side of the patch reef. However, the larger reef to seaward of the spawning site appeared to be used by some scarids as a shelter area and some fish were observed to swim across the sand channel to the spawning site to join conspecifics already on the site. Scarids appeared to arrive at the site from different directions, usually in small groups.

Scarid spawning behavior

Summaries of the observations of spawning behavior of three different species of scarids, principally *S. rubripinne* and the queen parrotfish, *Scarus vetula*, are found in Table 1. Both of these species were observed spawning on 27 June and 7 July. The third species observed in spawning mode was the stoplight parrotfish, *Sparisoma viride*, but those observations were made on 9 June and were limited to 3 spawning events (Table 1). When divers arrived at 0955 h on 7 July, spawning was already in progress with both *S. rubripinne* and *S. vetula* spawning at the same time (Table 1). Sunrise on 7 July was at 0617 h Atlantic Daylight Time and it is not known when spawning commenced or for how long it continued after observations ceased. The total number of spawning events documented over the 3 days of observations were: *S. rubripinne* – 46, *S. vetula* – 11 and *S. viride* – 3 (Table 1). Two other species of scarids, the redband parrotfish, *Sparisoma aurofrenatum* and the princess parrotfish, *Scarus taeniopterus*, were recorded at the site but neither was observed to spawn (Table 1). Two species of acanthurids, the blue tang, *Acanthurus coeruleus*, and the ocean surgeon, *A. bahianus*, were also observed and were seen moving across the spawning site in groups (Table 1) but they did not re-

TABLE 1. Summary of diving observations at a multispecies spawning aggregation site in 2003 off the southwest coast of Bermuda. Observations on species in 2 families are presented, parrotfishes (Scaridae) and surgeonfishes (Acanthuridae). Species are listed alphabetically within family commencing with Scaridae. IP = initial phase and TP = terminal phase fishes. Lunar phase — dbfm: days before full moon, dafm: days after full moon. See text and Figure 2 for behavioral details.

Date and observation period (h)	Lunar phase	<i>Mycteroperca bonaci</i> present (predation attempts)	Observed species	Estimated abundance	Observations
June 9 (1300 – 1355 h)	5 dbfm	3 (0)	<i>Sparisoma aurofrenatum</i>	15	Milling and TP chasing IP fish, no spawning
			<i>Sparisoma rubripinne</i>	15	Milling but no chasing or spawning
			<i>Sparisoma viride</i>	60	Milling, TP chasing IP fish, 3 pair spawns
			<i>Acanthurus coeruleus</i>	40	Group streaming across spawning site, moving offshore
June 27 (1045 – 1140 h)	13 dafm	8 (3)	<i>Scarus taenopterus</i>	10	Mixed with group of <i>Scarus vetula</i> streaming, no spawning behavior
			<i>Scarus vetula</i>	55	Groups of TP (25) and IP (30) fish streaming separately, mixed at site followed by 3 pair spawns
			<i>S. rubripinne</i>	25	From 1055–1102 h, 6 group spawns (10–12 fish/group), all IP, gamete clouds, TP males not active during spawning
			<i>Acanthurus bahianus</i>	50	Milling seaward of spawning site
			<i>A. coeruleus</i>	55	Streaming across site moving offshore
July 7 (0950 – 1100 h)	7 dbfm	9 (6)	<i>S. vetula</i>	20	From 0955–1045 h, 8 pair spawns (1TP+1IP), TP color changes, gamete clouds
			<i>S. rubripinne</i>	100	Milling at site, from 0955–1024 h, 26 group spawns (10–12 fish /group), all IP, gamete clouds. From 1035–1045 h, 14 pair spawns (1TP+1IP), gamete clouds
			<i>A. bahianus</i>	25	Streaming across site moving offshore
			Total predation attempts = 9		Total spawning events: <i>Scarus vetula</i> = 11 <i>Sparisoma rubripinne</i> = 46 <i>Sparisoma viride</i> = 3

main during observations. These species did not exhibit any courtship or spawning behavior.

The spawning behavior of the two principal scarid species, *S. rubripinne* and *S. vetula* is illustrated in Figure 2. In *S. rubripinne*, subgroups of 10–12 IP fish moved together upward (1–2 m) from the main group in a ‘rapid spawning rush’ (Domeier and Colin 1997) with the release of gametes at the apex of the rush, which was clearly visible. These fish then immediately descended back to the main group. The entire spawning sequence occurred in 2–3 sec. Several *S. rubripinne* TP fish were present but did not appear to participate in the spawning sequence. During a period of intense spawning activity, group–spawns were occurring every 20–30 sec (Table 1). On 7 July, *S. rubripinne* switched from

group–spawning to pair–spawning (1 TP + 1 IP) after a brief interval when no spawning activity was recorded. A total of 14 pair–spawns were recorded in a 10 min period (Table 1). In one instance, 3 separate pair–spawns occurred in a period of only 10 sec.

Scarus vetula was only observed to pair–spawn (Figure 2) but the spawning sequence was similar to that described for *S. rubripinne*. Pairs (1 TP + 1 IP) were observed to rise upward (2–3 m) from the main group in a spawning rush with gamete release at the apex of the rush (Figure 2). The spawning sequence lasted only a few seconds and, on 7 July, a total of 8 pair–spawns occurred at the site over a period of 50 min (Table 1). One TP male was observed to pair spawn twice in 30 sec and on descending after the second spawning rush,

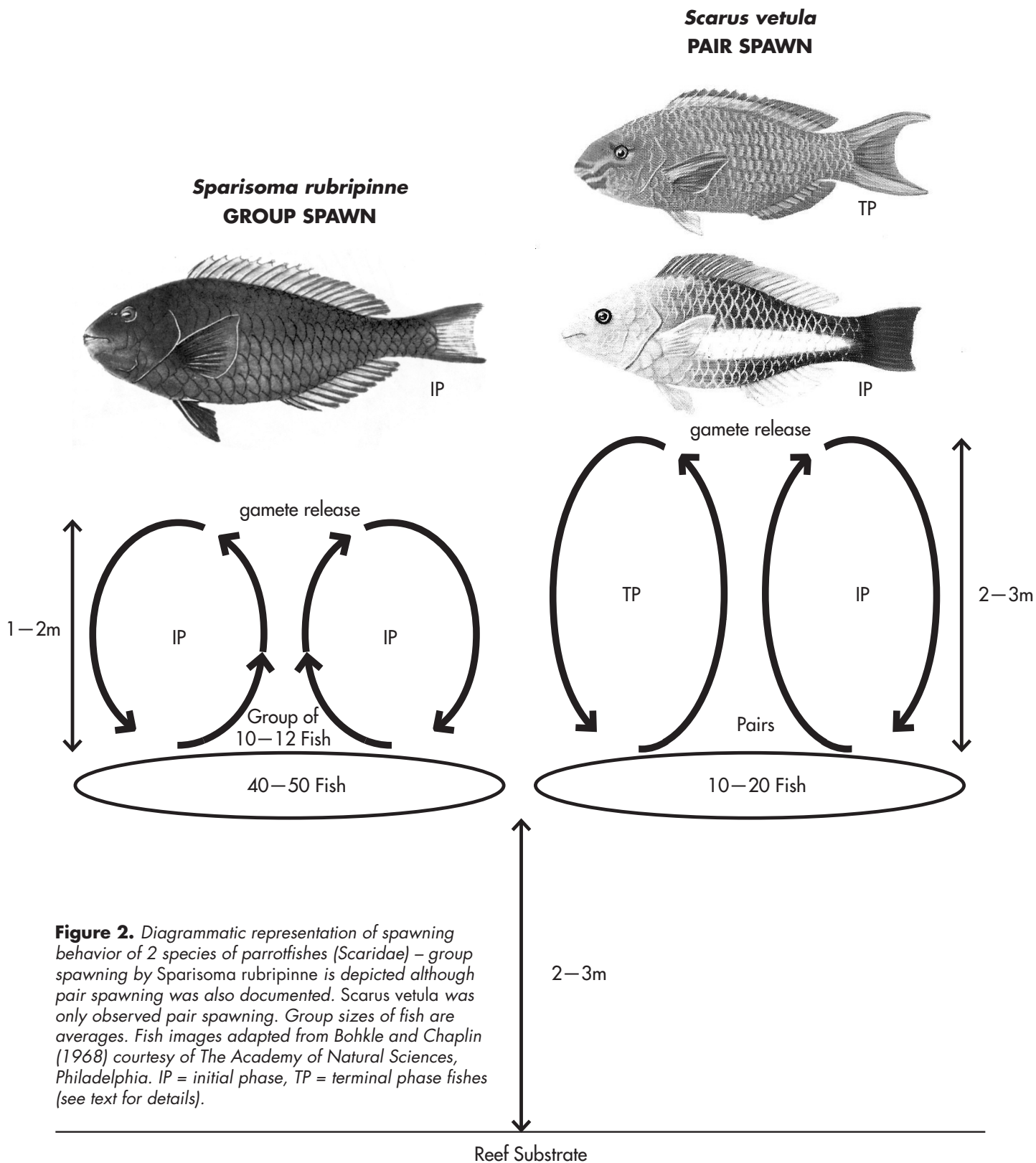


Figure 2. Diagrammatic representation of spawning behavior of 2 species of parrotfishes (Scaridae) – group spawning by *Sparisoma rubripinne* is depicted although pair spawning was also documented. *Scarus vetula* was only observed pair spawning. Group sizes of fish are averages. Fish images adapted from Bohkle and Chaplin (1968) courtesy of The Academy of Natural Sciences, Philadelphia. IP = initial phase, TP = terminal phase fishes (see text for details).

a black grouper lunged at this TP male and then chased it for about 5 m (see section below). Pair-spawning of *S. viride* was observed only 3 times but appeared to be similar to that described above for *S. vetula*.

Predation behavior of black grouper

During observation periods, the number of black grouper in close proximity (about 10 m) to the spawning aggre-

gation site ranged from 3-9 (Table 1). The majority of fish were estimated to be >120 cm fork length, a size considered to be male in this sex-changing species (Luckhurst 2010). These fish generally hovered above the substrate in a loose group, were quiescent, and were mostly observed at the seaward end of the sand channel leading to the spawning aggregation site. As scarid spawning activity intensified (Table 1),

several black grouper slowly moved up the channel and positioned themselves near the perimeter of the site. The scarids formed what is termed here a “prey envelope” around the black grouper as it approached, as if the grouper were “in a bubble.” However, the scarids always maintained a minimum distance between themselves and the black grouper as it moved.

A total of 9 predation attempts on scarids were observed during which lunges were followed by brief chases. These predation attempts almost all occurred when the fish were descending towards the substrate following a spawning rush (Figure 2). Predation behavior was observed toward both *S. rubripinne* and *S. vetula* (total of 57 spawning events) but no attempts were successful.

Discussion

Scarid spawning behavior

Given the limited observations at this multispecies spawning aggregation site, generalizations about the overall spawning behavior of the three scarid species described are not warranted. However, this is the first documentation of a resident spawning aggregation site in Bermuda used by more than one species of scarid. In addition, the presence of other known species of resident spawners (i.e., acanthurids) suggests that this spawning site may be used by other species as well. Although no acanthurid spawning was observed, it is possible that spawning did occur outside of the observation periods. For example, Colin and Clavijo (1988) reported that both *A. coeruleus* and *A. bahianus* formed resident spawning aggregations in the late afternoon near the shelf break in Puerto Rico, a time period outside of the observation periods in this study.

Sparisoma rubripinne was observed at the site on the 3 days of observation but spawning was only observed in the morning. In contrast, Randall and Randall (1963) never saw this species at their spawning site until 1100 h and the majority of spawns occurred in the afternoon in their study. Furthermore, they only observed group-spawning whereas I report both group spawns and pair spawns sequentially during the same observation period in the morning. Consistent with the observations by Randall and Randall (1963) and Robertson and Warner (1978) in the San Bias islands of Panama, I did not observe *S. rubripinne* TP males participating in group spawning but only in pair-spawning. Robertson and Warner (1978) did not observe any group-spawning and only observed pair-spawning in the late afternoon. It appears from these limited observations that there is considerable variability in the spawning modes and times of this species.

Scarus vetula was only observed during morning observations but spawning occurred on 27 June and 7 July with only pair-spawning (1 TP + 1 IP) being recorded when there were up to 55 fish at the site. Colin and Clavijo (1988) reported only pair-spawning of *S. vetula* TP males and IP fe-

males only during mid to late morning and at no other time. Their description of TP males swimming in the water column a few meters above the bottom and then being joined by a female *S. vetula* in a spawning rush is broadly consistent with the behavior outlined here. Colin and Clavijo (1988) also report that gametes in this species are often released (at the apex of the spawning rush) 6 m or more above the substrate which is consistent with my estimate. Robertson and Warner (1978) never witnessed spawning in this species, although Randall and Randall (1963) report seeing a *S. vetula* TP male pair-spawn with an IP fish in St. John, U.S. Virgin Islands.

The third parrotfish, *S. viride*, observed spawning at the site did so in the afternoon (9 June) and was not present during morning observations. Only three pair-spawns (1 TP + 1 IP) were observed. Robertson and Warner (1978) and Colin and Clavijo (1988) reported that this species pair-spawned throughout the day over a broad range of times.

Predation by black grouper

None of the 9 observed predation attempts by black grouper on spawning scarids was successful, however, the total number of spawning events (57) for the 2 principal species observed represent a small sample size. As a result, these data should not be used as an estimate of predation success. Colin and Clavijo (1988) witnessed thousands of spawning events and they reported that attempts by piscivores to prey on spawning fishes were rare. They were unable to confirm a single successful predation event. Sancho et al. (2000) determined that piscivores differentially selected group-spawning species during spawning rushes over pair-spawning and non-spawning fishes. Predation attempts by piscivores on a group spawning scarid, *Chlorurus sordidus*, were observed in only 3.6% of the total number of spawns (3,749) witnessed in this species. Of these attacks, only 5.2% were successful (Sancho et al. 2000). Overall, attack rates by piscivores on adult spawning fishes were higher than by planktivores feeding on recently released eggs. No feeding on gamete clouds by planktivores was observed in this study.

In Bermuda, black grouper are known to feed on scarids as identifiable scarid remains were found in the stomach contents of several black grouper examined while conducting a fishery biology study on this species (Luckhurst, pers. obs.). **There may be an increased frequency of predation attempts by black grouper while scarids are spawning as they may be less wary but this would require further study to evaluate.** Sancho et al. (2000) found that almost 85% of all recorded predation attempts took place on fishes involved in spawning rushes. My limited observations suggest similar behavioral selection by this large benthic predator on spawning fishes rather than on groups of fishes milling over the substrate.

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