

**Observations of a Nassau Grouper (*Epinephelus striatus*)
Spawning Aggregation Site in Little Cayman,
Including Multi-species Spawning Information**

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ABSTRACT

The precipitous decline in mass spawning aggregations of Caribbean grouper and snapper species has been well documented. One-quarter to one-half of the known Caribbean aggregation sites are now inactive due to the ease with which aggregating species are caught. Historically, five spawning locations have been documented in the Cayman Islands. Today, three of these sites are dormant or commercially extinct. In January 2002, an expedition was led by the Reef Environmental Education Foundation (REEF) to Little Cayman Island to document a recently discovered spawning aggregation of Nassau grouper (*Epinephelus striatus*) on the island's west end. A team of divers conducted visual and video surveys on the aggregation site and on nearby reefs for ten days surrounding the full moon. Size and abundance estimates, color phase, and courtship and spawning behavior were documented. The Nassau grouper at the aggregation site shifted from mostly white belly phase early in the aggregation cycle to predominately dark phase in the middle of the cycle to mostly bicolor phase at the end. Toward the middle of the aggregation cycle the number of animals reached a maximum of approximately 5,200 fish. Courtship behaviors were documented each night and spawning was witnessed on four nights beginning five days after the full moon. Courtship coloration and behavior were documented in ten additional fish species. Five of these species were seen spawning. Hook and line fishing occurred daily on the aggregation. The Cayman Islands Department of the Environment reported a total catch of 1,934 Nassau grouper during the 10-day project, with an average landed size of 61.9 cm and a female to male sex ratio of 1:1.6 for all landed fish (39% females).

KEY WORDS: Spawning aggregations, Nassau grouper, *Epinephelus striatus*

Observaciones de un Sitio de Freza del Nassau Grouper (*Epinephelus striatus*) en Little Cayman, Incluyendo Información de la Freza Multi-especie

La declinación empinada en agregaciones frezando de las especies del Caribe del grouper y del snapper se ha documentado bien. Casi una mitad de los sitios del Caribe sabidos de la agregación están inactivo ahora debido a la facilidad con la cual la especie que es típicamente solitaria puede ser cogida mientras que se junta. Históricamente, cinco localizaciones de grouper se han documentado en las islas de Cayman. Hoy, tres de estos sitios son inactivos o comercialmente extintos. En enero de 2002, la Fundación Ambiental de la Educación del Arrecife (REEF) condujo una expedición a Little Cayman a documentar la recientemente descubierta agregación frezando del Nassau grouper (*Epinephelus striatus*) en el extremo del oeste de la isla. Un equipo de buceadores condujo encuestas visuales y de vídeo sobre la representación en el sitio de la agregación y los arrecifes próximos por diez días que rodeaban la luna llena. Las estimaciones del tamaño y de la abundancia, la fase del color, y el comportamiento del courtship y del grouper fueron documentados. Los grouper de Nassau en el sitio de la agregación cambiaron de puesto a partir sobre todo de la fase blanca del vientre temprano en el ciclo de la agregación a la fase predominante oscura en el centro del ciclo sobre todo a la fase bicolor en el extremo. Hacia el centro del ciclo el número de animales alcanzó un máximo de aproximadamente 5.200 pezes. Los comportamientos de courtship fueron documentados cada noche y la freza fue atestiguada por 4 noches que comenzaban 5 días después de la luna llena. La coloración y el comportamiento de courtship fueron documentados en diez especies adicionales de los pescados. La freza de cinco de estas especies fue documentado visualmente. La pesca del gancho y de la línea ocurrió diariamente en la agregación. El Departamento del Ambiente de Little Cayman divulgó un retén total del Nassau grouper de 1.934 durante el proyecto de 10 días, con un tamaño aterrizado medio de los 61,9 cm y una hembra al cociente masculino del sexo de 1:1.6 para todos los pezes aterrizados.

PALABRAS CLAVES: *Epinephelus striatus*,

INTRODUCTION

Nassau grouper (*Epinephelus striatus*) are large sized, long lived fish within the family Serranidae, subfamily Epinephalinae. The distinguishing characteristics of this species include a large black saddle near the caudal fin and five dark bars along the body. Sexes do not exhibit differences in color or shape. However, as with other serranids, Nassau grouper can rapidly blanch their color in response to entering cleaning stations, movement from one habitat to another, or predator/prey interactions (Colin 1992, Carter et al. 1994). Nassau grouper have an average life span of 16 years (Sadovy and Ecklund 1999), can reach a length of 91 cm TL, and

weigh up to 25 kg (Olsen and LaPlace 1979, Domeier and Colin 1997). Originally thought to be protogynous hermaphrodites, evidence now suggests that Nassau grouper are gonochoristic with the capacity to change sex (Sadovy and Colin 1995, Sadovy and Eklund 1999). Sexual maturation is reached at approximately 1.87 kg (Sadovy et al. 1994b) or 40 – 45 cm, which is between four and seven years old (Sadovy and Eklund 1999). Their geographic distribution includes North Carolina to Florida, Gulf of Mexico, Bahamas, and the Caribbean to Venezuela (Bohlke and Chaplin 1993, REEF 2002). Historically, Nassau grouper were also found in Bermuda but the species has become locally extinct due to harvest pressure (Luckhurst 1996). Adults are normally solitary and territorial and live on coral reefs and rocky bottoms.

Several species of grouper, including Nassau grouper, are known to migrate to specific sites during the winter full moons in order to reproduce in mass aggregations (Domeier and Colin 1997, Bolden 2000, Sala et al. 2001). The benefits of aggregating to spawn include reduction of egg predation, increased genetic exchange, and higher fertilization rates (Domeier and Colin 1997, Bolden 2000, Sala et al. 2001). Spawning aggregation (SPAG) locations are typically at a reef promontory near a drop-off (Colin et al. 1987, Colin 1992). The environmental and social triggers that cause fish to aggregate are not well understood, although studies have suggested changing lunar light conditions, water temperature, currents, learned behavior, geomorphology, or a combination of multiple factors (Colin et al. 1987, Carter 1989, Tucker et al. 1993, Domeier and Colin 1997, Sadovy and Eklund 1999, Paz and Grimshaw 2001). While females have been seen repeatedly spawning in one evening, it is not known if the same fish aggregate in every aggregation month or even each year (Sadovy and Eklund 1999).

Five Nassau grouper spawning aggregation sites existed on the Cayman Islands: one each on the southeast corners of Little Cayman and Cayman Brac and three on Grand Cayman (Tucker et al. 1993). Of the total Nassau grouper currently harvested per year in the Cayman Islands, it is estimated that fishermen take 90% or more from aggregations (P. Bush, pers comm). This intense harvest has resulted in the commercial extinction or complete disappearance of 3 of these sites. The east end SPAG on Little Cayman had been fished since 1903 (Colin et al. 1987). In 1987, four days before the full moon in January, fishermen landed 1,000 Nassau grouper from Little Cayman's east end SPAG in one evening (Colin et al. 1987). In 1995, this site no longer contained an aggregation. The east end SPAG on Cayman Brac had also been fished for nearly 100 years (Colin et al. 1987). Between 1984 and 1991, the aggregation was dormant. In 1992, an aggregation was found approximately 1.2 km north of the dormant Cayman Brac site and was intensively fished the following four years (1993-1996). Since 1996, catches from this site have sharply declined (P. Bush pers. comm). Tucker et al. (1993) documented the three Grand Cayman spawning aggregations for five consecutive seasons (1987-1991) and found declines in harvest yield during this time in at least one site. Since Tucker et al.'s study of Grand Cayman SPAGs (1993), one has disappeared (southwest corner), one has become commercially extinct (northeast corner), and the third

(Twelve Mile Bank) yields a variable amount of Nassau grouper but is fished by only a few fishermen (P. Bush, pers comm).

In 2001, fishermen discovered aggregated Nassau grouper on the west end of Little Cayman Island. That year, fishermen harvested 2,000 Nassau grouper during the aggregation. In the winter of 2002, the Reef Environmental Education Foundation (REEF) coordinated an expedition to document this new aggregation site. REEF staff and volunteers collected information on the size and spatial extent of the aggregation over the course of the January/February aggregation cycle, as well as behavior of aggregating fishes. In this paper we present the results of this expedition.

METHODS

Study Area

The Cayman Islands are a British Crown Colony located in the western Caribbean. The three islands, Grand Cayman, Little Cayman, and Cayman Brac, lie between 19° 15' and 19° 45' N latitude and between 79° 44' and 81° 27' W longitude. Little Cayman lies approximately 145 km to the east-northeast of Grand Cayman and is about 10 km from Cayman Brac. The island is oriented in a northeast to southwest direction. The fringing reefs that surround most of the island contain shallow reef crests (rubble ramparts) as well as mid-shelf and shelf-edge fore reefs (Blanchon and Jones 1997). The aggregation site documented in this study was located at the terminus of the southwestern end of the island's shelf. The area features a sloping drop-off extending 0.6 km from shore to the 15 m depth contour (delineating the shallow terrace) and then continues as a deeper terrace to approximately 24 m. Benthic habitat of the shelf edge between 24 and 33 m featured low relief ridges and plateaus, interspersed with wide (30 m) sand patches. At 33 m the shelf edge precipitously drops off to a sheer wall. The area's currents are complex and range from slack to estimated speeds of three knots. Surface water temperature during the project was 26°C. Horizontal visibility ranged from 20 – 30 m.

The west end aggregation site was initially believed to be a new area for grouper reproduction on the island. However, anecdotal information from local fishermen now indicates that grouper historically aggregated at this site as recently as the 1960s.

Field Observation

Field work was conducted in January/February 2002 on Little Cayman Island. Underwater observations began the day before the full moon (dbfm) and lasted ten days (January 27 – February 5). A team of seven divers documented activity at the west end aggregation site each night, beginning the evening of the full moon (January 28). In addition, staff from the Cayman Islands Department of the Environment (CIDOE) and local dive operators accompanied the core team of

observers on several evenings. The team entered the water 10 to 72 minutes before sunset (mbs) each night and remained in the water approximately 40 minutes. In an attempt to minimize the impact of the divers' presence on the groupers' activities, the divers maintained positions approximately 7 m from the bottom and 10 m from dense aggregations of fish. Dives averaged 30 m in depth. Five members of the team estimated the number of individual Nassau grouper present, estimated color phase composition, and recorded the presence of distended abdomens and courting/spawning behavior. On the evenings when spawning was observed, divers reported the time of each gamete release. Because the amount of overlap of releases observed between divers is unknown, the maximum number reported by a given diver is presented here. Observations on the presence and activity of other fish species were also recorded. Two additional divers took underwater video using digital video cameras without lights.

The dimensions and size of the aggregation were estimated using topographic reference points and point counts of individuals. Each night, density estimates were obtained from multiple divers and then an average was calculated. Estimates were generated using counts within visually determined 3.3 m³ 'quadrats'. Multiple estimates were made for both the plateau and the shelf edge to generate mean values.

In addition to the observations made on the aggregation site each evening, five members of the team conducted multiple daytime visual surveys on reefs around Little Cayman using the Roving Diver Technique (RDT; (Schmitt and Sullivan 1996). During RDT surveys, the divers recorded all fish species encountered and relative abundance categories for each [Single (1), Few (2-10), Many (11-100), Abundant (> 100)]. Divers also recorded information on the size, depth, color phase, presence of a distended abdomen, group size (if traveling with others), and direction of movement (if any) for all sighted Nassau grouper.

Fishermen were present on the aggregation site each day of the project but most rarely fished on the aggregation after sunset. The total number of boats at any given time ranged from one to thirteen and each boat carried two fishermen. All fishing was artisanal hook and line. No special license was needed; however, Cayman Island law only permits Caymanians to fish aggregation sites during grouper spawning season. CIDOE sampled catches throughout the aggregation period to obtain length and sex of aggregated Nassau grouper. CIDOE also collected daily landing numbers.

RESULTS

A total of 67 visual RDT surveys were conducted on 14 reefs around the island (Figure 1) during daytime hours, representing 60 hours of survey time. A total of 176 fish species were documented, including four species of grouper in the genera *Epinephelus* and *Mycteroperca*. Sighting frequency (%SF) of the four species during the visual surveys were 79.1 % (tiger grouper – *M. tigris*), 62.6 % (Nassau grouper), 41.7 % (yellowfin grouper – *M. venenosa*), and 13.4 % (black grouper –

M. bonaci). These values were similar to those calculated for 153 RDT surveys collected during summer months of 2000 and 2001 from Little Cayman reefs (REEF 2002). However, the mean 2000/2001 summer % SF value for Nassau grouper was 80.3 %, considerably higher than what was encountered during the aggregation period. The complete data summary for the RDT data can be accessed from REEF's Website (REEF-GMP 2002).

The aggregation site (Figure 1; Site A1) was surveyed for nine nights beginning on the full moon (January 28).

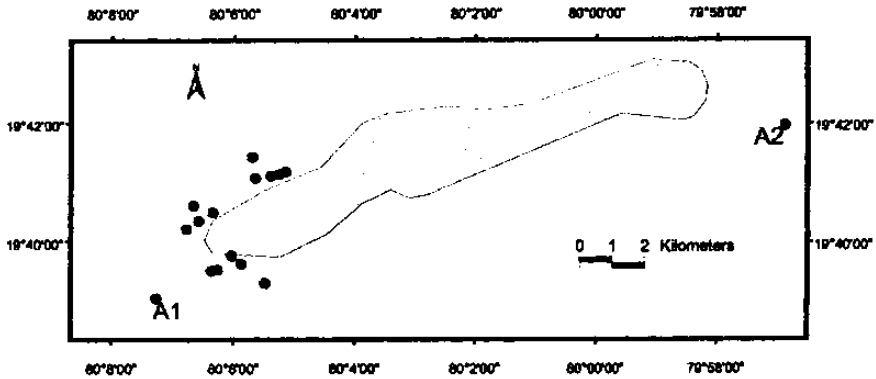


Figure 1. Map of the study area, indicating location of west end aggregation site (A1), the historical east end aggregation site visited on February 4 (A2), and the 14 reef sites surveyed during the day (indicated by dots).

Aggregation Characteristics

The average estimated number of Nassau grouper present at the aggregation site ranged from 408 on the 8th day after the full moon (dafm), the last evening the aggregation was documented, to 5,200 individuals 2 dafm. During the aggregation cycle, a total of 1,934 Nassau grouper were harvested from the aggregation site. The mean estimated numbers present on the aggregation each night and the total catch reported each day are shown in Figure 2.

Staff from the CIDOE recorded total length of 275 Nassau grouper, representing approximately 14 % of fish landed. Based on the individuals sampled, the average TL of harvested fish was 61.9 cm (47 - 86 cm), which equates to an 8+ year old fish (Sadovy and Eklund 1999). Approximately 22 % of the catch (431 fish) was sexed. The female to male sex ratio varied through time; the aggregation was dominated by males early and late in the aggregation cycle with females dominating just prior to the peak of spawning activity (Figure 3). The average female to male sex ratio was calculated to be approximately 1:1.6 (39 % females, 166 females and 265 males). A sub-sample of those sexed was also measured and little difference was found between males and females (67.5 cm and 72.3 cm mean TL in females and males, respectively).

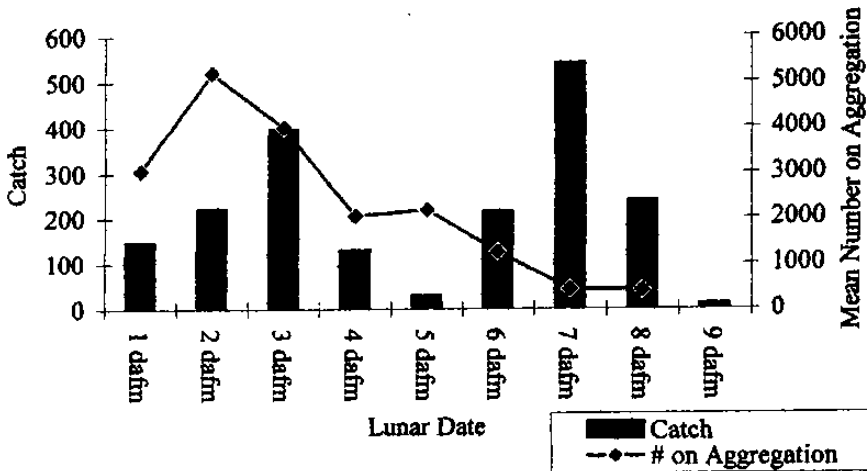


Figure 2. Daily catch and mean number of Nassau grouper visually estimated at the aggregation

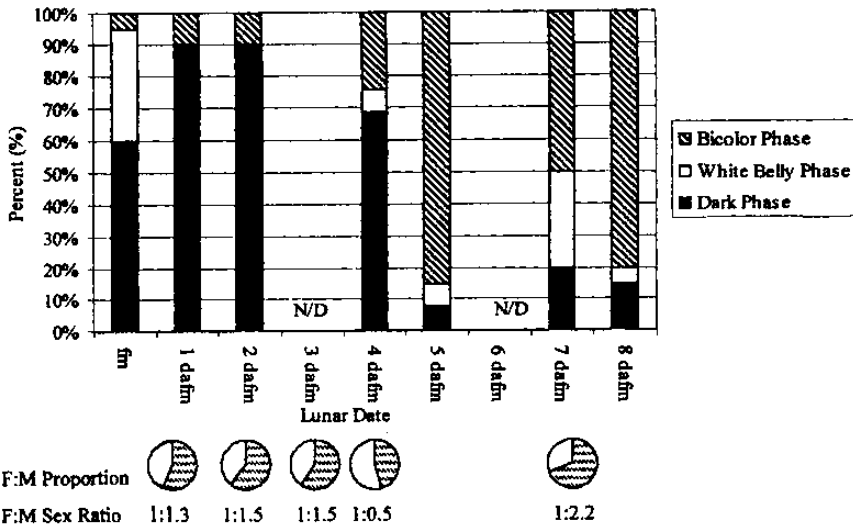


Figure 3. The shift in color phases during the aggregation cycle and the sex ratios based on catch data. Bars indicate the proportional color phase composition at the aggregation site. Pie charts show the proportional sex composition, based on landed fish, with the corresponding sex ratio (female:male) below each pie. Within each pie, hash marks are male and white is female.

Nassau Grouper Movements and Coloration

Characteristics and Behavior on Reef Sites — During daytime dives early in the aggregation cycle (1 dbfm – 4 dafm), approximately half of the Nassau grouper displayed courting colorations (white belly and dark) and had distended abdomens. Most fish with distended abdomens were in white belly phase. The majority (65 %) of all individuals seen were traveling in a directed manner along the shelf edge between 19 and 38 m. Of those in transit, most individuals were traveling in groups of two to eight individuals. The direction of travel was evenly split between going southwest (toward the location of the aggregation site) and going northeast. Most of the migrating individuals were seen at sites on the northwest side of the island. On two occasions, individual grouper were observed changing color phases while in transit; one barred phase changed to bicolor phase and one dark phase changed to barred phase.

Surveyors documented the largest number of grouper 2 dafm, with 27 fish seen during one dive. By the 5th dafm, the number of Nassau grouper seen during daytime dives decreased, and those that were seen were all in the barred (normal) color phase and were not migrating. Mean TL for all Nassau grouper observed during daytime dives was 42 cm, ranging from 26 cm to 60 cm. The smallest individual seen migrating was 32 cm.

Coloration Shifts and Behavior on the Aggregation Site — During the initial days of observation (full moon – 4 dafm), surveyors documented a consistent pattern of crepuscular movement and shift in dominant color phases. Throughout each evening during this time, the composition of color phases shifted to predominantly dark phase as sunset approached and the entire aggregation would move from hovering 1 – 6 m above the plateau to over the shelf edge (Figures 4a and 4b). Bicolor phase fish constituted less than 10 % of the fish present between the full moon and 4 dafm. Barred phase fish were observed on or near the bottom along the perimeter and interior of the aggregation. When present, white belly phase fish were always near the bottom of the aggregation near the substrate.

Interactions between individuals during this time period were rare, but when they occurred, the interaction appeared to be a herding or courting activity in which one dark phase individual was closely followed and partially surrounded by a few other fish (often bicolor phase). The closest pursuers would sometimes nudge the leader on the belly.

As the lunar phase approached 5 dafm, the herding activity became common and the grouper moved more rapidly. In addition, bicolor phase fish dominated (85 % of fish present) and the aggregation concentrated over the shelf edge (Figure 4c, Figure 3).

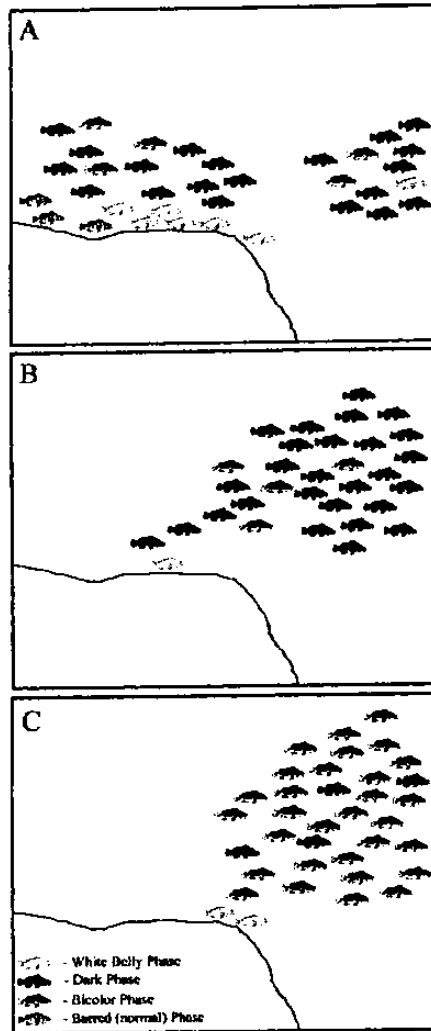


Figure 4. Crepuscular and lunar phase shifts in color phase composition and location of the aggregation. A and B) Crepuscular shifts seen early in the aggregation cycle (full moon – 4 dafm). Prior to sunset (A), all color phases were present. As sunset approached and passed (B), most fish were in the dark phase and the entire aggregation moved from the plateau to over the shelf edge. The proportion of bicolor phase fish remained low (approximately 10 %) during the entire early period of the aggregation cycle. C) Later in the aggregation cycle (5 dafm – 8 dafm), there was no nightly shift in color phase or location. The aggregation formed a cone out over the shelf edge with most fish in bicolor phase.

Courting and Spawning Behavior

Nassau grouper spawning was documented on four nights, beginning 5 dafm (February 2 - 5). On each of those evenings, divers were in the water from 28 to 30 mbs to between 7 and 15 minutes after sunset (mas). The highest level of spawning activity was documented 6 dafm, when at least 30 gamete releases occurred. A significant level of spawning activity was also documented 7 dafm; minimal activity was seen 5 and 8 dafm. On the two evenings of significant activity, the earliest spawning was documented 26 mbs and activity continued for up to 15 mas.

On each of the nights that spawning was observed, the grouper formed a cone, with the thickest layer around 33 m, tapering off up to a depth of approximately 18 m. Several types of pre-spawning movement behavior were seen, including 1) vertical spirals, 2) vertical movement without spiraling, 3) rapidly coming together after a short vertical movement and then radiating outward ('bursts'), and 4) rapid horizontal runs near the substratum (Colin 1992). Gamete release was only documented during the radiating outward bursts (ROBs). Each ROB started with 1 - 7 bicolor fish chasing one dark phase fish. The group, led by the dark phase individual, would run vertically for 3 - 6 m, resulting in gamete release before radiating outward. Additional bicolor fish would often join in during the ascent. Most ROBs ranged in size from 6 - 25 individuals, but up to 50 individuals were seen in a few ROBs. ROBs often initiated additional ROBs and up to 4 ROBs were seen within a minute.

Multiple Species Observations

Surveyors documented several other primarily large predatory species of fishes at the west end aggregation site. Small, site-attached reef fish were scarce. Spawning coloration, courting behavior, and/or spawning were witnessed in ten species - tiger grouper, yellowfin grouper, black grouper, horse-eye jack (*Caranx latus*), bar jack (*Caranx ruber*), black jack (*Caranx lugubris*), yellow jack (*Caranx bartholomaei*), mackerel scad (*Decapterus macarellus*), dog snapper (*Lutjanus jocu*), and ocean triggerfish (*Canthidermis sufflamen*). Of those, actual gamete release was documented in five species (Table 1).

Tiger grouper were seen in the characteristic tricolor phase known to occur during courting and spawning (Sadovy et al. 1994a) 4 - 8 dafm, and spawning was documented 5 and 8 dafm. The tricolor phase featured a pale head, white rectangular ventral blotch, and a dark dorsal area. The tiger grouper ROBs consisted of 5 - 12 individuals; eight dafm, the first ROB was documented at 5 mbs and a total of six ROBs were observed before divers exited the water at 15 mas. There were approximately 150 tiger grouper present in the area and all were in the tricolor phase at 15 mas. Two small groups of yellowfin grouper (2 and 4 individuals) were seen 8 dafm with distended abdomens, but no courting behavior or color patterns were seen. On two different evenings, a small group (3 - 4 individuals) of black grouper circled above the Nassau grouper cone. Seven dafm, the black grouper were seen with distended abdomens and were heard booming. Large schools of horse-eye, black, and bar jacks were seen spawning most nights

and all displayed courtship color patterns. Horse-eye jacks took on a bicolor coloration with a dark dorsal and white ventral pattern and a dark tail, black jacks displayed brilliant white tips on their tails, and bar jacks displayed a yellow tail and would flash dark bars on their body during the release of gametes. Yellow jack, which are typically solitary or in small groups, were present in schools of several hundred on two evenings and were most likely aggregating to spawn (Domeier and Colin 1997). Mackerel scad were seen spawning 5, 6, and 8 dafm, between 1 and 8 mas. A small group of dog snapper (4 individuals) was seen exhibiting spawning behavior (circling each other and performing upward spirals) 4 dafm and again 8 dafm. Eight dafm, the snapper also flashed white bars on their sides as they courted. Two and 4 dafm, ocean triggerfish were seen displaying courting coloration that featured a dark bar on each cheek that extended from below the eye to the jaw.

Seven dafm, a daytime dive was made on the east end of the island to an area historically known as a Nassau grouper aggregation site (Figure 1; Site A2). This site has not been fished during grouper spawning since at least 1995. Small groups (2 - 5 individuals) of Nassau, black, and yellowfin grouper were seen, along with a large aggregation (250 individuals) of tiger grouper.

In addition to those species seen courting or spawning, requiem sharks (Carcharhinidae), great barracuda (*Sphyræna barracuda*), spotted eagle ray (*Aetobatus narinari*), greater amberjack (*Seriola dumerili*), bigeye scad (*Selar crumenophthalmusi*), and rainbow runner (*Elagatis bipinnulata*) were all seen actively swimming around the Nassau grouper aggregation. The only fish seen eating gametes of any species were bigeye scad, which came in a large school to consume horse-eye jack spawn on one evening. During that same event, several great barracuda fed on the bigeye scad.

Table 1. Summary of spawning seen in other species by lunar date. Colorations and other courting behavior are noted in the text.

Lunar Date	Tiger Grouper	Horse-Eye Jack	Bar Jack	Black Jack	Mackerel Scad
2 dafm		spawning		spawning	
3 dafm		spawning			
4 dafm		spawning			
5 dafm	spawning	spawning	spawning	spawning	spawning
6 dafm		spawning	spawning	spawning	
7 dafm			spawning		
8 dafm	spawning	schooling	spawning		spawning

DISCUSSION

Reproductive aggregations in mobile marine species are common, yet poorly understood. Documenting the location and spatial and temporal dynamics of aggregations, as well as the behavior of aggregating individuals is of paramount importance in order to understand the reproductive biology of animals that

aggregate. This is particularly true for species deemed 'at risk' from a conservation stand point, as aggregations tend to increase the vulnerability of individuals to harvest. Additionally, because animals that exhibit this type of life history rely on behavioral interactions that may be mediated by density, declines in the number of individuals may result in disproportionate declines in the reproductive potential of the population (Alec 1931).

The high number and large size of Nassau grouper present at the SPAG site on the southwest corner of Little Cayman, along with the degree to which the aggregation site is used by other species, sets this site apart from other currently active Nassau grouper SPAGs in the Caribbean. It is difficult to say how many Nassau grouper used the SPAG site given that fish were undoubtedly both leaving and joining the aggregation over the course of the aggregation cycle and because the site was being intensively fished. However, at least 5,000 fish were present at the aggregation on January 30 based on the visual estimates. Based on these counts, the Nassau grouper spawning aggregation documented here is undoubtedly the largest known aggregation currently in the Cayman Islands. Additionally, the mean size of aggregating grouper (62 cm TL) was larger than any other aggregation documented in the Cayman Islands or elsewhere (Sadovy and Eklund 1999). Use of aggregation sites by multiple species has been documented previously (Carter 1989, Aguilar-Perera 1994, Carter et al. 1994, Luckhurst 2001, Paz and Grimshaw 2001), although the diversity of species documented spawning in this study is unique. This could be in part due to the large number of observers participating in the expedition. Nonetheless, it is clear that this area has properties that are of great reproductive benefit for many species of marine fish.

The role of coloration in Nassau grouper aggregations has received considerable attention in the literature. There is general agreement that both sexes exhibit bicolor and white belly phases (Colin 1992, Carter et al. 1994, Aguilar-Perera and Aguilar-Davila 1996). Colin (1992) postulated that the bicolor phase signals submissive behavior, and is thus important for large schools of aggregating individuals who are typically territorial. Paz and Grimshaw (2001) suggested that the bicolor and white belly phases were forms of cryptic coloration specific to the unique habitats of the aggregation site. There has been conflicting speculation as to whether dark color phase fish are either male (Paz and Grimshaw 2001) or female (Colin 1992). Based on the results of this study, it seems likely that both sexes exhibit dark phase coloration at least some of the time. We have drawn this conclusion from the lack of consistency between the sex ratios of daily fish catches and nightly proportions of fishes exhibiting dark phase coloration (Figure 3). For instance, the first night after the full moon fishermen caught 56 % males, while 90 % of the fishes observed on that evening were dark phase. All ROBs observed were led by dark phase fish followed by bicolor phase fish, suggesting that at the point of gamete release, females exhibit dark phase and males exhibit bicolor phase. The shift in color phase of fish each night early in the aggregation cycle to mostly dark individuals has been previously reported by (Colin 1992). It may be that early in the aggregation cycle, when spawning is not occurring, all sexes assume dark phase as light levels drop and

it becomes a more effective cryptic coloration than bicolor or white belly phases.

Later in the aggregation cycle when spawning is occurring, bicolor phase is maintained throughout the evening to distinguish and advertise sex among spawners. The overall sex ratio of 1:1.6 female to male during the aggregation period contrasts strongly with other aggregation sites in the proportion of males present. For instance, Little Cayman's historical east end SPAG had a smaller proportion of males early in the cycle when the proportion of males is expected to be near its highest point (1:0.5 female to male, 4dbfm, Jan 20, 1978). If protogynous hermaphroditism plays a bigger role in Nassau grouper's sexuality than gonochorism, the difference in sex ratios between the historical east end SPAG versus the west end SPAG could be explained by the differences in fishing pressures. In this scenario, the demography of a fished population would be skewed towards smaller/younger individuals, a high proportion of which would be females who have not matured enough to undergo sex change. Little Cayman's historical east end SPAG was fished intensively until exhausted in 1995. Carter (1994) also found that heavily fished Nassau grouper aggregations in Belize showed higher female to male sex ratios than did unexploited aggregations. In heavily fished aggregations in the Bahamas, female to male sex ratios varied from 1:0.2 to 1:0.3 (Colin 1992). In each of these examples there appears to be a link, perhaps causal, between heavy fishing pressure and a high proportion of females. This conclusion is consistent with the facts that the east end aggregation was intensively fished for almost 100 years and had a high proportion of females while the west end aggregation has only been fished for the past two years and has a high proportion of males. It is important to note that the change in sex ratio typically seen through the spawning cycle can complicate comparisons of sex ratios across aggregations, as catch statistics are often not reported throughout the entire duration of the aggregation.

Over the past two seasons, the Little Cayman west end aggregation has been fished heavily. In 2001, fishermen harvested an estimated 2,000 Nassau grouper during the aggregation, including 1,200 fish by a single Cayman Brac fisherman. In 2002, fishermen were present on the aggregation site each day of the project and cumulatively harvested nearly 2,000 fish. The majority of vessels were from Cayman Brac, two were from Grand Cayman, and three were from Little Cayman. In 1985, the Cayman Islands Governor in Council issued a general license for all residents to enter the grouper spawning areas, but prohibited the use of fish traps, spear guns, explosives, seine nets or any other form of nets. In late February 2002, the Cayman Island Marine Conservation Board defined a spawning season of November 1 – March 31 and implemented 'no trapping' 1 nautical mile buffer zones around each designated spawning area, along with an alternate year fishing strategy. During fishing years (i.e. 2004 and 2006), only 12 Nassau grouper may be taken per boat per day. No Nassau grouper may be taken from aggregation sites during non-fishing years. While the west end aggregation site has not been designated as a spawning area yet, it will be before the 2003 Nassau grouper aggregation. If new legislation is properly enforced, the strategy should reduce fishing mortality by half or more. Given that most of the fishermen exploiting the aggregation are from Cayman Brac,

it seems likely that at least some will choose not to make the 40 km journey to Little Cayman each day for only 12 fish.

The west end aggregation appears relatively healthy despite fishing pressure in recent years, given both that males numerically dominated the aggregation, and that the size of harvested fish were large in comparison to other aggregation studies. Anecdotal evidence suggests that a few patriarchal fishermen were aware of this spawning aggregation as recently as the 1960s. However, it has not been exploited since 1987, when the Cayman Island government began monitoring the fishery, and probably has gone largely unexploited since the 1960s. It is likely that most if not all Nassau grouper participating in the west end aggregation are residents on Little Cayman given the deep waters surrounding all three islands and the relatively high abundance of Nassau grouper on Little Cayman (Pattengill-Semmens and Semmens in press). Tagging studies would be useful in determining where aggregating individuals go after leaving the aggregation site. In the Cayman Islands as a whole, Nassau grouper stocks have demonstrated some degree of resilience under fishing pressure perhaps due to the cumulative effects of inclement weather during aggregations, recruitment from proximal offshore banks, possible shifting of aggregation sites, and the existence of minor satellite aggregation sites that remain unfished. However, over the last two decades, catch statistics indicate a steady decline in the Nassau grouper fishery. While small, the Cayman fishing fleet is potent in its effects on seasonal reproductive aggregations. At present, the west end on Little Cayman is the only known Nassau grouper aggregation in the Cayman Islands that could reasonably be considered healthy. As such, it is likely that this aggregation is providing a high proportion of the total local recruitment of Nassau grouper to the Caymans. Clearly, maintaining the health of this aggregation is of paramount importance in order to protect Nassau grouper stocks and the viability of the fishery now and in the future.

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