# Status of a Yellowfin (*Mycteroperca venenosa*) Grouper Spawning Aggregation in the US Virgin Islands with Notes on Other Species

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ABSTRACT

Many commercially important groupers (Serranidae) and snappers (Lutjanidae) form large spawning aggregations at specific sites where spawning is concentrated within a few months each year. Although spawning aggregation sites are often considered important aspects of marine protected areas many spawning aggregations are still vulnerable to fishing. The Grammanik Bank, a deep reef (30 - 40 m) located on the shelf edge south of St. Thomas USVI, is a multi-species spawning aggregation site used by several commercially important species of groupers and snappers: yellowfin (*Mycteroperca venenosa*), tiger (*M. tigris*), yellowmouth (*M. interstitialis*) and Nassau (*Epinephelus striatus*) groupers and cubera snapper (*Lutjanus cyanopterus*). This paper reports on the population characteristics of *M. venenosa* with notes on *E. striatus* and other commercial species. In 2004, the total spawning population size of yellowfin and Nassau groupers were 900 and 100 fish, respectively. During recent years commercial and recreational fishing have targeted the Grammanik Bank spawning aggregation. Between 2000 and 2004 an estimated 30% to 50% of the yellowfin and Nassau grouper spawning populations were removed by commercial and recreational fishers. These findings support the seasonal closure of the Grammanik Bank to protect a regionally important, multi-species spawning aggregation site.

KEY WORDS: Marine protected areas, reef fish spawning aggregations, fisheries management

# La Condición de Agregaciones Reproductivas de Cuna Cucaracha y Mero Gallina: Dinámica de una Multi-especie Agregacíon Reproductiva en el USVI

Muchos meros (Serranidae) y pargos (Lutjanidae) forman agregaciones reproductivas en sitios específicos por un par de meses cada año. Aunque sitios de desove se consideran un aspecto importante de áreas marinas protegidas, muchos agregaciones reproductivas son vulnerable a la pesca. El Banco de Grammanik se usa por varias especie comercialmente importante de meros y pargos. Es un arrecife profundo (30 - 40m) localizado en el sur de los USVI y es un sitio que tiene una multi-especie agregacion reproductiva. Buzos han documentado el desove de cuna cucaracha (*Mycteroperca venenosa*), cunas (*M. tigris y M. interstitialis*), mero gallina (*Epinephelus striatus*) y el pargo guasinuco (*Lutjanus cyanopterus*). Durante años recientes, pescadores commerciales y recreativas han concentrado en la agregacíon reproductiva de cuna cucaracha. La pesca amenaza no sólo esta especie pero también el mero gallina, que se extirpó localmente en el los 1980s, pero puede ser que se recupera en este sitio. Este manuscrito describe los cambios anuales y estacionales en abundancia, la utilización del habitat, y describe las características de la población reproductiva del cuna cucaracha y mero gallina.

PALABRAS CLAVES: Áreas marinas protegidas, agregaciones de desove, las Islas Virgenes de los EEUU

## INTRODUCTION

Many commercially important groupers (Serranidae) form large spawning aggregations at specific sites and at which spawning is concentrated within a couple of months each year (e.g. red hind *Epinephelus guttatus* and Nassau grouper *E. striatus* (Colin et al. 1987), tiger grouper *Mycteroperca tigris* Valenciennes (Sadovy et al. 1994). These spawning aggregations may be the primary source of larvae that replenish the local fishery through larval retention and recruitment (Sadovy 1996).

In the late 1970s and early 1980s, unregulated fishing on grouper spawning aggregations sites throughout the U.S. Virgin Islands led to the extirpation of Nassau grouper and brought the red hind grouper population to the verge of collapse (Olsen and LaPlace 1978, Beets and Friedlander 1992). In 1990, through the recommendations of the Caribbean Fisheries Management Council and support of local fishers, two important red hind spawning aggregation sites (Red Hind Bank, St. Thomas and Lang Bank, St. Croix) were closed seasonally during spawning to protect the breeding populations of red hind. In 1999, the Red Hind Bank Marine Conservation District (MCD) was established as the first no-take fishery reserve in the USVI. Recent evidence suggests that the closure of the Red Hind Bank has been successful in protecting this spawning subsection of the population. By 1997 the average size of spawning hind had increased by over 6 cm (Beets & Friedlander, 1998). Even more impressively, the number of spawning individuals increased dramatically from 4.5 fish /100 m$^2$ in January 1997 to 23 fish /100 m$^2$ in January 2001 (Beets and Friedlander, 1998, Nemeth 2005). Similar responses to protective management measures have been shown for other species throughout the Caribbean (Bohnsack 1990). Unfortunately not all grouper spawning aggregations are afforded the necessary protection to sustain their populations.

Prior to the year 2000, the Grammanik Bank was known as a deep coral reef bank utilized by local commercial fishermen. Commercial fishermen knew of the existence of a yellowfin grouper spawning aggregation but did not harvest these fish since they were known to contain ciguatera poisoning. In February 2000, scientists at the University of the Virgin Islands first surveyed the Grammanik Bank as part of a study to compare fish populations inside and outside of the Red Hind Bank Marine Conservation District (Nemeth and Quandt 2004). Considerable attention was focused on this deep coral bank when commercial and recreational fishermen landed an estimated 10,000 pounds of yellowfin grouper within a week following the full moon in both March 2000 and 2001 (K. Turbé Personal communication). These unusually large catches of grouper were verified in monthly commercial catch reports (USVI Division of Fish and Wildlife, unpublished data). It was also reported that many of these yellowfin grouper were gravid with well developed ovaries (H. Clinton, Personal communication) and that many Nassau grouper were also caught as bycatch and sold. It was estimated that over 500 *M. venenosa* and 50 *E. striatus* were removed from the spawning aggregation each year. Following collapse of the Nassau grouper fishery in the late 1970s there has been no known spawning aggregation for this species on the shelf south of St. Thomas or St. John. Currently, a lack of enforcement at this site could mean the collapse of the yellowfin grouper and/or the delayed recovery of the Nassau grouper population which may be re-forming a potentially spawning aggregation at this site. Although the Grammanik Bank was recommended for closure as early as November 2000, the Caribbean Fisheries Management Council has only recently approved an interim seasonal closure of the Grammanik Bank from February through April 2005. The data presented in this paper provides baseline spawning population information on these vulnerable grouper species and will allow an assessment of the response of these grouper populations to the recent protective measures.

## METHODS

### Locate Primary Spawning Aggregation Site

To locate the primary spawning aggregation sites of *M. venenosa* and *E. striatus* within the Grammanik Bank, the entire bank was surveyed using scuba and underwater scooters several days before and after the full moon in March 2003 and March and April 2004. GPS coordinates were recorded by a boat following a diver-towed surface buoy to determine the area of the bank.

### Grouper Spawning Density, Fish Size, and Behavior

Diver surveys were conducted between February 2001 and August 2004. Since several species of groupers and snappers are particularly wary and tend to swim away from divers prior to being counted along a transect line (RSN, personal observations), a combination of belt transects, stationary point counts, and roving diver searches were used to accurately estimate fish densities as well as total spawning population size of all commercially important Serranids and Lutjanids. Point counts were conducted by recording all fish within a 10 m radius of a stationary diver for a period of four minutes. Belt transects were 30 m x 2 m and conducted by swimming along the linear axis of the reef while a transect tape unreeled behind the diver. The size of all fish observed along transects or point counts were estimated in 10 cm size classes. Roving diver searches were typically constrained by scuba limits at deep depths, and therefore, were conducted for periods of 15 minutes. Roving divers would swim at a constant speed and survey a 10 m wide area while towing a surface buoy. These roving dives allowed reasonably accurate estimates of total population size since divers surveyed non-overlapping areas of the narrow reef (<100 m wide) and several sequential dives could cover the entire length of the Grammanik Bank (1.69 km).

**Tagging and Population Sex Ratios**

Baited Antillian fish traps and hook and line were used to collect groupers. Due to the depth from which the fish were collected, expansion of air within their gas bladders resulted in buoyancy problems and occasional embolisms. A sterilized large-bore hypodermic needle was used to extract gas from the over-inflated air bladder. Once buoyancy was restored, each fish was measured for total length (to the nearest mm) and tagged through the dorsal fin pterygiophores with a numerically-coded Floy dart tag (FT-2). Dart tags contained the following information: identification number, reward $20, University of the Virgin Islands, and a contact telephone number. The recapture location of returned tags provided information on distance travelled by fish departing the aggregation site and a detailed picture of the source of spawning groupers. Prior to release, the gender of each fish was determined by using ultrasound and by gently squeezing the body wall above the vent to extract milt and possibly eggs. Fish were released using a release cage which could be remotely opened once the cage reached the sea floor, thus minimizing mortality due to predation and ensuring re-pressurization of groupers.

## RESULTS

**Location of Primary Spawning Aggregation Sites**

The Grammanik Bank lies on an East-West axis at the edge of the insular shelf south of St. Thomas, USVI (Figure 1). The bank extends 1.69 km at its longest point (between 18º11.30N, 064º57.50W and 18º11.60N, 064º56.60W). During visual surveys the northern and southern margins were clearly visible, and the bank was estimated to be less than 100 m wide for virtually its whole length. Depths on the coral reef varied between 35 and 40 m and the coral bank is bordered to the east and west by shallower (25 to 30 m) hard-bottom ridges along the shelf edge, sparsely colonized by corals, gorgonians and sponges. The bank is bordered to the north by another coral bank and to the south by the steep drop off. The primary spawning aggregation site for *M. venenosa* was discovered on April 9, 2004. It was located over colonized hard bottom approximately 300 m west of the dominant coral reef. During this same time period, we observed Nassau groupers, some with the bicolor spawning coloration and others with visibly extended abdomens. This presumed spawning aggregation site for *E. striatus* encompassed the west end of the coral reef bank to the *M. venenosa* site. A spawning site for *M. tigris* was also located at the western tip of the coral reef bank. A spawning site for *M. interstitialis* was located along the southwestern margin of the coral reef bank. Finally, the spawning site for *Lutjanus cyanopterus*, the cubera snapper,

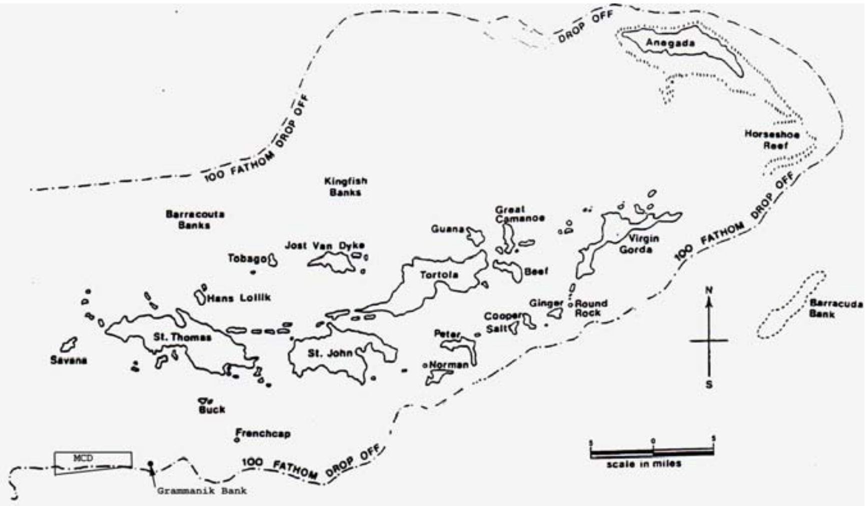


**Figure 1.** Map of the Northern Virgin Islands showing location of the Grammanik Bank (*) and the Marine Conservation District (MCD) along the southern edge of the insular platform. Dashed line shows 100 fathom depth contour.

**Grouper Spawning Density, Fish Size, and Behavior**

Visual surveys (belt transects and point counts) were conducted on various dates from February 2000 to August 2004 but most were done around the full moon from February through April in each year (Table 1). Densities of commercially important groupers varied considerably between months and years (Figure 2). *M. venenosa* densities were highest in March 2003 and April 2004, *E. striatus* and *M. interstitialis* densities peaked on March 2002 and March 2003, respectively, and *M. tigris* showed high densities in April 2001 and 2004 and February 2002 (Figure 2, Table 1). From December 2002 through February 2003 the densities of *M. venenosa* and *E. striatus* were very low, and there was no evidence that these species were aggregating. While densities of most groupers remained the same throughout March 2003, the average density of *M. venenosa* increased almost fourfold (Table 1) by 19 March, one day after the full moon (Table 1). Whether this represents an overall population increase or clustering of individuals towards a single location was unknown. With the exception of *M. tigris*, all other serranids departed the Grammanik Bank aggregation site by early April 2003 (Table 1). Throughout March 2004 point counts provided fairly consistent estimates of grouper densities (Table 1). However, observations of fish behavior indicated that as evening approached groupers began to depart their daytime positions, suggesting that fish were possibly moving toward the actual spawning aggregation site. Since point counts were not effective at locating the spawning aggregation site, scooter surveys were primarily utilized throughout April 2004.

**Table1**. Grouper density (#/100m$^2$ ± SD) from belt transects and point counts on the Grammanik Bank, St. Thomas USVI, between February 2000 and August 2004. Dashed lines indicate that no data was collected using that method. N = number of transects or point counts.

| Date | Belt transects | | | | | Point counts | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | N | *M. venenosa* | *E. striatus* | *M. tigris* | *M. interstitialis* | N | *M. venenosa* | *E. striatus* | *M. tigris* | *M. interstitialis* |
| **2000** | | | | | | | | | | |
| 17 Feb | 6 | 0 | 0 | 0.28 ± 0.68 | 0 | - | - | - | - | - |
| **2001** | | | | | | | | | | |
| 11 Apr | 3 | 0 | 0 | 2.54 ± 2.54 | 0 | - | - | - | - | - |
| 19 Jul | 6 | 0 | 0 | 0.28 ± 0.68 | 0 | - | - | - | - | - |
| 6 Sep | 6 | 0.28 ± 0.68 | 0 | 0 | 0.28 ± 0.68 | - | - | - | - | - |
| **2002** | | | | | | | | | | |
| 1 Mar | 4 | 0 | 2.78 ± 2.54 | 2.22 ± 1.92 | 0 | - | - | - | - | - |
| 27 Mar | 15 | 0.83 ± 2.41 | 0.68 ± 2.50 | 0.28 ± 0.65 | 0 | - | - | - | - | - |
| 18 Dec | - | - | - | - | - | 6 | 0.21 ± 0.26 | 0.05 ± 0.13 | 0 | 0 |

**Table1(cont.).** Grouper density (#/100m$^2$ ± SD) from belt transects and point counts on the Grammanik Bank, St. Thomas USVI, between February 2000 and August 2004. Dashed lines indicate that no data was collected using that method. n = number of transects or point counts.

| | N | *M. venenosa* | *E. striatus* | *M. tigris* | *M. interstitialis* | N | *M. venenosa* | *E. striatus* | *M. tigris* | *M. interstitialis* |
|---|---|---|---|---|---|---|---|---|---|---|
| **2003** | | | | | | | | | | |
| 12 Feb | 8 | 0.21 ± 0.60 | 0.42 ± 0.77 | 0.42 ± 0.77 | 0.21 ± 0.59 | - | - | - | - | - |
| 4 Mar | 5 | 0.67 ± 0.91 | 0.33 ± 0.75 | 0 | 0.83 ± 1.39 | - | - | - | - | - |
| 18 Mar | - | - | - | - | - | 3 | 2.23 ± 0.32 | 0.32 ± 0.32 | 0 | 0.42 ±0.74 |
| 19 Mar | - | - | - | - | - | 7 | 2.64 ± 0.57 | 0.41 ±0.70 | 0.50 ±0.55 | 0.27 ±0.22 |
| 3 Apr | 2 | 0 | 0 | 0.83 ± 1.18 | 0 | 2 | 0 | 0 | 0.16 ±0.22 | 0 |
| 11 Dec | 8 | 0 | 0.21 ± 0.59 | 0 | 0 | - | - | - | - | - |
| **2004** | | | | | | | | | | |
| 7 Jan | 8 | 0 | 0 | 0 | 0.21 ± 0.59 | - | - | - | - | - |
| 27 Feb | - | - | - | - | - | 2 | 0.47 ±0.68 | 0.16 ±0.22 | 0 | 0.32 ±0.45 |
| 2 Mar | - | - | - | - | - | 15 | 0.32 ±0.36 | 0.06 ±0.13 | 0.13 ±0.23 | 0.08 ±0.14 |
| 3 Mar | - | - | - | - | | 5 | 0.38 ±0.35 | 0.13 ±0.28 | 0 | 0 |
| 4 Mar | - | - | - | - | - | 3 | 0.21 ±0.18 | 0.21 ±0.37 | 0 | 0 |
| 5 Mar | - | - | - | - | - | 11 | 0.32 ±0.32 | 0.20 ±0.26 | 0 | 0 |
| 7 Mar | - | - | - | - | - | 11 | 0.64 ±0.64 | 0.17 ±0.22 | 0 | 0 |
| 8 Mar | - | - | - | - | - | 6 | 0.26 ±0.24 | 0 | 0 | 0 |
| 12 Mar | - | - | - | - | - | 2 | 0 | 0 | 1.75 ±0.68 | 0 |
| 13 Mar | - | - | - | - | - | 5 | 0.25 ±0.14 | 0.13 ±0.17 | 2.80 ±1.68 | 0 |
| 12 Apr | - | - | - | - | - | 3 | 2.02 ±0.80 | 0 | 0 | 0 |

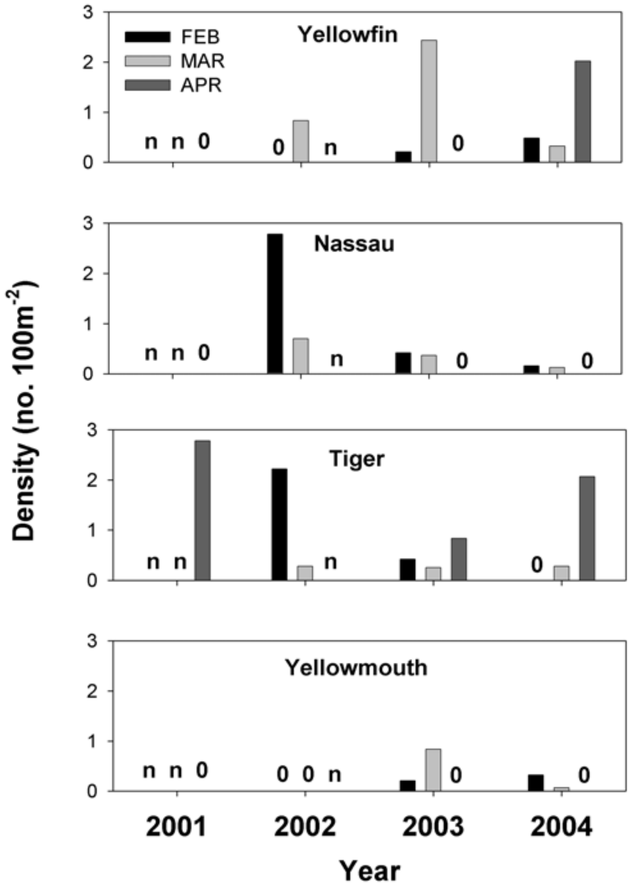


**Figure 2.** Density of four spawning grouper species: yellowfin (*Mycteroperca venenosa*), Nassau (*Epinephelus striatus*), tiger (*M. tigris*) and yellowmouth (*M. interstitialis*) for February, March and April 2001 to 2004. n = no data, 0 = no fish seen. Calculated from point counts and transects.

During roving diver surveys of the whole bank on 11 and 12 March 2003 (six days prior to the full moon), the highest density of *M. venenosa* was seen in a small (approximately 50 $m^2$) section of the bank. Other individuals were observed scattered across the reef and the total population estimate for *M. venenosa* grouper at this time, across the entire bank, was about 50 individuals. Population estimates for *E. striatus*, *M. tigris* and *M. interstitialis* for March 2003 were 5, 7 and 13 groupers, respectively.

More frequent roving diver surveys in April 2004 (full moon on April 5) improved our population estimates for *M. venenosa* and *M. tigris* (Figure 3). Total population estimates for *E. striatus* declined dramatically from March to April 2004 and may have been a result of fishing mortality from the three to five fishing boats seen on the bank each day over the course of several weeks.

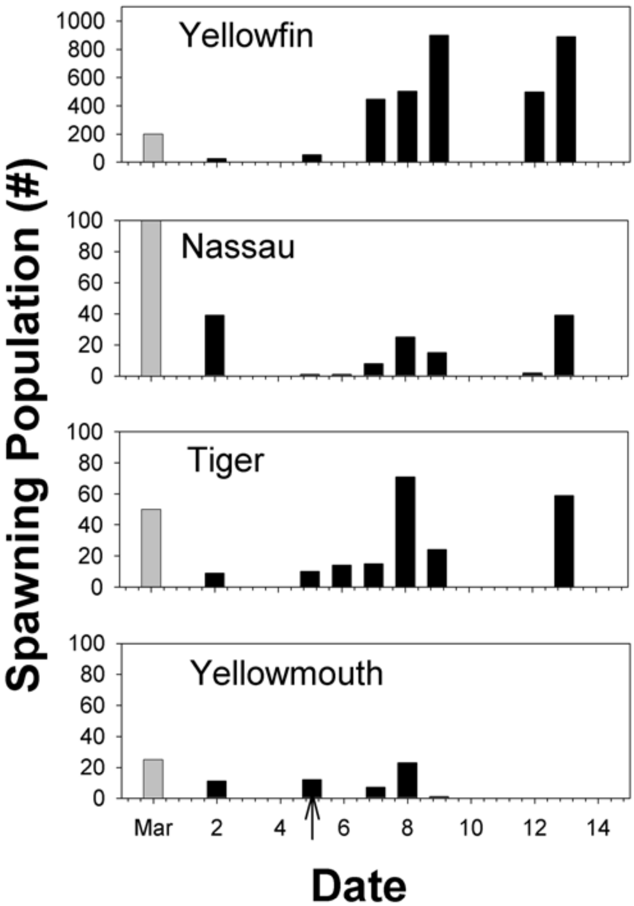


**Figure 3.** Total population size for four spawning grouper species: yellowfin (*M. venenosa*), Nassau (*E. striatus*), tiger (*M. tigris*) and yellowmouth (*M. interstitialis*) for March 11 (grey bar) and April 2-13, 2004 (black bars). The spawning aggregation sites were discovered on April 8 for *E. striatus*, *M. tigris* and *M. interstitialis* groupers and on April 9 for *M. venenosa* grouper. Full moon was on April 5, 2004.

The presumed spawning aggregations of *M. venenosa*, *M. tigris*, *M. interstitialis* and *E. striatus* were observed on April 8 to 13, 2004. During 2004, *M. venenosa* occurred in a large aggregation where about 50% to 75% of the fish were swimming two to five meters above the bottom, and the remainder swam near the bottom. Several color phases of *M. venenosa* were observed. The most common included the typical color pattern of irregular black spots on a white background. On other individuals, the dark spots were obscured on the dorsal half of the body by a deep red color. A final color pattern included fish with light colored head, white caudal fin with wide black margin and bright yellow on the margins of the pectoral fins and on the lips. Other individuals were observed with intermediate forms of these color phases. No spawning or courtship was observed for *M. venenosa. E. striatus* were noted in loose groupings and as pairs with one individual, presumably a male, in the bicolor phase and the other individual, presumably a female with visibly extended abdomen, displaying normal barred color pattern and resting on the bottom. At the Grammanik Bank only four of 60 *E. striatus* were seen displaying bicolor phase, but no courtship or spawning was observed. The bicolor phase male was observed either displaying laterally to the female, hovering one to two meters above the female, resting near the female on the bottom or swimming alone one to two meters above the bottom. *M. tigris* and *M. interstitialis* spawning aggregations had similar behavioral traits where about half of the individuals were hovering two or three meters above the bottom while the remainder where near the bottom among coral colonies. *M. tigris* was observed with three distinct color phases. Dominant males had pale yellow head, dark speckled body, and white patch with black spots on the ventral posterior portion of the body and base of anal fin. These fish were often observed cruising or hovering two to four meters above the bottom or displaying courtship behaviors to females which had distended abdomens. These resumed females displayed the barred color pattern typical of *M. tigris* and were typically seen swimming slowly or resting near the reef. A third color phase included smaller individuals with the typical body stripes obscured by a darkened body. These individuals were typically seen hovering two to three meters above the reef. *M. interstitialis* were observed with a bicolor phase similar to that of *E. striatus* and a lighter color phase typical of *M. interstitialis*. Both color phases were seen either resting near the bottom or hovering two to three meters above the reef. Courtship was not observed for *M. interstitialis*. Spawning was not observed for any of these grouper species.

The Grammanik Bank was surveyed for several months following the grouper spawning season in 2003 and 2004. In April 2003, one day after the full moon, more than 50 cubera snapper (*Lutjanus cyanopterus*) were observed during a roving survey. On the full moon in May 2003, divers estimated more than 300 *L. cyanopterus* on the bank. Three days following the full moon in June the population of *L. cyanopterus* on the Grammanik bank had declined to approximately 150 fish. The spawning season shifted from April to June in 2003 to June through August in 2004 (Figure 4). During the daytime several large (20 to 100 fish) roving schools of *L. cyanopterus* were observed throughout the bank with snappers most often concentrated on the northern margin of the bank. Toward evening roving schools of *L. cyanopterus* joined into one large school and fish displayed intensifying courtship interactions and spawning. Schoolmaster snapper (*L. apodus*) were also observed in large numbers in April (n = 180) and July (n = 120) 2004 but no signs of courtship or spawning was observed.

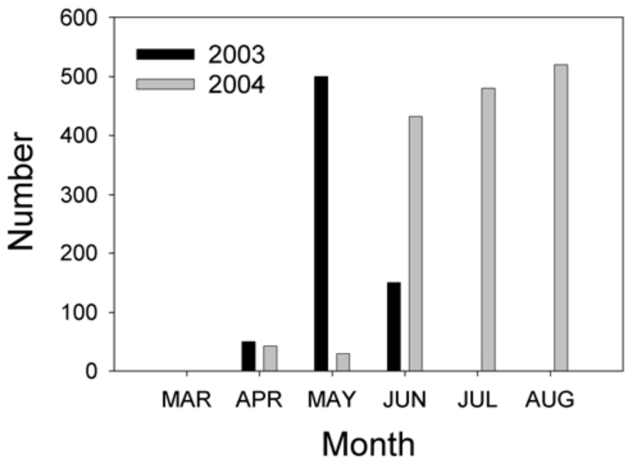


**Figure 4.** Total population size of cubera snapper (*L. cyanopterus*) spawning aggregation on the Grammanik Bank from March to August 2003 and 2004.

Size estimates of groupers from fish transects and point counts (categorized into 10 cm increments) ranged from 30 to 80 cm total length while mean lengths for *M. venenosa, E. striatus, M. tigris and M. interstitialis* were 53.2 cm, 45.6 cm, 47.0 cm and 43.7 cm, respectively. More detailed size frequency distributions and sex ratios were obtained from 28 *M. venenosa* and 62 *E. striatus* during trap and hook and line fishing. Male *M. venenosa* were significantly larger than females (ANOVA: $F = 16.4$, $p < 0.001$, Figure 5). Female to male sex ratio was nearly 1:1 for *M. venenosa*. The length of both sexes of *E. striatus* were nearly identical (ANOVA: $F = 0.48$, $p > 0.50$, Figure 5) but the female: male sex ratio was 2.4:1. Ultrasound analysis of *M. venenosa* and *E. striatus* showed that females and males of both species had well developed gonads with males of both species running ripe and females with hydrated eggs. During sampling in March 2004, two Nassau (male and female) and two male yellowfin groupers died due to air embolism. In April 2004, two additional Nassau groupers died. These last two fish were brought back to the lab and examined. The female was 55.9 cm total length and weighed 3,442 g. Its ovary weight and volume were 426 g and 410 ml, respectively. The male Nassua grouper was 64.8 cm total length and weighed 4,996 g. The weight of its testes was 322 g. A total of 23 yellowfin and 60 Nassau groupers were tagged and released on the Grammanik Bank between 8 March and 9 April, 2004. To date, no tagged groupers have been recaptured and returned to UVI for reward.

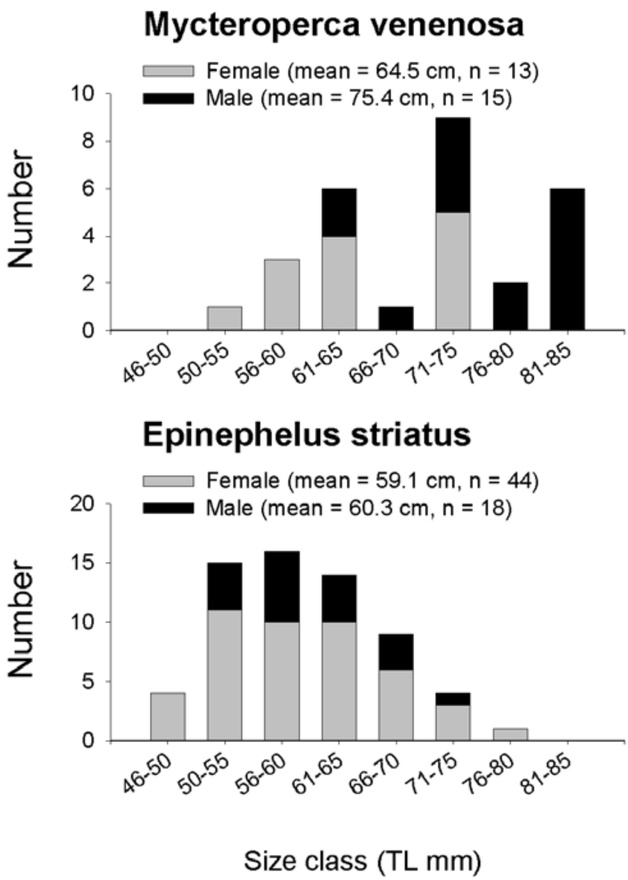


**Figure 5.** Size frequency distributions and gender for yellowfin (*M. venenosa*) and Nassau (*E. striatus*) groupers from the Grammanik Bank spawning aggregation site in April 2004.

## DISCUSSION

In March 2000 and 2001, the yellowfin grouper spawning aggregation on the Grammanik Bank was heavily targeted by local commercial and recreational fishermen. At this same time many Nassau grouper were also being caught as bycatch (K. Turbé Personal communication). It was estimated that over 500 *M. venenosa* and 50 *E. striatus* were removed from the spawning aggregation each year. Following these heavy catches, this study found that *M. venenosa* did not aggregate to spawn in 2002 but formed a small aggregation in 2003 (n = 50). These data were supported by the fact that fishermen caught almost no grouper in 2002 and very few in 2003 (RSN Personal observation). Unfortunately, it was not possible to determine if *M. venenosa* successfully spawned in either year. These low numbers, however, strongly suggest that the *M. venenosa* spawning aggregation was greatly reduced in this location during the 2002 and 2003 spawning seasons. Such a rapid reduction in numbers of fish on spawning aggregations in response to fishing pressure is not unusual (e.g. *E. striatus* grouper - Colin 1992, Sadovy and Eklund 1999) but serves to highlight the need for more responsive management action. In addition to *M. venenosa*, *E. striatus*, *M. tigris,* and *M. interstitialis* were observed on the Grammanik Bank. In 2002 small clusters of *E. striatus* possibly represented the earliest stages in the re-forming of a spawning aggregation. In March 2003, a single cluster of *E. striatus*, not previously recorded in either December or January, was present on the reef. However, there was no clear evidence (e.g. behavior, coloration) that *E. striatus* successfully spawned in 2002 or 2003 at the Grammanik Bank.

In March and April 2004, however, *M. venenosa E. striatus*, *M. tigris*, and *M. interstitialis* aggregated on the Grammanik Bank in much larger numbers than the previous two years. *M. venenosa* formed an aggregation of over 900 individuals. We are unsure why *M. venenosa* returned in such large numbers in 2004, but several possibilities exist. There are reports from fishermen that spawning aggregations of Nassua, yellowfin, and red hind in St. Croix were known to temporarily relocate to other sites if they received a lot of fishing pressure during one season (T. Daly Personal communication). For example the spawning aggregation in 2002 and 2003 may have relocated to an alternative spawning site these years in response to heaving fishing in 2000 and 2001 but returned to their historical spawning site on the Grammanik Bank in 2004. Recent data for red hind also suggests that this species may have peak spawning years that occur on a regular two-year cycle (Nemeth 2005). Thus, 2004 could have been a peak year, 2003 a low year and 2002 could have been a peak but was affected by heavy fishing in the previous two years.

*M. tigris* and *M. interstitialis* also formed spawning aggregations of 90 and 25 individuals, respectively. In contrast, *E. striatus* was observed in distinct pairs and did not form a larger aggregation (RSN Personal observation). Colin (1992) found that when *E. striatus* was present in large groups of greater than 500 fish the majority of fish within the spawning aggregation displayed the bicolor color pattern, whereas when they occurred in small spawning groups of less than 100 fish only about half were displaying the bicolor phase. *E. striatus* were typically observed in loose groupings swimming or resting near the reef. We also observed four of 60 *E. striatus* displaying the bicolor phase, but only three of these individuals seemed to be paired with a visibly gravid female. In group spawning species such as *E. striatus*, it is not known what minimum population size is needed to initiate group spawning behaviors, but the minimum aggregation size required to initiate courtship and spawning in *E. striatus* may be significantly larger than required by other haremic groupers such as red hind (*E. guttatus*) and *M. venenosa*

(Sadovy 2001). Colin (1992) recorded *E. striatus* in small groups of less than 100 fish which were spawning, but only about half were displaying the bicolor phase which typically preceeds spawning. He also found that courtship occurred in groups of only ten fish. An estimated 60 *E. striatus* were counted on the Grammanik Bank in April 2004, but courtship was seen only once, and spawning was not observed so it is possible that although an aggregation may be re-forming there may not yet be any successful spawning.

With the exception of *E. striatus*, the spawning season of all other grouper and snapper species observed on the Grammanik Bank was consistent with the reported literature from throughout the Caribbean (Sadovy et al. 1994, Claro and Lindeman 2003). Nassau typically form spawning aggregations from December through February, but have been found with ripe ovaries later in the spring as well (Olsen and LaPlace 1978, Thompson and Munro 1978, Colin et al. 1987, Colin 1992, Tucker at al. 1993, Sadovy et al. 1994, Claro and Lindeman 2003). Although *E. striatus* had previously spawned December through February in the Virgin Islands (Olsen and LaPlace 1978), spawning now seems to be following the seasonal pattern of *M. venenosa* (i.e. February to April). The seasonal shift could have two possible explanations. The historical site of the *E. striatus* spawning aggregation was located within the present boundaries of the red hind Marine Conservation District (Olsen and LaPlace 1978). Because the population "memory" of this historical aggregation site was lost when the spawning aggregation was fished to extinction in the late 1970s, the new cohort of *E. striatus* may have followed or copied the behavioral patterns and migratory routes of *M. venenosa* and *E. striatus* is just now reforming at a different location and season. The second alternative, as suggested by commercial fishermen, is that there are so many *E. striatus* at the historical spawning aggregation site that the fish showing up at the Grammanik Bank are over-flow from the historical spawning aggregation site. This alternative still needs to be verified.

The mean length (70.7 cm TL) and F:M sex ratio (1:1.1) of *M. venenosa* in this study was nearly identical to values reported by Thomson and Munro (1978) for the oceanic banks off Jamaica (mean TL = 68 cm, F:M = 1.2:1). According to Thomson and Munro (1978), these oceanic banks received relatively low fishing pressure. The similarity in length frequency and sex ratio of *M. venenosa* from unexploited oceanic banks off Jamaica in the mid-1970s and St. Thomas in 2004 may indicate that *M. venenosa* at the Grammanik Bank may be less impacted by fishing than previously thought. This would support the hypothesis that the groupers did, in fact, find an alternative spawning site during the two years when the aggregation did not form on the Grammanik Bank. Length-frequency data for *E. striatus* from this study were also similar to those reported for *E. striatus* in St. Thomas prior to its collapse and the relatively unexploited oceanic banks of Jamaica, Belize and Bermuda (Olsen and LaPlace 1978, Thompson and Munro 1978, Sadovy and Eklund 1999). The length frequency distribution also suggests that the age structure of *E. striatus* at the Grammanik Bank is dominated by four to six year old fish (Olsen and LaPlace 1978). Sex ratios from unexploited populations tend to be close to unity (Sadovy and Eklund 1999) whereas the female:male sex ratio at the Grammanik Bank was biased towards females (2.4:1) and similar to exploited populations in the Cayman Islands (Colin et al. 1987). Although the length frequency data reflects a size composition from unexploited populations, the biased sex ratio at the Grammanik Bank suggests that *E. striatus* continues to be exploited (Sadovy and Eklund 1999) as bycatch during the *M. venenosa* spawning aggregation in the Virgin Islands. This pattern may also indicate that sex ratios are very sensitive to even moderate fishing pressure on spawning aggregations. Alternatively, these biased sex ratios could also be present in the size structure of a reforming *E. striatus* spawning aggregation. As reforming aggregations have never been documented, this could just be the natural pattern and the number of males will increase as population size increases.

Continued fishing pressure on *M. venenosa* with associated catches of *E. striatus* will eliminate the likelihood that this *E. striatus* will re-form a spawning aggregation in this location. If fishing is allowed on the Grammanik Bank, the reestablishment of grouper spawning may be disrupted not only by the removal of individual fish but also by the disruption of complex behavioral patterns that are required to initiate courtship and spawning. Although the Grammanik Bank was recommended for closure as early as November 2000, the Caribbean Fisheries Management Council has only recently approved an interim seasonal closure of the Grammanik Bank from February through April 2005. Results from this study support the seasonal closure of the Grammanik Bank from February 1 to April 30, as the time period most likely to protect the yellowfin grouper spawning aggregations, and more importantly, to provide protection for a potentially reforming Nassau Grouper spawning aggregation. Future research will need to address how these commercially important species utilize the habitats within the Grammanik Bank during the spawning period but also during the entire spawning season to ensure that movement during spawning does not go beyond the proposed closure boundaries. Finally, this study also highlights the fact that the Grammanik Bank may be regionally important as a multi-species spawning aggregation site and management measures that suitably protect the spawning populations of several aggregating species of grouper and snapper that occur at this site from February through August each year will need to be evaluated.

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