

Preliminary evidence of increased spawning aggregations of mutton snapper (*Lutjanus analis*) at Riley's Hump two years after establishment of the Tortugas South Ecological Reserve

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In this note we describe the re-formation of a spawning aggregation of mutton snapper (*Lutjanus analis*). A review of four consecutive years of survey data indicates that the aggregation may be increasing in size. Mutton snapper are distributed in the temperate and tropical waters of the western Atlantic Ocean from Florida to southeastern Brazil (Burton, 2002). Juveniles and subadults are found in a variety of habitats such as vegetated sand bottoms, bays, and mangrove estuaries (Allen, 1985). Adults are found offshore on coral reefs and other complex hardbottom habitat. They are solitary and wary fish, rarely found in groups or schools except during spawning aggregations (Domeier et al., 1996). Spawning occurs from May through July at Riley's Hump (Domeier et al., 1996) and peaks in June, as indicated by gonadosomatic indices (M. Burton, unpubl. data). Mutton snapper are highly prized by Florida fishermen for their size and fighting ability, and the majority of landings occur from Cape Canaveral, through the Florida Keys, including the Dry Tortugas (Burton, 2002).

Reports of spawning aggregations of tropical reef fishes are abundant in the fisheries literature. Most documented aggregations of commercially important fishes are attributed to

members of the grouper family, Serranidae, including observations of spawning Nassau grouper (*Epinephelus striatus*), red hind (*E. guttatus*), and tiger grouper (*Mycteroperca tigris*) in the Caribbean (see review in Domeier and Colin, 1997, and references therein). Eklund et al. (2000) observed black grouper (*M. bonaci*) aggregating during their spawning season just outside no-take zones along the Florida Keys reef tract. Samoilys and Squire (1994) and Samoilys (1997) documented spawning aggregations of coral trout (*Plectropomus leopardus*) from the Great Barrier Reef, and Johannes (1988) described the aggregating behavior of squaretail coral grouper (*P. areolatus*) from the Solomon Islands. Most recently, Sala et al. (2003) observed aggregating behavior in two species of serranids—the sawtail grouper (*M. prionura*) and the leopard grouper (*M. rosacea*) from the Gulf of California.

There are fewer descriptions of spawning aggregations of the commercially important snappers (Lutjanidae) in the literature. Wicklund (1969) described spawning behavior of lane snapper (*Lutjanus synagris*) from southeast Florida, Carter and Perrine (1994) described a spawning aggregation of dog snapper (*L. jocu*) from Belize, and Sala et al. (2003)

described spawning behavior in two lutjanids from the Gulf of California (yellow snapper, *L. argentiventris*; Pacific dog snapper, *L. novemfasciatus*). Mutton snapper (*L. analis*) are perhaps the best known snapper to form spawning aggregations. Craig (1966) observed concentrated commercial fishing on an apparent "spawning run" of mutton snapper in August at Long Cay, Belize. Domeier and Colin (1997) described an aggregation of *L. analis* in the Turks and Caicos Islands in April 1992, and Domeier et al (1996) identified a spawning aggregation at Riley's Hump.

Because of their predictable nature with respect to location and time, spawning aggregations become extremely vulnerable to heavy exploitation once discovered by fishermen. The majority of annual catches of Nassau grouper in some areas comes from annual spawning aggregations (Colin, 1992; Aguilar-Perera and Aguilar-Dávila, 1996), whereas other aggregations have been completely extirpated (Olsen and LaPlace, 1978; Sadovy and Eklund, 1999; Heyman, 2003). Russ (1991) observed that uncontrolled fishing on spawning aggregations could lead to recruitment overfishing. During a May 1991 survey of Riley's Hump, a site of a known mutton snapper spawning aggregation in the Dry Tortugas, Florida, Domeier and Colin (1997) noted that fish were more scattered and far less abundant than they were at the Turks and Caicos site. The authors suggested that this difference was attributable to heavy commercial fishing pressure at Riley's Hump during the several years prior to 1991.

Although recent literature indicates that fishing pressure on Riley's Hump has been intensive for several years prior to 1991 (Domeier and Colin, 1997), anecdotal information indicates otherwise. According to a commercial hook-and-line fisherman who fished on Riley's Hump from 1978 through 2001, the first known

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instance of commercial fishing on this area occurred in 1968 by a fisherman named Riley.¹ However, the navigation device in common use in 1968 was LORAN (long range navigation) A; thus, the likelihood of a fisherman finding the exact spot where he fished previously was much less likely than with today's global positioning system (GPS) receivers. Large-scale commercial fishing of Riley's Hump began in 1976, with the introduction of the improved LORAN C navigation system.

Commercial fishermen began fishing the area with longline gear in 1979, and fish traps were introduced there in 1984. This was the period of the most intensive fishing; longliners harvested between 10 and 21 metric tons per trip and fish trappers typically landed an average of 11.5 metric tons (Gladding¹). It is necessary to rely on knowledgeable fishermen for anecdotal data such as this because the National Marine Fisheries Service (NMFS) did not separate out individual species in their data sets prior to 1986, instead consolidating all snappers into an unclassified snapper category. After 1986, landings from the Dry Tortugas were included with the rest of the Florida Keys in a Monroe County total; therefore it is virtually impossible to obtain an exact magnitude of the landings from the Dry Tortugas for this time frame without information from knowledgeable fishermen who were involved in the fishery at the time. In addition to the commercial effort, a small fleet of headboats ran multiday fishing trips to Riley's Hump and other areas in the Dry Tortugas (Dixon²).

Fishermen began to realize declining catches in the mid-1980s and brought this to the attention of the fishery management councils. The Gulf of Mexico Fishery Management Council (GMFMC) enacted a spawning-season closure in 1992, prohibiting fishing on Riley's Hump in May and June (Gulf of Mexico Fishery Management Council, 1992). An analysis of pre- and postclosure commercial landing data revealed that, as a result of the closure, there was a shift in effort to the months on either side of the period of closure, and landings during the two-month closure decreased in only one of the months while annual landings increased (Burton, 1997). After further urging by fishermen and an effort by the Tortugas Working Group (a group of stakeholders appointed by the Florida Keys National Marine Sanctuary [FKNMS] Advisory Council), the Tortugas South Ecological Reserve (TSER) was created in July 2001 specifically to protect the spawning aggregation and habitat of mutton snapper. Current regulations prohibit all uses of the reserve, except continuous transit through the reserve, for any vessels without a FKNMS research permit. The authors initiated data collection on Riley's Hump in July 2001 to document the effect of the newly designated ecological reserve on abundance of snappers and groupers.

Materials and Methods

Study area

Riley's Hump is a carbonate bank of Holocene origin located 20 km southwest of the Dry Tortugas National Park (DTNP) island of Garden Key (Ft. Jefferson). Riley's Hump sits in the northeast corner of the TSER within the FKNMS (Fig. 1). The area has a predominantly low-relief hardbottom and patchy hard coral and scattered gorgonian sponge-soft coral communities. Rising to within 30 m of the surface, Riley's Hump covers an area of approximately 10 km². Habitat mapping efforts by Franklin et al. (2000), who used a nine-tier habitat classification scheme, and visual observations from SCUBA dives revealed that Riley's Hump consisted mostly of areas of rocky outcropping and some patchy hard bottom in sand. More detailed multibeam mapping showed that the top of the bank is relatively flat and has an escarpment on the south side of the bank dropping from 30 m to well over 50 m deep (Fig. 2) (Mallinson et al., 2003).

Sampling

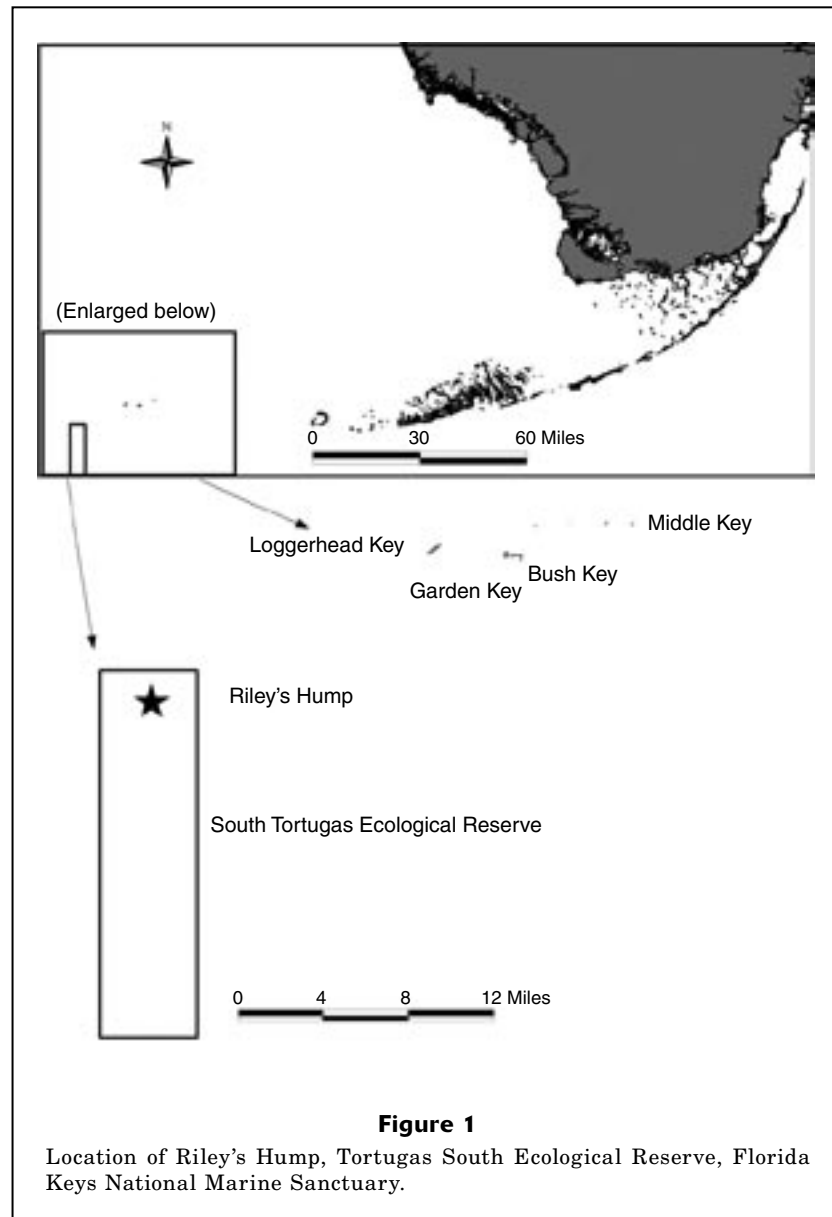
Initial sampling stations were selected in 2001 by dividing the top of Riley's Hump into a grid consisting of 0.40-km² sections and by conducting a census with the ship's depth sounder in order to identify (within as many grids as possible) reef habitat that could be reached by dives. Ten initial stations were selected according to this procedure. Five more stations were added in 2002 at the recommendation of our vessel captain, Peter Gladding (Fig. 2). Two-man dive teams conducted several 30-m visual census strip transects (Brock, 1954) at each station during the summer months of each year, enumerating all species of snappers and groupers observed.

Results

We summarize our observations of mutton snapper abundance and behavior on Riley's Hump in Table 1, along with the observation's relation in time to the lunar calendar. The initial sighting of an unusually large group of mutton snapper occurred on 17 July 2001. A group of 10 fish was observed by the senior author at station 2 (Fig. 2). The fish were swimming 0.5–1 m apart in a group approximately 1.5 m above the seafloor. The next year, on 27 May 2002, we observed a larger group of approximately 75–100 mutton snapper on the same site, station 2 (Fig. 2). These fish were exhibiting similar behavior to that observed the preceding year. The group remained schooled while the dive team completed one 30-m visual transect and then slowly dispersed as the divers returned to the aggregation location. On 15 June 2003, a team of divers discovered an aggregation of over 200 individual mutton snapper at station 12 (Fig 2). The fish repeatedly swam up to the diver doing the census transects and then slowly turned and swam

¹ Gladding, P. 2003. Personal commun. 27A 12th Avenue, Stock Island, FL 33040.

² Dixon, R. 2003. Personal commun. CCFHR, NMFS, NOAA, 101 Pivers Island Rd., Beaufort, NC 28516-9722.



away. The aggregation was spread out over a wide area, was not as dense as in the previous two sightings, and exhibited the milling behavior similar to that described by Thresher (1984) for several other species of lutjanids. This aggregation remained at the site throughout the entire 20-minute census dive. Later that day, divers recording their observations at nearby station 2 reported a group of approximately 100 mutton snapper. These fish were more widely dispersed and maintained a distance of 3–5 m from divers. Finally, on 4 July 2004, the senior author and another diver encountered a large school of approximately 300 mutton snapper at station 12, exhibiting behavior similar to that observed during the preceding year.

Discussion

We believe that the large groups of fish encountered at station 12 in June 2003 and again in July 2004 were spawning aggregations based on their behavior and on the timing and location of the aggregation. First, behavior of the snappers themselves was not typical of nonspawning individuals. Although Humann (1997) described them as being very curious, mutton snapper are typically described as solitary animals (Domeier and Colin, 1997), cautious of divers, and not allowing close approach. Many large reef fishes exhibit similar solitary behavior, such as Nassau grouper (Smith, 1972) and black grouper (Eklund et al., 2000). The

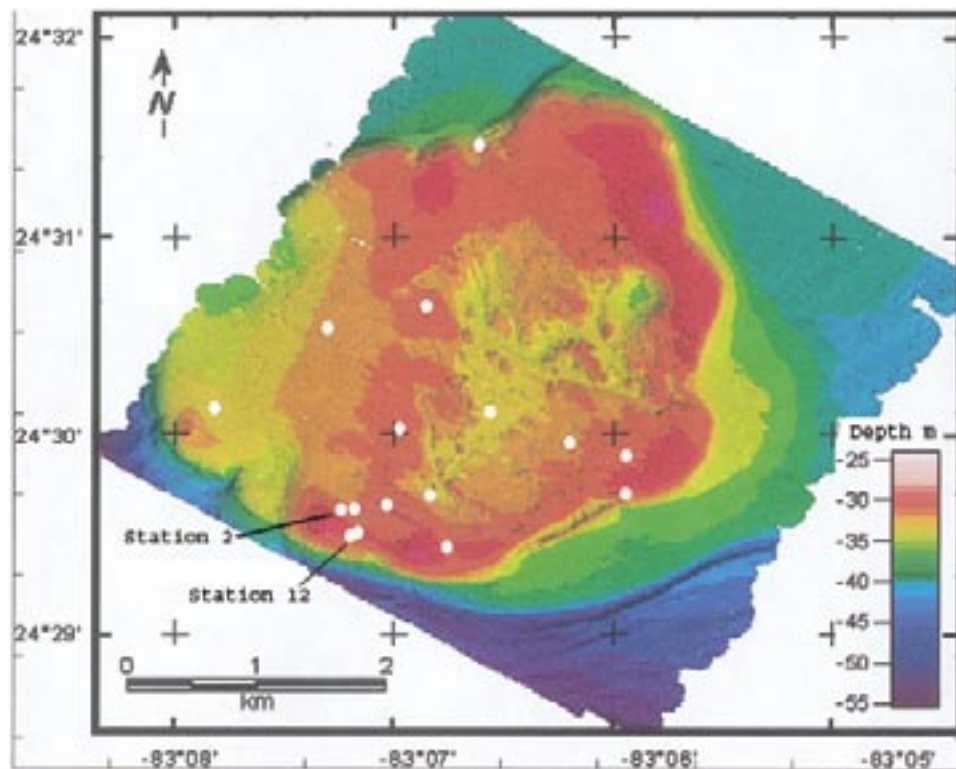


Figure 2

Multibeam bathymetric image of the top of Riley's Hump showing locations of visual census stations (white circles) and mutton snapper aggregation sightings (stations 2 and 12). Bathymetric image was provided courtesy of D. Naar and B. Donahue, Univ. S. Florida, from Mallinson et al., 2003.

Table 1

Observations on mutton snapper (*Lutjanus analis*) on Riley's Hump and their behavior as noted by the authors.

Date and station	Numbers observed	Behavior	Moon phase
28 May–1 June 1999	Solitary <i>L. analis</i> observed on 3 of 11 dives	Slowly swimming, diver avoidance	Full moon May 30
31 July–3 Aug 2000	Solitary <i>L. analis</i> observed on 5 of 6 dives	Slowly swimming, diver avoidance	New moon July 30
17 Jul 2001 Station 2	10	Swimming in a tightly packed group, 1.5 m off bottom	3 days before new moon
27 May 2002 Station 2	75–100	Swimming in tightly packed group, 1.5 m off bottom	1 day after full moon
15 June 2003 Station 2	75–100	Widely dispersed, diver avoidance	1 day after full moon
Station 12	200+	Widespread aggregation, actively swimming, did not avoid divers	
4 July 2004 Station 12	300	Widespread aggregation, actively swimming, did not avoid divers	2 days after full moon

senior author completed over 115 dives on Riley's Hump from 1995 through 2004, and the typical mutton snapper sighting during dives made outside the spawning season (February, 5 dives; August, 5 dives; October, 7 dives) was a single fish. In these instances, the closest approach allowed by the fish was 3 m, and when an attempt was made to approach, the fish would swim away, maintaining separation. The only exceptions to this behavior were the four sightings in which groups of fish were apparently unconcerned with the presence of divers (Table 1). Johannes (1981) described a condition he termed "spawning stupor" in *P. areolatus* from Palau. He took this term from the Palauan fishermen's description of the fish as "stupid." We do not believe that "stupid" in this context means unaware, but more closely approximates Johannes et al.'s (1999) modified description of spawning stupor as more of a lack of concern about divers. Mutton snapper in the spawning aggregation we observed seemed aware of our presence because they approached and retreated from the divers many times. Domeier and Colin (1997) asserted that spawning or courtship behavior is easily broken off by a diver's close approach or SCUBA exhalation, although Johannes et al. (1999) offered evidence showing that this is not always the case. We conducted our dive operations primarily in the day and thus did not witness spawning, which is thought to occur at dusk or later (Domeier and Colin, 1997). Courtship behavior has not been described for mutton snapper except by Domeier and Colin (1997) who observed that fish in the Turks and Caicos aggregation "milled in a dense school from the bottom to within a few meters of the surface." The mutton snapper we observed exhibited this milling behavior and did not change it because of our presence.

Consistent timing of spawning with respect to a specific lunar phase has long been thought to be a characteristic of many spawning aggregations. Johannes (1978) noted that the majority of fishes with known lunar-associated spawning rhythms spawned near the full or new moon. However, the published literature does not provide strong support for a correlation between spawning of most lutjanid species and any single lunar phase. The lane snapper aggregation observed by Wicklund (1969) occurred just after the new moon but has not been corroborated since this single observation. Spawning of dog snapper in Belize was variable, however, occurring three days after the new moon on Cay Glory (Carter and Perrine, 1994) and just after the full moon on English Cay (Domeier and Colin, 1997). Spawning peaks for gray snapper off Key West, Florida, were also variable, occurring on the new and full moons of June–August, although the strongest spawning peak was associated with the last quarter moon of August, half way between the new and full moons (Domeier et al., 1996). Back-calculated spawning dates of gray snapper collected in ichthyoplankton samples near Beaufort Inlet, North Carolina, have indicated that spawning takes place primarily at the time of the new moon and secondarily at the time of the full moon (Tzeng et al., 2003).

Evidence of mutton snapper spawning tends to support the argument that the species spawns during a full moon, in contrast to the examples of other lutjanids above. Mutton snapper aggregations off Gladden Spit, Belize, peaked during the April and May full moons and were heavily exploited by fishermen (Heyman et al., 2001). Domeier and Colin's (1997) observation of a mutton snapper aggregation off West Caicos occurred on the April 1992 full moon, and Domeier collected specimens with hydrated oocytes from the Riley's Hump location within one day of the full moon in May 1991 (Domeier and Colin, 1997). Our observation of a small group of about 10 mutton snapper at Riley's Hump in July 2001 occurred three days before the new moon. Our observations of groups of approximately 100, 200, and 300 fish, however, occurred one day after the full moons of May 2002 and June 2003, and two days after the full moon of July 2004, respectively. In contrast, the back-calculated spawning dates of mutton snapper collected in ichthyoplankton samples near Beaufort Inlet, NC, indicated that spawning occurred from two days after the full moon to three days before the new moon and that peak spawning occurred between the full moon and last quarter moon phase (Hare³). These data are not inconsistent, however, with our observations of fish beginning to aggregate on or around the full moon for spawning. Our sightings of such large groups of mutton snapper around the full moon indicate activity associated with a spawning aggregation.

Finally, many species of reef fishes consistently aggregate to spawn at specific locations at regular intervals (e.g., daily, annually). The two main hypotheses as to why reef fishes do this are to offer increased chances of 1) immediate survival of eggs and larvae, and 2) entrainment of larvae in favorable currents for transport to suitable nursery habitat (Johannes, 1978; Lobel, 1978; Gladstone, 1994), although the former hypothesis currently has more support (Hensley et al., 1994; Peterson and Warner, 2002). Without invoking the hypothesis of local adaptation to the aggregation sites on Riley's Hump, several studies have indicated that the physical oceanography of the region is favorable for transporting larvae spawned at Riley's Hump up the Florida Keys reef tract (Lee et al., 1994; Lee and Williams, 1999) and even as far north as Vero Beach, Florida (Domeier, 2004), presumably to suitable habitat. We believe that the specific location on Riley's Hump where we observed aggregations supports our conclusion that these were spawning aggregations.

In describing lutjanid behavior Thresher (1984) said, "A key feature of reproduction ... is an extensive spawning migration to select areas along the outer reef." Observations in the literature of reef fish spawning aggregations occurring on the outer reef edge, on seaward extensions or promontories, near the shelf-edge

³ Hare, J. 2002. Personal commun. Center for Coastal Fisheries and Habitat Research, National Ocean Service, NOAA, 101 Pivers Island Rd., Beaufort, NC 28516-9722.

break, on the reef slope or near drop-offs are numerous (Randall and Randall, 1963; Smith, 1972; Munro, 1974; Colin, 1992; Shapiro et al., 1993; Sadovy et al., 1994a, 1994b; Samoily and Squire, 1994; Sala et al., 2003, and others). Heyman (2003) described a single promontory on a Belize reef that harbored spawning aggregations of 26 different species throughout the year. The mutton snapper aggregation from West Caicos (Domeier and Colin, 1997) occurred on a reef near a drop-off into deep water. The south end of Riley's Hump drops quickly from 35 m to well over 50 m. The two sites where we have observed unusually large numbers of mutton snapper are in the vicinity of this drop-off. Station 2, where we observed aggregations of various sizes in all four years, is approximately 300 m inshore of the edge, whereas station 12, where we observed the largest aggregation in June 2003 and July 2004, is within 150 m of the edge (Fig. 2).

We conclude from behavior, timing, and location that we are observing spawning aggregations of mutton snapper beginning to re-form on Riley's Hump following more than two decades of intensive exploitation. Although the numbers we observed are not close to anecdotal descriptions of the numbers of fish caught during the height of the commercial fishery at this location, it is encouraging to note that we have seen an increasing number of fish for each successive year that we have surveyed these stations. It is too early to say definitively whether the fish are actually becoming more abundant, but preliminary indications are that one effect of the TSER has been to increase numbers of mutton snapper. Current research plans include continued annual monitoring of transects and increased exploration for additional spawning sites, as well as an expansion of our surveys to the last quarter and new-moon phases in order to continue to try to document the exact timing of spawning.

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