Assessment of the Reef Fish Community, Habitat, and Potential for Larval Dispersal from the Proposed Tortugas South Ecological Reserve

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ABSTRACT

The Florida Keys National Marine Sanctuary is in the process of creating one or more no-take marine reserves in the Dry Tortugas region. Initial recommendations call for the creation of two reserves: Tortugas North, encompassing the northern parts of Dry Tortugas National Park, Tortugas Bank, and adjacent areas; and Tortugas South, encompassing Riley's Hump and deepwater habitats to the south. These areas are expected to be important because they include reefs with high coral cover and fish spawning sites upstream from the Florida Keys, yet little is known about the habitat characteristics, reef fish community, and larval dispersal from these areas, especially the proposed Tortugas South reserve. We conducted visual surveys in the Riley's Hump area of the proposed Tortugas South reserve to characterize its habitat composition and reef fish community. Several surveys during the full moon of late May - early June 1999, a time of expected spawning activity, were focused on areas identified as potential spawning aggregation sites for mutton snapper, *Lutjanus analis*. Satellite-tracked drifter buoys, released at the expected time and location of spawning, were used to examine potential larval dispersal pathways.

Results suggest that, although coral cover is relatively low on Riley's Hump, reef fish diversity is high and includes species that are rare elsewhere in the Florida Keys. Snapper species occurred in relatively high densities, and several female mutton snapper with ripe eggs were collected, suggesting spawning occurred at this time. Larvae spawned on Riley's Hump at this time may have been transported to nursery areas in the Florida Keys and Biscayne Bay, possibly even as far north as Palm Beach. The information we collected is essential to understanding the potential importance of the proposed reserve area for conserving biodiversity, building spawning stock biomass, and supporting fisheries throughout the Florida Keys via larval replenishment.

KEY WORDS: Habitat, larval transport, reef fish

INTRODUCTION

Studies of no-take marine reserves around the world suggest they have the potential to provide a variety of benefits related to protecting ecosystem structure and function, enhancing our understanding of natural processes influencing marine ecosystems, enhancing non-consumptive economic opportunities, and maintaining or enhancing fisheries (Sobel 1996, Bohnsack 1998). In light of this potential, marine reserves are gaining popularity around the world for both conservation and fisheries management. In the United States, the Florida Keys National Marine Sanctuary (FKNMS) contains several small reserves that protect vulnerable areas with essential reef habitats, but are expected to provide limited benefits to fisheries (Dahlgren 1999, Dahlgren and Sobel in press). The FKNMS is also proposing to establish a much larger marine reserve, the Tortugas Ecological Reserve. Because of its proposed upstream location and large size, such a reserve is expected to protect essential habitats, and provide numerous benefits related to conservation and fishery management (Dahlgren 1999, Dahlgren and Sobel in press).

Initial recommendations for the Tortugas Ecological Reserve include establishing two marine reserves in the Dry Tortugas region (Figure 1). The larger proposed area, Tortugas North (ca. 429 km^2), encompasses waters within the FKNMS, Dry Tortugas National Park, and waters under state and federal jurisdiction. The smaller proposed reserve area, Tortugas South (ca. 206 km^2), is almost entirely within federal waters and contains deep reef habitats (30+ m) on Riley's Hump and deeper habitats off of the shelf edge to the south (Figure 1). Mutton snapper, *Lutjanus analis*, spawning aggregations have been documented on Riley's Hump (Domeier and Colin 1997) and reports from commercial fishermen indicate that other snapper species spawn there (Lindeman et al. in press). At present, a 38.2 km^2 area encompassing Riley's Hump is closed to fishing in May and June to protect mutton snapper spawning aggregations. A permanent closure of Riley's Hump is hoped to protect reef ecosystems there, conserve reef fish biodiversity, and benefit fisheries in the Florida Keys. Despite the expected importance of Riley's Hump, little is known about the habitats and reef fish community there, or the potential for spawning on Riley's Hump to replenish depleted stocks elsewhere in the Florida Keys and south Florida.

The primary objectives of this study were to describe the habitat characteristics and the reef fish community of Riley's Hump, and identify potential pathways for larval transport from spawning sites. Such information is essential to determine the potential for the Tortugas South reserve to provide the anticipated conservation and fisheries management benefits. Moreover, quantitative information on the reef fish community and habitats before reserve protection is critical to establishing a baseline for evaluating reserve effects over time. We focused specifically on the Riley's Hump area of the proposed Tortugas South reserve because it is expected to be the most important part of the proposed area from a fisheries management perspective (Lindeman et al. 1999).

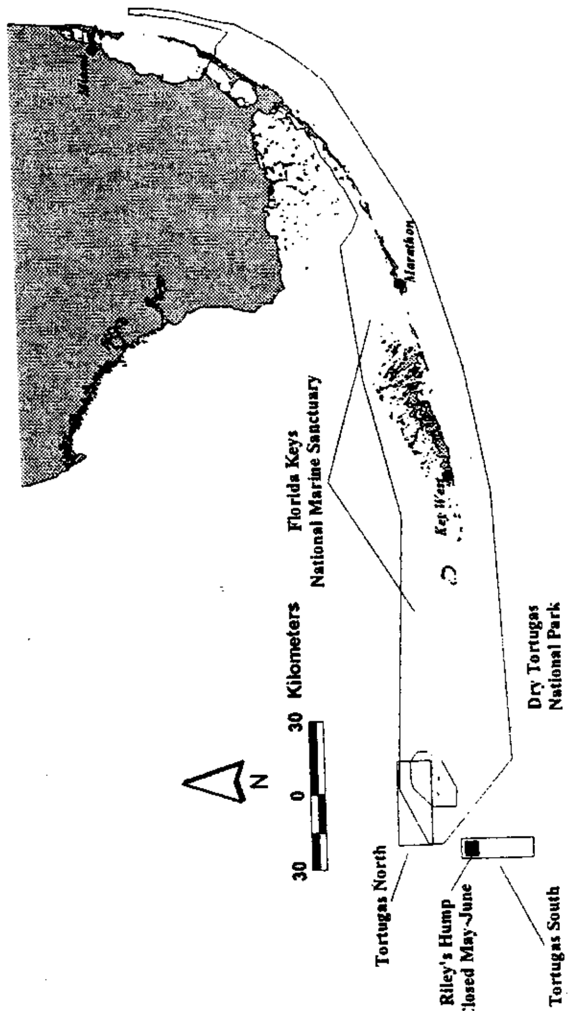

Figure 1. Chart showing the proposed boundaries of the proposed Tortugas Ecological reserve and existing protected areas in the region.

METHODS

Reef fish and Habitat

Divers quantitatively assessed the reef fish community and habitat composition of Riley's Hump at randomly selected sites. The Riley's Hump area was divided into 0.25 x 0.25 minute grid cells (cell area ca. 0.2 km^2). Bathymetric maps and information provided by local commercial fishermen were used to identify grid cells with water depths less than 33 m. Of the 50 grid cells identified, 19 were selected at random for fish and habitat surveys. Within each randomly chosen cell, divers were dropped where water depths were >33 m, and censuses conducted wherever the divers landed on the sea floor.

At each site, two divers (three divers at two sites) conducted quantitative visual censuses of fish and habitats in adjacent areas. Visual censuses followed a stationary census technique described in detail by Bohnsack and Bannerot (1986). Briefly, stationary divers identified all reef fish within a 7.5 m radius (ca. 177 m^2 area), and the cylindrical volume of water above this area, for five minutes, then estimated the abundance and size (minimum, maximum and average fork length) of each species observed. Species observed after the initial five minutes were noted, but were neither counted nor measured. Size estimates were made with the assistance of a ruler attached to the end of a meter stick. Species density (abundance per 177 m^2 census area) and mean size data were later averaged between censuses at each site.

After completing reef fish censuses, divers estimated the percent cover of all habitats within their survey area. Habitats were grouped into six categories: living coral, rock, unconsolidated rubble, gorgonians (and seafans), sponge, and sand. All other rare habitats were lumped into an "other" category. Percent cover of each habitat was later averaged between surveys at each site.

Quantitative fish censuses were supplemented by qualitative fish censuses using a roving diver technique (Schmitt et al. 1998). Supplementary censuses were conducted to note the presence of relatively rare species, or those whose appearance and/or behavior made them difficult to detect in stationary censuses. Roving censuses also increased the area surveyed for potential spawning aggregations.

Spawning and Larval Transport

Because a mutton snapper spawning aggregation has been documented on Riley's Hump, and other snapper species are expected to spawn there (Domeier and Colin 1997, Lindeman et al. in press), we were particularly interested in identifying sites where spawning aggregations occur, and examining characteristics of the site and fish at the aggregation. Potential spawning aggregation sites were identified based on information provided by commercial fishermen who have fished the area for over 20 years. For several days around the late May, 1999 full moon (expected to be the time of peak spawning for mutton snapper, Domeier and Colin 1997) divers conducted roving surveys of potential sites, specifically to determine if snapper were present at unusually high abundance. At potential spawning sites, several snapper were caught using hand line and spear to examine their gonads and determine whether or not spawning was likely to occur at this time.

The potential transport of larvae spawned on Riley's Hump during the May, 1999 full moon was examined using satellite-tracked drifter buoys (Argo-drifter, Technocean Inc.). Shortly after dark on the evening of May 30, 1999, the night of the full moon we released two satellite-tracked drifter buoys (Argo-drifter, Technocean Inc) at potential spawning sites on Riley's Hump. Drifters floated just below the sea surface, with only their antennae exposed to the air. Drifter positions were determined several times each day by Argos satellites until the drifters were retrieved or their batteries died. Drifters were retrieved after 38 days to encompass the expected mutton snapper planktonic larval duration of three to five weeks (Clarke et al. 1997, Watanabe et al. 1999, Lindeman et al. in press).

RESULTS

Reef Fish and Habitat

Fish and habitat censuses ranged in depth from 26 to 33 m and covered over 7,065 m^2 of the seafloor and the water column above it. In general, the areas censused were low relief areas of carbonate rock or sand, with varying amounts of rubble (primarily small pieces of dead coral), small coral heads (1 - 2 m diameter mounding coral heads), sponges, gorgonians or seafans. Rock and rubble were frequently covered with low growing macroalgae. Overall, rock and sand were the dominant habitats (Figure 2), covering over 65% of the area censused on average, but coral, rubble, sponges and gorgonians had high percent cover (up to 50%) at some sites.

During quantitative stationary censuses, 8,654 fish ($\bar{x}$ = 199.3 ± 69.7 per census) belonging to 97 species (30 families) were observed. A mean of 25.8 (± 5.3) species were observed at each site (17.1 ± 4.6 per individual census). The most frequently observed species were: bicolor damselfish, *Pomacentrus partitus*; bluehead wrasse, *Thalassoma bifasciatum*; yellowhead wrasse *Halichoeres garnoti*; gray snapper, *Lutjanus griseus*; saucereye porgy, *Calamus calamus*; and blue tang, *Acanthurus coeruleus*. A total of 11 families occurred in more than 50% of observations with damselfish (pomacentridae), snappers (lutjanidae), wrasses (labridae), and jawfish (opistognathidae) having the highest density (Figure 3). The high mean jawfish density was primarily due to an extremely high average density (191.7/census) of yellowhead jawfish, *Opistognathus aurifrons*, at a single site. Several infrequently sighted families also had high mean densities. For example, goatfish (mullidae) had the highest mean densities of any family ($\bar{x}$=64.7 ± 269 fish/census), but were observed at only 10.5% of study sites. High goatfish density resulted from a single site containing a large school of yellow goatfish, *Mulloidichthys martinicus*, (average site density: 1,175 fish/census).

During qualitative fish censuses, including fish observed after five minutes in stationary censuses, a number of species and families were recorded that were not observed in quantitative censuses. For example, sargassum triggerfish, *Xanthichthys ringens*, were not detected in quantitative censuses, but were locally abundant in qualitative censuses at one of the study sites. Similarly, 11 different jewfish, *Epinephelus itajara*, were observed and several tagged (up to 4 on a single dive) near a single large coral head over three days, but were not observed in quantitative censuses and rarely observed in qualitative censuses at other sites.

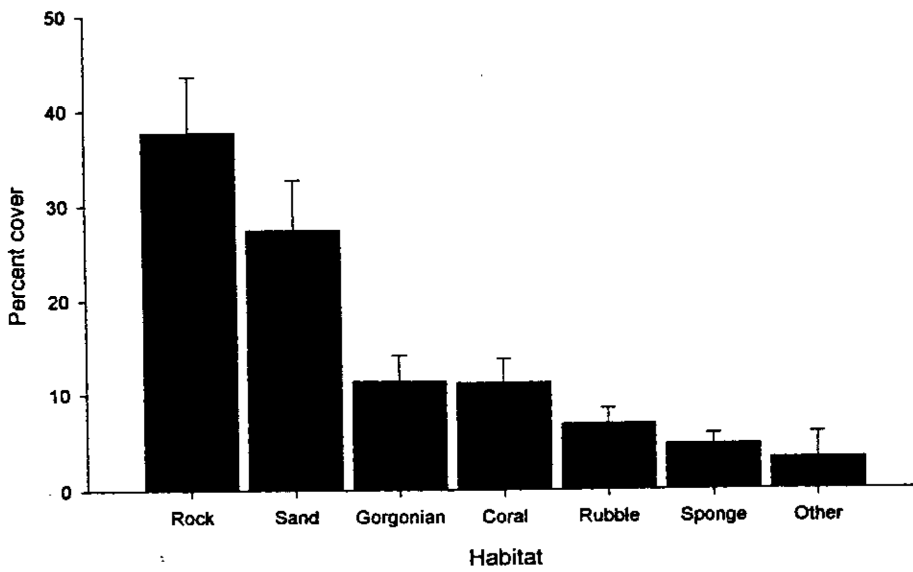

Figure 2. Percent cover of habitat categories in visual censuses on Riley's Hump (n = 19). Means represent site averages and error bars show standard deviation.

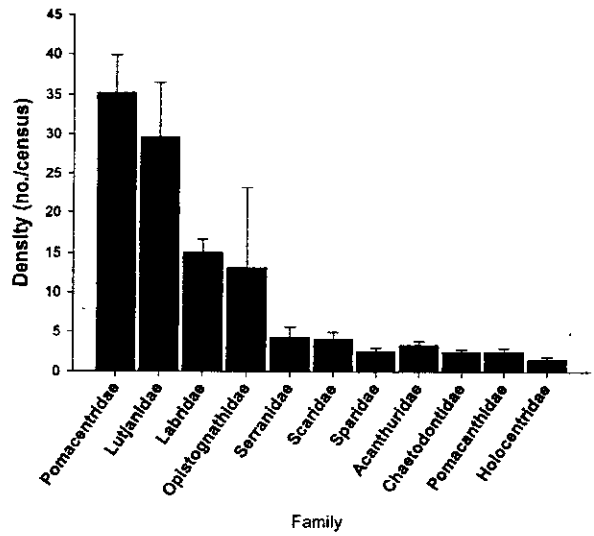

Figure 3. Density of fish (mean number observed per 177 m^2 census) belonging to all families observed at over 50% of study sites on Riley's Hump (n = 19). Means represent average site densities and error bars represent standard deviation.

Spawning and Larval Transport

At one site suggested by commercial fishermen as a potential spawning site, divers observed high abundance of both gray and mutton snapper. The site was near the edge of the hardbottom and coral reef area, where a relatively flat bottom surrounded a few large coral heads (>2 m diameter) that provided structure. On one late afternoon dive, >100 mutton snapper were observed congregating at the interface between the reef and sand plain. Nearby, schools of several hundred gray snapper were observed over the reef on several dives. Preliminary analysis of the gonads from several female mutton snapper caught at the site indicates that they contained mature eggs (M. Burton, National Ocean Service, Beaufort, NC, personal communication). The reproductive state of gray snapper was not examined, but several male gray snapper caught by handline released milt before being returned to the water.

One of the two satellite-tracked drifter buoys released at the time and location of expected spawning by mutton snapper, lost contact with the satellite within 24 hours of release due to low battery power. Twenty-one days after its release, however, a research vessel spotted this drifter offshore from Pompano Beach, FL (26° 12.385' N, 80° 04.165' W; Figure 4). The other drifter maintained contact with the satellite until it was retrieved on July 7, after drifting for 38 days. Upon release, this drifter began a slow drift to the west, followed by a gradual turn to the south. After 12 days, it was entrained in the Florida Current and began moving rapidly to the northeast. Three weeks after its release, the drifter entered Biscayne Bay, and remained in shallow waters of the Biscayne National Park until it was retrieved.

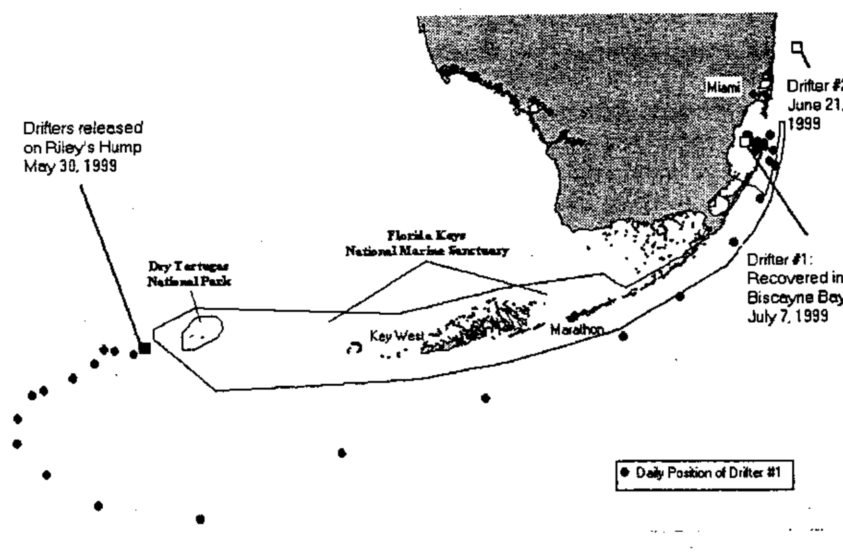

Figure 4. Daily position of a satellite-tracked drifter buoy deployed at the time and location of expected snapper spawning on May 30, 1999. The position of a second buoy, which immediately lost contact with the satellite but was later re-sighted, is also shown.

DISCUSSION

Quantitative assessment of habitat and living resources within a proposed reserve area is essential to determine potential benefits of reserve protection, and to establish a baseline for evaluating reserve effects. Despite its apparent importance to fishermen (Lindeman et al. in press), and seasonal closure, our study was the first to quantitatively assess the habitat and reef fish community of Riley's Hump. Our study also identified potential spawning aggregations and larval dispersal pathways from this area.

Riley's Hump can generally be characterized as low relief rocky reef mixed with pockets of sandy areas. Rock was often overgrown with corals, gorgonians, and sponges, which provided some structural complexity, but corals and rock ledges with vertical relief greater than two meters were rare. Thus, Riley's Hump is a different type of reef from others in the proposed Tortugas Ecological Reserve. The Tortugas North reserve contains many high relief (>10 m) coral pinnacles and reef with high coral cover and a variety of shallower reefs in the Dry Tortugas National Park (Rydene and Kimmel 1995, Authors' personal observations).

Despite the lack of vertical relief, low habitat complexity, and low coral cover, Riley's Hump had a relatively high diversity of reef fish, with 117 species belonging to 32 families observed overall. Although our visual censuses of Riley's Hump are likely to have missed many small, cryptic and rare species, our estimate of species richness for Riley's Hump is comparable to several other coral reef areas within the Florida Keys, where similar visual techniques were used (Jones and Thompson 1978, review by Chiappone and Sluka 1996). The mean number of species observed per individual census on Riley's Hump was comparable to reefs within Looe Key National Marine Sanctuary (now part of the FKNMS) and Biscayne National Park, where similar surveys were conducted (Bohnsack et al. 1987, 1992). Species-area curves derived from similar sampling techniques within Dry Tortugas National Park indicate that species diversity there is also comparable to our findings at Riley's Hump (Rydene and Kimmel 1995). Fish density at Riley's Hump was also similar to that reported from Biscayne National Park and most reef habitats within Looe Key National Marine Sanctuary (Bohnsack et al. 1987, 1992).

Despite similarities in fish density and species richness between Riley's Hump and other reefs, reef fish community composition differed between Riley's Hump and other reefs in the Florida Keys. For example, other studies using visual censuses reported that grunts (haemulidae) comprised between 15 to 20%, and snappers less than 5%, of fish on reefs throughout the Florida Keys (Bohnsack et al. 1987, 1992, Thompson et al. 1990, Rydene and Kimmel 1995). On Riley's Hump, however, less than 5% of all fish observed were grunts, and snappers comprised 15% of all fish. Qualitative censuses on Riley's Hump also included fish species, such as the sargassum triggerfish, *Xanthichthys ringens*, not reported in visual censuses from other parts of the Florida Keys (review by Chiappone and Sluka 1996). Differences between the reef fish community Riley's Hump and other parts of the Florida Keys are most likely due to several factors, including differences in depth, habitat, proximity to shallow nursery areas, and fishing pressure. Moreover, density of some species, such as gray snapper, *Lutjanus griseus*, may have been high at Riley's Hump during our study because they aggregate there to spawn (Lindeman et al. in press).

Although our study provided no direct evidence that spawning occurred, high abundance of mutton and gray snapper, and individuals in advanced reproductive states provided indirect evidence of spawning. If this was the case, the spawning aggregation that we encountered was much smaller than those reported for mutton snapper in elsewhere and on Riley's Hump in previous years (Domeier and Colin 1997). The reason for the small size of this aggregation is unknown. Reports from fishermen indicate that mutton snapper may not have formed typically large spawning aggregations during this full moon throughout the Florida Keys (P. Gladding, Key West commercial fisherman, personal communication). Alternatively, fishing pressure, particularly following the seasonal closure (Dahlgren, personal observation) may have reduced the abundance of mutton snapper on Riley's Hump.

Currents at the time and place of expected spawning until the time of expected settlement, suggest that larvae spawned on Riley's Hump during the late May-early June, 1999 full moon may have been transported throughout Florida Keys, Biscayne Bay, and along the east coast of Florida to Pompano Beach. Larval transport at this time appears to have been influenced by the Tortugas Gyre initially, then the Florida Current. A companion study, in which neutrally buoyant bottles were released at the same time and place as our drifters, produced similar results, with bottle recoveries ranging from the upper Florida Keys to Palm Beach 17 - 35 days after their release (M. Domeier, Pfleger Institute for Environmental Research, personal communication).

Using current patterns to assess larval transport, however, assumes that larvae are transported passively. In reality, larvae may be capable of swimming, and may exhibit behavioral patterns that limit dispersal distances of fish larvae (Sale and Cowen 1998). Thus, our results should be interpreted as a potential range of recruitment. Larval transport may also vary within and between years due to spatiotemporal variability in regional current patterns and local oceanographic or meteorological features (e.g., Shenker et al. 1993). Nevertheless, the regular occurrence of the Tortugas gyre, Pourtales gyre, and other features suggest that larvae spawned at Riley's Hump are likely to be retained in the Florida Keys and South Florida system frequently (Lee et al. 1994, Lee and Williams 1999).

Our study provides before-protection information on reef fish and habitats of Riley's Hump that is essential for the evaluation of reserve efficacy in the future. The results of our study also suggest that the protection of Riley's Hump within the proposed Tortugas South reserve may serve several purposes. Because the habitats and reef fish community of Riley's Hump differ from other reef areas proposed for protection in both the Tortugas North reserve, and deepwater areas of the Tortugas South reserve, protecting Riley's Hump is important for the conservation of biodiversity. The relatively high abundance of overexploited commercial and recreational fish species (e.g., snappers) on Riley's Hump may also contribute towards rebuilding these overfished stocks, or at least help to safeguard them against the possibility of management failure (Ault et al. 1998, Dahlgren and Sobel in press). The potential to provide fisheries benefits is further supported by direct and indirect evidence that the area is important for snapper spawning, and current patterns may transport larvae spawned there throughout the Florida Keys and south Florida. Thus, Riley's Hump may serve as an important source population for many of south Florida's overexploited fish stocks.

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