Preliminary Observations of Abundance and Distribution of Settlement-Stage Snappers in Shallow, Nearshore Seagrass Beds in the Middle Florida Keys

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ABSTRACT

Reef-dwelling snappers support valuable commercial and recreational fisheries. Snappers have been reported to use seagrass habitat as a primary nursery area in south Florida waters, although it is still largely unknown where newly recruited and early-juvenile stages of snappers are settling in the waters of the Florida Keys. Previous studies largely have been unsuccessful in locating and collecting these young-of-the-year fishes in seagrass beds. In order to determine the feasibility of collecting early-life stages of snappers in shallow (< 1.3m depth), nearshore seagrass beds and to describe snapper abundance and distribution, we conducted a six-month (June through November 2003), stratified-random-design pilot study using 21 m seines on the Atlantic side of the Middle Keys. We collected relatively high numbers of snappers (n = 363), of which more than half were settlement-stage individuals, including 69 new recruits ($\leq$ 20 mm SL) and 131 early-stage juveniles (> 20 and $\leq$ 40 mm SL). Mean standard length overall was 36 mm. The most abundant snapper collected was *Lutjanus griseus*. Snappers recruited consistently during the sampling period, and abundance did not significantly differ between months. Recruitment peaked during September, October, and November, suggesting that higher numbers of adult snappers were spawning in late summer and early fall. Snapper abundance differed significantly between sampling sites, most likely due to habitat differences. Abundance was positively and significantly correlated with *Halodule wrightii* cover and negatively correlated with *Thalassia testudinum* cover. Preliminary results indicate that shallow, mixed-species seagrass beds along Atlantic beachfronts in the Middle Keys may constitute an especially important settlement habitat for snappers, particularly *L. griseus*.

KEY WORDS: Seagrass, settlement, snapper

Observaciones Preliminares de la Abundancia y Distribución de Pargos Reclutas y Juveniles en Pastos de Hierbas Marinas Poco Profundo en los Cayos Centros de la Florida

Las especies de pargos arrecifales son muy abundantes y muy valiosos para las pesquerías recreativas y comerciales de los Cayos de la Florida. Se ha reportado que estas especies utilizan los pastos de hierbas marinas como un área primaria de criadero en las aguas del sur de la Florida. Sin embargo, todavía no se conoce donde reclutas nuevos y las etapas tempranas de los juveniles se establecen en las aguas de los Cayos. En estudios anteriores no pudimos localizar pargos juveniles en las praderas de hierbas marinas de poca profundidad (>1.3m) a lo largo de los Cayos. Un estudio piloto se realizo durante seis meses (junio 2003 hasta noviembre 2003) usando redes de cerco con una dimensión de 21metros de cobertura en el lado atlántico de los Cayos. Las áreas de muestreo se seleccionaron utilizando un sistema de estratificación al asar, con el propósito de determinar la viabilidad de recolectar pargos de edades tempranas en pastos de hierbas marinas con profundidades de <1.3 m y para describir su abundancia y distribución. Tuvimos éxito en capturar números relativamente altos de pargos [n = 363; n = 69 reclutas nuevos, $\leq$20 mm SL; n = 200 juveniles, $\leq$ 40 mm SL] en un corto período de tiempo y con solamente 72 caladas. Los tamaños de los individuos capturados fueron entre 10 mm y 190 mm con un promedio de 38 mm. El pargo más abundante fue *Lutjanus griseus*. Pargos se capturan con regularidad durante el verano y otoño; *L. griseus, L. apodus, L. analis, L. synagris,* y *Ocyurus chrysurus* estuvieron presente en los meses de septiembre, octubre, y noviembre. Reclutamiento para *L. griseus* alcanzó a su máximo durante los meses de septiembre a noviembre. Las densidades de pargos fueron estadísticamente diferentes entre los sitios de muestreo, esto es probablemente es debido a diferencias en el hábitat. Las densidades de pargos estuvieron una correlación positiva con la cobertura de *Halodule wrightii* y una correlación negativa con la cobertura de *Thalassia testudinum*. Estos resultados preliminares indican que pastos de hierbas marinas formado por varias especies en aguas poco profundas que se encuentran cerca de la costa en el lado atlántico de los Cayos de la Florida pueden constituir un importante, aunque limitado, hábitat para el reclutamiento de etapas tempranas de las especies de pargo.

PALABRAS CLAVES: Pargos, reclutamiento, asentamiento, hierbas marinas, hábitat

INTRODUCTION

Reef-dwelling snappers (Lutjanidae) are abundant and support large commercial and recreational fisheries in south Florida and the Florida Keys. Snappers occupy a variety of habitats throughout their life cycle. New recruits, juveniles, and young adult snappers have been reported to use inshore seagrass habitats as nursery areas before undergoing ontogenetic migrations to reefs, offshore habitats, and other areas as they approach maturity (Tabb and Manning 1961, Springer and McErlean 1962, Starck 1970, Bortone and Williams 1986, Rutherford et al. 1989, Lindeman et al. 1998, Burton 2001, Mateo and Tobias 2001, Allman and Grimes 2002, Watson et al. 2002). Many studies have examined the abundance and distribution of juvenile snappers, either directly or indirectly, in Florida Bay and the Gulf of Mexico (Odum and Heald 1972, Sogard et al. 1987, Thayer et al. 1987, Hettler 1989, Rutherford et al. 1989, Thayer and Chester 1989, Chester and Thayer 1990, Matheson et al.

1999, Thayer et al. 1999). We have also specifically targeted early-juvenile stages of snapper by conducting extensive sampling with otter trawls, offshore seines, visual censuses, and exploratory surveys throughout various habitats in the Keys and Florida Bay. These studies have collected relatively low numbers of newly settled snappers, despite scientists having used a wide variety of gear and methods. To date, researchers have been unable to determine the settlement locations of snappers in the Florida Keys because they collected insufficient numbers for useful analyses, either because of low abundance of snapper recruits in the areas studied or ineffective sampling gears.

Some studies have suggested that juvenile snappers may preferentially inhabit seagrass beds in shallow waters close to the beachfront shorelines of the Keys. A three-year seine study designed to collect bonefish in such habitats collected relatively high numbers of settlement-stage snappers (n = 222) (Harnden and Snodgrass In review). In addition, a single seining study conducted along a grassy shoreline in the Middle Keys from 1960 to 1961 was particularly successful in collecting even higher numbers of young juvenile snappers (n = 650) (Springer and McErlean 1962). Because of the comparative success of these studies, we established a six-month pilot study using 21.3 m seines in shallow, shorefront seagrass beds on the Atlantic Ocean side of the Middle Florida Keys. The objective of this study was to establish the feasibility of collecting newly settled snappers in numbers sufficient to provide preliminary information on species composition, abundance, size-structure, spatial and temporal distribution patterns, and habitat use.

METHODS

Sampling was conducted for six months from June through November 2003 in nearshore seagrass beds on the Atlantic side of the Middle Florida Keys from Long Key to Bahia Honda Key (Figure 1). A habitat-based, stratified-random-sampling procedure based upon the "Benthic Habitats of the Florida Keys" Geographical Information System (GIS) (FDEP and NOAA, 1998) was used to select sampling sites. In this system, the Keys were divided into one-longitudinal- by one-latitudinal-minute [~1 nautical mile $(nm)^2$] sampling "grids" (Figure 1). All grids touching land containing bottom habitat mapped as "Continuous Seagrass" or "Patchy Seagrass" were included in the sampling universe. Each of these resultant eleven grids (sites) was subdivided into 100 "micr11grids" (~0.01 nm^2) (Figure 1). A total of twelve of these microgrids were randomly selected and sampled each month.

Fish collections at each site were made using a 21.3 m center-bag drag offshore seine, constructed of knotless 3.2 mm #35 Delta nylon-mesh and a 183 cm x 183 cm x 183 cm bag. Each seine was hauled in open-water away from the shoreline (> 5 m). The net coverage area was approximately 140 m^2/haul.

One seine haul was conducted during daylight hours at each site. Hauls were made during high to mid-high tide whenever possible. All snappers were processed in the field, identified to the lowest possible taxon, and enumerated. Any snappers that were $\leq$ 100 mm SL were measured to the nearest mm. As needed, small subsamples of snappers were collected and brought back to the laboratory for identification purposes; all remaining fish were released.

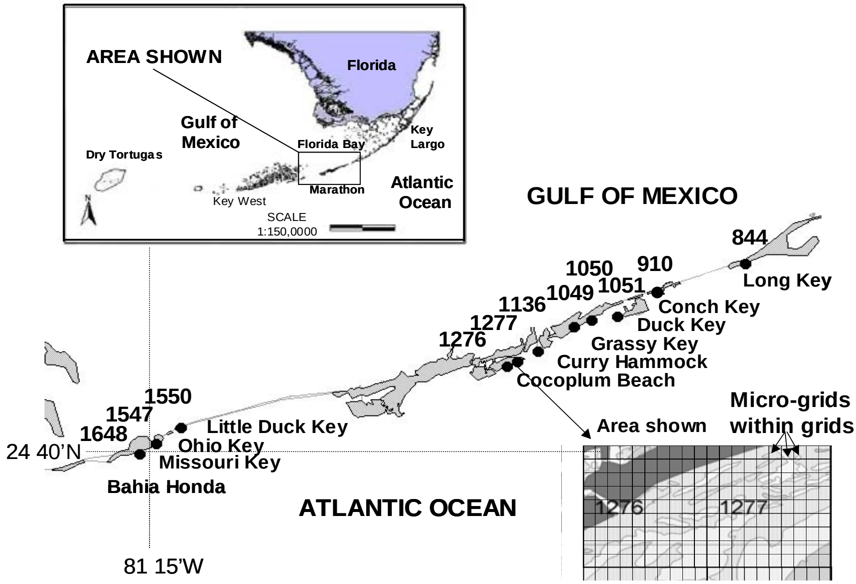

Figure 1. Map of sampling area in the middle Florida Keys showing location of eleven grids and inset of microgrid system.

Hydrographic data, atmospheric and sea conditions, and observations relative to bottom type including water depth, substrate type, submerged aquatic vegetation (SAV) types, and percent bottom cover of SAV were recorded at each site. Water temperature (ºC), salinity (‰), dissolved oxygen (mg/L), and pH were measured using YSI water-quality instruments. Turbidity was measured using a secchi disk.

Data were analyzed to describe spatial and temporal patterns of relative snapper abundance, species composition, and size-structure. Data from microgrids were pooled into their respective larger grids for analyses. Variation in snapper abundance between months and sites for all species combined, for abundant snapper species ($n > 50$), and for settlement-stage snappers was analyzed for temporal and spatial differences using the nonparametric Kruskal-Wallis test. The Kruskal-Wallis test was also used to determine if physical parameters and habitat characteristics differed between months and sites. Spearman's rho was used to determine significant relationships between snapper abundance and physical variables or habitat characteristics. All statistical tests were run using SPSS 11.0 for Windows. Results were considered significant at $p < 0.05$.

A total of 363 snappers representing five species (*Lutjanus griseus* [gray snapper], *L. apodus* [schoolmaster snapper], *L. analis* [mutton snapper], *L. synagris* [lane snapper], and *Ocyurus chrysurus* [yellowtail snapper]), were collected in 72 seines from June through November 2003 (Figure 2). The most abundant snappers collected were *L. griseus*, *L. apodus*, and *L. analis* (Figure 2). Additionally, eleven small (10 - 15 mm) snapper recruits could be identified only as *Lutjanus* spp. because meristics overlapped, and their coloration was not yet distinct; however, they were either *L. griseus* or *L. apodus*.

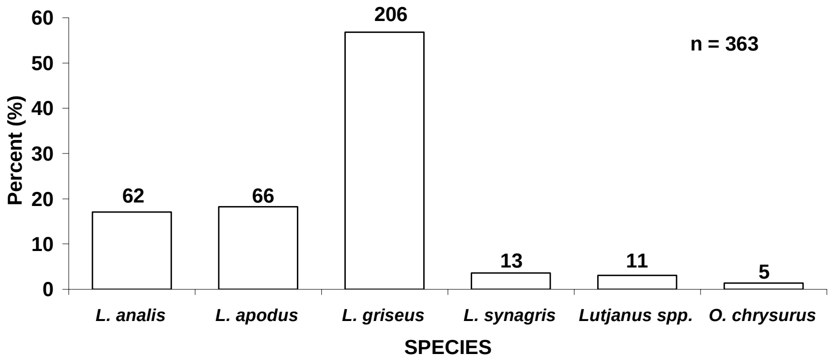

Figure 2. Percentage of the total snapper catch represented by each species. Numbers above bars indicate total number of each species collected.

Approximately 85% (n = 307) of the snappers collected were young juveniles ($\leq$ 100 mm SL) with a mean size of 36mm SL ($\pm$ 1.0 mm SE). More than half of the snappers (n = 200) were settlement-stage individuals ($\leq$ 40 mm SL), including 69 new recruits ($\leq$ 20mm SL) and 131 early-stage juveniles (> 20mm to $\leq$ 40mm SL) (Figure 3a). *Lutjanus griseus* was the only snapper species collected in sizes greater than 100 mm SL (n = 56) during the study. Of the 150 *L. griseus* measured, 68% were settlement-stage individuals with a mean size of 35 mm SL ($\pm$ 1.3 mm SE) (Figure 3b). *Lutjanus apodus* had the greatest mean size of all the snappers (45 mm SL [$\pm$ 2.1mm SE]); 45% were settlement-stage individuals (Figure 3c). The majority (68%) of *L. analis* collected were settlement-stage individuals with a mean size of 36 mm SL ($\pm$ 2.7 mm SE) (Figure 3d). *Lutjanus synagris* averaged 25 mm SL ($\pm$ 2.9 mm SE) in size; 85% of individuals were settlement-stage individuals (Figure 3e). Finally, of the few *O. chrysurus* collected, mean size was 27 mm SL ($\pm$ 4.6 mm SE), and 80% of the individuals were settlement-stage individuals (Figure 3f).

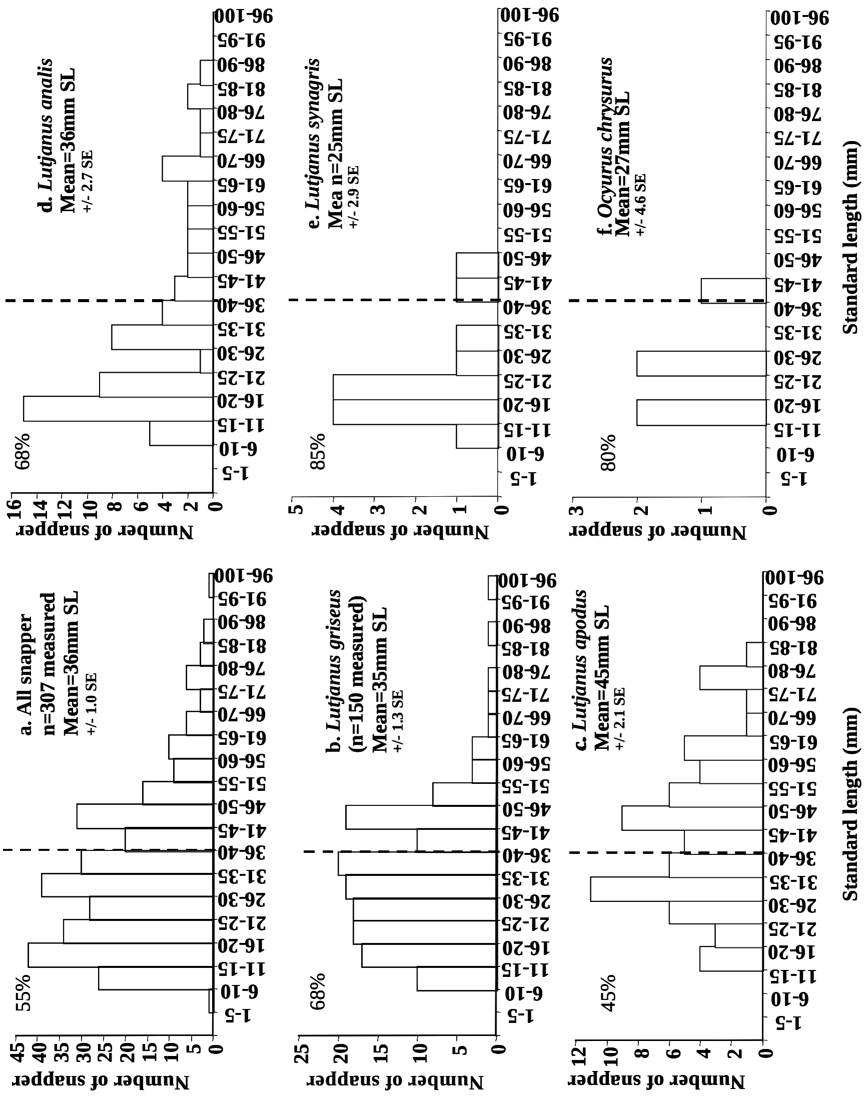

Figure 3. Length-frequency distributions of all snapper species that were measured (≤ 100 mm SL) during the study period. Total percentages of each species that were settlement-stage (≤ 40 mm SL) are indicated to the left side of the black dotted lines.

Abundance of all snappers combined and of *L. griseus*, *L. apodus*, and *L. analis* was not significantly different by month ($p > 0.05$). Statistical tests were not run on *L. synagris* or *O. chrysurus* because the total number collected of each was too low. Snappers were consistently caught throughout the summer-fall sampling period. The lowest mean numbers of snappers were collected in July (1.3 ± 0.8 SE) and the highest in October (10.8 ± 6.5 SE).

Lutjanus griseus, L. apodus, and *L. analis* were caught every month; all five snapper species were collected during September and October (Figure 4). Mean numbers of *L. griseus* were highest during September, October, and November, with a peak in October (7.8 ± 5.5 SE), whereas mean numbers of *L. analis* peaked in August (2.2 ± 1.1 SE; Figure 4). *Lutjanus apodus* were consistently caught throughout the sampling period, averaging 0.9 snappers (± 0.2 SE) per seine (Figure 4). *Lutjanus synagris* and *O. chrysurus* were most abundant in November (Figure 4).

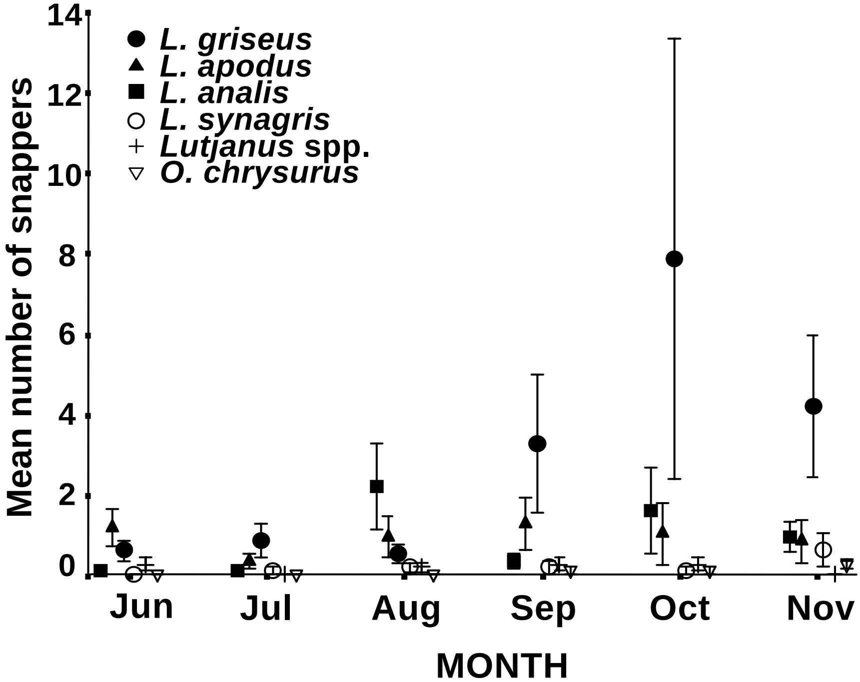

Figure 4. Monthly mean number of each snapper species collected during the study period. Error bars indicate mean standard error.

Abundance of all snappers combined (p = 0.006) and of settlement-stage snappers (p = 0.007) were significantly different between sites (Figure 5a). The majority of snappers (89%) were caught at four sites: 1049, 1050, 1276, and 1136 (Figure 5a). Almost 26 times as many snappers were captured at site 1049 than at sites 1051 or 1547. The lowest mean numbers of all snappers were captured at sites 1051 (0.5 ± 0.3 SE) and 1547 (0.5 ± 0.5 SE) (Figure 5a). A similar trend was observed for settlement-stage snappers, which were most abundant at the same four sites: 1050 (6.2 ± 3.1 SE), 1049 (5.8 ± 1.7 SE), 1276 (5.0 ± 1.7 SE), and 1136 (3.8 ± 1.3 SE) (Figure 5a).

Differences in spatial distribution also appeared to be species-specific. Mean numbers of *L. griseus* were significantly different between sites (p = 0.007); they were highest at sites 1049, 1050, 1276, and 1136 (Figure 5b). *Lutjanus analis* was most abundant at site 1276, whereas catches of *L. apodus* were highest at sites 1049, 1276, and 1050, but these differences in abundance were not statistically significant (p > 0.05; Figure 5b). Finally, mean numbers of *L. synagris* were highest at sites 1136 and 1277, whereas mean numbers of *O. chrysurus* were highest at site 1550 (Figure 5b). Statistical tests were not run on these two species because of low total numbers. The above trends were identical for settlement-stage snappers.

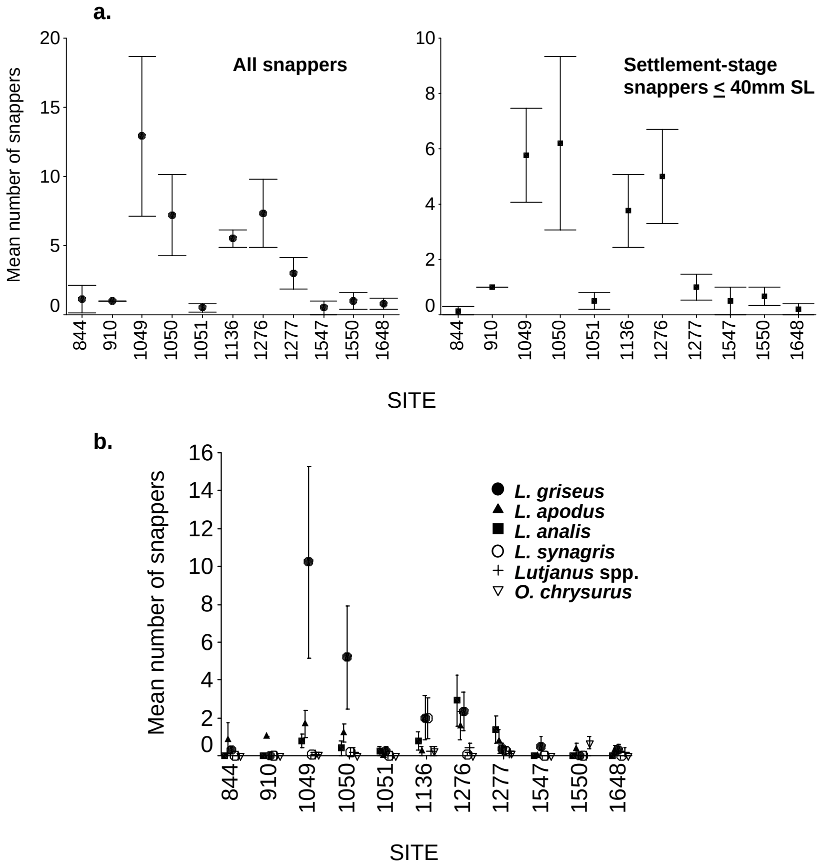

Figure 5. Mean number of all snappers and settlement-stage snappers (a.) and of individual species (b.) at each site during the study period. Error bars indicate mean standard error.

Water depths ranged from 0.3 m to 1.2 m, with a mean depth of 0.65 m (± 0.03 m SE). Physical conditions did not vary temporally or spatially. There were no significant differences in water temperature (ºC), salinity (‰), dissolved oxygen (mg/L), and pH among sites (p > 0.05). The abundance of all snappers combined and of individual snapper species was not significantly correlated with water depth or any physical parameters (p > 0.05).

Sampling sites were typically characterized by mixed-species seagrass beds consisting of *Halodule wrightii, Thalassia testudinum, Syringodium filiforme*, or mixed algae (Figure 6). All sites had a high percentage of seagrass cover (mean = 94.1% + 11.8). There was a significant difference in mean percent cover of *Thalassia* and *Halodule* between sites (p < 0.001; Figure 6).

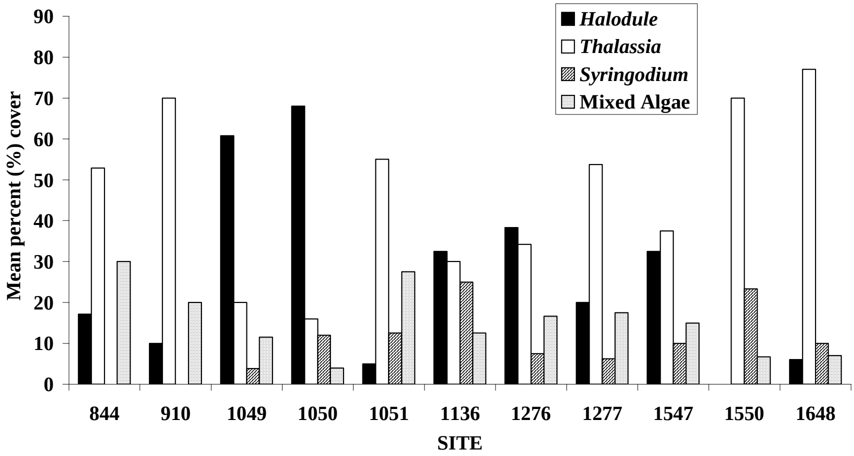

Figure 6. Mean percent bottom cover of submerged aquatic vegetation at each site. Error bars were removed for figure clarity.

Abundance of all snappers combined and of the most abundant snapper species (*L. griseus)* was positively correlated with *Halodule* cover (p < 0.01) and negatively correlated with *Thalassia* cover (p < 0.01). Mean percent *Halodule* cover was the highest at sites 1050 (68% " 5.7 SE) and 1049 (61% + 2.6 SE), where mean numbers of snappers were also high (Figures 5a, b), whereas mean percent *Thalassia* cover was the lowest (< 20%) at these sites (Figure 6).

Likewise, mean percent *Thalassia* cover was relatively high at sites 1648 (77% + 3.2 SE), 1550 (70% + 3.4 SE), 910 (70% + 3.0 SE), 1051 (55% + 1.0 SE), and 844 (53% + 2.5 SE), where lower mean numbers of snappers were collected (Figures 5a, b; Figure 6). No differences were detected in total percent bottom cover, percent mixed algal cover, or percent *Syringodium* cover between sites (p > 0.05; Figure 6).

DISCUSSION

Snappers are extremely valuable to the economy of South Florida. Identifying nursery habitats of settlement-stage snappers and examining recruitment dynamics and the causes of annual variability in fish stocks are crucial for conservation and sound fishery management (Rutherford et al. 1989, Lindeman et al. 1998, Allman and Grimes 2002). Consequently, over the years, FWC and other researchers have conducted extensive surveys throughout the Keys and Florida Bay targeting early-juvenile-stage snappers. During this pilot study, we collected many snappers from shallow, shorefront seagrass beds on the Atlantic side of the Middle Keys. More than half of the snappers caught were young, settlement-stage juveniles, and nearly 25% were newly settled recruits. The high percentage of young snappers collected and small average size confirm that these nearshore seagrass areas serve as important snapper settlement and nursery grounds, particularly for *L. griseus*.

Snappers recruited to our sites throughout the summer-fall sampling period. Abundance of all snappers combined and of individual snapper species did not differ by month. Nevertheless, highest recruitment occurred during September, October, and November, suggesting that higher numbers of adult snappers were spawning during late summer and early fall because larval duration is relatively short (25 - 40 days) in snappers (Rutherford et al. 1989). In other studies, snappers have been similarly observed recruiting to seagrass beds from May through February in Florida (Reid 1954, Tabb and Manning 1961, Springer and McErlean 1962, Rutherford et al. 1989, Allman and Grimes 2002, Watson et al. 2002, Barbieri and Colvocoresses 2003, Harnden and Snodgrass In review). Snapper spawning periods are not necessarily concurrent throughout Florida, and the exact timing of spawning, especially in the Keys, is not well established.

Snapper abundance differed significantly between sites, and differences appeared to be species-specific. A high percentage of the snappers were collected at four sites located in the center of the sampling area. Because seasonal or physical factors were not strongly correlated with snapper abundance, other factors, such as seagrass characteristics (e.g., quality, density, diversity, and species composition) or the proximity of alternative habitats, such as mangroves, hardbottom areas, or coral reefs, may have contributed to the observed patterns of species composition and abundance of settlement-stage snappers. These four sites are all situated along stretches of beachfront in areas far removed from any major channels; additionally, these sites have the largest area of continuous nearshore seagrass in the Middle Keys and are in closest proximity to nearshore coral reefs. Results indicate that the abundance of snappers was positively correlated with *Halodule wrightii* cover, which was most abundant at these four sites. It may be that the complexity and composition of bottom cover in seagrass habitats are the most influential factors determining the diversity and abundance of snappers. A prior study in Florida Bay found similar results in which juvenile *L. griseus* were most abundant in mixed-species seagrass beds with higher densities of *Halodule* and *Syringodium* (Rutherford et al. 1989). In addition, Thayer and Chester (1989) determined that fish species were found in highest abundances and with greatest frequencies in areas of western Florida Bay that have mixed-species seagrass beds containing abundant *Halodule* and *Syringodium*, high sediment organic content, and shallow water. Although we found no significant correlation between fish abundance and water depth or sediment type in our study, the homogeneity of environmental conditions within our study area may have precluded the examination of such effects.

Much debate exists over whether the sizes of adult fish populations are defined by events occurring before, during, or after settlement (Doherty 1991).

Abundance and survival of recruiting fish are most likely influenced by small-scale reef processes, such as predation, competition, presence or absence of conspecifics, density-dependent factors, or habitat preference, and by large-scale stochastic processes of larval supply before settlement (Milicich et al. 1992, Milicich and Doherty 1994, Tolimieri 1995, Danilowicz 1997). Kingsford and Choat (1989) found that distributions of recruiting larvae of some species were influenced by the proximity of reefs. Settling fish may have habitat preferences that direct them to recruit into different areas (Milicich et al. 1992, Lindeman et al. 1998). Research on early demersal habitat use in snapper species in Biscayne Bay found snappers to have species-specific habitat preferences (Lindeman et al. 1998). Newly settled *L. griseus*, as well as early stages of *L. analis*, *L. jocu* (dog snappers), and *L. cubera* (cubera snappers), were found principally in seagrass beds and were rarely recorded from hardbottom, whereas *L. synagris*, *O. chrysurus*, and *L. apodus* were more opportunistic in their habitat-use patterns, using either seagrass or hardbottom habitats.

Future research will involve larger-scale sampling of Atlantic-shorefront seagrass beds throughout the Keys to more fully determine spatial and temporal distribution patterns and recruitment dynamics of newly settled snappers. We also plan to better characterize the microscale habitat and environmental differences that may influence recruitment in these areas. In addition, we plan to collaborate with NOAA scientists by using microacoustic tags and otolith signatures to analyze early-life-history habitat requirements, site-fidelity, and home ranges of juvenile snappers and to establish the connectivity between nursery and adult habitats. Future research should provide sufficient data to establish recruitment signals that can be used as tuning indices for stock assessment and management of these economically important snappers in the Keys.

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