Spatio-temporal patterns and recruitment of young of the year snappers: mutton snapper (*Lutjanus analis*), lane snapper (*L. synagris*), schoolmaster snapper (*L. apodus*), gray snapper (*L. griseus*) and yellowtail snapper (*Ocyurus chrysurus*) (*Lutjanidae*) in the Middle Florida Keys between 2007-2019

Patrones espacio-temporales y reclutamiento de pargos jóvenes del año: pargo criollo (*Lutjanus analis*), pargo rayado (*L. synagris*), pargo amarillo (*L. apodus*), pargo gris (*L. griseus*) y pargo de rabirubia (*Ocyurus chrysurus*) (Lutjanidae) en los Cayos de Florida Central entre 2007-2019

Modèles spatio-temporels et recrutement des jeunes vivaneaux de l'année : vivaneau mouton (*Lutjanus analis*), vivaneau des chemins *(L. synagris*), vivaneau maître d'école (*L. apodus*), vivaneau gris (*L. griseus*) et vivaneau à queue jaune (*Ocyurus chrysurus*) (*Lutjanidae*) dans les Middle Florida Keys entre 2007-2019

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EXTENDED ABSTRACT

Recruitment is a major factor in the establishment and sustenance of local population structures of reef fishes. Insights on temporal and spatial recruitment variability are crucial to understanding the population dynamics of these commercially and recreationally targeted species. Given that small inter-annual differences in recruitment strength can lead to profound downstream effects in adult populations (Rothschild 1986) and may provide early indication of overfishing (Richards and Rago 1999; Barrowman and Myers 1996), long-term assessments of early juvenile abundance are a critical component of fisheries management. In dynamic coral reef fishery ecosystems such as the Florida Reef Tract, characterized by high and diffuse fishing effort (Ault et al. 2005), fishery-independent indices are especially important. Shallow-water snapper (*Lutjanidae*) comprise large commercial and recreational fisheries in the Florida Keys. Gray (*Lutjanus griseus*), mutton (*L. analis*), yellowtail (*Ocyurus chrysurus*), schoolmaster (*L. apodus*), and lane snapper (*L. synagris*) represent the bulk of shallow-water snapper landings. Considering recently proposed management action to protect snapper spawning and nursery habitats in the Florida Keys (NOAA 2019), and in the interest of providing recruitment indices for management, the objectives of this study were twofold: 1.) Develop retrospective annual recruitment indices for yellowtail, gray, lane, schoolmaster and mutton snapper from monthly seine surveys conducted in the Middle Florida Keys and 2.) characterize juvenile recruitment of each species as a function of environmental and habitat variables to elucidate processes effecting the location and timing of larval settlement.

Between 2007 and 2019, monthly beach seine surveys (n = 1535) were conducted in submerged aquatic vegetation (SAV) beds along the southern shoreline of Marathon, FL. In each survey, all fish were enumerated, their standard lengths (SL) measured in millimeters, and aquatic vegetation cover estimated by Braun-Blanquet cover classes. Environmental variables were either measured *in-situ* (water temperature) or were compiled later (lunar illumination, wind speed, wind direction, distance from shore). Recruitment of each of snapper species was characterized as a function of temporal and habitat variables using generalized linear mixed-effect models (GLMMs). Models of settlement-stage (< 40 mm SL) abundance were fit using a backwards selection routine using AIC as the value of determination.

Significant interannual recruitment variability was present in all recruitment models, with abundance fluctuations ranging from 300 % to 5000% between the highest and lowest producing years by species (Fig. 1a). Estimated abundances of mutton, lane, schoolmaster, and yellowtail snapper were lowest in 2010, the year of a historic cold spell in South Florida. In contrast, juvenile gray snapper abundance was highest in that year. Spawning seasonality was apparent in monthly recruitment indices for all species. Estimated settlement-stage abundances peaked for gray, lane, schoolmaster, and yellowtail in September, while newly settled mutton were most abundant in October (Fig. 1b). Based upon calculated post-hatch ages, peak spawning is estimated to have occurred in late July for schoolmaster, gray, and yellowtail, and mid-to-late August for lane and mutton. Relative to the other species assessed, a longer spawning season was noted for yellowtail and lane snapper based upon month-month recruitment variance, with inferred spawning lasting from March – November and April – November, respectively. Among spatial and environmental variables, within-site differences in distance from shore, SAV type, and SAV percent cover were the most important predictors assessed. Gray, lane, and schoolmaster all had pronounced, positive associations with *Halodule wrightii.* Yellowtail, and to a lesser extent, gray snapper abundance was significantly explained by *Thalassia testudinum* cover. Water temperature by month was a significant predictor for two species in two months each: yellowtail (May and July) and gray snapper (October and December). In all cases, temperature-recruitment effects correlated positively with increasing daily water temperatures in the spring and summer and negatively with decreasing water temperatures in the fall. Lunar illumination, wind speed, and wind direction were generally poor

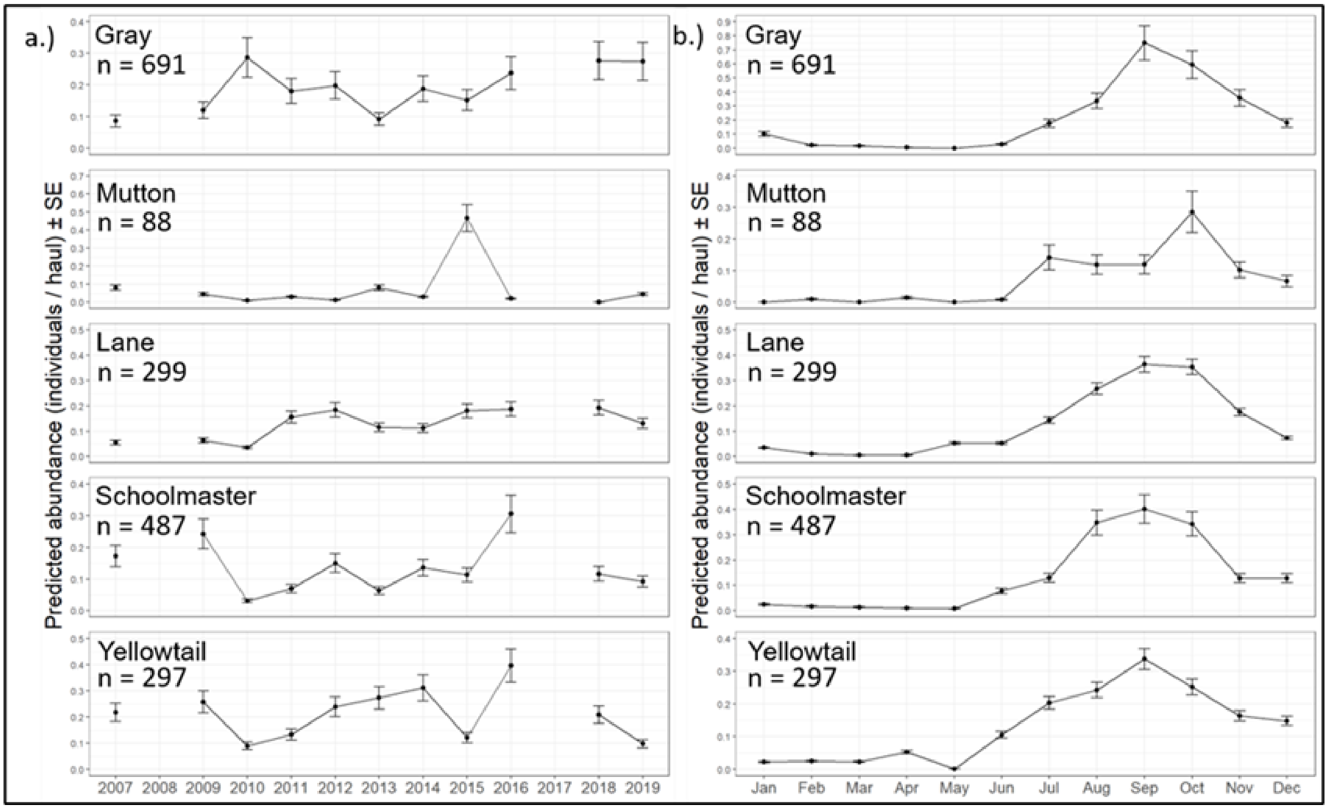

Figure 1. Predicted yearly (a) and monthly (b) abundance indices (individuals per haul) for settlement-stage snapper (< 40mm) from the best fitting models for each species. Data collected in 2008 and 2017 were not included in models due to sampling gaps during peak recruitment months. Note that y-axis scales differ between plots

predictors of settlement-stage abundance.

We found variation in the strength, timing, and location of snapper recruitment due primarily to interannual variability, spawning seasonality, and species-specific settlement preferences. Among interannual trends, low recruitment in summer and fall 2010 likely stems from prolonged, anomalously cold weather in January of that year which resulted in widespread fish and invertebrate mortality (Lirman et al. 2011; Boucek and Rehage 2014). In contrast, the fact that gray snapper recruitment peaked that year suggests that the species benefit from the cold spell. Increased gray snapper reproduction, decreased post-settlement competition, or both correspond with findings by Santos et al. 2016, who note that adult gray snapper CPUE increased in South Florida immediately following the January 2010 cold event while other species catches declined. Despite well established relationships between moon phase and spawning behavior for several species discussed here, lunar illumination was not an important predictor of snapper recruitment for any species. The lack of a lunar recruitment signal likely indicates either a disconnection of spawned larval supply from settlement-stage abundance due to planktonic processes (Pineda et al. 2010; Sponaugle and Pinkard 2004), that our sampling framed lacked the precision to detect lunar periodicity, or perhaps both. Among settlement habitat preferences, our findings largely confirm previous work documenting differential SAV preferences by species (Bartels and Ferguson 2006; Watson et al. 2002; Pollux et al. 2007). Incidentally, species whose recruitment showed negative relationships with offshore distance – schoolmaster, gray, and lane – are the species encountered among mangrove prop roots at subsequent life stages (Lindeman et al. 1998; Luo et al. 2009), potentially indicating a partial mechanism driving the selection of nearshore settlement habitat. Taken together, our results provide an updated picture of snapper recruitment in the Middle Florida Keys with implications for the management of essential habitats and species.

KEYWORDS: SCTLD, coral disease, intervention, monitoring,

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