Estimating the influence of modeled oceanographic variables on juvenile snapper abundance in the Middle Florida Keys

Estimación de la influencia de las variables oceanográficas modeladas en la abundancia de pargos juveniles en los Cayos de Florida Central

Estimation de l'influence des variables océanographiques modélisées sur l'abondance des vivaneaux juvéniles dans les Middle Florida Keys

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EXTENDED ABSTRACT

Many marine fishes exhibit life history strategies which include a pelagic larval phase. Oceanic conditions during this period affect the growth, survival, and dispersal of larvae thus influencing recruitment rates and subsequent adult population dynamics (Pineda et al. 2007). While it remains difficult to separate the effects of pre-settlement and post-settlement processes on recruitment, incorporating both types of variability into juvenile recruitment models has been shown to improve resulting indices (Miller et al. 2009). In the Florida Keys, larval retention, dispersal, and transport to nearshore settlement habitats are thought to be mediated by the offshore position of the Florida Current as well as the propagation of meso-scale and sub-mesoscale eddies (Lee et al. 1994, Lee and Williams 1999, Sponaugle et al. 2005). Meanwhile, biophysical interactions related to oceanic temperature and salinity gradients can moderate rates of larval growth and survival (D'Alessandro et al. 2013). The motivation of this work was to refine recruitment indices for fishery-important species in the Middle Florida Keys by isolating and assessing the effects of oceanic salinity, temperature, current speed, and current direction on post-settlement abundances.

Juvenile fish surveys have been conducted monthly since 2007 in nearshore seagrass beds of the Middle Florida Keys using a 21.3 m center-bag seine. Here, we modeled the abundance of settlement stage snapper (total length <= 40mm; *Lutjanus analis, L. apodus, L. synagris, L. griseus, Ocyurus chrysurus)* from data collected between 2007 and 2019 as a function of current speed, current direction, water temperature, and salinity produced by the Hybrid Coordinate Ocean Model (HYCOM; Chassignet et al. 2007).

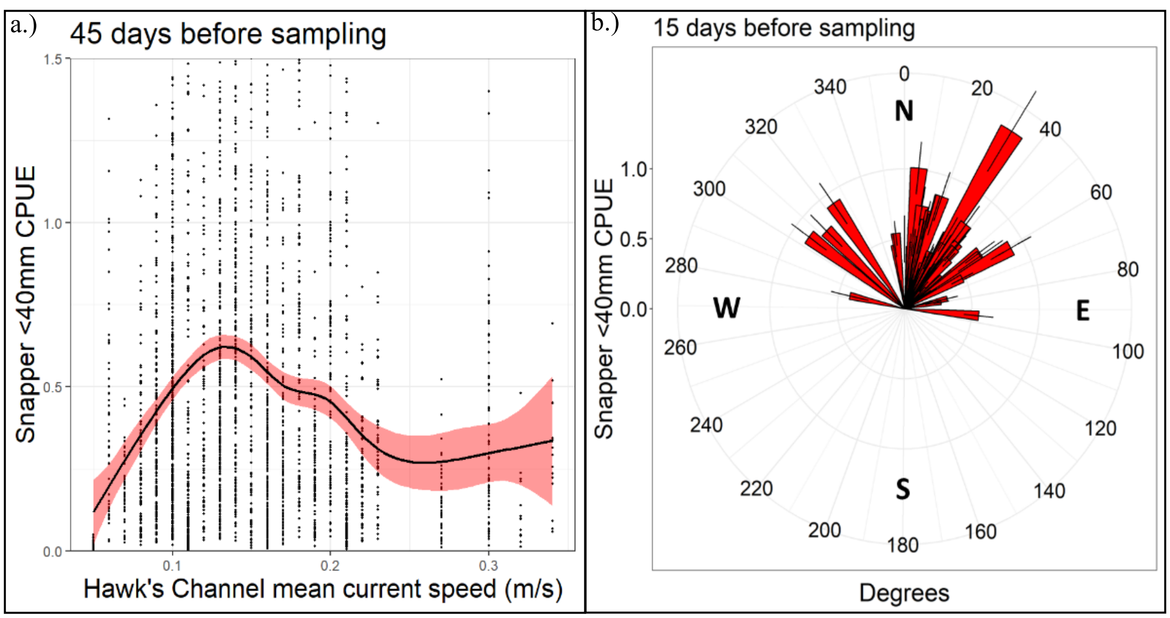

Figure 1. a.) Predicted settlement-stage (< 40 mm SL) snapper catch per unit effort (CPUE) by mean current speed (m/s) in Hawk's Channel, 45 days before sampling. Predictions produced from the best-fitting composite model of settlement-stage abundance. b.) Predicted settlement-stage (< 40 mm SL) snapper catch per unit effort (CPUE) by mean current direction (degrees), 15 days before sampling. Predictions produced from the best-fitting composite model of settlement-stage abundance.

Oceanic variables were extracted from the model at four lagged intervals per seine sampling date (day of sampling, -15 days, -30 days, and -45 days) to account for oceanic conditions during estimated pelagic larval periods of newly settled individuals. Variables were also partitioned into three offshore areas ('Hawk's Channel' (shore to fore reef), 'mid-shelf' (fore reef to 40 km from shore), and 'offshore' (40 to 70 km from shore) to account for spatial interactions with physical variables. Candidate generalized additive models (GAMs) of settlement stage abundance were assembled based upon hypothesized biophysical relationships and known larval dispersal pathways in the Florida Keys. Model fit was ranked by Akaike's Information Criterion (AIC) and composite models assembled from the most important predictors.

A total of 2185 settlement stage snapper were caught between 2007 and 2019. The most important predictor of abundance was mean current speed in Hawk's Channel, 45 days before sampling (Fig. 1a). Lowest subsequent settlement stage abundance in the best fitting composite model was predicted by the lowest mean current speed observed (0.05 m/s). Peak abundance was predicted by current speeds averaging 0.14 m/s. The second-best predictor of abundance was mean current direction in the mid-shelf region, 15 days before sampling. Highest predicted abundances occurred when current direction averaged 35° (Fig. 1b). A secondary, positive recruitment effect was detected when current direction averaged 300-360°, indicating shoreward flow. Among temperature and salinity variables, only Hawk's Channel temperature, 45 days before sampling, was identified as a top-contributing predictor and included in composite models. The predicted effect in this case amounted to a non-linear relationship with highest abundances predicted by low and high temperature extremes.

Among the oceanographic variables assessed, current speed and direction were stronger predictors of abundance than any temperature or salinity variable assessed. Our finding that current speed in Hawk's Channel, near the estimated time of spawning (i.e., 45 days before sampling) was most influential to subsequent recruitment aligns with known aspects of the larval ecology of broadcast spawning fishes. Specifically, given that newly spawned eggs and larvae are more vulnerable to predation before they develop increased swimming capabilities (i.e., ~9 days post-hatch), low current speeds, and thus slower dispersal away from spawning areas, subject newly spawned progeny to greater mortality from predators (Hamner and Largier 2012). Among current direction variables, current direction in the mid-shelf area 15-days before sampling best predicted recruitment. Given that larvae require sufficient time in the pelagic realm for growth and development prior to settling to comparatively more predator-dense nursery habitats, the timing of when they encounter toward-shore currents is ultimately a determinate of post-settlement survival. Assuming a pelagic larval duration of 25-35 days (Lindeman et al. 2001) and an average standard length (SL) of snapper sampled of 28 ± 0.16 cm, most individuals we caught are expected to have settled into seagrass habitats approximately 15-days prior to sampling. Thus, the fact that current direction during this period was most influential to juvenile abundance indicates that larvae were most sensitive to variation in current direction near the time of settlement. The most prominent, explanatory current direction signal occurred at approximately 35° (Fig. 1b) – the primary direction of the Florida Current. Dominant current regimes seaward of the Florida Reef Tract vary seasonally, with increased potential for onshore transport of larvae in the fall (Lee and Williams 1999). Closer passage of the Florida Current may benefit recruitment by decreasing the distance to settlement habitats for entrained larvae. Alternately, increased abundance associated with periodic onshore flow (i.e., 300-300°, Fig. 1b) in the mid-shelf zone, likely stems from the eastward passage of meso-scale cyclonic eddies (Lee and Williams 1999). Our results demonstrate that pre-settlement oceanic conditions can help explain variability in juvenile snapper recruitment to nearshore habitats in the Middle Florida Keys. Incorporating such data will likely increase the precision of annual snapper recruitment indices, thus benefitting fisheries management initiatives in the region.

KEYWORDS: Juvenile recruitment, fisheries management, larval ecology

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