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Lost opportunities: Coral recruitment does not translate to reef recovery in the Florida Keys

Robert van Woesik *, William J. Scott IV, Richard B. Aronson

Florida Institute of Technology, 150 W. University Blvd., Melbourne, FL 32901, United States

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ABSTRACT

We tested the hypothesis that the poor recovery of the coral populations on reefs in the Florida Keys is related to low coral recruitment. In the summer of 2011, we deployed 240 terracotta tiles at eight study sites in a balanced design: (i) among three depths; and (ii) between fished and unfished reefs. Corals recruited to ~40% of the deployed tiles, with more corals settling on tiles on unfished reefs than on fished reefs. The apparent effect of protection was not a consequence of different densities of herbivorous fishes, but was more likely related to local hydrography and the tendency of the no-take reserves to act as larval sinks, particularly in the lower Florida Keys. There was a mismatch between the coral taxa that recruited and the adult coral assemblages, suggesting that recruits were arriving but not surviving to contribute to coral recovery.

1. Introduction

If coral populations are to persist, coral recruitment must equal or exceed the rates of mortality of adult corals. The generation of recruits, particularly those with novel genotypes derived through sexual recombination, is necessary to maintain and restore coral populations, especially when environments are changing rapidly (Richmond, 1997; Gardner et al., 2003; Ritson-Williams et al., 2010). The increasing frequency and severity of perturbations to coral reefs are, however, reducing coral populations worldwide (Bruno and Selig, 2007). As coral cover continues to decline throughout the Caribbean, the supply of coral planulae may be insufficient to maintain and replenish coral-dominated communities (Vermeij, 2006; Gleason and Hofmann, 2011).

In response to signs of fish-population declines throughout the Florida Keys, the 9500-km^2 Florida Keys National Marine Sanctuary (FKNMS) was established in 1990 (Florida Keys National Marine Sanctuary, 1996). In 1997, 24 no-take reserves, distributed from Miami to the Tortugas Banks, were established within the Sanctuary to protect fish stocks. Although the Florida Keys National Marine Sanctuary was set up, in part, to ensure the sustainable use of the Florida Keys by "achieving a balance between comprehensive resource protection and multiple, compatible uses of those resources" (Florida Keys National Marine Sanctuary, 1996, p. 5), the placement of the no-take reserves was not independent of oceanographic setting (B. Causey, pers. comm.). There was already, in 1990, an understanding of the local hydrography. The reefs of the Dry Tortugas and the Florida Current interact to form a series of gyres. The largest and most frequently forming is the Tortugas Gyre, which extends up to 100 km in diameter and often persists for as long as 140 days. The smaller Pourtales Gyre is adjacent to Western Sambo Reef (Lee et al., 1992). The gyres diminish in size as they propagate to the northeast (Lee et al., 1992). Modeling studies have predicted that these gyres retain locally produced larvae that would otherwise be advected by the Florida Current (Lee et al., 1994; Criales and Lee, 1995). At least implicitly, there was potential for the no-take reserves in the FKNMS to concentrate larvae, hydrographically, and act as larval sinks.

A reasonable goal of marine reserves on coral reefs is that closing selected areas to fishing pressure should increase the biomass of target fish species. A less-tenable expectation is that preventing fishing pressure will increase stocks of herbivorous fishes, which will crop macroalgae and, therefore, improve the chances of coral recruitment and coral population recovery. Although the densities of carnivorous fishes have increased in the reserves (Kramer and Heck, 2007), there is no evidence that the reserves have had a beneficial, cascading effect on corals (Aronson and Precht, 2006; Schutte et al., 2010; Toth et al., 2014).

The recent decline of coral populations in the Florida Keys is thought to be largely a consequence of low coral recruitment (Tougas and Porter, 2002) or of mortality outpacing recruitment (Williams and Miller, 2012). To test these conjectures, we examined the spatial variation in coral recruitment in the Florida Keys

* Corresponding author.
E-mail address: rvw@fit.edu (R. van Woesik).

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in 2011. We deployed 240 terracotta tiles to determine whether corals were recruiting in large numbers or whether coral recruitment was indeed limiting the recovery of coral populations. We were also interested in whether coral recruitment differed between fished and unfished reefs, and whether shallow habitats received more recruits than deep habitats. We asked three overarching questions: (i) Does coral recruitment vary between levels of protection in the Florida Keys? (ii) Does coral recruitment vary among depths along the Florida reef tract? and (iii) Is there a difference in recruitment between the upper and lower Florida Keys?

2. Methods

2.1. Field methods

We examined patterns of coral recruitment at eight study sites along the Florida reef tract (Fig. 1). Four sites were established on unfished reefs and four on fished reefs. At each site, we installed 30 new, unglazed terracotta tiles (10 × 10 × 1.5 cm), deploying 10 tiles at each of three depths (2–5 m, 7–10 m, and 14–17 m). A total of 240 tiles were installed during the period 9–17 May 2011, 232 of which were retrieved during 23–27 September 2011 following a 133- to 141-day soaking period; these dates encompass the coral-spawning period for the Florida Keys (van Woesik et al., 2006).

Prior to attaching the tiles to the reef substrate, we drilled holes 0.5 cm in diameter into the non-living carbonate framework at randomly selected points using a pneumatic drill attached to a SCUBA tank. A ribbed, plastic, drywall anchor was inserted into each drilled hole, and a single stainless-steel screw (35 mm long × 3.2 mm wide) and stainless-steel washer (15 mm diameter and 1 mm thick) were used to attach the tile to the reef. Tiles were installed to match the reef contours to the greatest extent possible. Prior to removal, the angle of each tile was measured relative to the horizontal, to determine if substrate angle influenced recruitment. The substrate angle varied from 0° to 85°, with an average angle of 18° (standard deviation 19°). The proportion of the undersurface of the tiles exposed to herbivorous fish depended on the substrate angle and reef undulations. The tiles were photographed underwater using a Canon Powershot SD790 IS digital camera. The tiles were removed from the reef, placed in individually marked plastic containers, and transported to the Florida Institute of Technology for analysis.

2.2. Laboratory methods

Coral recruits were identified to the lowest taxonomic level possible and photographed using an Olympus SZX12 Stereoscope and Nikon Coolpix 8700 digital camera. We were able to categorize the coral recruits into three genera, *Siderastrea*, *Acropora*, *Porites*; and two families, Astrocoeniidae and Meandrinidae (Fig. 2). We also categorized the orientation of each recruit on the tile (i.e., top, bottom, or side), and determined the proximity of each coral recruit to crustose coralline algae. To determine the percentage cover of sessile, benthic organisms on the bottom surfaces of the tiles, where the majority of recruits settled, photographs were taken using a Nikon D80 digital SLR camera with an 18–55 mm f/3.5–5.6 G AF-S DX VR Zoom-Nikkor lens. The images were processed using the software Coral-Point-Count with Excel extensions (CPCe) (Kohler and Gill, 2006). A pilot study showed that 20 random points per tile was adequate to make accurate assessments of coverage. We classified each point as one of the following: (i) bare substrate; (ii) suspension-feeders (ascidians, sponges, barnacles, serpulid worms, and bryozoans); (iii) macroalgae (>1 cm high); (iv) turf algae (⩽1 cm high); or (v) crustose coralline algae. Recruits on the sides of the tiles were pooled with the recruits on the bottoms of the tiles. Only three recruits were observed on the tops of tiles, and they were not included in the analysis.

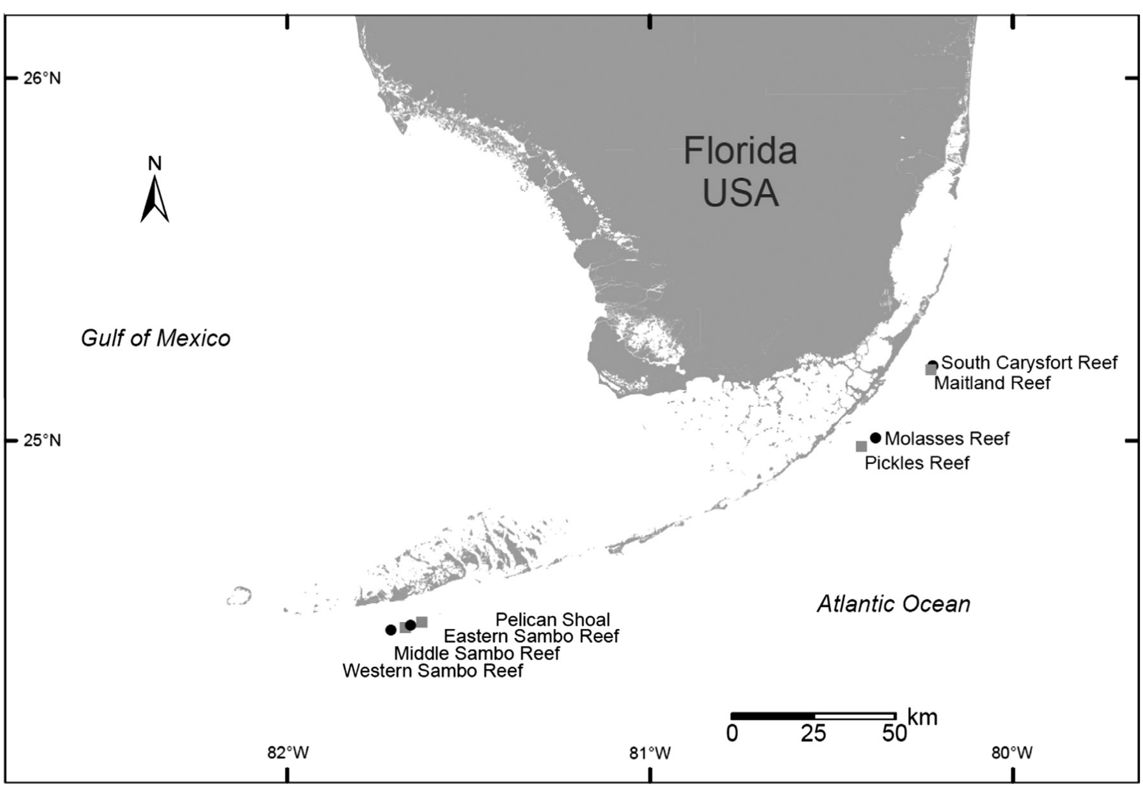

Fig. 1. Location of the eight study sites in the Florida Keys. Fished reefs are represented by gray squares and unfished reefs are represented by black circles.