INITIAL RECRUITMENT OF CORAL REEF FISH TO SMALL-SCALE ARTIFICIAL, COMPLEX STRUCTURES

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Abstract: With continuing coral decline, artificial reefs are being considered more often in reef conservation and management. We studied the effects of small-scale PVC artificial reef structures, of three levels of complexity, on fish recruitment in Grape Tree Bay, Little Cayman Island. Based on previous research, we hypothesized that fish abundance and percent juveniles recruited would be greater on structures of high complexity than those of low complexity. We also predicted that more fish and juveniles would recruit to artificial structures than control plots, and that abundance and richness would increase over time on structures of each complexity level. The presence of artificial structures increased the abundance, percent juveniles, and composition of initial fish recruitment, relative to control plots, but level of complexity had no detectable effect on recruitment.

Keywords: Fish recruitment, artificial coral reefs, diversity, back reef

INTRODUCTION

Maximizing the suitable habitat for juvenile fish may be critical in increasing the overall carrying capacity of juveniles in a patch reef area (Sale 1997; Leis et al. 2002; Gratwicke & Speight 2005). Habitat complexity is important for survival and recruitment of juvenile fish in natural habitats (Beukers & Jones 1998), juvenile fish in artificial reefs made from natural materials (Isbey & Gorbatkin 2007), and overall abundance and richness in artificial reefs made from synthetic materials (Charbonnel et al. 2002).

Over time, percent juveniles, richness, diversity, and/or abundance of recruited fish increased on artificial reef structures (Isbey & Gorbatkin 2007). Time scales of recruitment may vary for artificial reef structures constructed of synthetic materials vs. natural materials. We tested how the presence and degree of structural complexity of synthetic structures influence initial recruitment over several days post-placement to artificial structures in Grape Tree Bay, Little Cayman.

If juvenile fish are at higher predation risk than adults (Connell & Jones 1991), more juveniles should colonize complex habitats than adults, as recruited juveniles suffer high mortality in low complexity habitats (Connell & Jones 1991).

Based on the idea that the most suitable natural habitats are complex (Beukers & Jones 1998), and that the number of refuges within a coral reef limits fish abundance and juvenile survival, we predicted that fish abundance of new recruits, and percent juveniles, would increase from low to high complexity structures. Small-scale structures may also attract younger or smaller fish since small refuge size prevents larger, adult fish from recruitment. We also predicted that more fish would recruit to artificial structures than control plots, and that overall abundance and richness would increase over time in each reef type.

METHODS

On 6 - 10 March, 2008, we monitored initial recruitment on artificial structures along a ca. 225 m stretch of back reef in Grape Tree Bay, directly behind the Little Cayman Research Centre. Fifteen artificial structures (five replicates of each of three structure types) were placed 15 m apart and 2 m away from any coral heads. We expected a spatial gradient in fish assemblages along the back reef, so we blocked the structures when placing them. Each was anchored in place with two 2 lb weights. All substrate that provided additional shelter (rocks, algae, shells) was removed from under the structures. Descriptions and photos of structures are in Appendix A.

We monitored two control plots per block (n = 10) placed 7 m from any artificial structure and 2 m from any coral heads. Each control was 0.33 m x 0.30 m, covering ca. the same area as artificial structures. Within each block, we used one modified control (algae removed) and one unmodified control (unmanipulated substrate) to assess the effect of substrate manipulation on fish recruitment.

We placed artificial structures on the seabed floor on the morning of 6 March (day 1). The structures were placed on sandy sections of the seabed floor ca. 1.22 m - 1.52 m deep. We collected data from the afternoon of 6 March through the afternoon of 8 March (day 3). Each day, we observed each structure and controls for 3 - 5 minutes in the morning (ca. 10:00) and the afternoon (ca. 16:00). We recorded number, species, and lifestage (adult or juvenile) of recruited fish for each of the 15 artificial structures and 10 control plots.

Based on our predictions, we tested for the effect of structures on initial fish recruitment using linear contrasts testing for several response values (% juveniles, richness, Shannon-Weiner diversity index, and abundance of recruited fish). We tested for differences between structures and control plots, as well as between high and low complexity, and reported mean ± SE results for each of these.

We ran two repeated measures ANOVAs for the effect of time and reef type on abundance, one including al l controls (Day 2-3), and one excluding all controls (Days 1-3); we did the same for species richness. Because we met the assumption of sphericity, we report F-test values for all analyses. We were unable to include the controls to test for the effect of complexity for all 3 days because we began taking data on the un-manipulated controls on the morning of Day 2, and the manipulated controls on the afternoon of Day 2.

RESULTS

Over the course of the experiment, we made 137 fish observations across 23 species. We observed a total of 39 fish and 8 species at our last sampling period (day 3). Gobies and blennies were the most common fish found in low and medium complexity reef structures over 3 days (90.8 ± 3.8%, 78.1 ± 9.5%), while high complexity structures contained the same number of gobies and blennies (50 ± 18.4%) as other fish. We observed very few gobies and blennies in both control plots on day 3 (Cu = 1, Cm = 0). The Goldspot Goby was the most common species observed in artificial structures over the course of the experiment (low complexity = 19, medium complexity = 13, high complexity = 7).

Over the time period in which we had controls, neither time nor its interaction with reef type were significant predictors of species richness or abundance of fish (Table 1, Figures 1, Figure 2). However, when we considered our full time period, excluding controls, richness but not abundance increased over time (Table 1). Thus we present mean values ◎ SE and contrasts from our last observation period (afternoon of Day 3).

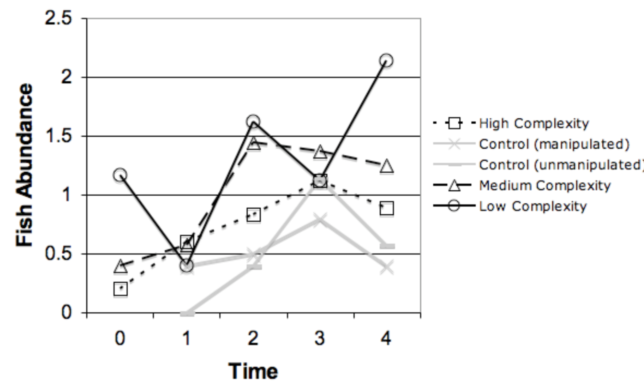

Figure 1. Abundance of fish recruited to artificial structures of varying complexity and control plots over 3 days on the back reef of Grape Tree Bay, Little Cayman Island. Time is categorized by morning and afternoon of each day of data collection (0 = afternoon Day 1, 1 = morning Day 2, 2 = afternoon Day 2, 3 = morning Day 3, 4 = afternoon Day 4).

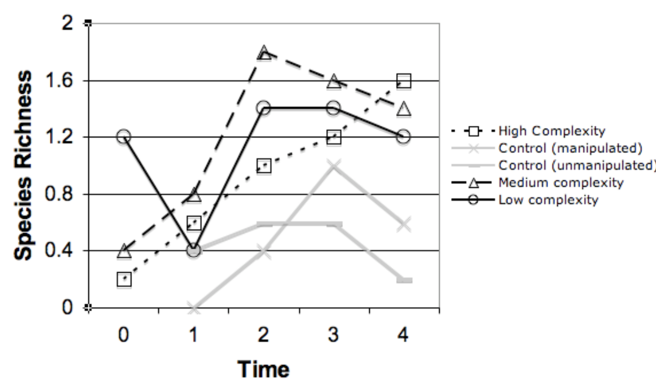

Figure 2. Species richness of fish recruited to artificial structures of varying complexity and control plots over 3 days on the back reef of

Grape Tree Bay, Little Cayman Island. Time is categorized by morning and afternoon of each day of data collection (0 = afternoon Day 1, 1 = morning Day 2, 2 = afternoon Day 2, 3 = morning Day 3, 4 = afternoon Day 4).

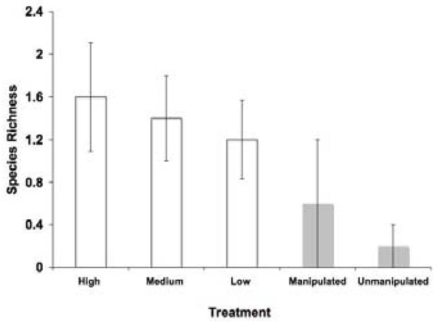

Figure 3. Species richness (mean ± SE) of fish recruited to artificial structures of varying complexity (high, medium and low) and control plots (manipulated and unmanipulated) on day three since placement in the back reef of Grape Tree Bay, Little Cayman Island. White bars = artificial structures (N=15), grey bars = control plots (N=10).

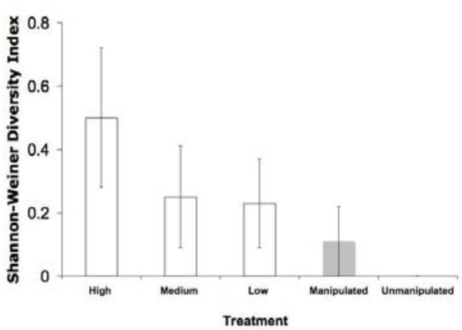

Figure 4. Diversity (mean ± SE) of fish species recruited to artificial structures of varying complexity (high, medium and low) and control plots (manipulated and unmanipulated) on day three since placement in the back reef of Grape Tree Bay, Little Cayman Island. White bars = artificial structures (N=15), grey bars = control plots (N=10).

Reef structures had greater fish abundance, richness, diversity and percent juveniles than controls (contrasts: abundance: $F_{1,20} = 6.67$, $P = 0.02$, richness: $F_{1,20} = 6.25$, $P = 0.02$, diversity: $F_{1,20} = 4.20$, $P = 0.05$, juveniles: $F_{1,20} = 5.18$, $P = 0.03$), but effects of complexity varied. The number of fish recruited to high complexity reef structures differed from low complexity structures (linear contrast, $F_{1,20} = 4.29$, $P = 0.05$). On average, low complexity structures contained more fish (2.14 ◎ 0.59,) than medium complexity (1.25 ◎ 0.31) and high complexity structures (0.89 ◎ 0.11). For richness and diversity, artificial structures did not differ between high and low complexity (richness: linear contrast, $F_{1,20} = 0.42$, $P = 0.53$; diversity: linear contrast, $F_{1,20} = 1.76$, $P = 0.20$). Percent juveniles recruited did not differ between high complexity and low complexity structures (linear contrast, $F_{1,20} = 0.45$, $P = 0.51$).

DISCUSSION

The presence of artificial structures increased the abundance and composition of initial fish recruitment relative to exposed control plots, whereas complexity had no apparent effect on recruitment. Though more complex artificial structures offered more potential resting areas in and outside of an overhang, we saw no increase in abundance with increasing complexity. The presence or absence of shelter may play a greater role in initial recruitment than its complexity (which increase the number of potential refugia within a shelter). Alternatively, the kinds of artificial structures that offer the best shelter to fish may be different than the ones we designed.

Juveniles used artificial structures more than adults, suggesting that resting and hiding habitat are limiting for juveniles, or that the size of artificial structures and refugia favored juvenile recruitment. Our artificial structures were too small to provide space for most species of adult fish, which may explain why adult gobies and blennies were more commonly recruited than adults of other larger, pelagic families.

Overall, time was not a significant predictor of abundance or richness of fish recruited to artificial structures. It may be that the time scale of our study was not relevant to synthetic artificial structures, as the modification of synthetic surfaces may be necessary for recruitment. Weathering or colonization by primary producers creates more suitable habitat for recruitment by making artificial structures resemble natural ones (Carr et al. 1997). If recruitment to synthetic surfaces is a function of such modification, then fish recruitment to synthetic artificial structures may increase over longer time scales.

As habitats within coral reefs become increasingly degraded due to climatic changes and anthropogenic effects (Rilov and Benayahu 1997; Golani and Diamant 1999; Strelcheck et al. 2005), artificial structures could play a key role in maintaining species richness and abundance in recovering reef systems (Clark et al. 1994, 1999). Understanding the factors affecting the habitat suitability and fish colonization of artificial structures is central to improving the contributions of artificial reefs.

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Table 1. Repeated measure ANOVAs testing the effect of time and reef type on the abundance and richness of fish recruited to artificial structures of increasing complexity (low, medium, high), with exposed control plots included (afternoon of day 2 - afternoon of day 3) and excluded (afternoon of day 1 - afternoon of day 3), on the back reef of Grape Tree Bay, Little Cayman Island.

	Abundance with controls			Abundance without controls		
Effect Tests	**df**	**F**	**P**	**df**	**F**	**P**
Between treatments						
Reef Type	4	3.275	0.032	4	0.8789	0.5101
Error	21			11		
Within Subjects						
Time	2	0.0885	0.9157	4	2.033	0.1939
Time * Reef Type	8	1.1332	0.364	16	0.5443	0.8922
Error	36			22		
	Richness with controls			**Richness without controls**		
Effect Tests	**df**	**F**	**P**	**df**	**F**	**P**
Between subjects						
Reef Type	4	2.754	0.0566	2	0.398	0.6802
Error	21			12		
Within subjects						
Time	2	0.3587	0.7032	8	0.9254	0.5191
Time * Reef Type	8	0.5316	0.8252	4	7.2957	0.007
Error	38			18		

Appendix A. Artificial structure Descriptions

We created three types of artificial structures from PVC pipe, each one being approx. 0.3048 m (1′) long. Each of the three artificial structures represented a different stage of complexity. We cut the 8″ PVC pipe sections using a skillsaw and drilled 1/8″ holes using a drill and a hole cutter. We tied each of the PVC connections to the 8″ PVC pipe base using nylon string. The 8″ PVC pipe was notched so as to keep each of the smaller PVC joints in place when tied with the nylon string. The three types of structures were:

Simple complexity structure – Very simple and smooth with no holes. 8″ thin PVC pipe cut in half with a 1 ¼″ strip of blue netting wrapped around it (Figure 5).

Medium complexity structure – 8″ thin PVC pipe cut in half. Five, 1/8″ holes and two, 1¼″ strips of blue netting wrapped around ends of PVC pipe. Two sets of four different PVC structures (described below) connected to the 8″ thin PVC pipe base (Figure 6).

Most complexity structure – 8″ thin PVC pipe cut in half. Ten, 1/8″ holes and four, 1¼″ strip of blue netting wrapped around it. Four sets of four different PVC structures connected to the 8″ thin PVC pipe base (Figure 7).

Four Different PVC Structures:

1″ 90◎ bend w/ ¾″ coupler for separation

¾″ 90◎ bend,

1″ T joint w/ ¾″ coupler for separation,

¾″ T joint

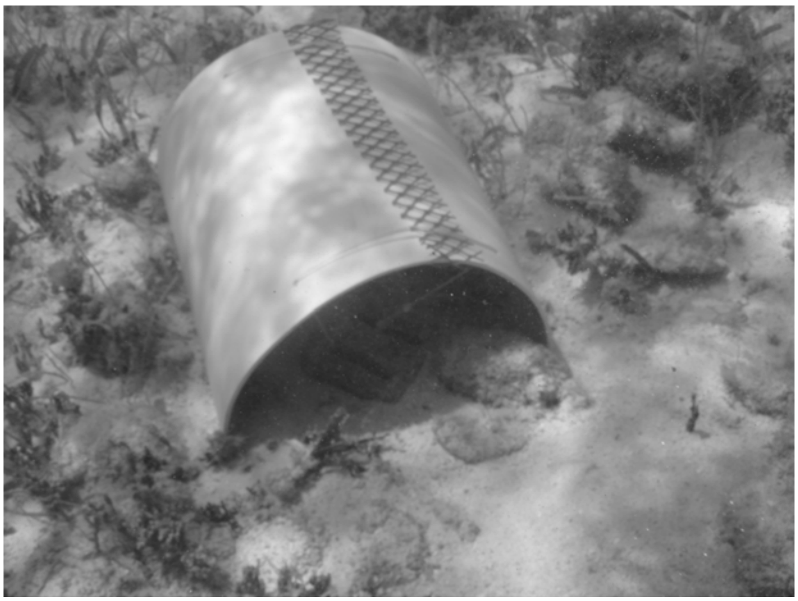

Figure 5. Up-close photograph of simple Complexity Structure. Photo: Yiran Gu

Figure 6. Up-close photograph of medium Complexity Structure. Photo: Yiran Gu

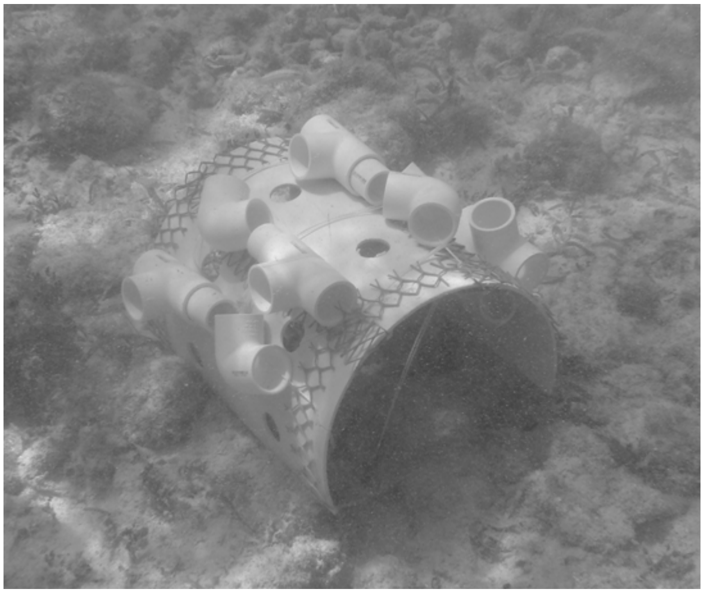

Figure 7. Up-close photograph of most Complex Structure. Photo: Yiran Gu