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Habitat similarity between an artificial reef and the surrounding natural hardbottom in Broward County, FL, USA

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Abstract: In order to mitigate for anticipated burial of natural hardbottom due to the Broward County Shoreline Protection Project, 3.6 x 10^{-2} km^2 (8.9 acres) of mitigative artificial reef were constructed in August/September 2003. To determine if the artificial reef was approaching community similarity to the surrounding nearshore natural hardbottom, benthic biological monitoring was conducted over five years at six discrete monitoring events. Twenty-seven, 30-meter transects were monitored on the artificial reef and 26, 30-meter transects were monitored on the natural hardbottom. Benthic monitoring utilized the Benthic Ecological Assessment of Marginal Reefs (BEAMR) methodology. The faunal and floral benthic community remained significantly distinct between the artificial and natural reefs five years post-mitigation; however similarity has increased notably over time. Changes in the biotic benthic community structure have slowed on the artificial reef and may be reaching stabilization. The ultimate limiting factor in community similarity between the artificial reef and the surrounding natural hardbottom may be attributed to the differences in structural complexity.

Key words: artificial reef, natural hardbottom, similarity, functional groups, benthic community

Introduction

Ecologically, there is an expectation that an artificial reef will resemble or exceed local natural environments over the long-term as assemblages associate with its surface, structure, and surrounding water column (Seaman and Jensen 2000). Long-term studies are essential to determine possible differences between artificial and natural reef communities.

Common initial settlers of artificial reef such as hydrozoans, polychaetes, mollusks, bryozoans, tunicates, and sponges constitute a 'minor' benthic component (percent cover) but are important in elevating the structural complexity of the artificial reef substratum, eventually establishing an area for coral settlement (Perkol-Finkel and Benayahu 2005). Connell and Keough (1985) found that recruitment of benthic flora and fauna onto an artificial reef occurs primarily by migration from adjacent substrate and by the settlement of spores and larvae. Physical factors such as currents, water depth, and the quality of the substrate influence the recruitment of benthic species onto the mitigation reef. Young (1995) suggested that the introduction of new substrate contributes to an increase in epibenthic organisms which, in turn, provide a larger quantity of food.

Due to the anticipated impact to natural hardbottom areas during beach renourishment activities in Segment III of the Broward County Shore Protection Project (SPP), the Florida Department of Environmental Protection (FDEP) required the placement of 3.60 x 10^{-2} km^{-2} (8.9 acres) of mitigative artificial reef in the nearshore environment. Segment III is approximately 10.97 km (6.8 miles) in length and is located between Port Everglades and the Broward/Miami-Dade County line in south Florida (Fig. 1).

The mitigative artificial reef was constructed as one layer of limestone boulders (1.2 - 1.8 m maximum diameter) placed in the nearshore zone in approximately 4 to 6 m mean water depths. The mitigation reef was constructed in six discrete areas between FDEP survey monuments R-101 and R-125 during August and September 2003.

The anticipated burial of natural hardbottom initiated a comparative evaluation between natural hardbottom areas and the mitigation reef. The monitoring program intended to measure the recovery potential that mitigative reefs provide to compensate for the anticipated burial of natural hardbottom.

Methods

Benthic assessment

Twenty-seven fixed 30-meter transects were monitored on the artificial reef and twenty-six fixed 30-meter transects were monitored on the natural hardbottom for comparison. Monitoring took place at six discrete sampling events between May 2004 and September

2008, and are referred to as the 9-, 12-, 18-, 24-, 36-, and 60-month post-mitigation monitoring events.

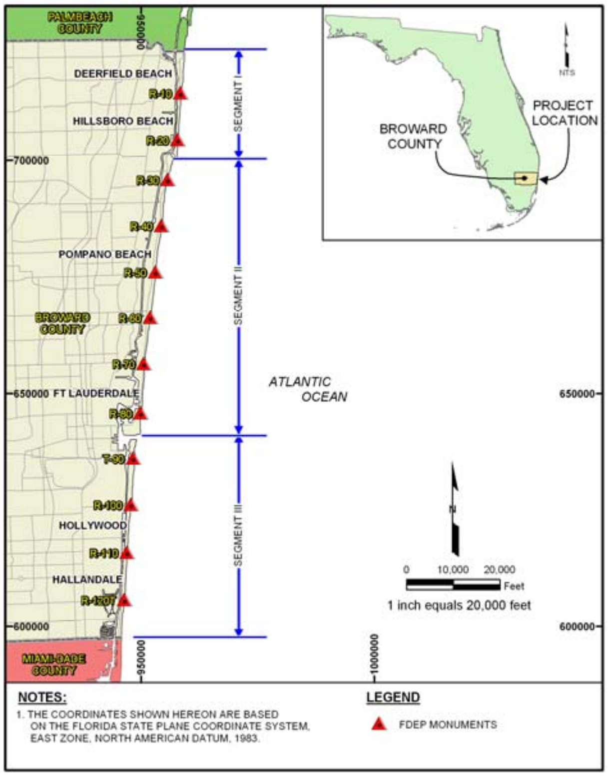

Figure 1: Location map of Broward County Segment III Shore Protection Project.

Benthic communities were evaluated using the Coastal Planning & Engineering, Inc. Benthic Environmental Assessment for Marginal Reef (BEAMR) method (Lybolt and Baron 2006) which uses percent cover as a proxy for abundance. BEAMR was conducted at each specified transect using 12 replicate 1.0-m^2 quadrats (1.0 m x 1.0 m) every 2.5 meters, starting at 0.0 m for a total of 12 m^2 planar area per transect. The 9-month post-mitigation BEAMR surveys were conducted using 0.25-m^2 quadrats (0.5 m x 0.5 m). The quadrat size was changed to 1.0-m^2 in order to align these data with the Shore Protection Project beach construction compliance *in situ* monitoring, a parallel project. All subsequent surveys used the 1.0-m^2 quadrats.

Statistical analysis

PRIMER v6 non-parametric statistical package (Clarke and Warwick 2001) was used to compare the benthic assemblage between the artificial reef and the adjacent natural hardbottom using transect-level average percent cover for functional groups and macroalgae genera. The data were standardized by total and transformed as appropriate. Similarity Percentages (SIMPER) were applied to determine which taxa contributed to the average dissimilarity ($\bar{\delta}$) between substrate types (artificial vs. natural). A Bray-Curtis similarity matrix was applied to the transformed dataset to generate multi-dimensional scaling (MDS) ordinations and analysis of similarity (ANOSIM) routines in order to determine changes in the level of similarity between the artificial reef and natural hardbottom over time.

Results

Functional Groups

Natural Hardbottom vs. Artificial Reef

Sediment is one of the functional groups sampled for in BEAMR but was removed from the dataset in order to compare the biotic benthic community between the two reef types. Table 1 presents percent contribution of each taxa to the average dissimilarity between the artificial and natural reefs with a cutoff of 70%. Macroalgae, zoanthid, and turf algae cover generally dominated the contribution to the average dissimilarity. By 60-month post-mitigation, the dissimilarity decreased to 25.54% between the reef types.

Table 1: The percent contribution of specific functional groups to the average dissimilarity between the artificial reef and natural hardbottom.

Functional Group	Percent contribution of the ith taxa to the average dissimilarity b/n the artificial reef and natural hardbottom					
	9-Mo	12-Mo	18-Mo	24-Mo	36-Mo	60-Mo
Macroalgae	15.90%	11.70%	11.71%	7.58%	11.59%	12.45%
Zoanthid	11.51%	14.04%	14.12%	14.38%	11.90%	13.00%
Turf algae	13.85%	8.97%		8.46%	12.32%	
Sponge	8.48%		5.97%		9.61%	11.99%
BHS	7.78%	10.90%	11.43%	21.77%	5.66%	
Octocoral		11.10%	9.25%	9.67%	11.64%	7.32%
Wormrock			11.58%	9.72%		5.87%
Bryozoan	10.19%					
Stony coral	7.44%	8.84%	8.38%		4.43%	
Encr red algae		6.93%				
Tunicate					5.14%	6.16%
Bivalve						8.27%
Hydroid						5.58%
Average dissimilarity ($\bar{\delta}$)	33.34%	34.27%	30.97%	41.88%	33.14%	25.54%

*BHS is bare hard substrate

Abiotic and floral groups were removed from the dataset to compare the faunal functional group assemblage between the artificial reef and natural hardbottom at each discrete monitoring event. MDS ordinations were generated and SIMPER and ANOSIM routines were applied to determine the average dissimilarity and the degree of similarity (R-value) between the two substrate types (Fig. 2).

Artificial Reef over Time

The biotic benthic community of the artificial reef was plotted in an MDS ordination to display change in community composition over time. Fig. 3 indicates progression towards a stabilizing community as the most recent datapoints cluster together. A post-hoc ANOSIM supports this hypothesis, where the lowest R-values are found between 18 and 60 months post-mitigation (Table 2).

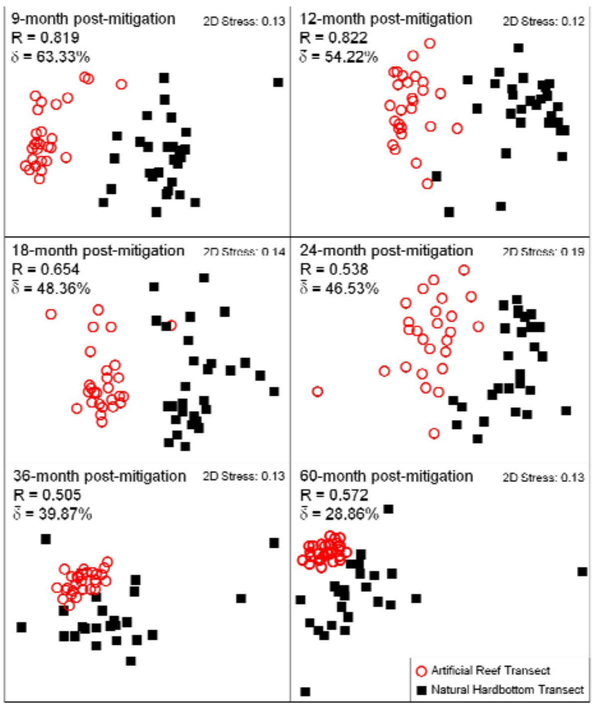

Figure 2: MDS plots of the artificial reef and natural hardbottom benthic faunal assemblages with associated ANOSIM and SIMPER results (R and $\bar{\delta}$).

Macroalgae

Macroalgal recruitment and community development was of particular concern on the artificial reef due to the anticipated loss of turtle foraging habitat from hardbottom burial. Makowski et al (2006) and Wershoven and Wershoven (1992) identified 12 genera of macroalgae that are common to the diet of juvenile green sea turtles (*Chelonia mydas*) in Palm Beach and Broward Counties. Six of the seven 'preferred' macroalgae that are found on the natural hardbottom were identified on the artificial reef.

In total thirty-four genera of macroalgae were identified on the artificial and natural substrates. Thirty-two were found on the natural hardbottom and 25 were identified on the artificial reef. Fig. 4 presents the average percent cover of macroalgae on the artificial and natural substrates as well as the average dissimilarity (determined from SIMPER) between the two substrate types at each monitoring event.

Macroalgae cover increased steadily with an associated decrease in dissimilarity, until a sharp decline after the 18-month monitoring event. This is likely a result of the intense hurricane activity experienced in south Florida in 2005, which may have caused scouring on both substrate types. Macroalgae cover recovered and continued to increase on the artificial reef by 36 months but remained relatively low on the natural hardbottom. As cover on both substrate types increased, dissimilarity decreased and vice-versa.

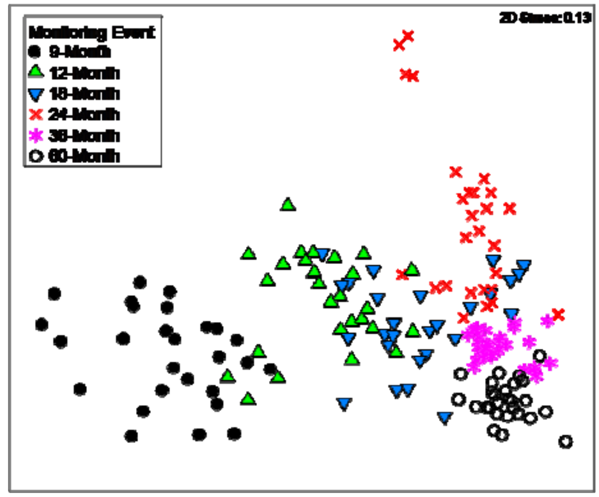

Figure 3: MDS plot of the biotic benthic community on the artificial reef over time.

Table 2: R-values from ANOSIM comparing the similarity in the biotic benthic community on the artificial reef over time.

ANOSIM R-value	9-Mo	12-Mo	18-Mo	24-Mo	36-Mo
12-Mo	0.688				
18-Mo	0.954	0.448			
24-Mo	0.981	0.731	0.520		
36-Mo	0.999	0.872	0.537	0.636	
60-Mo	0.999	0.928	0.795	0.733	0.670

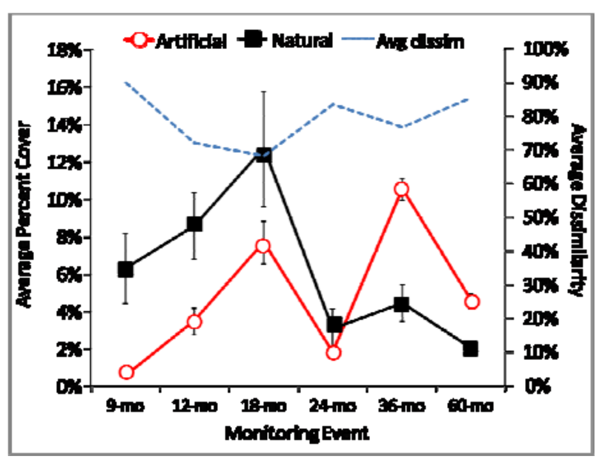

Figure 4: Average percent cover of macroalgae and average dissimilarity between the artificial and natural substrates over time.

Discussion

Connel and Keough (1985) surmise that assemblages on artificial reefs may through time converge towards an epibiotic assemblage on natural substrata. This study set out to determine if the benthic assemblage on the Broward County artificial reef is approaching habitat equivalency, or at least similarity, to the surrounding natural hardbottom using a long-term monitoring program.

The benthic community between the two reef types proved to increase in similarity but remained functionally distinct 5 years post-deployment of the artificial reef. The dissimilarity between the macroalgal community on the artificial and natural substrates fluctuated over time displaying no obvious trend except that the factors which influence macroalgae cover appear to affect both substrates concurrently.

The dynamic assemblages that are well known on natural hardbottom off the coast of Broward County may be markedly different from the developing assemblages found on the mitigative substrate due, in large part, to variations in the biological and physical environment created by the boulders. Structural differences between artificial and natural substrates can ultimately lead to two distinct reef communities (Perkol-Finkel and Benayahu 2007). The high relief of the artificial reef boulders in Broward County will likely be the limiting factor in reaching habitat equivalency to the surrounding natural hardbottom.

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