SOUTH BOCA RATON: ARTIFICIAL REEF RELIEF AND SAND MIGRATION CONUNDRUM

Erin A. Hague and Robert M. Baron
Marine Biologists, Coastal Planning and Engineering, Inc.
2481 NW Boca Raton Boulevard, Boca Raton, FL 33431
Phone: 561/391-8102 FAX: 561/391-9116
ehague@coastalplanning.net
rbaron@coastalplanning.net

ABSTRACT

Nearshore hardbottom communities are susceptible to fluctuations in temperature and salinity levels, higher natural sedimentation rates and turbidity and periodic burial from natural sediment migrations. The periodic presence of lower salinity / higher acid (tannin) content of interior waters which flows out of Boca Raton Inlet and settles over the nearshore rocks are an additional stress factor. These challenges present the complexities of comparative biological monitoring in an active nearshore zone, which is also susceptible to periodic burial from a bypassing bar.

KEYWORDS – Mitigation, hardbottom, fish community assemblage, ebb-tidal shoal

INTRODUCTION

The study area is located directly south of Boca Raton Inlet, which is a maintained natural inlet. The Inlet is situated 14.4 miles south of South Lake Worth Inlet (Boynton Inlet) and is the southernmost inlet out of four inlets located in Palm Beach County (Figure 1). The South Boca Raton Beach Nourishment Project was constructed by the City of Boca Raton, Florida in 2002. Between March 28, 2002 and April 5, 2002, approximately 343,000 cubic yards of sand was dredged from the ebb tidal shoal east of Boca Raton Inlet and placed along 5,060 ft of critically eroding beach located south of the inlet. The dredged material was placed between Florida Department of Environmental Protection (FDEP) monuments R-223.3 and R-227.9.

Potential direct and secondary impacts to approximately 2.39 acres of natural nearshore hardbottom located within the projected equilibrium toe of fill were identified and mitigated for as part of the project activities. The mitigation reef was constructed from May 31 through June 26, 2003 and installed south of Boca Raton Inlet, between FDEP monuments R-223 and R-224 (north mitigation site) and between R-226.5 and R-227.5 (south mitigation site). Both the north and south mitigation sites were constructed in water depths similar to the nearshore hardbottom habitat impacted by the project.

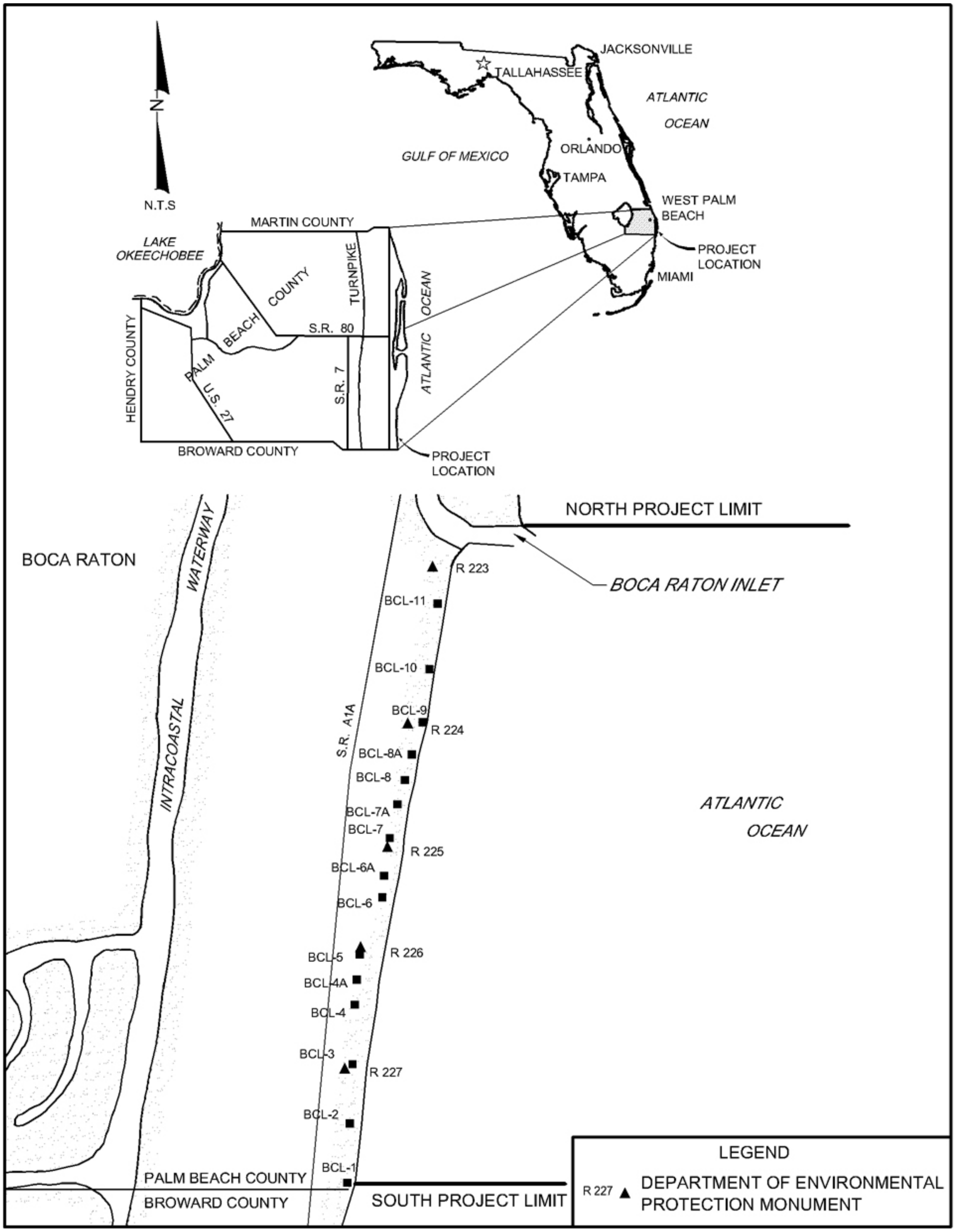

Figure 1. Study Area Location Map, Boca Raton, Florida

MATERIALS AND METHODS

The natural hardbottom areas found in the nearshore zone (300-700 ft offshore) of the project area are generally low in vertical relief ($\leq$ 1 ft) and located in water depths ranging from 0.3 to 3.0 m (–1 to –10 ft) (NGVD). Six permanent monitoring stations were established along the natural hardbottom habitat in February 2002, prior to construction of the beach nourishment project. Two 30 m transects (shore parallel and shore normal) were established at each station. A 1 m^2 permanent monitoring station was established at the intersection of the two transects.

The pre-construction (March 13, 2002), initial post-construction (June 3, 2002), one-year (April 2003), two-year (April/May 2004), and three-year post-construction (April/May 2005) biological monitoring surveys of the natural hardbottom habitats included biological inventory and photo-documentation of the epibenthos. Benthic communities were evaluated using a modification of the Atlantic and Gulf Rapid Reef Assessment (AGRRA) protocol (Ginsburg 2000; Miller 2002). Modifications to the AGRRA method included omitting the line-intercept, rover diver fish survey techniques and expanding the quadrat component. The algae portion of the quadrat component estimated the overall macroalgae, turf, and coralline algae percent cover, and estimated percent cover of the two dominant macroalgal species. The algae canopy height and maximum relief portions were omitted. The animal portion of the quadrat component enumerated octocoral and Scleractinia and measured the maximum dimensions. The presence of Porifera, Bryozoa, and Hydroidea were also recorded. Sand was noted if 100% of the quadrat was sand covered and no other epibiota were present. Sediment depths were also measured to account for the migration of sediment along both the shore parallel and shore perpendicular transects. This assessment method was employed along both transects every 3 meters using 0.0625 m^2 (25 x 25 cm) quadrat.

In November 2003, a total of eight (8) permanent transects were established along the north and south mitigation reefs. The transects originated on the west side of the reef and extended across the exposed rock to the eastern side of the sand / rock interface. Transect length averaged 15 to 20 m and spaced 20 m apart. Four transects (AR1 to AR4) were established on the south mitigation reef and four on the north mitigation reef (AR5 to AR8). A 1m^2 permanent monitoring station was established mid-transect for identifying 100% biotic coverage. Sessile organisms identified along the transects were also reported and identified to the lowest taxon practicable.

Digital video integrated with differential Global Positioning System (DGPS) was collected to document the location and benthic community coverage along each of the transects. This type of video collection method allows for the diver position and site description information to be incorporated directly onto the video record. Video surveys of the natural hardbottom formations were consistently filmed in an offshore (east) to onshore (west) direction, and from south to north along the shore parallel transect.

A series of photographs were taken inside of the six 1m^2 monitoring stations during each monitoring event to capture community coverage over time. These photographs were later placed together to form an enlarged mosaic view of the benthic organisms at each monitoring station. Pre-construction mosaics were compared to subsequent mosaics to capture community coverage over time and used to complement the modified AGRRA assessments.

In addition to benthic characterizations, fish community structure was also studied using the transect-count methodology for visual assessment along the mitigation and natural hardbottom transects. Transect-counts were utilized for visually assessing the fish assemblage structure along the mitigation and natural reefs. Currently, the transect-count is among the most widely used methods for visually assessing nearshore reef fish assemblages. The method is quantitative and open to detailed statistical analysis although only diurnally exposed fish species are observed while cryptic or hidden species can be neglected (Jones and Thompson, 1978; Brock, 1982; Willis, 2001). The use of destructive sampling techniques would be required to obtain a complete species list. In this study the use of any destructive sampling methods were avoided. Rotenone, explosives, trawls, or other invasive techniques would be required in order to attain an accurate assessment of the fish assemblage structure including cryptic or hidden species. Nondestructive methods (i.e. visual census techniques) are considered the most practical and accepted methods. These methods are utilized (with the assumption that certain species may be left out of the assemblage) because destructive or invasive techniques may damage or disturb coral reefs or reef associated biota (Sale and Douglas, 1981).

A total of sixteen 30 m permanent transects were established over the mitigation reef and adjacent natural hardbottom. A 30 m line was stretched out in a west-east orientation, with the west end of the transect set at the western edge of exposed hardbottom or artificial reef depending upon transect designation. A biologist swam above the transect recording all fish within an imaginary 60 m^3 tunnel (1m to either side and 1m above the line). Number of fish and total length (by size class: <2 cm, 2-5 cm, 5-10 cm, 10-20 cm, 20-30 cm, 30-50 cm and >50 cm) was recorded. A 1 m “T”-stick with the size classes marked was used to aid in identifying fish length and transect width. Species, numbers, and size classes associated with the mitigation reef were compared to those on nearby natural hardbottom.

The one and two-year post-construction fish monitoring events were performed during the months of May, June and July of 2004 and 2005. The spring/summer surveys were established to account for seasonal changes in shallow water fish communities along the natural hardbottom and artificial reefs. Quantitative assessments of the fish community were performed during each monitoring event using the visual census technique described above.

RESULTS AND DISCUSSION

A relatively large ebb-shoal occurs offshore of the South of Boca Raton Inlet. Deposition in the ebb shoal occurs due to trapping of sands transported alongshore by cross-shore tidal currents (Finkl 1993; Hine *et al.* 1986; Hayes 1980). A prominent geomorphic feature occurring south of Boca Raton Inlet is a shore-oblique bypassing bar. This bypassing bar is readily seen in high-resolution bathymetric images and aerial photographs near project limits (Figures 2 and 3). Bypassing bars are well-known in the published literature (Bruun 1978; Kraus 2000; Walton and Adams 1976). The South Boca Raton bypassing bar was further mapped and described by Benedet (2002) and

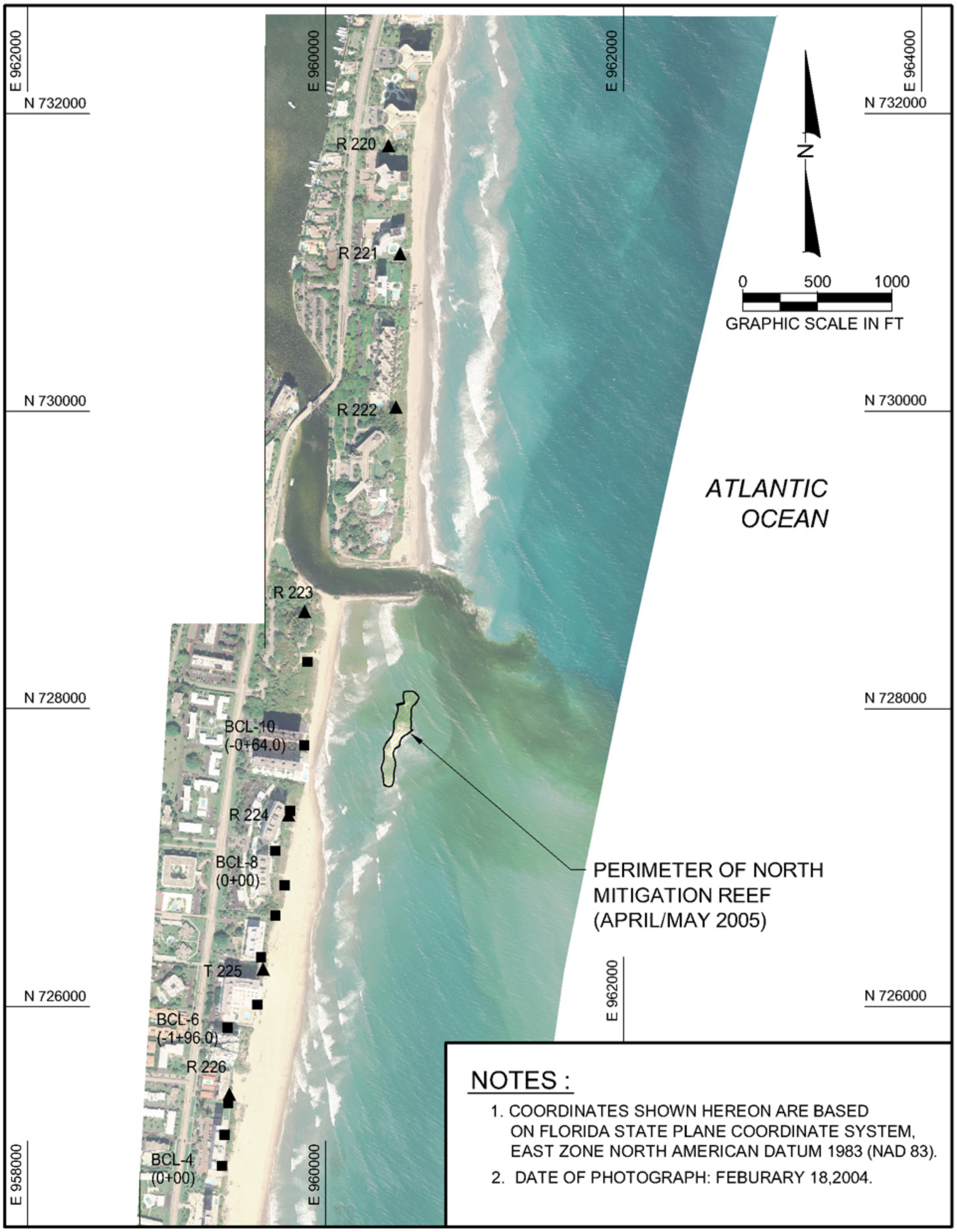

Figure 2. Linear bar feature observed north and south of Boca Raton Inlet in proximity to north mitigation reef.

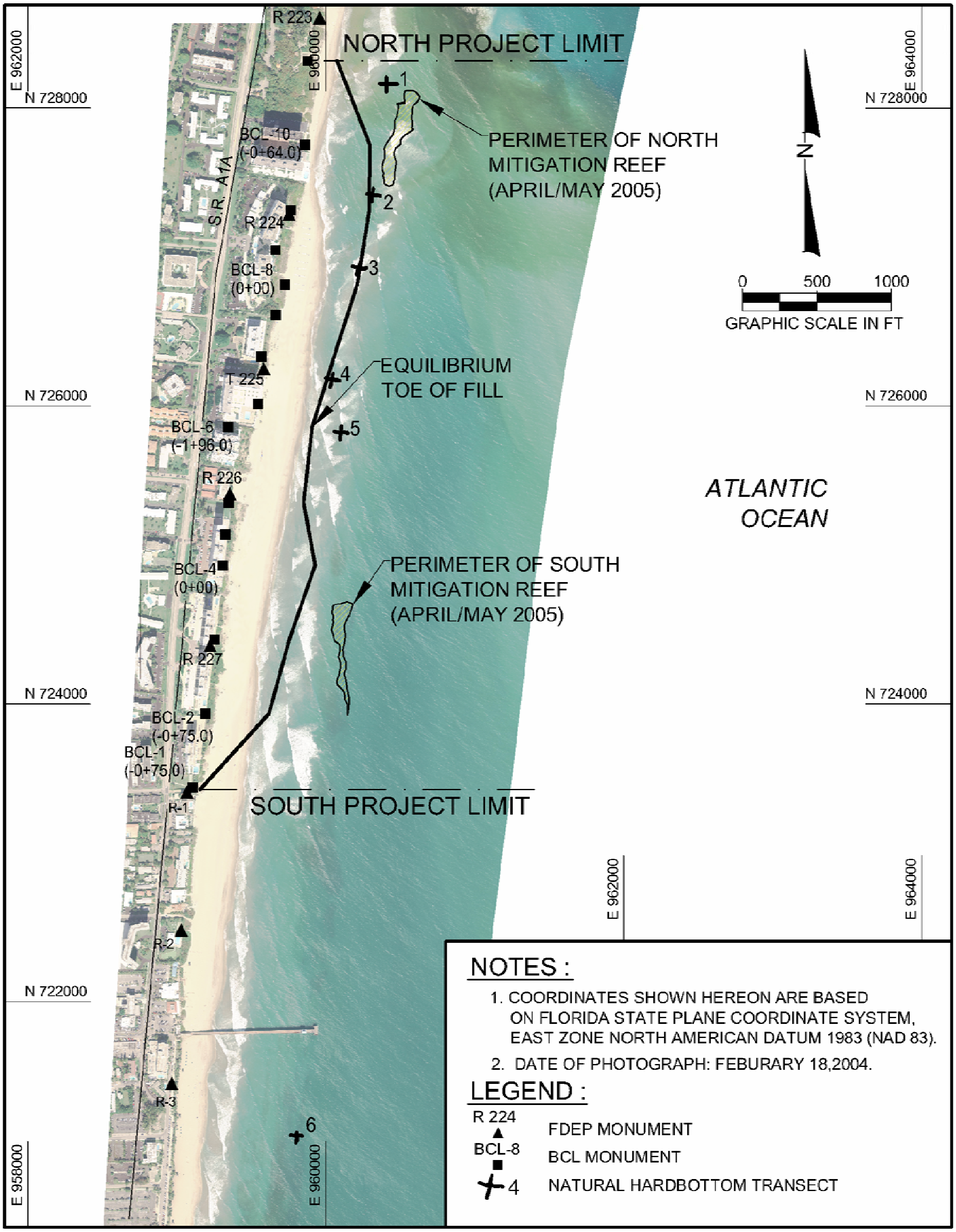

Figure 3. North and south mitigation reefs shown south of Boca Raton Inlet (R-223).

Benedet and Finkl (2003) and also described in Kruempel and Spandoni (1998); as well as Dombrowski and Mehta (1993).

Due to the excavation of 343,000 cubic yards of sand from the ebb tidal shoal in 2002, the volume of material being fed to the bypassing bar system was temporarily reduced. As a result, the sand volume that traditionally deposited south of the inlet and over buried hardbottom was temporarily reduced, providing a false indication that this area could be an acceptable artificial reef placement area. The original artificial reef project design included the placement of 2.39 acres of limestone boulders approximately 4,000 ft south of the Boca Raton Inlet, outside of the projected migratory path of the bypassing bar. However, during installation of the artificial reef rock Palm Beach County's assessment of the nearshore environment concluded that the area immediately south of the inlet was also suitable for mitigation. Consequently, the artificial reef was constructed in two locations: immediately south of the inlet (north mitigation reef) and approximately 4,000 ft south of the inlet (south mitigation reef). The south mitigation site is located along a continuous hardbottom platform that shows historic burial, providing for a natural transition from existing reefs to the artificial reef. Similar to ephemeral hardbottom habitats, the north mitigation reef is susceptible to frequent burial by the bypassing bar.

The natural hardbottom transects (Control Transects 1 and 6 and Compliance Transects 2 through 5) are located in an active sand migration zone that is susceptible to burial from the ebb tidal shoal regressing and transgressing the nearshore zone. The direction of migration has been observed from the south and east with sand depths measuring greater than 15-20 cm or greater in accumulation areas. Similar to the two-year monitoring event, all measured sediment depths shallowed to the west, indicating an offshore sand source.

The biotic response to the uncovering of the exposed hardbottom was best observed at Compliance Stations 3 and 5. During the two-year monitoring event, Compliance Station 3 reported the entire transect and central monitoring station buried under 15-24 cm of sediment. The three-year post-construction monitoring event reported a 46-79% sediment cover at each of the sample stations along the shore parallel and shore perpendicular transects. Macroalgae cover dominated the center monitoring station with up to 46% cover.

In April/May 2005, an average of 0.45 meters (1.5 feet) of newly exposed rock was observed along the north mitigation reef (AR5 to AR8). As a result of this, most of the pins (2.5 inch PK nails used for station establishment) previously established along these four transects in November 2003 were found. An average of 30-90 cm of relief was observed during this monitoring event.

Monitoring of the south mitigation reef (AR1 to AR4) in April/May 2005 reported worm rock (*Phragmatopoma caudata* (=*lapidosa*)) and two encrusting sponge types (*Monanchora unquifera* and *Holopsamma helwigi*) dominating the benthic community. Worm rock thickness was measured between 12-15cm (5-6 inches) at the limestone boulder/natural hardbottom interface at the west ends of the south mitigation reef (AR1, AR2 and AR4). Community coverage of boring and encrusting organisms was persistent throughout the south mitigation reef, thereby inhibiting pin location along each transect. Due to these limitations, transects at AR1 through AR4 were established using GPS positions acquired during the six-month and one-year post-construction monitoring events.

The percent cover of sessile benthos recorded during 2005 investigations along the artificial reefs ranged from 62-100%. While benthic organisms recorded along the natural hardbottom accounted for 47% biotic coverage at Station 3 and 65% biotic coverage at Station 5. Stations 2, 4 and 6 recorded 0% biotic coverage and Control Station 1 was limited to 4% biotic coverage.

Results from the fish monitoring dives include comparisons of the nearshore hardbottom benthic and fish communities to those of the mitigation artificial reef. In the 2004 survey, a total of 6,126 fish from 36 families were reported on both natural and artificial reef substrates. The 2005 survey reported a decrease in the number of fish families in 2005 (32 families), yet an increase in total fish counted (7,272 fish). Species richness also increased on the artificial reef in 2005 (74 species) compared to 67 species in 2004. However, species richness along the natural hardbottom decreased from 46 species in 2004 to 31 species in 2005. Higher abundance and species richness of fishes observed at the artificial reef transects can be attributed to the increase in relief and structural complexity. Whereas the natural nearshore transects were established on typically low relief hardbottom in water depths and distances from shore comparable to the artificial reef transects. The maximum vertical relief observed on the natural transects was approximately one foot compared to the maximum vertical relief in excess of two-three feet on the artificial reef.

Single factor ANOVA tests were used to test for significant differences in abundance and richness between the north and south mitigation reefs from the 2004 and 2005 monitoring events. When the tests were run, a statistically significant difference between the north and south mitigation reefs was reported when comparing the relative abundance (P-value = 0.01) and species richness (P-value = 2.44E-05).

The final three-year post-construction *in situ* monitoring of the natural hardbottom community was completed in April/May 2005. Per permit requirements, one additional biological monitoring event (three-years post-construction) is scheduled to occur along the north and south mitigation reefs in April/May 2006. The three-year post-construction fish survey is scheduled to occur in May, June and July 2006.

FINAL CONSIDERATIONS

Both the natural hardbottom and artificial reef monitoring areas have been documented to support a diverse and productive benthic community that includes macroalgae, sponges, tunicates, Scleractinians, and Octocoralia. Overall, the south mitigation reef appears to be supporting greater abundance and diversity of organisms due to the high, variable relief and available substrate, versus the natural hardbottom habitat (Photos 1 and 2). Despite the limited number of recruits found at the north mitigation reef, the diversity and total percent biota exceeds the coverage and diversity

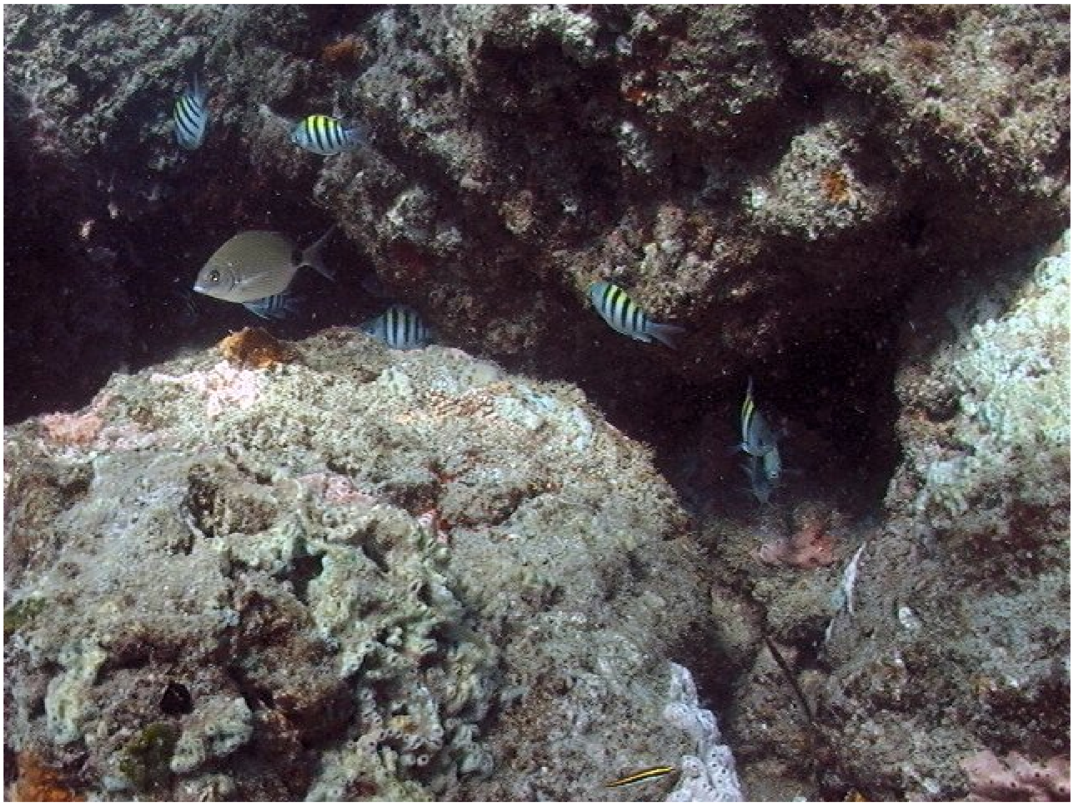

Photo 1. Sargent Majors (*Abudefduf saxatilis*) and Spottail Pinfish (*Diplodus holbrooki*) finding viable habitat and resources on the south mitigation reef.

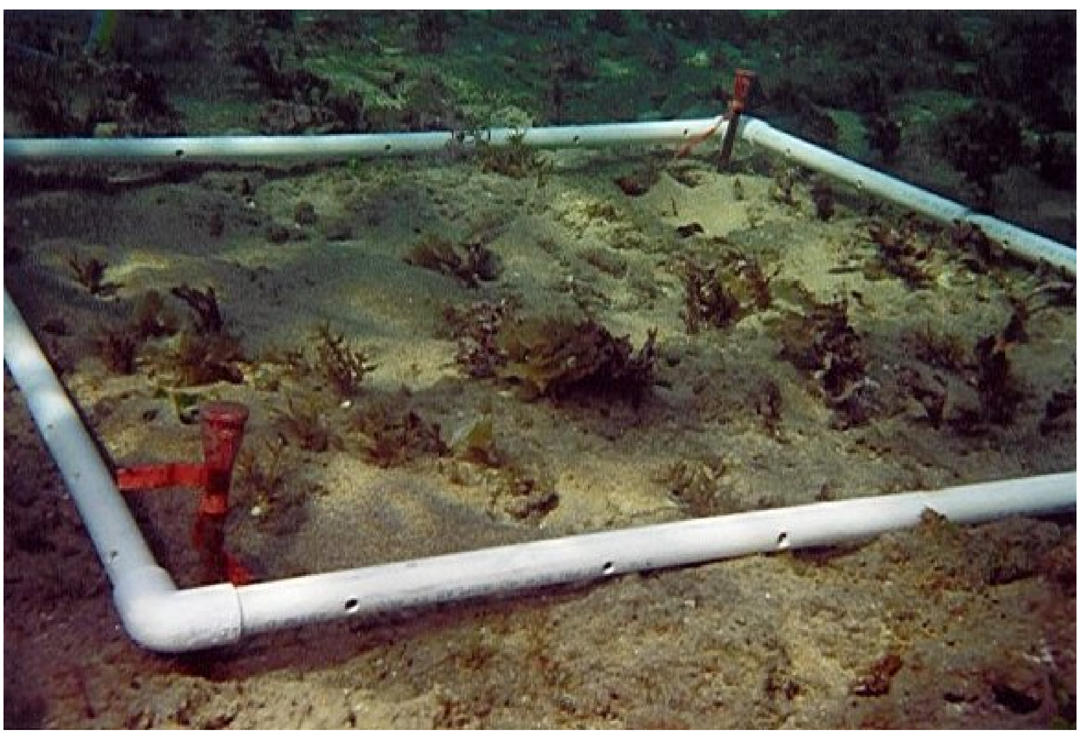

Photo 2. Low relief, nearshore hardbottom habitat (Station 5) dominated by Phaeophyta (brown algae) cover.

found along the natural hardbottom. As is typical of nearshore rock outcrops, the environmental extremes associated with the nearshore zone limit the diversity and density of benthic and sessile organisms.

Fish Community Assemblage

In 2004 and 2005, fish abundance was greater on the artificial reef transects than on the natural hardbottom transects. Higher abundance and species richness of fishes observed at the artificial reef transects can be attributed to the increase in relief and structural complexity. The maximum vertical relief observed on the natural transects was less than one foot compared to the maximum vertical relief in excess of two to three feet on the artificial reef.

Both the one and two-year post-construction monitoring events documented a greater percentage of juvenile fish on the natural hardbottom. Whereas a large number of adult and intermediate phase predatory fish and prey fish were reported on the artificial reef. The low percentage of juveniles reported on the artificial reef may be attributed to a variety of factors including: increased number of predatory and prey fish; increased substrate complexity and relief which provides gaps and small open spaces for juveniles, small and cryptic species, supplying ample space for shelter. The transect-count method does not allow for a complete species list especially for cryptic and hidden species. Only with the use of a destructive sampling technique, such as rotenone, would a complete species list be feasible. However the negative effects associated with the benthic community does not support the use of the rotenone method.

Artificial Reef Construction

The mitigation originally proposed by the City of Boca Raton included placement of the entire artificial reef at a distance of 4,330 feet south of Boca Raton Inlet, in a gap within the natural hardbottom platform and in an area where adjacent hardbottom had been relatively persistently exposed. However, the City's proposed reef siting plan was altered with much of the artificial reef placed near the end (mouth) of Boca Raton Inlet.

Unfortunately, the City was not consulted concerning the change in the artificial reef placement site, and much of the reef was constructed near the Inlet mouth. The north mitigation reef site was placed in an active sand shoaling environment just south of Boca Raton Inlet, while the south site was located 4,000 feet south of the Inlet. Since construction of the artificial reef, the ebb tidal shoal bypassing Boca Raton Inlet has returned to more normal size and volume following sand removal for the 2002 beach nourishment project. Not unexpectedly, the shoal covers a portion of the northern mitigation reef, resulting in a more biological diverse community on the south mitigation reef.

A 2.39 acre artificial reef was constructed from May 31 through June 26, 2003 as mitigation for coverage of surf zone rock formations resulting from sand placement. The 2005 mapping results of the exposed artificial reef structures were calculated as follows: north mitigation site yields 1.29 acres; south mitigation site yields 0.93 acres (total acreage equals 2.22 acres).

The north artificial reef is undergoing similar episodic burial events as the nearshore natural hardbottom as a result of the bypassing bar. Although the total artificial reef acreage amount is less than the constructed amount, the ephemeral nature of the artificial reef habitat is compatible with the adjacent nearshore natural hardbottom habitat.

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ACKNOWLEDGEMENTS

The dataset collected for the project is the result of a team-based effort by the CPE Environmental Studies Department, with assistance from the Survey Department. Funding for data collection and analysis were provided by the City of Boca Raton.