Artificial Reefs for Submerged and Subaerial Habitat Protection, Mitigation and Restoration

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INTRODUCTION

This paper presents methods for using artificial reefs to provide protection of existing natural reefs, mitigation of damages to natural reefs, and restoration and enhancement of marine and shoreline areas. Artificial reefs have been used for centuries for creating underwater habitat and increasing biological activity (Duedall and Champ, 1991). More recent applications of artificial reefs include the protection of existing natural reefs, environmental and eco-tourism enhancement, repair and mitigation of damaged reefs, and shoreline stabilization (Harris, 1995). Examples of these applications, their unique design aspects, and their performance are presented.

PROTECTION OF NATURAL REEFS

Artificial reefs can provide protection to natural reefs in several ways, including:

- increasing the amount of hardbottom habitat,
- reducing stresses on existing reefs,
- acting as obstacles to provide a deterrent for ships and nets,
- serving as guideposts for snorkel and diver trails.

To protect existing natural reefs, artificial reef units can be used to create new reef areas, providing additional hardbottom areas to increase the available habitat. With additional reef areas provided, stresses on the natural reefs can be decreased. Artificial reefs also can be used as obstructions for ships and nets to prevent shipping or fishing in protected areas.

Shallow, nearshore reefs are particularly susceptible to damages from boats and novice snorkelers. Surface markers can be used to mark the reef locations so that boaters can avoid reef areas, but snorkelers enjoying the underwater environment may inadvertently cause damages to the reefs by breaking off reef pieces with fins when swimming across shallow regions of the reef. For reef protection as well as eco-tourism enhancement, artificial reef units used as underwater snorkel trail markers can safely guide snorkelers and divers around shallow natural reefs, providing information and education on the reefs and their inhabitants, while also providing marine habitat themselves.

REEF PROTECTION EXAMPLES IN TURKS AND CAICOS ISLANDS

The use of artificial reefs for protection of natural reefs has been demonstrated in two different ways in the Turks and Caicos Islands. The first example utilizes the artificial reefs as trail marker mounts along underwater snorkel trails. The second example is the creation of a new reef in the nearshore areas. In both cases, environmental education and awareness are part of the protection plan.

Both projects were developed in an effort to lesson impacts to the limited nearshore reef areas. Although many small coral outcroppings do exist in the Grace Bay, Providenciales area, there are only two larger reefs that can be easily accessed from the shore. Locally known as Smith's Reef and Bight Reef, these reefs experience the brunt of the impact from numerous tourists that stay in the Grace Bay area. Without any simple means to regulate or control the access to these reefs, alternative plans were devised.

Underwater Snorkel Trails

The first plan of action was to create snorkel trails surrounding the two reefs. The trails were designed to lead the snorkelers along a path that would be "safe" for both the snorkelers and the coral, i.e. in areas where the depth and distance precluded the snorkelers from coming in contact with the coral. Like most trails, the effect tends to also localize what impacts do occur to a given area. Secondly, the trail markers included educational information that advises snorkelers on the rules and reasons for "reef etiquette" along with other interesting information on reef ecology and ecosystems.

The snorkel trails are unique in that the base portion or mount for the markers is a medium size Reef Ball^{TM} artificial reef unit. Eventually, the mount will overgrow with corals and other benthic organisms, becoming an extension of the natural reef. The marker portion is also unique to the underwater trail world with the use of hand made tiles with graphics embedded within the glaze coats (Figure1). The smooth surface helps to minimize fouling and is fairly easily cleaned.

Since 1997, growth has occurred on the artificial reefs, albeit slowly as expected in these oligotrophic waters. Initial sets of the corals *Favia fragum*, and *Millepora* species were noted after one year of submersion. Within the past year, small sets of *Porites* species (probably *P. astreiodes*) has also occurred. Other benthic encrustation includes primary algal growth, calcareous tube worms, bryozoans, tunicates, sponges and anemones. Inhabitation by numerous species of fish occurred within minutes of the reefs being in place and the reefs have continued to attract the motile species.

Figure 1. Snorkel Trail Sign Mounted on Reef Ball^{TM} Artificial Reef Unit

The total effect that the trails have had in reducing impacts to the two reefs has not been fully evaluated, but many tourists have been observed following the underwater trails and reading the information provided along them. Tourism has continued to escalate in the area since the trails were created in 1997, and a definite increase in the number of snorkelers to the two reefs has occurred. In particular, the Bight Reef sustains most of the impact with large numbers of tourists from nearby Beaches Resort and a new condominium development built directly onshore of the reef. A buoy line exclusion area has been added as an additional measure to the site to help protect the inner, more shallow regions of the reef. Further studies have been proposed to evaluate the impact to these and other snorkeling reefs in the area, which would include user statistics to assist in determining an appropriate carrying capacity. Once determined, management efforts can be made to further limit access if necessitated.

The NEC Visitor's Center Artificial Reef Site

To augment these initial efforts, it was suggested to create an artificial reef site as an additional nearshore snorkeling site. The location of this reef was key to the plan if to be utilized effectively, and the site chosen is located directly across from the National Environmental Center (NEC) currently under construction. The NEC will act in part as a Visitor's Center, complete with environmental educational information and displays. The site is also located within walking distance of the Bight Reef to the east, with Smith's Reef located further down and to the west.

The design of the artificial reef incorporates a series of Bay Ball size Reef Balls™ grouped together in pods of 8-10 balls each. These pods are located in a string-like series that leads the snorkelers from shore and around a loop that encircles some natural coral heads before heading back to the beach. To date, three pods have been added to the chain, with a total of 26 reef units. The artificial reefs deployed during the summers of 1999 and 2000 have experienced growth similar to that found on the underwater snorkel trails, with the exception of the initial sets of *Favia fragum*. Figure 2 shows one pod consisting of seven Reef Ball™ units.

Figure 2. Reef Ball™ Artificial Reef Offshore Visitor's Center

To date, funds and labor to construct the reef have been derived entirely through educational participant programs and voluntary services. The Reef Ball Coalition has spearheaded the efforts in organizing the participant programs. The first two programs included high school students from all over the United States that participated in a Living Classrooms Foundation Reef Restoration Program. The two week courses taught students fundamentals of marine ecology as well as participating in the fabrication and deployment of the artificial reefs. Four local students were also sponsored to participate in the programs.

Future programs include assistance from University of Georgia students that will arrive in the spring of 2002, and plans are being made for next summer's marine ecology programs. It is hoped that when the NEC is operational, further interest will be sparked through the Visitor's Center. The Center provides an opportune outlet for further environmental awareness materials on reef ecology and etiquette, while the new artificial reef gives tourists the opportunity to see a reef in its initial growth stages. It is hoped that the combined efforts of the two projects will help to protect and alleviate the pressure on the natural reef systems, while educating tourists on their role in reef preservation.

MITIGATION REEFS

Natural and anthropogenic activities including storms, ship groundings, anchoring, dredging operations, beach restoration projects, and pollution can cause severe damages to existing natural reef areas. Artificial reefs can be used for repairing natural reefs once damages have occurred, and for mitigation of damages that occurs due to construction projects. This can be accomplished using custom designed artificial reef units or waste materials, often referred to as "material of opportunity" (Harris, Mostkoff, and Zadikoff, 1996).

Figure 3 shows the use of concrete bridge rubble as artificial reef material for the nearshore mitigation reefs offshore Martin County, Florida in 5 to 6 meters of water depth. This mitigation reef was required to compensate for the nearshore reef areas that were covered over by a beach nourishment project. The demolition of a nearby bridge being replaced provided the materials for the reef, and the bridge contractor also provided the funds for the deployment of the reef materials as an economical method of waste disposal.

Figure 3. Concrete Bridge Rubble as Nearshore Artificial Reef

Typical damages to natural reefs include the breaking off of individual reef pieces, with more severe damages resulting in the destruction of the reef substrate. Repair techniques include substrate repairs using underwater concrete to restore the reef foundation, artificial reef units to replace damaged reefs, and re-attachment of broken pieces of coral (King, Barber, and Walsh, 2001).

Figure 4 shows coral transplants on Reef Ball^{TM} artificial reef units located offshore of the Island of Mustique.

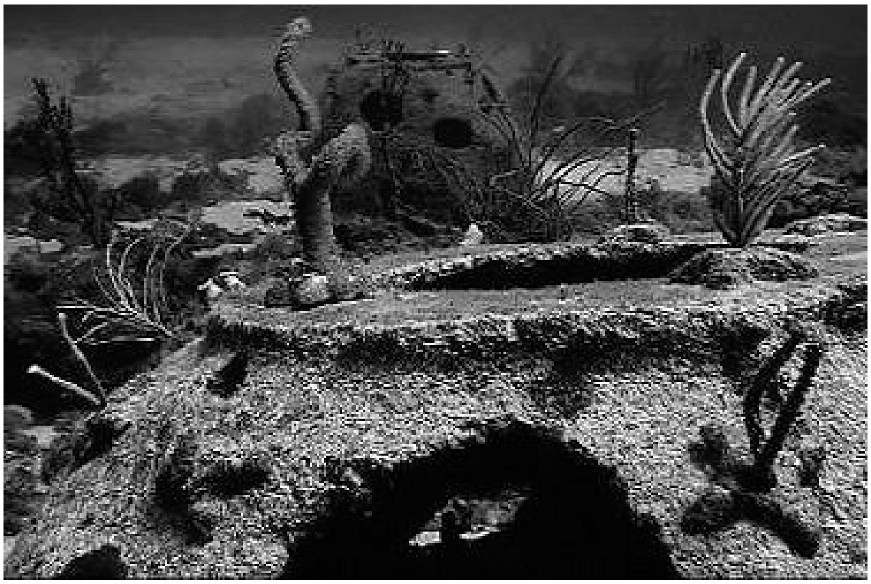

Figure 4. Coral Transplants on a Reef Ball^{TM} offshore of the Island of Mustique

SHORELINE STABILIZATION

Just as natural reefs can provide calm areas in their lee, protected from wave attack and beach erosion, artificial reefs can be used for shoreline stabilization. This requires the reef structure to serve as a submerged breakwater, with the crest of the reef in close proximity to the water surface. This exposes the reef to much greater wave forces and other important design considerations (Harris, 1998).

The design and performance of artificial reefs as submerged breakwaters are evaluated in terms of the wave attenuation and shoreline stabilization provided, with special design considerations for safety and stability of the reef units, and the environmental enhancement provided by these structures.

Submerged Artificial Reef Breakwater Example

Approximately 450 Reef Ball^{TM} artificial reef units were installed offshore of the Gran Dominicus Resort on the southern Caribbean coast of the Dominican Republic during the summer 1998 to form a submerged breakwater for shoreline stabilization, environmental enhancement and eco-tourism (Harris, 2001). The individual units used for the breakwater were 1.2m and 1.4m high Reef Ball^{TM} units, with base diameters of 1.8 meters. The breakwater system consisted of three segmented breakwater sections, using three rows of Reef Ball^{TM} units for each segment (Figure 5 and 6). The breakwater was installed in water depths of

1.6m to 2.0m, so that the units were 0.2m to 0.8m below the mean water level (the tide range in the project area is approximately 0.4m).

Figure 5. Submerged 3-row Reef Ball™ Breakwater

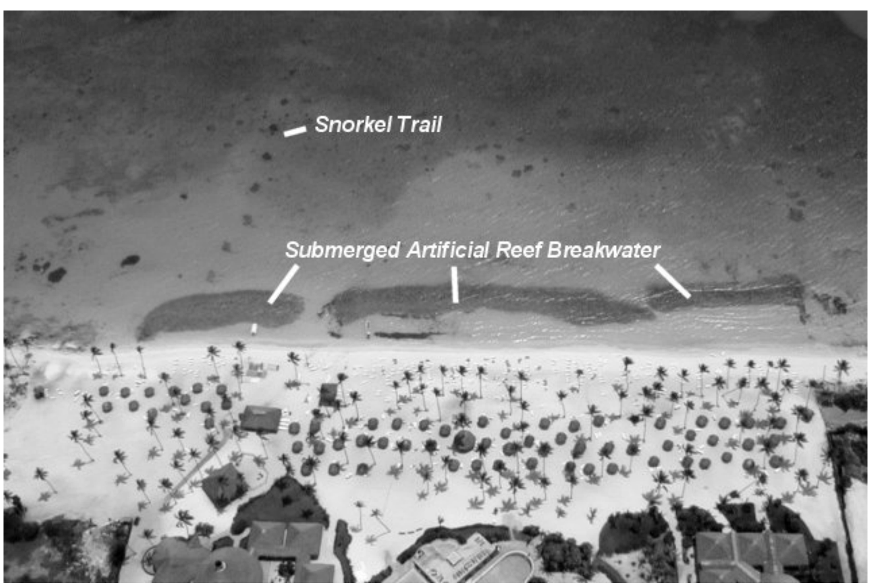

Figure 6. Reef Ball™ Artificial Reef Submerged Breakwater.

Survey data taken in April 2001 is compared to that taken in February 1999 after project installation and hurricane impacts of the previous fall. Figure 7 displays the plotted beach profile data, which show a shoreline advance of 10 meters and a large gain in sand volume due to the wave reduction in the lee of the submerged artificial reef breakwater. The effects on adjacent beaches must be considered in the design of submerged breakwaters, to avoid increased erosion of adjacent shorelines. The beaches adjacent to this project showed stability during this same time period, but with minimal accretion.

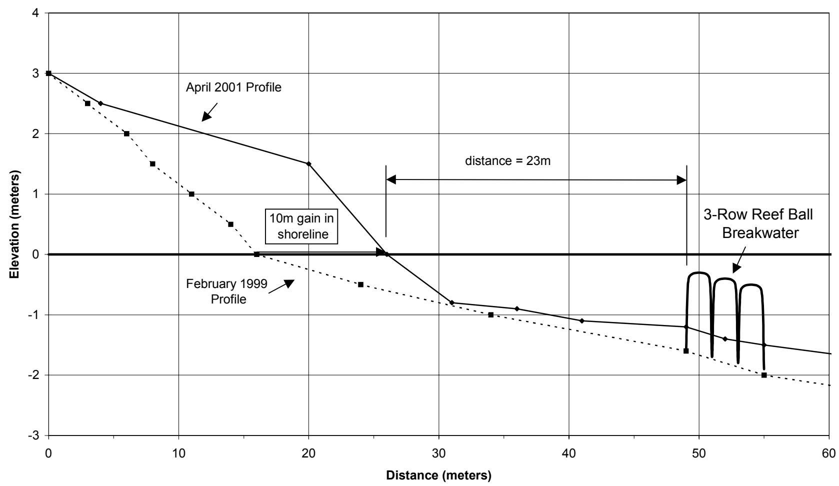

Figure 7. Artificial Reef Breakwater - Beach Profile Changes

The artificial reef submerged breakwater project presented in this paper demonstrates the technology available to provide shoreline stabilization due to wave attenuation at a site with a low tidal range and low to moderate wave climate (except during tropical storms and hurricanes). In addition, the use of artificial reef units for the breakwater also provides habitat enhancement for the marine life, which can be enjoyed by divers and snorkelers. Habitat for the smaller motile species was provided by adding small rocks in the hollow centers of the artificial reef units.

CONCLUSIONS

This paper presents some newer uses of artificial reefs, in addition to the traditional uses of artificial reefs for providing increased hardbottom habitat. Artificial reefs can be utilized to protect existing natural reefs and shorelines by increasing available hardbottom, providing obstacles to boats and nets, serving as guideposts for snorkelers, providing repair and mitigation for damaged reefs, and providing shoreline stabilization through wave attenuation. Examples are presented in this paper that can be employed at other locations.

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