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PLANTING SMALL MASSIVE CORALS ON SMALL ARTIFICIAL CONCRETE REEFS OR DEAD CORAL HEADS

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There is a general thought that natural reefs cannot rebuild themselves fast enough to meet human demands (Hughes, 1994; Grigg and Dollar, 1990). Thus, there is a concern to identify management options to protect and restore coral communities. One of these management options proposed is the establishment of effective methodologies for coral propagation through human activities. Coral transplantation as a reef management option for the rehabilitation of degraded reefs has been discussed by several authors (see Clark and Edwards, 1995; Harriot and fisk, 1988; Maragos, 1974, 1992). The basic approach is to introduce new colonies of fast-growing species into the reef. The establishment, growth, development, and maturating of these colonies may increase larvae production and recruitment locally or the increase the number of colonies by the establishment of broken-off fragments from transplanted colonies (Bowden-Kerby, 1996). There is a widespread use of branching species for restoration plans because of their high survival rate, fast growth rate, aesthetic appeal, and increased vertical stratification (Bowden-Kerby, 1996; Harriot and fisk, 1988).

Massive corals also have the ability to reproduce asexually by the propagation of broken fragments of individual colonies. This provides enhanced colony survival, propagation, and dispersion of the genet. However, massive corals are limited by their slow growth rate. To increase coral cover by transplantation of fragments or small massive colonies (without transplantation of very large colonies) requires long-term survival studies. Thus, this limitation may repress our willingness to actively transplant massive corals to increase coral cover and vertical stratification of reef microhabitat.

Reef Ball™ structures are concrete artificial reefs designed by Reef Ball Development Group, Ltd. that are being used increasingly worldwide for fisheries enhancement. To a certain extent, Reef Balls mimic large, eroded, massive, corals heads, a commonly found formation on Caribbean reefs, which provide important fish habitat. Similar to the study by Hudson et al. (1989), these artificial structures may be appropriate for planting several massive coral colonies. Such planted structures are useful for restoring reef appearance as well as for creating a small reef patch on sandy back reef areas. The potential ability of some massive corals to spread over artificial reef structures may reduce colony development time while enhancing vertical stratification of reef microhabitat. The object of this study was to investigate the possibility of planting small massive corals over artificial Bay Ball structures and over dead coral heads. Bay Ball is one of several model reefs designed by Reef Ball Development Group, Ltd. The goal of this preliminary experiment was to test survivorship and attachment of massive coral species on Bay Balls and coral heads.

Materials and Methods

Study Area.—Three back reef sites in La Parguera, southern Puerto Rico were selected for this study: (1) East of Enrique Reef; (2) West of Enrique Reef; and (3) Mario Reef. In March 1998, one concrete Bay Ball™ was deployed over sandy bottom at each site (10–15 ft depth).

BAY BALL CONSTRUCTION AND TRANSPORTATION.—Bay Ball (0.61 m height × 0.9 m width, 2.8 m^2 of surface and weighing 250 kg) were constructed on land, using molds loaned from CORALations, Inc., and following a modified protocol provided by Reef Ball Development Ltd. Two modifications to the protocol were implemented: (1) no silicate compound was used in the mix in order to reduce the recruitment of algae over the ball; and (2) we attached Styrofoam wheels over the inner part of the mold to create small holes (9 cm dia) over the surface of the ball. These small holes were useful to keep the corals attached to the surface of the Bay Ball before and after the cement cure. Bay Balls were transported to the study sites by using floats and towing with a small boat.

COLLECTION SITES.—Small massive corals (<20 cm dia) of several species (*Diploria* spp., *Montastraea* spp., *Colpophyllia* spp. and *Siderastrea siderea*) were collected from two shallow (0.5 m) reef flat zones on the west side of Laurel Reef and from the east side of Enrique Reef. These were transported in buckets with seawater to the transplantation sites. Most of those colonies collected were found unattached over sandy bottom or coral rubble.

PLANTING CORALS.—Colonies were attached to the Bay Balls and to dead coral heads using underwater cement. Cement was prepared by mixing, five parts per volume of Portland type I cement to one part of molding plaster. After mixing with enough water (approximately 3 parts), a small ball of cement was applied immediately into the small holes created using Styrofoam. Once the cement was in place, the colony was affixed as soon as possible to the Bay Ball and to the coral heads. Colonies affixed over dead coral heads were only planted on the upper surface.

RESULTS

Sixty-two colonies were transplanted in the three study areas (Tables 1,2). One year after transplantation the overall survivorship of transplanted corals in colonies affixed onto Bay Balls and colonies on dead coral heads was 90% (93% for Bay Balls [n = 42], 85% for dead coral heads [n = 20]). No significant difference was observed between mean survival of colonies planted over Bay Balls vs colonies planted over dead coral heads. These preliminary results indicate a very successful rate for this methodology, considering that coral colonies overcame the storm surge wave action, which occurred during Hurricane Georges and widespread bleaching that occurred during this year. The omission of silicate, which reduces the pH of the cement mix, did not restrict coral growth over the surface of the ball. Although, overall coral growth was usually low (<0.5 cm in 1 yr), we observed several colonies (12 *Diploria* spp. and three *M. annularis*) spreading 1 cm along localized contact sites. Also, we observed a recruitment of five coral species

Table 1. Number of colonies of each coral species planted on each Bay Ball™ at the start of the investigation and number of colonies dead after one year.

Corals species	Bay Ball™ at Enrique Reef east		Bay Ball™ at Enrique Reef west		Bay Ball™ at Mario Reef	
	planted	dead	planted	dead	planted	dead
Diploria strigosa	4	0	4	0	6	0
Diploria clivosa	1	0	2	1	1	0
Diploria labyrinthiformis	1	0	3	1	5	0
Colpophyllia natans	2	0	4	0	1	0
Montastraea annularis	1	0	3	1	3	0
Siderastrea siderea	1	0	0	0	0	0
Total	10	0	16	3	16	0

Table 2. Number of colonies of each coral species planted on dead coral heads at two study sites at the start of the investigation and those dead after one year.

Corals species	Enrique Reef		Mario Reef	
	planted	dead	planted	dead
Diploria strigosa	4	1	4	1
Colpophyllia natans	2	1	2	0
Montastraea annularis	4	0	4	0
Total	10	2	10	1

and other invertebrates over and within the Bay Ball (Table 3). The inner part of the Bay Balls were covered with encrusting sponges, bryozoans and other organisms not reported in Table 3.

Discussion

One of the major problems of past transplantation studies (Birkeland et. al, 1979; Clark and Edwards, 1995; Plucer-Rosario and Randall, 1987) is the loss of coral colonies from its cemented position. The preliminary results of this pilot study indicate that the methods used are an efficient technique for coral colony transplantation, since no colonies were

Table 3. Number and classification of organisms recruited on each Bay Ball™.

Observed organism	Enrique Reef east	Enrique Reef west	Mario Reef
Hard Corals			
Favia fragum	7	2	16
Colpophyllia sp.	2	0	0
Porites astreoides	0	0	5
Agaricia sp.	0	0	2
Diploria strigosa	0	0	2
Polychaetes			
Spirobranchus giganteus	3	2	0
Crustaceans			
Panulirus argus	2	0	0
Stenopus hispidus	2	2	0
Percnon gibbesi	3	0	1
Echinoderms			
Diadema antillarum	8	3	0
Lytechinus variegatus	0	3	0
Echinometra lucunter	0	0	8
Tunicates			
Ascidia nigra	5	1	0
other tunicates	12	3	0
Total	44	16	34

lost. Hudson et al. (1989) built a small patch reef using 23 hollow concrete domes (similar to Bay Balls) which were implanted with 32 hard corals of 10 species. Ten years after immersion, the dome showed no signs of deterioration and the overall coral survivorship was 87.5%. The study of Hudson et al. (1989) and the present study indicate that the use of artificial coral-like structure planted with corals has widespread application potential for the creation of small patch reefs in suitable areas devoid of vertical stratification and hard substrate to attach corals.

An important consideration in the collection of coral colonies for transplantation are the effects of collection on natural populations. Preliminary observation in Puerto Rico have identified numerous small massive coral species recruiting to areas of extremely shallow depths (<0.5 m). Long-term survival to adulthood for these colonies may be lessened in this shallow zone, many of these corals are unattached or weakly attached to the substrate and could therefore be transported by storm currents to deeper sandy areas. These jeopardized coral populations offer a potential source for transplants.

Conclusion

Planting corals over natural substrate is an option to reduce the time of coral colonization. However, if substrate condition changes and coral support is impractical, artificial reef structure may be another option. Currently, Bay Balls are being used to construct artificial reefs; it is surprising that these have not been planted in order to reduce the establishment time of coral species. A possible cause of this may be the suggestion by the Reef Ball Development Group, Ltd., that Bay Balls have the capacity to recruit corals (T. Barber, pers. comm.). After 1 yr of observation, a total of 36 hard coral colonies recruited on the three Bay Balls (Table 3). Hudson et al. (1989) reported 45 scleractinian corals comprising seven species and a total of 89 octocorals comprising 15 species recruited in 10 yrs to concrete domes. Even though these concrete structures are able to recruit coral colonies, transplantation methodology allows the selection of specific coral species and reduces the time required for their successful establishment. This may also be of practical use in the establishment of small patch reefs in areas unsuitable for coral recruitment (i.e., sandy areas).

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