Building a Coral Nursery at Biscayne National Park

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Introduction

Biscayne National Park is one of nine coral reef parks in the National Park System. Five are in the western Atlantic (Virgin Islands National Park, Buck Island Reef National Monument, Biscayne National Park, Dry Tortugas National Park, and Salt River Bay National Historical Park and Ecological Reserve). Coral reefs provide relief, habitat, and substrate to a diverse community of organisms that rivals the diversity of a tropical rain forest. The western Atlantic coral reef parks are very near commercial shipping lanes and popular recreational locations, and are heavily used by commercial and recreational fishers. The coral reefs in each of these parks have a high potential for being damaged by boat and ship groundings, anchors, gear placement (including recovery and loss), and breakage from direct human contact.

Background

Coral reefs are home to a complex and diverse biological community. The scleractinian corals, in particular, are capable of building massive limestone reefs through the accumulation and coalescence of dead coral skeletons loosely cemented together by coralline algae. Coral reefs range in depth from 0.5 m to more than 30 m. The coastal location of coral reefs make them very susceptible to both natural and anthropogenic disturbances, yet they support a variety of potentially damaging activities because of their physical beauty and species abundance and diversity. Tropical tourism depends heavily on the attraction of coral reefs, and many fisheries depend on the large biomass of fish populations. Coral reefs are not readily visible to the average boater and reefs are rarely marked, increasing their vulnerability to boat damage. Groundings, coupled with the added pressure of over-harvesting and other anthropogenic and natural stressors on limited resources, make coral reefs one of the most endangered ecosystems on the planet.

The structure of coral reefs can be undermined by both natural and anthropogenic events. Destruction of the reef framework by tropical storms and hurricanes can be considerable, yet these types of events are analogous to fires in forests, critical to the health and rejuvenation of the ecosystem. In general, both coral reefs and forests have two basic ecological processes occurring simultaneously: (1) accretion, the growth of the forest or coral reef, such as the accumulation of substrate; and (2) degradation, the erosion of living tissue and of the substrate, which is essential for nutrient recycling and for opening niches for recruitment. The balance between the processes of calcification and reef growth and mechanical destruction and bioerosion is important for the persistence and recovery of disturbed coral reefs.

Our understanding of forest ecosystems is broad enough to allow the reconstruction of devastated sites to conditions that are almost identical to pre-event conditions. Further, we know enough to manipulate their community structure and function to achieve a particular aesthetic or functional value. In both forests and coral reefs, system recovery is slow, often requiring decades to centuries for full recovery. In forests there is a latent source of seeds, and volunteers, available in the understory and soil to initiate the recovery process, rapidly stabilizing damaged areas. There is no analogous process for coral reefs. Forests are more robust, capable of withstanding air and soil pollution levels several orders of magnitude above that tolerated by most marine organisms. Biologists are just beginning to understand coral reefs and how biological, chemical, physical and geological processes interact in reef systems. Coral reef reconstruction with a goal of “restoration to pre-event conditions” is a daunting task, well beyond our limited understanding of reef processes and the currently available technology.

Catastrophic grounding events occur within National Park Service (NPS) areas once or twice a decade. Smaller groundings or reef-damaging events occur more often, with a frequency somewhat inversely proportional to vessel size. At Biscayne National Park there have been five major groundings in 25 years, and there are more than 20 documented (vessels stuck on the reef long enough to be observed, or requiring commercial assistance) groundings every year. Undocumented groundings probably double if not triple that number. Small-vessel groundings damage approximately 5 to 30 m^2 per event, and most require some sort of rehabilitative action to stabilize the broken coral colonies, salvage coral fragments, and minimize further damage from wave surge.

Coral reefs worldwide are declining rapidly, mostly from consumptive activities. Other symptoms of stress, diseases and bleaching events, are increasing in frequency, duration, and degree. New coral diseases are being described almost quarterly, and summer temperatures are increasing steadily. Two of the five major coral species in the Atlantic, *Acropora palmata* and *A. cervicornis*, are currently being considered for listing as endangered species under the Endangered Species Act. Compounding these impacts, exotic species are being found in ever-increasing numbers along the Atlantic coast.

Rehabilitation

Coral reef rehabilitation projects have largely focused on areas mechanically damaged during vessel groundings, and rarely involve more than the stabilization of the remaining reef framework and transplanting a large number of hard-coral colonies into the area, letting nature do the rest. Some restoration efforts have been more creative, reconstructing the topography in an effort to restore habitat complexity. A few projects have transplanted other coral reef organisms from the area being rehabilitated. Transplanted corals used for rehabilitation typically come from one of two sources: the damaged area itself through the recovery of larger colony fragments and dislodged soft corals, or by harvesting material from the surrounding intact reefs. Transplanting hard- and soft-coral colonies generally works; however, harvesting coral colonies from surrounding reefs for the purpose of rehabilitation is both environmentally and legally questionable. Harvesting coral colonies—in effect, damaging coral reefs already under stress to rehabilitate another reef—is a questionable practice, and the collection of coral is illegal in Florida and in most protected areas under U.S. jurisdiction. Unfortunately, there is no other source of coral available to managers or contractors for restoration or habitat enhancement.

The Original Concept

Biscayne National Park established three prototype coral nurseries in 1993, using Americorps volunteers and year-end funding. It has been shown that corals transplanted for rehabilitation will grow at a new site and there is an expanding literature reporting the growth of coral under laboratory conditions. The operational plans for the coral nurseries in the park are based on those concepts.

The initial design question was where to locate the nurseries to achieve maximum growth rates. Three sites were selected for the pilot project. One was located on the seaward edge of the coral reef platform, an area strongly influenced by the Florida Current. Another was located near the longitudinal center of the reef platform (mid-platform), an area of active patch reef development. The last site was in a tidal creek connecting estuarine Biscayne Bay to the seaward reef platform. Here the water is turbid, with strong tidal currents and wide seasonal fluctuations in temperature. In 1993, colony fragments approximately 5–10 cm in size were transferred to structures at each site from an "orphan" grounding site and a seawall damaged during Hurricane Andrew. The coral fragments were attached to nursery structures using a two-part underwater epoxy (Z-Spar).

We hypothesized that maximum coral growth would occur on the mid-platform nursery structures and minimal growth would occur on the tidal creek structures. The structures placed off-shore were quickly destroyed during early winter storms. The mid-platform structures withstood winter storms and grew well. The structures also recruited a spectrum of other reef organisms such as sponges, tunicates, and soft corals. The corals placed on the tidal creek structures grew even better. However, at this site, only turf algae grew between the attached coral fragments.

Our nursery goal is to have enough hard coral colonies in culture to supply the needs of rehabilitation projects in the Florida Keys. We chose to use tidal creeks for nursery purposes because they supported coral growth, are easily accessible during any weather, contain islands that provide a suitable area to stage maintenance and monitoring activities, do not require SCUBA diving skills to conduct our research activities, are accessible by boat or land, and provide a strong potential for the non-diving public to learn about coral reefs and even participate in the maintenance and monitoring of the nursery stock. Another advantage of the tidal creeks is that they are not a visual intrusion on the park's visitor experience. The disadvantage to locating nurseries in tidal creeks is that temperature of the water leaving Biscayne Bay can fluctuate dramatically, from very cold during periodic winter cold fronts to warm in the summer. Exposure to temperature extremes can result in high coral mortality.

The Current Nursery Concept

The operational premise of the park's coral nursery is very similar to the field aspect of terrestrial nurseries that are used to stock trees for forest restoration. Like terrestrial nurseries, the coral nursery in Biscayne National Park requires a source of corals. Terrestrial nurseries do this by purchasing seeds, collecting seeds from the wild or their own stocks, or using cuttings from existing stock. The coral nursery can do the same thing: sourcing material from grounding sites (the wild), from the nursery stock itself (cuttings), and from the culture of settled coral gametes captured during spawning (seed acquisition). None of these stock sources violates the National Park Service mandate "to preserve and protect for future generations" (as stated in the 1916 National Park Service Act and Biscayne's enabling legislation, P.L. 96-287).

Wild Stock

On average, each boat grounding damages between 1 to 10 coral heads. Much of this material can be salvaged by re-attachment at the grounding site, but many fragments are far too small to survive even if re-attached. These are recovered for stocking the nursery. Collected fragments range in size from several cm^2 to about 700 cm^2. Larger fragments are cut into 2-cm^2 squares using a standard 10-inch lapidary saw and seawater coolant. Much of the coral rock is removed, leaving the healthy coral over a skeleton about 1.5 cm thick. The corals are then epoxied to PVC (polyvinyl chloride) stakes, our equivalent of the flowerpot. Passive integrated transponders (PIT tags) are placed between the PVC rod and coral fragment to give each fragment a unique 12-digit identification number that can be electronically read both in and out of the water (see Figure 1). This allows us to follow the history of the coral fragment throughout its life in the nursery. At the present time we have over 250 coral colonies in culture.

Figure 1. PIT tag inserted in epoxy with coral fragment removed.

The research question is, “How small can we cut the pieces to get a reasonable number of colonies within the next ten years, assuming that we will have a catastrophic grounding within that time frame?” Initial work under laboratory conditions indicates that coral fragments having at least five polyps will survive and grow, but we have no idea if that is true in our field-level nurseries, nor how large the polyps must get before we can place them in the field nursery.

Cuttings

As the coral colonies grow, they will eventually take on a spherical shape, and some of the corals that were placed in the nursery one year ago are already starting to round out nicely. Coral colonies will be kept in the nursery until they reach sexual maturity. Some researchers speculate that, for the non-branching corals, this will occur when they are about 15 cm in diameter (10–15 years in the nursery). When they reach this size, the lower hemisphere (the side with the PVC post) will be cut away and cut into several sections to increase the nursery population. The upper hemisphere will be transplanted to a suitable rehabilitation site.

Seed Collection

The final way to increase the number of coral colonies in the nursery is to collect coral gametes during the annual coral spawning and culture them to the settlement stage. Settled coral larvae will be kept in a laboratory environment until they grow large enough (3 cm^2 diameter) to survive the rigors of life in the natural environment in the field nursery. We have attempted this over the last three years for the annual spawn of the *Montastraea* corals. Our collections, and those of our collaborators, have been alive only for approximately the length of time required for fertilized gametes to reach the settlement phase.

The Greenhouse

Our original grow-out structures used in the field nurseries were three-sided concrete pyramids. The problem with them was that as the corals grew, they expanded onto the concrete substrate, making it difficult to recover an undamaged coral colony, collect growth data, and find an easy way of identifying which colonies came from where, other than mapping their location on the structure.

We have revised the structure design to accommodate these problems, ending up with a coral rock quadri-pod with centered holes drilled on all sides (see Figure 2) to accommodate rods of coral mounts as described earlier. The PIT tag reader may also be used underwater, allowing accurate positioning of the corals fragments on the nursery structures as needed for various experiments.

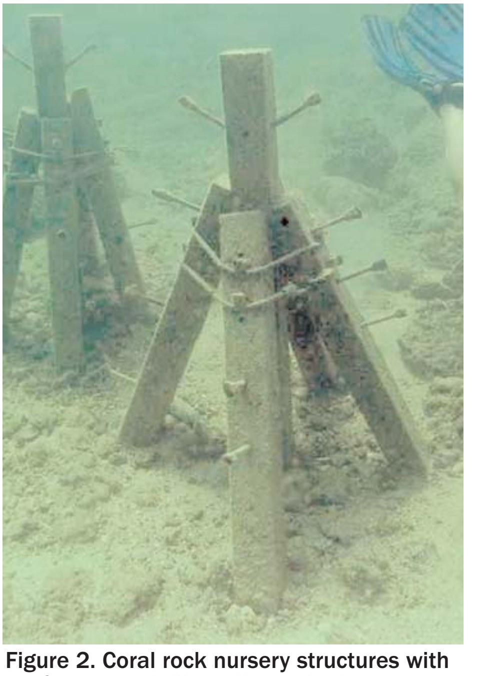

Figure 2. Coral rock nursery structures with fragment “lollipops” attached.

Gardening

We are just starting to study how to maintain the nursery for optimal growth. After only a short time in the field, the PVC rod and the block of epoxy become encrusted with algae and other fouling organisms. We can only speculate about whether the encrusting organisms along the coral margin are impeding growth. We assume for now that they do, so we remove them (weeding). To obtain quantitative growth information, we need to remove the encrustation from the PVC rod and the epoxy. Since the corals are not permanently attached to the structure (the PVC rods are inserted into holes in the structures), we can easily remove them, scrape off any encrusting organisms, measure weight and volume, and count the number of polyps.

The hermatypic corals have a mutualistic symbiosis with a photosynthetic dinoflagellate (zooxanthellae). Some researchers think that the corals do not need to feed on plankton to survive, getting the nutrition they need from the zooxanthellae. Recent laboratory research (Capo and Carter 2002) has shown that periodically feeding the corals brine shrimp increases growth rates (fertilizing), as does lengthening the photoperiod and elevating water the temperature. The research challenge here is to determine an effective method for manipulating these conditions in a field-level nursery.

Early Results

It wasn't until late 2001 that we started a quantitative approach to the growing of coral for coral reef rehabilitation, and the data collected so far are insufficient to report any significant findings. However, we have observed that corals to which the epoxy was applied only to the lower surface of the fragment appear to show a rapid growth of tissue over the exposed skeletal surface, whereas growth appeared to be inhibited in those in which the cut surfaces were covered with epoxy. Our preliminary data also show that there is an initial period of almost no growth upon transfer to the nursery structure, followed by a steady increase in growth and colony weight.

Reference

Capo, Thomas R., and Robert W. Carter. 2002. Efficacy of coral nurseries for reef restoration in South Florida, Final Report, National Park Service Contract. Unpublished report.