Restoration and Reclamation Review
Student On-Line Journal
Vol.2, No.3, Spring 1997
Department of Horticultural Science
University of Minnesota, St.Paul, MN

A New Technology for Artificial Reef Construction in Coastal Ecosystems

Cynthia Warzecha

Reef ecosystems have suffered from a variety of anthropogenic stresses during the past several decades. Offshore recreational activities, siltation, sewage discharge, excessive nutrient input, thermal pollution, (Rinkevich 1995) and overfishing (Luoma 1996) have contributed to the declining health of many reefs. Divers, snorkelers, and boat and cruise ship anchors can physically damage corals by breaking them, abrading large coral forms, and burying coral fragments in sediment (Rinkevich 1995). Overfishing of algae-eating fish can lead to accelerated algae growth that in turn smothers corals (Luoma 1996). Anthropogenic stresses have contributed to the loss of ten percent of the world's coral reefs and an additional two-thirds are at risk of serious decline (Luoma 1996). Zoologist Marjorie Reakea-Kudla (1996) predicts the loss of seventy percent of the world's coral reefs by the year 2036.

Various techniques have been employed to create habitats for reef-dwelling organisms. In United States coastal waters, most efforts have focused on increasing fish populations to provide enhanced experiences for recreational fishing and sport-diving (Hutchings 1996). Activities such as the deliberate sinking of ships or oil drilling platforms successfully attract fish. However, it is unclear whether these structures provide suitable habitat for reproduction or just enhance the local population by attracting fish from other areas (Weisburd 1986).

New techniques have begun to focus on the restoration of coral reef ecosystems. Of all marine ecosystems, coral reefs are the most diverse and complex. The building blocks of the reef are symbiotic animals that rely on specialized algae called zooxanthelae for nutrients. Through photosynthesis, the algae produce sugars and starches. In exchange for these products, the corals share a portion of the nitrogen and phosphorus they obtain by capturing tiny organisms (Luoma 1996). Some coral species produce calcium carbonate skeletons. The accumulation of these skeletal structures forms the coral reef. Each coral species, of which there are hundreds, has its own growth pattern (Sorokin 1993). Staghorn, elkhorn, and finger coral colonies produce branching shapes while flower, star, and brain corals produce rounded structures of various sizes (Greenberg 1986). Coral formations provide the framework for a diverse ecosystem that includes a multitude of fish, crustaceans, invertebrates, and other marine organisms.

The world's first, although unintentional, large artificial reefs were sunken ships. Ships, as well as military tanks (Heins 1995), a retired Boeing 727 (Fritz 1994), junked automobiles, old toilets (Weisburd 1986), tires and other scrap materials have been used to construct artificial reefs along the eastern and southeastern coasts of the United States. The procedures for the construction of these reefs vary depending on the types of materials used. Ships, tanks, planes, and cars are drained of gasoline, oil, and other polluting fluids. Generally, the engine and any buoyant materials are also removed (Meier and Martin 1985). The removal of brass fittings, commonly found in ships, is important because brass is toxic for some marine organisms (Reef Ball Development, Ltd. 1997). Deployment of ships is usually done with explosives. Ships are transported with tugboats to the target location and the explosives are detonated. Barges are used to transport cars and other materials to the artificial reef site.

Scrap tires have been used in artificial reefs off the coasts of Virginia, North and South Carolina, (Meier and Martin 1985) and Florida. One of the largest scrap tire reefs, the Osborne Reef off the Florida coast, contains nearly two million tires. An essential part of the preparation process includes punching holes in the tires to eliminate flotation problems. Goodyear has developed a device that punches three large holes in the circumference of the tire. Other devices, such as electric drills, are also effective. After the tires are punched, they are compressed into bundles of ten to twelve tires and bound together using nylon banding materials. If the location of the artificial reef is prone to stormy weather or strong currents, the tires must be filled with cement ballast. Boats or barges can be used to deploy the tires. More fish are attracted to the reefs if the bundles are stacked on top of one another (Candle 1985).

Obsolete petroleum platforms are a common albeit controversial artificial reef material. A decline in oil drilling in the Gulf of Mexico off the Texas coast has led to the scrapping of increased numbers of platforms (Texas Parks and Wildlife 1996). Before the oil rigs can be converted to reefs, the platform decks, equipment, and living quarters are removed. Explosives are used to sever the legs and sink the platform (Hutchings 1996). These explosions can have potentially detrimental effects on the plants and animals that have already become established on the rigs.

A relatively recent development (1993-94) in artificial reef construction is the use of prefabricated concrete structures called Reef Balls. These hollow dome-shaped structures resemble natural coral heads produced by some coral species. They have holes of different sizes which allow fish and other marine organisms to enter the interior. The holes are designed to create a whirlpool effect inside the ball to feed the invertebrates and corals. Reef Ball design recognizes the fact that the profile of a structure alone will not support fish. Surface areas need current, light or both to be productive.

The balls are formed by pouring concrete into a fiberglass mold which contains an internal, inflatable bladder. Holes are made in the wall of the Reef Ball by placing rubberized balls of assorted sizes between the fiberglass mold and the inflatable bladder before pouring the concrete into the mold. The bladder can be left inside the ball and used as a flotation device during deployment. Reef Ball molds are available in a number of sizes (Table 1). Total production time for one Reef Ball ranges from thirty minutes to one and one half hours depending on the size of the ball.

Table 1. Reef Ball specifications

Name	Width	Height	Weight	# of holes
Ultra Reef Ball	6.5 feet	5 feet	5,000 - 7,500 pounds	29 - 40
Super Reef Ball	6 feet	5 feet	4,000 - 6,000 pounds	29 - 34
Reef Ball	6 feet	4 feet	3,000 - 6,000 pounds	29 - 30

Pallet Ball	4 feet	3 feet	1,500 - 2,200 pounds	23 - 28
Bay Ball	3 feet	2 feet	375 - 750 pounds	14 - 18

Source: Reef Ball Development Group. Ltd. Internet Brochure

Almost any kind of concrete can be used in the construction of Reef Balls. However, additives are necessary to strengthen the balls and make them suitable for the growth of marine life. Ordinary concrete has high pH levels due to calcium hydroxide in the mixture. The addition of microsilica reduces the pH level to about 8.3, which is the average pH of sea water. Additionally, microsilica reacts with calcium hydroxide to help strengthen the balls, giving them an expected life of at least five hundred years. If microsilica is not available, Reef Balls should be cured in freshwater for three to six months to leach out the calcium hydroxide which is toxic to some marine organisms. If the Reef Balls are not cured, organisms that are resistant to the high pH level will colonize the Reef Ball. By the time the Reef Ball has reached a normal pH level, the resistant organisms may have set up defense systems to inhibit the growth of other marine life forms thereby disrupting the order of natural settlement.

Several different surface textures can be applied to Reef Balls to enhance colonization of marine organisms. One technique involves spraying the inside of the mold with sugar water before casting. The outer layer of concrete will resist hardening and can be washed away when the mold is removed. The resulting rough texture can be further enhanced by the application of an additive that creates tiny pits in the surface. The pits provide places for marine organisms, such as larval corals, to attach.

Several methods may be used to transport Reef Balls. The bladder can be left inside the ball and used as a flotation device enabling easy towing with almost any boat. (The recommended towing speed is between two to three knots.) When the site has been reached, the bladder is deflated and removed. Divers can assist in deployment by controlling the descent and precise placement of the balls. The use of divers can help minimize the danger of destroying the natural portions of the reef. Their assistance is especially important when Reef Balls are used to repair damaged reefs (Reef Ball Development Group, Ltd. 1997). Volunteers of the Coffman Memorial Reef Project used PWC (Personal Water Craft) to deploy two different sizes of Reef Balls. The test was successful and demonstrated the ease with which the balls can be transported and deployed (University of Central Florida Dive Club 1997). Reef Balls can also be deployed by barge without divers.

Reef Balls are designed to stay in place once they are positioned on the ocean floor. The dome shape of Reef Balls is the key to their stability. They are designed so that more than fifty percent of the weight is in the bottom near the ocean floor. The top of the dome is open to reduce the lifting effects of wave action and turbulence during stormy weather. The weight of the balls can be customized to meet the demands of the environment in which they are placed. The balls can be cast up to double the standard weight to accommodate high energy zones.

Reef Balls have proven stable enough to endure severe weather conditions. Divers in Destin, Florida reported that the 180 Reef Balls they deployed in eighty feet of water survived the direct hit of a category three hurricane. Although nearly all other artificial reefs on the Florida panhandle were either lost or damaged in the 1995 hurricanes, Reef Balls remained in their original position (Reef Ball Development Group, Ltd. 1997).

The success of artificial reef construction depends on the goal of the project. Reefs built with scrap materials frequently meet the objective of attracting fish. One study, conducted near Marco Island, Florida, in 1972 reported significant increases in fish catches after the deployment of a tire reef (Candle 1985). Before the tire reef was constructed, personnel from the Marco Applied Marine Ecology Station fished the proposed reef area located two kilometers off shore. The average catch was approximately 0.5 fish per hour. A follow-up survey was conducted several years later, after 100,000 tires had been placed at the site. The catch rate had increased by a factor of twelve. By 1985, charter boat captains were regularly taking their customers to Marco Reefs (Candle 1985). The shortcoming of such "before and after" studies is that they document increased numbers of fish but do not verify increased productivity.

Although reefs constructed with scrap materials do attract fish, such reefs are not particularly successful at promoting the establishment of coral colonies. Oil rig platforms, sunken ships, and discarded tanks contain steel that promotes the growth of marine invertebrates and plants requiring iron. The flora and fauna that become established do not reflect the diversity of species found on natural coral reefs (Reef Ball Development Group, Ltd. 1997). Over time, tires decompose and automobiles, ships, and other metal objects are oxidized and disintegrate. Corals that have colonized these surfaces fall off due to the lack of a stable substrate (Weisburd 1986). Because many coral colonies do not reach adequate spawning sizes until they are over a hundred years old, constructing the artificial reef structures from durable materials is critical.

Artificial reef materials should also be stable enough to remain in place on the ocean floor. Ships and sunken airplanes are too light or have too high a profile compared to their weight to remain stable on the ocean bottom. They can be moved about by storms and can damage existing natural reefs. Existing growth is often torn away in the process. Even when the growth remains attached, the organisms are often oriented differently to the current and light and may perish (Reef Ball Development, Ltd. 1997).

Placement of artificial reefs depends on the desired results. If the goal is to attract fish for recreational diving or fishing, placement does not appear to be critical. Fish are attracted to nearly any underwater structure whether natural or artificial. Aside from providing food and hiding places from predators (Hutchings 1996), some fisheries biologists suspect that underwater structures may serve as reference points from which fish can forage and navigate on an otherwise featureless ocean floor. Other scientists speculate that reef structures may divert currents and provide resting places for fish. Still others suggest that the force of the currents against underwater structures creates sound signals and pressure waves that attract fish from afar (Weisburd 1986).

In contrast to reefs intended to restore fish populations, placement of artificial reefs intended to restore the structure and function of natural coral reefs require suitable locations. Careful attention must be given to water temperature regimes and depth of the site. Corals cannot grow in waters where temperatures are cooler than 18-19° Celsius. These symbiotic animals need light for photosynthesis and will survive no deeper than 80-100 meters below the surface (Sorokin 1993). Areas near natural reefs provide suitable conditions for coral reef restoration. Because placement is critical, obsolete oil platforms are *not* feasible structures for coral development. Oil rigs are located in areas where the oil has been discovered, not because the site is suitable for reefs (Greenpeace Internet Site).

The success of artificial reefs in restoring coral reef ecosystems is not entirely known. Since this technique is less than four years old, long-term studies have not been conducted. The Palm Beach County Reef Research Dive Team has monitored the West Palm Beach Reef Ball test site using photographs and video recordings. Monitoring efforts recorded substantial growth on the Reef Balls one year after deployment. Sponges and soft corals had reached lengths of over 18 inches and hard corals had achieved one inch of growth. Equally important was the diversity of species observed. Divers reported seeing finger corals, numerous species of soft corals and sponges, invertebrates such as sea squirts, scallops, tube worms, and feathery hydroids. Among the crustaceans seen were lobster, and several shrimp and crab species. Divers also saw over thirty species of fish, including many juveniles (Reef Ball Development, Ltd. 1997).

Several independent studies of Reef Ball reefs are currently being conducted. Since late 1994, researchers at Nova Southeastern University in Fort Lauderdale have been studying fish recruitment to Reef Ball reefs. The study, "A Preliminary Study of Fish Recruitment to Reef Ball Artificial Reefs in Shallow and Deep Water", will continue for several years before a final report is published (Reef Ball Development, Ltd. 1997).

Dr. Joshua Feingold, a visiting professor at Nova Southeastern University, is currently studying the differences in coral recruitment between natural and artificial substrates (Reef Ball Development, Ltd. 1997). His research could provide valuable insight into how coral propagules, which can be either vegetative or sexual, colonize natural and artificial reefs. Waves and currents transport both types of propagules which settle and start new colonies (Sorokin 1993). If habitat conditions in the new location are similar to those of the mature corals (water movement, depth, temperature, and turbidity) and the substrate allows for easy attachment, it seems reasonable that colonization of natural and artificial reefs would be similar.

Reef Balls represent an exciting advancement in artificial reef technology. Their innovative design, stability, and ease of deployment make them an attractive alternative to scrap materials. Using old tires, junk cars, and obsolete aircraft as building blocks for reefs does save space in landfills. However, these materials may leach dangerous toxins into the ocean harming flora and fauna populations. The motivating factors in the construction of oil rig reefs may be suspect. Petroleum companies save large sums of money by sinking defunct platforms. For example, a Houston-based oil firm spent two million dollars to topple a natural gas platform in the Gulf of Mexico in 1993. It would have cost an extra $770,000 to dismantle the platform (Fritz 1994).

Much of the available data about Reef Balls comes from Reef Ball Development, Ltd. It can be argued that the information may be biased due to the company's interest in promoting its product. However, the mission statement of the all volunteer company emphasizes "on-going research, public education, community involvement, and reefs that promote and support natural species diversity and population density" (Reef Ball Development, Ltd. 1997). The company sponsors a program that provides Reef Ball molds, free of charge, to non-profit, governmental, educational and scientific organizations when reefs are used in new areas. As independent studies are completed, more information about this technique will be available from other sources.

Reef Ball technology appears to be a promising technique in the restoration of coral reefs. Further research and development of this and other techniques could help restore these valuable ecosystems. However, it is important to remember that artificial reefs cannot replace natural coral reefs. Unless measures are taken to remove the numerous stressors damaging natural reefs, they will continue to decline in productivity and diversity.

LITERATURE CITED

Candle, R. 1985. Scrap Tires as Artificial Reefs. Pages 293-301 in F. M. D'Itri, editor. Artificial Reefs: Marine and Freshwater Applications. Lewis Publishers, Inc., Chelsea, Michigan.

Fritz, S. 1994. The Oceans: Octopus inns. Popular Science. 244:30.

Greenberg, I. 1986. Guide to Corals & Fishes. Seahawk Press. Miami.

Greenpeace. http://www.sn.no/greenpeace/rigreef.html

Heins, S. 1995. Tanks for the anemones. New York State Conservationist. 50:9.

Hutchings, C. 1996. Industrial revolution. Geographical Magazine. 68:14-16.

Luoma, J. 1996. Reef Madness. Audubon. 98:24-28.

Meier, M. and J. Martin. 1985. Artificial reefs in Virginia: Old beginnings and new directions. Pages 339-341 in F. M. D'Itri, editor. Artificial Reefs: Marine and Freshwater Applications. Lewis Publishers, Inc., Chelsea, Michigan.

Reef Ball™ Development Group, Ltd. 1997. http://www.reefball.org/faq.htm

Reaka-Kudal, M. 1996. In S. Pain, author. Treasures lost in reef madness. New Scientist. 149:9

Rinkevich, B. 1995. Restoration strategies for coral reefs damaged by recreational activities: The use of sexual and asexual recruits. Restoration Ecology. 3: 41-251.

Sorokin, Y. 1993. Coral Reef Ecology. Springer-Verlag, Heidelberg.

Texas Parks and Wildlife. 1996. Rigs to Reefs. http://www.tpwd.state.tx.us/fish/reef/artreef.htm

University of Central Florida. 1997. Coffman Reef Project. http://pegasus.cc.ucf.edu/~ucf-dive/coffmanr.htm

Weisburd, S. 1986. Artificial reefs. Science News. 130:59-61.