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ARTIFICIAL REEF MATRIX STRUCTURES (ARMS): AN INEXPENSIVE AND EFFECTIVE METHOD FOR COLLECTING CORAL REEF-ASSOCIATED INVERTEBRATES

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ABSTRACT Collecting reef-associated invertebrates usually involves disturbance of the reef area, often damaging the habitat and sometimes damaging live corals. We introduce a nondestructive, inexpensive, and effective method for collecting coral reef-associated invertebrates using approximations of small coral heads constructed of concrete, PVC pipes, nylon cleaning pads, and other materials easily obtainable in most tropical (coral-rich) countries. An example showing the effectiveness of the method is presented based on fieldwork in the eastern Caribbean.

INTRODUCTION

Coral reefs are well known as areas of extremely high biodiversity (e.g., Sheppard 1980, Huston 1985, Briggs 1986, Jackson 1991, Sebens 1994, Gray 1997, Reaka-Kudla 1997, Roberts et al. 2002, Rohwer et al. 2001, 2002). However, studying this diversity is often hampered by the logistics involved in conducting research in tropical areas and the difficulties of extracting small organisms from the reef itself. For several years, we have conducted a survey of marine invertebrates in the eastern Caribbean, on and around the coral reefs of Guana Island, British Virgin Islands. The survey has yielded numerous new genera and species of marine invertebrates (e.g., Martin 2002, Haney and Martin 2004, Fitzhugh, in press a, b, Felder and Martin 2003) as well as material for molecular phylogenetic studies (e.g., Wetzer et al. 2003). Although several collecting methods were employed during the course of the survey (hand collecting while snorkeling or SCUBA diving, light traps, yabby pumps, baited traps, etc.), some of the most productive sampling (both in terms of the number of specimens and the number of new species recovered) resulted from the use of what we have termed "artificial reef matrix structures" (ARMS). In this paper, we discuss the materials used to build ARMS, their construction, deployment, and harvesting, and some of the preliminary results obtained from our survey.

MATERIALS AND METHODS

Construction

ARMS consist of a 2-part structure (Figure 1). The top section is intended to mimic a coral head and is composed of a stack of 4 concrete plates and 2 types of algae-mimicking material. The bottom section consists of a "rubble basket" made of one-half inch plastic mesh lined with finer-mesh nylon or fiberglass window screen, suspended from a frame of 2.5 cm (1") dia PVC pipe.

For the top section, the 3 top-most plates were made by pouring a sand-patch concrete mix into cardboard molds. Plastic trash bags were used to line the inner surface of the cardboard molds so that the plates could be removed easily from the forms after drying. For the molds we used cardboard forms (from boxes used to hold twelve 750-ml bottles). This mold produces a plate about 36 x 27 x 6 cm. Minimal water was used in making the concrete mix, which allowed the mix to be sufficiently viscous to mold tunnels of various diameters using different sizes of PVC pipe. Tunnels are semi-circular impressions extending about 21 cm across the bottom surface of the slab, with alternating openings on either side of the long axis (Figures 1, 2A). Into the top-most plate were molded 6 tunnels using sections of 1.2 cm (0.5") dia PVC, which were pressed into the wet concrete and then removed. Four tunnels were molded into the second plate using 2.5 mm (1") dia PVC, and 2 tunnels were molded into the third plate using 5 cm dia PVC. The bottom-most plate was slightly wider, longer, and thinner (about 42 x 29 x 5 cm) than the other plates and was formed using the cardboard tray from a case of canned soda. No tunnels were formed in this plate. The dried plates were stacked and bound together with plastic cable ties (36 mm and 124 mm). Plates could be removed from the molds and deployed less than 24 h after the concrete was mixed. A piece of latex-coated coconut husk fiber pad (Frost King™ washable furnace filter), cut to fit the dimensions of the top plate, was tied to the top plate, and 6 round, nylon pot scrubber pads (about 12 x 8 x 4 cm) were attached at various points on the stack (see Figures 1, 2A).

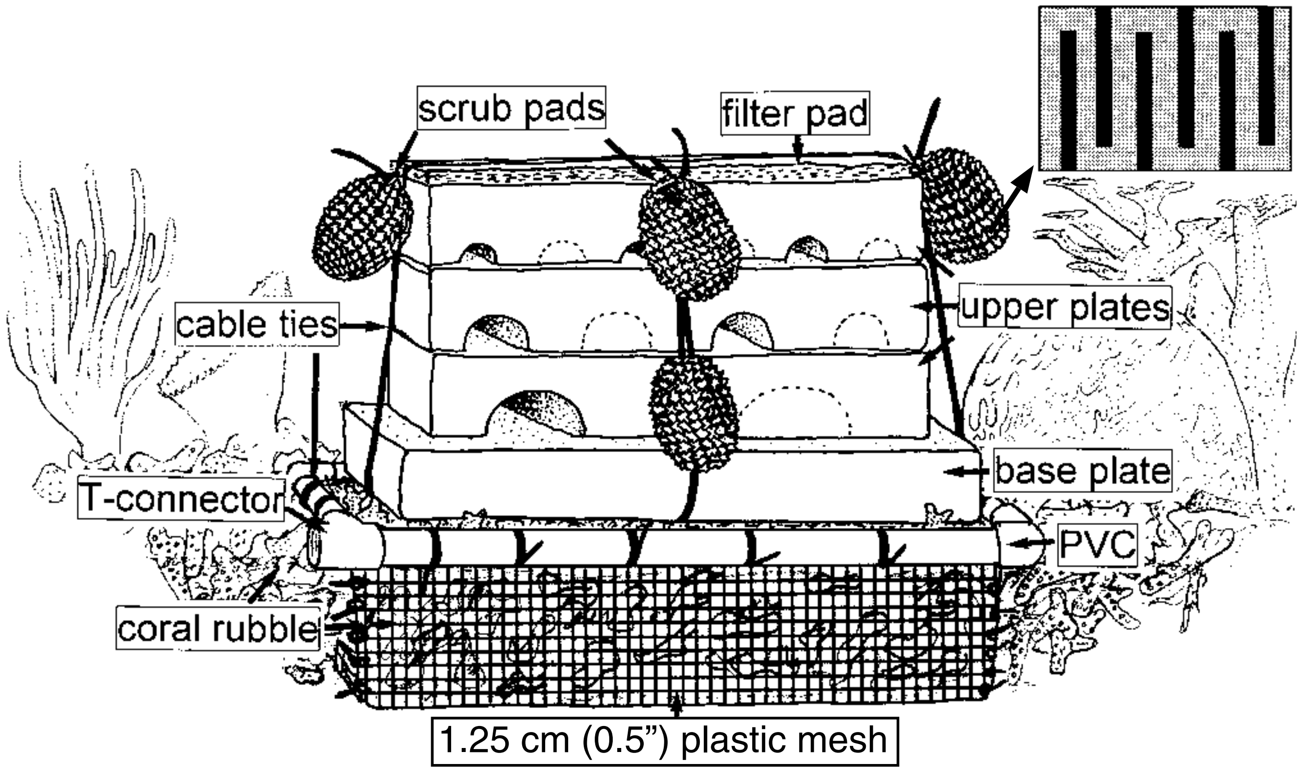

Figure 1. Diagram of a completed ARMS in place, cutaway view showing rubble basket beneath plates. Inset at upper right is a schematic view of the underside of the top plate, showing alternating tunnel orientation. Dashed lines on concrete plates indicate approximate location of tunnels having openings on the opposite side (not visible in this view).

The rubble basket beneath the concrete plates consisted of a square frame (0.5 m x 0.5 m) of 2.5 cm dia PVC pipe joined with two 90º elbows and two "T" connectors. The "T" connectors provided openings in the PVC frame at opposite corners of the frame. These openings allowed invertebrates to enter the pipe and, by allowing water in, facilitated the submergence of the frame. A 10-cm deep basket was made from sheets of 1.2-cm mesh extruded black plastic, joined at the corners by plastic cable ties of various sizes. An inner liner of plastic/fiberglass window screening with finer mesh size (about 2 mm) was placed into the basket. The basket was attached to the frame using plastic cable ties.

Total cost of materials for a single ARMS (concrete, PVC pipe, trash bags, furnace filter, scrub pads, cable ties, plastic 0.5" mesh, window screening) was less than US$20. The PVC, cardboard molds (boxes), and cement mix were purchased in the BVI; other materials were packed and shipped as luggage.

Deployment and retrieval

Deployment and retrieval of the ARMS was carried out by a team of 2 to 4 SCUBA divers operating from a small boat. The upper (concrete) section of the ARMS, which weighed about 29.55 kg (65 lbs), was lowered to the sea floor using a rope; it was then carried by a diver to the desired location. Once an ARMS was in the desired place, the divers dug a depression in the sand and coral rubble, and the rubble basket was placed into this depression so that the PVC frame was more or less flush with the bottom. The basket was then filled with rubble. The concrete plates of the upper section were then placed atop the basket, and the entire assembled ARMS was left in place for about one year.

To retrieve the ARMS, each scrub pad, and the top filter pad, was carefully removed in situ by divers and sealed in a labeled plastic bag. The bound concrete plates were then placed into a large nylon duffel bag, bound with nylon webbing, and sent to the surface with an airlift bag guided by a diver. The rubble basket was then placed into a second duffel bag, bound with nylon webbing, and sent to the surface in the same manner. Each duffel bag was placed into a large plastic wash tub and transported quickly to shore. On shore, the concrete plates were separated and photographed, individual specimens were collected by hand, and the surfaces of the plates were scraped to obtain as many of the attached invertebrates as possible. The rubble from the basket was sorted by hand and then subjected to a dilute seawater-formalin bath to extract any additional animals.

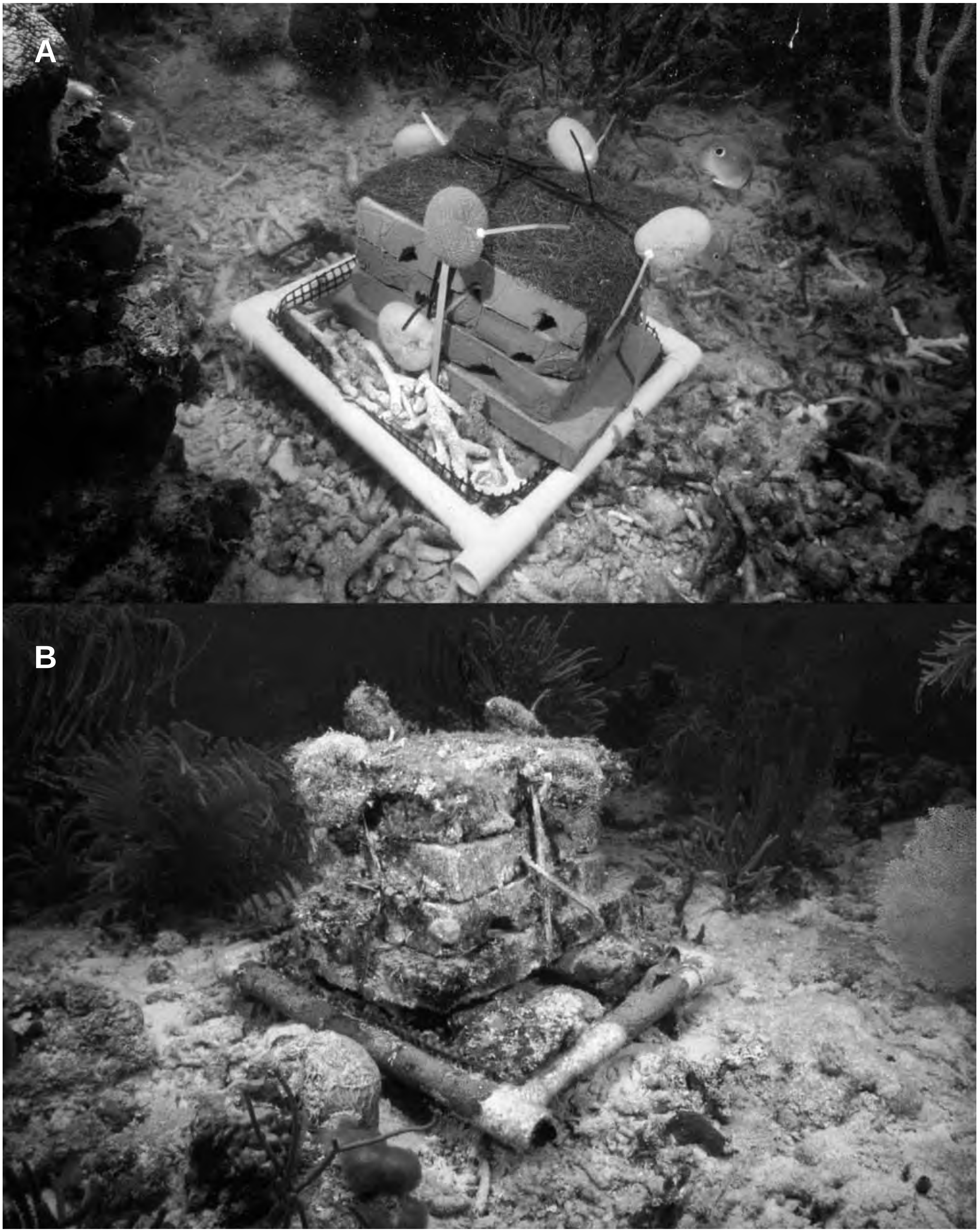

Figure 2. Photographs of two of our ARMS in the field. A) recently deployed ARMS in place at Long Point, Guana Island. B) the ARMS at Bigelow Beach (Guana Island) after about 1 yr in the field.

TABLE 1

Number of specimens of selected taxa found within one pot scrubber pad removed from the ARMS collecting device at Pelican Ghut (Atlantic side, BVI 2000, 96A3) and from 2 pads removed from the ARMS at North Beach (BVI 2000, 97A3 and 97A1). *Numbers for tanaids and isopods at North Beach 97A1 ARMS pot scrubber pad are possibly slightly off, as many of the specimens originally determined to be isopods were later determined to belong to the Tanaidacea. However, the total number, 631 for isopods and tanaids combined, is accurate.

	Pelican Ghut	North Beach 97A3	North Beach 97A1
Annelida			
Polychaeta	177	333	656
Crustacea			
Isopoda	67	6	401*
Ostracoda	5	23	228
Amphipoda	4	17	59
Caprellidea	0	0	1
Cumacea	0	5	0
Tanaidacea	16	13	230*
Copepoda	10	69	84
Leptostraca	0	0	42
Mollusca			
Bivalvia	6	12	43
Gastropoda	19	62	213
Polyplacophora	1	0	12
Nemertea	3	0	0
Nematoda	0	0	3
Echinodermata	1	11	32
Platyhelminthes	0	0	2
Cnidaria	0	0	2
Insects (chironomids)	0	0	44
Other insects	0	0	1
Sipunculida	0	0	8
Pycnogonida	0	0	7
Porifera	sponge fragments	sponge fragments	sponge fragments

RESULTS

Within days of being deployed, fish and shrimps were observed inhabiting the tunnels in the concrete plates. At the end of one year (when the ARMS were retrieved), the structures were covered with fouling organisms (Figure 2B). The pot scrubber pads, top filter pad, and rubble basket yielded the greatest number of individuals. The tunnels in the plates contained mainly fishes and encrusting organisms (polychaetes, molluscs, tunicates, and sponges), with occasionally larger, non-sessile invertebrates (ophiuroids, polychaetes, etc.). Stomatopods and large alpheid shrimps were commonly found inhabiting the PVC frame of the basket. Photographs of many of the species collected to date can be viewed on our preliminary project web site (see URL at Zimmerman and Martin, 2000–2003).

Pot scrubber pads are a commonly used device for quantitatively sampling small invertebrates after a colonization period (e.g., see Schoener 1982, Gee and Warwick 1996). In our study on Guana Island, the relatively fine mesh of the pads yielded high numbers of small worms and peracarid crustaceans. Preservation of the organisms was superb, providing us with specimens with delicate appendages still attached. Table 1 is an example of the quantity of specimens collected from these small pads.

Compared to the costs of constructing, deploying, and retrieving the ARMS, the cost of sorting and identifying the collected organisms is by far the greatest expense incurred. For 2 people working about full time (8 h/d), the time needed to sort specimens from the pad, and from the sediment trapped within the pad in some cases, and to identify them to phylum or to lower taxon as well as separate them and count individual specimens, was between 8 and 9 d (8.5 d for Pelican Ghut, 9 d for North Beach 97A3, and 9 d for North Beach 97A1).

The more open structure of the furnace filter pads was colonized by both small and slightly larger invertebrates (worms, molluscs, small decapods, etc.).

DISCUSSION

Although there is a vast amount of published literature on the use of artificial reefs, most of the interest has focused on large-scale reefs created and studied for fisheries purposes (e.g., see papers presented at the Florida Artificial Reef Summit 2001, on the web at: http://www.broward.org/bri01908.pdf; supplement 59 to ICES [International Council for the Exploration of the Sea] *Journal of Marine Science*, October, 2002; and *Bulletin of Marine Science*, vol. 55, numbers 2–3). Use of artificial reefs or other artificial substrates as a collecting source for reef-associated invertebrates also has a fairly long history (e.g., Schoener, 1974, 1982, Virnstein and Curran 1986, Edgar 1991). What is unusual, and to our knowledge novel, about the ARMS is the combination of substrates (concrete, furnace pads, scrub pads, PVC pipe, and coral rubble) to mimic a reef area in microcosm.

A single ARMS provided a much greater abundance and diversity of organisms (especially delicate and/or highly motile decapod crustaceans) than the same team of divers could collect by hand, as compared to results from our previous collecting efforts. In addition to providing us with undescribed species (e.g., *Microprosthema jareckii* Martin 2002), in many cases (e.g., stomatopods) a single ARMS provided more individuals of a given species than were collected by divers in the entire previous field season. Thus, ARMS are an effective way of collecting large numbers of marine invertebrates with relatively little effort, cost, or disturbance to the reef.

The rubble baskets placed beneath the ARMS served a three-fold purpose. First and foremost, these baskets collected additional invertebrates that were either attracted to or were already resident in the coral rubble in each basket. Second, these baskets created a secondary "catch" zone for invertebrates that might immediately flee the ARMS when it was retrieved. Such escapes often occur when a shrimp or stomatopod quickly exits the ARMS and immediately burrows, and by placing a basket beneath each ARMS we hoped to circumvent this type of loss. Third, the baskets allowed us to place each ARMS on a uniform substrate that was flush with the surrounding seafloor.

The use of ARMS as described herein does not guarantee a representative sample of marine invertebrates living on or in a reef ecosystem. Organisms having an association/dependence with live algae or live coral, as well as boring animals (e.g., some polychaetes, sipunculans, burrowing barnacles), may be under represented. ARMS appear to mimic the physical attributes and habitats of reefs. In this sense, the ARMS are obviously very selective devices, as is true of all artificial reefs.

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