Restoration Ecology

THE JOURNAL OF THE
SOCIETY FOR ECOLOGICAL RESTORATION INTERNATIONAL

Volume 17, Number 2, March 2009

WILEY-BLACKWELL

ISSN 1061-2971

Restoration Ecology
THE JOURNAL OF THE SOCIETY FOR ECOLOGICAL RESTORATION INTERNATIONAL

SHORT COMMUNICATION

A Novel Technique for the Reattachment of Large Coral Reef Sponges

Steven E. McMurray[1] and Joseph R. Pawlik[1,2]

Abstract

Sponges are dominant components of coral reef ecosystems, often exceeding reef-building corals in abundance. Large sponges, often more than 1 m in diameter, may be hundreds to thousands of years old. When damaged or dislodged, large sponges usually die because they are unable to reattach to the reef substratum. Because suitable methods for reattaching dislodged sponges are lacking, they are typically excluded from coral reef restoration efforts. Here we present a novel technique for the reattachment of large sponges that was tested using the Caribbean Giant barrel sponge, *Xestospongia muta*. Transplants of *X. muta* were conducted at 15- and 30-m depth off Key Largo, Florida. Despite the active hurricane season of 2005, 90% of deep and 35% of shallow transplants survived, with nearly 80% reattaching to the substratum and growing after 2.3–3 years. This technique may be generally adapted for securing large sponges in coral reef restoration efforts.

Key word: sponge coral reef remediation.

Introduction

The worldwide decline of coral reef ecosystems has prompted many local restoration efforts (Jaap 2000; Precht 2006). Funding devoted to restoration can be substantial; for example, one 1994 ship grounding on a coral reef resulted in a $3.9 million remediation settlement (NOAA 1997). Efforts typically focus on reattachment of reef-building corals (e.g., Hudson et al. 2007). Despite their dominance on coral reefs (Diaz & Rutzler 2001), large sponges are generally excluded from restoration efforts because of a lack of suitable methods for sponge reattachment.

Small, fast-growing reef sponges often employ fragmentation as a form of asexual reproduction and quickly recover after disturbance events. In contrast, large sponges do not reattach to the substratum when dislodged. In particular, the giant barrel sponges, *Xestospongia muta*, in the Caribbean and *X. testudinaria* in the Indo-Pacific are species having large individuals that may exceed 100 years of age, and are sometimes more than 1,000 years old (McMurray et al. 2008).

Large sponges may be damaged by a variety of natural events and human activities including severe storms, vessel groundings, and the cutting movements of chain, rope, or monofilament line moved along with debris by strong currents (Schmahl 1999; Chiappone et al. 2002, 2005). After these events, detached large sponges are commonly found, still alive and intact, between reef spurs on sand or rubble where they slowly erode under the action of oscillating currents. The success of past attempts at reattaching sponges using cement or epoxy has been limited (Jaap 2000; Collier et al. 2007) because adhesives do not bind to sponge tissue. Herein we describe a novel technique for reattaching *X. muta* that could be generally applied to the restoration of other large sponge species dislodged by human activities or storm events.

Methods

This sponge reattachment technique was developed as part of two experiments conducted on Conch Reef, Florida (lat 24.95°N, long 80.45°W) that required detached sponges to be held in place for subsequent monitoring; full details of the experimental design will be presented elsewhere (McMurray et al. 2008). For both experiments, 10 *Xestospongia muta*, about 20–30 cm in height and base diameter, were transplanted from the adjacent reef Conch Wall (about 80-m distance), to both a shallow (15 m) and deep (30 m) site on Conch Reef. The first experiment was conducted on 6–8 November 2004, and the second, 25–26 July 2005. For both experiments, sponge reattachment was examined and a qualitative assessment of sponge condition was conducted monthly for 6–7 months, and then 1 year and 2.3–3 years following transplantation.

Sponges were detached at the level of the substratum using long knives and transported underwater to their reattachment sites. For each sponge, an area of about 1 m^2 of bare flat limestone substratum was cleaned of loose debris and algae with a wire brush prior to sponge

[1] Department of Biology and Marine Biology, Center for Marine Science, University of North Carolina, Wilmington, NC 28409, U.S.A.
[2] Address correspondence to J. R. Pawlik, email pawlikj@uncw.edu

doi: 10.1111/j.1526-100X.2008.00463.x

reattachment. Two pairs of sponge holders (Fig. 1) were positioned perpendicularly with 10- to 20-cm distance between each holder and the sponge surface (Fig. 2). Each holder consisted of a slotted piece of polyvinyl chloride pipe anchored in a concrete block that was set on a plastic (vexar) mesh base (Fig. 1). The plastic mesh base of each holder was secured by driving three to four washer nails through the mesh and into the substratum. Each sponge was skewered horizontally through the slots in two opposing holders with each of two 60-cm stainless steel threaded rods, perpendicular to each other, at a height of about 15 cm from the substratum (Fig. 2). Once the cut surface of the sponge was seated tightly against the substratum, the sponge was secured to the holders by tightening down stainless steel washers and zinc-plated steel nuts along the ends of the threaded rods (Fig. 2).

Temporal and spatial differences in survival and reattachment were tested using log-linear models (Sokal & Rohlf 1995). Analyses were conducted for each of the two transplants separately due to differences in survey dates between the two experiments. For each experiment, analyses were based on separate three-way contingency tables with the explanatory variables time, T, and depth, D, for both tables and the response variables survival, S, and attachment, A, for the two tables, respectively. The null hypotheses, the models TD, S, and TD, A, were compared with marginal models containing the TS, DS, TA, and DA interactions.

Results

The sponge reattachment technique was originally designed solely to keep sponges stationary for two manipulative experiments (McMurray et al. 2008); however, it was discovered that some sponges were reattaching to the substratum after only 6 months. For the first experiment, all but

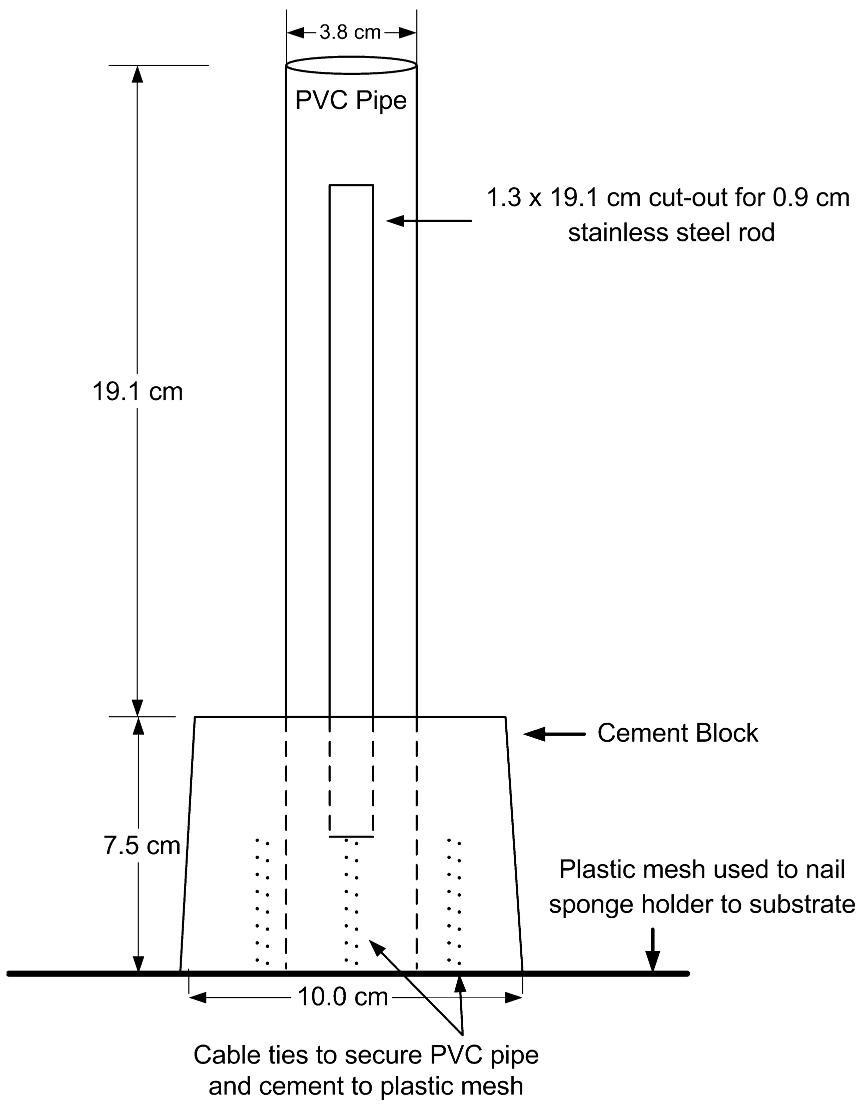

Figure 1. Schematic of sponge holder. Two pairs of holders were used to secure each sponge.

Figure 2. Specimen of *Xestospongia muta* secured to the substratum at 15-m depth, Conch Reef, Florida. (A) Side view. Long edge of slate is 16 cm. (B) Same sponge, top view.

one sponge was healthy after 6 months, and six had reattached to the substratum at the deep site. Sponges transplanted to the deep site had significantly greater survival compared to sponges at the shallow site ($\chi^2 = 30.432$, $df = 1$, $p < 0.001$) and survival did not significantly change through time. All sponges survived tropical storm Arlene, which passed Key Largo about 7 months after transplantation, but seven sponges from the shallow site that had yet to reattach disappeared as a result of hurricane Dennis, about 8 months after transplantation (sponge holders remained intact) (Table 1). The 13 surviving sponges were alive and healthy after 1 year, and 6 had reattached to the substratum. After 3 years, two sponges that were reattached became dislodged, but an additional five sponges had reattached. No difference in sponge reattachment was found between sites or through time. A total of 12 sponges survived and 9 had reattached to the substratum (Table 1).

Again for the second experiment, survival of sponges was significantly greater at the deep compared to the shal-

Table 1. Total number of 10 *Xestospongia muta* attached to the substratum, unattached, and dead after 1 and 2.3–3 years at shallow and deep sites for both transplants.

Transplant	*Time After Transplant (Years)*	*Depth*	*No. Attached*	*No. Unattached*	*No. Dead*
1	1	Shallow	0	3	7
1	3	Shallow	2	0	8
1	1	Deep	6	4	0
1	3	Deep	7	3	0
2	1	Shallow	3	2	5
2	2.3	Shallow	4	1	5
2	1	Deep	3	5	2
2	2.3	Deep	7	1	2

low site ($\chi^2 = 4.054$, $df = 1$, $p = 0.044$), but survival did not significantly change through time. All sponges were healthy until exposed to storm events. Hurricanes Katrina, Rita, and Wilma passed approx. 2, 3, and 4 months after transplantation, respectively, removing five sponges from the shallow site (again, sponge holders remained intact). Two sponges at the deep site subsequently died from a disease-like condition, "sponge orange band," which also killed *Xestospongia muta* on adjacent reefs at the same time (Cowart et al. 2006). Sponge reattachment was found to significantly increase over time ($\chi^2 = 4.434$, $df = 1$, $p = 0.035$) and did not differ between sites. All 13 surviving transplants were alive and healthy after 1 year and 6 had reattached to the substratum (Table 1). After 2.3 years, all 13 surviving sponges were still alive, all 6 that had reattached after 1 year remained attached, and an additional 5 had reattached to the substratum, for an 85% reattachment rate (Table 1). After the final survey for both transplants, the apparatus was successfully removed from all sponges that had reattached.

Discussion

Twenty specimens of the Caribbean giant barrel sponge were reattached at Conch Reef using the technique described herein, despite an unusually rigorous testing regime that included four hurricanes. Despite these storm events, 62.5% of sponges in both experiments survived at least 2.3–3 years, and 90% of the sponges at the deep site survived.

Sponges reattached to the substratum after being held stationary by sponge holders for as little as 6 months. About 20% of the surviving sponges did not reattach because unevenness in the substratum prevented complete contact between the sponge base and the substratum; in other cases, currents induced by storm events "rocked" the sponges in their holders to prevent attachment. Attachment success was clearly greater when the base of the sponge was in firm contact with the substratum, and when sponges were reattached at greater depths where storm events had less effect. Removal of the rods after reattachment left small wounds, which healed rapidly (Walters & Pawlik 2005). It is advisable to remove the apparatus as soon as reattachment is complete because it may become entangled in debris during storm events, promoting dislodgement.

Although *Xestospongia muta* is the dominant large sponge on Caribbean coral reefs, the technique described herein may also be useful for attaching less common large species, particularly *Geodia neptuni, Agelas conifera*, and *Verongula gigantea.* Of these species, the first has a stony tissue consistency similar to that of *X. muta*, while the second and third have progressively more elastic tissue that may be difficult to fix in place, and additional modification of the attachment method may be required.

Implications for Practice

- Dislodged specimens of the Caribbean Giant barrel sponge, *Xestospongia muta,* can be reattached to the reef substratum in as little as 6 months using the apparatus described herein.
- Sponges have greater potential for survival if reattached on deep-water reefs where damage from storms during reattachment is less likely.
- The apparatus should be removed as soon as reattachment is complete.
- This technique may be used to reattach other species of large sponges that become dislodged.

Acknowledgments

This study was funded by grants to J.R.P. from the National Undersea Research Program at UNCW (NOAA NA96RU-0260) and from the National Science Foundation, Biological Oceanography Program (OCE-0095724, 0550468). Particular thanks to Daniel Aten, who assisted with the construction of the sponge holders and Timothy Henkel for assistance in the field. Additional assistance in the field was provided by Nick Fowler, Adam Jones, Wai Leong, Susanna López-Legentil, Tse-Lynn Loh, and Kyle Walters. Chris Finelli assisted with artwork.

LITERATURE CITED

Chiappone, M., H. Dienes, D. W. Swanson, and S. L. Miller. 2005. Impacts of lost fishing gear on coral reef sessile invertebrates in the Florida Keys National Marine Sanctuary. Biological Conservation **121:**221–230.

Chiappone, M., A. White, D. W. Swanson, and S. L. Miller. 2002. Occurrence and biological impacts of fishing gear and other marine debris in the Florida Keys. Marine Pollution Bulletin **44:** 597–604.

Collier, C., R. Dodge, D. Gilliam, K. Gracie, L. Gregg, W. Jaap, M. Mastry, and N. Poulos. 2007. Rapid response and restoration for coral reef injuries in southeast Florida (http://www.dep.state.fl.us/coastal/programs/coral/reports/MICCI/MICCI_Project2_Guidelines.pdf) accessed 8 November 2007.

Cowart, J. D., T. P. Henkel, S. E. McMurray, and J. R. Pawlik. 2006. Sponge orange band (SOB): a pathogenic-like condition of the giant barrel sponge *Xestospongia muta*. Coral Reefs **25:**513.

Diaz, M. C., and K. Rutzler. 2001. Sponges: an essential component of Caribbean coral reefs. Bulletin of Marine Science **69:**535–546.

Hudson, J. H., J. Anderson, E. C. Franklin, J. Schittone, and A. Stratton. 2007. M/V Wellwood coral reef restoration monitoring report, monitoring events 2004-2006. Florida Keys National Marine Sanctuary Monroe County, Florida. Marine Sanctuaries Conservation Series NMSP-07-02. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Sanctuary Program, Silver Spring, Maryland.

Jaap, W. C. 2000. Coral reef restoration. Ecological Engineering **15:** 345–364.

McMurray, S. E., J. E. Blum, and J. R. Pawlik. 2008. Redwood of the reef: growth and age of the giant barrel sponge *Xestospongia muta* in the Florida Keys. Marine Biology **155:**159–171.

NOAA. 1997. NOAA gears up for reef restoration at Looe Key: university agrees to $3.9 million settlement for damage in Florida Keys Sanctuary. Press Release (http://www.publicaffairs.noaa.gov/pr97/nov97/noaa97-r423.html) accessed 8 November 2007.

Precht, W. F., editor. 2006. Coral reef restoration handbook. CRC Press, Boca Raton, Florida.

Schmahl, G. P. 1999. Recovery and growth of the giant barrel sponge (*Xestospongia muta*) following physical injury from a vessel grounding in the Florida Keys. Memoirs of the Queensland Museum **44:** 532.

Sokal, R. R., and F. J. Rohlf. 1995. Biometry: the principles and practice of statistics in biological research. 3rd edition. W.H. Freeman and Co., New York.

Walters, K. D., and J. R. Pawlik. 2005. Is there a trade off between wound-healing and chemical defenses among Caribbean reef sponges? Integrative and Comparative Biology **45:**352–358.