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Recovery of injured giant barrel sponges, *Xestospongia muta*, offshore southeast Florida

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Abstract. Giant barrel sponges, *Xestospongia muta*, are abundant and important components of the southeast Florida reef system, and are frequently injured from anthropogenic and natural disturbances. There is limited information on the capacity of *X. muta* to recover from injury and on methods to reattach *X. muta* fragments. In late 2002, hundreds of barrel sponges offshore southeast Florida (Broward County) were accidentally injured during an authorized dredging operation. In early 2003, two to three months post-injury, 93% of 656 assessed injured sponges appeared to be recovering. In 2006, three years post-injury, nearly 90% of 114 monitored sponges continued to show signs of recovery. Growth rates were estimated by measuring sponge height above visual injury scars and ranged from 0.7 cm yr^{-1} to 6.0 cm yr^{-1}. Information on the artificially reattached fragments is limited but did show that *X. muta* fragments can reattach. This study provides evidence that *X. muta* in southeast Florida can naturally recover. Details on sponge size class associated recovery processes and growth were not collected due to event associated legal issues limiting the study. Studies to determine detailed growth rates and recovery success for different injury and restoration scenarios will further facilitate restoration decision making by resource managers.

Key Words: Barrel sponge, *Xestospongia muta*, recovery, reattachment, restoration

Introduction

The giant barrel sponge, *Xestospongia muta*, is an abundant, large, and important component of the southeast Florida reef system. Sponges are potentially very long-lived (McMurray et al. 2008) and have important ecological roles in reef ecosystems including filtering large volumes of water, contributing to habitat complexity, and increasing diversity with numerous associated infauna and microbial communities (Diaz and Rutzler 2001; Hentschel et al. 2006). Offshore Florida, *X. muta* colonies are often injured by marine construction activities (e.g. dredge projects), ship grounding and vessel anchoring events, line fishing, and storms (Schmahl 1999; Chiappone et al. 2002; Collier et al. 2007). Although *X. muta* has been shown to successfully heal small scale wounds, such as those caused by fish predation, few studies have focused on monitoring recovery from more severe injuries (Schmahl 1999; Walters and Pawlik 2005). There is also scant literature on the ability of *X. muta* fragments or dislodged barrels to reattach to the substrate. The limited availability of information on sponge fragment attachment success and natural recovery of severely injured sponges constrains the ability of resource managers to determine primary and compensatory restoration actions following injuries to *X. muta* populations (Jaap 2000; Collier et al. 2007).

In November 2002, during an inlet channel improvement project, steel tow cables were accidentally dragged over middle and outer reef areas offshore Broward County, southeast Florida. Damage to coral reef communities included the complete dislodgment of and various degrees of injury to hundreds of *X. muta* sponges. Injury assessment and primary restoration activities included the identification of injured barrel sponges and the reattachment of sheared sponge fragments. A monitoring effort was designed and included a representative sample of tagged injured sponges and transplanted fragments. Although legal issues (outside the scope of this paper) limited the monitoring effort, this study provides important information on the ability of *X. muta* to recover following severe injury and fragment attachment success.

Materials and Methods

Initial recovery

From December 2002 to February 2003, one to four months after the injury event, reef injury areas were assessed and mapped. As directed by the resource trustees (state of Florida), two types of additional assessments (transect and total-count) were conducted to document initial *X. muta* recovery within a portion of the injury areas. Within seven mapped injury areas a total area of 900m² was assessed using 24, 0.75m x 50m, non-fixed, belt-quadrat transects. Four transects were completed within each of five of these injury areas and two transects were completed within two injury areas, and all transect locations were placed such that their entire length were within the mapped injury areas.

Within six total-count injury areas, which had a total injured area of 7,272m², all barrel sponges were counted and classified. For both of these rapid assessments, the trustees only requested information on the number of recovering sponges. No quantitative information on sponge sizes was collected. Injured sponges were classified as: *sheared*, with the entire barrel removed (Fig. 1), or *notched*, with only a portion of the barrel removed and most of the sponge remaining intact (Fig. 2). The condition of each sponge was also noted as recovering or not recovering. A recovering sponge was defined by the absence of necrotic tissue, darkening of the internal tissues exposed by the injury, and/or visible new growth.

Figure 1: Base of a sheared barrel sponge with a completely removed barrel and recently exposed internal tissues (white).

Fragment attachment

Also between December 2002 and February 2003, 401 *X. muta* fragments (sheared barrels) were collected and artificially attached to the substrate within the injury areas. Two methods were employed. In both methods, prior to attaching fragments, loose sediments, algae, and other material were removed to promote sponge growth onto the substrate. For the first method (210 of the 401 fragments) two lengths of stainless steel wire were crossed and draped over the fragment. The wire was pulled tight pressing the fragment against the substrate. The ends of the wire were secured to the substrate with cut nails. The second method (191 of the 401 fragments) utilized Portland cement to attach a portion of the fragment directly to the substrate. At the time of reattachment no data was collected on fragment size.

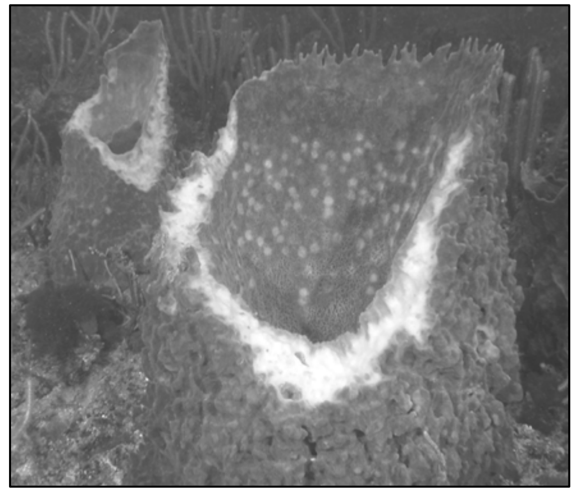

Figure 2: Two sponges with notched barrels and recently exposed internal tissues (white).

Long-term recovery

In March 2003, 11 monitoring zones were established to document long-term *X. muta* recovery within the injury areas. Four (zones 7, 9, 10, and 11) monitoring zones included injury areas within which the initial recovery assessments were completed. Zones were marked by a permanent center pin and included area around the pin defined by a radius of approximately 15m. Artificially reattached fragments and injured sponges within each zone were mapped and tagged. All sponges were alive and showed signs of recovery at the time of tagging. In December 2006 and January 2007, the 11 monitoring zones were visited and the tagged barrel sponges were assessed. For injured sponges and reattached fragments, condition was noted as recovering (alive) or missing (tag found but sponge missing). For the injured recovering sponges only, sponge height was recorded and new growth was estimated (when possible) by measuring (nearest cm) the height of tissue above the injury ‘scar’ (Fig. 3). Growth rates were estimated by dividing the measured new growth by the number of months between the injury and the time of measurement. This monthly growth rate was then multiplied by 12 for yearly growth. Growth had to be estimated due to the legal issues which stopped the project prior to collecting initial quantitative data in 2003 on sponge sizes. These same legal issues did not permit visits to the zones prior to the late 2006/early 2007 monitoring event.

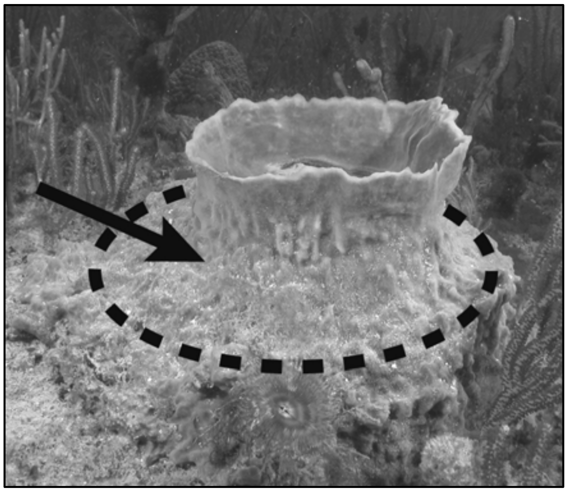

Figure 3: Injured barrel sponge in 2007 with the area of new growth (arrow) above a visible injury scar (dotted line).

Results

Initial recovery

Within the 24 transects 180 injured *X. muta* were identified with 13 classified as notched and 167 as sheared. Of these 180 sponges, 100% of the notched and 92% of the sheared (154 sponges) showed signs of recovery for a total initial recovery of 93% (167 sponges) (Table 1).

A total of 476 injured *X. muta* were identified within the six total-count injury areas. Forty-eight sponges were classified as notched and 428 as sheared. Forty-five notched sponges (95%) and 400 sheared sponges (93%) were recovering for a total recovery of 93% (Table 1).

Fragment attachment

Within the 11 monitoring zones, 26 reattached fragments were present and tagged. Six fragments were secured with cement and 20 with wire. During the 2006/2007 monitoring event, only five fragments (all wire) remained alive and had attached to the substrate (Fig. 4). The monitoring tags of the remaining 21 fragments (six secured with cement and 15 with wire) were found but the fragments were missing.

Figure 4: Artificially reattached barrel sponge fragment in 2007. Note the wire used to secure the fragment and the change in fragment growth orientation from vertical to horizontal.

Table 1: Initial recovery summary data for the seven transect and the six total-count (T-C) injury areas. Sponge totals for each assessment type and combined totals for both types are indicated (T = total sponges, N = notched sponges, S = sheared sponges).

Injury Area/	No. of	Area (m^2)	Injured			Recovering			Percent Recovering		
Assess. Type	Transects	Assessed	T	N	S	T	N	S	T	N	S
1 / Trans	4	150	33	4	29	31	4	27	94	100	93
2 / Trans	4	150	25	5	20	25	5	20	100	100	100
3 / Trans	4	150	19	1	18	17	1	16	90	100	89
4 / Trans	4	150	9	0	9	7	0	7	78	NA	78
5 / Trans	2	75	15	0	15	14	0	14	93	NA	93
6 / Trans	2	75	29	2	27	25	2	23	86	100	85
7 / Trans	4	150	50	1	49	48	1	47	96	100	96
Sub-Total	24	900	180	13	167	167	13	154	93	100	92
8 / T-C	NA	1,506	30	5	25	30	5	25	100	100	100
9 / T-C	NA	475	85	13	72	81	13	68	95	100	94
10 / T-C	NA	1,635	82	8	74	76	8	68	93	100	92
11 / T-C	NA	358	83	8	75	80	8	72	96	100	96
12 / T-C	NA	2,722	126	14	112	112	11	101	89	78.6	90
13 / T-C	NA	576	70	0	70	66	0	66	94	NA	94
Sub-Total	NA	7,272	476	48	428	445	45	400	94	94	94
		Total All	656	61	595	612	58	554	93	95	93

Long-term recovery

In 2003 within the 11 monitoring zones, 114 injured *X. muta* were tagged (Table 2). In late 2006/early 2007, 102 (90%) were found alive (recovering). Of the 11 monitoring zones, five had 100% recovery, and only one zone (zone 3) had less than 80% recovery (71.4%) (Table 2). Estimated new growth rates (recovery) of 101 surviving colonies ranged from 0.7 cm yr^{-1} to 6.0 cm yr^{-1}, with a mean of 2.78 cm yr^{-1} (± 0.11 SEM). It was noted during the late 2006/early 2007 monitoring event that many of the recovering sponges had multiple barrels. Notes were recorded for 92 recovering sponges, and 59 were identified with one barrel, 14 had two barrels, and 19 had three or more barrels (Fig. 5).

Table 2: Number of sponges tagged within each monitoring zone (MZ) in 2003, and the number of sponges recovering, missing, and percent recovery from the late 2006/early 2007 monitoring event.

MZ	Total Tagged	Recov.	Missing	% Recov.
1	15	13	2	87
2	15	12	1	80
3	14	10	4	71
4	12	11	1	92
5	12	11	2	92
6	11	11	0	100
7	5	5	0	100
8	10	10	0	100
9	10	10	1	100
10	2	2	0	100
11	8	7	1	88
Total	114	102	12	90

Figure 5: Recovering barrel sponge with multiple barrels growing from the sheared base.

Discussion

The high latitude southeast Florida reef system is offshore a heavily populated coast and is therefore subject to multiple natural and anthropogenic stressors. Strong storm events, unauthorized injury events such as ship groundings, and authorized coastal construction projects potentially impact reef resources. There have been few efforts with almost no information recorded on restoring sponge populations and documenting recovery. Generally, reef restoration activities and recovery monitoring efforts concentrate on stony corals. Sponges are a dominant component of the southeast Florida reef system contributing greatly to benthic cover and density (Gilliam et al. 2007, 2008). Therefore, information on the capacity of sponges to recover and techniques to restore sponge populations following injury are needed.

Even though legal issues limited the information that may have been available, this study provides an example of the capacity of the giant barrel sponge, *Xestospongia muta*, to recover from severe injuries. Observed recovery of all sponges (notched and sheared) within several months of the injury event was over 93% and after four years was nearly 90% (Tables 1 - 2).

These recovery rates are higher, yet comparable to, those documented for *X. muta* offshore the Florida Keys, in which 30 out of 37 (81%) *X. muta* were considered recovered 13 months after suffering injury from a ship grounding (Schmahl 1999).

Although the growth rates of the recovering sponges in this study were estimates only and were highly variable, they fell within the range of other documented upward linear growth rates in the Florida Keys (Schmahl 1999, McMurray et al. 2008). Interestingly, mean injured sponge growth rates were higher in Broward County (2.78 cm y^{-1}) than recovering sponge growth rates in the Florida Keys (1.94 cm yr^{-1}, Schmahl 1999). Regardless of this difference, these elevated growth rates provide some evidence for the supposition that recovering sponges have higher-than-normal growth rates (1.85 ± 1.10 cm yr^{-1}, McMurray et al. [2008]).

Two methods were used to reattach sponge fragments. Although 401 total fragments were reattached, at the time the monitoring zones were established only 26 fragments were identified within the 11 zones. The exact fate of the remaining 375 fragments is unknown. They were either lost prior to zone establishment or were present within the injury areas but outside of the established zones. None of the six monitored fragments secured with cement were present in late 2006/early 2007. Observations immediately after cementing showed that the fragment was initially held to the substrate. It is likely that due to the mortality of sponge tissue in contact with the cement, the fragment was not held in contact with the substrate for a time period necessary for the sponge tissue to grow. Five of 20 monitored fragments attached by the wire were found attached to the substrate in late 2006/early 2007. For those five the wire was able to hold the fragments tight against the substrate long enough for sponge tissue to grow. Growth was also observed over the wire. This limited data suggests that if *X. muta* fragments can be secured tightly against the reef substrate for a sufficient length of time, they are capable of forming a new attachment and will continue to grow. Because of the small sample size we can not conclude the attachment of *X. muta* fragments using wire is the best method and other methods should be evaluated. For some of the fragments, wave and surge conditions created a "sawing" effect with the wire, where it sliced downward into sponge tissue. Subsequently, the fragment was unable to remain in contact with the substrate, thereby preventing the stability required for reattachment. It is also interesting to note that several fragments that were not placed in their original growth orientation were still able to successfully reattach. These fragments were essentially "half barrels" and the portion of the barrel top, which was initially vertical, was attached horizontally (Fig. 4).

This study was interrupted for a period of three years due to legal issues associated with the injury event. This gap resulted in a significant amount of data loss especially in terms of sponge size class associated rates of new growth and causes of mortality. Nonetheless, this limited study does provide important information on the recovery of *X. muta* offshore southeast Florida, USA and supports the necessity for comprehensive, long-term monitoring efforts. Current research includes a controlled study to further explore *X. muta* recovery, growth, causes of mortality, and effectiveness of reattachment methods.

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