A Comparison of Regeneration Rates over Depth in Two Tubular Sponges, *Iotrochota birotulata* and *Verongia longisama*

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Abstract:

Conspicuous inhabitants on the northern coast of Jamaica are the tubular sponges. These sponges have an extended form which tends to suffer ~~high incidences~~ of fragmentation and penetration. We set out to examine the rate of recovery from these two forces on the sponges Iotrochota birotulata and Verongia longisama. In Discovery Bay, Jamaica, from March 1-6, 1985, we penetrated 62 holes at two depth gradients to observe and record regeneration rates. Percent recovery was ranked according to healing class so that data could be analysized by means of a G-test.

We found a significant difference in the regeneration rates over depth, with shallower organisms healing faster than those at the deeper site. We also found the I. birotulata had a significantly more rapid regeneration than either V. longisama or the gorgonian, Briareum asbestinum.

We attribute I. birotulata's superior regeneration to a less dense, less complex

morphology. It appears this simple sponge has a high success along the fore-reef terrace of the coral reef.

Introduction:

Survival of sessile organisms in coral reef communties depends on their ability to colonize substrate, utilize a sufficient food resource, and reproduce successfully. Tissue damage resulting from predation or physical stress such as turbulence, storms, and sedimentation can severly decrease a sessile organism's chance of survival. Fast regeneration of damaged areas proves to be vital in maintaining overall fitness. The disadvantages of a slow regeneration period include; loss of feeding tissue, loss of reproductive potential, and increased probability of larval recruitment by superior competitors (Jackson & Palumbi, 1978).

redundant

To date, there have not been any studies which have addressed in detail the dynamics of tropical sponge regeneration. Jackson & Palumbi (1978) described regeneration as edge extension, cell proliferation and immigration followed only later by division into distinct functional units. Then, a second study in 1983 by Ayling calculated the regeneration rates of ten thinly encrusting demosponges from temperate waters and found them to be 22 to 2,900 times greater than their natural growth rates. Both studies indicate that sponges have adapted fast and efficient means by which to maintain their structure. This ability to repair injured tissue rapidly proves significant for it decreases the chance of predation colonization? ? by encrusting algae and bacteria, thus, decreasing branch or colony mortality.

We found sponges to be conspicuous inhabitants of the Jamaican coral reef. Their widely distributed population along the reef can be found at depths between 5 to 60 meters. We observed two common morphs — a low, encrusting form and an erect, hollow or tubular form. Of these two morphologies, the most susceptible to damage seemed to be the rope sponges which extend sprawling branches in all directions. This usually slender and flexible branching could be easily torn and shredded during times of high turbulence and, hence may have evolved special regeneration patterns to compensate for such losses.

In this study we examined the regeneration rates of two rope sponges, *Iotrochota birotulata* and *Verongia longisama*. We predict a more rapid regeneration of sponge tissue in the shallower depths of the fore-reef where particulate organic material is more readily available. (Reiswig 1971, 1975) Furthermore, the selective pressures for faster regeneration of injured tissue would be greater at shallower depths because of an increase in turbulence and turbidity. We also propose that damage near the tip of a branching individual or colony should heal quicker than one at the base, since growth cells are concentrated at the tip. Finally, we will examine the rate at which sponge segments can bind to rubble signifying fragment recolonization.

why would turbidity favor high regeneration rates?

why is this important?

On a note of interest, our study also includes the octocoral *Briareum asbestinum* (Pallas) for the purpose of comparing and contrasting the healing dynamics of two different ~~phylums~~ phyla.

Methods:

The field site ~~chopsen~~ chosen for this study was Mooring 1 on the West fore Reef Terrace in ~~Descovery~~ Discovery Bay, Jamaica, West Indies. The fore-reef in Discovery Bay consists of a buttress zone composed mainly of Staghorn coral rubble alternating with sandy patches and channels sloping northward. Communities of coral are intermixed on mounds of rubble; however, populations were drastically reduced by Hurricane Allen in August, 1980. In contrast, the abundance and diversity of the phylum Porifera on today's fore-reef is substantually the same as it was prior to the hurricane.

We established two stations at different depths along the fore-reef slope. In order to examine rates of regeneration, we induced lesions into two sponge species and one species of soft coral. With the aid of a 5mm diameter cork borer, we punctured wounds 5mm into the tissue of the organism. The two rope sponges used in our field manipulations were _Iotrochota birotulata_ and _Verongia longisama_. Both specimens have erect, sprawling branches varying in length and diameter. _Iotrochota birotulata_ tissue had little resistence, hence some difficulties were encountered puncturing a cylindric hole into its tissue. In addition to the two sponge species, we induced lesions into _Briareum asbestinum_, a soft coral with vertical stalks 3 cm thick and ranging from 15 cm to 1 meter in length. The number of replications varied with species and depth. Sample size ranged between 2 to 8 replicates within each species; a total of 62 holes were bored. In all cases we selected healthy colonies of approximately the same size. All holes were bored within 5 cm of the tip and the base on a single branch. A total of 2 holes ~~were~~ was produced per individual specimen. Depth readings were taken and specimens ranged between 29 – 35 feet (shallow site) and 62 - 70 ft (deep site). Individuals were marked with the aid of floating bottles for identification. Each specimen was examined daily

why so far from the tip?

from March 1st to 6th, 1985 to determine a rate of regeneration.

To measure the rate of regeneration, we developed a quantitative scale. We ranked the regeneration according to the percent recovery observed in the damaged tissue. The 6 categories used included:

Class	Percent
0	0%
1	1-25 %
2	25-50 %
3	50-75 %
4	75-99 %
5	100 %

To estimate the time required for fragments of tissue to reattach onto a substrate, 5cm segments of Iotrochota birotulata, Verongia longisama, and Briareum asbestinum were cut and tied to coral rubble. Two replicates of each species were included. Segments of I. birotulata and B. asbestinum were prepared on March 2nd, 1985 and V. longisama were prepared on March 5, 1985. All segments were placed on rock outcroppings at 30 feet, where they were exposed to the environment but stationary. On March 8, 1985 all six segments were removed and examined in the wet lab.

Data ~~was~~ were analyzed for significance using the G-test. Comparisons for significant differences were conducted between each species for tip and base recovery rates. When no significant difference was determined between these two holes, each species' regeneration rates were combined to test inter and intra species relationships.

Results:

A within species comparison of tip and base regeneration rates showed no significant difference (G-test) in all cases. (Table 1).

Species	Depth	G-Value	α
I. birotulata	deep	2.48	NS
I. birotulata	shallow	1.98	NS
V. longisama	deep	3.58	NS
V. longisama	shallow	0.09	NS
B. asbestinum	deep	6.6	NS
B. asbestinum	shallow	4.8	NS

Table 1.

To determine whether regeneration rates differ over a depth gradient, measurements from tip and base of each individual species ~~was~~ were combined and tabulated. A G-test was employed to define any healing pattern present among species. We found no significant difference in the regeneration patterns of the three species along a depth gradient. Consequently, wounds healed significantly faster (G-test, $\alpha < .025$) in all species in shallower water (30 feet). To distinguish any intra or inter specific differences in healing rates, we preformed another G-test comparing rates between the possible pairs at both deep and shallow stations. We found I. birotulata regenerates significantly faster in both 30 feet and 70 feet than either Verongia longisoma or B. asbestinum. However, no significant difference was found between the healing rates of V. longisoma and B. asbestinum (G-tests presented in table 2.)

Fragmentation Experiment Results:

1 out of 2 I. birotulata fragments

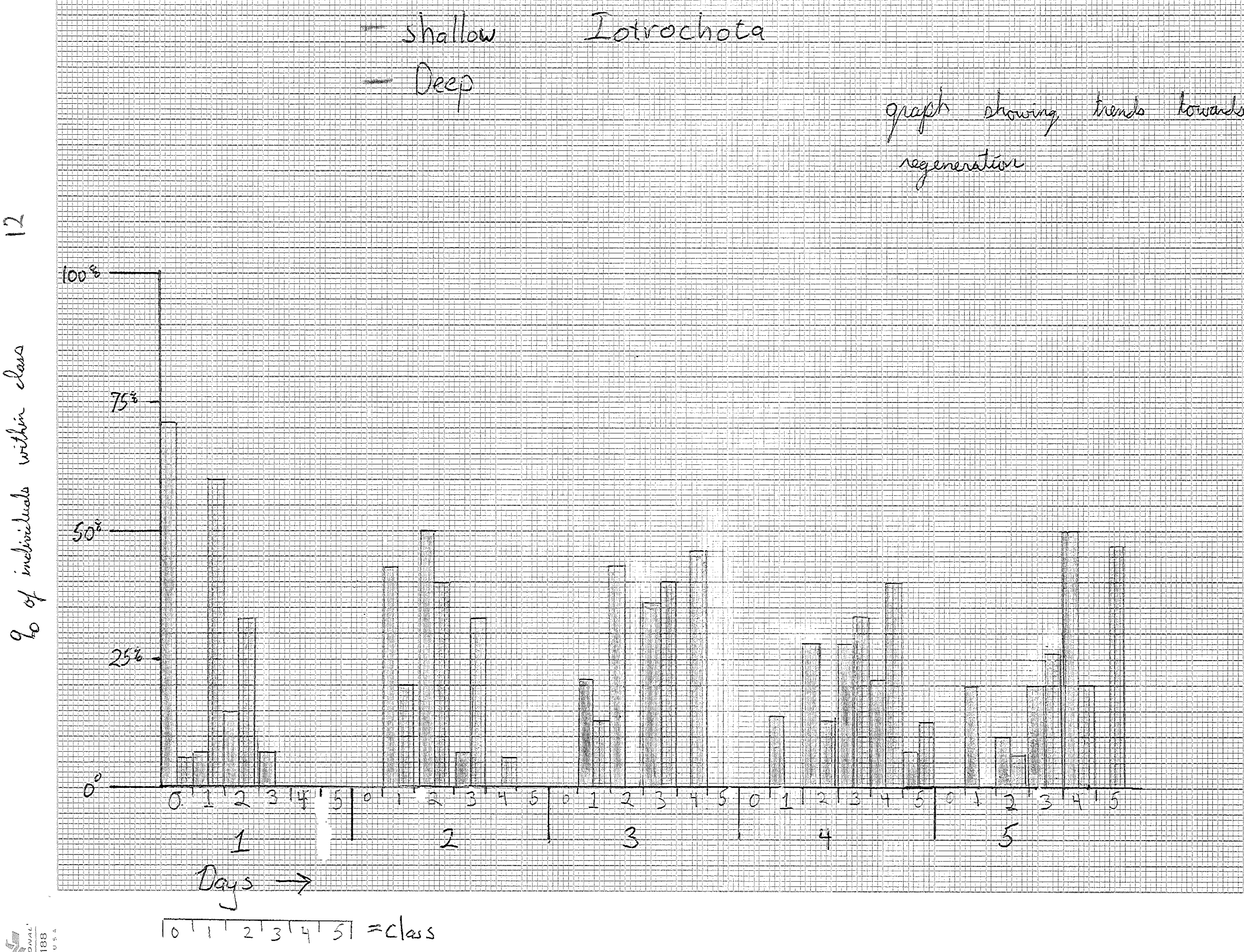
Table 2.

	G-Value	α
D x C x S	122.44	<.001
D x S	1.44	NS
D x C	13.02	<.025
S x C	146.04	<.001
Iotrochota vs. Verongia (Shallow)	81.8	<.001
Iotrochota vs. Briareum (Shallow)	98.3	<.001
Verongia vs. Briareum (Shallow)	-79.28	NS
I vs. V (deep)	15.44	<.01
I vs. B (deep)	28.52	<.001
V vs B (deep)	10.08	>.05

KEY

C= healing class, D = depth, S= species

readhered to rubble. A 2 cm long segment of tip tissue was significantly attached to the substrate. Separation between sponge and rubble would result in torn tissue. Similarly, 1 out of 2 V. longisama fragments readhered to rubble. In this case, a 1 cm long segment of tip tissue reattached to the substrate. Neither of the B. asbestinum fragments attached to their substrate.



shallow
Deep
Iotrochota
graph showing trends towards regeneration
% of individuals within class
100%
75%
50%
25%
0%
0 1 2 3 4 5
1
2
3
4
5
Days →
0 1 2 3 4 5 = class

Discussion:

In our results it was first important to determine if there was a significant difference between the tip and base regeneration rate for each organism. Since there proved to be no significant difference (G-test, $\alpha > 0.5$) we could then proceed to combine all the hole regeneration rates per species per depth. Such a combination is justified and allows for more accuracy due to an increased sample size.

Addressing the results of no significant difference between tip and base regeneration leads us to suspect the sponge's tissue is much more homogenous than previously hypthosized. If the tissue has rapid growth and a high rate of tissue turnover, then the concentration of growing cells within the sponge structure must be uniform. A uniform distribution of growing cells results in no significant difference in regeneration rates anywhere on the epidermal tissue. However, because sponge growth occurs at the tip, and because reattachment occurs at the tip, we suspect that a small concentration or nucleus of growing cells are distributed directly behind the tip.

Our second test demonstrated a dependence of regeneration on both species and depth (G-test, $\alpha < .001$). Therefore, we did a comparison of each species in the two different depths. In all three species there was a significantly different regeneration rate in the shallower depths. In accordance with our hypothesis the three species regenerated significantly faster in the shallower sites. In addition, *Iotrochota* proved to have a significantly higher rate of regeneration than either *Verongia* (G-test, $\alpha < .001$) or *Briareum* (G-test, $\alpha < .001$). However, there was no significant difference between the regeneration rates of *Verongia* and *Briareum*. A similar pattern was found at the deeper site.

As to why regeneration was significantly faster in all three species at shallower depths, we propose that an increase in availability of food allows for but turbidity slows down sponges' pumping rates

more energy to be converted toward regeneration. In general, shallower depths have increasing concentrations of P.O.M. (particulate organic material) (Reiswig, 1975). Sponges feeding in those more turbid areas can ingest a higher quantity of particulate material (a substrate rich in bacteria and other micro-organisms). Since sponges gain more nutrients from such particles, they have more energy available for growth and maintenance. Hence, an increase in the availability of food biomass allows for a greater quantity of energy allotment toward regeneration.

maybe

Another possible explanation as to why we found faster regeneration rates in shallower depths involves aspects of selective pressures. To survive and propogate in a turbulent environment, sponges have adopted a quick regeneration rate, [thus, preventing competitive displacement.] In deeper waters, where physical stress and competition are less intense, energetics and maintenance rates would possibly decrease.

We have hypothesized several explanations as to why *Iotrochota* proves superior in regeneration. First of all, *Iotrochota* is less dense then the other two species. Therefore, its lost tissue has less biomass (per unit volume) to replace than those of the other species. Accordingly, energy expenditure remains minimal for tissue regeneration. Also, *Iotrochota* has the simpliest vascular system of the three species studied. This simple system of oscula and canals takes less time to rebuild than the complex systems of *Verongia* and *Briareum*. So in all, *Iotrochota's* simple porous structure ends ups being the quickest and most efficent to reproduce.

what's the evidence for this?

Another possible explaination for *Iotrochota's* rapid regeneration could be found in the surface morphology of the sponge. *Iotrochota* has an irregular "lumpy" surface. This surface has a higher proportion of surface area to radius than that of *Verongia*. The increased surface area means more tissue for filtration resulting in more nutrients coming into the system. Again, nutrient advantages could be utilized for growth and regeneration superiority.

This argument doesn't follow since the filtration surface is the flagellate chambers inside the sponge.

A final explanation for *Iotrochota's* regeneration superiority could be explained by some unknown concentrations of symbiotic bacteria. It has been found that symbiotic bacteria can increase carbon induction benefiting the sponge nutritionally (Wilkinson and Garrone, unpublished data).

Briareum's slower regeneration can be explained by the same principles of energy dynamics. When a sponge loses tissue, the tissue can be fairly easily replaced by proximal cells. However, in the case of *Briareum* more than just two or three simple cell structures must be rebuilt. When we punctured *Briareum* we destroyed several layers of specialized tissue (along with five or six polyps). Rebuilding a polyp requires major energy expenditure for; gonads, mesenteral filaments, tentacles, etc. must be replicated. Instead of spending the energy to rebuild these complex structures, our octocoral simply sealed off the wound from possible infection. It would be economically "wise" for the octocoral to simply leave this wound or heal it very slowly to conserve energy for maintainance of its healthy structures. Either way a very slow recovery would ensue, which is exactly what we observed.

In the field, we witnessed two different strategies in cavity regeneration. Iotrochota's wounds tended to heal by filling from the bottom of the cavity upwards. In contrast, Briareum and Verongia tended to have their epidermal peripheral cells expand, sealing of the top of the hole. We can explain such phenomena by the same principle of tissue variation. As stated before, Iotrochota has a morph of seemingly homogonous cells. Since the interior cells are genetically similar to those of the epidermis they can readily be converted to "external" cells upon exposure. Than while growing the new epidermal cells rise to the previous surface level for re-establishment of efficient filtration.

evidence?

However, the more advanced Verongia and Briareum require alternate strategies. Within the first or second day, these organisms had expanded their circumferencing epidermal cells resulting in constriction of the wound's opening. Such a constriction facilitates the protection of specialized cells located near the core or axial rod (in the case of gorgonians) of the organism. Here, unlike *Iotrochota* the internal cells can not be adapted to surface functions, therefore, the organism attempts to protect or seal off these internal cells. Then the next likely step in the recovery process would be regeneration of the lost specialized cells within the newly sealed cavity. Still such a process has one definite disadvantage, in turbid waters sediments may enter the cavity. By "capping off" the cavity, the organisms could be exposing their ~~selves~~ delicate internal tissue to irritation and possible disease. Unlike *Iotrochota* that expels such debris during the outward cell expansion, *Verongia* and *Briareum* probably have an internal system ~~of fagotization~~ phagocytosis to eliminate such harmful impurities. Again, this advanced system would take more than just five days of observation to positively define.

Finally, we would like to comment on

our findings of fragment reattachment. First of all *Briareum* showed no signs of attempted reattachment over six days. Secondly, *Verongia* appeared healthy and reattachment (although only slight) was observed in only one fragment. Lastly, we did witness one complete and one partial reattachment in the two *Iotrochota* fragments. The first fragment showed signs of extending several of its external black spicules into the algae covered substrate. The second fragment had a definite tip attachment, consisting of a dark tissue extension onto the coral rubble. This tissue firmly 'glued' the fragment to its substrate. It is interesting to note that both *Iotrochota's* adhesion attempts were conducted by the sponges black - not green - tissue portions. Perhaps, the black tissue is used in growth and adhesion while the green serves some other function.

In conclusion we found that all three species regenerated more rapidly in shallower depths. Of the three species in our study *Iotrochota* proved to be the most able to regenerate wounds and readhere fragments to the substrate. Because *Iotrochota* has a less dense tissue it is more susceptible to penetration and fragmentation. However, since the organism reproduces 'vegetatively this structure proves to be an actual advantage in colonization. In general, Porifera's primitive cell organization does allow for successful existence in the ~~turbid~~ turbulent environment of the coral reef.

Very nice study.

Discussion on pp. 16-19 is much too long since it is very speculative.

References

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note, we are also grateful for information and consultation on our project by Janie Wolf.