

Relative Spicule Abundances and Regeneration Rates
in the phylum Porifera over a Depth Gradient.

Very good job on a subject
in which it is difficult to
come up with crisp hypotheses.
Good, critical discussion. Good
data analysis and presentation.

Chris Lena

Greg Zittel

Abstract

LENK

The coral rubble in Discovery Bay on the northern coast of Jamaica is littered with sponges of all shapes and sizes extending over a depth gradient from 10-30m. This study examines the regenerative capabilities of four species of sponges with respect to depth and relative spicule abundance. We propose that individuals in shallower regions will have a higher spicule density to better protect their structures from damage due to the increased turbulence in these regions. We also suggest that the regeneration rates for individuals in shallow regions could be faster than for their conspecifics in the deeper water regions, due to increased nutrient availability, possible symbiotic organisms which would benefit with increased light exposure, or increased selection for high regeneration rates to reduce tissue losses due to turbulence. We also predict that those individuals with a higher relative spicule abundance would experience lower regeneration rates because of the high energetic cost associated with spicule production.

In Discovery Bay, Jamaica, from Feb. 28 - March 7 1987, we bored 90 holes in 31 sponges over a 33' depth gradient. Samples collected from each sponge were examined in the lab under a compound microscope for a relative count of spicule abundance. Regeneration was estimated every two days for each sponge and tabulated as a final percent recovery rate. These values were then used in further analyses such as correlations and Student t-tests.

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There were no significant trends in relative spicule abundance or regeneration rate over depth. The regeneration rate for ~~the~~ Ircinia (Pineapple sponge) showed a marginally significant $.1 < p < .05$ for negative correlation with spicule density. The mean regeneration rates were different for different species.

Introduction:

(Almost)

plasmal)

All most no data exists on the effects of depth or spicule content on sponge regeneration rates. Similarly, little information is available that demonstrates a change in spicule density over a depth gradient. However, researchers like A. M. Ayling (1981, 1983) and Jackson and Palumbi (1978) have demonstrated that regeneration of damaged tissue in sponges does occur. One study by Ayling (1981) found that the rate of regeneration of *Stylioporus*, an encrusting sponge, was 200 times that of the normal growth rate of the species. A short-term study performed by Dartmouth students (Chase, and Kyllstra, 1985) further demonstrated that regeneration of damaged tissue in some species of sponges at Discovery Bay can begin almost immediately. (1-2 days). With regard to spicules, most studies have focused primarily on classification of the many different types and sizes of spicules found in a variety of sponge species. Also, several researchers have shown that spongins fibers, in addition to spicules, or alone can provide the necessary support needed for some sponge species.

The main purpose of this study was to determine the effects of spicule content on regeneration rates in reef sponges. Spicules are very important in maintaining the gross structure of the sponge, but spicule secretion requires a large percentage of the sponge's energy budget. Undoubtedly, these two factors effect the regeneration rates in sponges with high spicule density. First, restructuring tissues with high spicule density may require more time because of the increased energy necessary to produce spicules. Second, sponges with higher spicule density are most likely subject to less mechanical damage. Therefore, past selection pressures for faster regeneration rates have not been as intense as those sponges which are frequently subject to tissue damage. The ~~major~~ major hypothesis to be tested in this study is that regeneration rates of sponges decrease with increased relative spicule content.

Two additional ideas which will be examined are the effects of depth on spicule content and regeneration rates. Increased turbulence in shallower waters ~~should~~ increase the need for more

structural support in the sponge tissue. It seems logical that shallower depth sponges should have adapted higher spicule densities over time. ~~Assuming~~ Assuming that spicules do indeed deliver more structural support and adequate flexibility as compared to spongin fibers) whether regeneration rates are faster in shallower waters because of increased frequency of tissue damage, or slower because of higher spicule density remains to ^{be} tested.

Study Site - Materials - Methods :

The study was conducted over a six day period (3-2-87 - 3-8-87) at Discovery Bay Marine Laboratory in Jamaica, West Indies. The experimental area (Mooring #1) was composed of rough reef buttresses which were divided by sand channels that contained small patch reefs. Our study plots were established on both reef buttresses and reef patches, over a depth gradient of 33 ft.

(27 ft to 60 ft) Sponge diversity and abundance at shallower depths (< 35 ft) seemed reduced as compared to those observed at deeper depths.

This may be a result of the damages sponges received from Hurricane Allen (1980), or more likely, that sponge species prevalent at Discovery Bay fail to colonize shallower waters or are out-competed for substrate space.

Eight sponge species were examined in the experiment, but only four species were observed over a depth gradient. (A total of 31 sponges were tested in the experiment.) Regeneration rates were determined by boring 3 holes (6 mm diameter and 1 cm depth) around the middle

section of each experimental sponge with a cork borer. Subsequent regeneration was then examined after 2, 4, 5 or 6 days of regrowth.

At every observational interval all 3 holes of every sponge were examined and scored from 0-4 depending on the amount of regeneration ^{that} took place. (0 = 0%; 1 = 1-25%; 2 = 26-50%; etc.)

Sponge samples were also obtained from each sponge by cutting a small piece with a scalpel. These samples were used to determine spicule size, type and relative abundance.

All sponge samples returned to the laboratory were cut by a 5mm diameter cork borer and again cut to a length of 1mm. Those specimens were placed in small plastic petri dishes (set at an angle) with 5 drops of Clorox bleach, and allowed to sit undisturbed for 24 hours.

The next day 5 additional drops of water were added to each dish and the partially dissolved tissue removed. The remaining liquid sample was drawn into an eye dropper and the 3rd drop of each sample was placed onto a glass slide. Slide

Covers were added and specimens were observed under a compound microscope, (10x)

The slide was first studied for spicule type and average spicule size. Then, three random viewings (all spicules seen in the center) were counted. Mean spicule number was determined by averaging these three recordings.

Correlation tests and student t-tests were used to determine if any significantly differences existed either intra or inter-specifically between sponge species in reference to relative spicule abundance, regeneration rates, and depth.

~~It would have been a good idea to describe, and possibly draw, each of the sponge taxa investigated, in light of the fluid nature of sponge taxonomy, and any uncertainty you may have had in identifications to species.~~

Results:

Figure 1 - Spicule number vs. depth.

*Aplysina longissima** was the only sponge species to exhibit a positive correlation between spicule # and depth ($r = .95$; $p < .01$). All other species failed to demonstrate any significant correlation - *Nestospongia* ($r = -.648$), *Black volcano* ($r = .501$) and *Irininia* ($r = -.693$).

*

Shallow samples may have been similar looking gorgonians instead of sponges.

Figure 2 - Regeneration rates vs depth

None of the species tested demonstrated a positive correlation between regeneration rates and depth existed. - *Nestospongia* ($r = .576$); *Aplysina* ($r = -.608$); *Black volcano* ($r = .902$); *Irininia* ($r = .601$)

Figure 3 - Regeneration rates vs spicule number

Irininia was marginally significant ($r = .700$; $p \approx .07$), but all the other species exhibited no positive correlation between regeneration rate and spicule number. - *Nestospongia* ($r = -.134$)

Aplysina ($r = -.464$); Black volcans ($r = .078$).

Table 1 - Data of 31 sponges

Table 1 includes a list of parameters and values tested in our experiment. In addition to information already stated on the graphs (Fig 1-3) values for *Spongia*, *Verongula avidis*, *Agerias septem*, and *Iotrochota* sponges are present.

Figure 4 - Regeneration rates between species.

- *Iotrochota* seems to stand alone at the top of the regeneration rate hierarchy. *Keskspongia*, on the other hand, is significantly slower at regenerating than all other sponges tested.

Spicule number vs. depth, regeneration rate vs. depth, and spicule number vs regeneration rate were tested ~~to~~ across all species (31) to see if a positive correlation occurred in any of the tests. None did. (r values respectively were $r = .083$, $r = -.071$, $r = .155$)

Figure 1 - Spicule # vs Depth

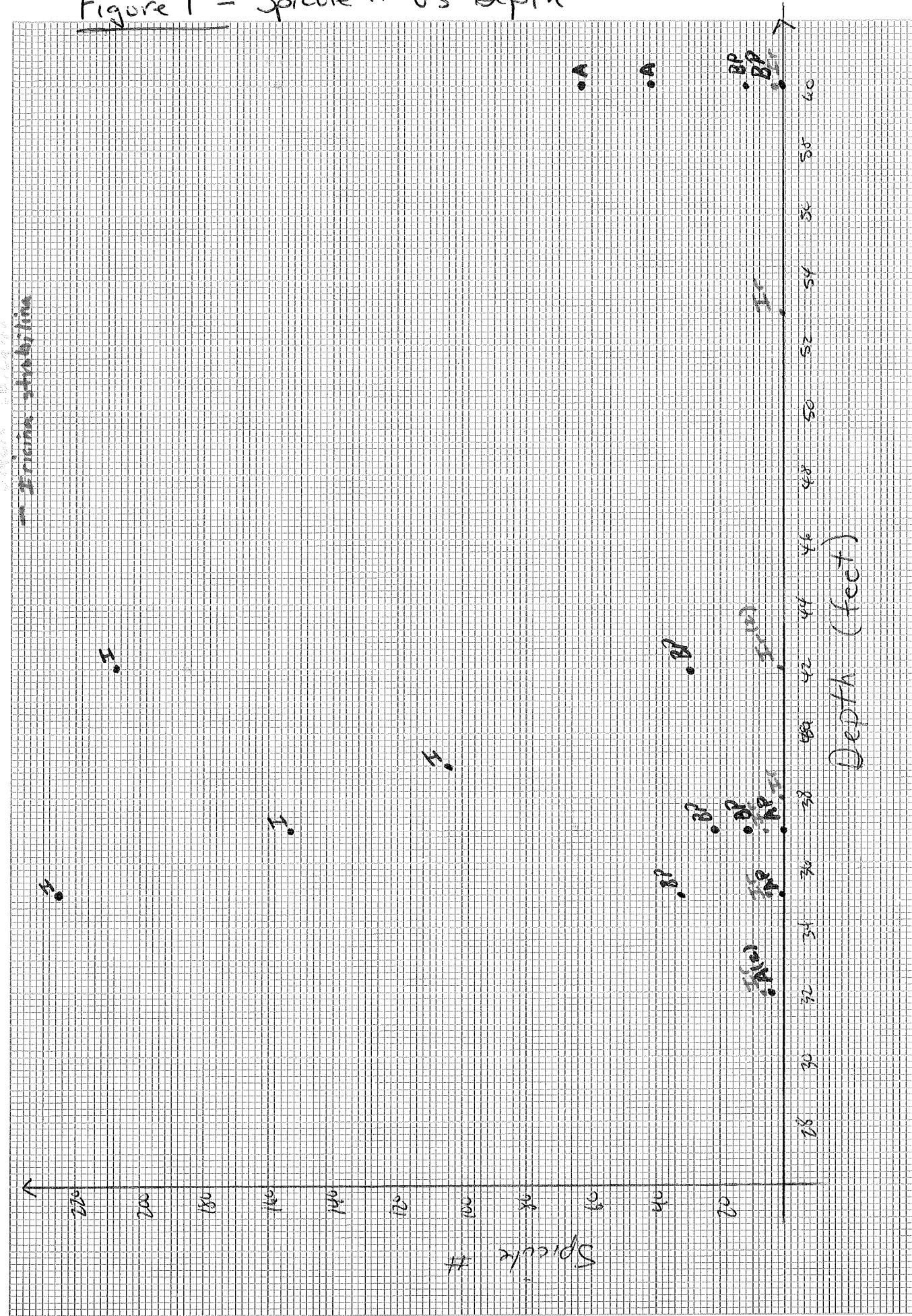


Figure 2 - Regeneration Rates vs Depth

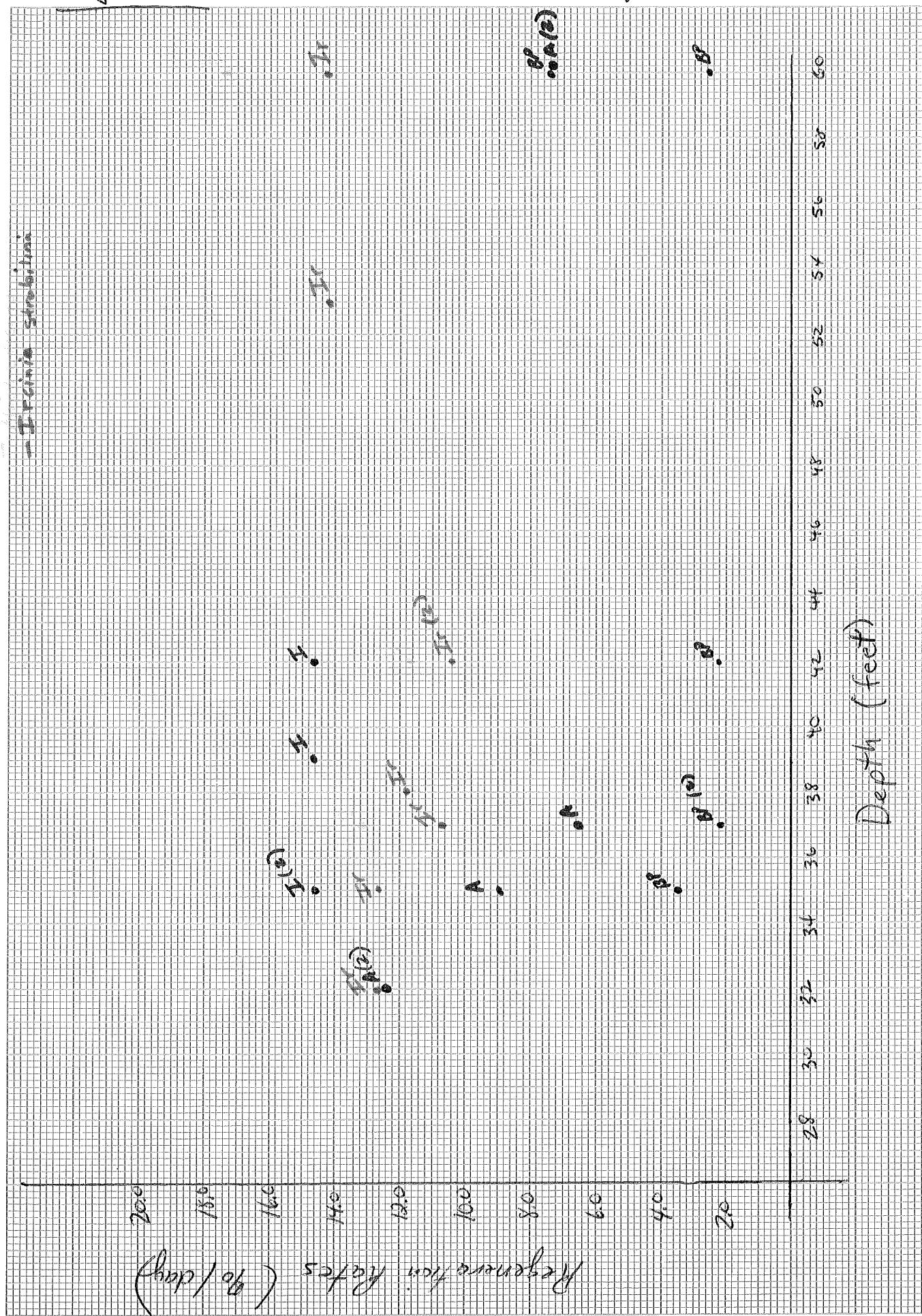


Figure 3 - Regeneration Rates vs Spicule #

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- = *Tetraclita biretulata*
- = *Xestospongia testudinaria*
- = *Aplysina longissima*
- = *Ecteinascidia strobiformis*

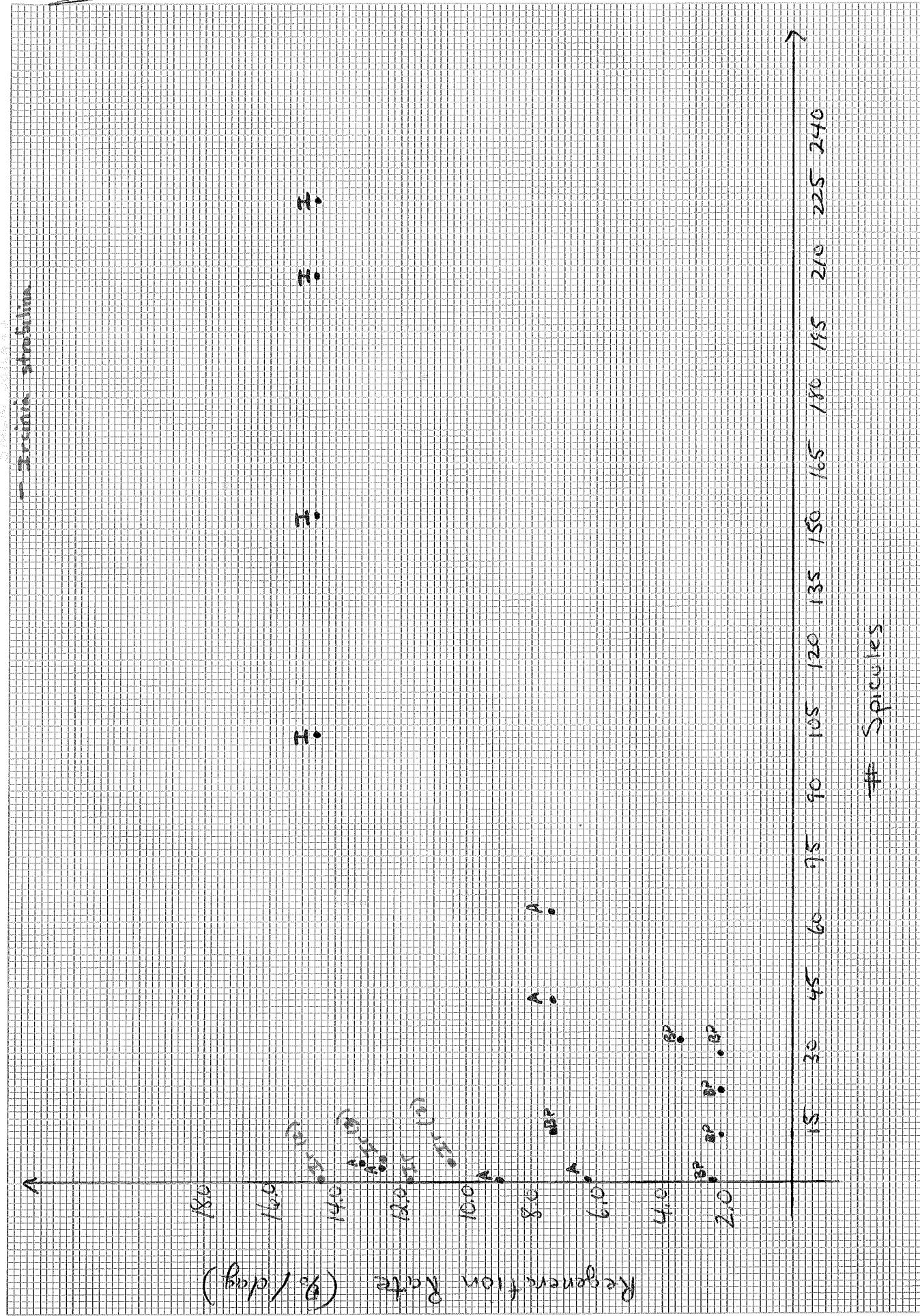
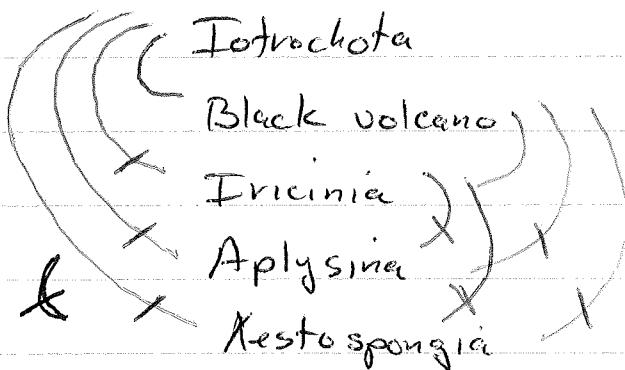


Table 1 - Raw Data of 31 Sponges Tested. 14

#	Species	depth	Spicule			Regeneration rates (%/day)
			type	size (mm)	Relative abundance	
1	Spongia	27	-	-	-	14.6
2	Verongula ardis	32	-	-	-	14.2
3	Aplysina	32	glossy	.4	rare	12.5
4	Agelas sceptum	32	glossy	.5-8.0	rare	2.5
5	Ircinia	32	glossy	.5-1.5	rare	12.5
6	Aplysina	32	screw	.8-1.2	6	13.2
7	Xestospongia	35	screw	.8	32	3.5
8	Aplysina	35	-	-	-	9.0
9	Ircinia	35	glossy	.4-1.2	rare	12.5
10	Iotrochota	35	glossy	1.1	225	14.6
11	"Black Volcano"	37	glossy	.35-6.7	65 rare	13.2
12	Xestospongia	37	screw	.8	21	2.1
13	Ircinia	37	glossy	1.0-3.0	rare	10.4
14	Iotrochota	37	glossy	1.1-1.3	153	14.6
15	Xestospongia	37	screw	.6	11	2.1
16	Aplysina	37	-	-	-	6.3
17	Ircinia	38	-	-	-	11.8
18	Iotrochota	39	glossy	1.4	103	14.6
19	Agelas	39	screw	.9	2.5	14.6
20	Ircinia	42	glossy	1.2-2.3	rare	10.4
21	Xestospongia	42	screw	.8	30	2.1
22	"Black volcano"	42	glossy	1.0	185	11.8
23	Iotrochota	42	glossy	.11	208	14.6
24	Ircinia	42	glossy	1.1	rare	10.4
25	Ircinia	53	-	-	-	14.2
26	Ircinia	60	-	-	-	14.2
27	Aplysina	60	screw	.8	63	7.5
28	Aplysina	60	glossy	.8-3.0	41	7.5
29	Xestospongia	60	-	-	-	2.5
30	"Black volcano"	60	glossy	.2-1.0	159	17.5
31	Xestospongia	60	screw	.8	12	2.5

Figure 4 - Regeneration rates between species



- lines with slashes through them mean that the mean regeneration rates between the two species are significantly different (student t-test)

Discussion

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Contrary to our first hypothesis we found that spicule content does not change with depth over all sponges. We based this hypothesis on work done by Palumbi which showed that transplants of genetically identical fragments to different depths would result in the production of different types of material at the different depths. Those transplanted to the shallower, more turbulent environments would produce a stiffer (more spongin and more spicules) tissue whereas those in the deeper, less turbulent habitats would produce soft tissue (Palumbi 1984). It is possible that the sponges which occur in the shallower regions could have growth forms which would be less affected by the turbulence and thus would not require the expected increase in spicule abundance.

Increased spicule content could possibly make sponges more brittle, whereas an increase in the spongin content could make them more flexible - which would be the desired support structure in the shallow regions.

There was a significant negative correlation between spicule abundance and depth for Aplysina (purple rope sponge).

It is most likely that this relationship is due to the fact that there is a purple gorgonian which closely resembles Aplysina and could have been mistaken for it in a few cases.

The sponges with longer regeneration times experience a loss of feeding tissue, loss of reproductive potential, and an increased probability of larval recruitment by superior competitors (Randall + Hartman, 1986).

longer regeneration times
loss of feeding tissue
loss of reproductive potential
increased probability of larval recruitment by superior competitors

also?

One would expect the pressures for faster regeneration rates to be greater in the shallower, more severe habitats. Those sponges in the shallow waters would also have the greatest accessibility to nutrients, and the individuals with symbiotic algae or bacteria would benefit from the high light intensities (Rützler, 1978). Instead, we found that there was no significant correlation between the regeneration rates and the depth. This result could be skewed by the different growth forms which would ^{experience} have variable selective pressures for increased regeneration rates. It is possible that the faster regeneration rates in shallow water sponges which would be observed under laboratory conditions are cancelled out by the disadvantageous effects of the increased turbulence.

Spicules and spongins are frequently used in sponges for structural support. The production of spicules is an energetically costly process which takes energy from other sponge processes. One would thus expect an increased spicule abundance to be associated with lower regeneration rates due to the increased energy requirements. The only negative correlation of these parameters we obtained was for the species Ircinia. This hypothesis was difficult to test because of the variations in regeneration strategies between species. The relationship does not exist in most of the species because, instead of regenerating the damaged portion of the sponge with similar material, the sponge could be regenerating by edge extension, cell proliferation,

and immigration followed only later by the division into distinct functional units (Jackson and Polumbi, 1978). Thus for the duration of our experiment the energetically costly process of siphon production probably did not occur, and the initially expected relationship would thus not occur.

We found that there was a significant difference between the mean regeneration rates for the different sponge species. Iotrochota, a tall rope sponge, has the highest regeneration rate of all. Being a rope sponge, with a fragile growth form this species is very susceptible to damage due to turbulence or grazing. This increased susceptibility could have placed selective pressures in the past for higher regeneration rates. One reason for the different regeneration rates between species is the different susceptibilities of the inner portions of the sponges to predation, colonization or future damage. The more susceptible sponges would most probably have higher regeneration rates. The brown plate-like sponge has inner tissue which is composed of coarse, seemingly, inedible material and it's growth form is such that there probably was not much pressure for faster regeneration rates.

One of the major limitations of our study was the inability to obtain a broad depth gradient. Because of diving depth limitations imposed on us by our friendly dive officer we were only able to obtain a depth gradient of 33' which may not have contained enough of a turbulence change to significantly affect our values for relative spruce abundance and percent regeneration. Our methods for measuring spruce density and regeneration rates may not have been accurate enough to detect the very small changes that may have been present. Different species of sponges with different regeneration strategies made it difficult to accurately quantify regeneration for analysis between different species.

Improvements in this study would include a greater number of replicates, a greater depth gradient and should concentrate on a smaller number of species with similar growth forms. The limitations of experimental methods did not allow for the original hypothesis to be properly tested. Spruce ~~density and regeneration rates~~ ^{related} ~~is a poorly studied topic that needs further research.~~ Spruce abundance and related regeneration rates ~~is the~~ over depth gradients is a poorly studied topic that needs further research.

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