Ecological Factors Influencing the Distribution of Cryptofauna

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ABSTRACT

At Discovery Bay Marine Laboratory, Jamaica, we examined the environmental factors of predation, ultraviolet radiation and sedimentation in order to determine what restricts cryptic sponges, bryozoans, tunicates and algae to these protected areas under coral rubble. In situ experiments at 15 and 2 meters revealed that sedimentation overwhelmed all upturned rocks to the extent that the effects of u.v. and predation were negated. Lab experiments using rubble obtained from 1, 4, 7, 10, 13 and 16 m. depths at Mooring 1 demonstrated that u.v. was a significant factor leading to high mortality among sponges and bryozoans, and bleaching among encrusting algae. Descriptions of sponges are provided and suggestions for methodological improvements and future experiments are made.

Introduction

The effects of site- and depth-specific regimes of water turbulence, sedimentation of particulate matter, grazing by fish and urchins, and sunlight on the community structure of exposed reef organisms have all been well documented. But beneath these exposed organisms, and on the undersurfaces of rocks and coral rubble in many areas of the Discovery Bay reef, live an abundance and diversity of sponges, algae, bryozoans, and tunicates whose community structure has been less extensively investigated. Still, these same factors — predation, UV radiation, and sedimentation — have been suggested as mechanisms which restrict these cryptofauna to their hidden habitats.

Bakus (1966) reported immediate and extensive predation by rasping fishes on cryptofauna exposed by overturning rocks. Proctor (1979) found that up to 36% of the cryptofaunal surface area was eaten off rubble overturned for 24 hours in Discovery Bay.

Jokiel (1980) demonstrated the adverse effects of shortwave solar radiation on many "shade-loving" reef organisms including cryptofauna. In three days, up to 80% of the cryptofaunal coverage on rocks overturned in shallow tanks was destroyed by direct sunlight. Similarly treated controls, except with UV radiation filtered from the sunlight showed no mortality over the treatment period.

Ham et al (1981) concluded that predation, and

UV was not specifically tested. 1

UV radiation operate to different degrees to structure cryptofauna communities at various depths in Discovery Bay. They also indicated that sedimentation and wave action, for which they did not control, might have caused mortality in experimentally exposed cryptofauna.

In this study, we examined the roles of predation, solar (UV) radiation, and sedimentation in the restriction of cryptofaunal communities to unexposed substrates. Using appropriate controls, we tried to determine the separate effects and comparative impact of each factor for different sites. We also examined the pattern of cryptofauna types, numbers, percent coverage along a depth transect through the west fore reef in Discovery Bay.

Methods

We performed the following in situ experiments in three sites on the Discovery Bay reef. The deepest site (15m.) was on the west fore reef in a sand channel beneath Mooring 1. We chose an intermediate site (5m.) in the sandy area between Jim's Hard and the east back reef. The shallowest site (2m.) was a sand patch in the west back reef area. At each site, we positioned an exclosure 2 - 10 m. from the nearest major reef structure (a lobe or the crest) and secured it with wire tied to coral outcroppings. We collected rubble with cryptofauna

from the area nearby each exclosure.

We collected rubble for the lab experiments along a depth gradient transect beginning in the sand channel beneath Mooring 1 (16m.) and continuing towards the reef crest to the Acropora palmata zone (1m.)

In situ

At each of the three sites, we selected 15-25 pieces of coral rubble harboring an above average abundance and diversity of cryptofauna. (We determined average abundance and diversity by sampling many pieces at each site). Rubble sizes varied from small pieces of A. cervicornis 15 cm long to large slabs of Agaricia and Montastrea 45 cm x 25 cm on their undersides. The rubble pieces at each site were apportioned into 5 groups such that all groups contained similar total surface areas of cryptofaunal coverage. Group sizes ranged from 2-5 rubble pieces. One group of rubble at each site was overturned, exposing cryptofauna to the water column and the effects of predation, sedimentation and UV radiation (group ④ in Fig. 1). Using a three chambered exclosure, we were able to expose the next three groups of overturned rubble to the separate effects of UV radiation but no sedimentation, neither UV radiation nor sedimentation, and sedimentation but no UV radiation (groups ①, ② and ③, respectively, in Fig. 1). The final group was kept as a control, not overturned, with

cryptofauna toward the ocean floor as found naturally. (group ⑤ in Fig. 1)

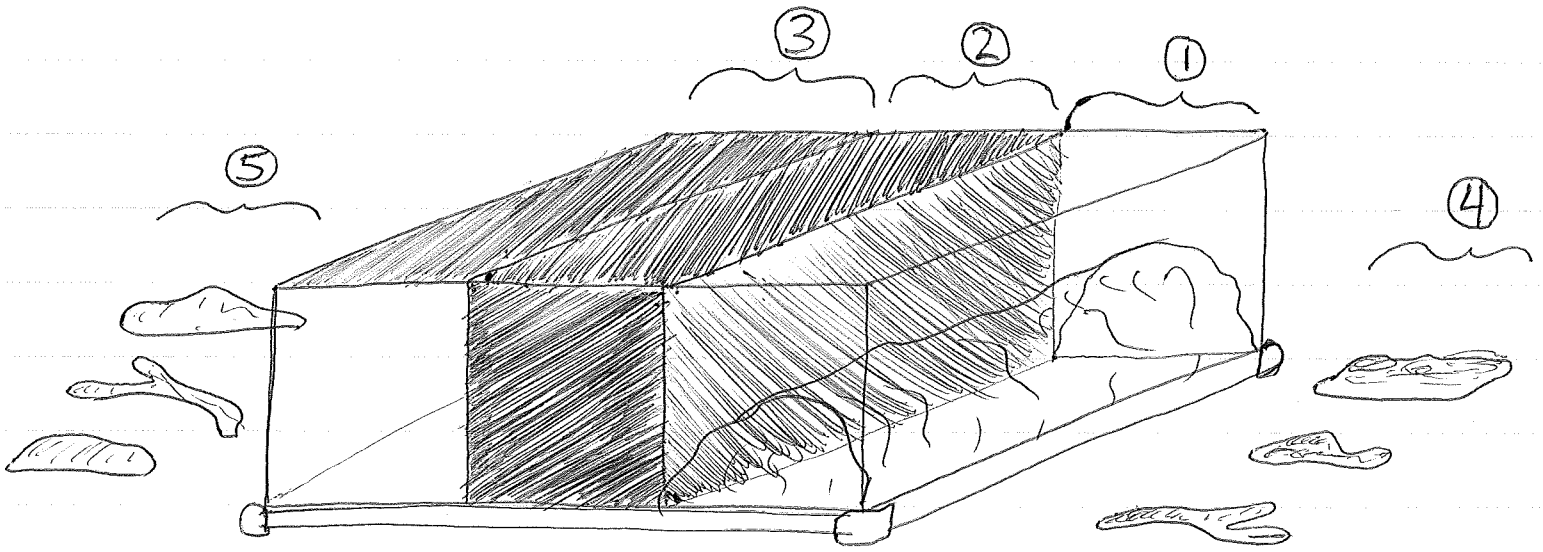

Figure 1. The exclosure setup at each site.

We took and developed black-and-white photographs of each group of rocks at the beginning of the treatment period. We also made sketches of the rubble and noted the general appearance of the cryptofauna at this time. After five days we removed all rubble pieces to the lab where we examined cryptofaunal morphology, texture, color, and condition, and, where possible, identified organisms. By comparing photos, sketches, notes, and these final examinations, we could determine changes in cryptofaunal coverage and condition for each rubble piece during the treatment period. Detrimental effects included bleaching

and discoloration for algae and bryozoans, and sloughing, discoloration, and loss of tissue consistency for sponges and tunicates. These changes and effects were used to assay the relative effects of predation, sedimentation and UV radiation on the crypto fauna at each site.

In the lab

For each of 6 depths on the west fore reef (1m., 4m., 7m., 10m., 13m., 16m.) we collected 4-9 pieces of coral rubble with an above average abundance and diversity of crypto fauna. We removed half of the rubble pieces from each depth to a sea water tank outside the DBML's wet lab area. We kept the rocks at an average depth of 20 cm. in these tanks, and positioned them to intercept sunlight daily. We placed the other half in a sea water tank inside the wet lab area and also at a depth of 20 cm. Both tanks received a regular flow of sea water so levels of particulate matter, O_2, and nutrients were similar in both tanks and probably close to those in the lagoon. The flow rate was quick enough that temperature differences between the outdoor and indoor tanks were small (maximum difference at midday - 28.5°C outside, 27°C inside).

We took black-and-white pictures of the rubble pieces at the beginning of the treatment, along with notes and sketches of [redacted] cryptofaunal coverage and condition.

We examined the cryptofauna daily and noted changes in color, texture, morphology, and condition. After four days, we removed rubble to the wet lab for final examination of tissue condition. We also identified as many organisms as possible. With no predation and low sedimentation in the sea water tanks, we could compare changes in the cryptofauna in the two treatment groups to determine the exclusive effects of UV radiation.

We also used our data on the numbers, types and percent coverage of cryptofaunal organisms on rubble from the 6 depths on the west fore reef to trace any patterns in cryptofauna communities with respect to depth.

Results

Full listings of the raw data summarized below, and of the sponge, algae, tunicate and bryozoan operational taxonomic units (otu's) we identified on rubble pieces for both the *in situ* and lab portions of the experimentation appear in appendices I and II at the end of this paper.

In situ

Table 1 summarizes the results for sponges of our *in situ* experimentation. It excludes data from the intermediate site. The exclosure at the east back reef was damaged by turbulence and other factors. Because we are

unsure of how adequately our controls were consequently maintained, we chose to ignore the treatment groups from this site. For the Mooring 1 data, chi-squared tests indicated no significant differences in the frequencies of damaged and undamaged organisms between any two treatments. For the west back reef, the only significant differences were between treatment ③ (no UV, no predation, sedimentation) and ⑤ (unaverturned control) ($\chi^2 = 11.3$, $\alpha < .025$, 3df). This demonstrates that exposure of cryptofauna to sedimentation increases sponge tissue damage at this site. Statistically, sedimentation was the only factor we examined that significantly caused sponge damage. Mortality in predation- and UV-exposed sponges did not differ statistically from the controls

Table 1. Percentage of sponges damaged* for each treatment† at each site

site	①	②	③	④	⑤
Mooring 1 (15m.)	0 (0/4)	33 (1/3)	57 (4/7)	67 (2/3)	33 (1/3)
West back reef (2m.)	—	60 (3/5)	100 (3/3)	67 (2/3)	0 (0/3)

* Percent damaged = (# of sponges damaged during treatment period / # of sponges present at the beginning of the treatment) × 100

† ① = UV, no predation no sedimentation ③ no UV, no pred, sed ⑤ control
② = no UV, no pred, no sed ④ UV, pred, sed

Chi-squared tests also showed no significant difference

in the freavencies of damaged and undamaged individuals in the same treatment between sites. Predation, sedimentation and UV radiation did not affect sponge condition differently at the different sites.

The sponges represented by these data were 39 individuals in 18 OTU's. The sample of rubble pieces from the in situ experiments also contained one tunicate which survived a group ③ treatment at Mooring 1 and three species of encrusting, calcareous red algae which were present on most of the rubble pieces and which survived all treatments at Mooring 1 and WBR.

In the lab

Table 2 summarizes the results of our lab experimentation for each major taxon studied. A significantly greater percentage of sponges and bryozoans exposed to direct sunlight were damaged than their shaded counterparts ($\chi^2 = 17.1$, $\alpha < .001$, 3df. for sponges; $\chi^2 = 7.9$, $\alpha < .05$, 3df. for bryozoans). No significant differences were found between the percentages of tunicates or two algal species damaged outside and inside the wet lab ($\chi^2 = .84$, $\alpha > .5$, 3df. for tunicates; $\chi^2 = 0$, $\alpha > .995$, 3df. for algae). One of the algae OTU's (#1) was affected by placement in direct sunlight. ($\chi^2 = 19$, $\alpha < .001$, 3df).

The coral rubble pieces collected for lab experiments contained 48 sponge individuals from 25 OTU's (9 of

which were shared with sponges from the in situ rubble), 11 bryozoan colonies from 2 OTUs, 5 tunicates from 3 OTU's and the same three algae OTUs we observed on the in situ rubble.

Table 2. Percentage of cryptofauna damage inside and outside the wet lab

	Sponges	Bryozoans	Tunicates	Algae OTU #2 + #15	Algae OTU #1
outside	63 (17/27)	80 (4/5)	33 (1/3)	0 (0/38)	62 (8/13)
inside	5 (1/21)	0 (0/6)	0 (0/2)	0 (0/18)	0 (0/24)

Table 3 and Figure 2 show how the abundance and percent cover of each of these organisms varies with the different depths from which rubble was collected. No major trend is visible in abundance data due to the low number of individuals per OTU. Also, the total numbers of cryptofaunal OTU's per depth were similar. With respect to percent cover, again no depth-specific trends are visible. In general, however, sponges averaged 0-5% coverage, seldom 5-20% and once 40-60%. Bryozoans always covered less than 5% of the rubble's undersurface area. Tunicates averaged between 0-5% and 5-20% coverage. Algae OTU's #2 and #15 were mostly 0-5% coverage, while algae otu #1 averaged between 5-20% and 20-40% coverage.

Table 3. Number of individuals per OTU found on rubble pieces from different depths

OTU	1m.	4m.	7m.	10m.	13m.	16m.
Orange Sponge #1		1		1	1	1
Orange Sponge #2		2		2	2	2
Orange Sponge #3	2					2
Orange Sponge #4				1		
Orange Sponge #5		1				
Orange Sponge #6				1		
Orange Sponge #7						1
Clear White Sponge #1			1	2		1
White Sponge #1			1	2	1	
White Sponge #2		1				
White Sponge #3		1				
White Sponge #6		1				
White Sponge #7	1					
White Sponge #8	1		1			
White Sponge #9						1
White Sponge #10		2				
Black Sponge #1	1				1	
Black Sponge #2	1					
Black Sponge #3	1					
Blue Sponge #3				1		
Blue Sponge #5				1		
Blue Sponge #6		1				1
Purple Sponge #1				1		
Green Sponge #2					1	
Orange Bryozoan			1	1	3	
Brown Bryozoan			2		1	
Green Sponge #3					1	
"Strawberry" Tunicate				1		
Blue Tunicate				1		
Tunicate #2	1	1			1	
Algae #1	5	5	9	8	7	3
Algae #2	4	5	6	6	1	1
Algae #15	2	3	2	2	5	1

1m. sample contained 5 rubble pieces

4m - 5 pieces

7m - 9 pieces

10m - 8 pieces

13m. - 7 pieces

16m. - 5 pieces

Blank boxes = 0

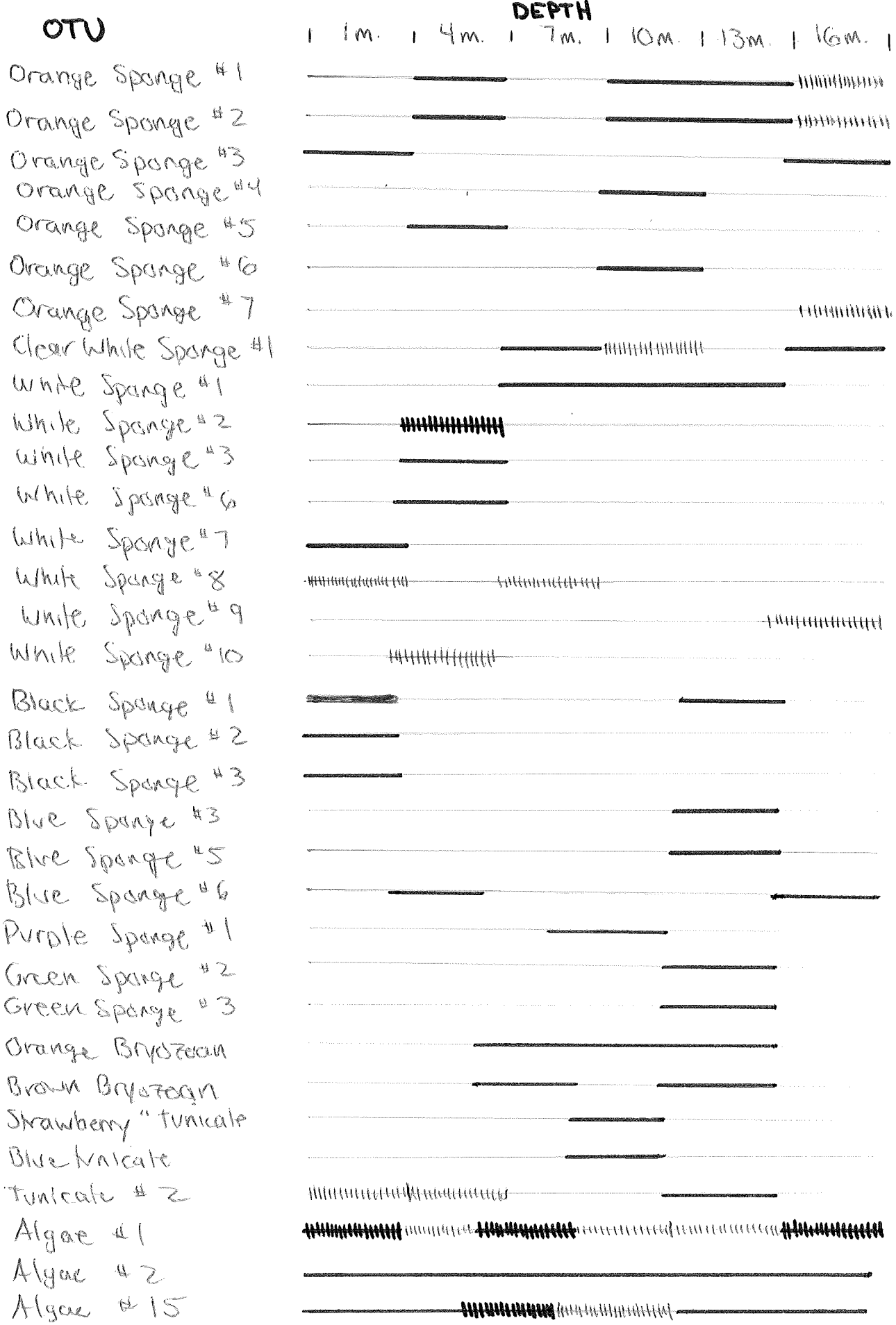

Figure 2. Average percent cover of each OTU on rubble from different depths.

Discussion

In situ experiments at Mooring 1 and West Back Reef (Table 1) reveal several environmental factors affecting cryptofauna that are not necessarily confirmed by statistical analysis. In general, our lack of significant difference between *in situ* treatments was more a result of small individual sample sizes than to a lack of important trends. Most important of these factors is sedimentation. At both cage sites, water surging had caused sand to heavily cover the rubble we deliberately exposed to sediment (treatments 3, 4 and 5), and more lightly settle on the rubble we attempted to shield (treatments 1 and 2). Indeed, sedimentation was so heavy in some treatments (8-10 cm) that we feel it shaded the rubble from any appreciable affects that U.V. radiation or fish predation may have caused. There are probably several reasons for this. First, we placed cages on sand channels, between reef lobes, thereby exposing them to a very high amount of turbulence that washed sediment back and forth over the rubble. Had cages been placed on reef lobes there would have been less sediment. Further, the cages themselves acted as sediment traps - "snow-fences", if you will, where sand accumulated more rapidly.

Predation was not a very significant threat to the cryptofauna in our study. When we collected rubble

there were a few instances of rainbow and blueheaded wrasse fish feeding on the bottoms of the rubble in our hands, but they were most likely eating zooplankton. Sponge predators, mostly Chaetodonids (the butterfly fishes) are fairly scarce here at Discovery Bay due to high local fishing pressure. Also, our cages were placed on sand channels and not on reef lobes where there is a higher abundance and diversity of fish.

We observed urchins grazing on rubble collected and placed in the wet-lab tanks for pre-experimental observations and cryptofaunal identification. Only once in the field, however, did we find an urchin on the bottom of a piece of rubble we collected. (Eucidarias tribuloides). Further, there was no visual evidence of predation on exposed rubble, and we never observed urchins near the cages at any time during the five exposure days. Also, one of the most common urchins usually found here, Diadema, is now scarce after the 1983 epidemic, which has doubtless reduced urchin predation pressures greatly. This fact, coupled with cage placement, low Chaetodonid presence and high sedimentation on rubble, reduced predation pressure to practically nothing. This is somewhat borne out by examining treatments 3 and 4, where they received

equal exposure to sedimentation, but one (3) was protected from predation, yet the percent damages observed were similar. The effect of sediment is more strongly suggested when one compares treatments 3 and 4 with the control (5), and especially at WBR where there was a significant difference of percent damage between treatments 3 and 5.

We had hoped to test for the effects of U.V. irradiation in situ, but, since sedimentation was so overwhelming, our lab treatments provided a more convincing examination. At the wet-lab, coral rubble could be tested for only the effects of U.V. irradiation, since sedimentation and predation were basically nonexistent. Table 2 reveals that certain organisms were affected more severely than others. Sponges suffered almost complete mortality, with only blue and black boring sponges surviving. This may be due to protective pigments filtering-out U.V., similar to those found by Jokiel (1980) in corals and anemones with symbiotic zooxanthellae. U.V. radiation is probably more severe in outdoor lab tanks than in the lagoon or forereef, where greater depths and higher particulate matter results in an exponential extinction. Nevertheless, we feel our lab experiments resulted in cryptofaunal death that would have occurred anyway at shallow back reef depths, only at a more rapid rate. From the depth transect we conducted at

Mooring 1, no trends revealing distribution or percent cover emerged because our sample size was too small, and many individual OTU's were identified that were unique to single depths or rocks.

The most abundant taxonomic group we encountered were Poriferans. In the appendix we have provided drawings of spicules and spongin, where appropriate, along with physical descriptions of size, shape and so forth. We encountered many different OTU's of sponges, yet almost all were similar in that they were encrusting and/or boring, which leads us to speculate as to the adaptiveness of their form, which allows them to occupy the undersides of rubble, where space and water flow are limited. Since space is one of the limiting factors in the coral reef ecosystem, overlap in the utilization of space may result in competetive interactions among co-occurring populations (Benayah and Loya, 1981). Sponges living on the undersides of coral rubble may be avoiding this intense competition for space, therefore, in addition to the benefits they derive in protection from U.V. radiation and fish or urchin predation. Each individual sponge, then, is probably exploiting these cryptic environments for a variety of reasons, the importance of each varying according to the individual's unique susceptabilities. The relative importance

of each variable could be "teased-out" if one were to identify and isolate several known sponges, or other cryptofauna and subject different morphs to similar pressures examined in this paper. Which brings us to discuss some methodological improvements and ideas for future work in this area.

The first improvement we suggest is to increase the sophistication of the rubble enclosures so they will seal-out more sediment, yet still effectively block U.V. and predation. We think plexiglass boxes, perforated to allow sea water to flow through, yet still block fish and most sediment would work well. Second, these new enclosures might be placed on the reef lobe, and not on the sand channels, in order to reduce sediment, and, where appropriate, expose rubble to fish in an environment where they are more abundant.

Next, and most obvious from our discussion, we feel that more rubble should be collected and/or the number of treatments these rocks are subjected to should be reduced. Further, more effort should be made to identify and collect rubble with similar cryptofauna (i.e. the same sponge) so that more meaningful comparisons of treatments can be made.

Finally, we found that cryptofauna abundance and

variety differed between rubble collected on sand channels versus those collected on reef lobes comprised of *Acropora cervicornis* and *A. palmata*. Comparisons could be made between rubble found at each reef type, or between them. Therefore, many improvements on our basic theme can be made, and many new aspects of cryptofauna ecology remain to be investigated.

A fine attempt at the very difficult task of sorting out the importance of several different variables. Excellent write up of observations, problems, and suggestions for improvements.

Literature cited

Backus, Gerald J. 1966. Some relationships of fish to benthic organisms on coral reefs. Nature. 210: 280-284.

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Proctor, Elizabeth. unpublished. Predation and the cryptofauna of Discovery Bay. Dartmouth Tropical Biology Program 1979, Discovery Bay, Jamaica.

Appendix I a.: in situ raw data

number of indiv. damaged during treatment / number present in beginning

OTU	Treatment Groups * ①	②	③	④	⑤	①	②	③	④	⑤
Purple Sponge #1			0/1	2/2						
Purple Sponge #2			0/1							
Purple Sponge #3									1/1	
Blue Sponge #1				0/1						
Blue Sponge #2					0/1					
Blue Sponge #3							0/1		1/1	
Blue Sponge #4							1/1			
Blue Sponge #5								1/1		
Blue Sponge #6								1/1		
White Sponge #1			0/1							
White Sponge #2					0/1					
White Sponge #3							0/1			
White-blue sponge										0/4
Gray-blue sponge									0/1	
Orange Sponge #1	0/1	1/1	3/3		1/1					
Orange Sponge #2	0/3	0/2					1/1	1/1		0/4
Yellow Sponge #1			1/1							
Green Sponge #1							1/1			
All Sponges	0/4	1/3	4/7	2/3	1/3		3/5	3/3	2/3	0/8
Algae #1	0/4	0/3	0/2	0/4	0/4		0/2	0/3	0/2	0/4
Algae #2	0/1		0/3				0/2	0/3	0/2	0/3
Algae #15			0/3				0/2	0/3		
Tunicate #1			0/3							

* Blank boxes = 0/0

MOORING 1 WEST BACK REEF

* ① = UV, no sedimentation, no predation ③ = no UV, sed. no pred ⑤ control (unoverturned)
② = no UV, no sed., no pred (overturned in exclosure ④ = UV, sed, pred (overturned outside exclosure

Appendix I b: lab raw data

number of indiv damaged during treatment / number present in beginning *

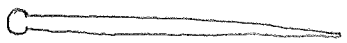
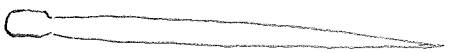
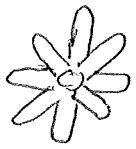
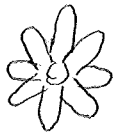
OTU	OUTSIDE	INSIDE
Orange Sponge #1	0/6	0/4
Orange Sponge #2	5/6	0/2
Orange Sponge #3	2/2	0/2
Orange Sponge #4	0/6	0/1
Orange Sponge #5	0/1	0/6
Orange Sponge #6	1/1	0/6
Orange Sponge #7	0/1	0/6
Clear White Sponge #1	1/3	0/1
White Sponge #1	2/2	0/2
White Sponge #2	1/1	0/6
White Sponge #3	1/1	0/6
White Sponge #6	0/6	0/1
White Sponge #7	0/6	0/1
White Sponge #8	1/1	1/1
White Sponge #9	0/6	0/1
White Sponge #10	1/2	0/6
Black Sponge #1	0/1	0/1
Black Sponge #2	0/1	0/10
Black Sponge #3	0/1	0/6
Blue Sponge #3	1/1	0/8
Blue Sponge #5	0/6	0/1
Blue Sponge #6	0/1	0/2
Purple Sponge #1	0/6	0/1
Green Sponge #2	0/6	0/1
Green Sponge #3	1/1	0/6
Orange Bryozoan	3/3	0/5
Ruana Bryozoan	1/2	0/1
"Strawberry" Tunicate	0/6	0/1
Blue Tunicate	0/6	0/1
Tunicate #2	1/3	0/6
Algae #1	8/13	0/24
Algae #2	0/12	0/13
Algae #15	0/11	0/6

* Numbers are for individuals of each OTU from all depth groups combined

This table compares tissue damage rates in cryptofauna placed in sea water tanks outside the wet lab (exposed to sunlight) and inside the wet lab (not exposed).

APPENDIX 2

SPONGE O.T.U.

DESCRIPTION	Spicule / Sponge	Length (mm)
ORANGE SPONGE #1 bright orange, fleshy, boring FAM: Spirastrellidae (?)	Tylostyle 	.3 - .5
ORANGE SPONGE #2 dark red/orange, boring/encrusting.	Subtylostyle 	.2 - .5
ORANGE SPONGE #3 Light yellow/orange, encrusting	Strongyle 	.3
ORANGE SPONGE #4 encrusting, thin, hard orange - translucent w/ small oscula covering surface	1) Strongylaster  2) Oxysphereaster 	.2 - .4
ORANGE SPONGE #5 orange, firm, fleshy raised from rubble surface 3-4 mm.	Triod  Styloid 	.1 - .3
ORANGE SPONGE #6 encrusting, fleshy, bright orange	Strongylaster 	.02 - .05

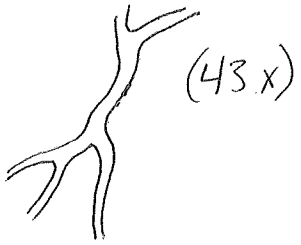
ORANGE SPONGE # 7 | Spicule / Spongin | Length (mm)

orange, encrusting, fleshy | Hastate | .5 - .7

Clear - WHITE SPONGE

small (1-4 mm high), white,
forming bulbs usually 1mm wide

Spongin



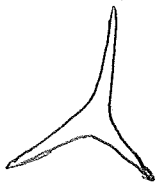
Spicule Microxea.

.2 - .4

WHITE SPONGE #1

thin, hemispherical, gritty-tissue

Triod



.2 - .4

WHITE - SPONGE #2

off-white, small (1cm) - hemispherical
mound
Dense matrix of overlapping spicules, Hastate

.4 - .7

WHITE-SPONGE #3

Very small, hemispherical (.5cm thick)
encrusting. Tissue dense, gritty. Hastate

.3 - .5

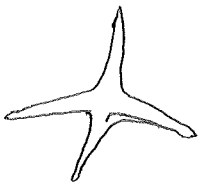
Length (mm)

WHITE SPONGE #6

flat, encrusting < .16 mm thick

tissue gritty

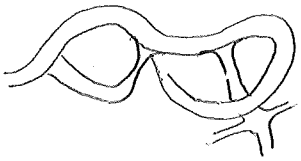
tetrad



.1 - .3

Hastate

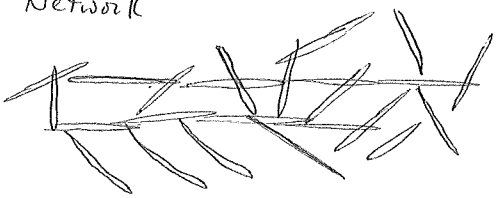
Spongin



White-SPONGE #7

encrusting ~~.3-.5 mm thick~~

Spicule Network



.3 - .5

WHITE SPONGE #8

white, gritty texture

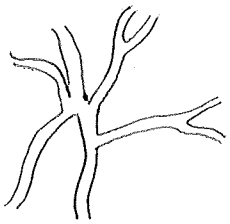
Fusiform oxea

.1 - .2

WHITE-SPONGE #9

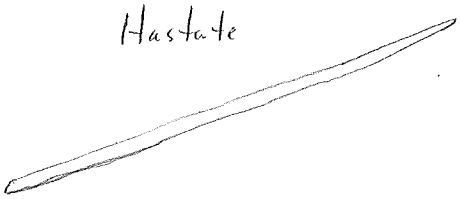
Fleshy, white

spongin



.8

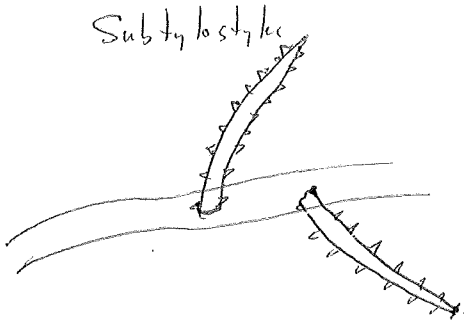
Hastate



Length (mm)

WHITE-SPONGE #10

Spicules embedded in spongin fibers

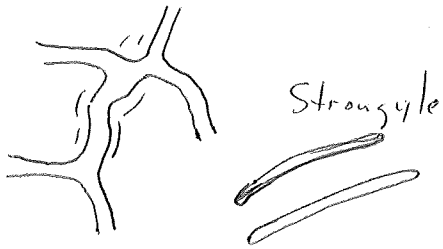


.3 - .5

(Clathrina ?)

PURPLE SPONGE #1

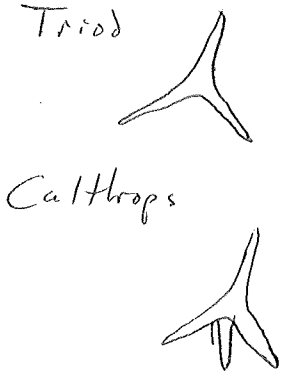
~~encrusting~~, purple, fleshy texture. .7mm thick



.2 - .5

PURPLE SPONGE #2

1 - 3.5 cm thick
thin epidermis

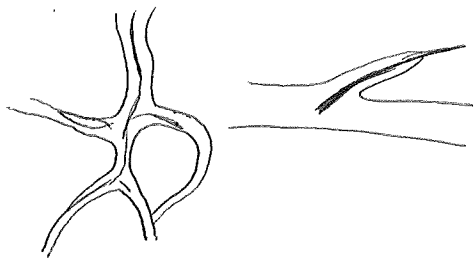


.3 - .4

BLUE-SPONGE #1

~~thin, encrusting 3-4 mm thick~~

spicules (covered) w/ spongin tissue



.1 - .2

BLUE SPONGE #2

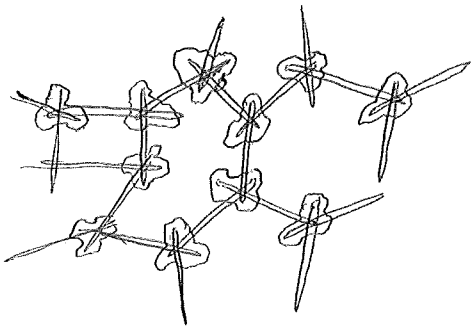
Fleshy, spongin binding together bunches of straight, thin spicules

.1 - .2

Length (mm)

BLUE SPONGE #3

encrusting, 1 cm height
spicules cemented together
w/ spongin forming
geometric network



.2

BLUE SPONGE #4

encrusting, very thin 2-3 mm

Triod

.025

BLUE SP. #5

single spicules

Tylote

.1

BLUE SP #6

thin, dense matrix of overlapping spicules

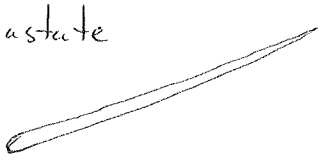
Hastate

.2 - .25

BLACK - SPONGE #1

thin - encrusting 3-4 mm. thick, no spongin visible
single spicules, dense, overlapping

Hastate



.4 - .6

BLACK - SP. #2

thin, flexible .7 cm
no visible spongin

Oxysphenester

.2

Length (mm)

BLACK - SPONGE #3

Small < 4 mm.
encrusting, Fleshy

Triod 

.1 - .3

Hastate 

GREEN SPONGE #1

Small < 3 mm
encrusting,

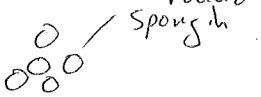
Strongylaxea 

.5

GREEN SP. #2

Small < 1 cm., boring

Oxysphaerester

round spongin 

.05

GREEN SPONGE #3

Boring < 2 mm

Strongyle 

.3 - .4