

THE ASSOCIATION BETWEEN
IOTROCHOTA BIROTULATA COLONIZED
BY THE
TOXIC ZOANTHID PARAZOANTHUS SWIFTII
AND THE
BRITTLE STAR OPHIOTHRIX SVENSONII



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proportionately more are inhabited by multiple brittle stars.

Brittle star size is not related to the density of zoanthids on the

Tetrochota, but number of brittle stars is related. Finally, O. suensonii preferentially settles on sponge pieces with zoanthids in a controlled laboratory study.

They also are preyed upon less when tethered to a sponge than when tethered to non-sponge substrata. O. suensonii may preferentially settle on Tetrochota sponges that are colonized by the zoanthid P. swiftii, and they also may survive longer on sponges with zoanthids. The dark color and bumpy surface of the sponge itself may also confer some protection to the brittle star. The combination of the dark sponge and the toxic zoanthids seems to allow O. suensonii to inhabit the surface of Tetraclita by day & possibly feed, whereas most other species of brittle stars can only feed at night. Possibly this confers a competitive advantage to Suenson's brittle star.

Abstract could be more concise. You can just give the results and their significance; you needn't present the hypotheses in detail before giving the results.

INTRODUCTION

Brittle stars are well known, although not abundant, benthic organisms.

Until the late Mesozoic era, brittle stars (Ophiuroids)

occurred at low densities throughout the world's oceans.

occurred in huge aggregate beds throughout the world's oceans

(Aranson, 1987). During the late Cretaceous period, bony fish

(Teleostei) evolved new adaptations to hunt brittle stars with

predators that had adapted to eat prey with hard skeletons, ~~such as~~,

and the fossil record suggests that these fish dominated many

bottom waters around the world during the Paleogene and Neogene.

epifaunal suspension feeders, including stalked crinoids, brachiopods,

and brittle stars (Aranson 1987). Many fish today, including cod,

flatfish, and wrasse, feed extensively on brittle stars, including the

genus Ophiothrix. For example, Ophiothrix species comprise up to

15% of the diets of several wrasse species in the West Indies

(Randall, 1968). This extreme predation forces many species of

brittle stars to hide in tube sponges or under coral reef rubble

during the day and only emerge at night to feed when predation

pressure by fish is lowest (Rugolo 1982).

However, at Discovery Bay, Jamaica, many Ophiothrix

sensu lato brittle stars cling to the surface of the green finger

sponge Tetrochota binotata during the day, often near the apical end of the sponge where they are the most exposed. This sponge is one of the favorite prey items of the sponge-eating fishes of the West Indies due to its low spicule content (Randall 1968).

Green (1977) found a direct relationship between exposed sponges

and their toxicity. However, Tetrochota is both non-toxic and

exposed, rendering it extremely vulnerable to predators. It is

protected from predation, however, when colonized by the

symbiotic Parazoanthus swiftii, which wraps around the sponge,

covering up to 50% of the sponge surface (West 1979). West (1976)

demonstrated that 0.5-0.65 mg P. swiftii is toxic to fish,

inducing 100% mortality, and that Tetrochota with P. swiftii

suffers significantly less predation than Tetrochota without the

zoanthids. In areas of intense fish predation, Tetrochota only

survives when colonized by P. swiftii (West 1976). The

yellow zoanthid contrasts dramatically with the dark green color

of the sponge, making it an easy target for the predators.

colonies of the Tetraclita, and West's experiments with artificial
zoanthids indicate that sponge predators are visually deterred
by this aposematic coloration.

We were interested in determining whether or not a defense association exists between Svensson's brittle star and Tetraclita that are colonized by P. swiftii. Specifically, we hypothesized that because the toxic zoanthid deters sponge predators, it may also deter potential brittle star predators, and thus more brittle stars will inhabit sponges with zoanthids than sponges without zoanthids. We postulated that brittle star size and number per sponge is dependent on zoanthid density on the sponge. We also hypothesized that if presented with two sponges, one with and one without zoanthids, in a controlled laboratory situation, the brittle stars would preferentially inhabit an Tetraclita with zoanthids rather than a zoanthid-free Tetraclita. Finally, we expected that the sponge itself may offer

... since protection to Sower's brittle star, so that brittle

stars tethered to an Tetrosidea would experience less predation

than those tethered to other, similarly-shaped substrata.

Methods:

This study was conducted at the Discovery Bay Marine Laboratory from February 27th to March 5th, 1989.

We censused Iotrochota biroulata sponges at between 20 and 60 ft, Mooring 1, Arena, LTS, and Columbus Park, tagging each sponge encountered and noting the presence

or absence of the zoanthid, Parazoanthus swifti and

the Brittle Star, Ophiothrix suensonii. A G-test

was then performed to determine whether there significant difference in the proportion of brittle stars on sponges with and without zoanthids.

and without zoanthids that are colonized by brittle stars.

In a separate census at Mooring 1, Arena and Columbus Park, between 20 and 60 ft, we measured the number and disk size of all Brittle Stars colonizing each sponge encountered. We ~~used~~ the

compared number and disk size to zoanthid density of each sponge.

Categories for zoanthid density are

- 1 - no zoanthids - 0% cover
- 2 - some zoanthids - ^{approximately} between 0 and 40% cover
- 3 - very dense zoanthids - ^{approximately} > 40% cover

We performed a linear Regression Analysis to

determine what percent of the variability in

number and size of Brittlestars is due to zoanthid density.

Another part of this study involved a substrate preference test for Brittlestars ^{in the} laboratory. We

collected sponges with and without zoanthids and

23 the Brittlestars. The Brittlestars and sponges were

kept in an indoor running water aquar^{um} when

not in use in an experiment. Each trial

consisted of two sponges (one with and one without

zoanthids) anchored in a large bucket with sand. The sponges were of approximately equal size. If the sponges^{were} to be used as zoanthid-free had a few zoanthids, we scraped these off, taking care to cause as little disturbance as possible. To standardize this effect, we scraped an equal amount from the sponges with zoanthids. We did this to insure that the brittle stars did not choose one of the sponges preferentially due to the disturbance effect.

Six trials were performed in which three to four brittle stars were placed in the bucket with the sponges for two hours. During this two hour period, the bucket was undisturbed with a

constant supply of running salt water. At the conclusion of each two hour period, we recorded the number of Brittle Stars on each type of sponge. We also performed a 7th trial in which we placed all 16 of the Brittle Stars in the bucket to determine whether or not space is a limiting resource on the sponge. We used a Chi-Square Contingency Table to compare the number of Brittle Stars on each substrate type.

In the ~~fourth~~^{fourth} experiment we compared predation on Brittle Stars colonizing sponges ~~in~~ versus Brittle Stars colonizing other substrate. We tethered Brittle Stars using a needle and thread from the oral cavity through the aboral ~~anterior~~ surface. Previous studies by ~~Shand et al.~~

9 Sanders (1987 Bio FSP) indicate that this is a successful tethering technique. Due to the paucity of Brittle Stars we were forced to accept this technique without controlling for the effect of the surgery.

We tethered two to three Brittle Stars to each of three Iotrochota sponges without zoanthids and three sticks. Each of the sticks had the same approximate dimensions as the sponges and was placed in the rocky substrate and secured with string. We set these out in pairs, each of which contained a sponge and a stick. The pairs were located in damselfish territories.

We noted the number of legs on each Brittle Star before beginning the experiment. The

Brittle Star remained tethered for 24 hours.

An individual was considered predicated upon if it had a net loss of legs. We used a G-test to determine if there was a difference in predation between the two types of substrate.

RESULTS:

◦ DISTRIBUTION PATTERNS OF OPHIOTHRIX SWIFTII ◦

Of the 112 sponges censused in mooring 1, LTS, Arena, and Columbus Park, 36 sponges (32.14%) were colonized by P. swiftii. Of these, 12 (33.33%) were also inhabited by the brittle star Ophiothrix swensonii. 76 ~~sponges~~ censused sponges (67.86%) were not colonized by P. swiftii, and of these zoanthid-free sponges, only 8 (10.5%) were inhabited by O. swensonii. The frequency of brittle star colonization of sponges with zoanthids is significantly higher than the frequency of brittle star colonization of sponges without zoanthids (Appendix, Table 1. $\chi^2 = 8.14$, $p < 0.005$, $df = 1$). In comparing the proportions of sponges with zoanthids between Columbus Park and the fore reef sites (LTS, mooring 1, Arena), we found no significant difference ($\chi^2 = .08$, $p > 0.05$, $df = 1$). When we compared the frequency of brittle star colonization of sponges with and without zoanthids ~~between~~^{for} Columbus Park and the fore reef, separately, the fore reef exhibited significant differences (Appendix Table 3A, $\chi^2 = 6.92$, $p < 0.01$, $df = 1$) but Columbus Park did not, possibly due to a small sample size (Appendix Table 3B, $\chi^2 = 1.46$, $p > 0.5$, $df = 1$).

The mean number of brittle stars on sponges with zoanthids was

also significantly ~~different~~ higher than on sponges without zoanthids (Figure 1, Appendix Table 4. $t=2.71$, $p<0.01$, $df=110$). When we compared the actual numbers of brittle stars on sponges with and without zoanthids, proportionately more sponges with zoanthids were inhabited by multiple brittle stars (Appendix Table 5. $G=14.9$, $p<0.025$, $df=6$).

The size of the colonizing brittle star was not significantly related to the density of zoanthids on the sponge ($r^2=0.047$, $p>0.05$, $df=16$). However, 31% of the variability in the number of brittle stars per sponge was attributable to zoanthid density on the sponge (Appendix Table 6. $r^2=0.31$, $p<0.01$, $df=26$). A greater number of brittle stars inhabited those Tetrochete sponges with denser zoanthid colonies.

~ SUBSTRATE PREFERENCE OF SVENSON'S BRITTLE STAR ~

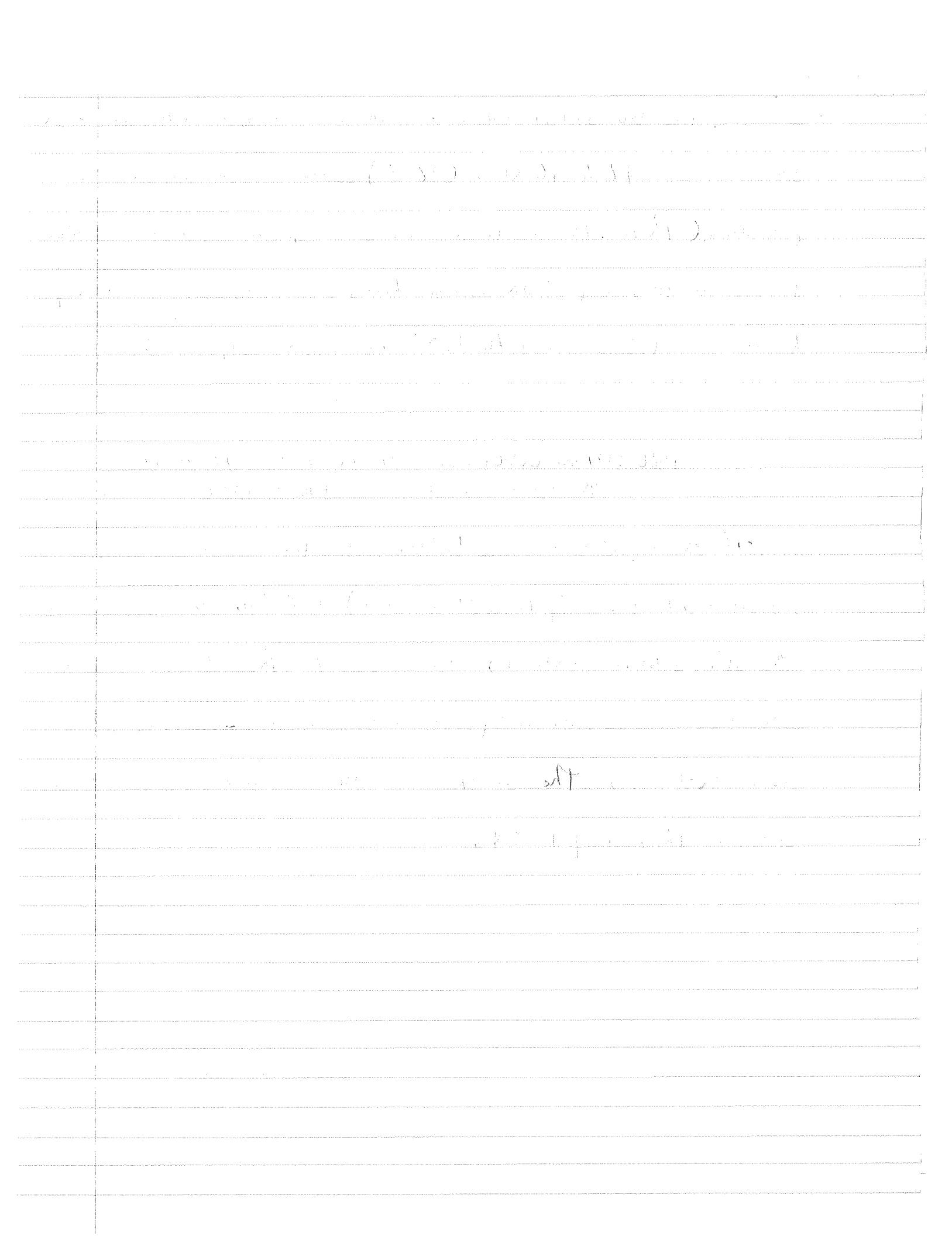
Upon being placed in the bucket, most brittle star tended to move immediately to the sponge with zoanthids. Of the 23 brittle stars tested, 20 settled on either of the two sponge choices and the other 3 remained on the sand or mesh. 16 brittle stars (80%) settled on the sponge with zoanthids.

When 16 brittle stars were placed in the bucket together, 13 settled on

either of the two sponge choices and the other 3 again remained on the sand or mesh. 12 brittle stars (92%) settled on the sponge with zoanthids. These observed frequencies were significantly different than the expected frequency of the sponges being settled by equal numbers of brittle stars (Appendix Table 7. $\chi^2 = 16.04$, $p < 0.01$, $df = 1$).

~ PREDATION LEVELS ON BRITTLE STARS TETHERED
TO SPONGES AND OTHER SUBSTRATA. ~

Of the 6 O. suessoni brittle stars tethered to sponges, 100% remained intact. Only 20% (1 out of 5) of brittle star tethered to the other substrate (sticks) remained intact. These frequencies of predation were significantly different (Appendix Table 8. $G = 9.0$, $p < 0.05$, $df = 1$). Four of the 5 brittle star tethered to the sticks suffered the loss of 1-3 legs.



Discussion:

West (1976) showed that "virtually no Lotrochota bimaculata occurred on deep reefs without its zoanthid symbiont. However, on the inner shallow reefs where H. tricolor and other sponge predators are uncommon, I. bimaculata was often found without Parazoanthus swiftii." In Discovery Bay, of all 112 Lotrochota sponges censused, only 32.14% are colonized by P. swiftii. This seems to indicate that the fish predation on sponges is minimal in this area and doesn't seem to affect the sponge population as much as it does in other areas. We believe that extensive fishing in Discovery Bay has decreased the fish population greatly, including angelfish, the main Lotrochota predator. It could also be that many of the sponges are protected from predation because of their location in damselfish territories.

Despite the fact that only 33% of sponges with zoanthids have Brittle Stars, this is three times

the amount observed on sponges without zoanthids.

Such a low proportion may indicate that there is a small population of Brittle Stars in Discovery Bay. Brittle Stars could be limited first by their method of reproduction. Both sperm and egg are released into the water column and unite by chance, "Hence, millions are wasted." (Kaplan, 1982)

They may also be limited by predation during the larval and adult stages, and by the inability of the larvae to reach a sponge with zoanthids.

However, the fact that there are more Brittle Stars on the sponges with zoanthids indicates the possibility of a defense association. It may be that Brittle Stars either preferentially settle on sponges with zoanthids or simply survive longer on sponges with zoanthids, or a combination of these two factors.

Due to the haphazard way the larvae settle,

Brittle Stars
on sponges
with

one would expect a random distribution of Brittle Stars on sponges with and without zoanthids. Thus an interpretation of our results would suggest that they simply survive better on sponges with zoanthids. However, our substrate preference experiment shows that they do preferentially settle on sponges with zoanthids. This mechanism for preferential settlement is unknown. Brittle Stars are able to detect light gradients and they press themselves into very dark areas, such as crevices. Since the Jensen's Brittle Star settles on the outside of sponges it seems there must be some type of chemical cue that allows them to recognize the sponges with zoanthids.

Despite the fact that they do preferentially settle on those with zoanthids, some do settle on sponges without zoanthids. Our predation experiments show that Brittle Stars survive better on sponges

(without zoanths) than on similarly-shaped non-sponge material. Therefore, the sponge itself may provide some protection. Iotrochota is darkly colored and appears mottled dark green and black in the water. Its surface is also very bumpy and irregular. When the Brittle Star presses itself into the surface irregularities it is rendered nearly invisible and virtually inaccessible to fish predators.

Given this, it seems that sponges with ~~more~~ zoanths would deter even more predators and confer more protection than those without zoanths, because it is possible that any one fish species may be immune to either one of these deterrents.

Therefore, there should be more Brittle Stars on sponges with zoanths due to preferential settling and better survival, and these should be larger due to better survival on the zoanthid-covered sponges than on the zoanthid-free individuals.

Our results have shown that sponges with higher densities of zoanthids support more Brittle Stars. However, they failed to show a similar trend with size of Brittle Stars. Other factors, such as Brittle Star placement in the sponge, and location of the sponge (i.e. in a damselfish territory) or in a reef slope (intense predation) versus a reef flat (less intense predation) area could account for this. A larger sample size may have shown a clearer trend.

Due to the irregular surface and dark coloration of Iotrochota sponges and the presence of zoanthids on Iotrochota's surface, Swenson's Brittle Star is able to survive on the outer surface of the sponge, whereas most other species of Brittle Star must take refuge inside the sponge or beneath reef rubble during the day, allowing them to feed only at night. Swenson's Brittle Star is thus able

to feed during the daylight hours when most other species of Brittle Star are not able to feed, and this may confer a competitive advantage to them.

Future Studies could explore the mechanism by which Brittle Stars find the zoanthid-covered sponges. We also recommend that more predation experiments be conducted to compare the predation levels for Brittle Stars on sponges with zoanthids to those for sponges without zoanthids, to further resolve the importance of the zoanthids in the association of Tetrochete sinuata and S. suensonii.

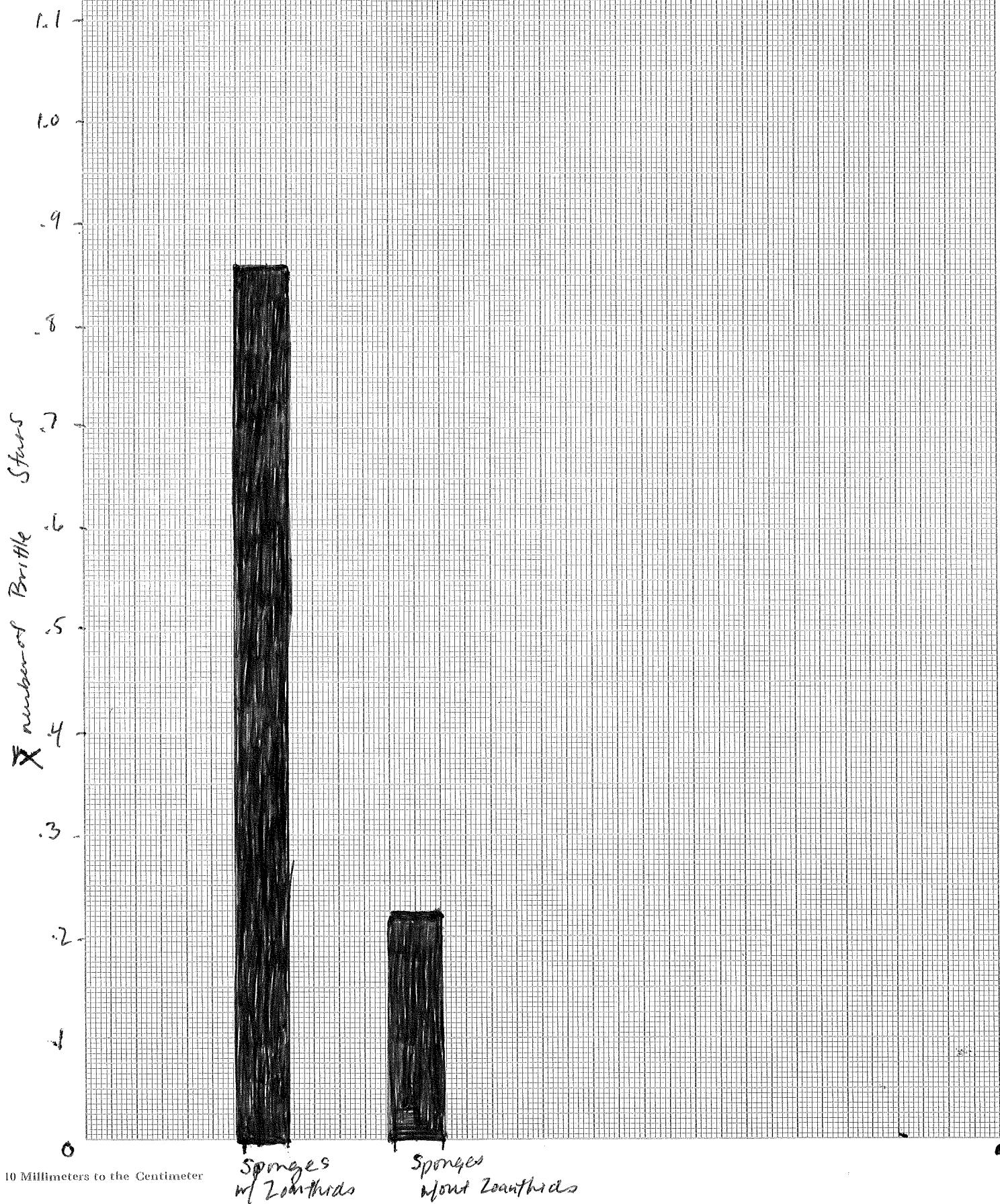
Erin/Julia:

Excellent study and write-up.
First rate.

(A)

John

Figure 1: Mean number of Brittle Stars in Sponges with and without Zoanthids



10 Millimeters to the Centimeter

(APPENDIX CONT'D)

TABLE 3.B

FREQUENCY OF OPIOTHERIX SUENSONII COLONIZING
LOTROCHOTA BIROTULATA WITH AND WITHOUT PARAZOANTHUS
SWIFTII AT COLOMBUS PARK.

SPONGES WITH ZOANTHIDS
SPONGES WITHOUT ZOANTHIDS

	WITH BRITTLE STARS	WITHOUT BRITTLE STARS
2	7	7
1	16	16

$$G=1.46, p>0.5, df=1.$$

TABLE 4.

MEAN NUMBER OF OPIOTHERIX SUENSONII ON
ALL CENSUSED LOTROCHOTA BIROTULATA - WITH AND
WITHOUT PARAZOANTHUS SWIFTII.

	ON SPONGES WITH ZOANTHIDS	ON SPONGES WITHOUT ZOANTHIDS
X	0.86	0.224
S.D.	± 1.69	± 826
S ²	2.75	.682
n	36	76

$$t=2.71, p<0.01, df=110$$

(APPENDIX CONT'D)

Table 7: Frequency of Ophiothrix Svensoni colonizing Iotrochota Birotulata with and without Parazoanthus swiftii in the laboratory. Substrate Preference Experiment.

	with Zoanthids	without Zoanthids
observed	28	5
expected	16.5	16.5

$$\chi^2 = 16.04 \quad p < 0.001 \quad df = 1$$

Table 8: Frequency of Ophiothrix Svensoni preyed upon in Iotrochota birotulata without zoanthids and Non-Sponge substrate (stick) when tethered.

	Non-Sponge (Stick)	Iotrochota Sponge
preyed upon	yes	0
	4	0
	1	6

$$G = 9.36 \quad p < 0.005 \quad df = 1$$

Table 8
Set up
Sponges
b9

	Yes	No	Total
Non-sponge	4	1	5
Sponge	1	6	6
	4	7	11

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APPENDIX

TABLE 1.

FREQUENCY OF OPHIOTHRIX SUESONII COLONIZING

IOTROCHOTA BIROTULATA WITH AND WITHOUT PARAZOANTHUS

SWIFTII AT MOORING 1, LTS, ARENA, AND COLUMBUS PARK.

		WITH BRITTLE STARS	
		WITHOUT BRITTLE STARS	
# SPONGE WITH ZOANTHIDS	# SPONGE WITHOUT ZOANTHIDS	12	24
		8	68

$$G = 8.14, p < 0.005, df = 1.$$

TABLE 3A

FREQUENCY OF OPHIOTHRIX SUESONII COLONIZING

IOTROCHOTA BIROTULATA WITH AND WITHOUT PARAZOANTHUS

SWIFTII AT MOORING 1, LTS, AND ARENA.

		WITH BRITTLE STAR	
		WITHOUT BRITTLE STAR	
# SPONGE WITH ZOANTHIDS	# SPONGE WITHOUT ZOANTHIDS	10	17
		7	52

$$G = 6.92, p < 0.01, df = 1.$$

TABLE 2: Frequency of IOTROCHOTA BIROTULATA with and without Parazoanthus Swiftii for the fore reef versus Columbus Park.
IOTROCHOTA WITH IOTROCHOTA WITHOUT Parazoanthus P. Swiftii

Columbus Park	9	17
Fore Reef	27	59

$$G = .08 \quad df = 1 \quad \text{not sig}$$

(APPENDIX CONT'D)

TABLE 5.

FREQUENCY OF LOTROCHOTA BIROTULATA COLONIZING BY
INCREASING NUMBERS OF OPHTHOThrix SUENONI. A
COMPARISON BETWEEN SPONGES WITH AND WITHOUT
PARAZOANTHUS SWIFTII.

# SPONGE WITH ZOANTHIDS	# BRITTLE STARS ON SPONGE.						
	0	1	2	3	4	5	6
24	5	3	0	2	1	0	1
69	3	4	0	0	0	1	0

$$G = 14.9, p < 0.025, df = 6.$$

TABLE 6.

CORRELATION COEFFICIENT OF DEPENDENCE OF NUMBER
OF OPHTHOThrix SUENONI ON THE DENSITY OF
PARAZOANTHUS SWIFTII COLONIZING LOTROCHOTA
BIROTULATA.

$r = 0.555$
$r^2 = 0.31$
$p < 0.01$
$df = 26$