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A CONTINUED SURVEY OF SUCCESSIVE COLONIZATION
OF AN ANCHOR DAMAGED CORAL REEF
IN GREATER LAMESHUR BAY, ST. JOHN, USVI

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ABSTRACT

This study is a follow-up to the project started in November, 1986 by Jonathan Yoder in the School for Field Studies. Sometime between late July and mid-September, 1986, a large area of primarily Montastrea annularis was damaged by the impact of a boat anchor. The large coral heads were broken up, damaging much of the coral and creating new surface area. The anchor scar is located off Yawzi Point in Greater Lameshur Bay, St. John, USVI. The Yoder study in 1986 quantified the colonizing organisms found in six quadrats within the damaged area. The present study found some new organisms growing on the broken up substrate as well as continued growth of the previously recorded colonizing organisms. General observations of the site include increased algal growth and an increase in abundance and diversity of other species present.

INTRODUCTION

Once a coral has been damaged and new surface area exposed, algae quickly cover the bare substrate. If left undisturbed by herbivores this algal growth can inhibit coral recruitment, since the coral larvae need solid substrate on which to settle. Experiments done off St. Croix indicated that "coral survivorship had been greater in areas subject to some grazing pressure" (Fitz, 1983). From personal observation, some of the main grazers found in the area are parrotfish and damselfish. They have kept the algae cropped in most areas, perhaps allowing for the settlement of coral larvae on the hard substrate.

The area in question consists primarily of Montastrea annularis, with some Porities porities, Montastrea cavernosa, and gorgonians (Yoder, 1986). The scar is approximately seven meters deep, located off Yawzi Point with a compass bearing to Yawzi Point of 310° and to Cabritte Horn Point of 160°, shown in Figure 1.

The first survey done by Yoder in December of 1986 took place three months after the damage occurred. At that time, Agaricia agaricites was the only new scleractinian coral to colonize the area. The present survey was conducted approximately seven months after the coral was damaged in order to document the regrowth which has occurred since the last study. This study, if continued over time, will show how quickly the area is recolonized and the

abundance and diversity of the species which settle. This continuing survey will hopefully shed some light on the implications for the success of vital coral reefs which are heavily impacted by recreational boating and anchor damage.

MATERIALS AND METHODS

The anchor scar is located in an area off Yawzi Point which was previously marked with transects. The reference rebars are still in place, driven into the sand near the scar. After finding the location, a yellow line with a float was tied to the rebar in the middle of the sand area within the scar. This facilitated locating the site. The quadrats which Yoder used last December to survey the area were reconstructed using the measurements and vectors given:

Quadrat	Vector
A	58 cm, 250°
B	107 cm, 230°
C	60.5 cm, 315°
D	84.5 cm, 110°
E	78 cm, 35°
F	96 cm, 105°

The exact placement of the quadrats was reconstructed as close as possible to the originals. There was a nail in the middle of each quadrat from which the distance from rebar was measured. The quadrats used measured 35 cm x 35 cm. The angle of the quadrats in relation to the rebar are shown in figure 2.

A descriptive survey of the organisms present within the quadrats was carried out by mapping each of the six quadrats. The colonies of Agaricia agaricites were measured by circumference as well as by width and length. The soft corals were measured for height. A survey of the general area was also conducted to account for motile organisms and organisms growing near and around the impacted area. Photographs were taken of the impacted area and each quadrat, although drawn maps give a clearer indication of the community structure in detail. A comparison between the first study and the present study was made of species richness (Tables I-VI).

RESULTS

The overall structure of the area did not change drastically, though there are a few differences in individual organisms in addition to general growth. In quadrat A, there is greater Dictyota sp. growth. The urchin Echinometra lucunter and the alga Valonia sp. have moved into one of the crevices and the anenome Lebrunia danae and the polychaete Sabellastarte melonostigma (sic.), which were present in the first study, were gone. In quadrat B, one of the two small colonies of A. agaricites is gone. The other colony is still there and has grown. In quadrat C, there is an increase in purple coralline algae and encrusting green tunicates. A new, small Briarum asbestinum is growing under the crevice in the top

left corner. A small crab has moved into a small hole in the substrate. There is a new colony of Muniastrea annularis and new Millepora sp. in the top of quadrat D. There is also an increase of Dictyota sp. in quadrat C. There is a new E. askestinum and a new colony of M. annularis in quadrat D. An arrow crab, Stenorhynchus seticornis, lives in the crevice at the bottom of the quadrat. The crevices in quadrat E are now occupied by a spotted eel and three Lima scabra in addition to the original Rhodactis sanctithomas. There is also a new growth of Eunicea sp. Quadrat E had the highest number of small A. agaricites colonies from the first study and increased the number by three. Quadrat F has a new growth of the colonial anenome Zoanthus sp. and two new, large solitary tunicates. It lost one A. agaricites and gained a new one in a different location.

In general, Dictyota sp. as well as encrusting purple algae are abundant. Encrusting green, yellow, and orange tunicates are also relatively abundant. There are numerous A. agaricites colonies on the bare substrate both in the quadrats and in the general area of the scar. The most damage was done to the area around quadrats A and B, which show the most exposed substrate (Yoder, 1986). The maps of quadrats in figures 3-8 show the composition of the present communities and can be compared to the maps drawn from the last survey to show the changes taking place.

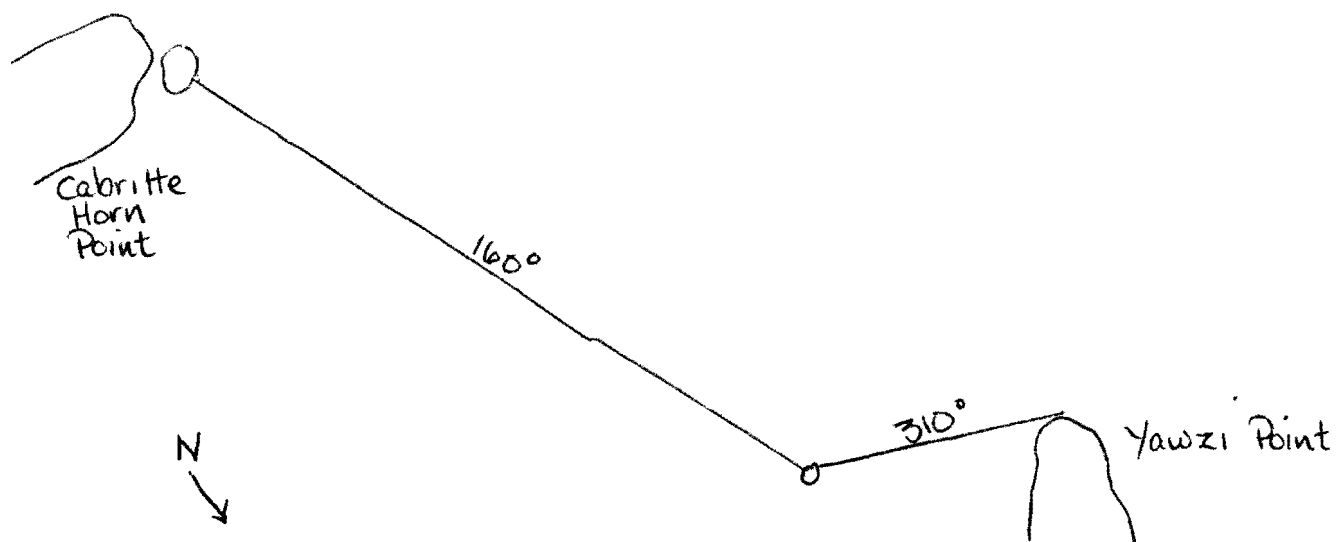


Figure 1: General location of anchor scar in relation to Yawzi Point and Cabritte Horn Point.

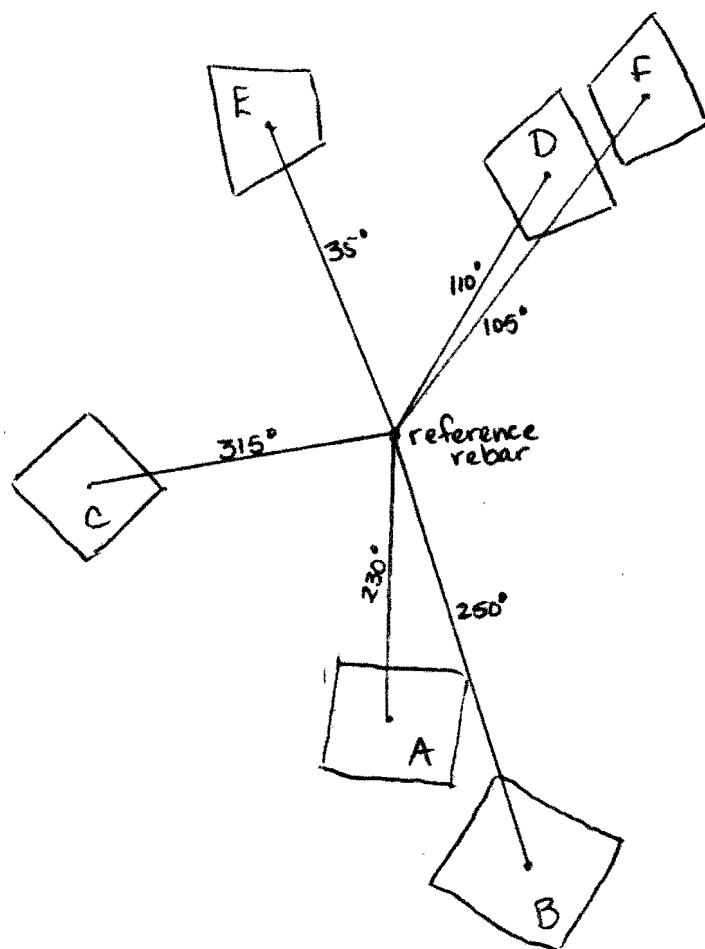
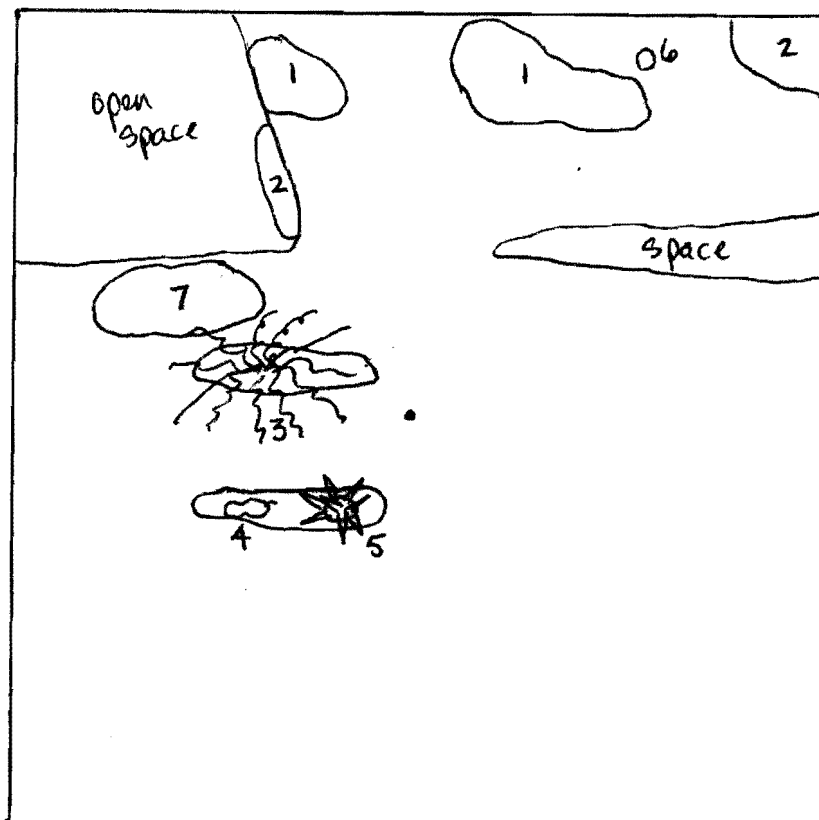


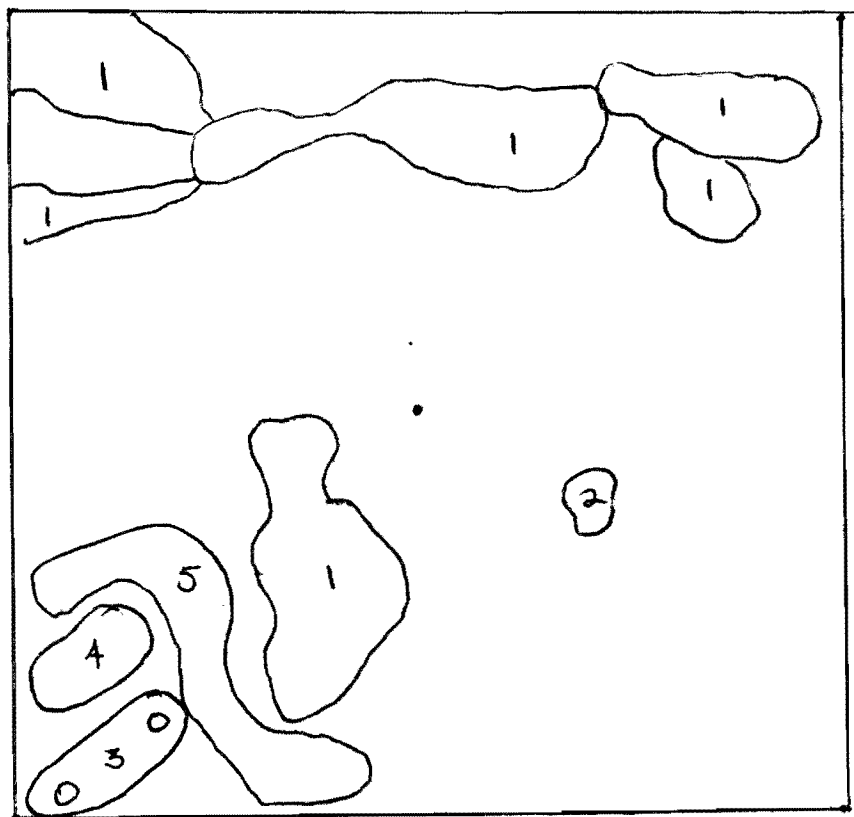
Figure 2: Placement and angles of quadrats within anchor scar area.



Drawing Key:

1. Montastrea annularis
2. Dictyota sp.
3. Bartholomea annulata
4. Valonia sp.
5. Echinometra lucunter
6. small fan worm
7. orange coralline algae

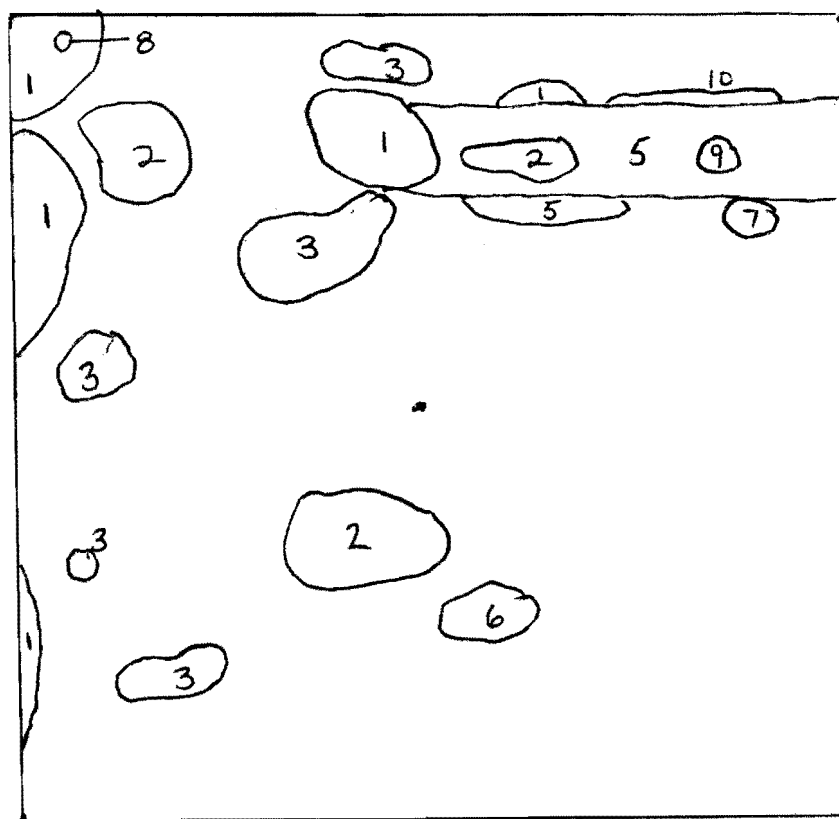
Figure 3: Quadrat A off Yawzi Point in Greater Lamesher Bay, St. John, USVI.



Drawing Key:

1. Montastrea annularis
2. Agaricia agaricites
7.5 cm circumference
1.5 cm x 2 cm
3. Verongia sp.
12.5 cm circumference
5.5 cm x 2.5 cm
4. purple coralline algae
5. orange coralline algae

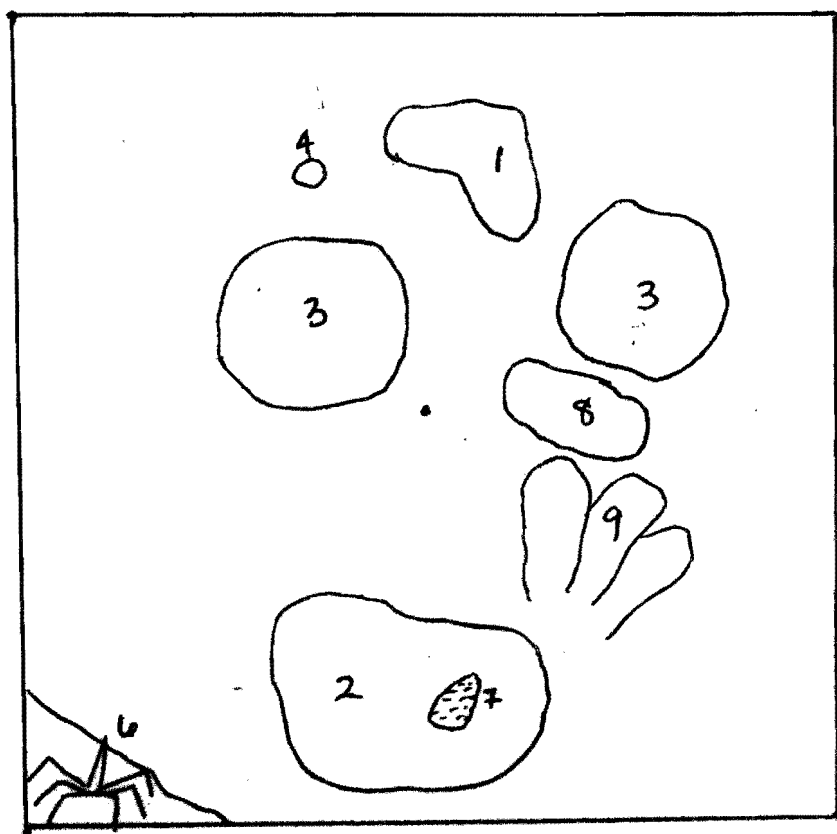
Figure 4: Quadrat B off Yawzi Point in Greater Lameshur Bay, St. John, USVI.



Drawing Key:

1. Montastrea annularis
2. Dictyota sp.
3. encrusting green tunicate
4. orange boring sponge
5. purple coralline algae
6. orange coralline algae
7. Briararium asbestinum
2 cm long
8. fan worm
9. small crab
10. Millepora sp.

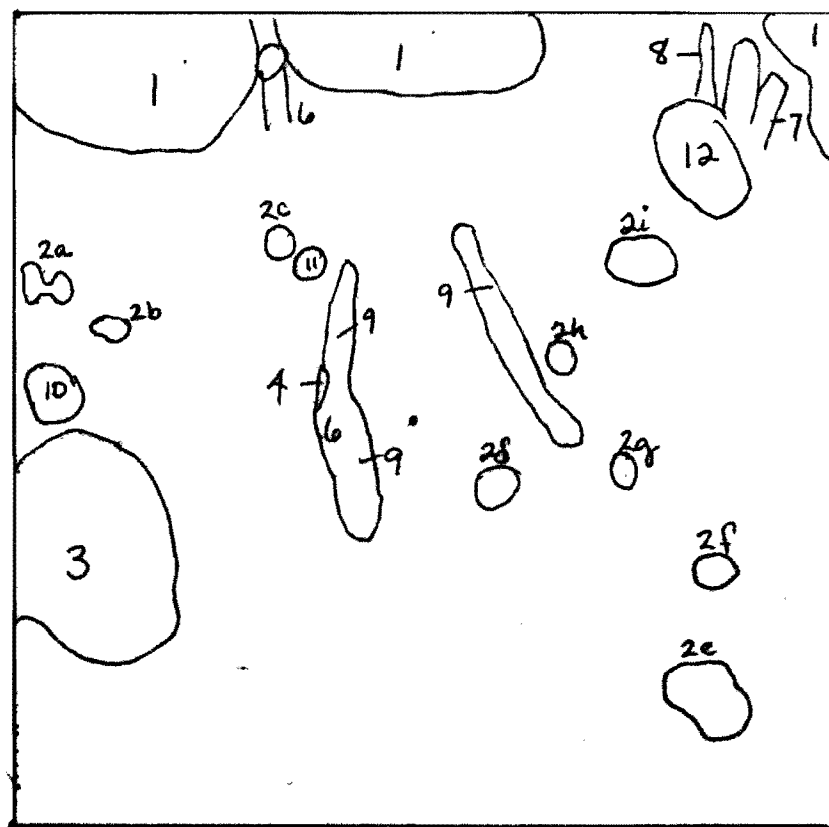
Figure 5: Quadrat C off Yawzi Point in Greater Lameshur Bay, St. John, USVI.



Drawing Key:

1. Montastrea annularis
3 cm x 2 cm
2. Dictyota sp.
3. purple coralline algae
4. orange boring sponge
5. Briarium asbestinum
1 cm long
6. Stenorhynchus seticornis
7. Atrina rigida
8. orange coralline algae
9. dead finger coral covered with algae

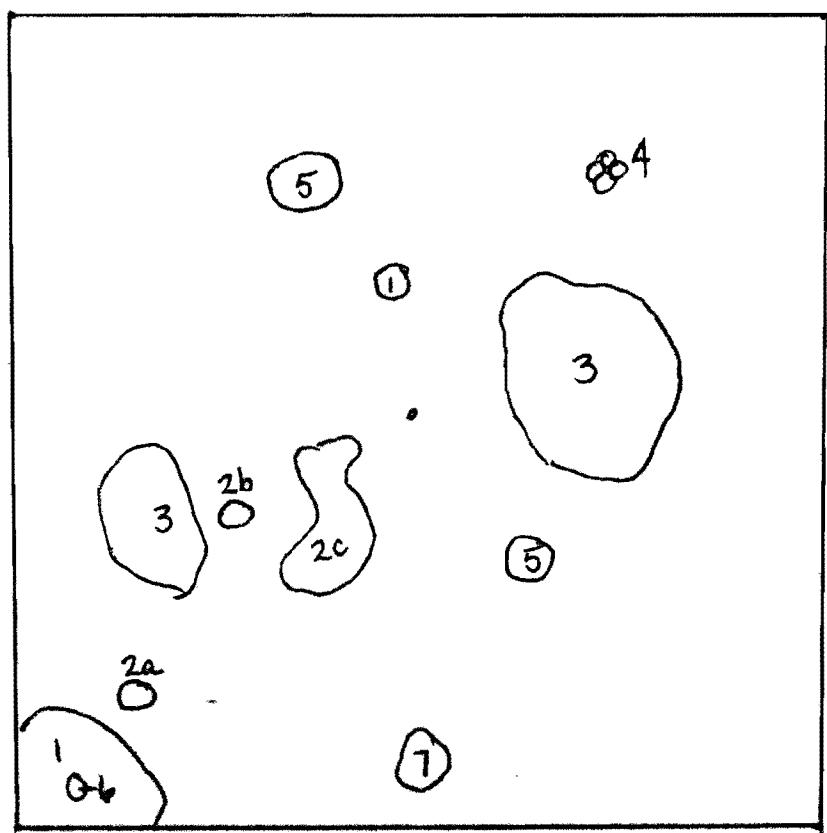
Figure 6: Quadrat D off Yawzi Point in Greater Lameshur Bay, St. John, USVI.



Drawing Key:

- | | |
|--------------------------------|-------------------------------------|
| 1. <u>Montastrea annularis</u> | 3. <u>Dictyota sp.</u> |
| 2. <u>Agaricia agaricites</u> | 4. <u>Rhodactis sanctithomae</u> |
| 1 x w | 5. <u>Gymnothorax moringa</u> - |
| | spotted moray eel |
| a) 3 cm x 2 cm | 6. orange boring sponge |
| b) 2 cm x 1.5 cm | 7. <u>Briarium asbestinum</u> |
| c) 1.5 cm x 1.5 cm | 7 cm long |
| d) 3.5 cm x 2 cm | 8. <u>Eunicea sp.</u> - 5.5 cm long |
| e) 3 cm x 2 cm | 9. <u>Lima scabra</u> |
| f) 1.5 cm x 1.5 cm | 10. purple coralline algae |
| g) .5 cm x .5 cm | 11. yellow tunicate |
| h) 2 cm x 1 cm | 12. <u>Millepora sp.</u> |
| i) 3 cm x 4.5 cm | |

Figure 7: Quadrat E off Yawzi Point in Greater Lameshur Bay, St. John, USVI.



Drawing Key:

1. Millepora sp.
2. Agaricia agaricites

l x w	circumference
a) 1 cm x 1 cm	3 cm
b) 2 cm x 1 cm	6 cm
c) 4 cm x 2.5 cm	11 cm
3. purple coralline algae
4. Zoanthus sp. - white form
5. solitary tunicate
6. tube blennie
7. Bartholomea annulata

Figure 8: Quadrat F off Yawzi Point in Greater Lameshur Bay, St. John, USVI.

Table I:
Comparison of Species Richness in Quadrat A

<u>Species</u>	<u>Nov. 1986</u>	<u>April 1987</u>
<u>M. annularis</u>	+	+
<u>Dictyota sp.</u>	0	+
<u>B. annulata</u>	1	1
<u>Valonia sp.</u>	0	1
<u>E. lucunter</u>	0	1
small fan worm	0	1
orange coralline algae	0	+
<u>Lebrunia danae</u>	1	0
<u>Sabellastarte melanostigma</u> (sic)	1	0

Table II:
Comparison of Species Richness in Quadrat B

<u>Species</u>	<u>Nov. 1986</u>	<u>April 1987</u>
<u>M. annularis</u>	+	+
<u>A. agaricites</u>	2	1
<u>Verongia sp.</u>	1	1
purple coralline algae	+	+
orange coralline algae	0	+

Table III:
Comparison of Species Richness in Quadrat C

<u>Species</u>	<u>Nov. 1986</u>	<u>April 1987</u>
<u>M. annularis</u>	+	+1
<u>B. annulata</u>	1	0
encrusting greet tunicate	4	5
purple coralline algae	+	++
<u>Dictyota sp.</u>	0	+
orange boring sponge	0	1
orange coralline algae	0	+
<u>B. asbestinum</u>	0	1
fan worm	0	1
small crab	0	1
<u>Millepora sp.</u>	0	1

Table IV:

<u>Species</u>	<u>Nov. 1986</u>	<u>April 1987</u>
<u>M. annularis</u>	0	1
<u>Dictyota sp.</u>	+	+
purple coralline algae	+	+
orange boring sponge	0	1
<u>B. asbestinum</u>	0	1

Table IV: cont'd.

<u>Species</u>	<u>Nov. 1986</u>	<u>April 1987</u>
<u>S. setinervis</u>	0	1
<u>A. rigida</u>	0	1
orange coralline algae	0	+

Table V:

Comparison of Species Richness in Quadrat E

<u>Species</u>	<u>Nov. 1986</u>	<u>April 1987</u>
<u>M. annularis</u>	+	+
<u>A. agaricites</u>	5	9
<u>Dictyota sp.</u>	+	+
<u>R. sanctithomae</u>	1	1
<u>Gymnothorax moringa</u>	0	1
orange boring sponge	0	1
<u>S. asbestinum</u>	1	1
<u>Eunicea sp.</u>	0	1
<u>Lima scabra</u>	0	3
purple coralline algae	+	+
yellow tunicate	0	1
<u>Millepora sp.</u>	0	1

Table VI:

Comparison of Species Richness in Quadrat F

<u>Species</u>	<u>Nov. 1986</u>	<u>April 1987</u>
<u>Millepora sp.</u>	1	1
<u>A. agaricites</u>	3	3
purple coralline algae	+	+
<u>Zoanthus sp.</u>	0	1
solitary tunicate	0	2
tube blennie	0	1
<u>B. annulata</u>	0	1
<u>Codium sp.</u>	1	0

Table VIII:

Estimated Percentage Living Cover in Each Quadrat

<u>Quadrat</u>	<u>%</u>
A	6
B	32
C	13
D	16
E	20
F	12

DISCUSSION

In the 1986 Yoder study, the main colonizer of the impacted area was Agaricia agaricites. The present study found other organisms, such as sponges, tunicates, and soft coral to have settled in the area with both greater abundance and diversity since the previous survey. This increase in abundance and species diversity may require a certain amount of time to develop. Since the first study was done only three months after impact and this study seven months after impact, both results are relatively recent after the damage occurred. At this point in time no definite conclusions can be made as to the implications of generalized anchor damage on coral reefs, but further studies will tell more. The fact that it has taken seven months for even a small increase in diversity and abundance to occur shows how slowly a damaged area is recolonized.

In the Fitz experiment (1983), Agaricia comprised 81% of all the corals which settled the new substrate. In the present study A. agaricites is also the dominant coral colonizer in the anchor scar. Now that the area has been initially colonized, it might pave the way for other organisms to settle the area. Whether the early colonizers, like A. agaricites, are facilitators is not known. Two new colonies of M. annularis have appeared since the first study. It is not known whether the early colonization by A. agaricites is in any way connected to recruitment of the slower growing M. annularis.

Since the 1986 survey, the rate of recruitment of A. agaricites has slowed considerably. In the first three months after impact, a total of eleven new A. agaricites appeared. In the four months since the Yoder study, only four more new colonies have appeared and two have disappeared, bringing the new total to thirteen. Whereas M. annularis now appears to have gained a foothold with two new colonies, A. agaricites recruitment and survival appears to have slowed down. One possible explanation for the disappearance of the A. agaricites colonies could be predation by fish.

A general observation of the motile organisms present in the impacted area showed an increase since the first survey. Although only one Tridachia crispata was sighted vs. three in the first study, other organisms, such as an eel, S. seticornis, Lima scabra, and an increased number of B. annulata had moved into the area. As Yoder (1986) suggested, the crevices within the coral head provide an excellent home for these organisms. He questioned whether the organisms which were present at the time of the first study could have been in the cracks before the impact or could have colonized the area after the crevices were exposed. The new organisms which arrived since the last survey have definitely taken advantage of the increased number of crevices since the impact occurred.

From a comparison of species richness between November, 1986 and April, 1987 (see tables I-VI) the increase in species diversity is apparent. The crevices are particularly high in new motile organisms and the substrate covered with filamentous algae is high in new sedentary organisms.

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SPONGE DISTRIBUTION AND MORPHOLOGY IN VARYING HABITATS
IN LAMESHUR BAY, ST. JOHN, U.S. VIRGIN ISLANDS

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ABSTRACT

The dimensions of four sponge species, Ectoplasia ferox, Spirastrella spp., Iricinia strobilina, and Spheciospongia vesparium, were collected by measuring the maximum length by width by height of each individual sponge. This was repeated at four different sites, one high energy area and one low energy area, at both Tektite and Cabritehorn point. The relative amount of water movement through each site was calibrated by using clod-cards. The area that contained the clod-cards with the highest mean weight loss to control weight loss ratio was the habitat with the highest water movement, and so on down for the other three sites.

Smaller encrusting sponges are better adapt for inhabiting areas of high water movement while massive sponges are more adapted for inhabiting areas of low water movement. Some sponges show intraspecies phenotypic plasticity, most notably Iricinia strobilina. This sponge developes a morphology like that of other encrusting sponges in areas of high water circulation and a morphology similar to that of the massive sponge's phenotype in areas of low rates of water circulation. The ability to have a varying morphology gives the sponge a greater fundamental niche, and therefore, the ability to occupy a wider range of habitats than its competators.

INTRODUCTION

Ectoplasia ferox is an encrusting sponge that is long and cylindrical in shape. The ossicles are found in a straight line along the upper ridge. The sponge is smooth in texture and orange in color. Spirastrella spp, or more commonly called the "blood-shot eye," is fleshy red in color with a smooth surface texture. The "viens," ridges that emminate out from the ossicles along the surface, give the sponge its nickname. Unlike Ectoplasia ferox, Spirastrella spp's ossicles seem to be placed around the sponge in a random pattern (Bortz, pers. obs.). Ectoplasia ferox is also classified as an encrusting sponge (Barnes, 1980). Iricinia strobilina is a massive sponge, black in color, and has a rough surface area that is covered by large, spike like connules. Spheciospongia vesparium, the "loggerhead sponge," is also a massive sponge and is generally the largest in size of all the aforementioned sponge species.

These four species were the sponges used to test the hypothesis that smaller, encrusting sponges are more adapt at inhabiting areas of high water movement while larger substrate sponges are more adapt

at taking advantage of areas with lower water circulation rates. Erect sponges can not survive in high water energy zones because the water movement will break the massive sponges off at their bases (Wulff, 1984).

In addition, these sponge species were also used to test a second hypothesis that sponges have the ability to alter their phenotypes in early phases of development in order to be more successful and efficient in its use of existing currents to aid in viscous entrainment and filter feeding ability.

The research was completed at the Virgin Islands Ecological Research Station located at the western shore of Lameshur Bay, St. John, U.S.V.I. Two locations were used, Tektite and Cabrit Horn point. These two locations are relatively similar in appearance, with an abundance of flora and fauna. Two sites were used in order to increase the amount of replications of observations and data collected. Each location begins with a rock wall that extends from the ocean's surface down to about six meters in depth. Then a gradual sloping of the substrate increases depth to fourteen meters at Tektite and twenty meters at Cabrit Horn point, which is the end of the fringing reef. The deeper depths were included because larger erect sponges occur more frequently on flat surfaces on the outer slope between 20 and 25 meters (Vacelet and Vasseur, 1977).

METHODS

Sponge dimensions were measured in a high and low energy area at each location. The high energy area at Tektite was in 6.2 meters of water and at Cabrit Horn was in 7.75 meters. The low energy zone at Tektite was at 14 meters and the site at Cabrit Horn was at 20 meters. The high water movement sites were on the rock faces of both locations while the low energy sites were located in deeper water on a perpendicular line from shore.

Initially, the relative amount of water movement at the sites was estimated by its proximity to a surf zone and by the presence or absence of a current or surge as observed while diving off SCUBA. In order to get a more accurate measurement, clod-cards were made and placed (Doty, 1971). These dissolve in sea water at a rate that is comparable to the amount of water movement over their surface.

Four clod-cards were placed and secured to the substrate next to the sponges studied. These were left for 48 hours, recovered, dried for another 24 hours, and then weighed. Then the amount of weight loss as compared to the controls was calculated. The value used was the amount of weight loss of an individual clod minus the mean weight loss experienced by the control clods, the median for the site calculated, then scaled from highest to lowest with its group against the other clods from the other sites. The group with the highest mean weight loss were in the area of highest energy, and so on down through the sites.

Also, at each site, the abundance of Ectoplasia ferox, Spirastrella spp., Ircinia strobilina, and Spheciospongia vesparium was noted and

each sponge's maximum length by width by height (distance it extends outward from substrate) was recorded. Observations were also recorded. Any major intraspecific phenotypic plasticity between the two high wave energy zones and the low energy zones was specifically looked for. Any significant difference between the overall morphologies of the sponge of one species as compared to the morphology of the same species located in a site of contrasting water circulation rates was recorded and the differences in morphology explained.

RESULTS

The weight decrease of the clod-cards are given in Table 2. The mean weight loss of the clods placed at a given site minus the mean weight loss of the control clods gives the dissolution rate (D). The highest D value corresponds to the site with the highest water movement. The list of sites, in decreasing order of water movement, was Tektite-shallow, Cabrite-shallow, Cabrite-deep, and then Tektite-deep. The D values are also given in Table 2.

For each species the maximum height above the substrate at each site are shown in Table 1. The maximum height for Ectoplasia ferox and Spirastrella spp were not significantly different at the two different energy sites, but Iricinia strobilina was significantly higher at the two low energy sites (Table 1). Spheciospongia vesparium was not found at either of the two shallow, lower energy sites. Ectoplasia ferox was not found at the deep, low energy site at Cabrite.

The mean height of Iricinia strobilina in relation to the relative amount of water movement (D) occurring at that site showed a dramatic increase (Table 3). Spirastrella spp, Ectoplasia ferox, and Spheciospongia vesparium were the same population and showed no dramatic increase in heights over the two habitats.

DISCUSSION

The first hypothesis, that smaller encrusting sponges are better adapted for inhabiting areas of high water movement, whilst massive sponges are more suited for areas of lower water circulation rates, was supported. The important factor is the mean maximum heights of each sponge species in the low energy sites in relation to the high energy sites. The mean height gives a good indication of the sponge's morphology. The higher the mean height the more the sponge's volume increases. The other two measurements, length and width, were useless in determining the sponges relative morphology owing to the fact that the values did not represent the individual sponges resistance to water movement and height did.

Sponges do not extend upwards from the substrate in areas of high water movement. The encrusting morphology is better suited to the turbulent habitats because less sponge surface area is needed for viscous entrainment and filter feeding. Also, according to fluid dynamics, the smaller amount of surface area of the sponge exposed to

the current reduces the amount of drag created and increases the sponge's ability to stay attached to the substrate. If the sponge produces excessive drag, a strain is created on the sponge's attachment to the substrate. The strain can be too excessive and will eventually tear the sponge off the substrate. In order to have a high chance of survival the sponge must remain attached to the substrate, thus, an encrusting morphology in high water energy zones is the most advantageous morphology.

The morphologies that have greater volumes are better suited for areas of lower water circulation. Their larger volumes can maximize the available current. More of the erect sponge's surface area is extending into the water column and creating drag. The extra drag increases the massive sponge's ability to generate a sufficient amount of internal water flow. Enough internal current must be created to enable the sponge to filter feed and expell wastes sufficiently. However, the massive phenotype would not survive in areas of high water movement because of its resistance to water currents. It would eventually be torn from the substrate. It is therefore reasonable to state that erect phenotypes are not found in high water energy zones because the erect morphology is incapatable with a turbid environment.

The second hypothesis, that some sponge species show phenotypic plasticity in order to maximize the ability of the individual sponge to survive in its habitat, was aslo supported by the data. Iricinia strobilina was a small, flat shaped sponge in areas of higher water movement, with its maximum height from the substrate never exceeding 0.7 cm. In areas of lower water movement its morphology is completely different, having a greater volume and being spherical in shape. The sphere shape aids I. strobilina in increasing drag, and therefore increasing internal water circulation. The change occured because the individual I. strobilina realizes the conditions of its habitat when the young, growing colony first attaches to the substrate. Intraspecies phenotypic placticity then enables I. strobilina to produce the most advantageous morphology for the given habitat. A supported hypothesis on how I. strobilina realizes wether it should adopt an encrusting or massive phenotype can not be drawn from this set of data. However, the data from this project provides a solid starting point for future projects in that it reveals I. strobilina's phenotypic plasticity and under what conditions the two phenotypes found.

Why phenotypic plasticity was not observed for Spirastrella spp, Ectoplasia ferox, and Spheciospongia vesparium is not known. The amount of sites studied might not have been enough to recognize other species' patterns of itraspecies phenotypic plasticity. Or, the sponges could have exhibited phenotypic plasticity but were either overlooked or regarded incorrectly as a different species. Or, I. strobilina is a special case, different from the other sponge species studied. If in fact I. strobilina is special, then it can successfully inhabit a much broader range of habitats than its sponge competators.

If it is assumed that only I. strobilina posseses intraspecies phenotypic plasticity then two hypothosis' exist to why other sponge species do not exhibit phenotypic plasticity as well. One, phenotypic plasticity is a new ability for sponges and only I. strobilina has this

ability at present. Or, two, that the cost to benefit ration of having phenotypic plasticity is too high to make it advantageous for other sponge species to adopt it.

In conclusion, encrusting sponges are better adapted for areas of high water movement, massive sponges are better adapted for areas of lower relative water movement, and I. strobilina exhibits intraspecific phenotypic plasticity. I. strobilina's morphology is that of an encrusting spone in high water movement zones and that of an erect sponge in lower water movement zones.

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APPENDIX

A1

TABLE 1
MEAN SPONGE HEIGHTS AT THE FOUR SITES

ENCORUSTING			MEAN	S	N	T	P	CLOD LOSS
TEKTITE	Spirastrella	low	1.39	1.61	10.00	1.05	NS	10.38
		high	.43	.25	12.00			19.83
	Ectoplasia	low	.84	.19	5.00	.05	NS	10.38
		high	.82	1.06	10.00			19.83
CABRITE	Spirastrella	low	.50	.26	9.00	.83	NS	11.73
		high	.57	.49	14.00			18.10
	Ectoplasia	low	.00	.00	.00	*	*	11.73
		high	.59	.26	8.00			18.10
MASSIVES								
TEKTITE	Ircinia	low	11.79	2.51	11.00	6.04	<.001	10.38
		high	.26	.05	10.00			19.83
	Spherospongia	low	23.75	6.60	4.00	*	*	10.38
		high	.00	.00	.00			19.83
CABRITE	Ircinia	low	23.87	2.68	11.00	10.55	<.001	11.73
		high	.47	.45	14.00			18.10
	Spherospongia	low	42.80	10.31	5.00	*	*	11.73
		high	.00	.00	.00			18.10

LEGEND:

The table shows the results of the calculation of the mean maximum height, the standard deviation, the sample size, the t-test value and its corresponding p value, and the mean weight loss of the clods placed at the sites.

(* - lack of data point, NS - not significant)

TABLE 2
D VALUE FOR CLOD LOSS

		CLOD #	WEIGHT LOSS	CORRECTED	MEAN(D)	S
TEKTITE SHALLOW		1	17.7	16.06	18.17	3.72
		2	19.4	17.7		
		3	17	15.36		
		4	25.2	23.56		
	DEEP	5	8.4	6.76	8.74	3.21
		6	14.1	12.46		
		7	7.1	5.46		
		8	11.9	10.26		
CABRITE SHALLOW		9	17.5	15.86	16.46	1.31
		10	17.2	15.56		
		11	19.6	17.6		
		12	*	*		
	DEEP	13	11.9	10.26	10.10	1.10
		14	11	9.36		
		15	10.3	9.16		
		16	13.2	11.56		

LEGEND:

The table shows the relative amount of weight loss experienced by the four clod-cards placed at each site. The highest D value shows the greatest amount of water movement.

(* - lack of data point)

TABLE 3
CORRECTION COEFFICIENT

		HEIGHT	D	r	p
SPIRASTRELLA	SITE 1	.43	18.17	-.68	NS
	SITE 2	1.39	8.74		
	SITE 3	.57	16.46		
	SITE 4	.5	10.1		
IRCINIA	SITE 1	.26	18.17	-.88	.05
	SITE 2	11.79	8.74		
	SITE 3	.471	16.46		
	SITE 4	23.87	10.1		

LEGEND:

This table shows the correlation between water movement and mean height of the two sponge species that occurred at all four sites. It shows that SPIRASTRELLA's height did not significantly change in different habitats while IRCINIA's did.
(NS - not significant)

THE EFFECTS OF WATER MOVEMENT AND SEDIMENTATION ON CORAL REEF
COVER AND COMMUNITY STRUCTURE IN ST. JOHN

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ABSTRACT

The structure of coral community was studied at two sites on St. John, U.S.V.I. Percent of live coral cover was significantly different. At a high sediment area vs. a low sediment area, coral coverage was 55.2% in the high sediment area and 31.7% in the low sediment area.

Coral coverage at depths 4 and 6m, were studied at each site. Results at each site showed the four most common species were Montastrea annularis, Porites astreoides, Agaricia agaricites and Millepora spp. Depth effects on these species were variable; clear trends were not evident. Sedimentation rates were different between sites. Water movement was greater at the low sediment site.

INTRODUCTION

Both natural and human induced stress have adverse effects on coral reef communities (Endean, 1983). Both poor land and water use practices have detrimental effects on, and may cause the destruction of, coral reefs (Brown and Howard, 1985). Sedimentation in particular can have significant and lasting effects on coral growth (Brown and Howard, 1985). Whilst most corals are size specific sediment rejectors (Hubbard and Pocock, 1972), excessive sedimentation can result in reduction of skeletal growth, death of the coral, and/or a decrease in planula larval settlement and subsequent success (Endean, 1983). In addition, there appears to be an inverse relationship between sedimentation and coral species diversity on a reef (Loya, 1976).

Some authors (eg. Chappell, 1980 and Foster, 1983), also suggest that coral colony morphology can be modified in response to sedimentation which may lead to the evolution of more sediment resilient forms.

Other physical parameters, such as light intensity, current velocities, and water turbidity also have marked effects on growth and abundance of coral species (Huston, 1985). In the present study, the percent of coral cover and community structure were examined in two contrasting sites to determine whether current velocities, water turbidity and sedimentation affect coral reef communities.

STUDY SITE, MATERIALS AND METHODS

St. John lies at the northern border of the Caribbean Sea at 18°20'N, 64°45'W. Fringing reefs develop along the present shoreline of the island, where reef platforms extend 50-200 m offshore. The site of this study was Yawzi Point (YP), which served as the low sediment site, and Lesser Lameshur Bay (LLB), which served as the high sediment site. Both sites are located on the southeast side of St. John. The coral fauna was described with a modification of Loya's (1972) method. Transects were run at 4 and 6 m depths parallel to the shore. Transects of 10 m lengths were used to study the community structure of corals as it was determined that the maximal number of species was recorded at about this length. All species of corals beneath the transect line were recorded and their length of interception along the line measured to the nearest cm. Each coral colony was also measured at its widest point perpendicular to the transect. An individual was defined as any colony growing independent of its neighbors (i.e. whenever a space was recorded between two adjacent colonies). Where an individual colony was clearly separated into two or more portions by the death of intervening parts, the separate parts were considered as an individual. The relative abundance; percent of living cover beneath the transect; percent contribution of the four most common species to the total living cover; the relationships between coral living cover, water turbidity, water movement and water depth; and the average number of the four most common coral species, number of colonies and average size for each species; were determined after Cox (1972) (in Loya, 1976).

Water movement was measured according to Doty's methods (1971). Clods were made of plaster of paris. Their initial weights after air drying were 24.0 g $\pm$ 0.4 g. They were glued to vinyl clod-cards with contact cement. Five replicates were placed at each site, attached to a metal grid and anchored in place with lead diving weights. They were located at 5 m depths and left in the field for 28 hours before being collected. They were left to air dry before the final weights were taken.

Sediments were collected in glass test tubes, 1.2cm in diameter and 10cm in length. They were placed in test tube racks that were weighted down with lead diving weights. Six replicates were used for each site. These were located at 5 m depths for a period of 28 hours. After recovery, trapped sediments were poured onto pre-weighed filter paper, dried for 24 hours at 60°C and weighed.

RESULTS

A total of 19 species of scleractinian corals were recorded. The relative abundance of corals at each study site are shown in Table 1. The hydrozoan Millepora alcicornis was also included in the study as it is an important cementing organism of reefs in this area. Table 2. shows the mean values of species number, percent of transect with living cover and the percent of total living cover contributed by each of the four most common species. Table 3 gives the results of a t-test applied to the above values as they were compared between sites and depths. Figures 1, 2, 3, and 4 show the percent of total living cover contributed by each of the four most common species.

Table 1. The relative abundance of hermatypic corals in Lameshur Bay, St. John, U.S.V.I.

Species	Species Code	Y.P.4.	Y.P.6.	L.L.B.4.	L.L.B.6.
Montastrea annularis	Ma	dom.	dom.	abun.	dom.
Porites astreoides	Pa	abun.	abun.	com.	com.
Agaricia agaricites	Aa	abun.	dom.	abun.	dom.
Millepora spp..	M	dom.	abun.	dom.	spor.
Montastrea cavernosa	Mc	com.	com.	-	rare
Porites porites	Pp	com.	com.	spor.	spor.
Siderastrea siderea	Ss	com.	com.	spor.	com.
Diploria clivos	Dc	rare	rare	-	-
Diploria strigosa	Ds	rare	spor.	-	-
Diploria labyrinthiformis	Dl	spor.	com.	rare	rare
Colpophyllia natans	Cn	rare	spor.	-	-
Eusmilia fastigiata	Ef	-	rare	rare	-
Acropora cervicornis	Ac	rare	-	-	-
Meandrina meandrites	Mm	spor.	spor.	-	rare
Dichocoenia stokesi	DS	rare	rare	-	-
Dendogyra cylindrus	ds	rare	-	-	-
Favia fragum	Ff	spor.	rare	-	-
Siderastrea radians	Sr	-	rare	-	rare
Madracis decactis	MD	-	rare	-	-

* Index for relative abundance of corals: Average number of colonies per transect (10 m) is between 0.1-1.0 = rare; 1.1-2.0 = sporadic (spor.); 2.1-4.0 = common (com.); 4.1-7.0 = abundant (abun.); 7.1-11.0 = dominant (dom.).

Table 2. The average values of various statistics (per transect) calculated for Y.P. and L.L.B. (Standard deviations in parentheses).

Location	Depth (m)	# transects	# species	% cover	% living cover of 4 most common species	Ma	Pa	Aa	M
Y.P.	4	4	11.75	57.03	60.94	23.51	9.29	8.64	19.51
			(0.5)	(1.97)	(4.16)	(3.93)	(1.78)	(4.66)	(1.98)
	6	4	13.25	53.33	55.10	26.18	8.79	11.83	8.30
			(0.96)	(1.68)	(2.26)	(5.59)	(3.58)	(2.80)	(0.53)
L.L.B.	4	4	7.00	31.83	83.30	38.07	28.56	9.35	7.32
			(0)	(0.75)	(3.11)	(3.65)	(6.89)	(0.42)	(0.63)
	6	4	8.00	31.48	67.56	39.32	3.21	18.50	6.54
			(0)	(1.77)	(8.96)	(6.49)	(1.62)	(3.32)	(2.57)

Table 3. t-tests conducted on the average values of Table 2. between four possible combinations of the two sites of study.

Average values tested	# species	% cover	% living cover of 4 most common species	Ma	Pa	Aa	M
Y.P.4. vs. Y.P.6.	*	*	*	NS	NS	NS	**
Y.P.4. vs. L.L.B.4.	**	**	**	**	NS	NS	*
Y.P.6. vs. L.L.B.6.	**	*	*	*	NS	*	*
L.L.B.4. vs. L.L.B.6.	NS	NS	*	NS	NS	**	**

* $p < 0.05$; ** $p < 0.01$; NS $p > 0.05$.

M.annularius contributed more to the total living cover at L.L.B (t-test $p < 0.01$ at 4m and $p < 0.05$ at 6m). Millipora also contributed more to the total living cover at L.L.B. than at Y.P. (t-test $p < 0.05$). As seen in the figures, Millapora spp. also displayed a larger percent contribution at shallower depths for each site (t-test $p < 0.01$).

Table 2. also shows the percent contribution to total living cover by the four most common species. These species: M. annularis, A. agaricites, Porites astreoides, and Millopora together contribute 57% to Y.P. reef and 70% to L.L.B. reef. Table 4. shows the average colony sizes of the four most common species at each site and depth. In each case there is a decrease in colony size with an increase in depth.

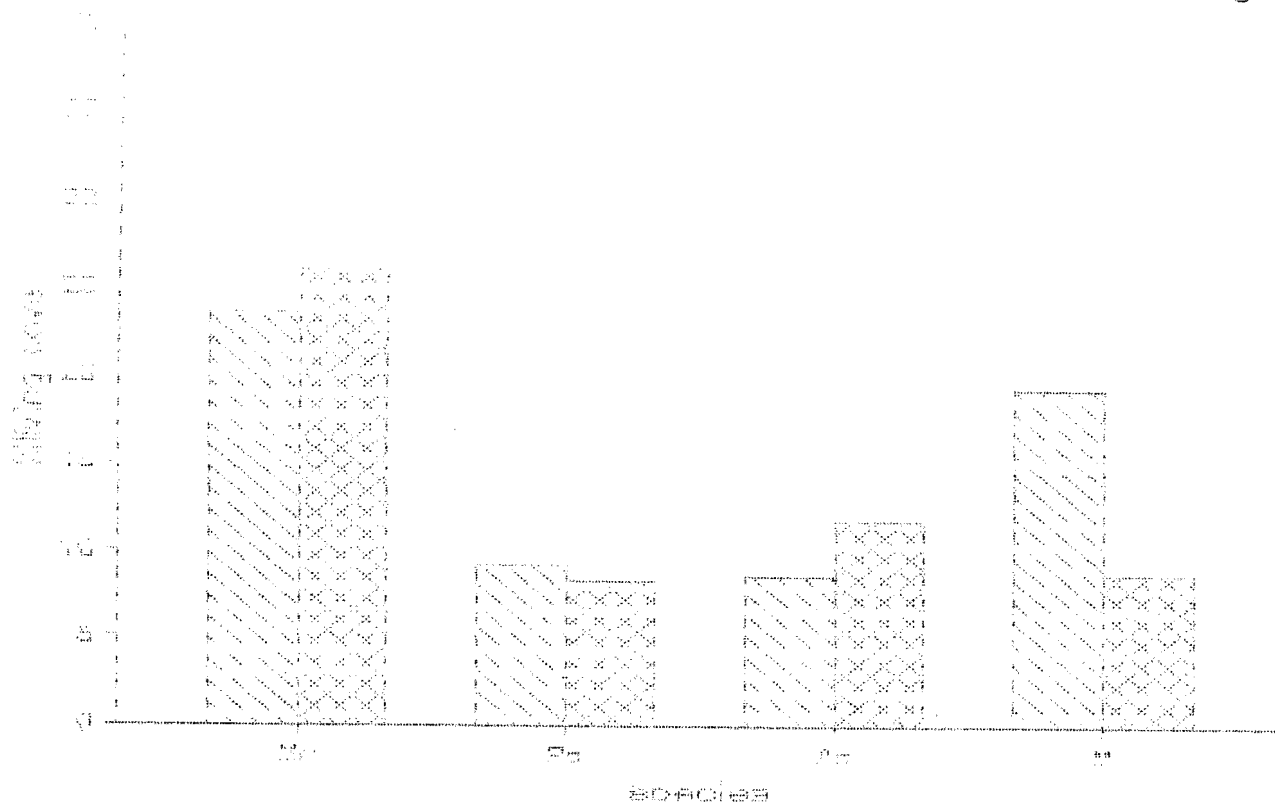


Figure 1. Average percent of living cover contributed by four most common species at YP 4m and YP 6m.

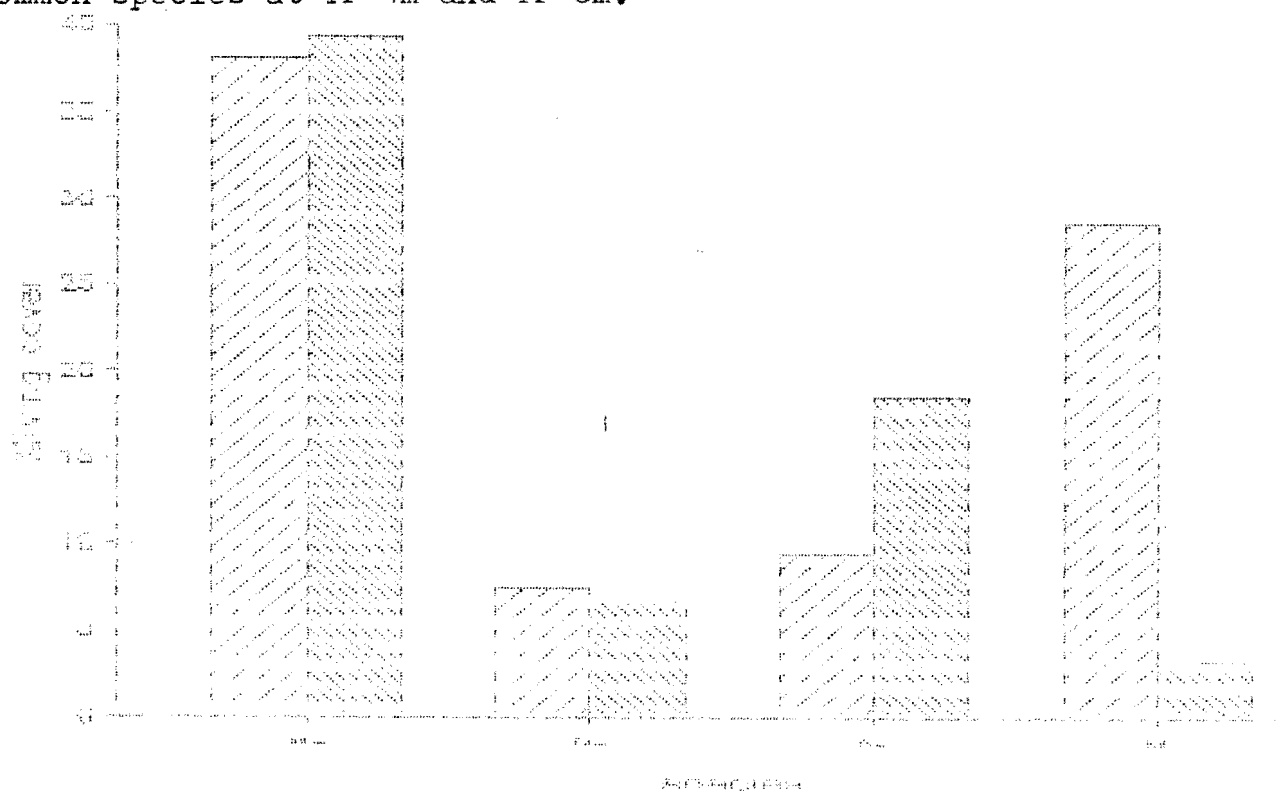


Figure 2. Average percent of living cover contributed by four most common species at LLB 4m and LLB 6m.

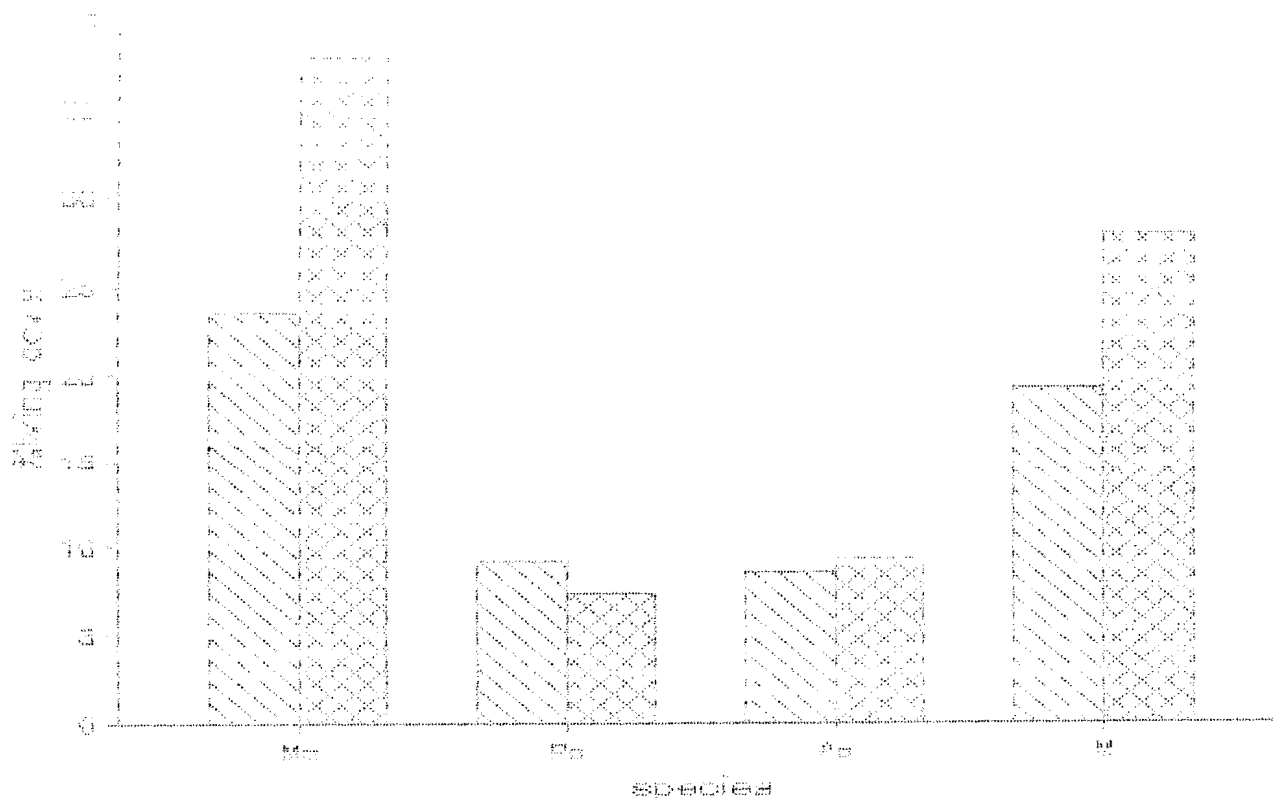


Figure 3. Average percent of living cover contributed by four most common species at YP 4m and LLB 4m.

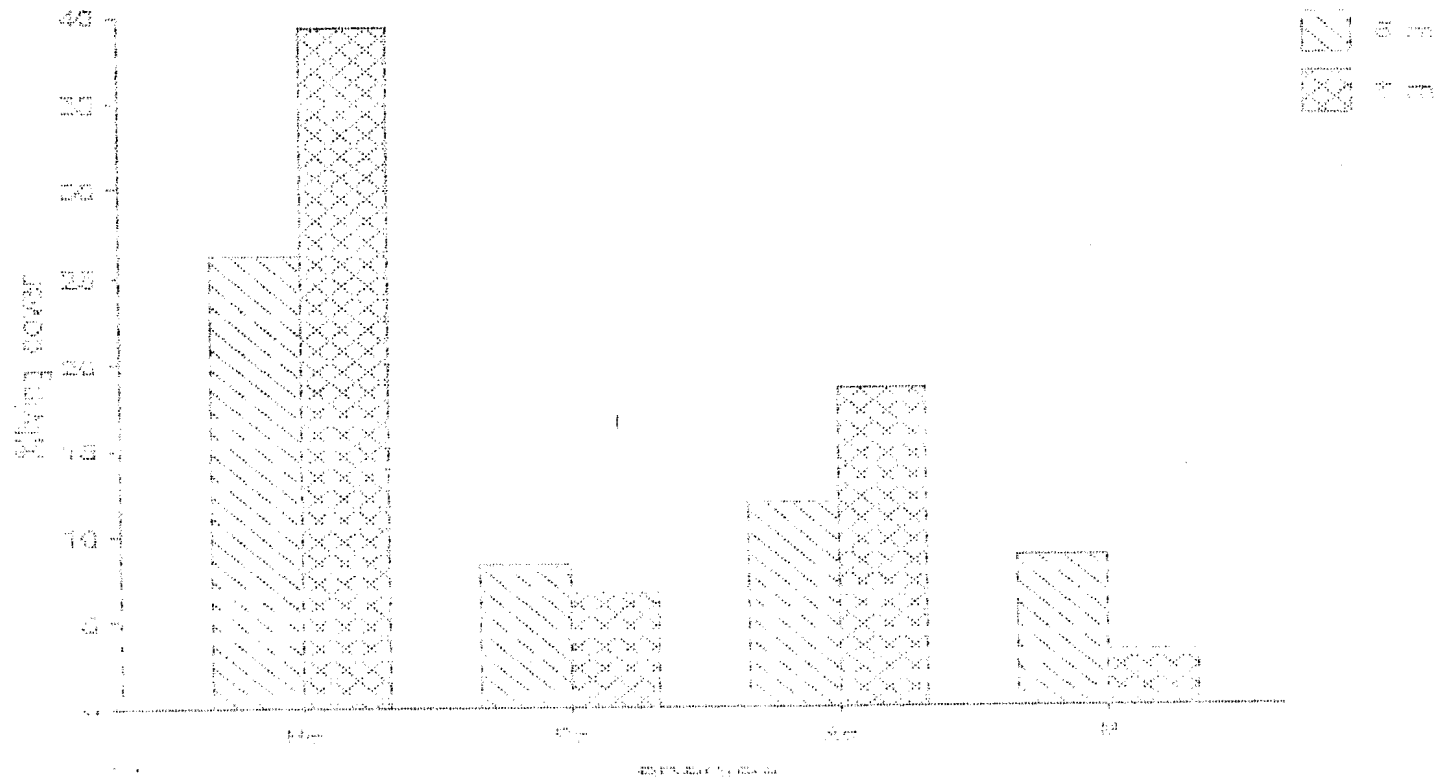


Figure 4. Average percent of living cover contributed by four most common species at YP 6m. and LLB 6m.

Table 4. Average size of the four commonest coral species ($\pm$ standard deviations) at Y.P. 4 and 6 meters and at L.L.B. at 4 and 6 meters; number of colonies measured in parentheses.

Species	Average size (cm)			
	Y.P.		L.L.B.	
	4 m	6 m	4 m	6 m
Ma	14.34 $\pm$ 2.16 (38)	12.18 $\pm$ 1.65 (46)	21.59 $\pm$ 3.89 (23)	12.89 $\pm$ 1.91 (41)
Pa	7.90 $\pm$ 0.79 (27)	7.35 $\pm$ 1.47 (25)	9.65 $\pm$ 2.21 (10)	8.08 $\pm$ 1.72 (10)
Aa	6.39 $\pm$ 1.19 (26)	6.46 $\pm$ 1.40 (39)	6.68 $\pm$ 0.70 (18)	6.16 $\pm$ 0.63 (38)
Ma	9.16 $\pm$ 1.19 (49)	6.86 $\pm$ 2.45 (27)	10.12 $\pm$ 3.13 (37)	4.88 $\pm$ 1.75 (8)

As expected, water movement at YP was significantly more intense than at LLB (t-test, $df=5$, $p < 0.01$). Also, sedimentation rates at LLB were higher than at YP. That is, LLB collects sediment at a rate of 9.6 mg/cm²/day, while YP collects only 6.4 mg/cm²/day.

DISCUSSION

Many authors assume a direct relationship between high sedimentation and low productivity of corals (Loya, 1976). However, mortality may be prevented in the presence of sediment settling if the coral displays sufficient ability to prevent burial and subsequent mortality (Loya, 1976). Montastrea annularis is known to be a dominant reef builder in many Caribbean reefs (Stoddart, 1961). But, with its small calyx size and lower calycal relief, it is a poorer sediment rejector than M. cavernosa (Loya, 1976). Loya (1972) suggested that M. cavernosa and Diploria strigosa should be the most abundant species found in a high sedimentation area since these species seem to be the most effective sediment rejectors. In the present study M. annularis was the most abundant species at two sites (see figures 1-4), that differed in sediment regime, implying that it too is effective, at sediment rejection.

Likewise, Agaricia agaricites with its small calices and few septa is said to be able to reject only fine sediments. In the present study, A. agaricites was found to be one of the four most common species studied at each site. The high occurrence of these two species (M. annularis and A. agaricites) suggests that sedimentation may not be so intense so as to prevent the growth of the said corals. Loya (1976) found sedimentation to occur at a rate of 15mg/cm²/day at his high sediment site and 3mg/cm²/day at his low sediment site. His findings were considerably more significantly different. Also Loya (1976) suggested that where sedimentation is not catastrophic or erratic, but rather constant, these otherwise fragile corals can indeed survive in areas of relatively high sedimentation.

Montastrea annularis proved to be the most abundant species at either site and contributed more to the overall percent cover of total living cover material at the high sediment area than at the low sediment area (23.5% and 26.2% at YP ; and 31.8% and 39.3% at LLB) (Table 2.) However, while this species contributed more to the total percent of total living coverage at LLB, there was considerably less total cover at this site than there was at YP (31.8% and 57.0% respectively). This could be the result of sedimentation preventing the growth of other species which normally add to the reef structure. This could also account for the significantly lower coral diversity found at LLB in comparison to YP (7 and 8 species vs. 11.8 and 13.3 species).

Similarly, Siderastrea siderea also has poor skeletal features for efficient sediment rejection (Hubbard and Pocock, 1972). The same authors have also shown it to be capable of rejecting coarse particles and actually described it as a competent sediment remover. In agreement with their findings S. siderea was found, in the present study, to be a common species at both the high and low sediment areas.

Loya (1976) suggests that differences in community structure, cover and diversity are a direct reflection of differences in water movement and sedimentation rates. Results of this study found that where sedimentation was high and water movement was low, cover of coral was low i.e. LLB had low coral coverage (Table 2.).

Assuming that the percent of bottom cover of coral is a good indicator of colonizing success of corals, it can be concluded that YP is the more suitable site for coral reef development of the two reefs examined. This is in part attributable to the topography of the area where the slope is steep and sediment can run off rather than settle on the coral. Conversely LLB is a relatively flat area which accumulates sediments which retards coral development. In addition, as seen by the results of the dissolving rates of the clod-cards at the two sites, YP experiences a higher amount of water movement than does LLB. This movement may facilitate the removal of sediments from the reef area. These results support Loya's findings (1976).

Another effect often noted in reef structures is an increase in surface area and a tendency to branching of the coral in response to high sedimentation (Edmunds, pers. comm.). This is beneficial in several ways. Firstly, space is a limiting resource and an increase in surface area, by assuming a branching morphology, compensates for the smallness of the coral which results from space competition. Secondly, surface area

is proportional to reproductive potential. Thirdly, coral may be in competition for food material and/or sunlight and an increased surface area will translate to an increase in nutrient consumption. Finally, as discussed previously, an increase in surface area aids the animal in sediment rejection.

It is said that sedimentation increases as depth increases (Huston, 1985). For this reason, and those mentioned above, coral colony size can be expected to decrease in size with an increase in depth. However, the results of this study regarding average colony size showed that Montastrea annularis and Porites astreoides, two of the most common corals present (Table 1.) both show an increase in size and thus, a decrease in surface area. Agaricia agaricites shows no difference in size at all. Millepora spp. was the only coral to show any decrease in average colony size and this did not prove to be statistically different. These results indicate that the two meter decrease in depth does not cause sedimentation to increase sufficiently enough to have an appreciable effect on coral growth.

Loya (1976) suggests an additional possibility of some interest. He proposes that coral success may be limited to areas with hard substrate suitable for polyp settlement. It is, in fact, generally accepted that coral planula larva will settle on solid substrate only (Edmunds, pers. comm.). The effect of placing transient solid substrate at such a site as LLB on living coral cover could provide valuable insight into the question of which environmental factors have the most marked effect on coral coverage.

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SUBSTRATE PREFERENCE AND INDIVIDUAL SUCCESS
OF THE POLYCHAETE SPIROBRANCHUS GIGANTEUS

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ABSTRACT

This study compares the size and morphology of the species Spirobranchus giganteus on two coral species, Millepora spp. and Montastrea annularis. One hundred thirty-three worms were sampled for diameter of the opening of their calcareous tube and number of spirals contained on their filter processes. They were noted for the substrate they occupied and the color of their filter processes. Worms on Millepora were significantly larger than worms on M. annularis in both diameter (9.53mm to 7.31mm) and number of spirals (5.73 to 5.07). This suggests that S. giganteus is more successful when associated with Millepora. Density of individuals on different coral reef substrates and bare rock were calculated by quadrat sampling. No significant differences were found between densities on Millepora and M. annularis. While a small number of individuals was found inhabiting bare rock during the sampling period, none were found in the quadrats.

INTRODUCTION

The Christmas Tree Worm, Spirobranchus giganteus, is recognized as a common inhabitant of the coral reef community (Vittor and Johnson, 1977). A sedentary worm, S. giganteus burrows into a coral head or other solid marine substrate and produces a protective calcareous tube from which it emerges to filter feed. The two brightly colored filters which protrude from the tube opening are spiral shaped with the largest circumference spiral nearest the opening and each successive spiral decreasing in size as the projection ascends, literally resembling a Christmas tree.

Previous work on marine substrates inhabited by S. giganteus has determined that polychaetes are distributed randomly with respect to substrates, and that successful recruitment depended on settlement of planktonic larvae on non-aggressive corals (Hembrough, 86). Hembrough, in his study of polychaete distribution, stated that S. giganteus inhabits Montastrea annularis, a boulder coral almost exclusively.

Whereas, M. annularis is the dominant coral substrate found in Lameshur Bay, the site of Hembrough's study, Millepora, a hydrozoan which resembles hard coral, is most prevalent in shallower waters, less than four meters deep (Cameron, 1987). Millepora is well known for its numerous dactylozooids, specialized polyps which house the cnidarian's nematocysts, and inflict a painful sting to many vertebrates, including man, upon contact (Barnes, 1980). Scleractinian corals which feature no

specialized organ for defense must rely on their singular polyp form to perform both defensive and regular life functions. It could be inferred that Millepora's defensive mechanisms would be superior to those of a scleractinian coral, and be considered more aggressive. Millepora has been identified as an environment inhabited by sessile polychaetes (Vittor and Johnson, 1977).

Hembrough concluded that S. giganteus is best suited for inhabitation of M. annularis due to high densities found on M. annularis in his study. He concluded that S. giganteus settles randomly and prefers less aggressive substrates. If this is the case, it would be expected that the two species would have coevolved and S. giganteus individuals would reach maximum growth and be subject to reduced predation when inhabiting M. annularis.

However, coral abundance may not be the only limiting factor which determines substrate preference. Settlement on a host avoided by predators, for example, Millepora, might provide better protection and reduce predation, promoting a longer life span. This life span could be measured proportionately with size of the individual. Other factors affecting growth might be depth or exposure to wave action. Food particles suspended in shallow waters or introduced by wave action may be more accessible to a filter feeder. If this is true, it would be expected that a substrate that provided better protection or enhanced feeding might be preferred.

In effect, other substrates may harbor more successful individuals regardless of densities. The purpose of this study is to discover whether coral abundance or substrate choice determines individual success and whether there is a preferred substrate.

MATERIALS AND METHODS

Four locations were sampled for S. giganteus in Greater Lameshur Bay, St. John, USVI during April, 1987. All four sites - the Tektite Cliffs, an area in the Coral Garden region, Cabritte Horn Point, and Donkey Bight - were characterized by rock walls (with the exception of Donkey Bight, in which large boulders make up a majority of the substrate) which extend along the shoreline and descend to coral covered flats no deeper than thirteen meters. One hundred thirty-three S. giganteus individuals found randomly in depths of between three and eight meters were noted for inhabited substrate, color, number of filter spirals, and diameter of tube opening. Spiral number was calculated as the number of rings descending down the filter projection. The diameter measurement was recorded in millimeters across the widest part of the tube opening.

Densities of the worms on each of the two substrates and a third, bare rock, were determined by placing one half meter squared quadrats randomly on each substrate at one location, Cabritte Horn Point. The number of S. giganteus individuals found within each quadrat were counted and recorded.

RESULTS

There was a significant difference in means of worm tube diameter between Millepora ($\bar{x}$ = 7.53mm, sd = 2.68) and M. annularis ($\bar{x}$ = 7.31, sd = 2.25) (fig. 1a; t-test, p < .001, t = 5.17). Further, this result was

also reflected in spiral numbers between the two substrates with Millepora's means ($x = 5.73$, $sd = 1.31$) again significantly different to that of M. annularis ($x = 5.07$, $sd = 1.04$) (fig. 1b; t-test, $p < .001$, $t = 3.21$). Data obtained from the quadrats showed an average of 4.33 individuals per meter squared of Millepora, 4.00 individuals per meter squared of M. annularis, and 0.00 individuals per meter squared of bare rock (while no individuals showed up in the quadrats, six worms were recorded during the sampling period). No significant difference was found in densities of worms on Millepora and M. annularis (t-test, $p < .5$, $t = .87$). Significant differences were, however, found between densities of worms on bare rock and Millepora (t-test, $p < .001$, $t = 14.99$), and between bare rock and M. annularis (t-test, $p < .001$, $t = 16.30$).

Color showed no obvious pattern differences between the substrates. However, worms with red in their plumes did appear to be the most prevalent (Millepora - 25 individuals, M. annularis - 26 individuals) among both substrates, (table 1).

DISCUSSION

The great difference in both average size and average number of spirals of the S. giganteus found on the two substrates suggests that S. giganteus is larger when inhabiting Millepora. Whether this is a result of reduced predation or increased growth, or a combination of the two is not known. Regardless, Hembrough's contention that S. giganteus has a proclivity for M. annularis, because it is a non-aggressive substrate, certainly does not hold true. Moreover, S. giganteus proved to be as common on Millepora as on M. annularis, but virtually ignored bare rock, the least aggressive substrate. If planktonic larvae descend from the water column randomly with no advantage gained by attaching to a particular substrate, then high densities of S. giganteus on bare rock would be expected. Certain individual characteristics inherent in a substrate must determine preference.

M. annularis was previously thought to be the preferred habitable substrate because it is appeared to be a relatively benign environment for a sedentary polychaete to settle and grow. Furthermore, M. annularis' abundance suggested that settlement would occur more frequently on M. annularis. However, it is possible that successfully settled larvae may not be an effective indicator of successful adults. A larger mean size of an individual on one substrate as opposed to another with equal densities, as this study has shown, might suggest that one substrate is inhabited by more juveniles, subject to greater individual turnover rate. Thus, M. annularis may be an easily settled substrate but may not provide the advantages required for successful growth that an alternate substrate might. In contrast, Millepora, with larger individuals present, may offer protection from predators or greater access to food, allowing longer lived individuals.

Successful growth may also be influenced by other factors not yet researched. Early on in this study, data collected on the re-emergence time of S. giganteus' plumes after disturbance was discontinued and not statistically analyzed due to high variability of the data points. Yet, what data was collected suggested that there may be a correlation between time and substrate. Another feature of S. giganteus that may have a role in determining a successful individual is a protective spike projected

outward from the lip of the worm's tube opening. Variable upike lengths and orientation (position with respect to substrate surface) were observed in the field. How this would affect growth is unknown.

Color, as indicated in this study, showed no distinct pattern between substrates. However, the distribution of colors in general is not equal. Plumes with any amount of red in them are definately most prevelent. What advantage would be gained from this pigmentation is not known. The two colors which might correspond with those of many reef coral, yellow and brown, and be used as cameflauge are not in the majority, yet appear with regularity. Further study of this may prove valuable.

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No. of
Individuals

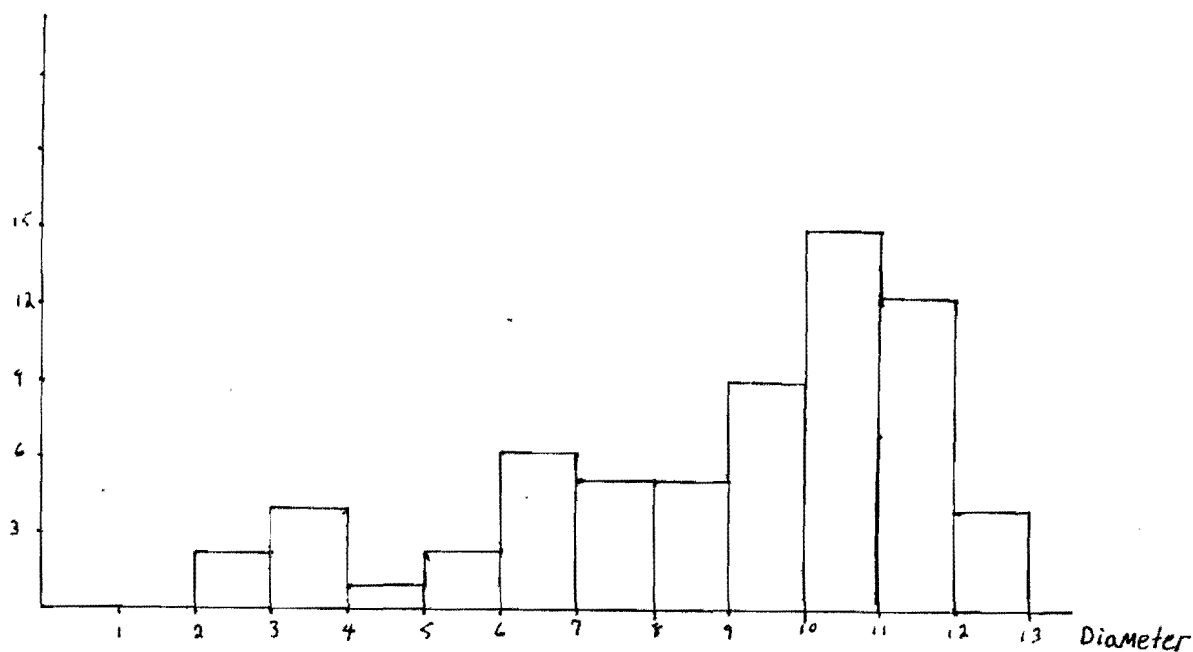


Figure 1a. diameters of Spirobranchus giganteus on Millepora spp.

No. of
Individuals

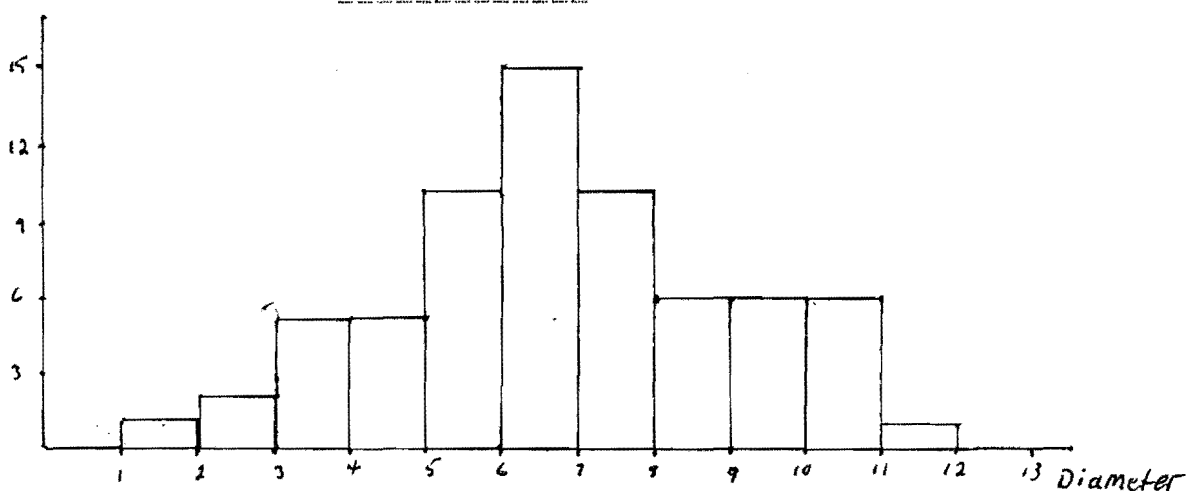


Figure 2a. diameters of Spirobranchus giganteus on Montastrea annularis.

Table 1. color distribution of Spirobranchus giganteus on both substrates.

Color	M.a.	S.g.
Brown	7	13
Red	26	25
Dark Red	10	5
Yellow	12	18
White	10	5
Orange	2	0

THE INFLUENCE OF MANGROVE NURSERIES ON REEF FISH POPULATIONS

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ABSTRACT

The effects of mangrove swamps on the size of reef fish populations was studied in two bays located on the southeastern shore of St. John, U.S.V.I. Adult and juvenile populations were sampled for Haemulon flavolineatum, Ocyurus chrysurus, and Mulloidichthys martinicus at both Lameshur and Europa Bays; the former containing a mangrove swamp at the head, the latter, not having one. It was hypothesized that a bay with a mangrove swamp might potentially have a greater total population of fish as well as a smaller juvenile: adult ratio than a comparable bay without one. Results from either of these studies indicated that the only significance was in the difference between O. chrysurus populations within the two bays ($0.001 < p < 0.005$); Europa Bay actually having none. This indicates that for this species the mangroves may have an impact. An examination of fishpot contents revealed that fishing at current intensity within Lameshur Bay probably has no real drastic impact on the levels of reef fish populations.

INTRODUCTION

There is currently a large controversy over what factors determine reef fish population size. There are intrinsic as well as external ecological factors involved. The important intrinsic factors, from within the population itself, includes survivorship and fecundity. Another is reef recruitment, or the number or proportion of juveniles accepted into an existing local population. This recruitment may be limited or dependant on adult interactions. (Anderson, et. al., 1980)

There are external ecological factors which may be considered important, because they are susceptible to man's impact and are often overlooked by resource managers as being significant. One is the existance of a special environmental condition, separate from the ecosystem in question, but playing an integral role in facilitating the success of reef fish populations. One environment, often altered by man's activities are mangrove estuaries. These mangroves represent sanctuaries where the juveniles mature and may find refuge from predators.

Fishing may also have an impact on fish population, by reducing the number of adults in certain reef fish communities. The types of fishing are by hook and line, netting, or by fish traps. Different types of fishing may have different intensities of selectivity and impact.

The focus of this paper is on estimating the effect of the mangrove environment and fishing pressure on populations of adult reef fish, the main emphasis on the impact of the mangroves. Two questions attempted to be answered are: 1) Is there a greater comparative size in populations of reef fish in a bay with a mangrove swamp as opposed to one where there isn't? 2) What is the proportion of juveniles in these communities?

METHODS

The populations of three different species of fish were examined- the yellowtail snapper (Ocyurus chrysurus), French grunt (Haemulon flavinoleatum), and yellow goatfish (Mulloidichthys martinicus). These species were chosen because earlier observations disclosed that juveniles of these existed in large number in the mangroves. The populations were compared in each of two sites- Greater Lameshur and Europa Bays. Greater Lameshur contains a mangrove swamp whereas Europa Bay does not. Lameshur Bay is also relatively sheltered compared with Europa Bay. Censuses for each were taken in an area approximately 50m long, extending from the rocky substrata near the shore of the bays in depths of approximately 2m out into the halos, over the patch reef at each site. Juveniles were defined as being less than 7cm for all species. Four replicates were done for each bay.

The main fishing pressure in Lameshur Bay is primarily from three fishpots maintained by a local resident. On a few occasions, the contents of these fishpots were examined, and the rate of capture of species caught was determined. This number was extrapolated to estimate a yearly catch rate.

RESULTS

For the two representative areas censused in each of the bays the mean for two replicate samples was calculated. A t-test for significant differences between sample means was calculated for each of the species. Only one of the three, O. chrysurus, showed a significant difference between the populations in the two bays (table 1).

The proportion of juveniles: adults for each sample was also determined. A chi square test was utilized in examining a possible difference in these ratios between Lameshur and Europa Bays. These ratios could only be compared for H. flavinoleatum and M. martinicus due to the absence of O. chrysurus in Europa Bay. The juvenile: adult ration for these was not significantly different for either population (table 2).

The sample catch of fish in three fishpots in Lameshur Bay on the two dates observed bore little resemblance to one another, in terms of both number and species caught. A summary of the contents is listed in table 3. From the nature of the probability of capture, it is difficult to ascertain an accurate extrapolation on an annual basis. An estimation was determined by averaging the samples and projecting this figure of weekly

table 1. The sample means for fish populations in two bays on St. John

	<u>Lameshur</u>	<u>Europa</u>	<u>t</u>	
<u>O. chrysurus</u>	13.75	0	5.589	0.001<p<0.005
<u>H. flavinoleatum</u>	34	29.5	0.976	0.25<p<0.5
<u>M. martinicus</u>	22.75	28	-1.235	0.05<p<0.10

table 2. Contingency tables for two fish species' juv:adult ratios in two bays on St. John

	<u>H. flavinoleatum</u>	
	juveniles	adults
Lameshur	11	22.75
Europa	5.5	24

	<u>M. martinicus</u>	
	juveniles	adults
Lameshur	1.5	21.25
Europa	2.75	27.75

table 3. The contents of 3 fishpots in Lameshur Bay, St. John on two dates.

3/10/87	4/11/87
6 schoolmaster	4 stoplight parrot
2 saucereye porgy	3 long-spined squirrel
1 stoplight parrot	2 saucereye porgy
1 yellow goatfish	2 blue tang
	1 peacock flounder

catch over an entire year. This results in the range of approximately 50-150 caught per annum.

DISCUSSION

It is inferred that if the mangroves were playing a large role in the stabilization of reef fish populations, one might expect population to be larger in a bay where this habitat existed. However, this may not necessarily be the case and may only be partially significant for O. chrysurus. It is also posed that in a bay that has mangroves compared to one that does not, the ratio of juveniles to adults will be expectedly smaller. More of the juveniles will be lingering in the mangroves. This was found to be inconclusive for either H. flavinoleatum or M. martinicus.

Regardless of the findings, the mangroves may still be important for juvenile populations. They appear to represent a sanctuary where they can hide from predators and find a wide selection of food from the nutrient-rich habitat. However, the area and volume of water within the mangroves in Lameshur Bay represents a relatively small proportion of the entire bay.

In the fishing study, it is interesting to note that there might be a greater frequency of transient species being caught in the fishpots than the reef residents. This may be likely because they are placed in the grassbeds just outside the halo, so it is obvious that transient species will come across them more often than the fish that remain resided on the reef. Intuitively, it is predicted that current fishing frequencies in Lameshur Bay will be within sustainable yields per annum.

More study is needed for each of these observed factors. A variety of different impacts was overlooked, including intrinsic factors within the population as well as other external ones. Survivorship and dispersal play roles within the communities. The absence of O. chrysurus from Europa Bay may also be because of sediment turbidity- this bay is much more exposed than Lameshur. To really determine how significant the impact of the mangroves is, one might do a time series study of the rate of turnover of juveniles from them. Another possibility is to examine where these juveniles are being born- if they in fact migrate there as larvae or if adults might be spawning there. If the latter were the case, then the mangroves are very important. More replicates were needed of fish catches. If these catches are in fact representing a random variable cross sample of the species found in the bay, then one might also do a time-series analysis of diversity and richness and determine if this is constant or if some species are decreasing. By getting a more accurate picture of each of these factors, resource managers can plan for the long run.

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BEHAVIORIAL DIFFERENCES IN FIDDLER, LAND, AND HERMIT CRABS DUE TO CHANGES IN HABITAT

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ABSTRACT

Behavior and distribution differences in the three different species of crabs that inhabit the Lameshure Bay area were studied. Fiddler, land, and hermit crabs were observed at different times of the day. The fiddler and land crabs were observed in the mangroves while hermit crabs were higher up in the VIERS camp. The daily activity pattern was related to water availability - with only fiddlers active in mid day and then only at high tide. Aggressive behavior was observed in fiddlers for shelters and hermits for shells. Land crabs proved too secretive for behavioral analysis. Due to different densities, feeding patterns, and home range, I concluded that each crab species necessitated different behaviors due to their differences in habitat.

INTRODUCTION

Several groups of crabs have successfully made the transformation from an aquatic to mostly terrestrial life. Three species of crabs that have made this switch are the fiddlers, land, and hermit crabs. All three of these crabs are found on St. John and other U.S. Virgin Islands. The major problem that controls these crabs lives, is water - daily activity patterns and home ranges were affected by its availability.

The first goal of this study was to look at the distribution patterns of the three. Land crabs are widely dispersed but are not very dense in area. For the fiddler, the opposite holds true. They are found throughout the mangroves but are otherwise not widely dispersed but are very dense in area. The land crab can be found up along the reef bay trail a little past Uropa Bay. These crabs inhabit areas in thicket where a ground cover exists and also in areas with barren ground.

A second goal of the study was to examine behavior. The two types of behavior I attempted to collect data on were feeding and aggression. Economically, defense of resources for the fiddlers is not worth it. The high density of crabs makes it not a viable option. There is aggression during courtship which makes burrows a necessary and protected item. For the land crabs, protection of burrows limits their resource area so that is protected as well. With hermit crabs, the dispersion of so few over a large area makes competition of resources

MATERIALS AND METHODS

For habitat use and density measurements, a 100 meter transect line was laid at the edge of a small body of water in the mangroves to Centerline road at Lameshore Bay, St. John. Along this line a 1 m² quadrat was laid at 1 meter intervals. In each quadrat, fiddler crab and land crab burrows were counted. Differences between the two crabs burrows was clear from the size of each entrance. In total 97 quadrats were counted. From this data, the relative densities of each species and the spatial distribution were calculated. For the hermit crabs, areas adjacent to VIERS camp were censused. The cabins distance from the road to a recorded landmark were measured.

For behavioral data, observations were made on the land and fiddler crabs for 4 days. Initially, crabs were observed during all hours. After the first day, observations were only done in the early morning and early evening for the land and hermit crabs, while fiddlers were studied during mid day. In order to have the least amount of disturbance on the crabs, I used a pair of binoculars to observe them in the distance. The length of each sitting period was determined by the degree of interference. This was either caused by donkeys or mongoose moving through the study area. However, each sitting usually lasted from 1.5 to 2 hours and were always at the same locations over the entire 4 day period.

RESULTS

FIDDLER CRABS

The behaviors of the fiddler crabs has several phases. When the crabs were walking around randomly, they would feed occasionally and show no signs of aggression. But, at times there were attacks by males on other males while wandering around. This aggression was shown by clashing claws and at times interlocking them. Pursuit of females also occurred during the wandering period. In the feeding quarters, grouping took place. During feeding a few individuals would begin to wander away moving on to a new area. As they crawled away, about 10 to 15 more crabs in the group would follow. The only sign of territoriality observed was in the protection of burrows. Males guarded these at times from other males. Usually burrows were explored before the crabs entered. Outside of the aggression, playing took place. In the water, one male would climb on top of another male and 5 to 6 more would follow until the pile toppled.

LAND CRABS

They were not as active as the fiddler crabs but were more aggressive. Territoriality was evident over both food and burrows. When the crabs were at they didn't wander far from the burrows.

When observing densities of these burrows, it is clear that the spatial distance of each is not random, as it is for the fiddler. Throughout the entire 30 quadrats of fiddler burrows, the density of

these fiddlers. With the land crabs, the density was constant and almost always had 2 burrows per quadrat. This can be seen in Fig. 1.

HERMIT CRABS

They were not territorial over area or food and didn't return to an area which was already visited unless a food source was still there. The density of this crab was 0.2 per quadrat.

All three species showed little overlap in distribution. Between the land crabs and the fiddlers, there exists a well defined border. The fiddlers inhabit an area down around the mangrove roots. The closer they are to water, the more dense the population. As you move towards higher ground, they continuously thin out. Once the mangrove roots end, the general population ends and the land crab begins.

The burrows of these land crabs were dug deep enough to penetrate the water level. These burrows are in a dry area as where the fiddlers are in a very moist area and their burrows are shallower than the land crabs. Considering the type of soil each lives in, the dry compacted soil of a land crab would be more difficult to penetrate than the soft soil of a fiddler. Therefore you can conclude that a land crab has much more reason to be territorial over burrows than a fiddler. The fiddlers were active throughout the day while the land crabs only emerged from their holes in the mid morning and early evening. For the hermits, their home is the shell on their back. They were active mainly at night but were seen feeding and traveling during the day too.

DISCUSSION

Fiddler crabs have the highest density of all three crabs. The food they ingest is found on the bottom of the pool. At any one time there are 300 to 500 individuals feeding in that pool. To defend a block of this territory would be impossible, and if it were possible, the costs of doing it would outweigh the benefits. I did find them to be territorial over their burrows. It has been noted that fiddler crabs often change burrows, although with courtship, a particular burrow is defended for the whole display phase (Schone, 1960). Burrows which are closer to food sources might also be of more interest. Individuals in these burrows may use less energy to get to the water to feed. The energy put into building a burrow may also make it worth fighting for.

The land crabs, were much more territorial over their holes than fiddler crabs. The habitat they live in is very dry and during the day they become inactive. Land crabs can only thermo regulate by staying in their burrows. These burrows are dug until they reach the water table. The cost of losing a burrow maybe very severe and that is why they don't wander from them. In comparison, the fiddler crabs homes are in the very saturated soils of the mangroves, and living in a moist area enables them to wander around more. There is not the worry of having to dig a new home and is easy to find an abandoned one. Land crabs are endowed with large claws which they use for eating and protection. These claws can't pick up the small particulate matter that the fiddler can. Therefore it is possible that the resources they utilize

the larger will be found lower down in the mangrove.

All three land crabs have adopted unique behavioral tactics to deal with the potential problems of living in a terrestrial environment. The main problem appears to be desiccation. Although the type of resources and the cost of losing a shelter appear to play an important role in their different behaviors.

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SIZE DISTRIBUTION AND DENSITY OF STROMBUS GIGAS
IN GREATER LAMESHUR BAY, ST. JOHN, USVI

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ABSTRACT

Populations of queen conch are being rapidly depleted due to an increased market for conch and over-fishing. Studies on conch populations are important as they can aid in setting up management and conservation in areas where needed.

Using a series of transect lines along the southeast area of the bay, the size and distribution of conch was mapped. Two separate areas were found to exist, one southern and one northern. The northern area had a significantly higher percentage of juveniles than the southern area. This may be because of predation or because the northern bed area is an egg laying territory.

Compared to a similar study done in November 1986, there was a noticeable absence of larger conch. This is most likely due to migration to deeper waters.

INTRODUCTION

Strombus gigas (queen conch) is a large marine snail which inhabits areas stretching from Bermuda and Southern Florida to areas throughout the Caribbean Islands. It is found at depths ranging from only a few inches of water down to 76 meters (Randall, 1964). It is generally found at shallower depths (6-30m), however, due to light restrictions and reduced or absent plant growth at deeper depths. It seems to feed on the epiphytic algae found on Thalassia and sandy areas, using an extendable proboscis to graze (Robertson, 1961).

S. gigas has been an important food source for the people of the Caribbean throughout its history. Recently, conch fishing has increased due to the development of a frozen conch meat market in the United States (Brownell and Stevey, 1981). Increased exports have led to a drastic decline in conch populations throughout the Caribbean due to over-fishing. Some conservation efforts, such as closed seasons (Belize), minimum size requirements (Belize), requirements that a portion of the catch be reserved for local consumption (Belize), establishment of sanctuaries (Venezuela), daily catch quotas (Florida), and the prohibition of export of unprocessed products (Bahamas) have been implemented to help preserve existing populations (Brownell and Stevey, 1981). This is important since little is known about the biology or larval rearing of conch, and a misuse of this resource now may result in its extinction in the future.

The present policy of the U.S. National Park Service on St. John is to allow the removal of two conch per day per person from any of the bays within park boundaries. At this rate, the entire conch

population of the island could be depleted in a short period of time. Size and age estimates for conch classify conch of 8.8 cm to be yearlings, conch of 12.6 cm as 2-year olds, and conch of 18.0 cm to be 3-year olds (Berg, 1976). At 2.5-3 years, the conch builds a flared lip; it continues to grow more meat, but at a slower rate. Sexual maturity is reached at 3-3.5 years of age. These estimates show that S. gigas reach marketable size before they are sexually mature.

A fairly large conch bed is located in the SE side of Greater Lameshur Bay. A population study was conducted during the Fall of 1986, and the following conclusions were made: 1) Two age classes were found. Small juveniles ranged from 8.9 cm to 15.2 cm (mean size 11.9 cm) and large juveniles ranged from 15.2 cm to 22.9 cm (mean size 18.0 cm). 2) Assuming that the bimodal distribution found represents real annual growth rates, the difference between the two means, 6.1 cm., corresponds to the average growth rate of juvenile conch per year. 3) A greater amount of small juveniles were found in the NW portion and a greater amount of large juveniles in the SE portion of the conch bed. 4) No adult conch were found. (Morrow & Conway, 1986)

The purpose of this study is to determine the distribution of S. gigas by size and to see whether last year's population has grown to adults or if the population has remained in the small-juvenile to large-juvenile size.

MATERIALS AND METHODS

The southeast section of Lameshur Bay, between Donkey Bight and the north Tektite region, was surveyed using a series of transect lines. Donkey Bight is a section of the rocky SE shore of the bay characterized by two large rocks that project off of the shore. The base marker of the first transect line is a rock at the far edge of the halo (see figure 1). From this starting point, there is a distinctive pointed rock 34.5 m away at 220° and a large smooth white rock (the beginning of the series of Donkey Bight rocks) is located 37 m away at 340°. From the base marker, two main baselines were laid out. The first baseline extended 150 m at a bearing of 135°. At each 10 m interval, a 30 m transect was set perpendicular to the baseline on each side and the conch were sampled. A "fill-in" baseline was placed 50-100 m at 135° out from the base beginning 30 m away (at 225°) from the baseline. Transects were extended out each 10 m distance to fill in the halo area.

The second main baseline was 130 m long at a 45° bearing from the base marker. From 30-80 m, 10 m transects were laid perpendicular to the baseline and conch were sampled. At 80 m, a "probe" was extended 100 m out at 315° and conch were sampled. At the 100 m and 120 m marks, a 50 m transect was extended at 135° and a 100 m probe was extended at 315°, and conch were sampled.

Sampling of the conch consisted of traveling the length of the transect on SCUBA with a one meter PVC pipe, measuring the spire length (spire to siphonal canal) and body length, and noting at what meter it was located for all conch within one meter of each side of the transect line.

Transects were also laid out and conch sampled at Cabritts Horn Point. To do this, a bearing of 45° was followed under water until

APPENDIX

Table 1: The means and standard deviations of total bite rates/min for Acanthurus coeruleus

	small solitary	large solitary
x # bites/min	31.5	13.4
Sd	12.12	10.34
	small individual/ school	large individual/ school
x # bites/min	47.94	46.84
Sd	10.13	9.92

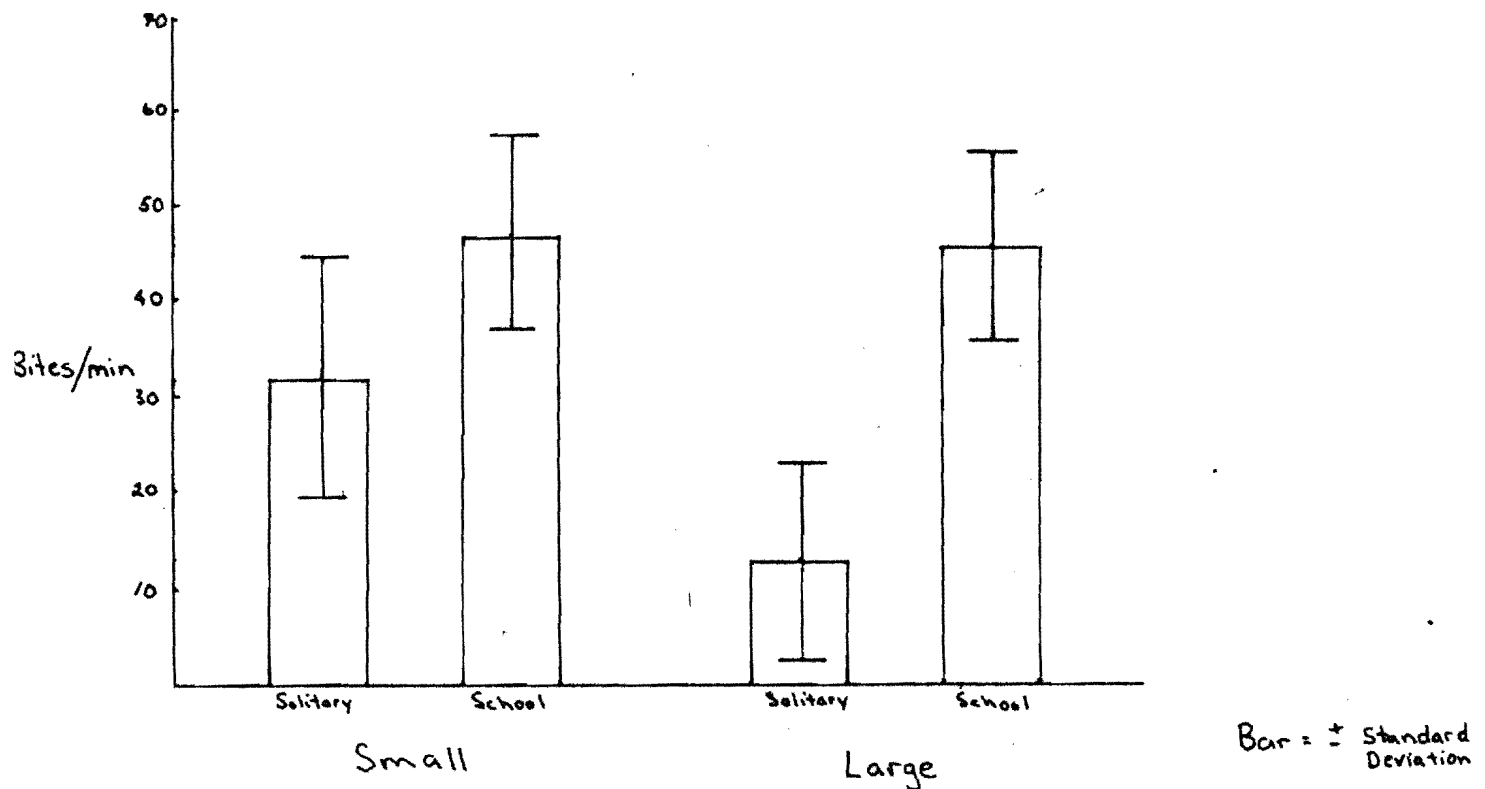


Figure 1. # of Bites taken by Small and Large Acanthurus coeruleus (solitary to Schooling individual)

Small
 Solitary $\bar{x}$ bites/min 31.5
 Sd $\pm$ 12.12
 School $\bar{x}$ bites/min 47.94
 Sd $\pm$ 10.13

Large
 Solitary $\bar{x}$ bites/min 13.4
 Sd 10.34
 School $\bar{x}$ bites/min 46.84
 Sd 9.92

the halo was reached. A point was selected at the edge of the halo. From this point, a 30m. transect was laid out at 45°, 135°, and 315° and conch were sampled. Our selection of the starting point may have been biased by seeing mature conch for the first time and a high density area was selected. On a different day, a transect was set out at 45° from the edge of the same halo area, and conch were sampled. This sample gave an unbiased sampling measure. Mature conch were sighted at the area off of Tektite, but no sampling was done.

Approximately twenty conch shells which were around the Virgin Island Ecological Research Station and had been harvested for food were measured by body length. (Conch is known to have been harvested if there is an oval hole on the top of the shell where it had been broken open to remove the meaty body from the shell). The shell sizes ranged from 27 cm. to 18 cm. This showed that conch as small as 18 cm. are fished for food. In this report, conch greater than 18 cm. in body length will be known as 'harvestable'.

RESULTS

1) Spire Length vs. Body Length.

When taking measurements of conch in our survey, both spire length and body length were recorded. Spire length ranged from 3.5 cm to 17 cm and body length ranged from 7 cm to 24 cm. In sampling, it was found that for a given spire length, there was a wide range of possible body lengths. Figure two shows spire length vs. body length. Because of the inconsistency of spire measurements, body length was used to map and compare conch size.

2) Size Distribution and Density of *S. gigas* in Greater Lameshur Bay.

There were two main areas to the conch bed in the bay. The bay was divided by first mapping the bay and then by noting the two separate areas of high density. The southern portion was found to have 87 juveniles (66%) and 45 harvestable conch (34%) for the 1950 m surveyed. This is a density of 4.5 juveniles/100 m² and 2.3 harvestable/100 m².

The northern portion (see figure 3a-3b) was found to have 269 juveniles (89%) and 32 harvestable conch (11%) for the 1656 m surveyed. This is a density of 16.2 juveniles/100 m² and 1.9 harvestable/100 m².

A Chi-Square analysis was done to see if the number of juveniles and the number of harvestable conch in the northern and southern areas were significantly different from expectations based on the predicted number of conch if they were evenly distributed over the two areas. (see table 1). χ^2 was calculated to be 125.8 with one degree of freedom; $p < 0.005$.

3) Size and Frequency

The mean size for the surveyed conch population was found to be 14.6 cm. Two distinct size classes were not found; instead there was a unimodal distribution of body length size (see figure 4).

When compared to the studies done in November 1986 (see figure 4), a large percentage of the larger sized conch (17 cm - 19 cm) were missing in our population sampling.

Table two shows the conch frequency for each size (7 cm - 24 cm) for November 1986 and April 1987.

4) Cabritte Horn Point and Tektite

Mature adult conch were seen at both the Tektite area, and Cabritte Horn Point. Two samples of conch were taken at Cabritte Horn Point. The first sample showed 13 conch in a 180 m area. The density was 6.6 conch/100 m² (see figure 5). Our second sample was taken from a point in the halo and the density was 1 conch/100 m². The second sample taken is a better estimate of the actual density of the bed.

DISCUSSION

From the comparison with last semester's project, it is apparant that a large part of the larger size class which was present in November 1986 is gone now in April 1987. This may be due to fishing in Lameshur Bay, but more likely, these conch have migrated to deeper water, such as areas around Tektite, Cabritte Horn Point, and beyond. Queen conch have been shown to migrate seasonally (Hesse, 1979). They also migrate within a "home range" when not in seasonal migration. The size of the home range is small for juvenile conch and becomes increasingly large as the conch grows. The difference in the number of larger conch this spring may be due to a seasonal migration of the larger conch, or a normal migration to a different area of its home range. The juveniles may also be migrating but their home range may not extend out of Lameshur Bay.

The variation in the number of juvenile and harvestable size conch in the two areas is significantly different. ($\chi^2 = 125.8$; $p < .005$) The substrates of both of these areas was varied. Higher densities of both juvenile and harvestable size conch were found to be on substrates which were a mix of bare sand regions and Thalassia (Anita Graf, 1987).

S. gigas migrate to shallower water to spawn (Randall, 1964) The northern conch bed may be the egg laying region and therefore the region with a higher percentage of juveniles. As the conch grow and mature, they move relatively close to the halo (they are not found in the middle section of the bay) out to deeper water. The southern area may be part of the route of migration from shallow to deeper water.

The southern conch bed is in an area which is exposed to a lot of coral regions along the edges. Juveniles were not generally found near the halo areas. This may be due to predation. Octopus, queen triggerfish, spiny lobster, and other reef-dwelling predators may travel to the edge of the grassbeds for feeding, and the juvenile conch are much easier to crack open than the larger sized conch. The northern conch bed, on the other hand, has less area exposed to the coral and a higher percentage of juveniles.

Larger conch have been sighted in halo areas and even next to corals. Only one mature flare-lipped conch was found in Lameshur Bay (not in our transect areas). Populations of mature conch were found at the Tektite area and at Cabritte Horn Point. The size of the conch bed could not be measured in these areas, but may stretch out for several hundred meters in all directions. This seems to be the area to which the larger conch migrate to. It may be that all sizes migrate out to the deeper water and the smaller juveniles are preyed upon quickly. This seems unlikely, however, being that no conch besides mature flare-lipped individuals were sighted.

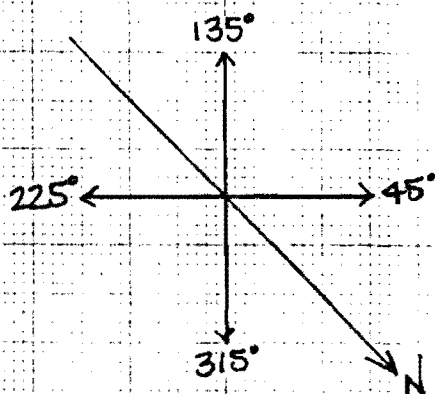
From this study, the distribution of conch by size has been mapped for Lameshur Bay, and the higher concentrated area of juveniles vs. harvestable size was found. Comparisons with research done last November indicates a difference in number of large individuals in the bay. This could pose some questions for further researchers and also aid in learning about seasonal migration patterns in Lameshur Bay.

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BEACH

DONKEY
BIGHT



KEY

- = halo
- = base marker
- Λ = sharp rock
- = smooth white rock
- └ = 10 meters

FIGURE 1. MAP OF AREA AND TRANSECT LAYOUT FOR CONCH SURVEY IN GREATER LAMESHOR BAY, ST. JOHN, U.S.V.I.

Spire Length vs. Body Length

Strombus gigas



Figure 2. Spire Length vs. body length of Strombus gigas; measured from conch in Lameshur Bay, St. John, USVI

No. of
Individuals

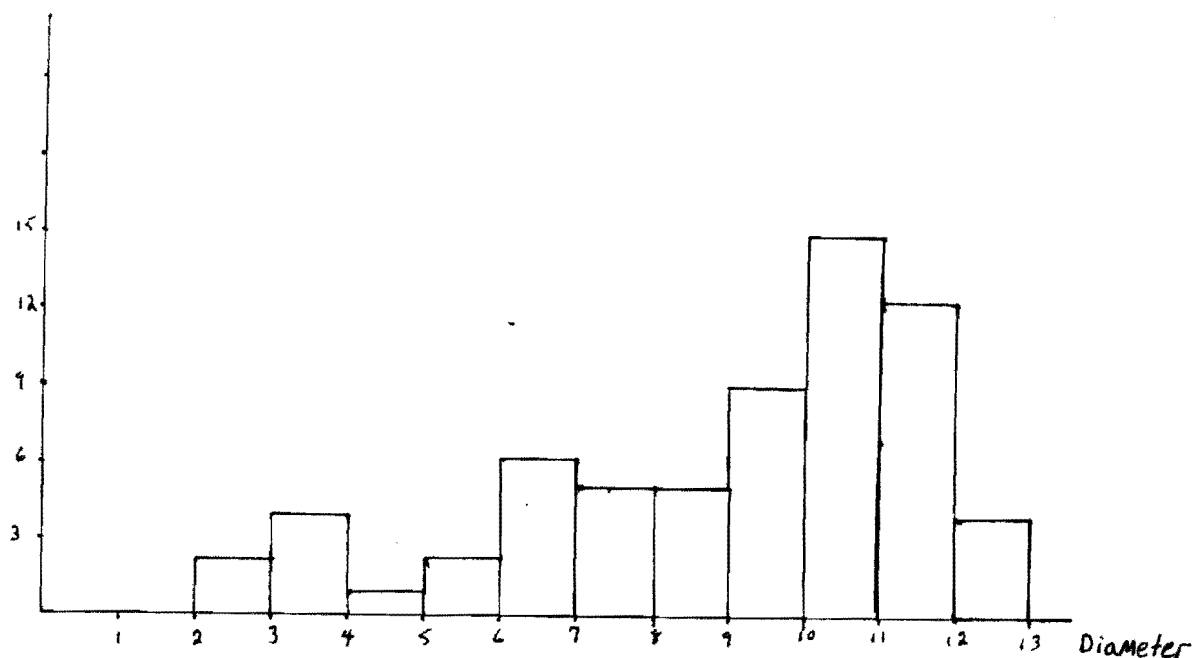


Figure 1a. diameters of Spirobranchus giganteus on Millepora spp.

No. of
Individuals

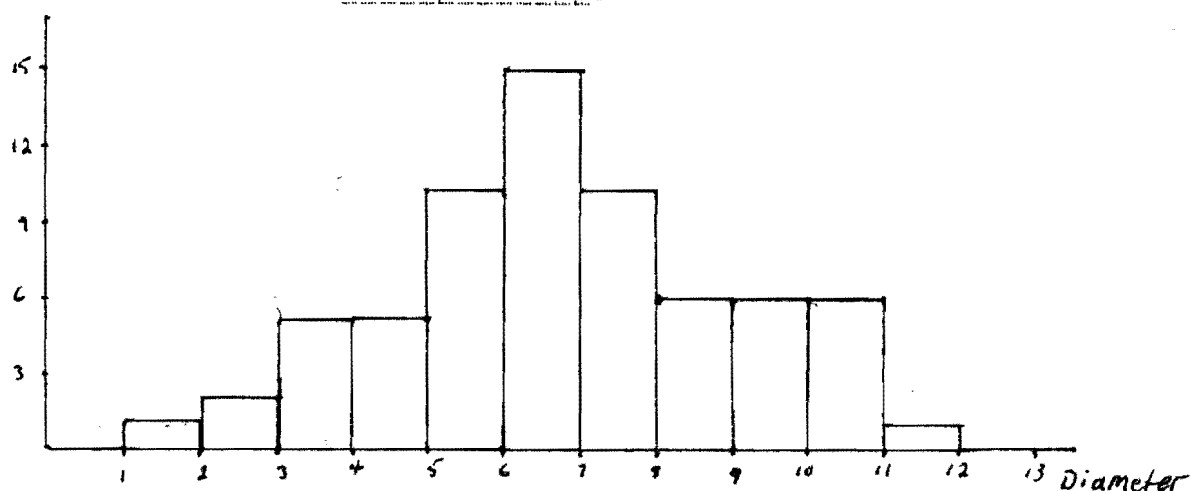


Figure 2a. diameters of Spirobranchus giganteus on Montastrea annularis.

Table 1. color distribution of Spirobranchus giganteus on both substrates.

Color	M.a.	S.g.
Brown	7	13
Red	26	25
Dark Red	10	5
Yellow	12	18
White	10	5
Orange	2	0

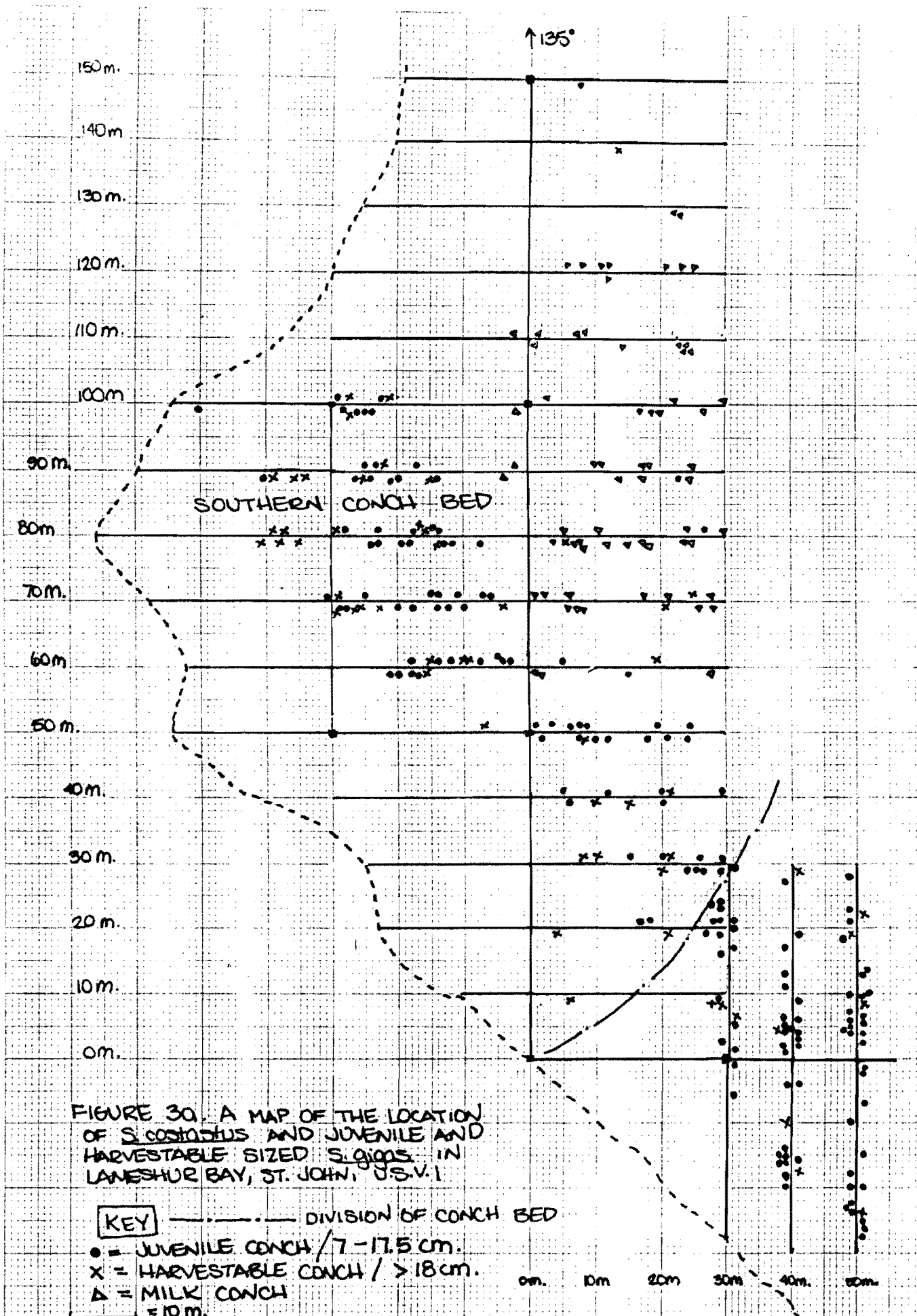
Conch Size Class Frequencies
of Strombus gigas

<u>size (cm)</u>	April 1987		Nov. 1986	
	<u>frequency</u>	<u>percent</u>	<u>frequency</u>	<u>percent</u>
7	1	0.21		
8	3	0.64		
9	2	0.42	3	0.37
10	5	1.06	98	12.13
11	10	2.12	169	20.92
12	57	12.08		
13	119	25.21	126	15.59
14	112	23.73	66	8.17
15	43	9.11	16	1.98
16	21	4.45		
17	17	3.60	72	8.91
18	21	4.45	129	15.97
19	21	4.45	80	9.90
20	17	3.60	39	4.83
21	12	2.54		
22	5	1.06	9	1.11
23	5	1.06	1	0.12
24	1	0.21		
Total	472	100.00	808	100.00

Table 2. Strombus gigas size frequency and percent found in
Lameshur Bay, St. John, USVI.

southern section		<u>juvenile</u>	<u>harvestable</u>	<u>total in each area</u>
	observed	87	45	132
	expected	192.2	41.6	
	χ^2	57.6	0.28	
northern section	observed	269	32	301
	expected	163.8	35.4	
	χ^2	67.6	0.33	
total # observed		356	77	
$\chi^2 = 125.8$		p	0.005	

Table 1. Chi-square analysis to determine if the southern and northern areas are significantly different in the frequency of juvenile and harvestable conch.



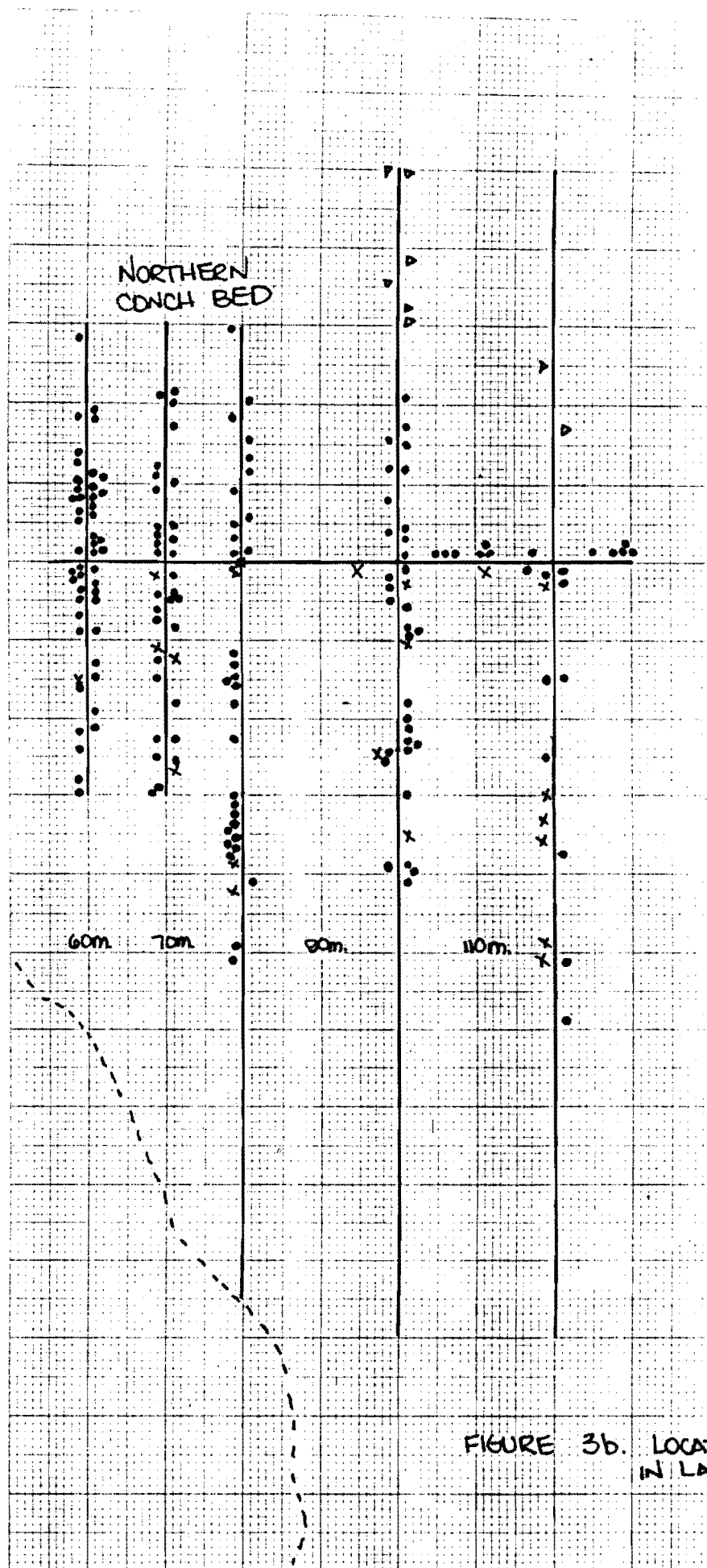


FIGURE 3b. LOCATION OF CONCH
IN LAMESHUR BAY, CONT.

Strombus Size Frequencies

April 1987 and November 1986

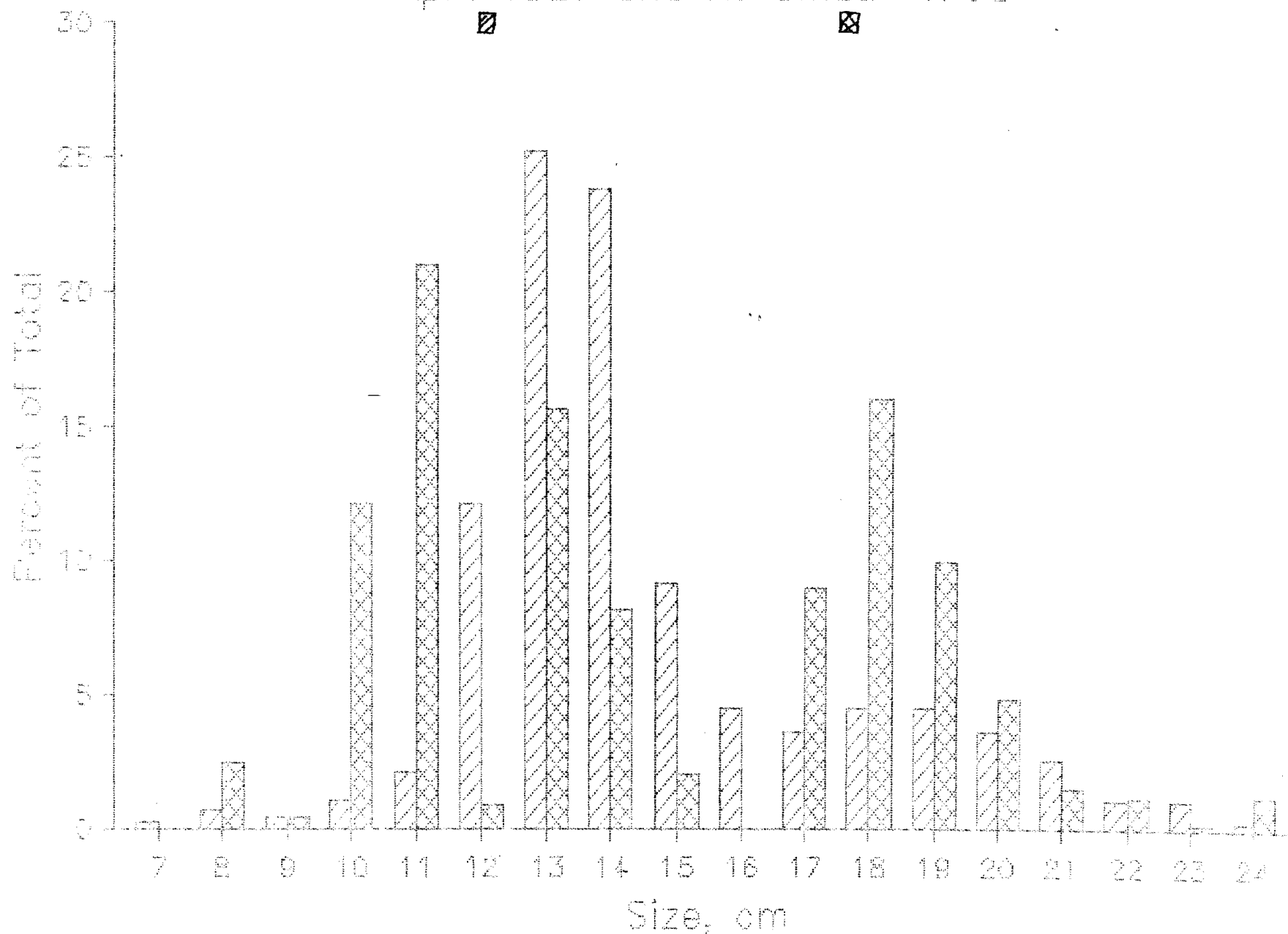
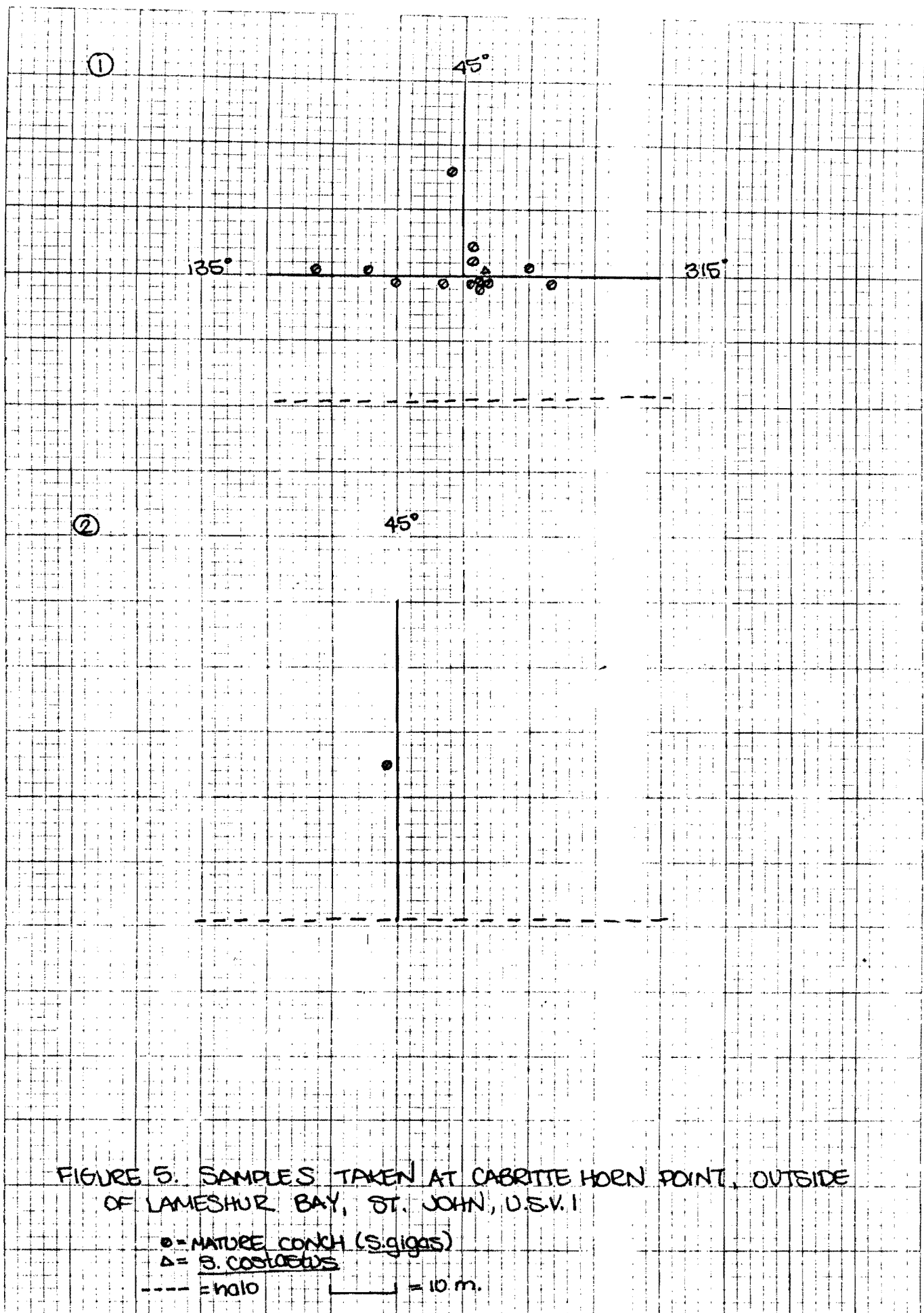


Figure 4. A comparison of size frequencies of *S. gigas* found in November 1986 and April 1987, in Greater Lameshur Bay, St. John, USVI.



DISTRIBUTION OF STROMBUS GIGAS IN RELATION TO SUBSTRATE
COMPOSITION IN GREATER LAMPSHAW BAY, ST. JOHN, USVI

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ABSTRACT

Mapping of a Strombus gigas population was carried out through April, 1987, along the northeast portion of Greater Lampshear Bay on St. John, USVI. Areas of low to high density were compared to a mapping of six classes of substrate found within the study site. The conch were significantly more abundant in areas of sand and Thalassia sp. than anywhere else. Implications of this study on management programs and general knowledge of conch biology are discussed. Further study is suggested and some in particular are described.

INTRODUCTION

Recognizing the commercial value and the resulting declining numbers of the queen conch, Strombus gigas, from over-fishing has made management studies and regulations of this popular mollusk crucial to its survival. Basic physiology, environmental habitats, predator-prey relationships, and behavioral characteristics have been studied (Randall, 1964; Hesse, 1979; Iversen et al, 1966), yet much remains to be known. Brownell and Stevely (1981) reported the geographic range of conch to be from the southern coasts of the Gulf of Mexico, along the northern coasts of Central and South America up to Bermuda and including all of the islands in the Caribbean. Conch are reported to live in shallow waters only a few cm deep down to depths of 76 m and they are commonly found on sandy bottoms that are stable enough to support the growth of algae and sea grasses upon which they are believed to feed (Brownell and Stevely, 1981). Food preference is still uncertain, yet studies by Robertson (1961) indicate that epiphytic algae on the sea grasses, particularly Thalassia, is more important than the grasses themselves. Randall (1964) reported feeding by conch during the night, especially for very small individuals, as well as the day. Hesse (1977) reported seasonal migrations of conch which resided parallel to shore during the summer (March-September) and shifted offshore during winter.

Fertilization is internal, and copulation precedes spawning by several weeks (D'Aunno, 1965; Randall, 1964). Females produce egg masses, and the larvae, or veligers, emerge after approximately five days (D'Aunno, 1965) and immediately assume a pelagic lifestyle. Within a month the larvae have completely metamorphosed (Brownell, 1977). Borg (1971) estimated that after up to three years of growth, building the shell in a spiral fashion, the adult mollusk has the flared lip, and

sexual maturity, is then retained well after the loss of the shell. The first lip at an age of 3-3.5 years (Brownell and Stodard, 1961). The list of conch predators is lengthy and well covered by Randall (1964). In April, 1967, we conducted a conch survey of the southeast grass bed of Greater Lameshur Bay on St. John, USVI, from Donkey Bight to Tektite (Figure 1). A small survey was also conducted at Cabbage Point. Lameshur Bay is part of the protected area on St. John within jurisdiction of the National Park Service making it a relatively undisturbed, isolated area appropriate for long-term population studies. We expect then that this study will be continued and our results will become part of the foundation of a well-studied population over time.

In December of 1966, Sybil Conway and Tracy Morrow did "star" transects within the Lameshur Bay grassbeds and first discovered the conch bed. They proved that the population was a non-random congregation of individuals and in addition they were able to distinguish a difference in location between two size-classes of juveniles. They found no adults. We were then able to compare our map with theirs for size distribution (J. Beeh, 1967) and estimated total conch numbers. In addition, this study was able to go further by doing daily movement studies of individual conchs (Dana Stoddard, 1967) and grass bed analysis in relation to conch distribution. This paper covers the latter.

A significant relationship between conch distribution and grass bed composition could aid in the protection, management, and mariculture of conch. It could also distinguish factors which would help analyze the status of other, less protected, more disturbed conch beds for the effects of over-fishing and loss of grassbeds due to anchor scars.

MATERIALS AND METHODS

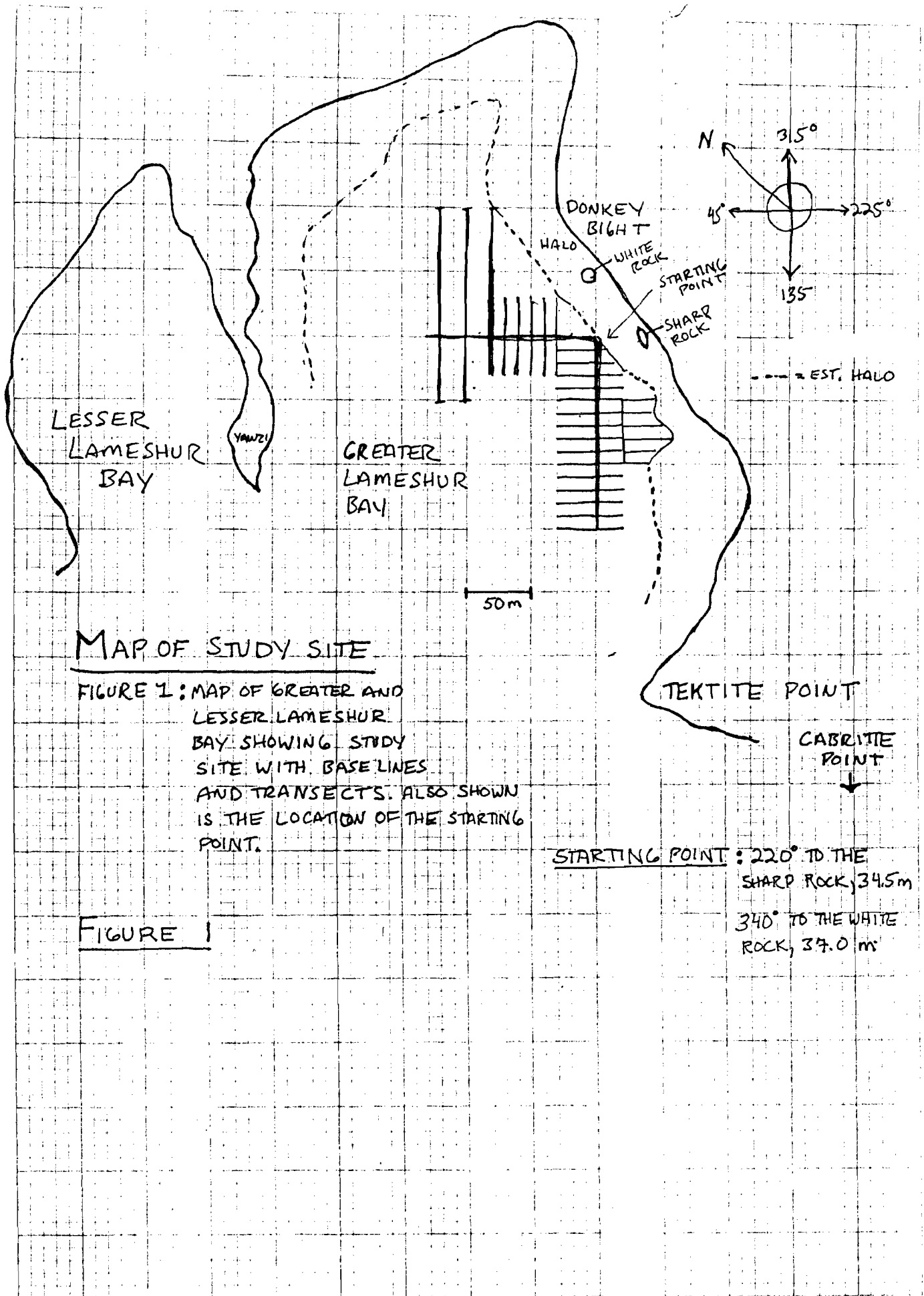
Using SCUBA, mapping was carried out by recording numbers and sizes of conchs within two meter wide bands perpendicular to six 50 meter baselines. The first three baselines were laid out end to end from a starting point near the shore by Donkey Bight to a point in more openwater between Donkey Bight and Tektite on a 315° bearing. All end markers, including the starting point were marked by tying styrofoam floats onto rocks. The starting point was measured from two prominent rocks south of Donkey Bight.

The starting point was 37p from the rock closer to Donkey Bight on a 340° bearing and 34.5m from the second rock on a 220° bearing. The pattern of subsequent baselines and transects and their relation to reef halo is shown in Figure 2. A baseline was first laid out then a transect was laid out perpendicular from it every 10m. Each buddy swam with a 1m long pole along each side of each transect and recorded at what meter each conch was found and the size (in cm) of the conch. Later we mapped the area by recording visual percent cover of the major seagrasses and algae on coral. All data was taken between 1 and 3 p.m. Areas within and near the reef halo around Tektite and Cabbage were observed for adults and a small survey of 200m² was taken at Cabbage using the same methods. The area from the study of Tektite to Cabbage was also surveyed for conchs.

RESULTS

Figure 1 shows the location of the study site within the SE section of Greater Lincoln Bay. Three main sections were surveyed, the first being an area from Donkey Right out toward Tokite; the second area from Donkey Right out toward the bay at a 90° angle from the first area and the third area out toward the northern shore of the bay from the end of the second area. New areas were chosen for their potential significant conch density (either found by snorkel or figured from previous mappings). Figure 2 shows the area in greater detail with the bearings and measurements from the shore and the pattern of baselines and transects used in relation to reef halo. Terminal ends of sections with declining numbers of conch were not pursued. Figure 3 shows the total extrapolated area of the conch bed with relative densities marked. A concentrated area of high density was found in the middle of the first area, covering almost the entire second area and the beginning of the third area. A total area of 3,606m², representing 21,430m², was actually covered. 133 conch were counted making the total estimated number of conch 2,557.

Grass bed composition was shown to exhibit a similar pattern (figure 4) with the area of sand and Thalassia mixed roughly equivalent to the area of highest conch density. Although several types of algae and sea grasses were observed on the substrate, the map was reduced to five areas which were dominated (>70%) by 1) bare sand, 2) Thalassia sp., 3) a mix of sand and Thalassia only or with small amounts of Syringodium filiforme, 4) a mix of sand and Syringodium sp. with no Thalassia present, and 5) Syringodium only. Table I shows the total area (m) covered by each of these five substrate categories, the percent of total area they represent, the extrapolated number of conch observed for each area and the number of conchs that would be expected if the conch population were distributed evenly (randomly) throughout each substrate. $\chi^2 = 625.58$, $df = 4$, $p < .005$, showing a 99.5% chance of non-random distribution. S. costatus were found in the bare sand areas on the outside and not mixing with the S. gigas population. No adult conchs (bearing the flared lip) were found within the bed around Donkey Right, but we observed areas of adults-only at Tokite and Cabrillo Points separated from the main bed by areas of no conch at all (personal observations with snorkel and SCUBA). These adults were found in predominantly sandy areas, often on clumps of Dictyota. Density at Cabrillo was surveyed at 4 conch per 100m².



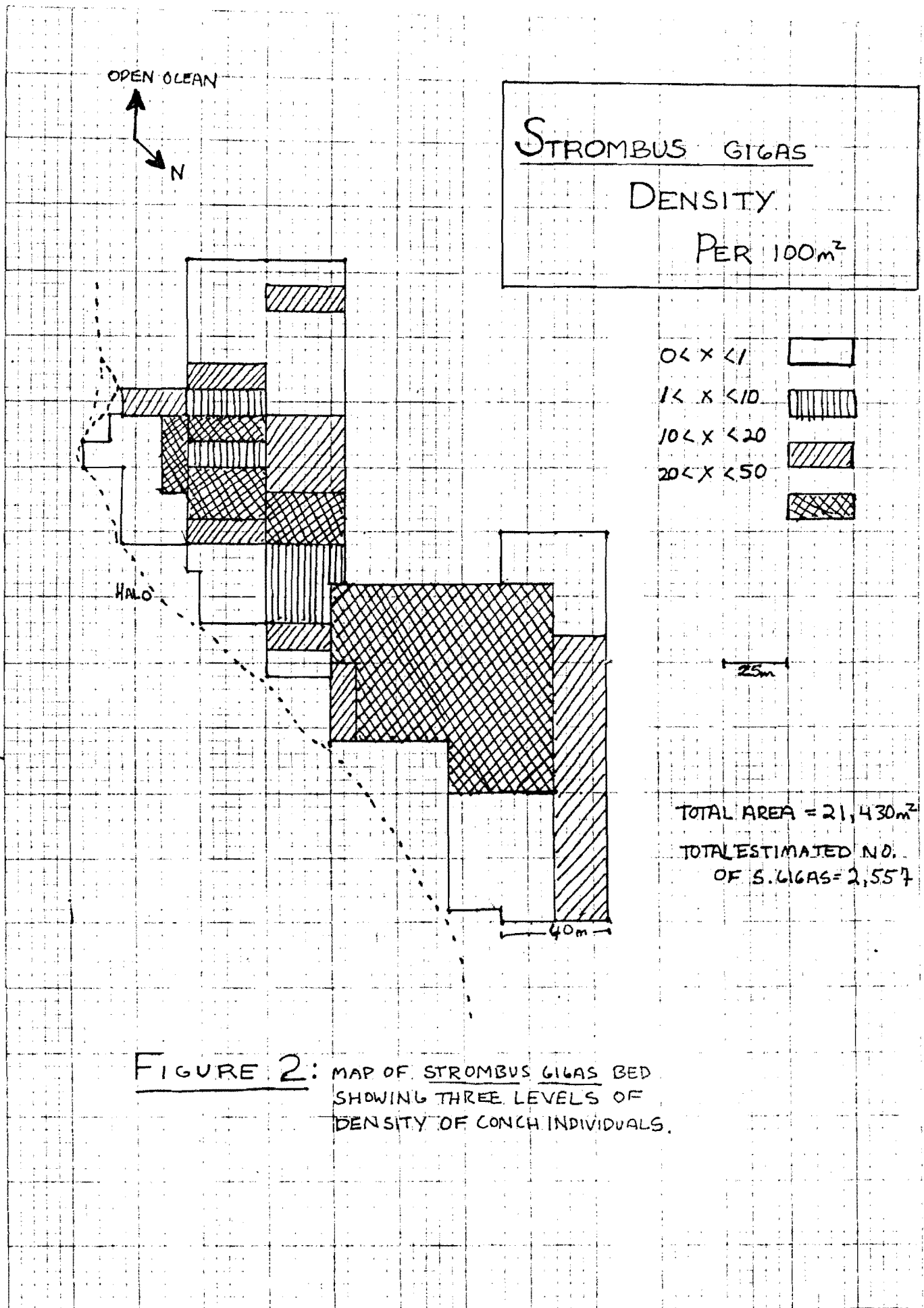


FIGURE 2: MAP OF STROMBUS GIGAS BED SHOWING THREE LEVELS OF DENSITY OF CONCH INDIVIDUALS.

DISTRIBUTION OF GRASSBED TYPES

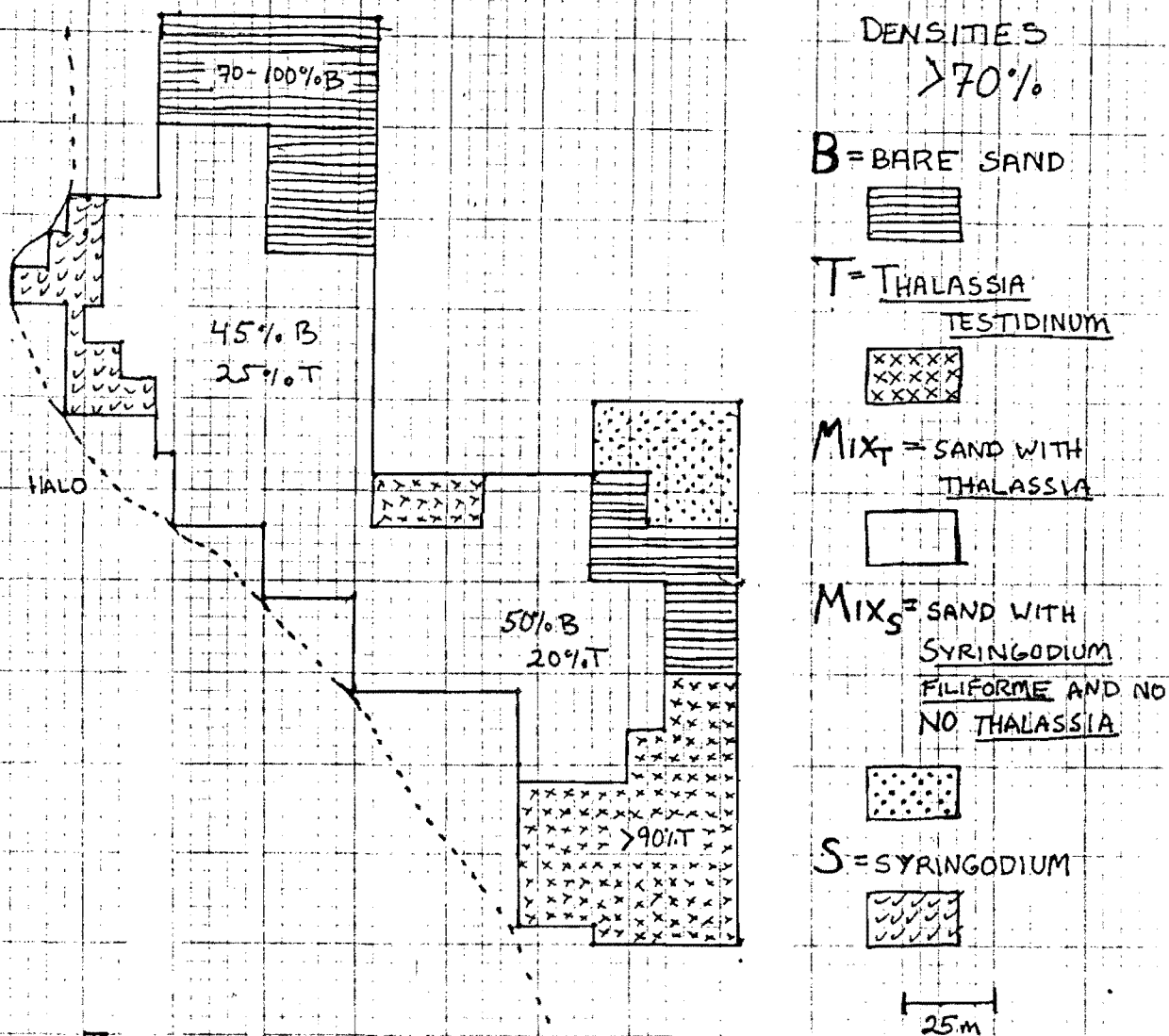


FIGURE 3: CONCH BED MAP SHOWING DISTRIBUTION OF FIVE CLASSES OF SUBSTRATE: BARE SAND COVERS 19% OF THE TOTAL AREA, TURTLE GRASS (THALASSIA TESTIDINUM) ALONE COVERS 18%, AREA OF MIXED SAND AND THALASSIA COVERS 53%, AREA OF MIXED SAND AND EEL GRASS (SYRINGODIUM FILIFORME) COVERS 5% AND AREA OF SYRINGODIUM ALONE COVERS 4%. ALL AREAS DENOTE THE SUBSTRATE TYPE THAT COVERS OVER 70% OF THE AREA.

H₀ : THERE IS NO SIGNIFICANT RELATIONSHIP BETWEEN CONCH DENSITY AND SUBSTRATE.

	TOTAL AREA M ²	% TOTAL AREA	EXP. # CONCH	OBS. # CONCH	X ²
<u>THALASSIA</u>	3,800	18	460	284	67
<u>SARE</u>	4,175	17	481	144	313
<u>MIXA</u>	1,175	5	128	16	98
<u>MIXL</u>	1,330	53	1,355	2,075	383
<u>SYRINGODIUM</u>	950	4	102	21	64

E X² = 325
 DF = 4
 P < .005

THEREFORE: H₀ NOT TRUE.

TABLE 1: Chi-square analysis showing probability that conch density is randomly distributed throughout five classes of substrate.

DISCUSSION

Total estimated number of conch and the total estimated size and location of the conch bed were found in our study to be roughly equivalent to that found in the December, 1986, study, even though both studies used different mapping techniques and were at different times of the year. This indicated that there has been no significant gain or loss in total number and that at least between these two seasons there was no significant net migration of the conch. Because size/age class distribution and abundance found in our study also compares with the Dec., 1986 study (Beck, 1987), it is unlikely that recruitment could have compensated for a migration. Seasonal migrations recorded by Hesse (1979) in the Turks and Caicos Islands showed that conch within her study area had the highest migration rates in March which does not seem to be the case for this population. Only a long-term study would give conclusive results, however. Distribution of size/age classes and possible explanations for significant congregations were studied and discussed by Jennifer Beck (1987) from our data.

Although the December, 1986, study noticed a preference for Thalassia sp. by S. gigas they were not able to distinguish a correlation between grassbed composition and conch distribution. We were able to prove a non-random distribution of individuals relative to dominant grassbed compositions which showed that the S. gigas are most abundant in areas of mixed sand and Thalassia. This supports our own observations of feeding on Thalassia and Robertson's (1961) finding that conch feed on the epiphytic algae on Thalassia (Brownell and Stevely, 1981), but it does not explain why the conch were not found in areas dominated by Thalassia-only or why the adult populations were found in predominantly sandy areas. It is difficult to know whether the grasses affect the distribution of conch or whether the distribution of conch determine grassbed composition. Transplant studies -- such as putting S. gigas in areas of high Thalassia and noting possible changes in grasses or migration of conch -- might help to determine the nature of the grassbed-conch relationship.

Our grassbed vs. conch bed studies are further significant when compared to observations in the literature which are vague at best. Randall (1964) says that S. gigas are found on sand flats, gravel, coral rubble, and hard coral reef habitat, and that conch feed on the dominant plants in their habitat. This last statement is not supported by our data. This brings up the fact that very little significant data have actually been taken on the biology of conch (Brownell and Stevely, 1981, agree) thus increasing the impact of every study on the literature.

Our findings of S. costatus outside the area of S. gigas compares to findings in the Dec., 1986 study and may indicate that the two species of conch are partitioning the bed. The fact that adult and juveniles of S. gigas were found in different habitats could mean that they have different nutrition and/or habitat needs.

In conclusion, the rapidly decreasing numbers of S. gigas from private and commercial over-exploitation certainly indicates the urgency for more and better study of the conch leading to effective management programs. Although this study showed a significant fall

of high fecundity, low larval and juvenile mortality over the month of April, the study should be replicated and continued throughout the year in order to get the most definitive conclusions on habitat selection. Other, relatively easy to carry out, experiments and studies have already been suggested, but in the meantime management policies need to be changed. It is our belief that limitations on beach fishing within the park are not strict enough and that the population could not withstand the impact of harvesting at limits even below the park limitations. Further, damage to grassbeds due to anchoring, sedimentation, and/or pollution could have drastic effects on conch populations and this should be considered in management planning and policy making.

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THE SYMBIOSIS BETWEEN OPHIOTHRIX SPP., NIPHATES SPP. AND
PARAZOANTHUS PARASITICUS

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ABSTRACT

Ophiothrix spp., a common genus of brittle star in Lameshur Bay, St. John, USVI, often occurs on the sponge Niphates spp. A colonial anenome, Parazoanthus parasiticus, often covers the surface of the surface of the sponge. Niphates spp. provides a substrate for shelter and food collection for P. parasiticus, while the sponge benefits as well. West (1976) has determined that P. parasiticus, due to its toxicity to sponge eating fish, serves as protection against predation for its host sponge. The purpose of the following study was to determine the distribution of Ophiothrix spp. on Niphates spp. in attempt to understand the role of Ophiothrix spp. in the symbiosis.

Distribution of Ophiothrix varied according to site, morphology of Niphates spp. and the presence or absence of P. parasiticus. More Ophiothrix spp. inhabited vase shaped sponges than would be randomly expected, independent of the height of the sponge. The presence of P. parasiticus was also associated with more brittle stars per sponge in general, but particularly in vase shaped sponges. The vase shaped sponges with P. parasiticus showed less of a tendency for brittle stars to find a spot to hide on the sponge than those without P. parasiticus. Differences between sites did not prove to alter the patterns of distribution on sponges of different morphologies, but abundance of brittle stars per sponge increased with increasing wave energy.

Data supports the conclusion that Ophiothrix spp. prefers vase shaped sponges, for increased surface area on which to filter feed, as well as the presence of P. parasiticus, for its predator inhibiting effects.

INTRODUCTION

Symbiosis is a common survival technique employed by many organisms. Some of the best examples are found in coral reef environments. Competition for space and food leads species to exploit their surroundings in order to increase their chances of survival. Examples of all forms of symbiosis can be found on the reef, from parasitic isopods that attach to the heads of fish, to mutualistic cleaning symbioses where small cleaner fish or shrimps receive food by eating parasites off the skin of other fish. Symbiotic relationships are so common throughout the diverse marine environment that some have not been studied.

A common example of mutualism is seen in Lameshur Bay between the

sponge Niphates spp. and the colonial anenome, Parazoanthus parasiticus. Niphates spp. serves as a substrate for attachment for the anenome in an environment where a place to grow is difficult to find. Although it may somewhat restrict the flow of nutrients into the sponge, West (1976) has shown that the presence of P. parasiticus is desirable for the host. P. parasiticus was proven toxic to sponge eating species of fish, thus the presence of the zoanthid increases the sponge's chance of survival. The West study also determined that the sponge-dwelling P. parasiticus almost always contrasts in color with the host sponge, the majority of which were favored by sponge feeding fish. The results confirmed that the coloration was aposematic, serving as a protection to predation. Thus the two organisms benefit each other, a display of mutualism. The visual contrast in coloration served as the cue which warned predators of the toxicity of the Parazoanthus spp.

Brittle stars of the genus Ophiothrix spp. are commonly found dwelling on Niphates spp., with or without the presence of P. parasiticus. Less is known of the relationship of the Ophiothrix spp. with the other two organisms. References used gave no specific feeding habits for the species of Ophiothrix common to the area. Barnes (1980), however, describes the feeding habits of O. fragilis, which uses its podia for filter feeding. It is likely that local species of the same genus feed in the same fashion, but it is possible that the brittle stars may actually be eating the host sponge or the anenomes if they are not toxic to them. More likely, however, they may be using the predator inhibiting effects of the P. parasiticus for their own protection. Kaplan (1982) states that brittle stars feed on a variety of organisms ranging from bacteria and microalgae to larval fishes, and that brittle stars that normally hide in sponges may leave their shelters at night to feed on epifauna, epiflora, on the host organism itself, or on plankton carried by passing currents which is caught in their long spines and podia.

The project was designed to examine the relationship between the three organisms. The presence of P. parasiticus and the morphology, size, and location of Niphates spp. were examined to determine which factors affected the distribution of Ophiothrix spp., and to better understand the symbiosis.

MATERIALS AND METHODS

By using SCUBA, population samples of Ophiothrix spp. were taken at five sites in Greater Lameshur Bay, St. John, USVI (Table 1.). General observations were also made at Saba, N.A., to confirm the existence of the three-way symbiosis elsewhere. The technique used was to survey and record data on the distribution of Ophiothrix spp. and P. parasiticus on each Niphates spp. found within the test area. Ten dives were spent collecting data on shape and substrate of sponge as well as the number, size, and location of brittle stars on each sponge. Size was determined by height of sponge, and each sponge was categorized as either finger shaped, vase shaped, encrusting, ear shaped (a small sponge with curvature at the top, but no true oscula), or erect and flat (no oscula). The oscula diameter was also recorded for the vase shaped sponges. The amount of P. parasiticus

was recorded on a judgement level of 0 to 3. Substrate pertained to the surface on which Niphates spp. grew. The size of Ophiothrix spp. was recorded according to arm length. Location depended on whether the brittle star occurred inside the oscula or on the outer surface of the sponge. The brittle stars residing on the outside were judged either sheltered; which included the area around the very base, or unsheltered; the exposed outer area, seemingly open to predators.

T-tests were performed to determine site differences in brittle star distribution. A one way ANOVA was used to prove a difference in the mean number of brittle stars per sponge. Contingency tables were analyzed by Chi square tests to determine the significance of the patterns of brittle star distribution. A Chi square test was also used to show that the increase in the mean number of brittle stars from the Coral Gardens to Cabritte Horn was due to site differences and not an increase in the number of vase shaped Niphates spp. present.

To determine if location of Ophiothrix spp. on sponges changes depending on time of day and/or migration, one dive was spent mapping an area at Tektite, measuring the size, appearance and location of brittle stars in each Niphates spp. in the area. Twice during daylight hours and twice at night the area was resurveyed. The feeding behavior was also observed on the night dives.

Several Ophiothrix spp. were collected from Saba, N.A. and dissected under the dissecting microscope to view gut content and possibly determine diet of the brittle stars. Small pieces of Niphates spp. containing P. parasiticus were also collected and dissected to compare with the gut content to see if the Ophiothrix spp. were possibly feeding on either on either organism.

RESULTS

The results of the data collected in the five sites studied appears in Table 2. An orderly change in average height of sponge was not found between sites. There did, however, prove to be a significant increase in the average number of brittle stars per sponge from site to site ($F=11.16$, $df=4$, $df=262$). By comparing two significantly different sites, the Coral Gardens and Cabritte Horn ($t=2.49$, $df=143$, $p=.025$), it was determined that the site was important in determining the number of brittle stars per sponge rather than the differing percents of shapes between the two sites. The Coral Gardens showed a higher diversity of morphs (56.7% vases), while Cabritte Horn displayed mostly vase forms (83.5%). It was shown that the higher incidence of brittle stars at Cabritte was not due to the fact that it contained more vases, however, but to some other factor within the site. The ratios of brittle stars existing in vases were very close to the expected values (Table 3: $\chi^2=.796$, $df=1$, $p=.9$).

Another difference seen between sites was the varying amount of P. parasiticus present on Niphates spp. It increased from the Coral Gardens (39.4%) to Tektite (31.0%) to Cabritte Horn (25.3%).

Morphology of Niphates spp. proved to be important in the frequency of brittle stars inhabiting the sponge. Although the number of Ophiothrix spp. present proved to be independent of sponge height ($r=-.59$, $df=4$, $p=0.05$, N.S.), shape was important. The contingency

table in Table 4 shows significant evidence that there are more Ophiothrix spp. on vase shaped sponges than the expected value under random circumstances ($\chi^2=15.23$, $df=1$, $p=.005$). The proportion of vase shaped sponges varied between sites. There were increasingly more vases from Coral Gardens to Cabritte Horn. The contingency table for the Coral Gardens shows that in an area where brittle stars have a choice of morphology, (57.6% vases), more settle on vase shaped sponges than expected (Table 5, $\chi^2=3.96$, $p=.05$). Cabritte Horn showed nearly all vases (83.5%).

Presence of P. parasiticus also proved important in Ophiothrix spp. distribution. More brittle stars inhabit sponges with P. parasiticus, independent of morphology (Table 6, $\chi^2=4.59$, $df=1$, $p=.05$).

The interaction of vase shaped Niphates spp., P. parasiticus, and Ophiothrix spp. was analyzed using contingency tables also. Of the vase shaped sponges, more brittle stars inhabited sponges with P. parasiticus than would randomly occur (Table 7, $\chi^2=7.39$, $df=1$, $p=.05$). Although the presence of P. parasiticus was shown to have no effect on whether the Ophiothrix spp. occurred inside or outside the vase, ($\chi^2=8.09$, $df=1$, $p=.95$), sheltered brittle stars were found more often than expected on sponges without P. parasiticus. There were more non-sheltered Ophiothrix spp. on sponges with P. parasiticus than expected (Table 8, $\chi^2=8.09$, $df=1$, $p<.005$).

When the mapped Tektite area was re-evaluated, no change was seen in the distribution of brittle stars from day to day. The brittle stars appear to stay in the same location on the same sponge day and night. They were somewhat more mobile at night, however, and waved their tentacles in the water, possibly feeding on plankton or organic matter, which was observed adhering to the barbed arm spines.

To determine if the symbiosis was facultative or obligate, a survey was done of the substrate on which all the Ophiothrix spp. found in the mapped Tektite area dwell. Of the 209 Ophiothrix spp. censused, 95.2% occurred on sponges. 22% of the total population resided on Niphates spp.

In order to determine if the relationship between the three organisms was limited to Lameshur Bay, or if it is more wide spread, general observations were made at Leinster Bay, St. John, and Saba, N.A. The symbiosis existed at both sites.

The lab work consisted of dissection of Ophiothrix spp., Niphates spp., and P. parasiticus under a dissection microscope. Spicules of Niphates spp. and polyps of P. parasiticus were examined. The gut content of Ophiothrix spp. proved to be amorphous, containing nothing resembling either the spicules or the polyps. The arm spines existed in pairs and contained barbs and a fleshy podium, ideal for capture and transport of planktonic material.

DISCUSSION

Analysis of the data leads to the conclusion that Ophiothrix spp. are not parasitic on Niphates spp. or P. parasiticus, but are filter feeding organisms which use Niphates spp. solely as a substrate for shelter and/ or a prop for filter feeding. Examination of gut content and night feeding behaviors seem consistent with Barnes' documentation of O. fragilis, which filter feed. It appears, instead, that the

Ophiothrix spp. use the predator inhibitory effects of the P. parasiticus for their own protection.

Several factors were shown to effect the distribution of Ophiothrix spp. on Niphates spp. Morphology proved to be the most significant factor. Although increasing height did not show an accompanying increase in the number of brittle stars present. Ophiothrix spp. did tend to show a preference for vase shaped sponges over other forms. This tendency was consistent in the samples, independent of the sites which varied in the percentages of vases present. Perhaps this is due to an increase in surface area on which to dwell.

Although the percentage of vase shaped Niphates spp. in a site did not prove to effect the average number of brittle stars found on each vase, the average number of brittle stars per sponge increased from site to site. Perhaps this is due to increasing wave energies, thus influx of organic material. The sandy area near Yawzi Point, the dock area, and the Coral Gardens are relatively low relief areas, more sheltered from direct wave action. The Tektite area is less protected from heavy surge and many sponges in the area studied grew on walls with high wave impact. Cabritte Horn represented the highest surge area. The brittle stars were more plentiful in general in the higher wave energy areas, possibly since there is a more plentiful and constant food supply brought in with the waves. Evidence points towards the hypothesis that the P. parasiticus, which aids Niphates spp. in warding off fish predators due to its toxicity, also shelters Ophiothrix spp. in the same manner. P. parasiticus has a positive effect on the distribution of Ophiothrix spp. on Niphates spp. More brittle stars are found on sponges of any morphology with the anenome present. Even more were seen on vases with P. parasiticus. More Ophiothrix spp. were found on non-protected areas of the sponge than expected when P. parasiticus was present, and more protected brittle stars existed on sponges without P. parasiticus than expected. Thus it appears that Ophiothrix spp. tends to choose a sponge with maximum surface area (i.e. vases) equipped with P. parasiticus for warding off predators. It seems unlikely that Ophiothrix spp. would be parasitic on either Niphates spp. or P. parasiticus. They were observed to inhabit the same sponge over time, thus it would be to their disadvantage to eat their home. Although the literature reviewed gave no reference to the organisms that feed on brittle stars, fish have been observed to attack brittle stars when exposed from under rocks in Lameshur Bay (pers. obs.). If it is true that fish feed on Ophiothrix spp., then it would be to their advantage not to consume the P. parasiticus. The dissection of Ophiothrix spp. in the lab provides further speculation that they are filter feeders, most likely using the sponges for substrate and elevation for feeding and the P. parasiticus for protection.

Ophiothrix spp. are not obligate symbionts with Niphates spp., but they did show the highest preference for it over all other substrates surveyed (22%). Most Ophiothrix spp. inhabit sponges of some sort (95.2%), while a few were observed on other organisms with defense mechanisms, such as the stinging nematocysts of Millepora spp. They also occurred on a few species of Octocorallians and Scleractinians, but were usually directly adjacent to a species of sponge. Sponges may help to create an incoming current of organic material.

This association is not unique to the Lameshur Bay area. It was observed at both Leinster Bay, St. John, and Saba, N.A. The symbiosis developed is likely to be a highly successful benefit to the Ophiothrix spp. with little disruption of the hosts due to its diversity.

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TABLE 1. MAP OF FIVE STUDY SITES

- | # | SITE |
|---|---------------|
| 1 | YAWZI POINT |
| 2 | DOCK AREA |
| 3 | CORAL GARDEN |
| 4 | TEKTITE |
| 5 | CABRITTE HORN |

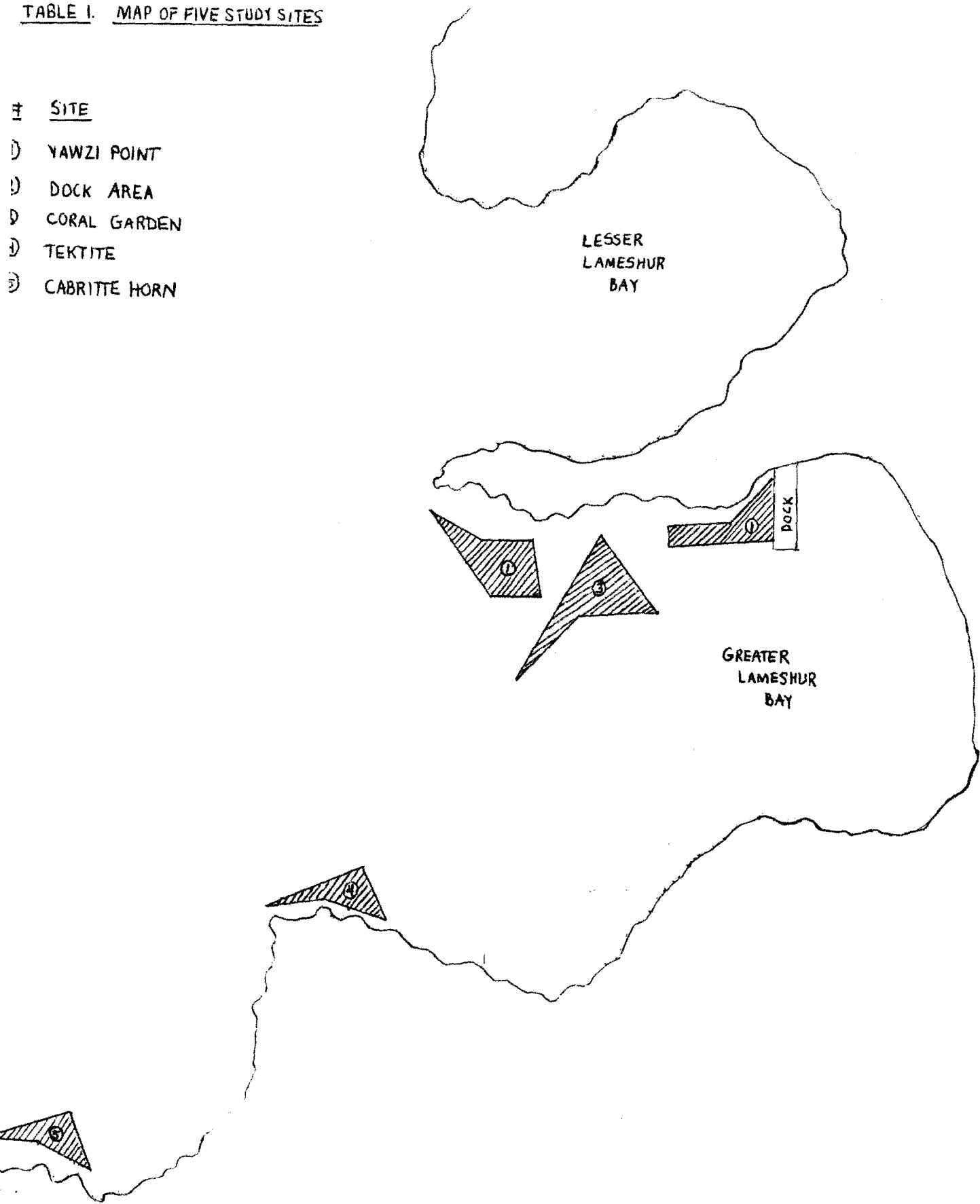


TABLE 2. RAW DATA

SITE	# NIPHATES SPP.	$\bar{x}$ NIPHATES SPP.	S NIPHATES SPP.	S ² NIPHATES SPP.	NIPHATES SPP. WITH P. PARASITICUS	NIPHATES SPP. WITHOUT P. PARASITICUS	# OPHIOTHRIX SPP.	$\bar{x}$ OPHIOTHRIX SPP.	S OPHIOTHRIX SPP.	S ² OPHIOTHRIX SPP.	OPHIOTHRIX SPP. IN NIPHATES SPP. WITH P. PARASITICUS	OPHIOTHRIX SPP. IN NIPHATES SPP. WITHOUT P. PARASITICUS
YAWZI POINT	29	10.34	5.10	26.02			8	.28	.45	.21		
DOCK AREA	35	14.89	8.78	77.05			15	.43	.61	.37		
CORAL GARDEN	33	10.48	5.26	27.88	13 39.4%	20 60.6%	23	.70	1.24	1.53	15 65.2%	8 34.8%
TEKTITE	91	10.54	7.56	57.11	22 31.0%	49 69.0%	117	1.29	1.63	2.65	25 35.7%	45 64.3%
CABRITTE HORN	79	8.61	5.30	28.11	20 25.3%	59 74.7%	122	1.54	2.40	5.76	67 54.9%	55 45.1%

TABLE 3. COMPARISON OF
VASE SHAPED
NIPHATES SPP. AT
2 SIG. DIFF. SITES

NIPHATES SPP. VASE SHAPE	
+	-
CABRITTE HORN 39	27
CORAL GARDENS 9	10

TABLE 4. OPHIOTHRIX SPP.
IN VASE SHAPED
SPONGES

NIPHATES SPP. VASE SHAPE	
+	-
OPHIOTHRIX SPP. + 86	9
OPHIOTHRIX SPP. - 59	29

TABLE 5. OPHIOTHRIX
SPP. ON VASES
IN THE CORAL
GARDENS

NIPHATES SPP. VASE SHAPE	
+	-
OPHIOTHRIX SPP. + 9	3
OPHIOTHRIX SPP. - 10	11

TABLE 6. OPHIOTHRIX SPP.
ON NIPHATES SPP.
WITH P. PARASITICUS

PARAZOANTHUS PARASITICUS	
+	-
OPHIOTHRIX SPP. + 37	58
OPHIOTHRIX SPP. - 20	68

TABLE 7. OPHIOTHRIX SPP. ON
VASE SHAPED SPONGES
WITH P. PARASITICUS

VASE SHAPED NIPHATES SPP. P. PARASITICUS	
+	-
OPHIOTHRIX SPP. + 27	59
OPHIOTHRIX SPP. - 7	52

TABLE 8. SHELTERING OF
OPHIOTHRIX SPP. IN
RELATION TO P. PARASITICUS ON VASES

VASE SHAPED NIPHATES SPP. P. PARASITICUS	
+	-
OPHIOTHRIX SPP. SHELTERED 19	63
OPHIOTHRIX SPP. NOT SHELTERED 8	5

RESPONSES OF THE NERVOUS SYSTEMS OF MONTASTREA
CAVERNOSA AND PORITES PORITES TO LIGHT, SATIATION
AND DISTURBANCE

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ABSTRACT

Data were collected for reactions of two species of corals, Montastrea cavernosa and Porites porites to light at different times of day, satiation requirement, disturbance and polyp extension at night after satiation during day. Also observed was polyps ability to convey stimulus and the two corals ability to act on this as either a whole unit or on an individual polyp basis. Data was charted and reactions to light were tested by analysis of variance. Results showed distinct patterns of reactions to different light intensities, disturbances, and nutritional need. Also noticed was the ability for M. cavernosa to act by extending individual polyps as well as a whole colony's.

INTRODUCTION

This research examines three factors upon coral polyps tentacular expansion: light intensity, nutritional need, and disturbance. Depending on a corals feeding habits it may extend tentacles durring day or at night (Barnes 1980). An autotrophic coral extends its tentacles primarily durring daytime to obtain sunlight while a heterotrophic coral extends at night to obtain zooplankton (Porter 76). Autotrophic corals tend to have small polyps and a high surface area to volume ratio aiding in capture of sunlight while heterotrophic corals tend to have large polyps and a low surface area to volume ratio aiding in capture of prey. (Porter 76). These expansions or contractions may be initiated from reception by light sensors or by a behavioral pattern.

A corals nutritional need may also determine tentacal expansion or contraction. A heterotrophic coral may extend its tentacals due to need for nutrients contracting after satiated. An autotrophic coral may get its required calories from its photosynthetic zooxanthellae, however nutrients not provided by photosynthesis (amino acids, minerals) may still be needed.

Disturbance can be said to be a detrimental action or change

which initiates a defensive response, tentacle contraction. A disturbance also can be said to have a degree of magnitude depending on the amount of area disturbed on a colony and the number of tentacles contracting and how far they contract. Disturbances can be caused by weather (storms, debris), fish (feeding on polyps, accidental brushing) or touch by a foreign object other than food causing damage to a polyp or polyps. The types of disturbance referred to in this report are accidental touch during human feeding of corals and fish.

These stimuli of tentacle extension or contraction may also have two levels of response. Either a coral may react with a colony wide response (extending/contracting all tentacles) or a localized reaction (extending/contracting only polyps receiving the stimulus). It is known that corals gastrovascular cavities are connected and that they all grow above the same horizontal sheet of tissue (Barnes 1980). Communication and nutrients may pass through the entire colony in this way and a primitive nervous system may be evaluating stimuli and effecting response.

Two corals were observed, Montastrea cavernosa and Porites porites. These corals were chosen for their differences in morphology and behavior. M. cavernosa has large polyps and tends to extend them at night while P. porites has small polyps and extends them more often during daylight (Porter 74). Also M. cavernosa shows more of a dependency for heterotrophic feeding, extending tentacles for capturing zooplankton, while P. porites extends tentacles mainly during day to obtain sunlight for photosynthesis (Porter 76). P. porites also shows a tendency to extend its polyps at night although not as much as day (Porter 74). This may be to obtain nutrients not provided from photosynthesis.

Experiments were mainly conducted in the coral gardens of Greater Lameshur bay, St. John. Other sites include reefs off the islands of Anguilla, St. Bartholemey, and Saba.

METHODS

Data was collected in Lameshur bay on St. John and reefs on the islands of Anguilla, St. Bartholemey, and Saba. Expansion of tentacles was assessed at 10:00am, 12:00pm, 2:00pm, 4:00pm, and 8:30pm. This was recorded for two corals, Montastrea cavernosa and Porites porites as the percentage of polyps extended over the entire colony. Mean extensions were calculated using arc sin transformed data. Depths of coral heads surveyed were from 15-35 ft. All data was collected underwater by scuba or by snorkel. Surveys of fifteen replicates were taken for three days or more for each time.

Using meat or meat extract, coral heads of P. porites and M. cavernosa were fed until all polyps had contracted and remained

so for fifteen minutes defined as satiation. The percent of the coral head having to be fed before all polyps contracted as well as the percentage of polyps re-extending fifteen minutes after closing was recorded. M. cavernosa was fed by placing similarly sized particles of food into each individual polyp by hand. P. porites was fed using solutions of the meat extract in a syringe. Clouds of extract were squirted in the area of the coral head until satiated. In some cases the feeding initiated a defensive response causing some or all polyps to contract. Data for amount of polys disturbed and time for re-extensions was recorded as well as whether the reaction occurred over the whole colony or just at the disturbance site.

Lastly, data were obtained from a night snorkel for re-extension of polyps after satiation. During the day a head of M. cavernosa consisting of five sections separated by dead coral on all sides was fed to satiation. Two other separate heads had partial sections of their colony's polyps fed. In each case the case the sections surrounded a large blemish. One head was left as a control and was not fed. In a bed of P. porites five heads were fed to satiation. Two heads were partially fed by actual placing of solid food on a portion of a finger. One head was left as a control. All coral heads were at a depth of twenty-five ft.

Disturbances were caused by accidental touching of corals during feeding. Magnitude of disturbance in number of polyps was recorded as well as time before re-opening of polyps. Also recorded was whether the contraction was limited to the area of disturbance or if it was colony-wide.

RESULTS

Figure 1 shows mean polyp extensions for 10:00am, 12:00pm, 2:00pm, 4:00pm, and 8:30pm. Figures for means showed P. porites to be most extended during the day at 12:00 while M. cavernosa had its lowest extension at this time. M. cavernosa showed a rapid increase in extension towards night. P. porites showed the inverse decreasing to its lowest extension at night.

A one way ANOVA was completed for both Montastrea cavernosa and Porites porites to see if the mean figures of the times were significant. M. cavernosa's mean values were found significant with a P value of $<.05$. P. porites figures, however, proved not significant with a P value $>.05$. It can be taken into consideration that when collecting data some coral heads had zero percent polyp extension while others had one hundred percent. These odd-ball figures may have been caused by a defensive response or by any number of factors.

Observed : Presence of fish was noted at several contracted coral heads of both species. Also M. cavernosa was extended often in portions of its colony not in direct sunlight while portions

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of the colony in sun were contracted.

In figure #1 polyp extension means were plotted in a line graph over time. Error bars were drawn in to show standard deviations at each sample time. M. cavernosa is abbreviated as 'cav' and P. porites as 'por'.

Feed Poultry Experiments over 1 Year

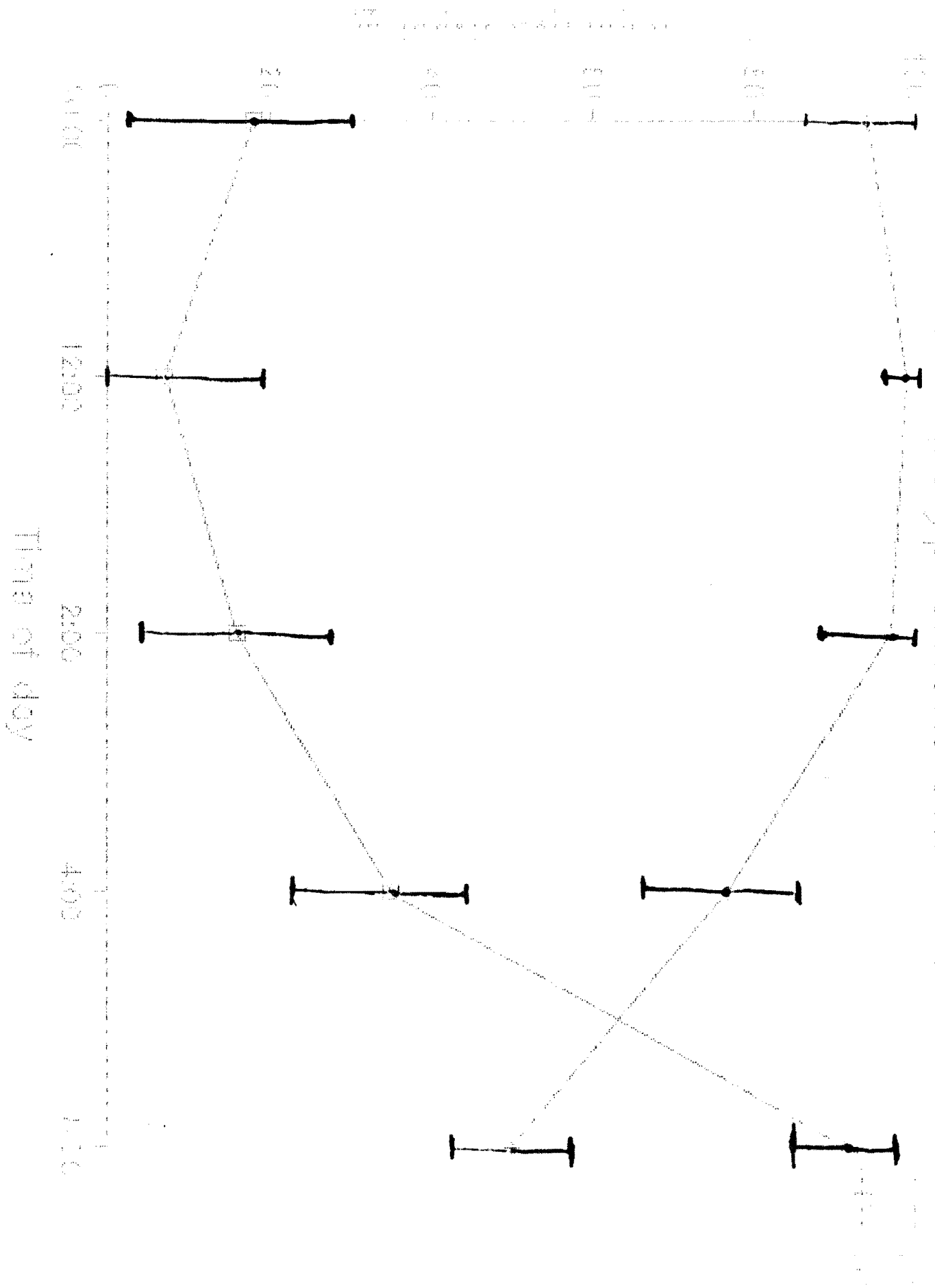


Table two, below, shows the percentage of polyps fed to cause all polyps to contract. It also shows if polyps re-opened and the percentage of polyps which re-opened on that coral head. The mean is the mean percentage of polyps needed to be fed before whole colony contraction of tentacles. The re-open average is the number of heads which re-opened divided by total number of heads. The re-open degree average is the average percentage of the polyps which re-opened.

Figure #2: Corals reaction to satiation

<u>M. cavernosa</u>				<u>P. porites</u>			
replicate	#	1st	re-open	1st	re-open		
	1	+ 80%	+ 10%	+	+ 100%	+	+
	2	+ 90%	+	+	+ 100%	+ 100%	+
	3	+ 50%	+ 20%	+	+ 100%	+	+
	4	+ 80%	+	+	+ 100%	+ 100%	+
	5	+ 30%	+ 10%	+	+ 100%	+	+
	6	+ 70%	+	+	+ 100%	+ 100%	+
	7	+ 80%	+ 50%	+	+ 100%	+ 100%	+
	8	+ 90%	+	+	+ 100%	+	+
	9	+ 90%	+	+	+ 100%	+	+
	10	+ 90%	+ 10%	+	+ 100%	+	+
	11	+ 90%	+	+	+ 100%	+ 100%	+
	12	+ 100%	+	+	+ 100%	+	+
	13	+ 90%	+	+	+ 100%	+	+
	14	+ 90%	+ 10%	+	+ 100%	+	+
	15	+ 60%	+	+	+ 100%	+ 100%	+
	16	+ 90%	+	+	+ 100%	+	+
	17	+ 90%	+ 30%	+	+ 100%	+	+
	18	+ 90%	+	+	+ 100%	+	+
	19	+ 90%	+	+	+ 100%	+ 100%	+
	20	+ 90%	+	+	+ 100%	+ 100%	+

	<u>cavernosa</u>	<u>porites</u>
mean% contraction :	82%	100%
Re- open average :	35%	40%
amount re-opened :	20%	100%

Table: #3 shows the results for polyp extensions at night after satiation.

#	before	fed to	after	#	before	fed to	after
+ 1	+ POS	+ SATIATION	+ NEG +	+ 1	+ POS	+ SATIATION	+ NEG +
+ 2	+ POS	+ SATIATION	+ NEG +	+ 2	+ POS	+ SATIATION	+ NEG +
+ 3	+ POS	+ SATIATION	+ NEG +	+ 3	+ POS	+ SATIATION	+ POS +
+ 4	+ POS	+ SATIATION	+ NEG +	+ 4	+ POS	+ SATIATION	+ NEG +
+ 5	+ POS	+ SATIATION	+ NEG +	+ 5	+ POS	+ SATIATION	+ NEG +
+ 6	+ POS	+ CONTROL	+ POS +	+ 6	+ POS	+ CONTROL	+ POS +
+ 7	+ POS	+ PARTIAL	+ PART+	+ 7	+ POS	+ PARTIAL	+ POS +
+ 8	+ POS	+ PARTIAL	+ PART+	+ 8	+ POS	+ PARTIAL	+ POS +

<u>Montastrea cavernosa</u>				<u>Porites porites</u>			
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This table shows POS or NEG depending on polyp extension. Fed to refers to what degree the replicate was fed to satiation, partial or none in the case of the control. For M. cavernosa the first five replicated are all separated sections on one large head. Replicates six, seven and eight are all separate colonies. For Porites porites all replicates refer to separate heads of a large bed.

Table #4: Chart of disturbance

replicate							
#	#	time		#	#	time	
#	disturb	re-open	place	#	dist.	re-open	place
+ 1	+ 1	+ 10 minutes	+ area +	+ 1	+ 1	+ 1 hour	+ all+
+ 2	+ 2	+ 15 minutes	+ all +	+ 2	+ 10	+ 30 min	+ all+
+ 3	+ 5	+ 20 minutes	+ all +	+ 3	+ 5	+ 10 min	+ all+
+ 4	+ 1	+ 15 minutes	+ area +	+ 4	+ 1	+ 15 min	+ all+
+ 5	+ 1	+ 15 minutes	+ area +	+ 5	+ 2	+ 30 min	+ all+
+++++							

Montastrea cavernosa

Porites porites

Data is shown here for disturbance magnitude in number of polyps, time for polyps to re-open after disturbance, and area which initiated the defensive response being either a whole colony 'all' or a part of a colony 'area'.

DISCUSSION

Most heads of M. cavernosa are extended at night whilst P. porites is extended most at noon gradually decreasing until night. Both corals initiate a response to the presence of light. M. cavernosa contracts its polyps and P. porites extends them. Even if this is a behavioral response it shows two mechanisms for extension state in the presence of light. This action can also be for individual polyps or groups of polyps as it was observed on colonies of M. cavernosa that dark portions of a colony were extended and light ones contracted. P. porites, however showed an all or none response either extending or contracting all of its polyps depending on light. From this observation M. cavernosa displays the ability to distinguish different light intensities while P. porites doesn't necessarily do this.

Table #2 shows that M. cavernosa needs a mean of 82 percent of its polyps fed before contracting them all. 35 percent of the time 20 percent of the polyps re opened to obtain more food. P. porites showed a mean of 100 percent of its polyps needed to be fed for total contraction with 100 percent of polyps re opening 40 percent of the time. M. cavernosa shows an ability to extend partial portions of its colony for more feeding. Also not all polyps need be fed to cause total contraction. Communication is taking place between different polyps of the colony. The needs of the individual polyps and the entire colony cause responses to individual polyps. Feeding only part of a colony may satisfy the entire colony's needs thus causing contraction of remaining polyps. The same reaction can not be determined for P. porites due to the method of feeding. Only the fact that 100 percent of polyps were re extended 40 percent of the time holds relevant that P. porites uses an all or none response to nutrient need.

Table #3 shows some interesting results. 100 percent of the sections of M. cavernosa satiated remained closed at night, Only the control being extended. This shows that satiation induced a response to contract tentacles and keep them closed even though normal patterns call for them to be open. Also two heads which were partially satiated only extended parts not satiated. This supports that polyps can act individually since only those polyps needing nourishment extended their polyps. For P. porites 4 out of 5 heads remained contracted at night after satiation. This shows a colony's ability to extend or contract tentacles according to need. The control remained extended and the two heads partially fed were extended as well. P. porites again shows a lack of ability for individual polyp reactions. The entire colony either contracts or extends depending on need.

Table 4 shows for M. cavernosa an average of 15 minutes for tentacle re-openings after a disturbance. The chart also shows that for small disturbances there was a response localized to the

area of disturbance while for a large disturbance there was a colony wide response. M. cavernosa shows ability for both individual polyp and entire colony reactions to disturbance. Also there may be a threshold where an entire colony response is initiated vs. an area or polyp response. Laboratory experiments would be needed in order to investigate this. P. porites illustrated re-opening times from 15min to an hour. A whole colony response was always initiated for a disturbance of any magnitude.

Another observation of disturbance was the presence of fish near non-extended coral heads. Apparently the fish biting initiates a whole colony response in both corals keeping the rest of the colony safe..

In conclusion, corals are able to react to stimuli: light, feeding desire, and disturbance by initiating a response for tentacle expansion or contraction. Detection from a few or many polyps can result in two reactions. Either a whole colony response is initiated as with P. porites and M. cavernosa or an individual polyp response only with M. cavernosa. Indeed there seems to be an intricate connection between individual polyps and the entire colony.

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THE EFFECTS OF GRAZING BY THE SCARIDAE ON
THE REEF SUBSTRATE IN GREATER
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ABSTRACT

Coral reefs in tropical ocean waters show a high amount of diversity. This diversity supports many types of reef fish, one family of herbivorous fish are the Scaridae. This project studies the effect of the Scaridae's grazing on the reef community at two different wave intensity sites. It was found that there was not a significant difference in the rates of grazing between the two sites, but that the grazing was more dependent on what type of substrate was available for the Scaridae to feed on.

INTRODUCTION

The high diversity centered around coral reefs in tropical ocean waters is partly a result of the ecosystem's productivity and its ability to recycle important nutrients usually lacking in nutrient poor tropical water. Coral reefs have the highest rates of photosynthetic carbon fixation, nitrogen fixation, and limestone deposition of any ecosystem (Goreau et al, 1979). The frame building scleractinian corals found on the reefs are responsible in a large part for the productivity of the reef. In addition to the scleractinians, soft corals and filamentous and encrusting calcareous algae play an important role in the structure and nutrient cycling of the reef community (Goreau et al, 1979). On coral reefs, algal communities are responsible for a majority of the reefs primary production (Carpenter, 1986). A result of this high productivity is the ability to support a large number of fish species. These fish rely upon the reef for protection and for food, and can be classified according to their food preferences. Herbivorous fish feed mainly on algal turfs which are mats of encrusting algae found on the rocks in coral reefs. The canopy height of algal turfs is controlled by the herbivorous reef fish including the Pomacentridae, Acanthuridae, and the Scaridae. These fish are a major component of the Caribbean fish fauna (Randall, 1968). The parrot fish are particularly important herbivores because they have a strong pair of jaws which are used to scrape away the substrate. Although parrot fish are frequently described as grazing on algae and coral polyps (Robins, p. 207, 1986). Randall (1968) observed that "not once was a parrot fish seen grazing on corals." To date, no data are available to refute or verify Randall's statement, and the quantitative significance of coral polyps in the parrot fish diet remains unknown.

The effects of the parrot fish on the structure of the reef community is also unknown. Competition for space is intense and any method of creating open reef substrate has the potential ability to change the reefs structure. The effect of parrot fish scraping away and exposing bare rock and coral may vary depending on environmental conditions, such as wave exposure and water turbidity. These factors influence the maneuvering ability of the parrot fish and thus may change the feeding habits of the fish on algae.

The proposed research has two aims, firstly to determine the nutritional significance of the algal community versus the coral community in the Scaridae's diet, and secondly to assess the effect of the Scaridae on the community structure. It is hoped that by understanding the feeding biology of the Scaridae, it will be possible to make an estimate of the transfer of organic material from the benthic to the pelagic community. The focus of the project will be on the different feeding rates between areas where corals are absent and where they are abundant, particularly Monastrea annularis, and what effect this feeding has on reef development. These data may lead to an insight to the recolonization of coral reefs in different locations.

Methods

The two sites studied were in Greater Lameshur bay, St. John, USVI. The first site is Yawzi point and a portion of the bay called the "coral gardens" located on the western edge of the bay in four to eight meters of water. The second site is at Tektite cliffs, and Cabrite horn on the eastern side of the bay. All data were collected between 10:30 and 16:00 from 4-9-87 to 4-21-87.

In order to determine the overall effects of parrot fish grazing it is necessary to get figures for the abundance of parrot fish and also the bites per minute of the parrot fish. The overall abundance was estimated by laying thirty meter transect lines at Yawzi point in 6 m of water in random directions, waiting ten minutes, and then swimming at a constant rate one meter above the line. The number of parrot fish within two meters of each side of the line were counted and their feeding behavior recorded. All species of parrot fish were counted in order to provide sufficiently large figures of abundance for statistical considerations. This method was used for the first two transect lines. For the next eight counts of overall abundance, a unit time method was implemented instead and the transect line was not used to avoid disturbing the fish and to eliminate the ten minute waiting period. The time it took to swim along the thirty meter transect line was recorded and used to swim a constant distance (30 meters). The number of parrot fish were then counted within a four meter perpendicular range of the observer (two meters on each side as if swimming above a transect). This was repeated ten times at each site. When the fish were counted it was also noted if they were feeding at the time or not.

Values were obtained for bites per minute for each of ten fish at each site. Individual fish were watched for one minute and the number of bites counted. The species of parrot fish was recorded. Also each

of ten fish were observed for ten minutes to get an idea of where they were grazing. It was noted whether they were grazing on exposed rocks, crevices, algal mats, or corals. The number of bites taken on each surface was recorded.

Scraped areas of Monastrea annularis that were made by feeding parrot fish on the corals were measured using calipers with a measurement error of ± 0.05 mm. The abundance of the scraped heads was then determined by counting the number of scraped heads of M. annularis in a 50m by 30m area at both study sites. The density of all living M. annularis colonies was measured at each site by counting the number of colonies in a 10m by 10m area. In the same area, figures for the percent cover of soft corals, sand, rocks and algal mats were calculated.

RESULTS

A comparison of the bites per minute between the two sites is shown in Table 1. There are no significant differences between the two sites when the two populations, or the three individual species are compared.

The number of parrot fish feeding at Yawzi point and at Tektite were not significantly different (Table 2). The percentage of feeding Scaridae was significantly different at $P < 0.05$.

Table 1 A Comparison of bites per minute between Yawzi point and Tektite sites for three species of parrot fish. The t test statistics, degrees of freedom, and significance are shown.

YAWZI POINT

Species	mean	SD	n
Queen	24	12.0125	5
Stoplight	15	6.8702	5
Princess	23	2.8284	2
Total	20	9.4948	12

TEKTITE

Species	mean	SD	n	t	d	
Queen	11	5.6568	2	1.8812	5	N.S.
Stoplight	15	2.8635	5	0.0	8	N.S.
Princess	23	8.5049	3	0.0	3	N.S.
Total	17	6.8669	10	0.9236	20	N.S.

The average area of coral removed by grazing parrot fish at the Tektite site was $0.7606 \pm 0.166 \text{ cm}^2$ and 0.5808 ± 0.071 at Yawzi point (Table 3). These values were significantly different ($P < 0.05$).

By using the values found for the total number of parrot fish at the Tektite site the average area of coral removed by grazing parrot fish at the Tektite site was $0.7606 \pm 0.166 \text{ cm}^2$ and 0.5808 ± 0.071 at Yawzi point (Table 3). These values were significantly different ($P < 0.05$).

$$(13 \text{ fish}/100\text{m}^2) \times (0.518 \text{ fish feeding}) \times (20 \text{ bites}/\text{min}) \times (0.58008 \text{ cm}^2) = 78 \text{ (bites}/100\text{m}^2)/\text{cm}^2/\text{min.}$$

For Tektite this value is,

$$(17 \text{ fish}/100\text{m}^2) \times (0.423 \text{ fish feeding}) \times (17 \text{ bites}/\text{min}) \times (0.7606 \text{ cm}^2) = 92 \text{ (bites}/100\text{m}^2)/\text{cm}^2/\text{min.}$$

Table 2 The number of parrot fish feeding at Yawzi point and Tektite. The t test statistics, degrees of freedom, and significance are shown. * $P < 0.05$

YAWZI POINT

	mean	SD	n
Total Scaridae (x/100 m ²)	13	4.7919	10
Percent feeding	51.8	2.38	10

TEKTITE

	mean	SD	n	t	df	
Total Scaridae (x/100 m ²)	17.0	7.6194	10	1.405	18	N.S.
Percent feeding	42.3	11.6	10	2.376	18	*

Table 3 The size of the bite scars at Yawzi point and Tektite. The t test statistics, degrees of freedom, and significance are shown. * $P < 0.05$

Yawzi			Tektite			t	df
mean	SD	n	mean	SD	n		
0.58008	0.1958	40	0.7606	0.2306	10	2.278	48 *

95% limit = ± 0.0705

95% limit = ± 0.166

Using Table 4 and the mean percentage of bites on different substrates, it is possible to calculate the amount of material consumed from the rocks, crevices and corals. These values in bites/cm²/min are in Table 5. The relative abundances of the substrates available are in Table 6.

Davies (1980) determined the respiration rates for Monastrea annularis in Discovery Bay, Jamaica, and normalized his data to unit area and unit biomass. By assuming that M. annularis is similar throughout the Caribbean, it is possible to calculate the unit area biomass of M. annularis as 9.7 mg/cm². Hence the amount of M. annularis removed at the Yawzi point site by the parrot fish is

$$9.7 \text{ mg/cm}^2 \times 0.184 \text{ bites/cm}^2/\text{min} = 1.78 \text{ mg/min}$$

and at the Tektite site the amount removed is

$$9.7 \text{ mg/cm}^2 \times 0.017 \text{ bites/cm}^2/\text{min} = 0.165 \text{ mg/min.}$$

The bite scars on M. annularis are an indicator of how often the parrot fish graze on the coral because the scars exist for a limited amount of time. To obtain a value for the frequency of grazing on Monastrea annularis it was necessary to get an estimate of the density of the grazed M. annularis, and an idea of the intensity of the grazing on these heads, see Table 5. At Yawzi point in a 1500m² area, there were a total of 152 colonies grazed. In a 100m² area there were 14 heads of M. annularis. This gives an estimated value of 210 heads of M. annularis in the 1500m² area, or 75 % of the heads were grazed. At Tektite, there were a total of 108 grazed heads in

Table 4 The percent of the bites on the types of substrates between the two sites. The t test statistics, degrees of freedom, and significance are shown. *** P < 0.001

	rock			crevice		
	mean	SD	n	mean	SD	n
Yawzi	0.743	0.057	10	0.24	0.054	10
Tektite	0.993	0.0194	10	6.67E-3	0.0177	10
t	13.13 ***			12.98 ***		

	coral			algal mat		
	mean	SD	n	mean	SD	n
Yawzi	2.36E-3	6.32E-3	10	2.79E-3	6.24E-3	10
Tektite	0.0	0.0	10	2.04E-4	2.05E-3	10
t	1.16 N.S.			0.963 N.S.		

Table 5. Amount of material consumed from the rocks, crevices, and corals at the two sites. Values are in bites/cm²/min.

	Yawzi	Tektite
rock	58.0	91.3
crevice	18.7	0.614
coral	0.184	0.170

1500m², and in a 100m² area there were 27 heads. Thus the estimated value for M. annularis heads is 405, or 27% of them had been grazed. The number of bites on the coral heads is shown in Table 7. An important difference between the two sites was the size of the coral colonies counted as heads. At Tektite, the range in the size of M. annularis colonies was from 15 cm in diameter to 50 cm in diameter. At Yawzi point, the range was from 25 cm to 100 cm.

Carpenter (1985) recorded a value of 7.08 mg/cm² for 'algal turf' in Teague Bay, St. Croix. Values for the amount of algae removed from the rocks and crevices in the present study can be calculated by using this figure and the figures in Table 5 for rocks and crevices. These are presented in Table 8.

Table 6 The percent abundance of reef cover at both study sites in a 100 m² area.

	Yawzi	Tektite
Stoney corals	45%	27%
Soft corals	5%	10%
Sand	10%	25%
Rocks	10%	3%
Crevice	29%	20%
Algal mats	1%	5%

Table 7 The number of bites on M. annularis in a 1500m² area at both study sites.

number of bites	heads at Yawzi	heads at Tektite
1-20	46	84
20-50	45	22
50-100	43	2
over 100	24	0

Table 8. Calculated amount of algae removed from rocks and crevices using the biomass value of 7.08 mg/cm².

	rocks	crevices
Yawzi	411 mg/min	133 mg/min
Tektite	646 mg/min	4.35 mg/min

CONCLUSIONS

By comparing the feeding habits of Scaridae at different sites, a number of general patterns were observed. Since there is no significant difference in the bites/minute of the feeding parrot fish at the two different wave intensity sites, Table 1, the fish must therefore, be feeding at the same rates. The number of fish feeding however, and the size of the bite marks do show differences. More fish were feeding at Yawzi point, Table 2, but more material was being removed by the fish at Tektite, Table 5. Although these data appear to counter act

one another, the total surface area removed per unit area per unit time show that almost 30% more substrate is being removed at Tekite. This is mainly because the average size of the bite marks is larger at Tekite. Significantly more of the substrate is being removed from the crevices at Yawzi point and from the rocks at Tekite than from the other surfaces at both sites. These figures suggest that the wave energy of the water has an effect on where the fish are feeding. These figures do not consider the relative abundances of each particular type of substrate at each site. There is greater percentage of rock cover at Tekite than at Yawzi point, and there also is a greater percentage of crevices at Yawzi than at Tekite (Table 6). This site specific utilization can explain differences between amounts of algae removed from different substrates, Table 8. There was no significant difference between the two sites for parrot fish feeding on corals (Table 4). However the relative abundance of substrate figures suggest that if the corals were a major source of food in the Scaridae's diet, then more feeding would occur at Yawzi point since there is a greater percentage cover of corals (Table 6). More predation on the corals does occur at Yawzi point as is shown by the percentage of heads grazed at each site, 75% vs 27%. These data, along with the fact that after 200 minutes of observation, only 11 bites were observed to be made on coral substrate, proves that the coral does not make up a large portion of the parrot fishes diet. Only 1.78 mg coral/min were observed to be removed at Yawzi point and none was observed at Tekite. Randall (1968) was, in part, correct. He was in error however when he said that parrot fish do not feed on corals.

With the present data the problem of how the high number of grazed heads arose when there was not a significant amount of grazing on corals observed. On 4-9-87 a head of Monastrea annularis, 50 cm x 30 cm, was estimated to have 188 recent bite scars. The scars were very white and showed no signs of recovery. The coral head was revisited 11 days later and 55 of the scars were covered with algae. The remainder had turned an orangish color suggesting a regrowth of coral tissue. Thus the heads of M. annularis showing white bite scars within the 1500m² area were no more than 11 days old. The minimum number of bites in the 1500m² area at Yawzi point can be estimated to be 5500 by assuming that each grazed head had the minimum number of bites for each category in Table 7. By finding the bites /min taken on coral over an estimated 11 day period, assuming that 11 days is the maximum age for scars that were counted as recent, and assuming that parrot fish feed only 12 hours a day, it is possible to get an approximation how often parrot fish feed on corals in the 1500m² Yawzi point area. This is 0.694 bites/min/1500m². This value is 12.5 times greater than the 11 bites/200 min (= 0.055 bites/min) that parrot fish were observed feeding on corals during this study. The observed value is not per 1500m² however, but is over a much smaller range since one observer cannot watch 1500m² at one time, consequently the chance of seeing the bite scars being made is very much reduced.

The difference in water movement between the two sites did not appear to have an effect on the parrot fishes ability to graze the substrate.

Bite marks on the corals were larger at the high energy Tektite site suggesting that maneuverability within the substrate was not limited, and that the parrot fish are larger in size at Tektite. The data suggests that the relative abundance of the substrate available to feed upon has a larger effect on the Scaridae's grazing than the water turbidity had. The parrot grazed mainly on algae. Their grazing leaves areas of scraped rocks, crevices and corals open for recolonization by other reef inhabitants, although algae was often the first to settle on the grazed corals. The amount of feeding on M. annularis is minimal compared to the amount of feeding on the algal communities, and the predation on the corals was never observed to be at such an extent that the coral tissue could not grow back. It is concluded whilst parrot fish do graze on Montastrea annularis the nutritional input of this coral is small compared to that of other food sources. Predation by Scaridae on Montastrea annularis has no major effects on these established coral colonies.

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THE EFFECTS OF INDIVIDUAL SIZE AND DIEL
MIGRATIONS ON THE FEEDING
PATTERNS OF THE ARROW HEAD
CRAB, STENORINCHUS SETICORNIS.

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ABSTRACT

The effects of the individual size and diel migrations on the feeding rates on Stenorinchus seticornis were observed in Greater Lameshur bay St. John, USVI. At different times of the day and night, individual crabs were observed for five minute periods, recording size, location, and feeding rates (body to mouth and substrate to mouth). Both the amount of time spent in crevices and the feeding rates were greatest for small crabs. These times and rates decreased with increasing size of the crabs. The feeding rates were higher when the crabs were in crevices. When in crevices S. seticornis feeds more from detritus on its body than on the substrate.

INTRODUCTION

Stenorinchus seticornis is found in crevices in stoney corals and rocks throughout the reef, especially near areas of sandy substrate. They are detritus scavengers, using their chelipeds to pick up food and transfer in to their mouths. In 1971, Louis Barr studied arrow heads in Greater Lameshur bay. He determined that crabs have two main areas of detritus feeding, the substrate around them, and their bodies. He observed that they can actively store detritus on their rostrum or have it collect on the rough surface of their legs and carapace. By studying the crabs movements, Barr concluded that S. seticornis follows a diel migratory pattern, leaving their crevices at dusk and returning to them at dawn, and while out of their crevices arrow heads eat less than when in their crevices.

What Barr alludes to, but never provides conclusive data for, is how size of an individual effects the migratory process and what the primary feeding source is for the crabs when they are in and out of their crevices. For each specific size class, this project examines the effect of these factors by looking at migrations and the substrate to mouth/ body to mouth rates when the individual is in or out of crevices.

METHODS

On eighteen SCUBA dives made from April 10 to April 21, Stenorinchus seticornis was studied. Data was collected at Caprite horn, Tekitlo, Yawzi point, the Coral gardens, Donkey Bite, and under the dock in

Greater Lameshur bay (Figure 1). Dives were made in six observational periods, 3:00-6:00, 6:00-7:00, 7:00-15:00, 15:00-18:00, and 18:00-22:00. On each dive as many randomly chosen crabs as possible were observed for five minute periods. To avoid disrupting the arrow heads behavior, distances between the observer and the crabs were kept as large as accurate data collection would allow (approximately 1m).

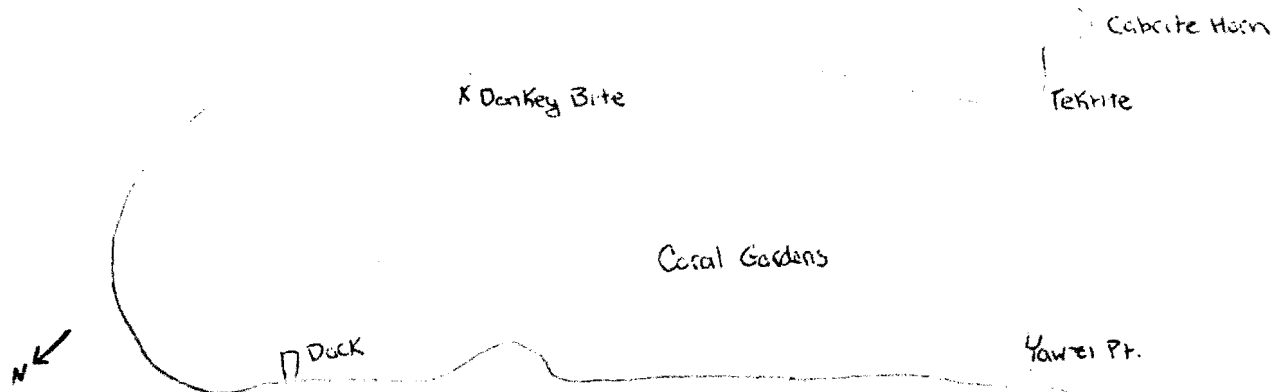


Figure 1 Data collection sites in Greater Lameshur bay.

For each individual, location, size, and body to mouth/ substrate to mouth feeding rates were recorded. Location was either In or Out, depending on whether the crab was in or out of the crevice. The three size classes was first determined by visual estimate. Measurements to determine length from the rostrum to the end of the carapace were made: small < 1 cm, mediums > 1 cm and < 2.2 cm, larges > 2.2 cm.

RESULTS

Individual location through time. There was a significant difference in the number of Stenorinchus seticornis found In versus Out for the different observational periods (Figure 2). There was not a significant difference in the number of smalls found In between day, 6:00-18:00, and night, 3:00-6:00 and 18:00-22:00, (chi test, $\chi^2=1.17$, $df=1$, $P<0.5$, $n=20$). Table 1 a,b, and c show that the mediums and larges did show a significant difference of In-Out over time (chi test medium, $\chi^2=9.98$, $df=1$, $P<0.005$, $n=43$ and chi test large, $\chi^2=7.54$, $df=1$, $P<0.005$, $n=27$).

For the total time of observation, smalls were In significantly more than larges (Table 1a and c, chi test, $\chi^2=7.78$, $df=1$, $P<0.01$). The numbers of smalls In and mediums In was not significantly different (Table 1a and b, $\chi^2=3.34$, $df=1$, $P<0.1$, $n=63$).

Table 1. The number of S. seticornis found in and out of crevices for each size class at different observational periods.

a) small	In	Out	b) medium	In	Out	c) large	In	Out
night	5	4	night	2	13	night	0	14
day	11	0	day	27	1	day	7	6

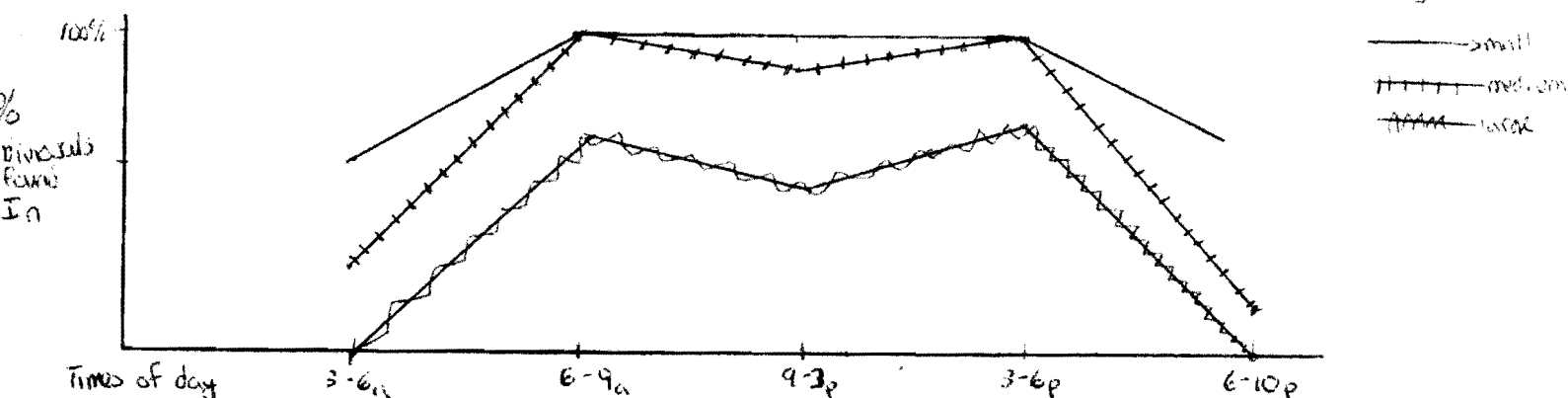


Figure 1 The percent of individuals found in crevices.

Total feeding rates through time. For each size class, there was a difference in feeding rates between night and afternoon, 15:00-18:00. Smalls however were not significantly different (Table 2, t-test, $t=1.12$, $df=13$, $P<0.5$, $n=14$). Mediums and larges had a significant difference being more active in the afternoon (Table 2, mediums t-test, $t=5.78$, $df=22$, $P<0.001$, $n=23$; larges t-test, $t=3$, $df=16$, $P<0.01$).

Between the size classes there were differences in the feeding rates for different times of the day. At night smalls are feeding significantly more than mediums (Table 2, t-test, $t=5.45$, $df=23$, $P<0.001$, $n=24$) and mediums are feeding significantly more than larges (Table 2, t-test, $t=7.72$, $df=3$, $P<0.001$, $n=29$). At noon, 9:00-15:00, smalls eat significantly more than mediums (Table 2, t-test, $t=1.89$, $df=15$, $P<0.001$, $n=16$). In the afternoon the feeding rates for large crabs was significantly less than both smalls and mediums (Table 2, smalls t-test, $t=3.00$, $df=16$, $P<0.01$, $n=8$; mediums t-test, $t=2.57$, $df=7$, $P<0.05$, $n=18$).

Table 2 Means and standard deviations of feeding rates of S. seticornis through time.

size	Time of day		
	night	noon	afternoon
small	24.33	22.33	31.60
	(7.51)	(15.03)	(13.42)
	(9)	(3)	(5)
medium	9.43	9.07	34.00
	(4.27)	(5.48)	(11.63)
	(15)	(13)	(8)
large	1.71	5.20	13.30
	(2.12)	(5.70)	(6.45)
	(14)	(5)	(3)

For all the time observed, small crabs had the highest feeding rates and largest the least (Figure 3, ANOVA, $F=83.66$, $df=1,34$, $P<0.001$, $n=1201$).

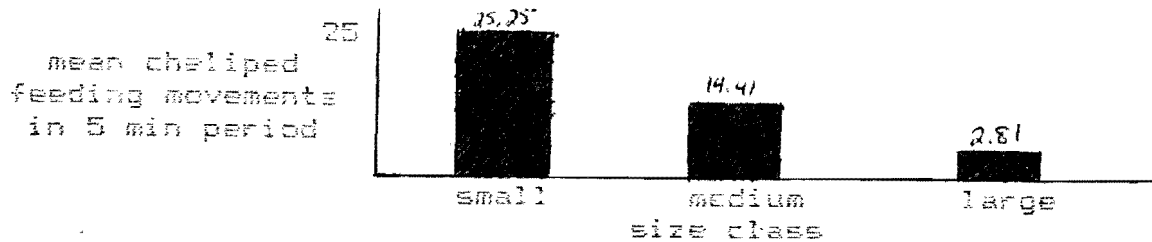


Figure 3 Mean number of cheliped feeding movements for individual Stenorinchus seticornis for each size class at all times of day, In/Out of crevices.

Comparisons of substrate to mouth/body to mouth feeding rates When in crevices, each size class of S. seticornis feeds more from the detritus collected on their bodies than from the substrate: smalls (Table 3, g-test, $g=38.54$, $df=1$, $P<0.001$, $n=505$), mediums (Table 3, g-test $g=38.54$, $df=1$, $P<0.001$, $n=620$), larges (Table 3, g-test, $g=20.36$, $df=1$, $P<0.001$, $n=76$).

Table 2 The body to mouth (B-M) and substrate to mouth (S-M) feeding rates for each size class of S. seticornis in and out of crevices.

	smalls		mediums		larges	
	B-M	S-M	B-M	S-M	B-M	S-M
In	295	126	357	122	22	9
Out	27	55	25	114	9	56

DISCUSSION

During the day, arrow head crabs spend more time in crevices (Figure 2) and more time feeding when in crevices (Table 1). When In, body to mouth feeding is the greatest (Table 2), thus detritus collected on their bodies was the greatest source of food for the crabs. This detritus would seem to be collected at night when the crabs are out of their crevices, as shown by the reduced feeding rates (Table 1). If this were true that the primary purpose of the diel migrations was the detritus collection, then smalls, who spend most of their time in crevices, should not have the highest feeding rates (Figure 3). An explanation for this could be in the quality of the food obtained. Detritus in the water column is continually settling on the substrate, therefore, if crabs are in crevices the amount of detritus collected would be less than being in the outside environment. So possibly smalls have to feed at a higher rate because there is less detritus matter on their bodies.

It would then seem advantageous for crabs to spend as much time as possible out of crevices where the food supply is greatest. Arrow

crabs spend more time Out at night than in the day, and the amount of time spent In increases with decreasing size classes (Figure 2). This may be because of predation or intraspecific cannibalism. While diving many crabs were observed missing legs or chelipeds and a large crab was seen feeding from the detritus on a medium crab it had trapped. This would explain why smalls were not Out as much, and that larges, who would seem the least prone to predation, were out the most (Figure 2).

Unfortunately this study was hampered by the regulations of the U.S. National park. If it were possible to collect specimens, then test that measured detritus collection rates at different times of day for individuals In and Out of crevices could be done. Also, it would be possible to test the effect of the amount of detritus collected on the individuals to the individual feeding rates.

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A COMPARISON OF FEEDING BEHAVIORS BETWEEN
ADULT AND JUVENILE BROWN PELICANS
IN LESSER LAMESHUR BAY, ST. JOHN
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ABSTRACT

The Brown Pelican (Pelicanus occidentalis) is frequently seen diving in the shallow waters of Lesser Lameshur Bay. From day to day, overall pelican group size as well as group foraging activity varies. The purpose of this project was to determine if there are significant differences in foraging success, and overall activity between adult and juvenile pelicans. Observations were made intermittently in Lesser Lameshur Bay. Group sizes, foraging success, and activity budgets were recorded for both the juvenile and adult birds. The results of the study showed that substantial differences do exist in the percentages of foraging attempts that were successful, and activity budgets of the juvenile and adult Brown Pelican (P. occidentalis) during foraging. The juvenile proved to have a lower success rate in foraging than the adult while at the same time spending more time engaged in foraging activity.

INTRODUCTION

Foraging success of pelicans is a major determinant of their survivorship. The methods of foraging, however are not innate, nor are they taught to the young by the parents. Methods of foraging are learned solely through observation of other feeding pelicans (Schreiber 1975). This vital survival technique is often difficult to master for the young birds, and it has been estimated that approximately 3/4 of pelican deaths up to the age of 1 year occur because of starvation (Schreiber 1975).

Both the adult and juvenile brown pelicans (P. occidentalis) forage in Lameshur Bay. Adults are readily distinguishable from juveniles by a white patch on their head as, compared to that of a juvenile which is usually brown or dark grey (Bond 1980). This project is aimed at determining differences between adults and juveniles in overall success of feeding dives, and activity budgets. Judging from their relative inexperience in diving, it would be hypothesized that the juvenile pelican would have a lower success rate than the adults.

MATERIALS AND METHODS

Observations were made and data collected eight times from 3/17/87 thru 4/13/87 on pelican foraging behavior in Lesser Lameshur Bay. The observations were made mainly in the late afternoon (app. 3-5 pm) at which time the most intense pelican activity was observed. Length of these observations varied from 20 minutes to 1 hour, depending upon the amount of time that the pelicans spent foraging. Pelican behaviors were categorized to include, flying (circling bay in flight in search of food), diving (descending into bay from flight to capture food, bill first), and resting (perching out of water on rocks or in trees). Data recorded included pelican activity budgets for amount of time spent foraging (includes diving and flying) and resting (perching) and number and results of foraging dives (# of successes and failures). Successes were observed to be when, after completing a dive, the pelican tilted back it's head to swallow it's successfully captured prey (Schreiber 1975). In order to determine what differences existed in foraging success rates between the adult and juvenile, total successes and failures of both specimens were calculated, and then percent-success rates of both were determined. A G-test was then used to determine if the relationship was significant.

Also, success rates and foraging attempts/minute/pelican were compared for adults and juveniles to see if any correlation existed between foraging rate and foraging success. A correlation test was then used to see if this correlation was significant.

Differences in amount of time spent foraging and amount spent resting were also compared between the adult and the juvenile. Each observation period was used as an independent sample, with the amount of time each group spent foraging being compared. A sign test was then used to compare percent of time spent foraging for the eight sample periods.

RESULTS

Table one summarizes the results of adult and juvenile foraging success rates. In total combined foraging dives, the adult pelicans had a 50% higher rate of success than the juvenile. In each observation sample, the adults also showed a higher percentage of success in foraging than the juvenile (figure 3).

In a comparison of adult and juvenile success rates vs. foraging amounts (figure 2), adult specimens had a relationship between success rates and foraging attempts per minute ($r = .78$, $p < .05$). The juveniles, on the other hand showed no such pattern, with their attempts per minute having no relationship to the success rate ($r = .4$, $p > .05$).

The percentage of time spent foraging for both adults and juveniles is shown in figure 3. Although the juveniles were less successful in foraging attempts than adults, in each observation they were found to have a higher percentage of foraging activity (sign test: $p < .0078$).

TABLE 1
TOTAL FORAGING EVENTS

	# SUCCESSFUL	# UNSUCCESSFUL	% SUCCESS
ADULTS	291	191	= 60%
JUVENILES	151	217	= 40%

G-test:
 $g = 31.4$
 $p < .005$

FIGURE 2: COMPARISON OF SUCCESS RATE AND FORAGING AMOUNT

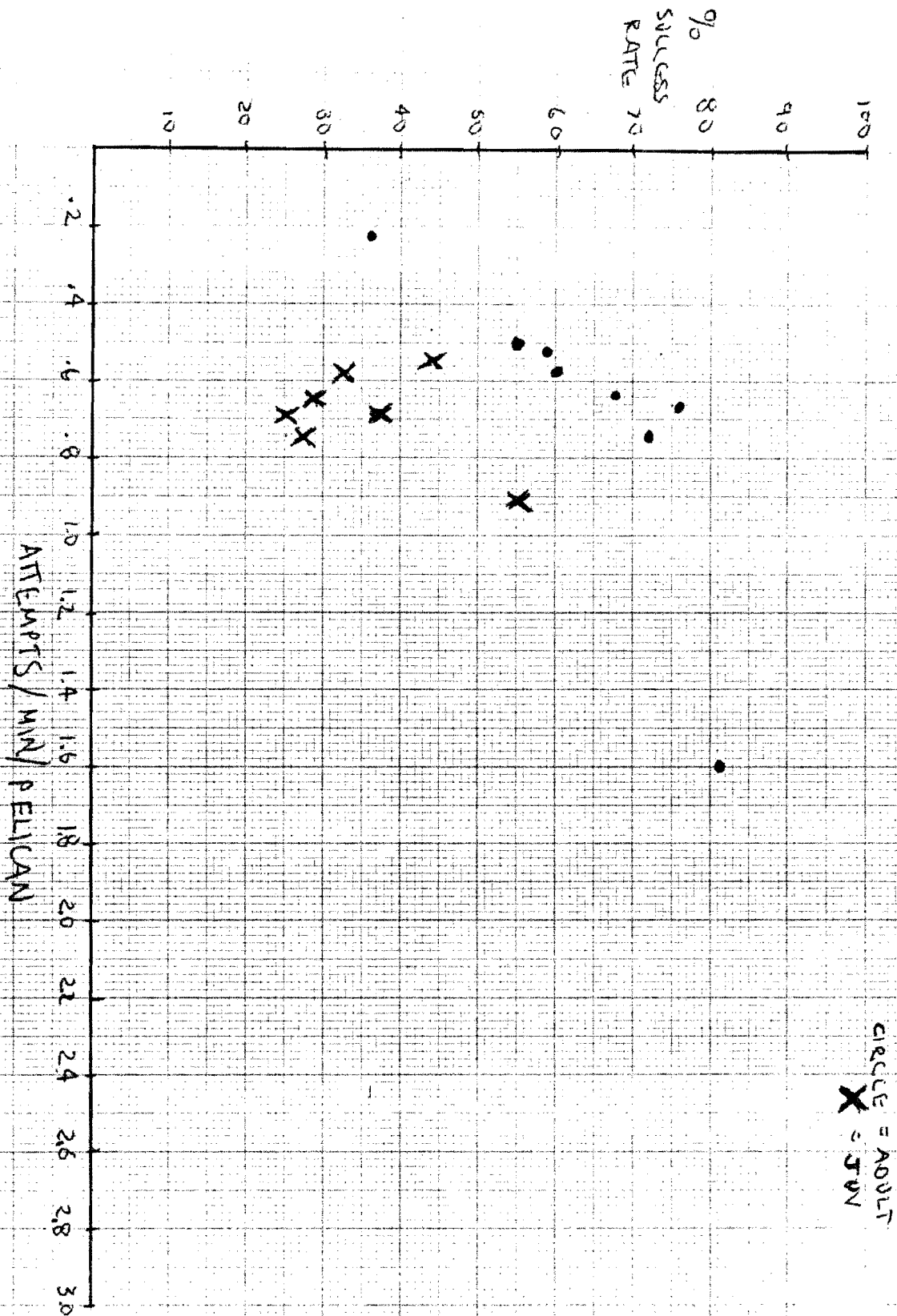


FIGURE 5

FORAGING DIVING SUCCESSES
AND ACTIVITY BUDGETS

FORAGING DIVE
SUCCESS

DIVES:

SUC UNS SUCCESS RATE

3/12/87
3 ADULTS
3 JUV
10:45-11:35 AM

A	45	14	- 76%
J	24	25	- 49%

4/13/87
2 ADULTS
1 JUV
1:00-5:30 PM

A	39	69	- 36%
J	16	46	- 26%

4/14/87
2 ADULTS
1 JUV
5:00-5:20 PM

A	17	8	- 68%
J	10	8	- 56%

4/16/87
2 ADULTS
1 JUV
4:25-4:45 PM

A	52	12	- 81%
J	28	32	- 46%

4/16/87
ADULTS
JUV
2:20-2:55 PM

A	36	14	- 72%
J	9	15	- 37%

4/16/87
2 ADULTS
2 JUV
3:40-4:15 PM

A	22	18	- 52%
J	15	31	- 32%

4/18/87
2 ADULT
2 JUV
3:30-4:00 PM

A	14	14	- 50%
J	11	28	- 28%

4/19/87
3 ADULT
1 JUV
4:45-5:45 PM

A	61	42	- 59%
J	12	32	- 27%

ACTIVITY BUDGET

FORAGING RESTING % TIME FEEDING

A	66	24	- 73%
J	81	9	- 90%

FORAGING RESTING

A	136	44	- 75%
J	79	11	- 87%

FORAGING RESTING

A	30	10	- 75%
J	17	3	- 85%

FORAGING RESTING

A	34	6	- 46%
J	18	2	- 65%

FORAGING RESTING

A	51	14	- 73%
J	27	8	- 77%

FORAGING RESTING

A	37	43	- 46%
J	52	28	- 65%

FORAGING RESTING

A	43	17	- 71%
J	48	12	- 80%

FORAGING RESTING

A	176	104	- 42%
J	38	22	- 63%

DISCUSSION

The results of the study show that there do exist significant differences in the foraging success rates of juvenile and adult brown pelican (P. occidentalis). Adult pelicans have a 50% higher success rate than juveniles (A:60% J:40%). The relatively low success rate of juveniles may be an important factor in explaining the high juvenile mortality rate of brown pelicans (P. occidentalis). Due to the inability to forage successfully, it has been estimated that 3/4 of all brown pelican (P. occidentalis) deaths up to the age of one occur due to starvation (Schreiber 1975). One would expect that as rate of foraging success increased, so would the number of foraging attempts. This was shown to be true for the adult pelican which had a relatively linear increase in foraging attempts for an increase in success rate, and not true for the juvenile which showed no significant relationship between number of attempts and success rates. This difference could be due to the fact that the juveniles inexperience does not enable him to recognize the relationship between the two factors.

In the percentages of time spent foraging, it was shown in the results that juveniles spend more time in foraging activity than the adults. This result was important for although the juveniles spent a higher percentage of time foraging than adults, they were less successful in foraging dives. But, since the juveniles future foraging success depends upon it's ability to learn to forage effectively when young, the more time the juvenile spends practicing, the more quickly he will learn proper foraging techniques.

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A STUDY AND COMPARISON OF THE FEEDING HABITS OF BARTHOLOMEA
ANNULATA AND CONDYLACTIS GIGANTEA

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ABSTRACT

This study compares the feeding behaviour of two anemones, Condylactis gigantea and Bartholomea annulata which are abundant throughout Greater Lameshur Bay. The feeding habits of both anemones were compared. B. annulata uses more tentacles and takes longer to transfer the food to the oral disc than C. gigantea. Because of these differences, it is suggested that C. gigantea is more likely to eat large prey, while B. annulata consumes smaller particles.

INTRODUCTION

Actinarians exploit the polypoid body form; a coelenteron covered on the oral side with a large number of nematocyst-armed tentacles. Nematocysts are used to capture food materials. The tentacles move it to a central mouth opening where it is ingested. In previous studies, researchers have examined the specific, rudimentary nerve responses following stimulation with certain proteins (Linstedt, 1971). After introduction of pieces of animal prey to the water around the tentacles, the anemones expand their oral discs and begin waving their tentacles around as a prefeeding response. Chemoreceptors, for both portions of feeding behaviour are located in the ectoderm of the tentacles and the oral disc. The chemoreceptors detect certain proteins and vitamins released by the prey. This speeds up the rate of capture. After the tentacles contact the food material, the nematocysts on the tentacles discharge and the tentacles move the food towards the mouth opening (Van Praet, 1985).

Once the food has been captured, the anemone can digest it extracellularly or intracellularly as soon as it contacts the mesenterial filaments (Van Praet, 1985). Anemones can eat both macrophagous and microphagous materials. Usually, anemones that remain sedentary eat small motile animals like planktonic larvae, isopods, and polychaetes (Van Praet, 1971). However, some larger anemones like Condylactis gigantea eat large prey and depend on heavy wave action to fulfill this requirement (Van Praet, 1971).

This study is much more general in methodology but examines the same general concept, the tentacular responses to food material in two anemones. The two anemones found abundantly in the coral crevices in Greater Lameshur Bay are Bartholomea annulata, the ringed anemone, and Condylactis gigantea, the purple-tipped anemones. This study compares the actual feeding behaviours to see whether or not they differ. Specifically, the average number of tentacles that initially

contact the food and the time it takes to reach the mouth will be examined for each species. This paper determines which anenome is better suited to capture prey because of its size and its tentacular structure.

MATERIALS AND METHODS

The feeding habits of Bartholomea annulata and Condylactis gigantea were observed in situ and in the laboratory. Various locations were chosen to accurately observe these two species so that the same organism was not retested. In order to get a statistical comparison, ten or more of each species were looked at. Before any tests were made, the number of tentacles of each individual were roughly counted. Visually, the organism was radially divided into four portions so that the tentacles in each quarter could be counted and then extrapolated to the total. To examine the feeding behaviour, a consistent foodstuff of processed ham was used. Food particles of approximately 1 cm³ of ham, were released approximately 2 cm from the tentacles. The initial number of tentacles which contacted the food was recorded. Next, the elapsed time before the food reached the mouth was recorded. Additional tests were done to compliment the research. Finally, to get an indication of the ecological distribution, the numbers of each anenome were counted in a 10m by 10m quadrant in 2 different locations in Greater Lameshur Bay.

RESULTS

For both Condylactis gigantea and Bartholomea annulata, the mean number of tentacles initially contacting the food are shown in Table 1 and are significantly different between species. The result of the T-test is 3.76 with a probability of less than .01 (df=20).

The time that the food took to reach the oral disc of both Bartholomea annulata and Condylactis gigantea are shown in Table 2. The mean times were significantly different between the two species (T-test=2.82, df=20, p<.02).

The number of tentacles on the food and the total number of tentacles per individual per both species of anemones are shown in Table 3 and plotted in Figure 1. There is no significant correlation between Condylactis gigantea ($r=0.1894$, $df=8$, $p=.05$) and Bartholomea annulata ($r=0.4911$, $df=10$, $p=.05$).

The ecological distribution of Condylactis gigantea and Bartholomea annulata in two different locations in Greater Lameshur Bay are significantly different. In the high wave action location of Donkey Bite close to shore, the density of C. gigantea per 100m² was 3 while the density of B. annulata per 100 m² was 11. In the coral garden, the population of C. gigantea was 1 while the density of B. annulata per 100 m² was 9.

DISCUSSION AND CONCLUSION

In addition to the unique morphological structure between the two anemones, the feeding behaviour of Condylactis gigantea differs from that of Bartholomea annulata. The long, bulbous tentacles of

Condylactis gigantea about 10 cm in length are extremely different than the thin, small, fine ringed tentacles of Bartholomea annulata about 5 cm in length. Similarly the mean 15 cm diameter of the tentacular crown of C. gigantea is twice that of the mean nine cm diameter of the tentacular crown of B. annulata. These observations suggest that C. gigantea will eat larger food material than B. annulata.

For each anemone, the feeding ability as measured by the number of tentacles that contact the food was not related to the size of the anemone as measured by the number of tentacles. One problem with this comparison is the accuracy of the number of estimated tentacles. This could be made accurate by photographing each anemone and subsequently counting the number of tentacles of each anemone. Then, the difference between the number of initial tentacles that contact the ham by both species can easily be distinguished in Figure 1.

Condylactis gigantea uses significantly fewer tentacles to capture the ham than Bartholomea annulata (Table 1). The force in the tentacles of C. gigantea was greater than that of B. annulata. During the feeding tests, the force was easily felt when their nematocysts discharged on my hands. Before feeding the anemone, C. gigantea detected the presence of food because of chemoreception and began moving its tentacles around in search of food. Sometimes, the tentacles grabbed my hand and attempted to pull it in. During the feeding tests of B. annulata, the anemone often contracted into its crevice before it could even feed. During successful observations, the exerting force of B. annulata was weaker than that of C. gigantea. The attempts to measure the force failed.

Condylactis gigantea may consume a regular diet of larger food material than Bartholomea annulata. Basically, C. gigantea needs fewer tentacles to retrieve the same amount of food as B. annulata. Likewise, C. gigantea could eat more food than B. annulata during the feeding tests which suggests that it has a larger diet to fulfill its food requirements. On top of this, C. gigantea could push the food to the oral disc faster than B. annulata. Since it has a faster tentacular response, one might assume that C. gigantea feeds on a larger prey because it needs to subdue the prey fast by ingesting it as quickly as possible.

The population densities of the two anemones in Greater Lameshur Bay relates to the feeding habits of each anemone according to previous research. It would be expected that C. gigantea would occur in shallow water so the heavy wave action can supply large prey (Van Praet, 1985). Bartholomea annulata should be found in coral reefs where the larvae of corals and fish is abundant. The ratio of C. gigantea to B. annulata is greater at Donkey Bite where the wave action is higher than at the coral garden where the wave action is low. This ratio suggests that C. gigantea does depend on high wave action to supply its diet of large prey while B. annulata depends on corals to supply larvae and other small particles.

Table 1. Comparison of number of initial tentacles on food
for Bartholomea annulata and Condylactis gigantea

# of Initial Tentacles Contacting Food			
(Average of 2 trials)		(Average of 3 trials)	

	<u>Bartholomea annulata</u>		<u>Condylactis gigantea</u>
Anemone #	1	6.5	4
	2	7.0	3.0
	3	5.0	3.3
	4	4.0	4.0
	5	7.0	3.3
	6	5.5	2.3
	7	5.5	.0
	8	5.5	3.3
	9	6.0	2.0
	10	6.0	4.0
	11	8.0	
	12	.0	
Average		5.5	2.9
Standard Deviation		2.0	1.2
Number		12.0	10.0

T-test=3.76 df=20 p<.01

Table 2. Comparison of the time that elapses until the food reaches the mouth for Bartholomea annulata and Condylactis gigantea.

Anemone #	Time until Food Reaches Mouth	
	(Average of 2 trials)	(Average of 3 trials)
	<u>B. annulata</u>	<u>C. gigantea</u>
1	79.5(seconds)	36.7(seconds)
2	125	63.7
3	34.5	26.7
4	110	33.7
5	63.5	19
6	44.5	19.7
7	80	46.3
8	78	20
9	57.5	54.3
10	37.5	0
11	63	
12	0	
mean	64.4	32
standard deviation	33.9	19
number	12	10

T-test=2.82, df=20, $p < .02$

Anenome #	Total Tentacles	# of <u>B. a.</u> Tentacles	# of <u>C. g.</u> Tentacles
1	29	6.5	
2	40	7	
3	60	5	
4	50	4	
5	150	7	
6	80	5.5	
7	120	5.5	
8	30	5.5	
9	200	6	
10	200	6	
11	200	8	
12	95		4
13	120		3
14	110		3.3
15	80		4
16	200		3.3
17	100		2.4
18	150		3.3
19	50		2
20	100		4

Table 3. Comparison of number of tentacles on food for each anenome versus the total number of tentacles per each species.

No significant correlation. The r of Condylactis gigantea = C. g. is 0.4911 (df=10 @ $p=.05$). The r of Bartholomea annulata = B. a. is 0.1894 (df=8 @ $p=.05$).

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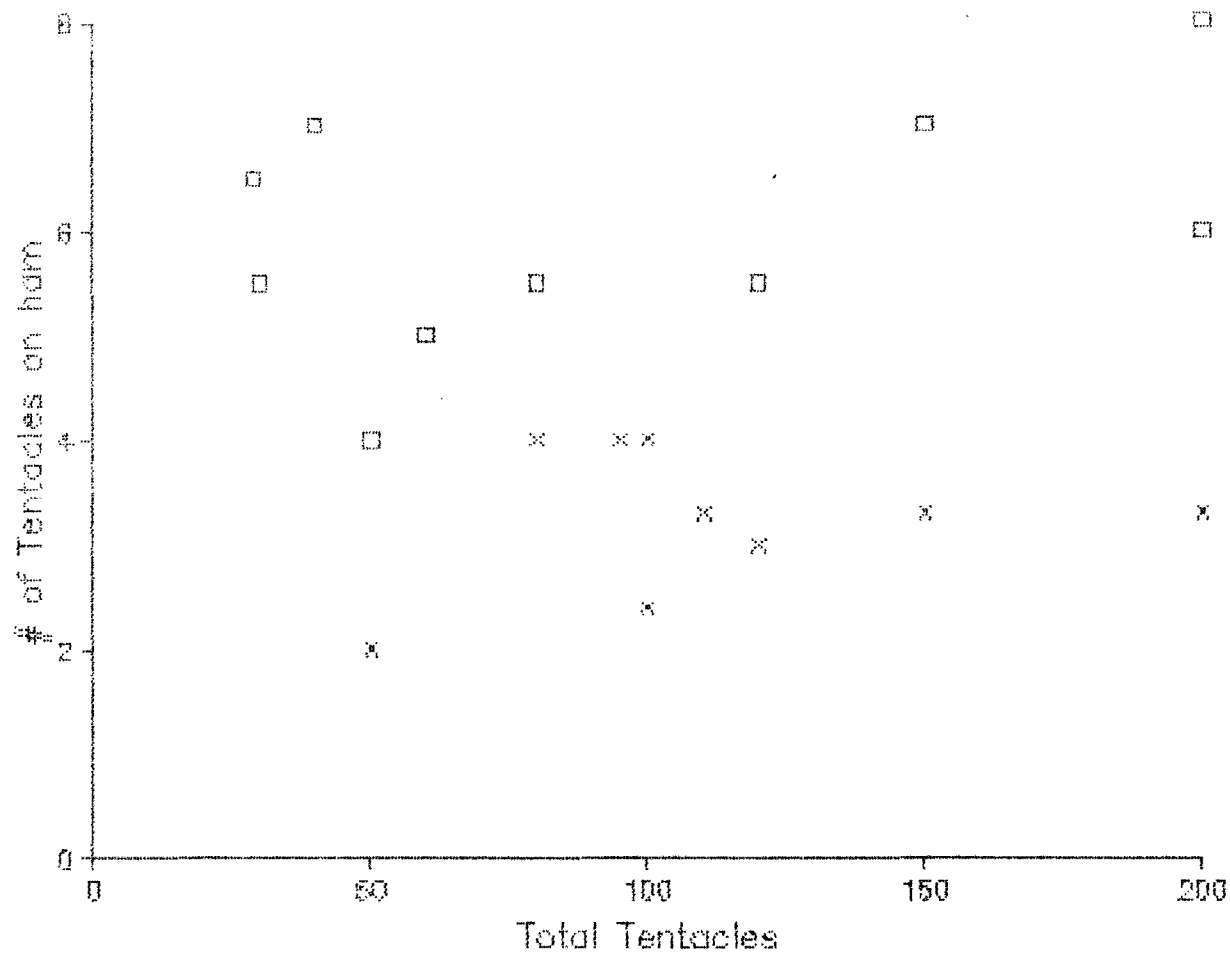


Figure 1. Comparison of the total number of tentacles for each species versus the # of initial tentacles contacting food.

Legend:

X = Condylactis gigantea

□ = Bartholomea annulata

EFFECTS OF WATER MOVEMENT AND SEDIMENTATION ON THE COMMUNITY STRUCTURE
(DIVERSITY) OF SCLERACTINIAN CORALS, ST. JOHN, U.S.V.I.

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ABSTRACT

The community structure of Yawzi Point and Lesser Lameshur Bay, St. John, U.S.V.I. was defined in terms of number of species, number of colonies, percentage of living cover, Shannon and Weaver's diversity index and Pielou index of evenness. Transects 10 meters long were used for the present study. They were located at 4 and 6 meter depths at both sites. Water movement and sedimentation rates were measured at both sites. A correlation between sedimentation and water movement was found. Yawzi Point proved to have lower sedimentation rates and greater water movement. This site showed greater number of species and colonies as well as a higher percentage of coverage and diversity index (%cover= 53 and 57% and $H'_n = 2.156$ and 2.253 for both depths, respectively). On the other hand, Lesser Lameshur Bay proved to have higher sedimentation rates and lower water movement. This site displayed lower number of species and colonies as well as inferior percentage of cover (%cover= 31.8 and 31.4% and $H'_n = 1.670$ and 1.732 for both depths respectively). It is suggested that sedimentation and water movement affect community structure on tropical reefs. A total number of 18 scleractinian species were found in the area and the four most common species were Montastrea annularis, Millepora alcicornis, Porites astreoides and Agaricia agaricites.

INTRODUCTION

Concern about natural diversity has risen in the public conscience recently over the imminent extinction of thousands of species as a result of pollution and habitat destruction (Lewin, 1983). Ecologists have failed to predict the consequences of this havoc on natural resources and the intrinsic stability of natural systems. Many consider these consequences to be potentially disastrous (IUCN, 1984). If we are to predict changes in system function following depauperization, we need to understand processes responsible for generating and maintaining diversity in biological communities.

Local diversity is the deterministic outcome of local processes and community diversity often parallels variations in local physical conditions (Ricklefs, 1987). However, many authors consider community diversity to be the result of other factors. Competition, and particularly, competitive exclusion experiments, are likely to affect diversity indices (Pianka, 1974). Predation, on the other hand, may influence diversity as it can manipulate interspecific interactions. Finally, disturbance itself, by interrupting the return of systems to equilibrium, may retard competitive exclusion and thereby promote diversity (Hubbell, 1978).

Coral reef communities have generally been described as extremely heterogeneous environments and are often compared to tropical rain forest communities (Hubbell, 1978). Numerous factors, may be important in controlling coral distributions and species diversity (Huston, 1985). The purpose of this work was, firstly, to determine species composition and diversity indices of scleractinian corals on the reefs of St. John, U.S.V.I., secondly to determine whether or not physical conditions such as depth, high sedimentation rates and water movement, affect coral reef structure.

STUDY AREA, MATERIALS AND METHODS

The island of St. John lies along the northern boundary of the Caribbean Sea at 18°20'N, 64°45'W. Fringing reef development is common along the present shoreline of St. John, where reef platforms typically extend 50-200 m offshore (Robinson, 1982). The site for the present study was Yawzi Point and Lesser Lameshur Bay; both places are located at the southeast part of the island. Loya's modified method, "straight line transect" was used for this study. A review of methods used in quantitative studies is presented by Loya, (1978).

Transects were run parallel to the shore at a depth of 4 and 6 m. In the present study, transects 10 m in length were used as it was determined that observed species diversity peaked with transect lines of approximately this length. All species of corals beneath the transect line were recorded and their length under the transect were measured to the nearest cm. An individual was defined as any colony growing independently of its neighbors (i.e. whenever an empty space was recorded between two adjacent colonies). Where an individual colony was clearly separated into two or more portions by the death of the intervening parts, the separate parts were considered an individual (Loya, 1972).

The measurement of species diversity may refer to the number of species assembled, or it may be a more complex measurement which takes into account the number of individuals of each species (Loya, 1976). In this study diversity was defined by Shannon and Weaver's (1948) index of diversity:

$$H' = -\sum p_i \ln p_i$$

where

$$p_i = \frac{n_i}{N}$$

where p_i is the proportion of individuals of the i th species and

$$H'_{\text{c}} = -\sum p_i \ln p_i,$$

where p_i is the proportion of coverage for the i th species.

Also Pielou's (1966) evenness index

$$H'_{\text{c}} \text{ observed} / H'_{\text{max}}$$

was used, which is essentially a measure of the degree of dominance in a sample.

Water movement was measured according to Doty's method (1971). Clods used were made of plaster of Paris. Their initial weight after air drying was 24.0 ± 0.4 g. They were glued to vinyl clod cards with contact cement and attached to a metal grid with lead weights for anchoring. Five replicates were placed at 5 m depths at each site and left in the field for a period of 28 hours before being collected. They were left to air dry for a period of 24 hours before their final weight was measured.

Sedimentation was measured using sample tubes placed in test tube racks that were weighted down with lead diving weights. Six replicates were located at 5 meter depths at each site for a period of 28 hours. Trapped sediments were poured onto pre-weighed filter paper, dried for 24 hours at 60°C , and weighed again.

RESULTS

Coral abundance

A total number of 18 scleractinian corals were found in the areas of study (Table 1). The hydrozoan Millepora alcicornis was also included in this project as it constitutes an important cementer in these particular reefs.

Other coral species found in the area but not intercepted by the transect line because of their scarcity were: Mycetophyllia spp., Madracis mirabilis, and Mussa angulosa.

Table 1 .-

Relative abundance* of hermatypic corals off Lameshur Bay, St. John, U.S.V.I.

species code	species	Yawzi Point		Lesser Lameshur Bay	
		4 m	6 m	4 m	6 m
M	Millepora alcicornis	Dominant	Abundant	Dominant	Sporadic
Ac	Acropora cervicornis	Sporadic	Rare	---	---
Aa	Agaricia agaricites	Abundant	Dominant	Abundant	Dominant
Ss	Siderastrea siderea	Common	Common	Sporadic	Common
Sr	Siderastrea radians	----	Rare	---	Rare
Pp	Porites porites	Common	Common	Sporadic	Sporadic
Pa	Porites astreoides	Abundant	Abundant	Common	Common
MD	Madracis decactis	----	Rare	---	---
Dc	Diploria clivosa	Rare	Rare	---	---
Ds	Diploria strigosa	Rare	Sporadic	---	---
DI	Diploria labyrinthiformis	Sporadic	Common	Rare	Rare
Cn	Colpophyllia natans	Rare	Sporadic	---	---
Mm	Meandrina meandrites	Rare	Sporadic	---	Rare
Ma	Montastrea annularis	Dominant	Dominant	Abundant	Dominant
Mc	Montastrea cavernosa	Common	Common	---	Rare
Ds	Dichocoenia stokesii	Rare	Rare	---	---
Ef	Eusmilia fastigiata	----	Rare	Rare	---
Ff	Favia fragum	Sporadic	Rare	---	---
Dc	Dendrogyra cylindrus	Rare	---	---	---

* Index of relative abundance of corals: Average number of colonies per transect (10 m) is between 0.1-1.0 = Rare; 1.1-2.0 = Sporadic; 2.1-4.0 = Common; 4.1-7 = Abundant; 7.1-11.0 = Dominant.

@ Classification according to Wells (1956).

+ Hydrozoan.

Yawzi Point Table 1 shows a comparative analysis of the relative abundance of corals recorded at the Yawzi Point site. It was found that Montastrea annularis, Montastrea cavernosa, Porites astreoides, P. porites, and Agaricia agaricites constituted the most abundant species in this site serving probably as the main framework builders. Millepora alcicornis was also found to be an abundant species in the area.

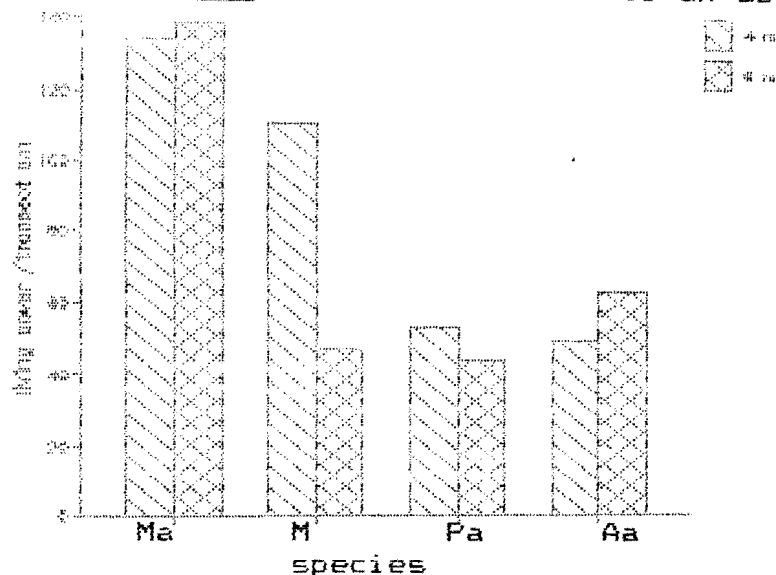


Figure 1. Mean living coral per transect (n = 4) of the four most common species in the Yawzi Reef at 4 and 6 m.

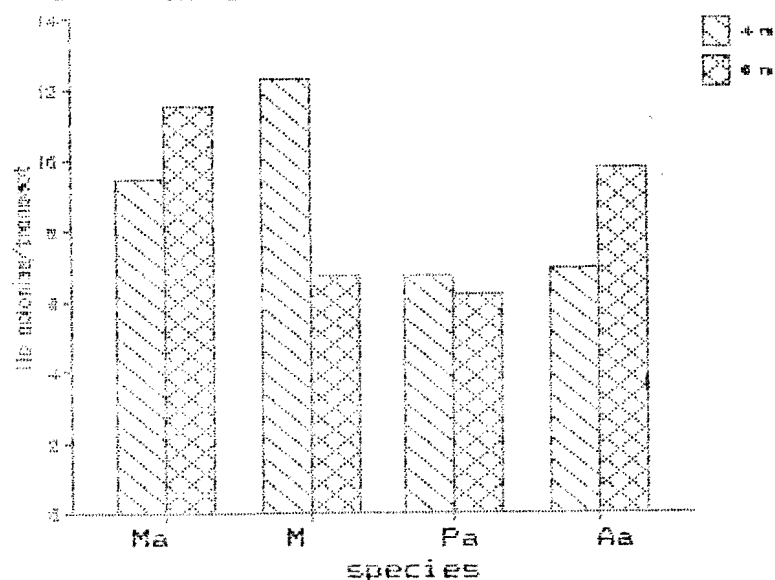


Fig 2. Comparison between the mean number of colonies per transect (n = 4) of the four most common species in the Yawzi Reef at 4 and 6 m.

Figure 1 shows the mean living cover of the 4 most common species at the depth of 4 and 6 m depth. Figure 2 shows the mean number of colonies of the 4 most common species at 4 and 6 m depth. Excluding Millepora alcicornis all other species were equal in number and cover when comparing the two depths (t-test $p < 0.05$, $df = 6$).

Montastrea annularis constitutes the major framework builder of the area with a mean living cover of 13.5 and 14 % at each depth (figure 1) with a contribution to the total living coral per transect of 23.5 and 26.2 % (data not shown).

Coral diversity and abundance characteristics at both depths are shown on Table 2.

After testing for the equality of variance, four possible combinations for comparison were tested (t-test), and the results are given in Table 3.

Table 2. Average values of various statistics (per transect) calculated for the Cliff Reef and Bay Reef. (Standard deviations in parentheses.)

Location	Depth (in m)	No. transects	No. species	No. colonies	Cover %	H' _n Index	H' _c /H' _{max}
YAWZI REEF	4	4	11.75 (0.05)	52 (3.36)	57.02 (1.96)	2.156 (0.018)	0.877 (0.008)
	6	4	13.25 (0.95)	53.5 (2.64)	53.32 (1.68)	2.253 (0.030)	0.881 (0.020)
BAY REEF	4	4	7 (0)	26 (1.82)	31.82 (0.75)	1.670 (0.022)	0.816 (0.170)
	6	4	8 (0)	31.5 (2.64)	31.47 (1.77)	1.732 (0.009)	0.816 (0.014)

Table 3. t-test conducted on the average values of table 2 between four possible combinations of the 2 sites at two different depths. YR = Yawzi Point Reef; BR = Lesser Lameshur Bay Reef. 4 = 4 m; 6 = 6 m.

Average values tested	No. species	No. colonies	Cover (cm)	H' _n index	H' _c /H' _{max}
YR4 vs. YR6	*	N.S.	N.S.	**	N.S.
BR4 vs. BR6	N.S.	**	N.S.	**	N.S.
YR4 vs. BR4	**	**	**	**	N.S.
YR6 vs. BR6	**	**	**	**	N.S.

* p < 0.05; ** p < 0.01; N.S. p > 0.05, df = 6.

Lesser Lameshur Bay Reef Table 1 shows a comparative analysis of the relative abundance of hermatypic corals in this area. Figure 3 shows the mean living cover of the four most common species at 4 and 6 m. The mean number of colonies found at 4 and 6 m are shown in figure 4.

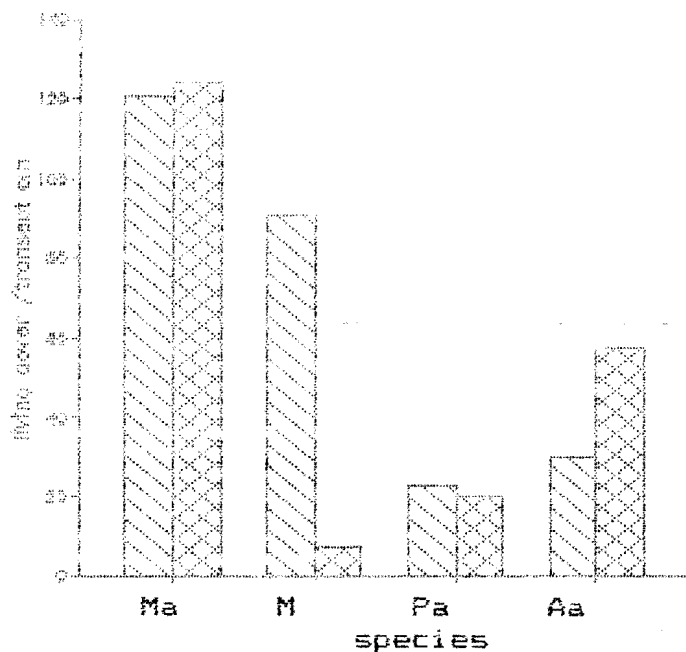


Figure 3. Mean living coral cover per transect ($n = 4$) of the four most common species in the Lesser Lameshur Bay Reef at 4 and 6 m.

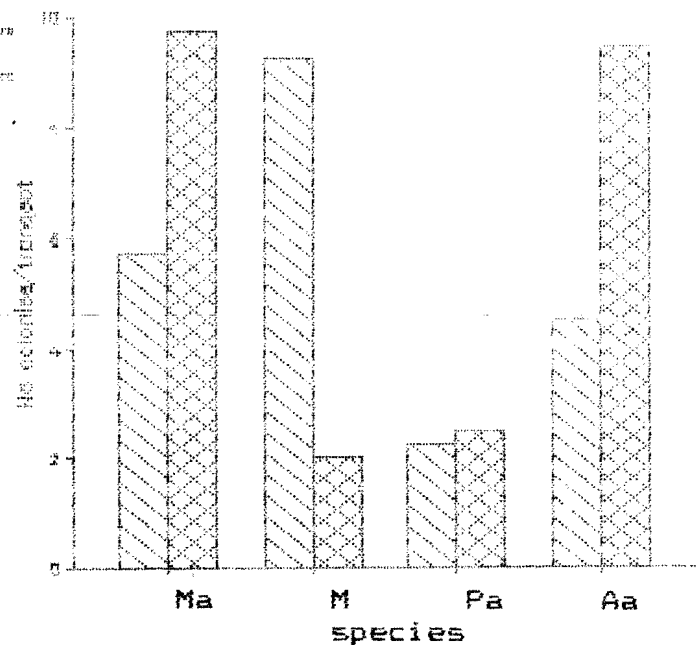


Figure 4. Mean number of coral colonies per transect ($n = 4$) of the four most common species in Lesser Lameshur Bay Reef at 4 and 6 m.

Again in this case Millepora alcicornis appears to be the most variable species in number of colonies and coverage. A mean of nine colonies per transect were found at 4 m while the number was only two at 6 meters. Coverage by Millepora was also significantly different between depths (t-student, $p < 0.05$, $df = 6$). M. annularis total coverage contribution was approximately 12% at both depths. However the number of colonies of M. annularis was significantly different (t-test $p < 0.05$, $df = 6$) at 6 meters suggesting larger colonies at 4 m. Coral diversity and abundance characteristics are shown in Table 2 for both depths. The number of colonies and the diversity index were found to be statistically different. Mean size of M. annularis at 4 m was found to be 21.47 cm ($S = 4.01$) and at 6 m was found to be 12.88 ($S = 1.91$).

Water movement and sedimentation.

Cards exposed at Yawzi Point showed a mean decrease in weight of 18.3 g ($S = 0.4472$, $n = 6$) while those in Lameshur Bay a mean lost weight of only 14.06 g ($S = 0.4650$, $n = 6$). The mean losses were statistically different (t-test, $p < 0.01$, $df = 10$).

The sedimentation rate in Lesser Lameshur Bay was $9.6 \text{ mg/cm}^2/\text{day}$. The sedimentation rate in Yawzi Point was $6.4 \text{ mg/cm}^2/\text{day}$. (The six replicates had to be weighted together in order for the scale to register a weight. This procedure did not allow a calculation of standard deviations and the mean was simply calculated dividing the total weight by 6).

Effects of water movement and sedimentation on coral reefs

Table 1 shows the relative abundance of hermatypic corals recorded in this study. Species diversity (number of species) as well as its relative abundance in Lameshur Bay Reef is considerably lower when comparing the results with those of Yawzi Point.

Figure 5 shows the mean number of colonies per transect of the 4 most common species in the Yawzi Point Reef and in the Lesser Lameshur Bay Reef at 4 m. Figure 6 makes a comparison between the mean living cover per transect of the four most common species at 6 m in the Yawzi Reef and in the Bay Reef.

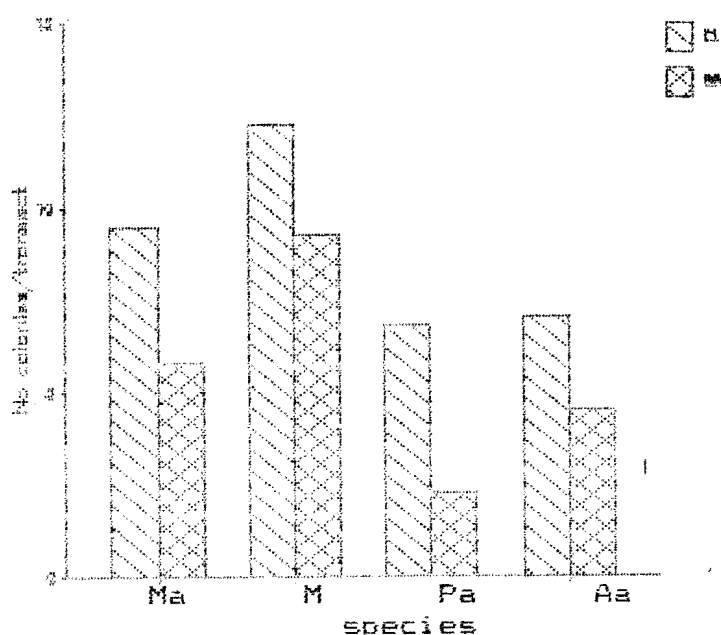


Figure 5. Comparison between the mean number of colonies per transect of the four most common species in Yawzy Reef and Lesser Lameshur Bay Reef at 4 m.

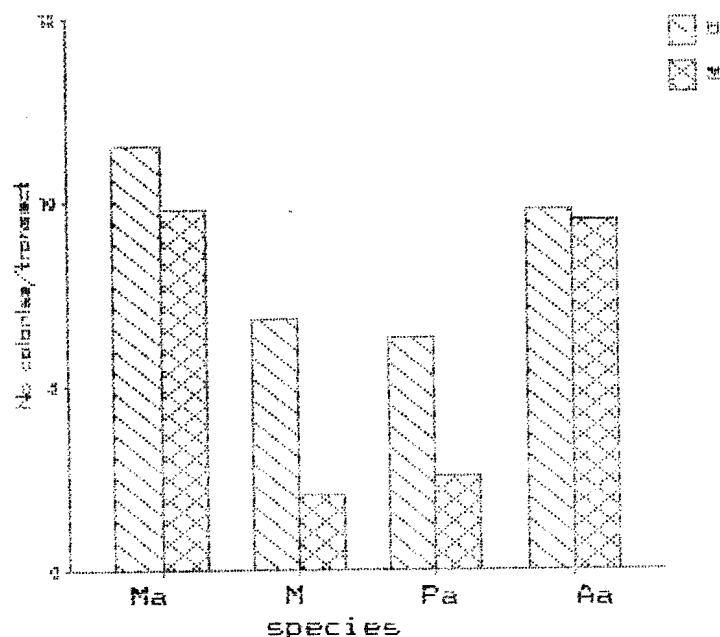


Figure 6. Comparison between the mean number of colonies of the four most common species in Yawzi Reef and Lesser Lameshur Bay Reef at 6 m.

In all cases the number of colonies was lower in Lesser Lameshur Bay where sediment tend to accumulate and water movement is lower.

As sedimentation was the most outstanding enviromental feature, parameters shown in table 2 were compared between the two places. When compairing these parameters at their respective depths, they all proved to be significantly different except for Pielou index of eveness (table 3).

DISCUSSIONS

No references of previous studies were encountered concedrning the total number of species present on the island of St. John. The list of 18 scleractinian species (Table 1) should provide valuable information for further studies.

Effects of depth

Community diversity is usually measured in order to determine its relationship to properties such as productivity and stability, or to physical characteristic of the environment (Pielou, 1975).

Numerous factor may be important in controlling coral distribution and species diversity. These include light, usually correlated with depth; sedimentation; temperature; wave energy; plankton availability; frequency of mortality caused by storms or tidal exposure and grazing by fish and urchins (Huston, 1985a).

In spite of the heterogenity of coral reefs, strong evidence suggests that predictable patterns of species exist along a depth gradient (Huston, 1985a). Diversity (measured by species richness and/or H') is low near the surface and increases to a maximun at approximately 20 meters in depth (Huston, 1985a).

In the present work, diversity increased with an increase of depth at both sites (Table 2). This increase in diversity was due either to an increase in the number of species (Yawzi Reef), or to an increase in the number of colonies (Lesser Lameshur Bay Reef, Table 3).

Changes in diverstiy with depth may bé related to the fact that some species, adapted to particular environmental conditions, are to become abundant in some communities replacing and overgrowing other species. Some corals are adapted to differents depths such as Acropora palmata growing in shallow waters. Although some differences can be estimated from Table 1 regarding coral depth preferences, a further study would be necessary in order to reveal any significant depth preferences for scleractinias growing in these areas.

A remarkable difference, however, is distinguished for the species Millepora alcicornis. At both sites, an increase in depth resulted in a decrease of living cover and number of colonies by M. alcicornis (fig. 1,2,3,4). This pattern may be the result of two combined factors (a) high disturbance in shallow waters due to wave energy and (b) disturbance increasing the chances of organisms becoming adapted to

high energy conditions allowing such organisms to overgrow other species and thus becoming more abundant.

Depth influence may also be related to other results. Diversity index and number of species were found to be statistically different in Yawzi Reef when comparing the two depths. This suggests that the high living coverage in Yawzi Reef at 4 m, is due to cover dominance by fewer species, while more species are contributing to the high living coverage found at the Yawzi Reef at 6 m (Table 2 and 3)

On the other hand, the results for Lesser Lameshur Bay show that the number of colonies and the diversity index were found to be statistically different. This suggests that the living cover observed in the Bay Reef at 6 m is due to different number of colonies, while in Bay Reef at 4 m, this is due to a larger size of colonies (Table 2 and 3).

A relationship between Millepora alcicornis and Agaricia agaricites was found at the Lesser Lameshur Bay Reef. A. agaricites number of colonies and percentage of cover, directly contrasts M. alcicornis growth (fig 3 and 4). This suggests that when M. alcicornis does not grow in a particular place, A. agaricites takes its place to some degree. Further evidendence supporting this idea is the fact that M. alcicornis is seing growing over A. agaricites corals; detected by M. alcicornis texture.

M. annularis proved to be the major framework builder at both sites. M. annularis did not show any differences for preferential depth at either site. However, it was seen that less colonies contributed to the same living coverage in the Bay Reef.

Sedimentation and water movement

It has long been suggested that wave energy and reef geometry were the main controls of sedimentation on a reef. Sedimentation, in turn, affects the distribution of benthic organisms (Stoddart, 1969).

Porter (1972) discovered that cliff-edge zones have always higher diversity values than back-shelf regions. It has also been suggested that the most abundant coral growth generally occurs at the edges of steps where sediment drainage is most efficient, while the least growth takes place on level sites where sediments tend to gather (Goreau and Wells, 1967).

Sedimentation can affect corals by both setting directly on coral and thus interfering with feeding and/or photosynthesis, and also by reducing the amount of substrate suitable for coral growth (Huston, 1985a).

The results found in this study agree with the above mentioned authors (Tables 2 and 3). It is thus proposed that differences in diversity and community structure are a reflection of sedimentation and water movement.

The significant reduction of living cover in the Lesser Lameshur Bay Reef is most likely a result of the limited amount of hard substrate available for coral growth, while the reduction in the number of species and therefore diversity in the same site is certainly due to the direct effect of sediments on coral.

Montastrea annularis colonies were more abundant at the Bay Reef at 6 m. However their size was significantly smaller than those found at the same place at 4 m. This may be explained by the fact that sedimentation is generally greater in deeper water (Huston 1985a). This, in turn, may cause partial mortality and therefore more colonies of smaller size at this site at 6 m.

Many factors affecting the distribution and abundance of scleractinian corals in tropical reefs, as already discussed in the introduction. This study corroborates previous ideas on how sedimentation, location and water movement are related to the community structure of reefs. Further studies should be done to focus on biotic interactions such as predation by corallivores and competition among corals. Other factors that provoke disturbance should also be considered as a way to predict if the intermediate disturbance hypothesis that foresees a higher diversity, could be applied in the study and management of coral reef ecosystem.

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FREQUENCY OF ISOPOD FISH PARASITES AT SEVEN LOCATIONS IN THE
CARIBBEAN

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ABSTRACT

The frequencies of isopod parasites were observed in various areas of the Virgin Islands on six species of fish. The fish examined were Mulloidichthys martinicus (yellow tail goat fish), Flammeo marseanu (long spine squirrel fish), Epinephelus striatus (Nassau grouper), Chromis multilineatus (brown chromis), Holacanthus tricolor (rock beauty), and Haemulon flavolineatum (french grunt). The study sites on the southeast shore of St. John, U.S.V.I., were Tektite, Coral garden in Greater Lameshur Bay and Pelican rock and Yawzi Point in Lesser Lameshur Bay. Sites on the islands Saba, Prickly Pear Cays (Anguilla, N.A.), and Salt Island, B.V.I., were also briefly observed for parasite frequencies on the fish. It was found that brown chromis and rock beauties have a high frequency of parasites located on one or both sides of their face. Adult brown chromis had a 41.6% chance of having a parasite and rock beauties have a 42.1% chance of having a parasite if they live in the Coral garden. Goatfish, on the other hand, had no isopods on them in any area. Squirrel fish had a 6.7% chance of being a host; nassau groupers a 10.53%, and french grunts 18.1% chance. There was a significant difference ($p < 0.005$) of isopod frequencies between species of fish. It was found that the frequency of parasites on fish is independent of the site ($p < 0.005$).

INTRODUCTION

Isopods, (class Crustacea) are very important in the ecosystem and are adapted to a wide range of environmental conditions, terrestrial and marine. Most species are major reducers and scavengers of the ocean (Schultz, 1969, p. 10). They range in size from 1mm to 30cm. There are only a small number of isopods found in the Caribbean. Parasitic isopods are Cymothoids, six of these species of parasitic isopods have been named. Some of these parasites are species specific, or have only been found on one species of fish up to date. For example the isopod found on Squirrel fish is Anilocra laticauda. Some isopods are only parasitic as juveniles. Most of these are parasitic on boney fishes, but have been found on sharks, squids and skates. They are diecious and protandrous. Yet some are hermaphroditic. The hermaphroditic kind

determine their sex by the order they arrive on the fish. The first one becomes the female while the next arrivals will be males. In some orders of isopods the males are so small that they live within the females and others are hyperparasites of the female. Incubation time is from one to two months. The larger the female the larger the brood size she produces (Schultz, 1969). The brood emerges as free swimming larvae.

The purpose of this project is to see if certain species of fish have a higher frequency of hosting a parasite than others. And to see if there are higher frequencies in different areas than others by observation and statistical analysis of the data.

There are a few books on the identification of isopods which include material on their life histories and importance.

METHODS AND MATERIALS

The study sites were located in Lesser and Greater Lameshur Bays, on the southeast side of St. John, U.S.V.I. Data were taken at Tektite, Pelican rock, and Yawzi point three times each and Coral gardens five times (Fig. 1.). The coral gardens are located on the west side of Greater Lameshur. This data were taken from a large rectangular area running along the shore on one side and along the halo on the other. The width of the area was approximately 15 meters long. The depth of the site was 5 to 7 meters deep. The most abundant coral in the garden is Montastrea annularis. There are many other kinds of hard and soft coral, a few sandy patches, sponges and a wide variety of fish and invertebrates. Tektite, just outside of Greater Lameshur Bay on the east side, is an area of steep cliffs up to 10 meters deep. There are more soft corals and sponges at Tektite than in the gardens, yet M. annularis is still the most abundant species. Pelican rock is a series of large rocks just off the beach on the west side of little Lameshur Bay. The maximum depth is 3.5m. Millepora, M. annularis and Porites asteroides are abundant there. The rocks contain many holes and crevices. The area used at Yawzi point is a rocky stretch along the shore with much Millepora and algae. The depth varies from one to three meters. There are many parrot fish and damsel fish present. The depth of the sites at the other islands was 10 to 25m. These sites were highly diverse in their morphologies.

A visual census of isopods on six different species of fish was taken during the months of March and early April. Observations were made using Scuba and snorkling gear. During the dives the same area was not covered twice to try to eliminate redundancy.

Each of these fish have slightly different microhabitats, but all live closely together. In the same area of, for example, 2x2x2 meters one might see all of them. The parasite is located on the head of the fish between the eyes or on either side of the face below the eye near the operculum.

Frequencies of parasites on each species of fish was found by dividing the number of parasitized fish of each species by the total number of that fish seen each dive, then they were averaged. The frequencies of each site were averaged separately. To see if there was a significant difference between the frequencies on each species of fish the G-test was used in a statistical analysis. Chi square analysis and the G-test with the Williams correction (Sokal/Rohlf, 1981) was performed to see if there is a significant difference of frequencies between sites.

RESULTS

The G-test was performed with the average frequencies of parasites on each species of fish at each site to see if there was a significant difference of frequencies between fish species. It was found that there was a significant difference ($p < 0.005$). The null hypothesis, different species of fish have the same frequencies of parasites was rejected. With the data from the Coral garden the frequencies of parasitism were found to be 0% for goatfish, 6.7% for squirrel fish, 10.5% for nassau groupers, 41.6% for brown chromis, 42.1% for rock beauties and 18.09% for french grunts. Chi square analysis was done with the G-test with the Williams correction (Sokal/Rohlf, 1981) to see if there was a significant difference of frequencies between sites. It was shown that the frequencies of parasites at each site was very similar ($p < 0.005$). Here the null hypothesis was accepted, isopod parasite frequencies is independent of the site.

DISCUSSION

The six fish that were examined were chosen because of their differences in life histories. Goat fish were selected because they are ground dwellers and scavengers. With their two specialized whiskers they move the loose sand around to find invertebrates hidden in it. Although isopods dwell near the ground at some point in their life cycle the frequency of parasites on goatfish is 0%. This implies that ground dwellers do not have an increase in the chance of having parasites. Squirrel fish were selected for study because earlier observations indicated that they had many parasites. Afflicted fish were commonly seen, yet the frequency of parasite occurrence on them is only 6.7%. Cleaning stations are frequented by nassau groupers, as is commonly seen while diving. At these stations cleaning gobies and shrimp eat the parasites off the cleanee. This may be responsible for the low frequency (10.53%) of parasites observed on this species of fish. This is probably the most inaccurate measurement because not many groupers were seen at a given time, which decreases the sampling size. Brown chromis school above high coral heads with blue chromis (which were never observed to have parasites). They are a smaller, planktivorous fish and are only seen in water 3 meters or more deep. They had a very high frequency of parasites (41.6%). Rock beauty are usually found at the same depth as the brown chromis and hover near a quick get away in the crevice of coral. These fish are also solitary, unlike the chromis. There is a 42.1% chance of any one Rock beauty hosting an isopod parasite in the Coral garden. French grunts live closely to squirrel fish. Some are found in large groups, 20 or more, or they can be found alone. The parasite that afflicts them is reddish in color. They have an 18.1% chance of being a host. Some species of fish are more readily found than others because of their habits and niches.

My results and calculations support well the hypothesis that certain species of fish are afflicted more than others with the parasite. The G-test shows that there is a significant difference, $p < 0.005$, in the frequencies of the parasites between the six species of fish averaged at a given site. This may be because some fish are more susceptible than others due to their morphologies or life cycles. Perhaps some are cleaned more than others and perhaps some have a natural immunity or defense mechanism against them. The coral garden sample is most likely to be the most accurate because it was sampled five times instead of three. The coral garden results were used in the Chi square analysis against all the other sites to see if there is a significant difference of frequencies between study sites. The calculation shows that there is no significant difference, in fact they are very similar. The null hypothesis is accepted: The frequency of isopod parasites on fish is independent of where they are located.

In conclusion the data and calculations support the hypothesis that there are higher frequencies of parasites on some species more than others ($p < 0.005$). The highest frequency of parasites was found to be on rock beauties, 42.1% and on the brown chromis, 41.5%. The

lowest frequency was found on the yellow tail goat fish, 0%. The second hypothesis was that isopod frequency is dependent on the site sampled. This was found to be false. The frequencies recorded at the five sites in the study were not significantly different, $p < 0.005$, than those measured in the coral gardens in Lameshur Bay, St. John, U.S.V.I.

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frequency of
fish with
parasites - %

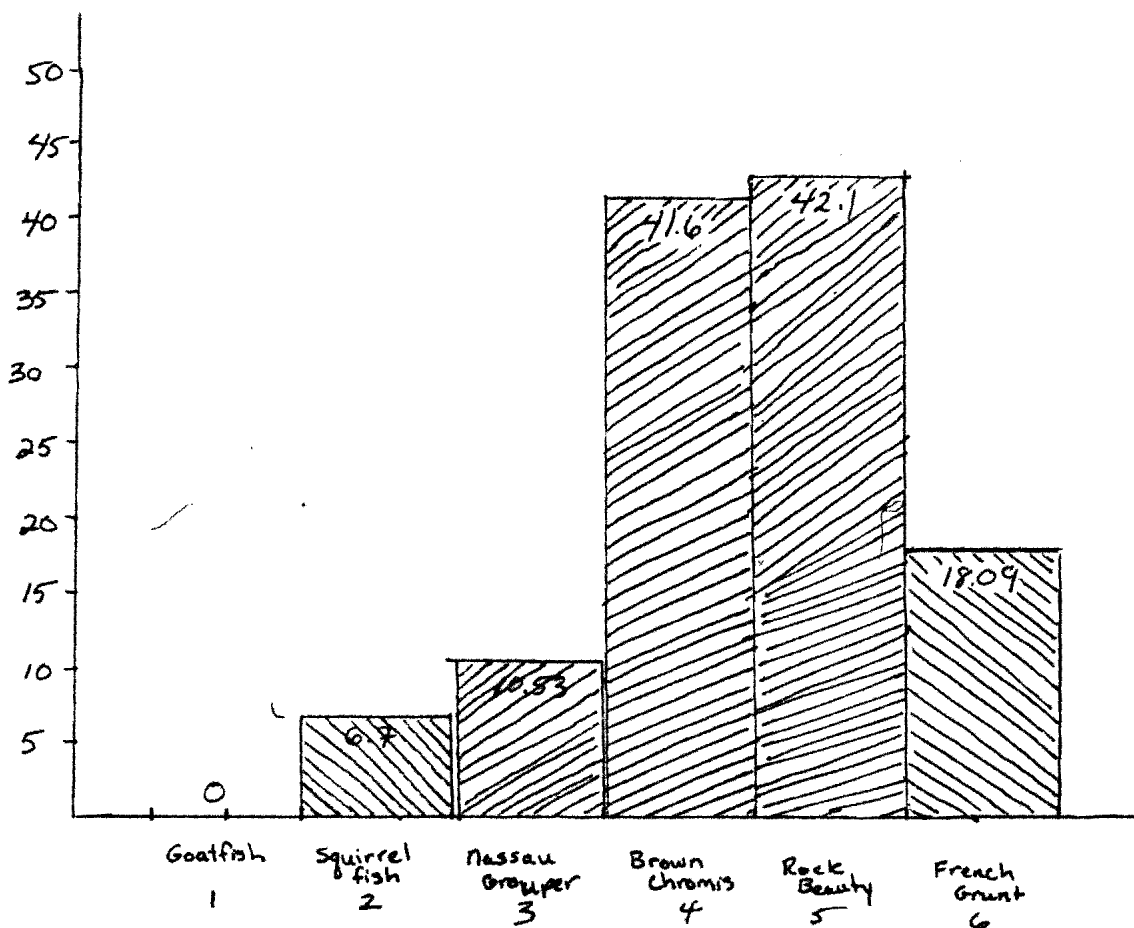


Figure 2. The comparison of the frequency of isopod parasites occurring on six species of fish in the Coral Garden

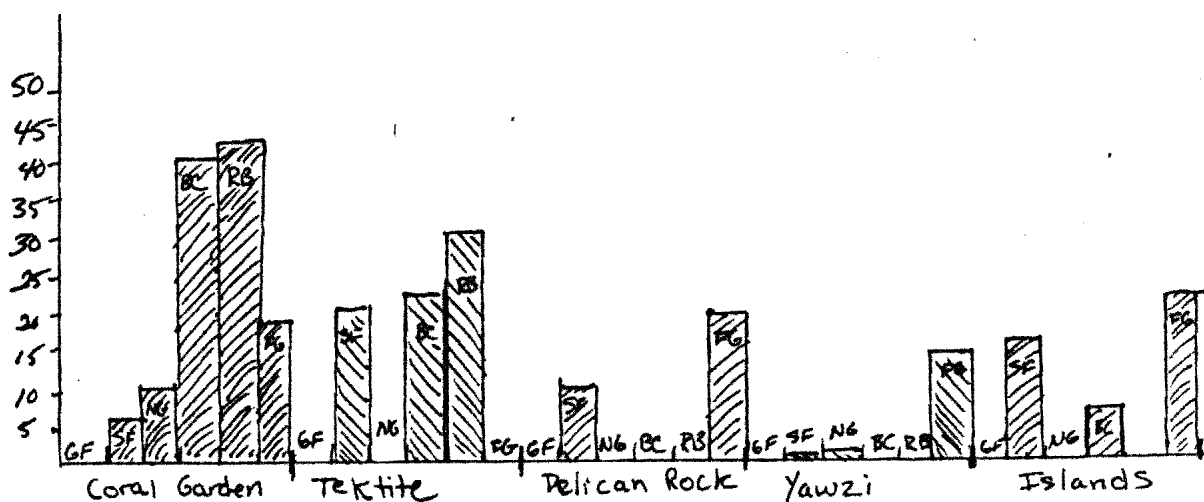


Figure 3. The comparison of the frequencies of isopod parasites of six species of fish between five sites
Key: GF - goatfish, SF - Squirrel fish, NG - Nassau grouper, BC - Brown Chromis, RB - Rock Beauty, FG - French Grunt