

# **EFFECTS OF WATER MOVEMENT AND SEDIMENTATION ON THE COMMUNITY STRUCTURE OF SCLERACTINIAN CORALS, ST. JOHN, VIRGIN ISLANDS (UNITED STATES)**

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## **INTRODUCTION**

Concern about natural diversity has risen in the public conscience 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 show that they are likely to affect diversity indices (Pianka, 1974). Predation, on the other hand, may influence diversity as it can manipulate interspecific interactions. Several solutions have been proposed to explain high species diversity. These have been grouped into equilibrium and non equilibrium hypothesis by Connell (1978), who believes that high diversity is only maintained because of frequent disturbance. Thus, disturbance, by interrupting the return of systems to equilibrium, may retard competitive exclusion and thereby promote diversity (Hubbel, 1979).

Coral reef communities have generally been described as extremely heterogeneous environments and are often compared to tropical rain forest communities (Hubbel, 1979). Industrial pollution, dumping, and dredging are known to affect these ecosystems. In nature, numerous factors, may be important in controlling coral distribution and species diversity (Huston, 1985a). The purpose of this work is, firstly, to determine species composition and diversity indices of scleractinian corals on the reefs

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of St. John, Virgin Islands, secondly to determine if physical conditions affect coral reef structure.

## MATERIAL AND METHODS

**Study area** - The island of St. John lies along the northern boundary of the Caribbean Sea at  $18^{\circ}20' N$ ,  $64^{\circ}45' W$  (Fig. 1). Fringing reef development is common along the present shoreline of St. John, where platforms typically extend 50-200 m offshore (Robinson & Feazel, 1974). The sites for the present study were Yawzi Point and Lesser Lameshur Bay, both places located at the southeast part of the island (Fig. 1) and data were collected in January-February 1989.

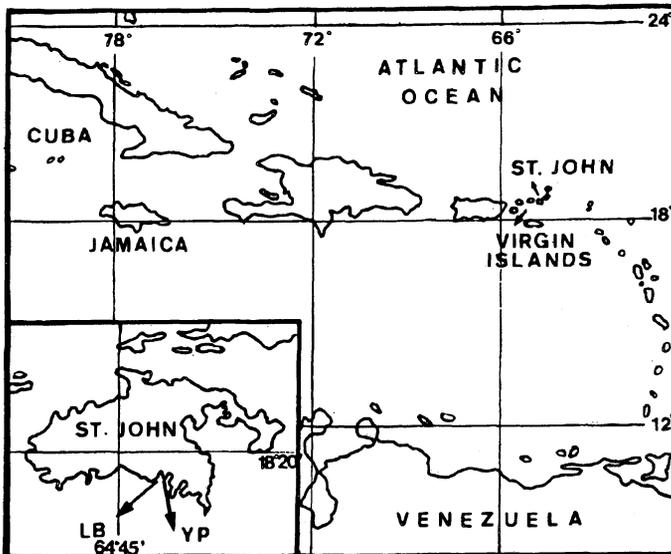


Fig. 1

Map and location of study sites. L.B.= Lameshur Bay, Y.P.= Yawzi Point

All species were identified by Dr. Peter Edmunds.

Loya's (1978) modified method, "straight line transect" was used for this study. Transects were run parallel to the shore at a depth of 4 and 6 m (four lines in each depth). Transects of 10 m length were used as it was determined that observed species diversity peaked with transect lines of approximately this length. All species were recorded and their lengths 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 as one individual (Loya, 1972).

The measurements 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). Diversity is defined as suggested by Shannon and Weaver's (1948) index of diversity:

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

where  $p_i = n_i/N_i$

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

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

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

Also Pielou's (1975) evenness index

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

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

Water movement was measured according to Doty's (1971) method. Clods used were made of plaster of Paris. Their initial weight after air drying was 24.0 g ( $\pm 0.4$ ). 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 depth at each site and left in the field for a period of 28 h before being collected. They were left to air dry for a period of 24 h before their final weight was measured.

Sedimentation was measured using sample tubes (15 mm diameter, 15 cm height) placed in test tube racks that were weighted down with lead diving weights. Six replicates were located at 5 m depth at each site for a period of 28 h. Trapped sediments were poured onto pre-weighted filter paper, dried for 24 h at 60 °C, and weighted again.

An index of relative abundance was determined by calculating the average number of colonies of each species per transect ( $n=4$ ). A subjective scale of: 0.1-1.0 = rare, 1.1-2.0 = sporadic, 2.1-4.0 = common, 4.1-7.0 = abundant, 7.1-13 = dominant; was established.

"t" tests were used to compare parameters between different sites and different depths (Sokal & Rohlf, 1981)

## RESULTS

### Coral abundance

A total number of 22 scleractinian coral species were recorded in both studied areas (Table 1). The hydrozoan *Millepora alcicornis* was also included in this analysis as it constitutes an important cementer in these particular reefs.

Other coral species found in the area but not intercepted by the transect lines because of their scarcity were: *Mycetophyllia lamarckiana* Milne Edwards & Haime, *M. ferox* Wells, *Madracis mirabilis* (Duchassaing & Michelotti), *Acropora palmata* (Lamarck), and *Mussa angulosa* (Pallas).

### Yawzi Point Reef

It was found that *Montastrea annularis*, *Montastrea cavernosa*, *Porites astreoides*, *Porites porites* and *Agaricia agaricites* constitute the most abundant species, serving probably as the main framework builders (Table 1). The hydrozoan *Millepora alicornis* was also found to be an abundant species in the area.

Excluding *Millepora alicornis*, all other species were equal in number of colonies and cover when comparing the two depths as shown in Figures 2 and 3 (t-test  $p < 0.05$   $df = 6$ ).

*Montastrea annularis* constitutes the major framework builder with a mean living cover of 13.5% and 14% at each depth (Fig. 2) with a total contribution to the living coral per transect of 23.5% and 26.2% respectively.

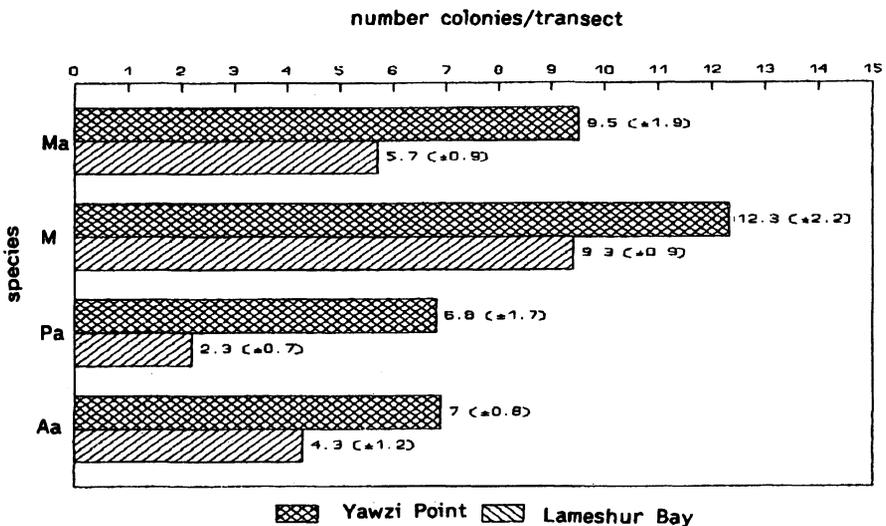


Fig. 2

Mean living coral cover per transect (n=4) of the four most common species in Yawzi Point at 4 and 6 meters. Ma = *Montastrea annularis*, M = *Millepora alicornis*, Pa = *Porites astreoides*, and Aa = *Agaricia agaricites*. Standard deviation in parenthesis. Hydrozoan

Coral diversity and abundance characteristics at both depths are shown on Table 2. After testing for the equality of variance, the four possible combinations were tested (t-tests) and the results are given in Table 3. The number of species and diversity indices were significantly different when the two depths were compared (t-test,  $p < 0.05$  and  $p < 0.01$  respectively,  $d.f.= 6$ ).

#### Lesser Lameshur Bay Reef

It was found that *Montastrea annularis* and *Agaricia agaricites* constitute the most abundant species in this site (Table 1).

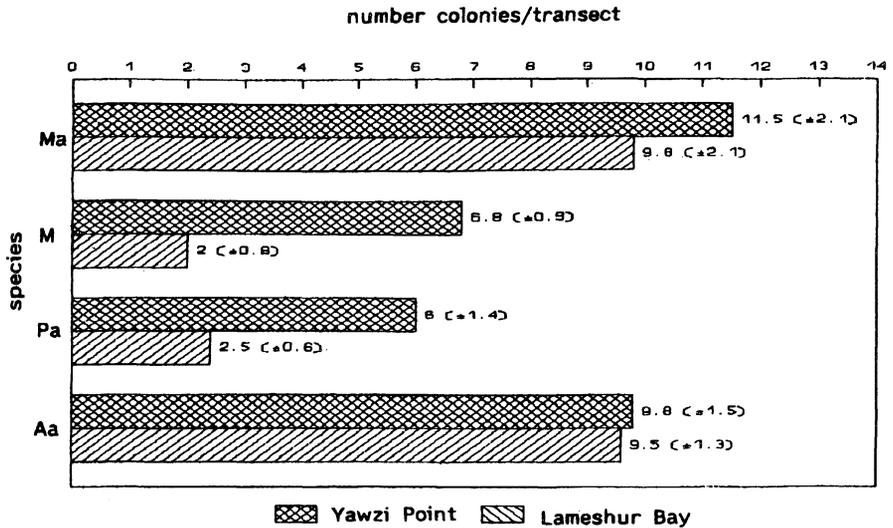


Fig. 3

Mean number of coral colonies per transect ( $n=4$ ) of the four most common species in Yawzi Point at 4 and 6 meters. Ma = *Montastraea annularis*, M = *Millepora alcicornis*, Pa = *Porites astereoides*, and Aa = *Agracia agracites*. Standard deviation in parenthesis. Hydrozoan

Again in this case, *Millepora alcicornis* was the most variable species in number of colonies and coverage (Figs. 4,5). A mean of approximately nine colonies per transect were found at 4 m while the number was only two at 6 m. Coverage by *Millepora alcicornis* was also significantly different between depths (t-test,  $p < 0.05$ , d.f. = 6). (Table 3)

*Montastrea annularis* total coverage contribution was approximately 12% at both depths. However, the number of colonies of *Montastrea annularis* were significantly different (t-test  $p < 0.05$ , d.f. = 6) at 6 m, suggesting larger colonies at 4 m. In fact, mean size of *Montastrea annularis* at 4 m was 21.47 cm ( $S = 4.01$ ) and 12.88 cm at 6 m ( $S = 1.91$ ).

Coral diversity and abundance characteristics are shown in Table 2 for both depths. The differences between the number of colonies and the diversity indices were found to be statistically significant when the two depths were compared (t-test,  $p < 0.01$ , df = 6).

#### Water movement and sedimentation

Plaster cards exposed at Yawzi Point showed a mean decrease in weight of 18.31 g ( $S = 0.4472$ ,  $n = 6$ ) while those in Lesser Lameshur Bay a mean lost weight of only

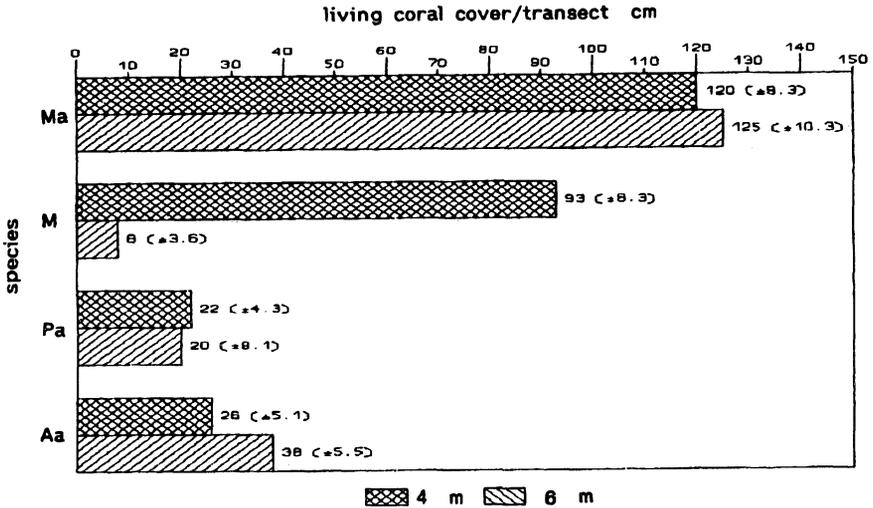


Fig. 4

Mean living coral per transect (n=4) of the four most common species in Lesser Lameshur Bay at 4 and 6 meters. Ma = *Montastraea annularis*, M = *Millepora alcicornis*, Pa = *Porites astreoides*, and Aa = *Agaricia agaricites*. Standard deviation in parenthesis. Hydrozoan

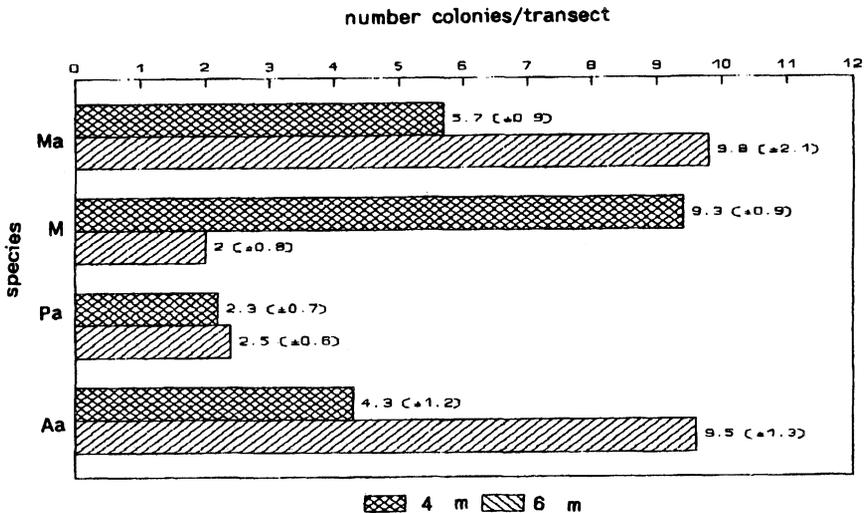


Fig. 5

Mean number of coral colonies per transect (n=4) of the four most common species in Lesser Lameshur Bay at 4 and 6 meters. Ma = *Montastraea annularis*, M = *Millepora alcicornis*, Pa = *Porites astreoides*, and Aa = *Agaricia agaricites*. Standard deviation in parenthesis. Hydrozoan

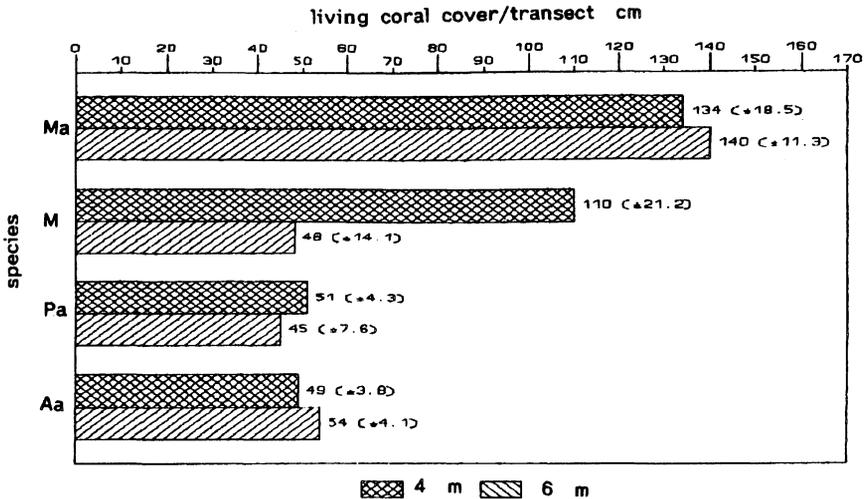


Fig. 6

Comparison between the mean number of colonies per transect of the four most common species in Yawzi Point and Lesser Lameshur Bay at 4 meters. Ma = *Montastraea annularis*, M = *Millepora alcicornis*, Pa = *Porites astreoides*, and Aa = *Agaricia agaricites*. Standard deviation in parenthesis. \* Hydrozoan

14.06 g ( $S = 0.4650$ ,  $n = 6$ ). The mean losses were statistically significant (t-test,  $p < 0.01$ ,  $d.f. = 10$ ).

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

#### Effects of water movement and sedimentation on coral reefs

Species diversity (number of species) as well as its relative abundance in Lesser Lameshur Bay were considerably lower when comparing the results with those of Yawzi Point (Table 1).

When comparing the two sites (Figs. 6,7), the number of colonies was always lower in Lesser Lameshur Bay where sediment tends to accumulate and water movement is lower.

As sedimentation was the most outstanding environmental measured feature differentiating Yawzy Point from Lesser Lameshur Bay, parameters shown in Table 2 were compared between the two sites. When comparing these parameters at their respective depths, they proved to be significantly different (t-test,  $p < 0.01$ ,  $d.f. = 6$ ), except for Pielou's index of evenness (Table 3).

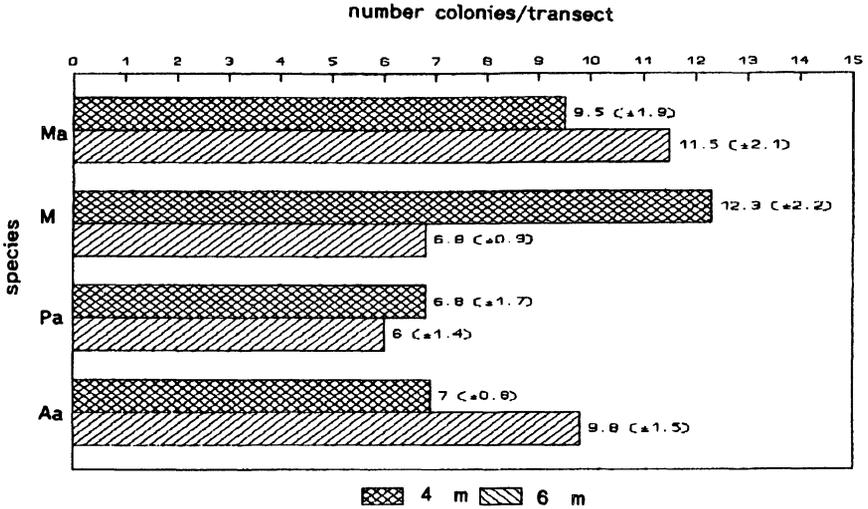


Fig. 7

Comparison between the mean number of colonies per transect of the four most common species in Yawzi Point and Lesser Lameshur Bay at 6 meters. Ma = *Montastraea annularis*, M = *Millepora alcicornis*, Pa = *Porites astreoides*, and Aa = *Agaricia agaricites*. Standard deviation in parenthesis. Hydrozoan

## DISCUSSION

No references of previous studies were encountered regarding the total number of coral species present on the island of St. John.

### Effects of depth

Community diversity is usually measured in order to determine its relationship to properties such as productivity and stability, or to assign biological characteristics to the environment (Pielou, 1975). Numerous factors 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. In spite of the heterogeneity of coral reefs, strong evidence suggests that predictable patterns of species exist along a depth gradient. Diversity (measured by species richness and/or H') is low near the surface and increases to a maximum at approximately 20 m in depth (Huston, 1985b).

According to these data, diversity increased with an increase of depth at both sites (Table 2). This increase was due either to an increase in the number of species (Yawzi Point), or in the number of colonies (Lesser Lameshur Bay). It is important to note however, that these variations were not as acute as those observed when compai-

ring the two sites. This may be due to the fact that a two meter difference in depth may not be sufficient to detect greater contrasts.

Although some differences can be detected from Table 1 regarding coral depth preferences, a further study would be necessary in order to reveal any significant depth correlation for scleractinians growing in these areas. A remarkable contrast however, is distinguished for the hydrozoan *Millepora alcicornis*. At both sites, an increase in depth resulted in a decrease of living cover and number of colonies (Figs. 1,2,3,4). This pattern may be explained by the fact that *Millepora alcicornis*, adapted to high disturbance areas in shallow water, is able to overgrow other species in this environment becoming thus abundant. An increase in depth allows for other species to compete and establish themselves.

Other results may also be related to the influence of depth. The variation of diversity index and number of species in Yawzi Point when comparing the two depths proved to be statistically significant (Table 3). This suggests that the high living coverage in Yawzi Point at 4 m, is due to cover dominance by fewer species, while more species contribute to the high living coverage found at Yawzi Point at 6 m (Tables 2 and 3). On the other hand, it was the number of colonies and the diversity index that were different in Lesser Lameshur Bay. These results proved to be statistically significant when comparing both depths (Table 3). This would imply that the living cover observed in Lesser Lameshur Bay at 6 m is due to different number of colonies, whereas at 4 m, this is due to a larger size of colonies.

A relationship between *Millepora alcicornis* and *Agaricia agaricites* was found at Lesser Lameshur Bay. *Agaricia agaricites*' number of colonies and percentage of cover, inversely correlate those of *Millepora alcicornis*. This suggests a competition between them. Further evidence supporting this idea is the fact that *Millepora alcicornis* is able to use *Agaricia agaricites* as substrate, covering and overgrowing it. This is detected by the texture adopted by *Millepora alcicornis* when growing over *Agaricia agaricites*.

*Montastrea annularis* proved to be the major framework builder at both sites. It did not show any preferences for the different depths at either site. However, it was observed that less colonies contributed to the same living coverage at Lesser Lameshur Bay.

## Sedimentation and water movement

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, 1985b).

It has long been suggested that wave energy and reef geometry were the main controls of sedimentation on a reef (Black *et al.*, 1990). 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 least growth takes place on level sites where sediments tend to gather (Goreau & Wells, 1967). Black *et al.* (1990) determined a direct correlation of stream currents, reef dimensions, tidal excursion and shelf depth on the amount of suspended material near reefs. Brown *et al.* (1990) found a reduction of as much of 30 % in living coral after nine months of dredging at Ko Phuket, Thailand. The results found here agree with those of the above mentioned authors. It is thus proposed that sedimentation and water movement were two of the factors affecting diversity and community structure of studied communities.

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

*Montastrea annularis* colonies were more abundant at Lesser Lameshur Bay at 6 m. However, their size was significantly smaller than those found in the same place at 4 m. This may be explained by the fact that sedimentation is generally greater in deeper water causing partial mortality and 'splitting' larger colonies into more and smaller ones.

Many factors affect the distribution and abundance of scleractinian corals in tropical waters. This study corroborates previous ideas on how sedimentation, location, and water movement are related to the community structure of coral reefs. Further studies in this area should focus on biotic interactions such as predation by corallivores and competition among corals. The hypothesis of intermediate disturbance foresees a higher diversity in natural communities. There are many other elements, human and natural, that are capable of provoking disturbances. Future research should focus in the application of these elements in managing these ecosystems and maintaining coral reef diversity.

## ACKNOWLEDGEMENTS

I would like to thank P. Edmunds for identifying the species of this study, his suggestions during the collection of data, as well as for his valuable criticism of earlier drafts. I would also like to thank Dr. L. Bernardello and two anonymous reviewers for their valuable revision and correction of the manuscript. Finally, I would like to express my gratitude to Northeastern University, School for Field Studies, Boston, Massachusetts, for a fellowship to conduct the present study.

## ABSTRACT

The community structure of corals of Yawzi Point and Lesser Lameshur Bay, St. John, U.S.V.I. was defined in terms of species, number of colonies, percentage of living cover, Shannon and Weaver's diversity index, and Pielou's index of evenness. Transects of 10 meters long were used in the present study. They were located at four and six meters depth at both sites. Yawzi Point proved to have lower sedimentation rates (6.4 mg/cm<sup>2</sup>/day) and greater water movement. This site showed a 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). Lesser Lameshur Bay has higher sedimentation rates ( $9.6 \text{ mg/cm}^2/\text{day}$ ) 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 the structure of studied communities. A total number of 22 scleractinian species were found in the area; the four most common species were *Montastrea annularis*, *Porites astreoides* and *Agaricia agaricites*, as well as the hydrozoan *Millepora alicornis*.

*Key words:* Scleractinia, diversity, sedimentation, U.S. Virgin Islands, Caribbean Coral Reefs.

## RESUMO

A estrutura da comunidade de corais escleractíneos foi estudada em dois sítios da Ilha St. John (Ilhas Virgens Americanas). A estrutura foi definida em termos de espécies, número de colônias, percentagem de cobertura viva, índice de diversidade específica de Shannon & Weaver e índice de uniformidade de Pielou. Para o presente estudo foram usados "transects" de 10 m de comprimento situados a quatro e seis m de profundidade. Yawzi Point que apresentou menor taxa de sedimentação ( $6.4 \text{ mg/cm}^2/\text{day}$ ) e grande movimento da água, mostrou um maior número de espécies, colônias, percentagem de cobertura viva e índice de diversidade (% de cobertura = 53 e 57%, e  $H'_n = 2.156$  e  $2.253$  para as duas profundidades, respectivamente). Lesser Lameshur Bay, que possuía maior taxa de sedimentação ( $9.6 \text{ mg/cm}^2/\text{day}$ ) e menos movimento da água, apresentou uma menor abundância de espécies, colônias, percentagem de cobertura e índice de diversidade (% de cobertura = 31.8 e 31.4%,  $H'_n = 1.670$  e  $1.732$  para ambas as profundidades respectivamente). É sugerido que o movimento de água e a sedimentação influenciam a estrutura das comunidades estudadas. Um total de 22 espécies de escleractíneos foi achado. As mais comuns foram *Montastrea annularis*, *Porites astreoides* e *Agaricia agaricites*, além do hidrozoário *Millepora alicornis*.

Palavras-chave: Escleractíneos, Diversidade, Sedimentação, Ilhas Virgens Americanas, Recifes de Coral do Caribe.

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Table 1. Relative abundance\* of hermatypic coral off Lameshur Bay. St. John, U.S.V.I. I.

| Species code | species   | Point 4 m | Yawzy 6 m | Lesser 4 m | Lameshur Bay 6 m |
|--------------|---|-----------|-----------|------------|------------------|
| M            | <i>Millepora alaicornis</i> Linnaeus {Hydrozoan}  | dominant  | abundant  | dominant   | sporadic         |
| Ac           | <i>Acropora cervicornis</i> (Lamarck)             | sporadic  | rare      | ---        | ---              |
| Aa           | <i>Agaricia agaricites</i> Linnaeus               | abundant  | dominant  | abundant   | dominant         |
| Ss           | <i>Siderastrea siderea</i> (Ellis & Solander)     | common    | common    | sporadic   | common           |
| Sr           | <i>Siderastrea radians</i> (Pallas)               | ---       | rare      | ---        | rare             |
| Pp           | <i>Porites porites</i> (Pallas)                   | common    | common    | sporadic   | sporadic         |
| Pa           | <i>Porites astreoides</i> Lamarck                 | abundant  | abundant  | common     | common           |
| Md           | <i>Madracis decactis</i> (Lyman)                  | ---       | rare      | ---        | ---              |
| Dc           | <i>Diploria clivosa</i> (Ellis & Solander)        | rare      | rare      | ---        | ---              |
| Dl           | <i>Diploria labyrinthiformis</i> (Linnaeus)       | sporadic  | common    | rare       | rare             |
| Cn           | <i>Colpophyllia natans</i> (Houttuyn)             | rare      | sporadic  | ---        | ---              |
| Mm           | <i>Meandrina meandrites</i> (Linnaeus)            | rare      | sporadic  | ---        | rare             |
| Ma           | <i>Montastraea annularis</i> (Ellis & Solander)   | dominant  | dominant  | abundant   | dominant         |
| Mc           | <i>Montastraea cavernosa</i> (Linnaeus)           | common    | common    | ---        | rare             |
| Ds           | <i>Dichocoenia stokesii</i> Milne Edwards & Haime | rare      | rare      | ---        | ---              |
| Ef           | <i>Eusmilia fastigiata</i> (Pallas)               | ---       | rare      | rare       | ---              |
| Ff           | <i>Favia fragum</i> (Esper)                       | sporadic  | rare      | ---        | ---              |
| DC           | <i>Dendrogyra cylindrus</i> Ehrenberg             | 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; 4.1-7.0 = Abundant; 7.1-13.0 = Dominant; --- = 0.

**Table 2. Average values of various statistics calculated for Yawzi Point and Lesser Lameshur Bay (standard deviations in parentheses)**

| Location                  | Depth<br>(in m) | No.<br>transects | No.<br>species  | No.<br>colonies | Cover<br>%      | H' <sub>n</sub><br>index | H' <sub>c</sub> /H' <sub>max</sub> |
|---------------------------|-----------------|------------------|-----------------|-----------------|-----------------|--------------------------|------------------------------------|
| YAWZY<br>POINT            | 4               | 4                | 11.75<br>(0.05) | 52<br>(3.36)    | 57.02<br>(1.96) | 2.156<br>(0.018)         | 0.877<br>(0.008)                   |
|                           | 6               | 4                | 13.25<br>(0.95) | 53.32<br>(2.64) | 53.32<br>(1.68) | 2.253<br>(0.030)         | 0.881<br>(0.020)                   |
| LESSER<br>LAMESHUR<br>BAY | 4               | 4                | 7<br>(0)        | 26<br>(1.82)    | 31.82<br>(0.75) | 1.670<br>(0.022)         | 0.816<br>(0.170)                   |
|                           | 6               | 4                | 8<br>(0)        | 31.5<br>(2.64)  | 31.47<br>(1.77) | 1.732<br>(0.009)         | 0.816<br>(0.014)                   |

**Table 3. T-test conducted on the average values of Table 2 between the four possible combinations of the 2 sites at two different depths. (YP = Yawzi Point, LL = Lesser Lameshur Bay, 4 = 4 m, 6 = 6 m).**

| Average<br>values<br>tested | No.<br>species | No.<br>colonies | Cover<br>(cm) | H' <sub>n</sub><br>index | H' <sub>c</sub> /H' <sub>max</sub> |
|-----------------------------|----------------|-----------------|---------------|--------------------------|------------------------------------|
| YP4 vs. YP6                 | *              | N.S.            | N.S.          | **                       | N.S.                               |
| LL4 vs. LL6                 | N.S.           | **              | N.S.          | **                       | N.S.                               |
| YP4 vs. LL4                 | **             | **              | **            | **                       | N.S.                               |
| YP6 vs. LL6                 | **             | **              | **            | **                       | N.S.                               |

\* p &lt; 0.05; \*\* p &lt; 0.01; N.S. p &gt; 0.05; df = 6