Morphology and Taphonomy of *Neogoniolithon* on San Salvador Island, Bahamas

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Neogoniolithon, a branching, red calcareous alga, is prevalent in the shallow, clear waters surrounding San Salvador and in the fossil record on the island. Calcareous algae are common throughout the Caribbean, past and present. Previous studies have suggested a correlation between the morphology of *Neogoniolithon* and the energy of the environment (Bosence, 1983). Where wave action is high, coralline algal heads tend to be densely packed with short, stubby, and relatively thick branches; in calm environments, the branches are longer, thinner, and more fragile. I concentrated on three locations with environmental energies ranging from the high energy of East Beach through the intermediate energy of Bonefish Bay to the sheltered low wave action of the Pigeon Creek area. I also studied a *Neogoniolithon*-capped fossil patch reef at Grotto Beach. To define the relationship between environmental energy and morphology, I first attempted to find quantifiable features of the branching algae reflecting local environmental factors. I measured three characteristics: the distance between bifurcations along individual branches, the diameter of the branches, and the angle of bifurcation. If these characteristics show a correlation with environmental energy and can be measured in the rock record, these data could be used to estimate the energy intensity of paleoenvironments containing coralline algae. Second, I studied the taphonomy of *Neogoniolithon* and also how it is represented in the sediment. To date, I have tumbled three algae heads to document their breakdown rate and have also studied sediment composition of the three modern sites.

Methods

Live *Neogoniolithon* heads were collected along transects at each of my three study locations on San Salvador Island: East Beach, Bonefish Bay, and Pigeon Creek. All organic matter was removed by submerging the head in a dilute mixture of household bleach. Some fossil *Neogoniolithon* heads at Grotto Beach were also analyzed. I collected sediment samples around the base of the patch reefs studied at East Beach and along the transects at the other two sites.

Measurements

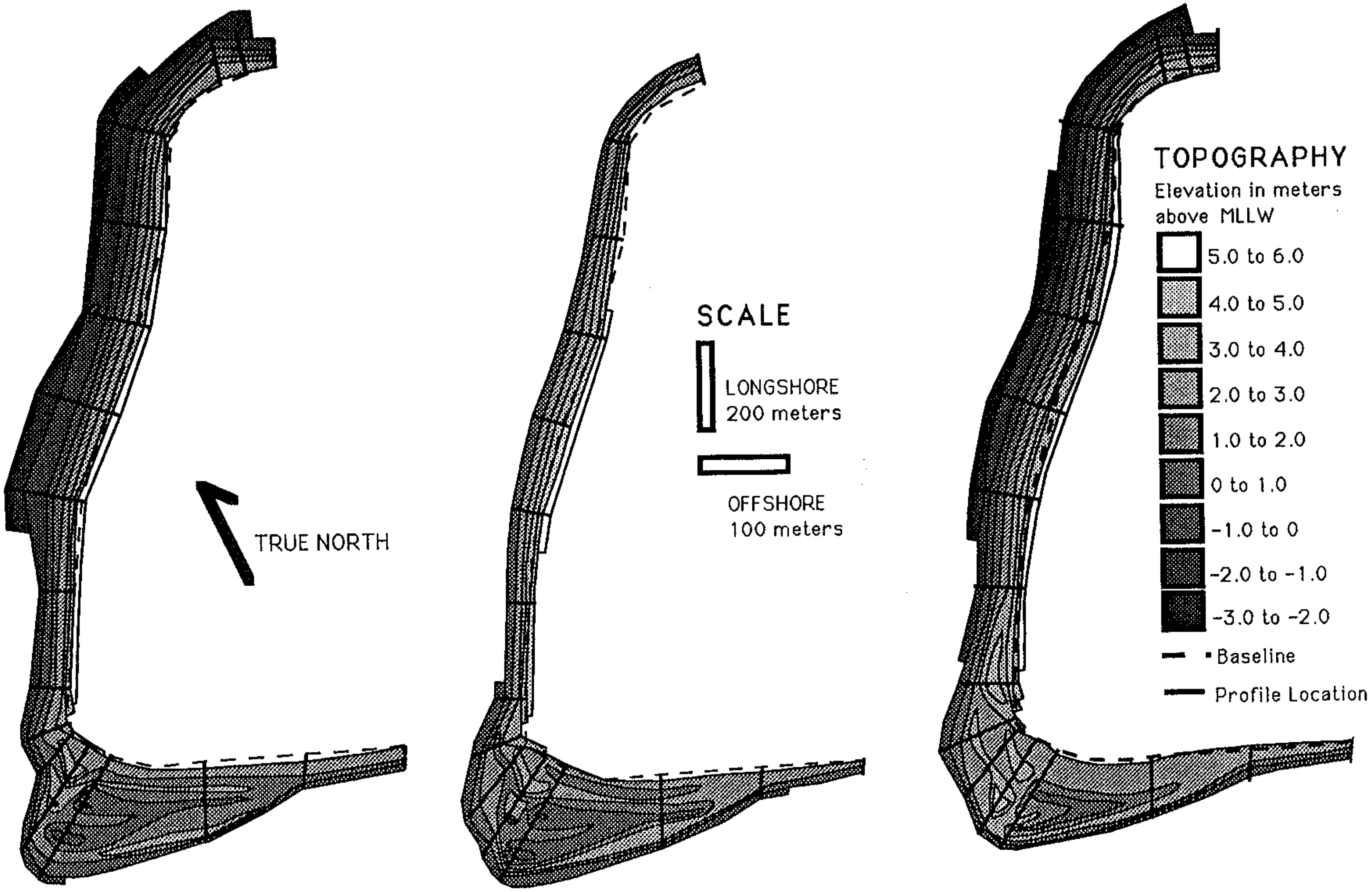
Three different types of measurements were taken using a caliper and a protractor to see if they reflected the environmental conditions of the area. 1) The distances between bifurcations of the branches were measured, 100/head (Figure 1). Branches from the outer third of the algal head were used because the inner portions were much harder to reach and more complex, with one branch merging into another. 2) The angles of bifurcation were measured (100/head), also on the outer third of the head (Figure 2). 3) Diameters were also measured and, due to the distinct difference in appearance between branch diameters of the outer rim and innermost core, I measured them separately (Figure 3). Only 75 measurements were taken of the outer branches; the deviation from the mean is significantly less than that for either the angles or distances. 30 measurements were about the maximum number that could be taken per head for the inner core branches. I calculated the average and standard deviations of the characteristics measured for each head and then overall averages for each location.

Tumbling

To investigate how the heads of *Neogoniolithon* broke down relative to one another and therefore relative to their differing energy regimes, the heads were tumbled. The methods I employed in my tumbling analysis were similar to those of Chave (1964). *Neogoniolithon* heads were tumbled at 30 revolutions per minute in a 4.5 liter, rubber-lined, hexagonal shaped tumbler with distilled water adjusted to the pH of sea water (about 8.0) using "Instant Ocean." The initial mass of each head was determined; after tumbling, the broken-off pieces were dried, sieved, and weighed. The mass of the broken-off pieces was subtracted from the original head mass and the results graphed with respect to total tumbling time (Figure 4). The sieve results at 17 hours for the three sites are shown in Figure 5.

Sediment

The carbonate sediment samples collected at the three study areas were split and made into "rocks" using an epoxy. They were then cut into thin sections for determination of *Neogoniolithon* fragment percentages and other general components.



Figures 3a, 3b, and 3c. Topographic maps for Sandy Point Beach for the beginning of June 1992, June 23, 1992, and January 1993. Contour interval 1 meter.

Observations and Results

Environment

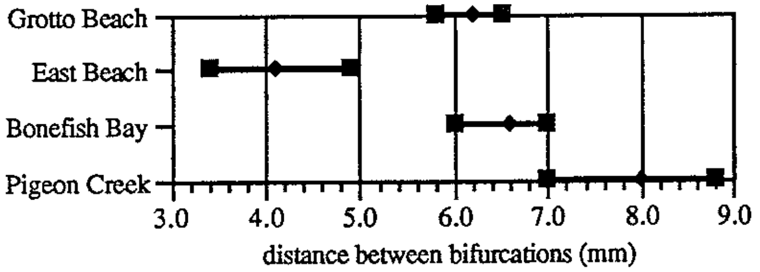
The three study sites have widely varying environmental energies, mainly due to their location around the island. The East Beach site is located on the east side of the island with only a barrier reef (500 m offshore) separating it from the Atlantic. This location gets the brunt of the summer trade winds and the counter clockwise hurricane winds moving toward the northwest in the fall. *Neogoniolithon* is common on near-shore patch reefs (about 45-70 m from the high-tide line) in 2-3 m of water. The heads on the highest parts of these reefs are exposed during low tides. Initial analysis of thin sections of "epoxy rocks" reveals that the very fine-grained sediment surrounding the patch reefs is notably lacking in recognizable fragments of *Neogoniolithon*.

The morphology of Bonefish Bay differs considerably and lacks the near-shore patch reefs found at East Beach. The bay faces the west, is about 2 km wide, and has a broad shelf area. The site is relatively calm because wave action is usually low; with the onset of westerly winds, however, Bonefish Bay can become quite choppy. The most severe storm effects occur as winter storm fronts bear down from the northwest. The shallow environment near the shoreline is dominated by a ridge that is about 25-40 m from shore and parallel to the beach. Closer to shore, the bottom is mainly carbonate, coarse to fine-grained sand; beyond the ridge, the hardground continues, but has the appearance of being karsted. *Neogoniolithon* is common on the ridge and farther out on the hardground to about 85 m from the high-tide mark. The concentration of calcareous algae occurs on the ridge where the waves break at low-tide. The aerial coverage decreases away from the ridge. Individual algal heads may occur in large coalescing masses, in some cases covering up to almost 2 m^2, but are more common as individual heads about 7-12 cm in diameter. The sediment samples reveal very few *Neogoniolithon* fragments.

Pigeon Creek, on the southeastern end of the island, is the most protected of all the areas. The site lies to the west of the Pigeon Creek ebb-tide delta, in a wide, shallow bay that is partially sheltered oceanward by two cays. The algae occur mainly in patches of *Thallasia* grass in the near-shore, shallow water; many heads are exposed during low tide. The heads in this location tend to lack a distinct, solid core holding the head together. I found it very difficult to collect specimens that, once pulled from their hold on the underlying hard surface, would remain as a coherent head. Preliminary thin-section data show that some fragments of the algae in the medium to granule-sized sediment.

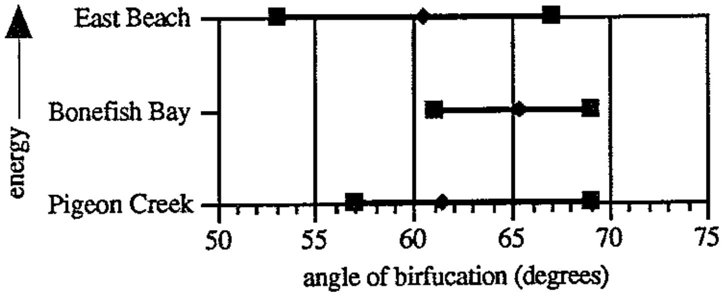
Measurement Results

The results of the measurements taken on the heads are summarized in Figures 1-3. Figure 1 includes the measurements on modern *Neogoniolithon* and fossil remains of the alga at Grotto Beach.



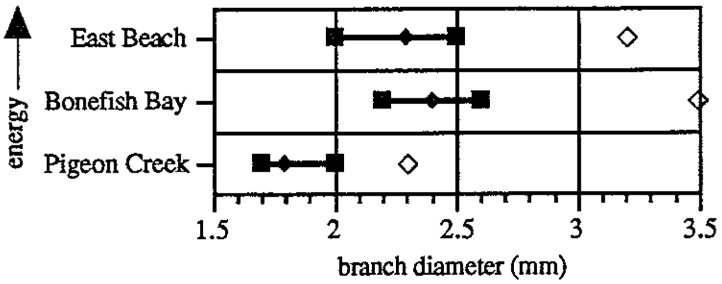
	# heads measured	Avg. length (mm)	Standard deviation
GB	3	6.2	2.5
EB	4	4.1	2.1
BB	6	6.6	3.2
PC	5	8.0	4.2

Figure 1. Distances between bifurcations of *Neogoniolithon* branches at the three modern sites (100 measurements/head) and the fossil site at Grotto Beach (75/head). Squares indicate range and diamonds indicate averages.



	# of heads measured	average angles (degrees)	standard deviation
EB	4	60.5	12.7
BB	5	65.4	10.4
PC	5	61.4	12.5

Figure 2. Summary of angle measurements (100/head), indicating range (squares) and average (diamonds).



	# of heads measured	outer diameter (mm)	core diameter (mm)
EB	3	2.3	3.2
BB	3	2.4	3.5
PC	3	1.8	2.3

Figure 3. Graph showing range (squares) and average (diamonds) of the outer-branch diameter. The open diamond indicates average inner-core diameter. 75 measurements were taken per head (outer diameter).

Tumbling Results

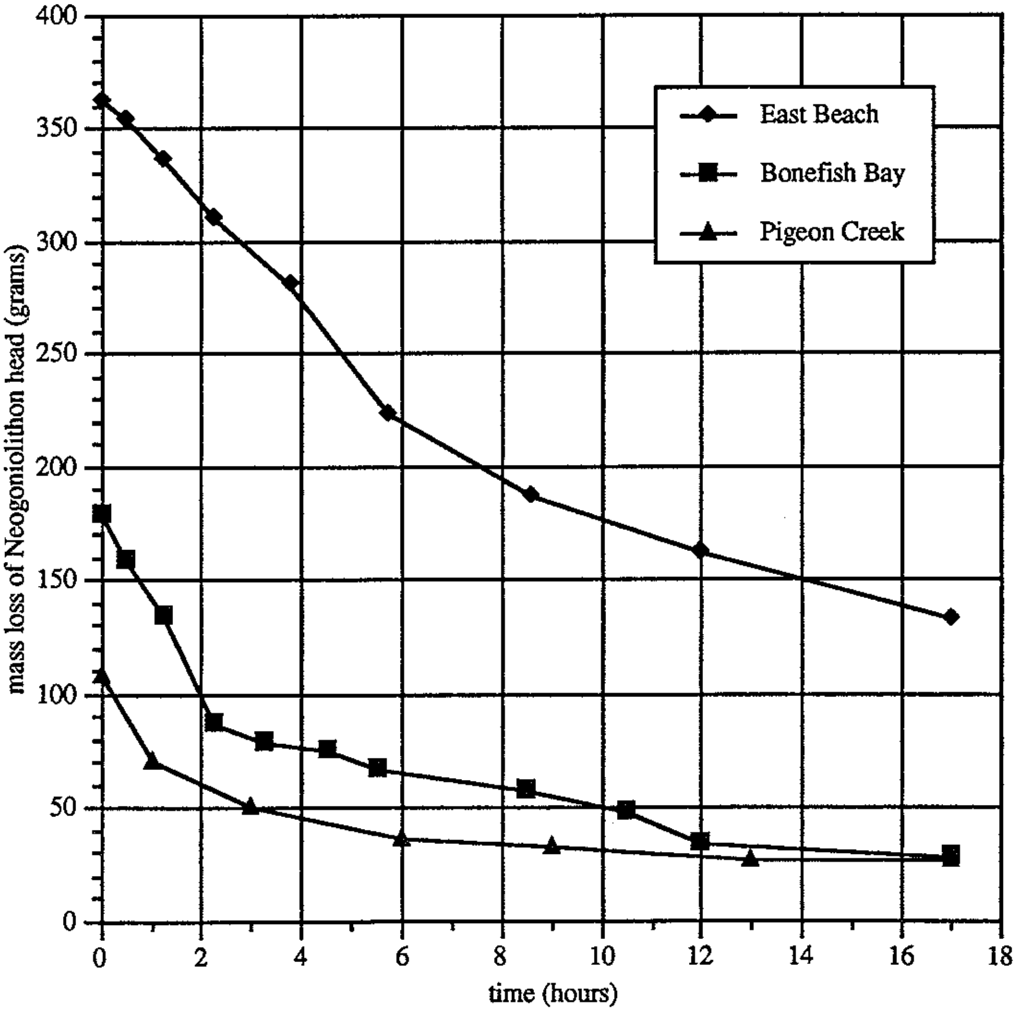


Figure 4. Initial results of the tumbling runs of one head from each of the three modern sites. Loss of dry mass from the tumbled *Neogoniolithon* heads is graphed with respect to time.

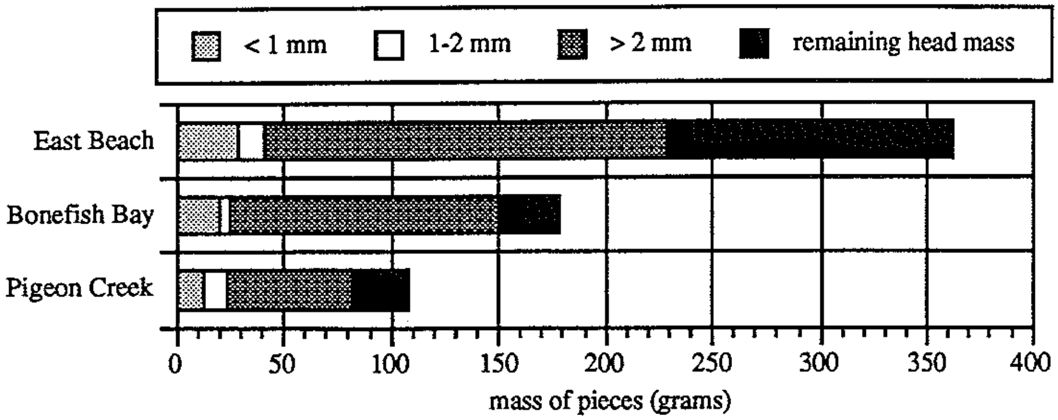


Figure 5. Sieve results, at 17 hours, for the heads shown in Figure 4. The length of the bar indicates the starting mass of the *Neogoniolithon* head; the black portion is the final head mass. The three other patterns represent various sieve sizes.

Discussion

It is evident from the graphs of branch diameter, angle of bifurcation, and distance between bifurcations that not all these factors are directly affected by the energy of the environment. Distance between bifurcations seems to be the most sensitive indicator of those I measured. *Neogoniolithon* heads at Pigeon Creek, the lowest energy area, exhibited the greatest length between bifurcations; East Beach had the shortest, corresponding to the highest energy, and Bonefish Bay fell in between the two. These results suggest that branch length is inversely proportional to environmental energy. The results from the distance measurements taken at Grotto Beach fall nicely into the moderate environmental energy of the Bonefish Bay range. This contradicts a previous study by Hattin and Warren (1989), who compared the Grotto site to the modern environment of East Beach. While it appears to be true that Grotto was a patch reef capped by *Neogoniolithon*, similar to the situation at East Beach, I believe that energy of this Pleistocene environment was measurably lower.

The branch diameter also seems to be a function of the energy of the environment, but not as directly. Pigeon Creek has the smallest diameter, but the average diameters of Bonefish Bay and East Beach are almost equal. So, diameter is relatively proportional to energy. The bifurcation angle measurements indicate that the overall average variation in all three environments is about the same, and that Pigeon Creek and East Beach have the lowest total averages. A possible reason for this at Pigeon Creek is that the algae have to compete with *Thallasia* grass in most places, and if the algae didn't branch at relatively low angles, the height of the head would not be great enough to receive sunlight in the grass. A possible reason for the lower angle at East Beach is that with the shorter and thicker branches, there just isn't room to branch at a higher angle.

Preliminary taphonomy results are shown in Figure 4. The Pigeon Creek and Bonefish Bay specimens exhibit a rapid weight loss for the first two to three hours of tumbling; from that point on, the loss levels off. The decline for the East Beach specimen, on the other hand, is less rapid and levels off somewhat at about seven hours, but not as abruptly or as much the other two heads. Please note was that the Pigeon Creek that was tumbled was the only one that remained as a coherent head after being shipped from the Bahamas to Beloit; therefore this head is probably not a good representative specimen of this environment. The stacked bars of Figure 5 show that generally, with increasing head mass, the mass in each size range increases. The exception of the 1-2 mm range for Pigeon Creek is a result of the smaller diameter of this specimen.

In conclusion, the measurements of the distance between bifurcations are inversely proportional to environmental energy. Branch diameter is relatively proportional to energy. These two characteristics offer a fairly accurate way to judge relative environmental energy at the sites on the coast of San Salvador Island.

References

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TAPHOFACIES ANALYSIS OF MODERN MOLLUSCAN FACIES: BONEFISH BAY & SNOW BAY, SAN SALVADOR ISLAND BAHAMAS

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INTRODUCTION

Recent taphonomic research has suggested that the physical, chemical and biological processes affecting sub-fossil skeletal material post-mortem are unique to particular environments. Taphofacies analyses were heralded as being useful tools because they operate independently of the phylogenetic affinity of the material under examination (Parsons and Brett, 1991). Therefore, taphonomic indicators of environment cross taxonomic boundaries and as a result may be more helpful in reconstructing paleoenvironments (Parsons, 1991). A variety of modern settings have been examined to be applied to the ancient: carbonate reef systems (Parsons, 1991), salt marshes and tidal flats (Meldahl and Flessa, 1990) and inner shelf facies (Staff and Powell, 1990). These studies do indicate that one can differentiate between bottom types using taphonomic indicators. However, only one of these studies (Staff and Powell, 1990) sampled from several sites within an environment. Their results suggested that "some taphonomic characteristics are as variable within the habitat as they were between habitats" (ibid., 1990). The variability of taphonomic indicators within a substrate was dismissed as the result of small changes in environmental factors (i.e. depth, sediment grain size and storm processes).

The impact of taphonomic variability within subenvironments may be assessed by a large data set and sampling of multiple sites within each substrate. Taphonomic indicators that have been found to be useful in previous studies have been applied here: abrasion, breakage, dissolution, percent coverage by encrusters and bioeroders, live-dead ratios, ligament remains, articulation ratios and presence of snail borings (Parsons and Brett, 1991). The methods used to analyze the taphonomic variables followed that of Davies *et al.* (1990), when possible, in order to render the results comparable to other studies. Environmental indicators, such as water depth, seagrass coverage and grain size were collected to define the environment. Results reveal that the delineation of taphofacies amongst a wide range of environments and within a substrate, may not be as straightforward as previous studies have indicated. This study concentrates on molluscs from patch reefs, grass and sand beds environments from the tropical western Atlantic island of San Salvador, Bahamas. A companion study was carried out by Swift in Pigeon Creek, San Salvador Island (see this volume). Further exploration of the data set is currently underway.

FIELD AREA AND METHODS

Bonefish Bay, located along the northwest, leeward margin of San Salvador island, is a high-energy lagoonal environment (see Curran, this volume). Its concavity creates a 1.5 km^2 area. A variety of environments comprise Bonefish: patch reefs, grass beds, rocky hard substrate areas and sandy areas with and without *Callianiassa* shrimp mounds. Snow Bay is another high energy lagoon. Rimmed by barrier reefs and cays, Snow Bay occupies a 2 km^2 area on the southeast, windward side of the island. The environments of the lagoon are dominated by a *Thalassia* meadow fringed by sands.

During June 1992, one transect was constructed in each bay. In Bonefish Bay, samples were collected along a 550 m transect, at 50 m intervals. A 600 m transect at Snow Bay was completed between Sandy Hook and High Cay, with 100 meter intervals between each sample site. All samples were collected with a shovel or an airlift powered by a SCUBA tank. Samples were collected in a 5 mm mesh bag; sieving was done in the field. Larger debris (sea grass, coral, rubble etc.) was removed from the samples onshore. The remaining mollusc specimens were then rinsed and stored in 5% formaldehyde solution.

At each site, a 10 x 10 cm quadrat was dropped randomly onto the substrate five times. The occurrence and number of blades of three seagrass species (*Thalassia testudinum*, *Syringodium filiforme* and *Haladoule wrightii*) in each quadrat were recorded. Miller's (1988) equation for the seagrass coverage coefficient was used:

$$V = 0.25(T) + 0.7(S) + 0.02(H)$$

and the five collected values averaged. In the equation T, S and H are *Thalassia*, *Syringodium* and *Haladoule*, respectively. Also records of water depth and sediment samples of the site were collected to be used as environmental indicators.