THE RESPONSE OF CORALLINE ALGAE TO HERBIVORY AND ENERGY OF THE ENVIRONMENT

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Coralline algae (Family Corallinaceae) are red calcareous algae that encase their cells in calcium carbonate. Because coralline algae calcify their cells, they have a relatively small surface area exposed to the environment for gathering light and exchanging gasses. The resulting decrease in photosynthesis causes coralline algae to grow slower than soft, fleshy algae, which are completely exposed to the environment. The difference in growth rates leads to fouling of coralline algae by soft algae. Because coralline algae have no means of remaining free of highly productive epiphytic soft algae, external mechanisms are required for the cleaning process (Steneck, 1986). The two main environmental mechanisms that prohibit soft algae from fouling coralline algae are herbivory and energy of the environment, i.e. wave action.

Intensity of herbivory and energy in the environment also help shape the morphology of coralline algae (Minnery, 1990). Thickly, more densely branched crusts dominate the intertidal or shallow subtidal zones where wave action and herbivory are moderate. In areas that experience higher energy and/or herbivory, thick crusts predominate. Finely branched or thin, delicate crusts typically are found in areas of low energy and minimal herbivory.

The morphology of coralline algae is very plastic, and each species may occur in many different forms (Steneck and Adey, 1976). These forms are controlled by the particular conditions of the environment in which the algae are living. These ecological characteristics of coralline algae, and their extreme preservability due to calcification, render them valuable in ecological and paleoecological analysis of shallow-marine environments. By studying the morphology, taxonomy, and spatial arrangement of coralline algae present under various modern conditions it is possible to make some interpretations about past environments by examining coralline algae preserved in the rock record.

During June, 1990, I studied three areas on San Salvador Island, Bahamas: Hanna Bay (off East Beach), Bonefish Bay, and the area just outside the mouth of Pigeon Creek. These areas represent widely differing environmental settings in terms of energy and herbivory.

Methods

I compared the coralline algae present in these environments in a number of ways that enabled me to make observations about the response of coralline algae to conditions of the environment. By mapping algal distribution, measuring energy, observing herbivory, and taking depth measurements of all three areas, I was able to document and compare the distribution of coralline algae in diverse environments. Samples were taken from each location, and from various sub-environments at each location, allowing me to compare dissimilar morphologies and taxonomies present in areas with differing environmental conditions.

I conducted experiments to test the response of coralline algae to a change in environmental conditions. I relocated heads of coralline algae to observe the success of morphologies in an environment different from the one in which they were growing. I isolated one patch of coralline algae at each site with wire cages to observe the effects of reduced grazing by herbivores.

Results and Observations

Branching heads of coralline algae dominated all three study sites. The density of branching and thickness of branches varied between locations. Crusts of coralline algae were present at each site, and finely branching forms grew at Pigeon Creek and in sheltered locations at East Beach.

	EAST BEACH	BONEFISH BAY	PIGEON CREEK
Relative Energy	High	Moderate	Low
Rel. Herbivory	Moderate	Moderate	High
Herbivore Type	Fish	Hermit Crabs	Fish
Branching Density	High	Low	Low
Ave. Branch Diameter	2.6 mm	2.0 mm	1.5 mm

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The head of coralline algae relocated from Bonefish Bay to Snapshot Reef on 8 June appeared unaltered on 28 June. The head moved from the reef crest to the reef bottom at East Beach collected sediment, and the heads relocated at Pigeon Creek were absent at the time of retrieval.

Bonefish Bay

Waves generally broke approximately 60 m from the baseline, where coralline algae grew with the highest frequency (Figure 1). None of the branching algae was exposed at low tide; a small portion of the coralline algal crusts are exposed at low tide. The main species of coralline algae occurring at Bonefish Bay is *Neogoniolithon strictum.*

I observed abundant numbers of hermit crabs living in heads of coralline algae and I conclude that they are the primary coralline algae-cleaning herbivore at Bonefish Bay. Other herbivores seen in the area include jothead porgie (*Calamus bahonado*), bluehead (*Thalassoma bifasciatum*), and less common, small stoplight parrotfish (*Sparisoma viride*).

A head of algae was cleaned of most hermit crabs and isolated with a wire cage on 8 June. The head was retrieved on 28 June, at which time there were still 3 hermit crabs present in the head; some macroalgae, which had not been present prior to isolation of the head, were growing on the coralline algae. Portions of the coralline algae had turned white and were dead.

East Beach

East Beach is on the east side of the island, exposed to the open Atlantic; wave energy was relatively high on the reef crest, and bottom currents were commonly strong. No coralline algae were exposed at low tide.

Branching heads of coralline algae dominated the top of the reef (Figure 2). Branching density of coralline algae is the highest at East Beach, and the branches are thicker than at the other sites. Crusts of coralline algae are also prevalent on the reef crest, where they overgrow the finger coral, *Porites porites.* The main species of coralline algae found on the reef top are branching heads of *Neogoniolithon strictum* and crusts of *Titanoderma prototypum* . Crusts of *T. prototypum* and *Mesophyllum mesomorphum* grow at the bottom of the reef. In more sheltered areas on the reef side, finely branched *Amphiroa* grows.

There are a fair number of fish present at East Beach. I observed stoplight parrotfish (small), queen parrotfish (small), redspotted hawkfish, bluehead, and blue tang grazing on algae growing as epiphytes on coralline algae at East Beach.

A head of coralline algae was isolated on the reef crest on 9 June and the head was retrieved on 26 June. At the time of retrieval, portions of the head were dead, and abundant macroalgae were growing on the coralline algae.

On 12 June a branching head of coralline algae was relocated from the reef crest to the reef bottom, where crusts predominated. Upon retrival on 26 June it was filled with sediment, but still alive.

Pigeon Creek

Pigeon Creek is on the southeastern end of the island. Strong tides account for most water motion in the area. Abundant amounts of algae were exposed at low tide.

The majority of coralline algae at Pigeon Creek occurred as isolated branching heads, or ridges of branching coralline algae (Figure 3). Crusts of coralline algae grow on heads of *Porites asteroides.* The main species found at Pigeon Creek is *N. strictum.*

Fish were the only herbivores seen actively cleaning coralline algae at Pigeon Creek. Species included: spotted burfish (*Chilomycterus atinga*), blue tang, stoplight parrotfish, rock beauty (*Holacanthus tricolor*), bluehead, and various species of the genus *Haemulon.*

Half of one crust of coralline algae was covered with a cage on 9 June. The other portion of the crust was left exposed as a control. On 26 June the cage was removed and the whole crust examined. There appeared to be no difference between the isolated and exposed coralline algae.

Discussion

The dominance of branching coralline algae relative to other morphologies seems consistent with past findings. Strongly branched coralline algae commonly dominate the Tropics, particularly in zones where wave action is frequent, but of low intensity (Steneck, 1986). I thus conclude that the hydraulic energy at all three sites on San Salvador is relatively low.

Although all three sites are of comparatively low wave intensity, the sites differed in the intensity of energy. Past studies have shown that as energy increases, branch length decreases and branch thickness increases (Steneck, 1986). My results agree with this relationship. At East Beach, where energy is the greatest, the coralline algae are the most densely and thickly branched. Bonefish Bay has moderate amounts of energy and the coralline algae are

Figure 1: Study Site at BONEFISH BAY

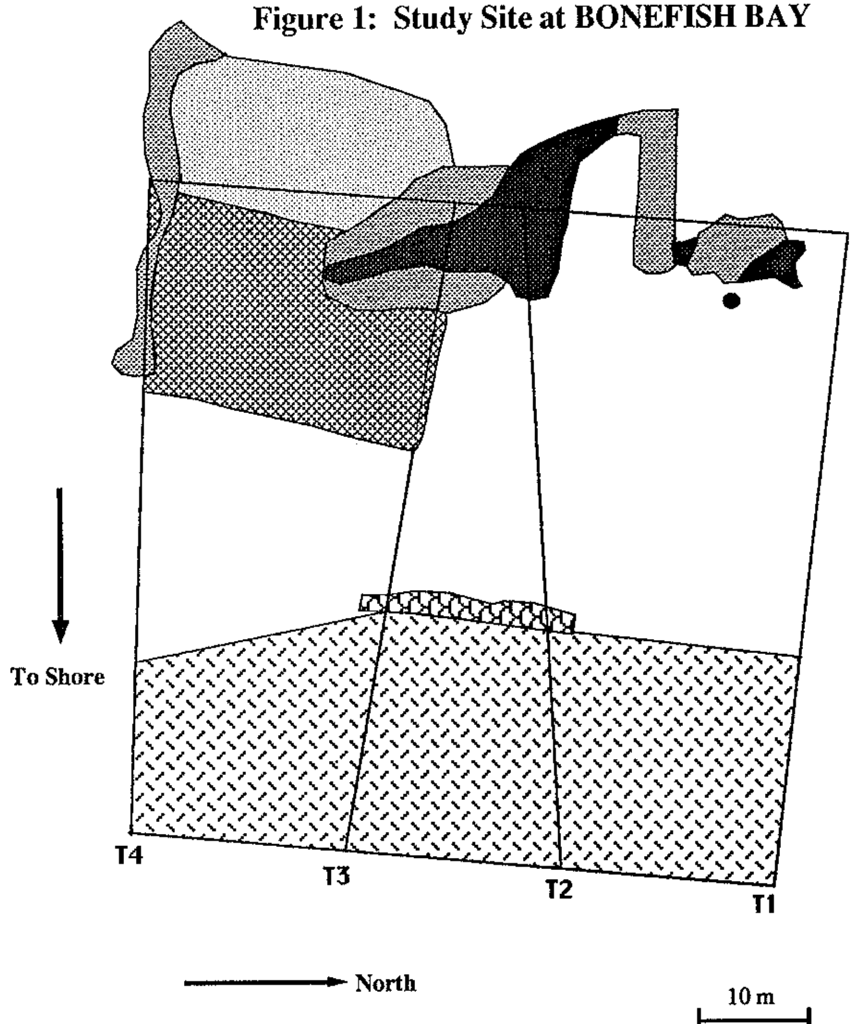
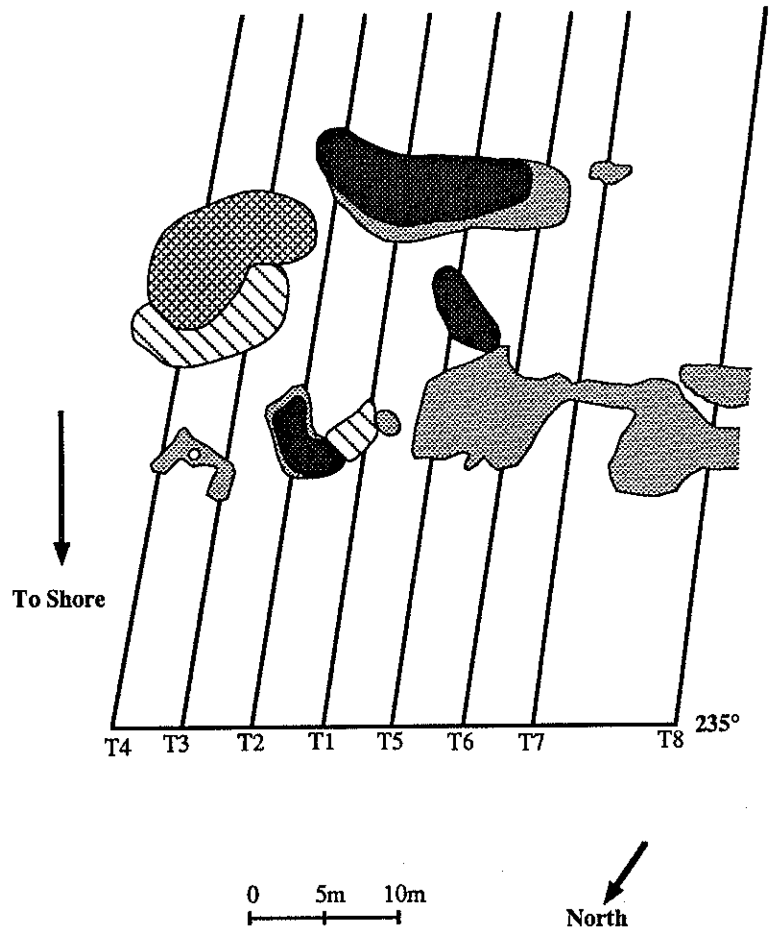


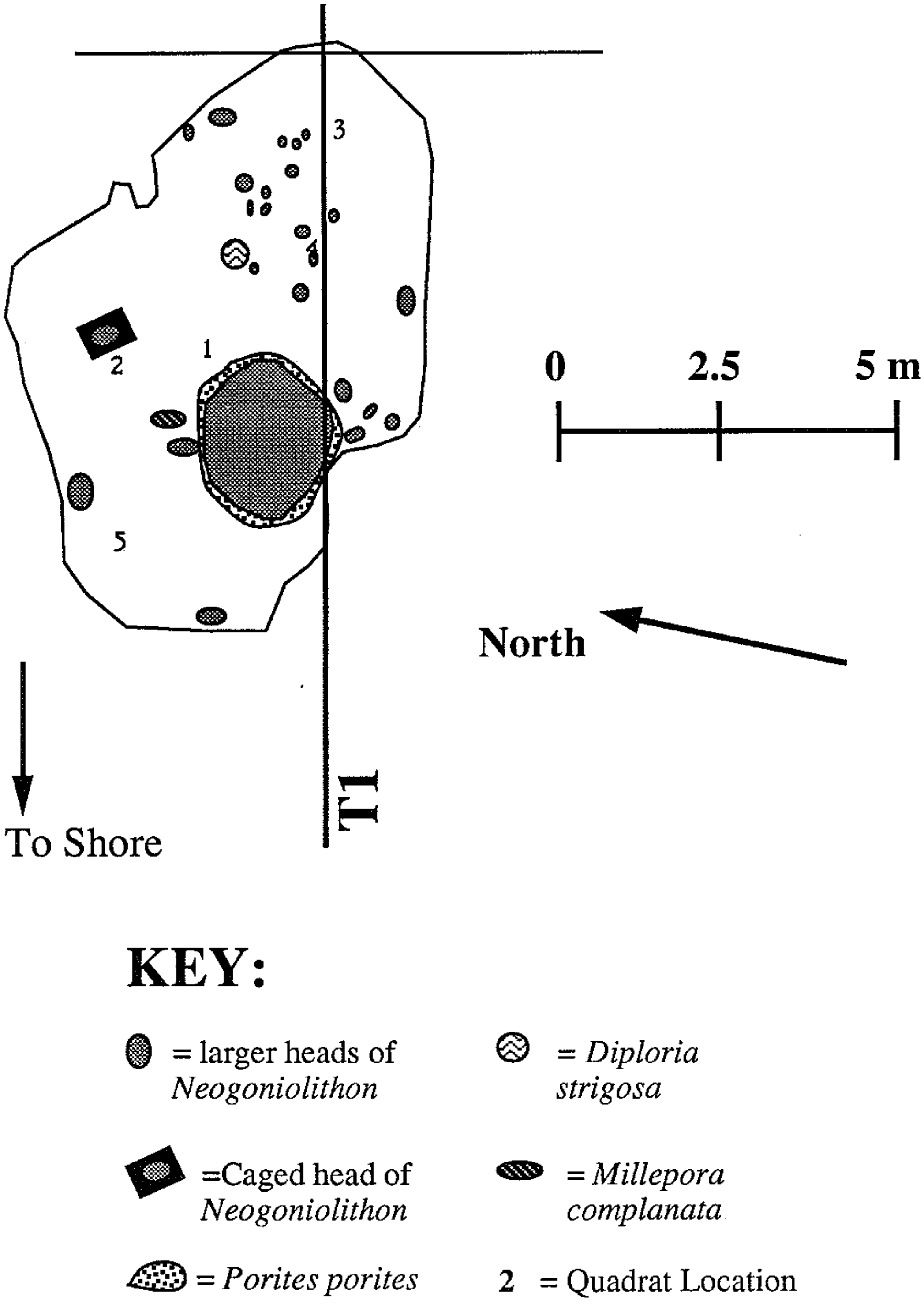
Figure 2: Study Site at PIGEON CREEK



KEY:

- More than 30 % Branching coralline algae
- 10 % to 30 % Branching coralline algae
- Biota
- *Sargassum*
- Crustose coralline algae
- Very sparse coralline algae
- Other Biota and sand
- *Thalassia* bed

Figure 3: Map of upper surface of small patch reef at East Beach showing distribution of coralline algae and selected corals.



less dense and the branches were thinner. Pigeon Creek experiences the least amount of wave energy and the branches of coralline algae are thinner than at any other location.

Branched coralline algae dominate on the reef cap at East Beach, but different morphologies dominate at different areas on the reef. I observed finely branched forms of coralline algae growing in protected areas on the reef side. Finely branched forms have been shown to have a higher photosynthetic rate than other morphologies (Littler, 1980), so this morphology could most likely survive better than the thicker branched coralline algae in this environment of reduced light and wave energy. Branching forms are absent from the reef bottom where crusts of coralline algae occur. My relocation of a head of branching algae from the reef top to the reef bottom demonstrated a possible reason for this; after only 2 weeks the transplanted branching head was buried in sediment. I suggest that the branches of algae baffle and trap sediment in the head of algae. Sediment deposited on the crusts at the bottom of the reef is easily removed by currents, and I therefore believe that the crustose morphology, although not as efficient in gathering light, is better adapted to the lower reef environment.

I believe that the concentration of coralline algae (in an area approximately 60 m from my shoreline transect) at Bonefish Bay was caused by the distribution of wave energy present. Most of the coralline algae grow in the zone where waves generally broke. Additionally, other factors such as substrate type and water depth did not vary in accordance with the percent cover of coralline algae. In the zone where the coralline algae thrive, other biota grew with less frequency possibly because of the greater energy or due to competitive exclusion by the coralline algae.

Pigeon Creek is exposed to extremely low levels of hydraulic energy. Fish are abundant in the area, and herbivory seems to be the major physical disturbance affecting the coralline algae. Fish were often seen actively grazing on soft algae that grow as epiphytes on coralline algae.

I constructed wire cages surrounding heads of coralline algae, intending to exclude grazing herbivores. In order to exclude the smaller herbivores I used small mesh screen. Consequently, the coralline algae possibly experienced reduced exposure to wave energy. A reduction in wave energy would have the same expected results as a reduction in herbivory. Therefore, I propose that the observed results must be interpreted as a result of reduction of both hydraulic energy of the environment and herbivory intensity.

After a period of isolation, heads of coralline algae from Bonefish Bay and East Beach were fouled by increased amounts of soft algae and appeared to be dead in areas. At the end of the exclusion period, the isolated coralline algal crust at Pigeon Creek did not differ noticeably from the control patch of coralline algae. Both sections of crust were fouled by soft algae before isolation and there was no noticeable difference after isolation. Low energy in the environment or the presence of large amounts of epiphytic algae prior to isolation may account for the lack of change in the isolated crust.

The patterns observed at the three sites studied on San Salvador were congruous with past findings; coralline algal distribution and morphology varied between environments. Although other environmental factors were not examined in detail, water motion and herbivory seemed to be the primary components controlling the distribution and morphology of coralline algae.

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