

# 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<sup>2</sup> area. A variety of environments comprise Bonefish: patch reefs, grass beds, rocky hard substrate areas and sandy areas with and without *Calliniana* shrimp mounds. Snow Bay is another high energy lagoon. Rimmed by barrier reefs and cays, Snow Bay occupies a 2 km<sup>2</sup> 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 *Halodule wrightii*) in each quadrat were recorded. Müller'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.

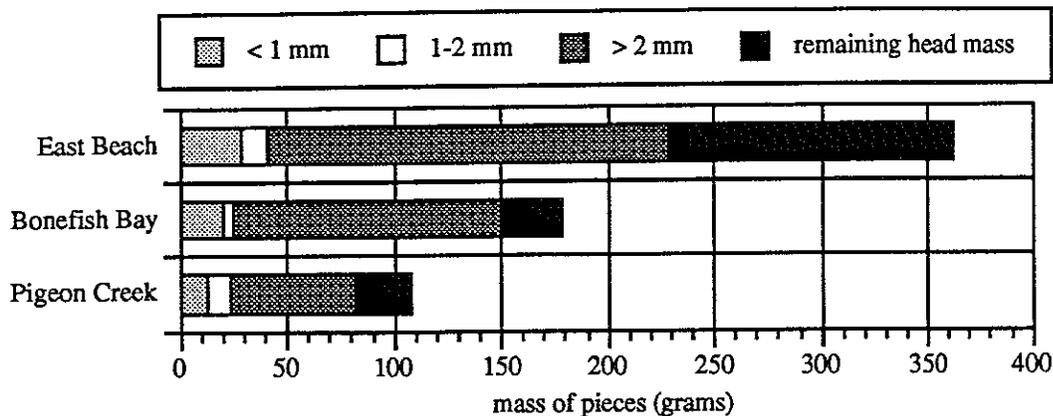


Figure 5. Sieve results, at 17 hours, for the heads shown in Figure 4. The length of the bar indicates the starting mass of the *Neogoniolithon* head; the black portion is the final head mass. The three other patterns represent various sieve sizes.

### 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 *Thalassia* 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 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.

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In the laboratory, each sample was first sorted by species of bivalve and gastropods and each specimen was viewed under a dissecting microscope at 10x power. The following attributes were recorded using a binary scale: ligament remains, articulation, right v. left valve (bivalves only), gastropod borings and live v. dead ratio. Breakage, dissolution (both chemical and biological) and abrasion were recorded using a qualitative scale of 0-5 (0 = total shell present, 1 = 1-19% missing, 2 = 20-39% missing, etc.) No differentiation between mechanical and biological abrasion was made. Biologic activity was measured by estimating percent coverage using a chart similar to that described by Pinchon (1978) and was divided into two categories: 1) bioerosion - resulting from the activities of algae, worms and sponges; 2) encrustation by corals, roots bryozoa, forams, calcareous worm tubes and activity by unidentified organisms. These attributes were measured on the interior and exterior of bivalve material while only the external surfaces of gastropods were examined.

## RESULTS AND DISCUSSION

A total of 4876 specimens representing 65 taxa were examined from 20 samples (see Table 1). These data were entered into an Excel spreadsheet and then imported to Systat. Values for each taphonomic variable were averaged by site reducing the matrix to twenty sample sites by twenty-six taphonomic attributes. Breakage, dissolution, abrasion and percent coverage by bioeroders and encrusters were used in a two-way cluster analysis (Pearson correlation and complete linkage method of clustering). Binary data (snail borings, ligament remains, live/dead and articulation ratios) were not used in the analysis.

Table 1. *Physical properties of the five described environments.*

Substrate	Samples	Sample Size		Seagrass Coefficient	Water Depth (m)
		biv.	gast.		
Rocky substrate	BB-00	607	42	0	0
Sandy area	BB-50, BB-100 BB-150, BB-350 SB-00, SB-600, BB-200	1521	621	0	0 - 3.8
Seagrass beds (sparse)	BB-400a, BB-400b BB-450, SB-100, SB-200	1009	307	0.77 - 3.4	1.8 - 3.9
Seagrass beds (dense)	SB-300, SB-400, SB-500	3	200	16.8 - 27.34	1.8 - 2.0
Reef	BB-250, BB-300 BB-500, BB-550	434	203	0	2.7 - 3.9

### *Q-Mode Analysis*

Q-mode analysis of the data set delineated five distinct clusters (see Figure 1). Sites BB-150, BB-200, BB-400a, BB-400b and BB-450 clustered together based on similar taphonomic attributes presented in the subfossil material. These samples were obtained from sandy areas or sparse seagrass bed environments. A second grouping of samples, BB-500, BB-550 and BB-250, joined samples obtained from three of the four reef environments. BB-100, BB-350 and SB-200 created another cluster of samples derived from sparse seagrass bed and sandy areas. A fourth assemblage of BB-50, SB-300 and SB-600 created an unusual grouping of samples located on two sandy substrates and that with the densest seagrass site. SB-00 and SB-100 were joined in a fifth cluster, one represents a sandy area, the other a substrate of sparse seagrass. Samples BB-0 and BB-300, both obtained from a hard substrate and the top of the reef did not exhibit sufficient similarity to be linked to a cluster.

### *R-Mode Analysis*

R-mode analysis of the data generated five clusters. Encrusting forams (exterior), worms (interior and exterior) and bryozoa (interior) were clustered with boring sponges (interior and exterior) based on their distribution among samples to form one group. A second group was formed by dissolution, encrusting forams (interior) and boring algae (interior). Abrasion, boring worms (interior and exterior) and encrusting

coral (exterior) created a third cluster. Breakage joined with unidentified encrusters (exterior) and boring algae (exterior) made up a fourth cluster. A fifth pairing of unidentified encrusters (interior) and encrusting roots (interior) was created. Encrusting root (exterior), coral (interior) and bryozoan (exterior) were not linked to a cluster, at a significant level of similarity.

#### *Two-way Cluster Analysis*

The largest cluster defined by the Q-mode analysis of samples obtained from sparse seagrass and sandy environments contain shells exhibiting medium to high dissolution with little breakage and small amounts of boring algae (exterior) and encrusting forams (interior). A second cluster of samples representing the majority of the reef environments contain shells that exhibited high dissolution levels, little breakage and boring sponge activity. Top of the reef and rocky hard substrate sites exhibited low levels of unidentified and foram encrusting and boring algae activity as well as minor amounts of breakage and dissolution. Material examined in samples obtained from sandy and the densest seagrass sites displayed medium to high levels of breakage and unidentified encrusters. The two dense seagrass sites included shells that were dominated by medium to high levels of boring algae, breakage and dissolution.

The two way cluster analysis is dominated by the overprint of two taphonomic indicators: breakage and dissolution. Parsons and Brett (1991) categorized these two as being not very useful and moderately useful, respectively, in generating taphofacies for carbonate environments. The omnipresent nature of these two variables suggest that they may be even less useful than expected. If present on virtually every specimen in nearly all environments, dissolution is not relevant in delineating between environments and therefore not moderately useful as described by Parsons and Brett (1991). Breakage needs to be reclassified as well, from not very useful to not useful. The other taphonomic variables lose their utility as environmental indicators when compared with the two that dominate the scale. One possibility, is to re-evaluate this data on a log scale. This way the variables with smaller values but noticeable presence may be emphasized relative to dissolution and breakage, within this framework. The data presented do delineate a few models. For example, the reef environments do contain shells with significantly similar taphonomic attributes. Taphofacies for the dense seagrass cluster are also indicated, but the variance within environments has yet to be accounted for.

The binary data deserve attention, by including those variables in an analysis, the models maybe further refined. On-going analyses of the large matrix by discriminate function analysis could provide a new set of models without the loss of information resulting from averaging the site data. At present, the taphofacies models generated by this data have the potential to raise queries over the previous studies conducted.

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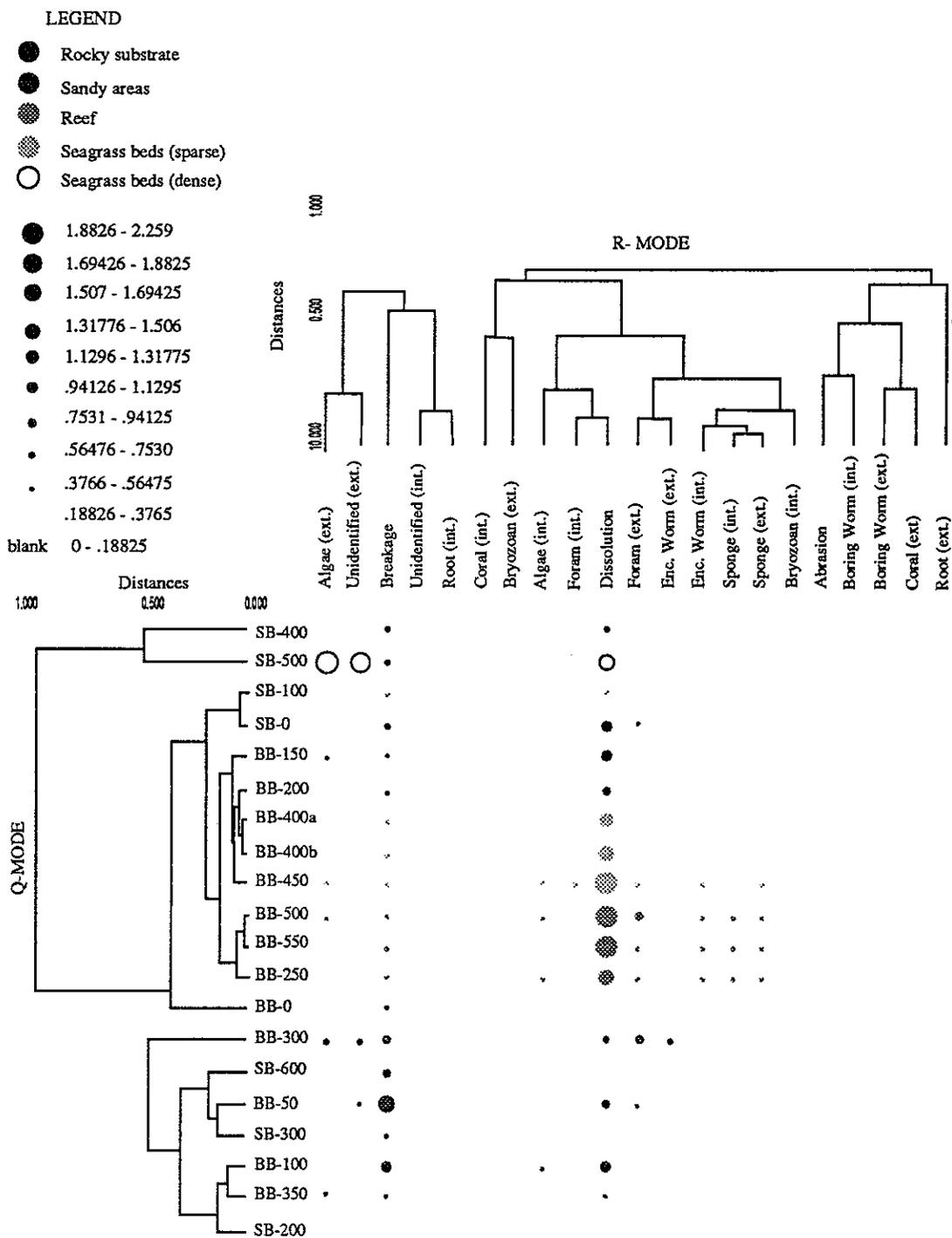


Figure 1. Two-way cluster analysis of taphonomic variable v. site

# TRANSECT, PROFILE, AND DATA ANALYSIS OF TELEPHONE POLE REEF, SAN SALVADOR, BAHAMAS

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## INTRODUCTION

In June of 1992 a study was undertaken of Telephone Pole Reef, located in Fernandez Bay, just south of Cockburn Town on the western side of San Salvador. My study site was a mature patch reef, 200 meters offshore, contained in a rectangular area 75 meters from west to east, and 37.5 meters from north to south (Fig. 1). This area constitutes the bulk of Telephone Pole Reef, while excluding most of its irregular boundaries. Telephone Pole Beach grades seaward from an area of consolidated beachrock, to a *Sargassum* algae zone, followed by an extensive and colorful soft coral zone. Telephone Pole Reef is separated from the soft coral zone by a large sand channel.

The eastern (landward) and northern perimeters of Telephone Pole Reef generally have the most relative topographic relief, while the western (seaward) edge of the reef gradually slopes downward and levels off at depths between 4.5 and 5.5 meters below sea level. Water temperature in the area of Telephone Pole Reef was approximately 82 F in June, and 79 F in January. Salinity ranged from 37-38%.

## METHODS

Four transects were created along a 270 degree bearing from Telephone Pole Beach. Each transect originated 200 meters from shoreline and extended 75 meters. The four transects were spaced 12.5 meters apart (Fig. 1). After marking the transects, detailed topographic profiles were constructed and all sessile benthic organisms were recorded along each transect.

Data was compiled on 32 prominent coral heads dominated by *Montastrea annularis*. Each head was approximately 0.5 x 0.5 meters in width and length or greater. The data included tabulation of *Montastrea annularis* morphotype (Knowlton, et al., 1992), percentage of live coral, percentages and species of all other coral present, and percentage and composition of algae, sponge, gorgonian, bare rock and sediment surface. In addition, the dimensions and general shape of each head was noted.

Eight of the most distinguishable of the 32 heads were located on a grid map using the transect locations (Fig. 1). These heads were chosen for their size and recognizability to be used in a later comparative survey in January of 1993.

## TRANSECT OBSERVATIONS

The primary goal achieved in creating the four transects, was to collect baseline data, as to the character and condition of Telephone Pole Reef, a patch reef that had not yet been systematically studied. Of the twenty coral species (eighteen scleractinian and two hydrozoan) identified on Telephone Pole Reef, eighteen were found directly along transect profiles. Of the six identified species of soft corals, four were found on profile lines. Similarly, three of the six identified sponges and three of the five 'other' cnidaria were present on the transects. In addition to the above, 36 species of fish were identified. Of the 11 species of algae identified, *Anadyomene sp.* was the most common, followed by *Lobophora sp.*, *Caulerpa sp.* and *Dictyota sp.*, in order of descending abundance.

Water depth, and therefore topographic relief, varies greatly along these transects. The greatest depth (5.9 meters) was recorded on transect B. The shallowest depth (2.9 meters) was recorded on transect A. Substrate was classified in one of three basic categories. The most common substrate consists of an algae-covered framework composed primarily of a dead coral matrix. Live organisms of all kinds thrive on this solid substrate that comprises the bulk of the reef. A second substrate type consists primarily of dead, algae-free, *Acropora palmata* and *Acropora cervicornis* rubble. The third type of substrate consists primarily of loose sand particles. Sort corals such as *Pseudopterogorgia sp.* and *Plexaurella sp.* thrive on this type of substrate.

## MONTASTREA ANNULARIS DATA

Due to its size and abundance, *Montastrea annularis* is one of the most important reef formers, and is often used in studies of environmental and paleoecological change (Knowlton et al., 1992). Three *Montastrea annularis* morphotypes, or sibling species, have recently been recognized (Knowlton et al., 1992). The three morphotypes are relatively easy to differentiate, as they are visually quite distinct. They